Model Library
PSS®E 34.8.2

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Chapter 1
Generator Models

This chapter contains a collection of data sheets for the generator models contained in the PSS®E dynamics model library.

Model	Description
CBEST	EPRI battery energy storage FACTS model
CDSMS1	American Superconductor DSMES device model
CGEN1	Third order generator model
CIMTR1	Induction generator model with rotor flux transients
CIMTR2	Induction motor model with rotor flux transients
CIMTR3	Induction generator model with rotor flux transients
CIMTR4	Induction motor model with rotor flux transients
CSMEST	EPRI superconducting electromagnetic energy storage FACTS model
CSTATT	Static condenser FACTS model
CSVGN1	SCR controlled static var source model
CSVGN3	SCR controlled static var source model
CSVGN4	SCR controlled static var source model
CSVGN5	WECC controlled static var source model
CSVGN6	WECC controlled static var source model
FRECHG	Salient pole frequency changer model
GENCLS	Classical generator model
GENDCO	Round rotor generator model with dc offset torque component
GENROE	Round rotor generator model
GENROU	Round rotor generator model
GENSAE	Salient pole generator model
GENSAL	Salient pole generator model
GENTPJ1	Type J Generator model
GENTRA	Transient level generator model
PLBVFU1	Model to Play-In known voltage and/or frequency signal

1.1. CBEST

EPRI Battery Energy Storage CBEST

CONs	Value	Description
J		P_{MAX} (pu on MBASE)
J+1		$O_{UT}E_{FF}$, output efficiency (≥ 1)
J+2		$I_{NP}E_{FF}$, input efficiency (≤1)
J+3		I_{ACMAX} (pu)
J+4		K_{AVR}, AVR gain
J+5		T_1, AVR time constant (sec)
J+6		T_2, AVR time constant (sec)
J+7		T_3, AVR time constant (sec) (>0)
J+8		T_4, AVR time constant (sec)
J+9		V_{MAX}, AVR speed limit (pu)
J+10		V_{MIN}, AVR speed limit (pu) (<0)
J+11		DROOP (pu)

STATEs	Description
K	AVR state 1
K+1	AVR state 2
K+2	I_Q, reactive current (pu)
K+3	Energy output (pu sec)
K+4	Energy input (pu sec) (< 0)

VARs	Description
L	P_{AUX}, supply signal (MW)
L+1	P_{INIT} (pu on MBASE)
L+2	P_{OUT} (pu on SBASE)
L+3	Q_{OUT} (pu on SBASE)
L+4	E_{OUT} total energy (pu on SBASE, sec)
L+5	Memory

This incorporates technology developed for the United States Electric Power Industry under the sponsorship of the Electric Power Research Institute (EPRI).

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IBUS, 'CBEST', ID, CON(J) to CON(J+11)   /
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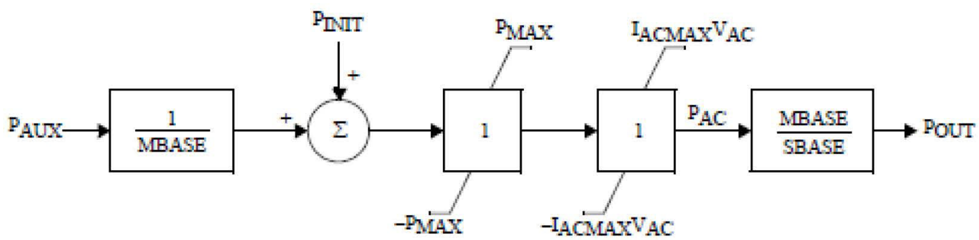
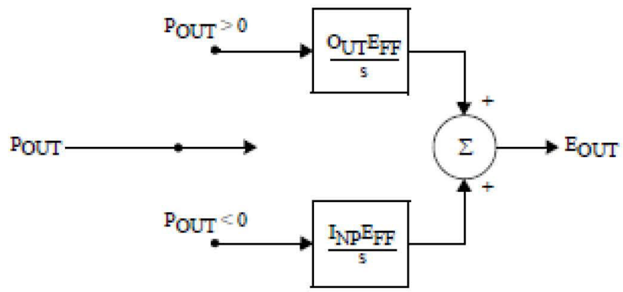
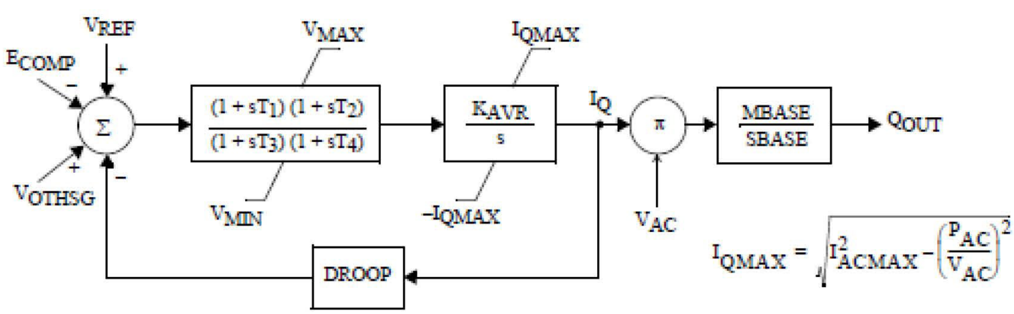

PINIT
PMAX
IACMAXVAC
PAUX
1
MBASE
Σ
1
1
PAC
MBASE
SBASE
POUT
-PMAX
-IACMAXVAC


POUT > 0
OUTEFF
s
POUT
Σ
EOUT
POUT < 0
INPEFF
s


VREF
ECOMP
VOTHSG
Σ
VMAX
(1 + sT1) (1 + sT2)
(1 + sT3) (1 + sT4)
VMIN
IQMAX
KAVR
s
-IQMAX
IQ
π
VAC
MBASE
SBASE
QOUT
DROOP
IQMAX = √(I²ACMAX − (PAC/VAC)²)

1.2. CDSMS1

American Superconductor DSMES Device

This model incorporates technology of American Superconductor Corporation (ASC) and was developed under the sponsorship of ASC.

ICONs	Value	Description
M		Frequency bias flag, 0 or 1
M+1		Power controller flag, 0 or 1

CONs	Value	Description
J		S_{RATED}, rated D-SMES MVA, must be equal to MBASE
J+1		V_{DC}, nominal coil voltage (kV)
J+2		I_{INIT}, initial coil current (kA)
J+3		I_{MIN}, minimum coil current (kA)
J+4		T_{DIS}, magnet full-discharge time (sec)
J+5		T_{ON}, minimum time interval after the magnet turning off before its new activating (sec)
J+6		T_{OFF}, minimum time interval after the magnet activating before turning it off (sec)
J+7		V_1, voltage threshold (pu) ($> V_2$)
J+8		V_2, voltage threshold (pu) ($> V_3$)
J+9		V_3, voltage threshold (pu) ($> V_4$)
J+10		V_4, voltage threshold (pu) (>0)
J+11		K_{AVR}, AVR (Q-path) gain
J+12		T_1, AVR time constant (sec)
J+13		T_2, AVR time constant (sec)
J+14		T_3, AVR time constant (sec) (>0)
J+15		T_4, AVR time constant (sec) (>0)
J+16		AVR_DROOP, AVR droop
J+17		PAUX_THRESH, P_{AUX} threshold (MW) (>0)
J+18		TOVLD, time interval of overload, when MVA output limit is maximum $-S_{LIMMAX}$ (sec)
J+19		TBACK, time interval when MVA output limit S_{LIM} is ramping from maximum value S_{LIMMAX} to nominal value S_{RATED} (sec)
J+20		KOL, overload parameter (percent)
J+21		TBOOST_BEG, boost control starting time (sec)
J+22		BOOST_DUR, time interval when the boost control is active (sec)
J+23		STEP_V_{REF}, voltage reference step used by the boost control (pu)
J+24		KOV, parameter determines the step-up transformer voltage when the remote bus control is abandoned (per cent)
J+25		V_{QMAX}, maximum limit for AVR state 2 (pu)

CONs	Value	Description
J+26		V_{QMIN}, minimum limit for AVR state 2 (pu)
J+27		I_{ACMAX}, maximum limit for the D-SMES AC current (pu)
J+28		P_{MAX}, maximum limit for P_{OUT} (pu on MBASE)
J+29		P_{MIN}, minimum limit for P_{OUT} (pu on MBASE)

STATEs	Description
K	I_Q, Q-path reactive current (pu)
K+1	AVR state 1 (pu)
K+2	AVR state 2 (pu)

VARs	Description
L	P_{AUX}, active power control signal (MW)
L+1	P_{OUT}, output active power (pu on SBASE)
L+2	Q_{OUT}, output reactive power (pu on SBASE)
L+3	IDC, output D_SMES DC current (kA)
L+4	I_L, coil current (kA)
L+5	V_{TR}, D-SMES step-up transformer low voltage (pu)
L+6 • • • L +22	Internal Storage

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IBUS, 'CDSMS1', ID, ICON(M) to ICON(M+7), CON(J) to CON(J+29)   /
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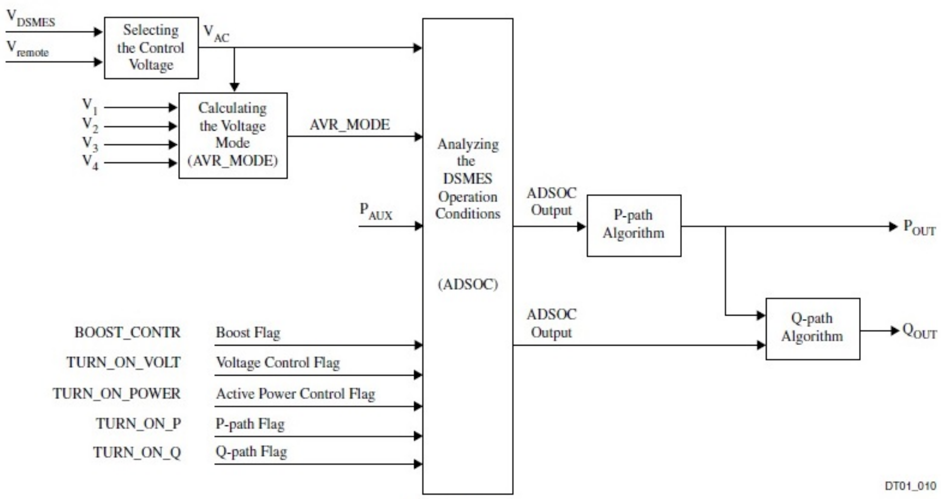
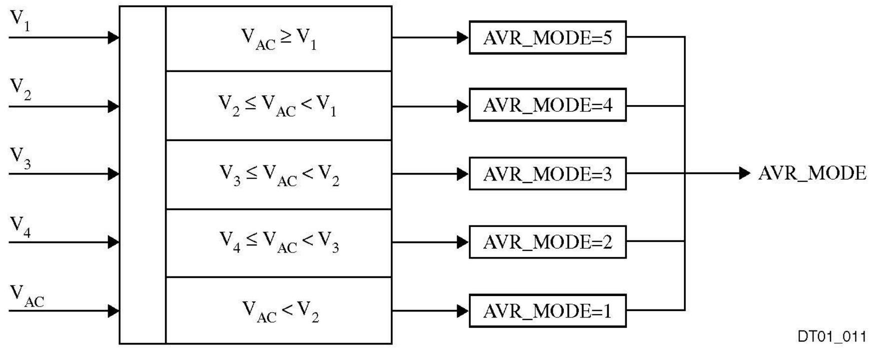


General Diagram

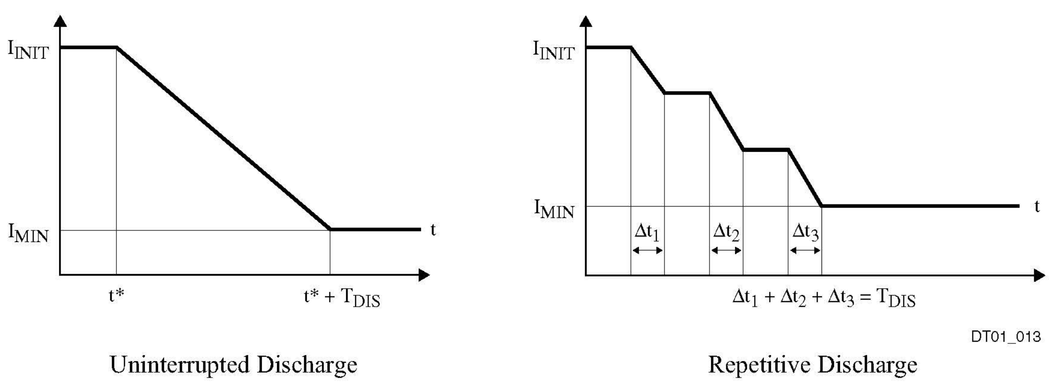
Calculating the Voltage Mode (AVR_MODE)

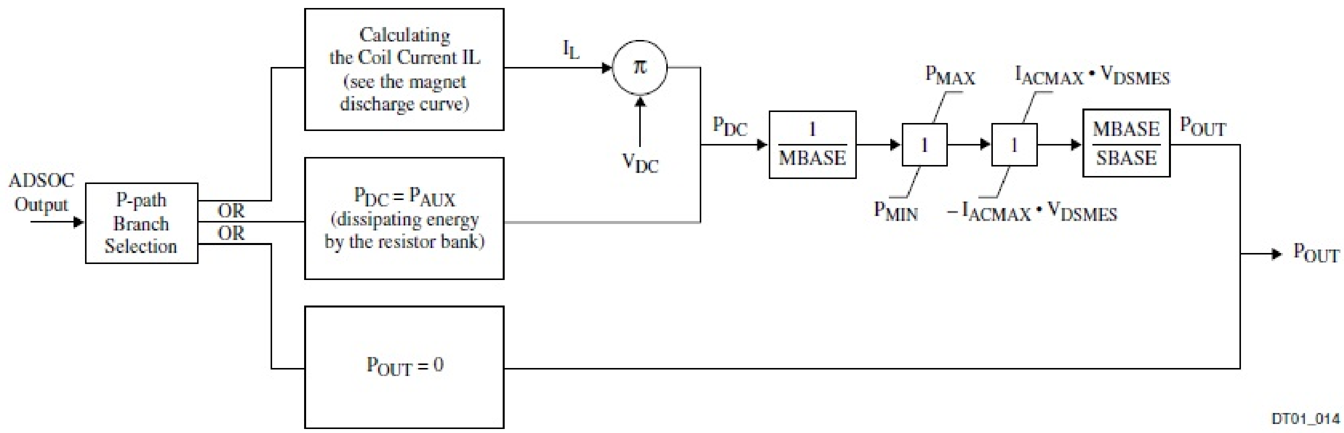


$V_{AC} \geq V_1$	The MW-injection DSMES is disabled.
$V_1 \geq V_{AC} \geq V_2$	The MW-injection DSMES is disabled.
$V_2 \geq V_{AC} \geq V_3$	The MW-injection DSMES is enabled, but MW can only be absorbed from the power system.
$V_3 \geq V_{AC} \geq V_4$	The MW-injection DSMES is enabled. MW can either be produced by the magnet discharge or absorbed from the power system, depending on the controls.
$V_4 \geq V_{AC}$	The MW-injection DSMES is enabled, but MW can only be absorbed from the power system.

The MW Injection of DSMES is also enabled immediately after V_{AC} quick crossing the $V_3 > V_{AC} \geq V_4$ range.

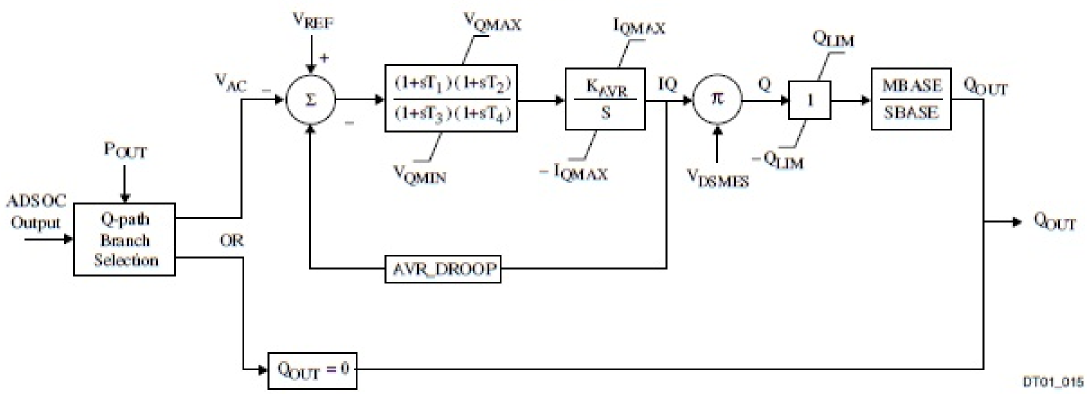
The Magnet Discharge Curve





P-Path Algorithm

Q-Path Algorithm

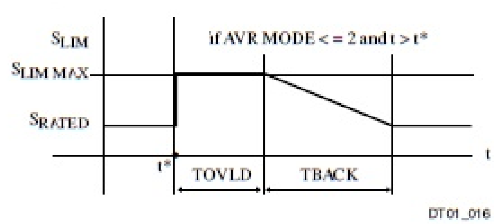


Overload Diagram

$$I_{QMAX} = \sqrt{I^2_{ACMAX} - \left(\frac{P_{OUT}}{V_{DSMES}}\right)^2}$$

$$Q_{LIM} = \sqrt{S^2_{LIM} - P^2_{OUT}}$$

$$S_{LIM\ MAX} = KOL \bullet S_{RATED}$$



$$\text{at } t^* : S = \sqrt{P^2_{OUT} + Q^2} > S_{RATED}$$

1.3. CGEN1

Third Order Complex Generator Model

CONs	Value	Description
J		H, Inertia
J+1		S(1.0)
J+2		S(1.2)
J+3		$L_{ld} > 0$
J+4		$L_{ad} > 0$
J+5		$R_{fd} > 0$
J+6		$L_{fd} > 0$
J+7		R_{md} (1)
J+8		L_{md} (1)
J+9		R_{kd} (1)
J+10		L_{kd} (1)
J+11		R_{md} (2)
J+12		L_{md} (2)
J+13		R_{kd} (2)
J+14		L_{kd} (2)
J+15		$L_{lq} > 0$
J+16		$L_{aq} > 0$
J+17		R_{kq} (3) > 0
J+18		L_{kq} (3) > 0
J+19		R_{mq} (1)
J+20		L_{mq} (1)
J+21		R_{kq} (1)
J+22		L_{kq} (1)
J+23		R_{mq} (2)
J+24		L_{mq} (2)
J+25		R_{kq} (2)
J+26		L_{kq} (2)

STATEs	Description
K	Δ speed (pu)
K+1	Angle (radians)
K+2	ψrd (1)
K+3	ψrd (2)
K+4	ψrd (3)
K+5	ψrq (1)
K+6	ψrq (2)
K+7	ψrq (3)

VARs	Description
L	Internal memory
L+1	Internal memory

All constants except S(1.0) and S(1.2) are in pu machine MVA base.

Set R_{md} (2), L_{md} (2), R_{kd} (2) and L_{kd} (2) to 0 for 2nd order d-axis model.

Set R_{mq} (2), L_{mq} (2), R_{kq} (2) and L_{kq} (2) to 0 for 2nd order q-axis model.

See diagram below for definition of various resistances and inductances.

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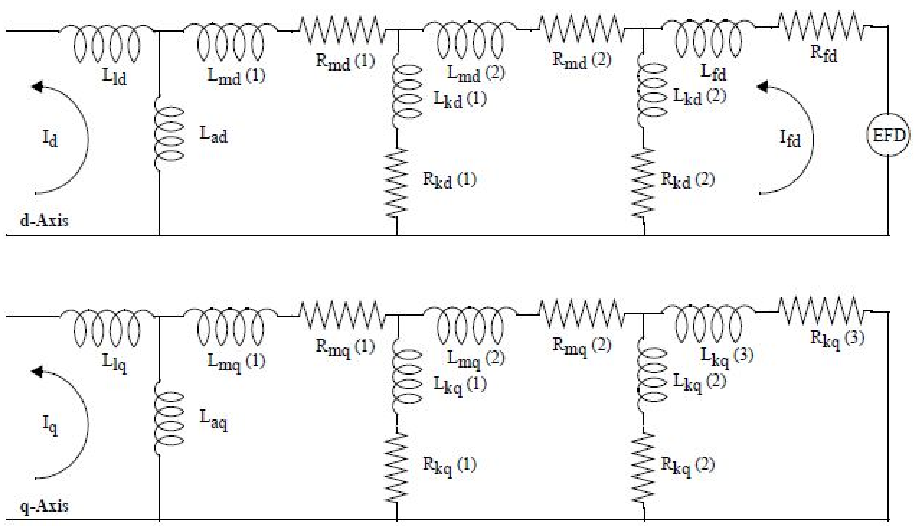
IBUS, 'CGEN1', ID, CON(J) to CON(J+26)   /
```



CGEN1 Equivalent Circuit

1.4. CIMTR1

Induction Generator Model

ICONs	Value	Description
M		Memory

CONs	Value	Description
J		T'(sec) (>0)
J+1		T"(sec) (≥0)[a]
J+2		H, Inertia
J+3		X
J+4		X'
J+5		X" (≥0)
J+6		Xl
J+7		E_1 (≥0)
J+8		$S(E_1)$
J+9		E_2
J+10		$S(E_2)$
J+11	0	Switch

[a]If T" = 0 or X" = 0, motor is assumed to be single cage and ZSORCE should be set equal to X'.

Note: X, X', X", X_l, and H are in pu, machine MVA base.

STATEs	Description
K	E'_q
K+1	E'_d
K+2	E''_q
K+3	E''_d
K+4	Δ speed (pu)

VARs	Description
L	Admittance of initial condition Mvar difference
L+1	Motor, Q
L+2	T_{elec}

```
IBUS, 'CIMTR1', ID, CON(J) to CON(J+11)   /
```

1.5. CIMTR2

Induction Motor Model

ICONs	Value	Description
M		Memory

CONs	Value	Description
J		T'(sec) (>0)
J+1		T" (sec) (≥0)[a]
J+2		H, Inertia
J+3		X
J+4		X'
J+5		X"[a]
J+6		X_l
J+7		E_1 (≥0)
J+8		$S(E_1)$
J+9		E_2
J+10		$S(E_2)$
J+11		D

[a]If T" = 0 or X" = 0, motor is assumed to be single cage and ZSORCE should be set equal to X'.

Note: X, X', X", X_l, and H are in pu, machine MVA base.

STATEs	Description
K	E'_q
K+1	E'_d
K+2	E''_q
K+3	E''_d
K+4	Δ speed (pu)

VARs	Description
L	Admittance of initial condition Mvar difference
L+1	Motor, Q
L+2	T_{elec}

```
IBUS, 'CIMTR2', ID, CON(J) to CON(J+11)   /
```

1.6. CIMTR3

Induction Generator Model

ICONs	Value	Description
M		Memory

CONs	Value	Description
J		T'(sec) (>0)
J+1		T" (sec) (≥0)[a]
J+2		Inertia, H
J+3		X
J+4		X'
J+5		X"1
J+6		X_l
J+7		E_1 (≥0)
J+8		$S(E_1)$
J+9		E_2
J+10		$S(E_2)$
J+11		Switch
J+12		SYN-POW, mechanical power at synchronous speed (>0). Used only to start Machine, otherwise ignored.

[a]If T" = 0 or X" = 0, Machine is assumed to be single cage and ZSORCE should be set equal to X'.

Note: X, X', X", X_l, and H are in pu, machine MVA base.

STATEs	Description
K	E'_q
K+1	E'_d
K+2	E''_q
K+3	E''_d
K+4	Δ speed (pu)
K+5	Angle deviation

VARs	Description
L	Admittance of initial condition Mvar difference
L+1	Motor, Q
L+2	T_{elec}

```
IBUS, 'CIMTR3', ID, CON(J) to CON(J+12)   /
```

1.7. CIMTR4

Induction Motor Model

ICONs	Value	Description
M		Memory

CONs	Value	Description
J		T' (sec) (>0)
J+1		T" (sec) (≥0) [a]
J+2		Inertia, H
J+3		X
J+4		X'
J+5		X" 1
J+6		X_l
J+7		E_1 (≥0)
J+8		$S(E_1)$
J+9		E_2
J+10		$S(E_2)$
J+11		D
J+12		SYN-TOR, synchronous torque (pu) (< 0). Used only to start machine, otherwise ignored.

[a] If T" = 0 or X" = 0, motor is assumed to be single cage and ZSORCE should be set equal to X'.

Note: X, X', X", X_l, and H are in pu, machine MVA base.

STATEs	Description
K	E"q
K+1	E'd
K+2	E"q
K+3	E"
K+4	△ speed (pu)
K+5	Angle deviation

VARs	Description
L	Admittance of initial condition Mvar difference
L+1	Motor, Q
L+2	T_{elec}

```
IBUS, 'CIMTR4', ID, CON(J) to CON(J+12)   /
```

1.8. CSMEST

EPRI Current and Voltage-Source SMES Device

ICONs	Value	Description
M		• 0 - Current-source converter • 1 - Voltage-source converter

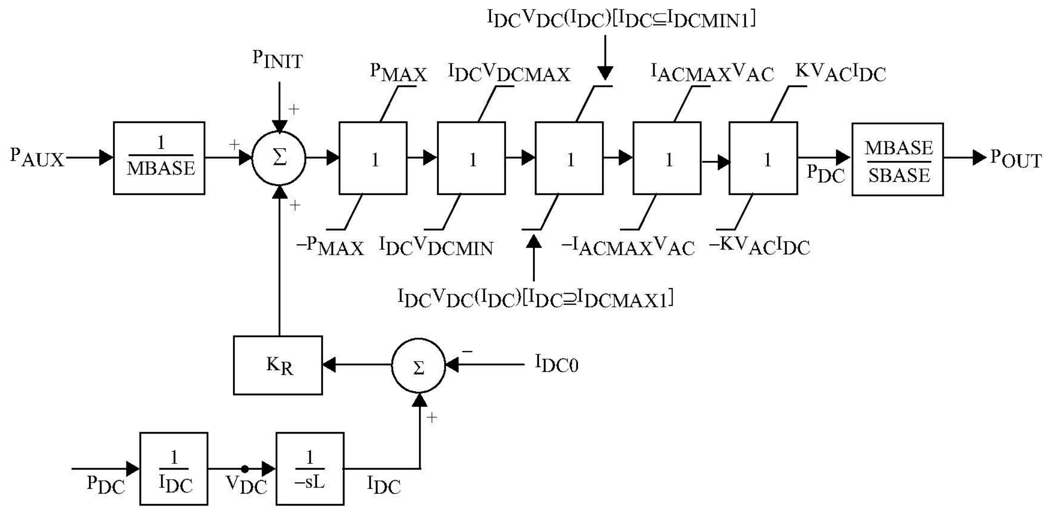
CONs	Value	Description
J		L, coil inductance (pu)
J+1		P_{MAX} (pu on MBASE)
J+2		V_{DCMAX} (pu)
J+3		V_{DCMIN} (pu)(< 0)
J+4		I_{DCMAX1} (pu)
J+5		I_{DCMAX2} (pu)
J+6		I_{DCMIN1} (pu)
J+7		I_{DCMIN2} (pu)(< 0)
J+8		I_{ACMAX} (pu)
J+9		K, Limiter K factor
J+10		I_{DC0} (pu)
J+11		K_R, I_{DC} reset gain
J+12		K_{AVR}, AVR gain
J+13		T_1, AVR time constant (sec)
J+14		T_2, AVR time constant (sec)
J+15		T_3, AVR time constant (sec)
J+16		T_4, AVR time constant (sec)
J+17		V_{MAX}, AVR speed limit (pu)
J+18		V_{MIN}, AVR speed limit (pu) (< 0)
J+19		DROOP, AVR droop

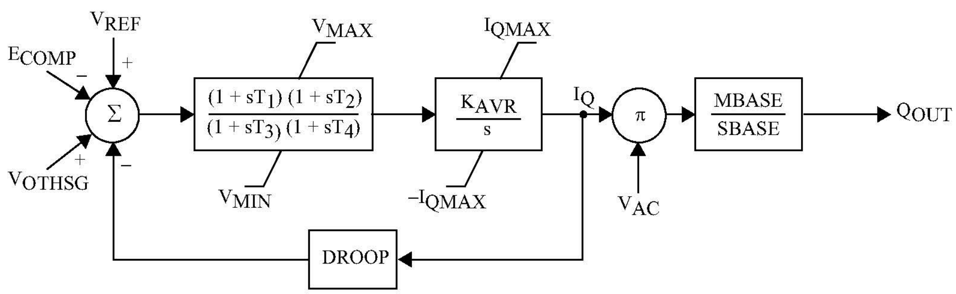
STATEs	Description
K	I_{DC}, coil dc current (pu)
K+1	AVR state 1
K+2	AVR state 2
K+3	I_Q, reactive current (pu)

VARs	Description
L	P_{AUX}, supplementary signal (MW)
L+1	P_{INIT} (pu on MBASE)
L+2	P_{OUT} (pu on SBASE)
L+3	Q_{OUT} (pu on SBASE)
L+4	V_{DC} (pu)
L+5	Memory

This incorporates technology developed for the United States Electric Power Industry under the sponsorship of the Electric Power Research Institute (EPRI).

```
IBUS, 'CSMEST', ID, ICON(M), CON(J) to CON(J+19)   /
```





Voltage-Source Converter:

$$I_{QMAX} = \sqrt{I^2_{ACMAX} - \left(\frac{P_{DC}}{V_{AC}}\right)^2}$$

Current-Source Converter I_{QMAX} is lowest of:

$$\sqrt{I^2_{ACMAX} - \left(\frac{P_{DC}}{V_{AC}}\right)^2} \quad \text{or} \quad \sqrt{(K \times I_{DC})^2 - \left(\frac{P_{DC}}{V_{AC}}\right)^2}$$

1.9. CSTATT

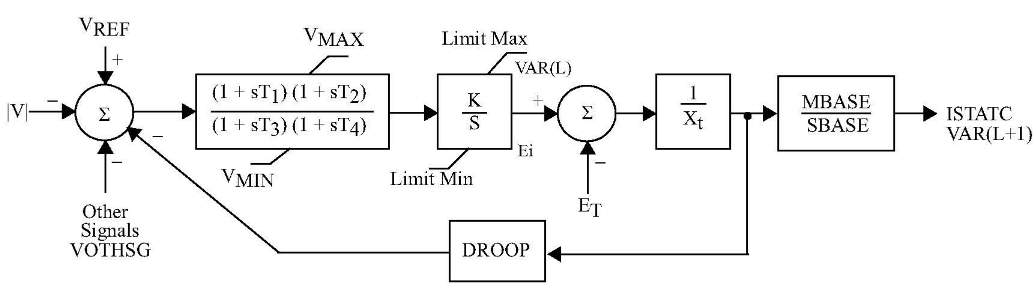
Static Condenser (STATCON)

CONs	Value	Description
J		T_1 (>0)
J+1		T_2 (>0)
J+2		T_3 (>0)
J+3		T_4 (>0)
J+4		K (Typical = 25/(dV/dEi)
J+5		DROOP (typical = 0.03)
J+6		V_{MAX} (typical = 999)
J+7		V_{MIN} (typical = -999)
J+8		I_{CMAX} (typical = 1.25)
J+9		I_{LMAX} (typical = 1.25)
J+10		V_{CUTOUT} (typical = 0.2)
J+11		E_{limit} (typical = 1.2)
J+12		X_T (typical = 0.1)
J+13		A_{CC} (typical = 0.5)

STATEs	Description
K	First regulator
K+1	Second regulator
K+2	Thyristor

VARs	Description
L	Ei, Internal voltage (pu)
L+1	ISTATC, STATCON current
L+2	Internal memory

```
IBUS, 'CSTATT', ID, CON(J) to CON(J+13)   /
```



Limit Max = $V_T + X_T I_{CMAX0}$

Limit Min = $V_T - XT\ I_{LMAX0}$

Limit Max ≤ E_{limit}

where:

$I_{CMAX0} = I_{CMAX}$ when $V_T \geq V_{CUTOUT}$

$$I_{CMAX0} = \frac{I_{CMAX} \times V_T}{V_{CUTOUT}}$$

$I_{LMAX0} = I_{LMAX}$ when $V_T \geq V_{CUTOUT}$

otherwise

$$I_{LMAX0} = \frac{I_{LMAX} \times V_T}{V_{CUTOUT}}$$

otherwise

Note: |V| is the voltage magnitude on the high side of generator step-up transformer, if present.

1.10. CSVGN1

Static Shunt Compensator

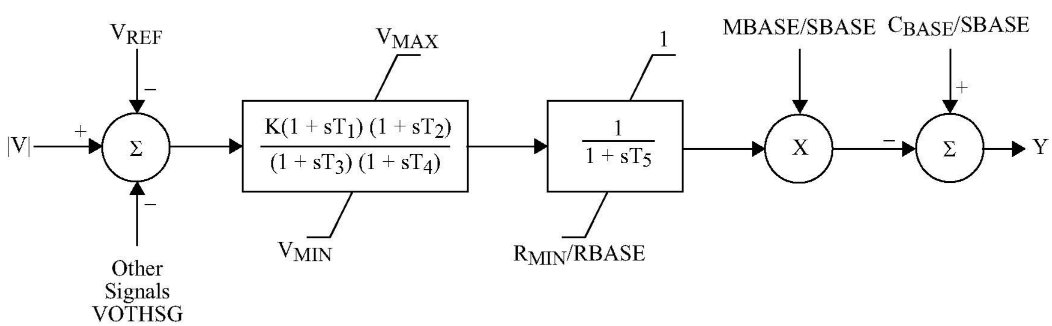
ICONs	Value	Description
M		Memory

CONs	Value	Description
J		K
J+1		T_1
J+2		T_2
J+3		T_3 (>0)
J+4		T_4
J+5		T_5
J+6		R_{MIN} (reactor minimum Mvar)
J+7		V_{MAX}
J+8		V_{MIN}
J+9		C_{BASE} (capacitor Mvar)

STATEs	Description
K	First regulator
K+1	Second regulator
K+2	Thyristor

VARs	Description
L	Y (model output)

```
IBUS, 'CSVGN1', ID, CON(J) to CON(J+9)   /
```



RBASE = MBASE

Note: |V| is the voltage magnitude on the high side of generator step-up transformer, if present.

1.11. CSVGN3

Static Shunt Compensator

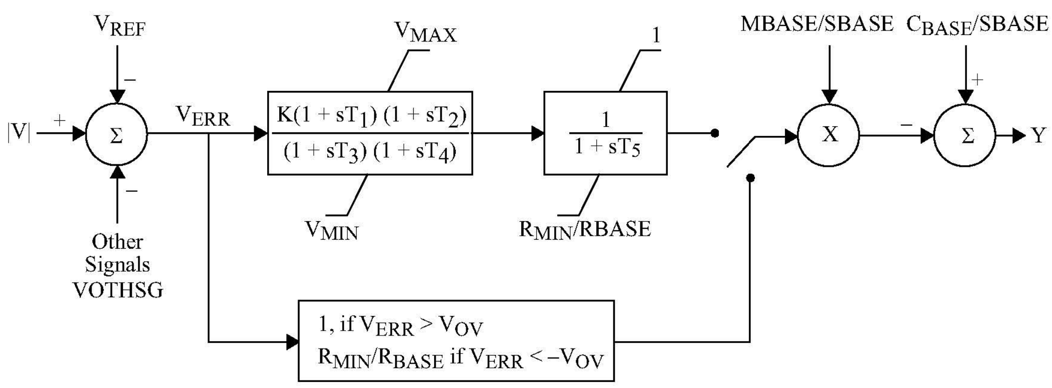
ICONs	Value	Description
M		Memory

CONs	Value	Description
J		K
J+1		T_1
J+2		T_2
J+3		T_3 (>0)
J+4		T_4
J+5		T_5
J+6		R_{MIN} (reactor minimum Mvar)
J+7		V_{MAX}
J+8		V_{MIN}
J+9		C_{BASE} (capacitor Mvar)
J+10		V_{OV} (override voltage)

STATEs	Description
K	First regulator
K+1	Second regulator
K+2	Thyristor

VARs	Description
L	Y (model output)

```
IBUS, 'CSVGN3', ID, CON(J) to CON(J+10)   /
```



RBASE = MBASE

Note: |V| is the voltage magnitude on the high side of generator step-up transformer, if present.

1.12. CSVGN4

Static Shunt Compensator

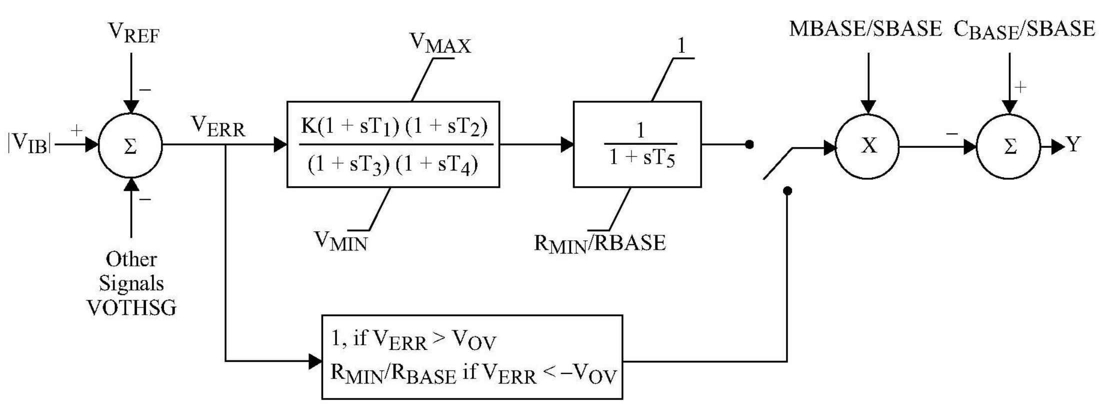
ICONs	Value	Description
M		IB, remote bus to regulate or zero to regulate terminal voltage
M+1		Memory

CONs	Value	Description
J		K
J+1		T_1
J+2		T_2
J+3		T_3 (>0)
J+4		T_4
J+5		T_5
J+6		R_{MIN} (reactor minimum Mvar)
J+7		V_{MAX}
J+8		V_{MIN}
J+9		C_{BASE} (capacitor Mvar)
J+10		V_{OV} (override voltage)

STATEs	Description
K	First regulator
K+1	Second regulator
K+2	Thyristor

VARs	Description
L	Y (model output)

```
BUS, 'CSVGN4', ID, ICON(M), CON(J) to CON(J+10)   /
```



RBASE = MBASE

1.13. CSVGN5

Static var Compensator

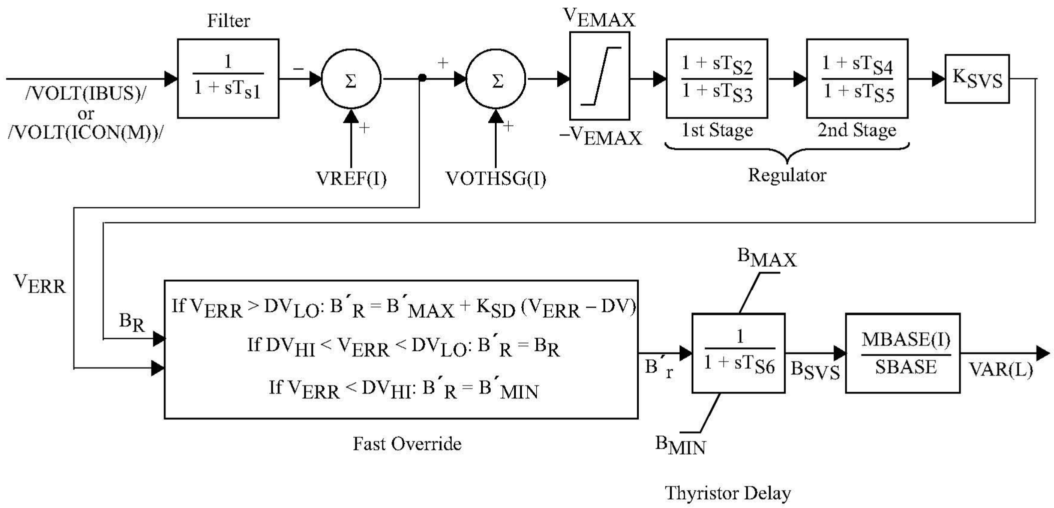
ICONs	Value	Description
M		IB, Remote bus number
M+1		Memory

CONs	Value	Description
J		T_{S1}
J+1		V_{EMAX}
J+2		T_{S2}
J+3		T_{S3} (>0)
J+4		T_{S4}
J+5		T_{S5}
J+6		K_{SVS}
J+7		K_{SD}
J+8		B_{MAX}
J+9		B'_{MAX}
J+10		B'_{MIN}
J+11		B_{MIN}
J+12		T_{S6} (>0)
J+13		DV

STATEs	Description
K	Filter output
K+1	First regulator state
K+2	Second regulator state
K+3	Thyristor delay

VARs	Description
L	Y (model output)

```
IBUS, 'CSVGN5', ID, ICON(M), CON(J) to CON(J+13)   /
```



If DV = 0,

$DV_{LO} = B'_{MAX}/K_{SVS}$

$DV_{HI} = B'_{MIN}/K_{SVS}$

If DV > 0,

$DV_{LO} = DV$

$DV_{HI} = -DV$

1.14. CSVGN6

Static var Compensator

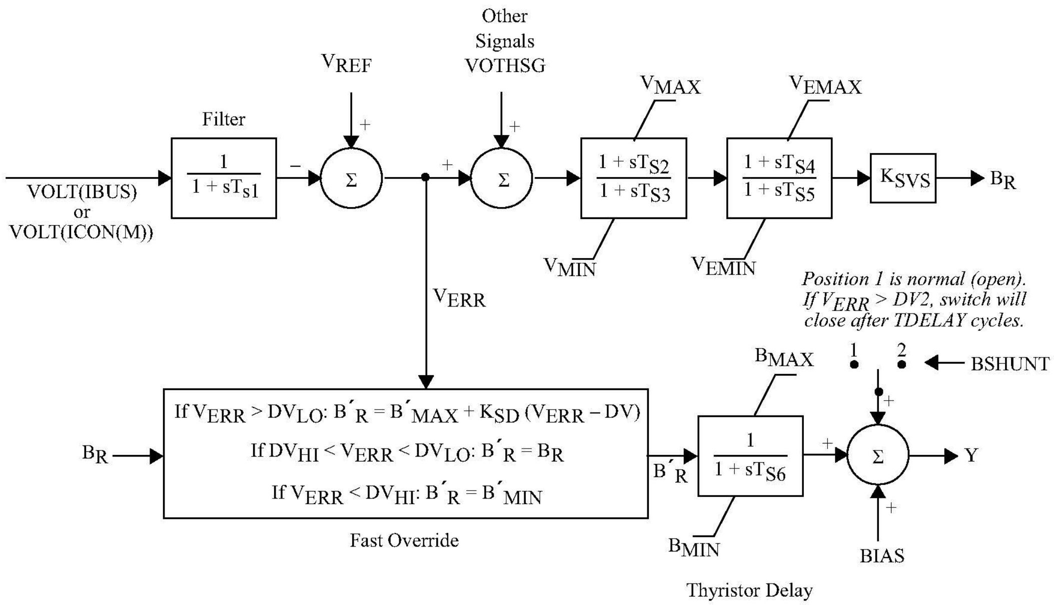
ICONs	Value	Description
M		IB, remote bus number
M+1		Memory

CONs	Value	Description
J		T_{S1}
J+1		V_{EMAX}
J+2		T_{S2}
J+3		T_{S3} (>0)
J+4		T_{S4}
J+5		T_{S5}
J+6		K_{SVS}
J+7		K_{SD}
J+8		B_{MAX}
J+9		B'_{MAX}
J+10		B'_{MIN}
J+11		B_{MIN}
J+12		T_{S6} (>0)
J+13		DV
J+14		V_{EMIN}
J+15		V_{MAX}
J+16		V_{MIN}
J+17		BIAS
J+18		DV2
J+19		BSHUNT
J+20		TDELAY

STATEs	Description
K	Filter output
K+1	First regulator state
K+2	Second regulator state
K+3	Thyristor delay

VARs	Description
L	Y (model output)
L+1	BSHUNT switch timer

```
IBUS, 'CSVGN6', ID, ICON(M), CON(J) to CON(J+20)   /
```



If DV = 0,
$DV_{LO} = B'_{MAX}/K_{SVS}$
$DV_{HI} = B'_{MIN}/K_{SVS}$

If DV > 0,
$DV_{LO} = DV$
$DV_{HI} = -DV$

1.15. FRECHG

Static var Compensator

CONs	Value	Description
J		T'_{do} (>0) (sec)
J+1		T''_{do} (>0) (sec)
J+2		T''_{qo} (>0) (sec)
J+3		H1, Inertia
J+4		D, Speed damping
J+5		X_d
J+6		X_q
J+7		X'_d
J+8		$X''_d = X''_q$
J+9		X_l
J+10		S(1.0)
J+11		S(1.2)
J+12		T'_{do} (>0) (sec)
J+13		T''_{do} (>0) (sec)
J+14		T''_{qo} (>0) (sec)
J+15		H2, Inertia
J+16		D, Speed damping
J+17		X_d
J+18		X_q
J+19		X'_d
J+20		$X''_d = X''_q$
J+21		X_l
J+22		S(1.0)
J+23		S(1.2)
J+24		FB_2, base frequency of to bus (Hz)

STATEs	Description
K	E'_q
K+1	ψkd
K+2	$\psi''q$
K+3	Δ speed (pu)
K+4	Angle (radians)
K+5	E'_q
K+6	ψkd
K+7	$\psi''q$
K+8	Δ speed (pu)
K+9	Angle (radians)

Notes:

From bus unit assumed to be on the same system base frequency as that in the working case.

To bus unit base frequency must be specified via CON(J+24).

CON(J) through CON(J+11), STATE(K) through STATE(K+4) are quantities for the from bus unit.

CON(J+12) through CON(J+24), STATE(K+5) through STATE(K+9) are quantities for the to bus unit.

X_d, X_q, X'_d, X'', X''_q, X_l, H, and D are in pu on the corresponding Machine MVA base. X''_q must be equal to X''_d.

H1*MBASE1 = H2*MBASE2

```
IBUS, 'FRECHG', IM, JBUS, JM, CON(J) to CON(J+24)   /
```

1.16. GENCLS

Constant Internal Voltage Generator Model

CONs	Value	Description
J		H, Inertia[a]
J+1		D, Damping constant

[a]H and D are in pu machine MVA base.1 If H is 0, then DSTATE(K) and DSTATE(K+1) will always be zero.

STATEs	Description
K	Δ speed (pu)
K+1	Angle (radians)

```
IBUS, 'GENCLS', ID, CON(J) and CON(J+1)   /
```

1.17. GENDCO

Round Rotor Generator Model Including dc Offset Torque Component

CONs	Value	Description
J		T'_{do} (>0) (sec)
J+1		T''_{do} (>0) (sec)
J+2		$T'qo$ (>0) (sec)
J+3		T''_{qo} (>0) (sec)
J+4		H, Inertia
J+5		D, Speed damping
J+6		X_d
J+7		X_q
J+8		X'_d
J+9		X'_q
J+10		$X''_d = X''_q$
J+11		X_l
J+12		S(1.0)
J+13		S(1.2)
J+14		T_a

Note: X_d, X_q, X'_d, X'_q, X''_d, X''_q, X_l, H, and D are in pu, machine MVA base.

X''_q must be equal to X''_d.

STATEs	Description
K	E'_q
K+1	E'_d
K+2	ψkd
K+3	ψkq
K+4	Δ speed (pu)
K+5	Angle (radians)

VARs	Description
L	T_{elec}
L+1	dc offset current
L+2	Phase at switch
L+3	Time of switch
L+4	i_d, Value at kPAUSE = 1
L+5	i_q, Value at kPAUSE = 1
L+6	i_d
L+7	i_q

```
IBUS, 'GENDCO', ID, CON(J) to CON(J+14)   /
```

1.18. GENROE

Round Rotor Generator Model (Exponential Saturation)

CONs	Value	Description
J		T'_{do} (>0) (sec)
J+1		T''_{do} (>0) (sec)
J+2		T´qo (>0) (sec)
J+3		T''_{qo} (>0) (sec)
J+4		H, Inertia
J+5		D, Speed damping
J+6		X_d
J+7		X_q
J+8		X'_d
J+9		X'_q
J+10		$X''_d = X''_q$
J+11		X_l
J+12		S(1.0)
J+13		S(1.2)

Note: X_d, X_q, X'_d, X'_q, X''_d, X''_q, X_l, H, and D are in pu, machine MVA base.

X''_q must be equal to X''_d.

STATEs	Description
K	E'_q
K+1	E'_d
K+2	ψkd
K+3	ψkq
K+4	Δ speed (pu)
K+5	Angle (radians)

```
IBUS, 'GENROE', ID, CON(J) to CON(J+13)   /
```

1.19. GENROU

Round Rotor Generator Model (Quadratic Saturation)

CONs	Value	Description
J		T'_{do} (>0) (sec)
J+1		T''_{do} (>0) (sec)
J+2		T'_{qo} (>0) (sec)
J+3		T''_{qo} (>0) (sec)
J+4		H, Inertia
J+5		D, Speed damping
J+6		X_d
J+7		X_q
J+8		X'_d
J+9		X'_q
J+10		$X''_d = X''_q$
J+11		X_l
J+12		S(1.0)
J+13		S(1.2)

Note: X_d, X_q, X'_d, X'_q, X''_d, X''_q, X_l, H, and D are in pu, machine MVA base.

X''_q must be equal to X''_d.

STATEs	Description
K	E'_q
K+1	E'_d
K+2	ψkd
K+3	ψkq
K+4	Δ speed (pu)
K+5	Angle (radians)

```
IBUS, 'GENROU', ID, CON(J) to CON(J+13)   /
```

1.20. GENSAE

Salient Pole Generator Model (Exponential Saturation on Both Axes)

CONs	Value	Description
J		T'_{do} (>0) (sec)
J+1		T''_{do} (>0) (sec)
J+2		T''_{qo} (>0) (sec)
J+3		H, Inertia
J+4		D, Speed damping
J+5		X_d
J+6		X_q
J+7		X'_d
J+8		$X''_d = X''_q$
J+9		X_l
J+10		S(1.0)
J+11		S(1.2)

Note: X_d, X_q, X'_d, X''_d, X''_q, X_l, H, and D are in pu, machine MVA base.

X''_q must be equal to X''_d.

STATEs	Description
K	E'_q
K+1	ψ''_q
K+2	ψkd
K+3	Δ speed (pu)
K+4	Angle (radians)

```
IBUS, 'GENSAE', ID, CON(J) to CON(J+11)   /
```

1.21. GENSAL

Salient Pole Generator Model (Quadratic Saturation on d-Axis)

CONs	Value	Description
J		T'_{do} (>0) (sec)
J+1		T''_{do} (>0) (sec)
J+2		T''_{qo} (>0) (sec)
J+3		H, Inertia
J+4		D, Speed damping
J+5		X_d
J+6		X_q
J+7		X'_d
J+8		$X''_d = X''_q$
J+9		X_l
J+10		S(1.0)
J+11		S(1.2)

Note: X_d, X_q, X'_d, X''_d, X''_q, X_l, H, and D are in pu, machine MVA base.

X''_q must be equal to X''_d.

STATEs	Description
K	E'_q
K+1	ψkd
K+2	$\psi''q$
K+3	Δ speed (pu)
K+4	Angle (radians)

```
IBUS, 'GENSAL', ID, CON(J) to CON(J+11)   /
```

1.22. GENTPJ1

WECC Type J generator model

CONs	Value	Description
J		T'_{do} (sec), d-axis transient rotor time constant
J+1		T''_{d0} (sec), d-axis sub-transient rotor time constant
J+2		T'_{q0} (sec), q-axis transient rotor time constant
J+3		T''_{q0} (sec), q-axis sub-transient rotor time constant
J+4		Inertia, H (>0), Inertia constant
J+5		D (pu), Damping factor
J+6		X_d, d-axis synchronous reactance
J+7		X_q, q-axis synchronous reactance
J+8		X'_d, d-axis transient reactance
J+9		X'_q, q-axis transient reactance
J+10		X''_d, d-axis sub-transient reactance
J+11		X''_q, q-axis sub-transient reactance (set X"q = X"d)
J+12		X_l, stator leakage reactance
J+13		S(1.0), saturation factor at 1 pu flux
J+14		S(1.2) , saturation factor at 1.2 pu flux
J+15		K_{is} ($0 < K_is < 1$), current multiplier for saturation calculation

STATEs	Description
K	E''_q
K+1	E''_d
K+2	E'_q
K+3	E'_d
K+4	$\Delta\omega$ (Speed deviation)
K+5	Angle (radians)

VARs	Description
L	Internal VAR used for calculation (not to be changed by the user)

```
IBUS, 'GENTPJ1', ID, CON(J) through CON(J+15) /
```

Notes:

1. GENTPJ1 is a generator model in which saturation is considered through inductances. The stator current affects saturation via parameter K_{is}.
2. The model allows for X''_d and X''_q (i.e., CON(J+10) and CON(J+11)) to be different (i.e., the model can handle subtransient saliency).
3. In power flow, the imaginary part of ZSORCE should be set equal to X''_d.
4. To represent a solid rotor machine, all rotor time constants and the reactances X'_d, X''_d, X'_q and X''_q should all be greater than zero

5. To represent a salient pole machine with a single amortisseur circuit on each axis, set $T'_{qo}=0$, $X'_q=X_q$

6. Reactance values to be entered must be the unsaturated values. Saturation is accounted for via a quadratic relation using the saturation factors S(1.0) and S(1.2) specified in the model DYR data record. The saturation level is calculated as a function of the air-gap flux plus K_{is} times the magnitude of terminal current.

1.23. GENTRA

Transient Level Generator Model

CONs	Value	Description
J		T'_{do} (>0) (sec)
J+1		H, Inertia
J+2		D, Speed damping
J+3		X_d
J+4		X_q
J+5		X'_d
J+6		S(1.0)
J+7		S(1.2)
J+8		AF, Acceleration factor

Note: X_d, X_q, X'_d, H, and D are in pu, machine MVA base.

STATEs	Description
K	E'_q
K+1	Δ speed (pu)
K+2	Angle (radians)

VARs	Description
L	E'_d

```
IBUS, 'GENTRA', ID, CON(J) to CON(J+8)   /
```

1.24. PLBVFU1

Model to Play-In known voltage and/or frequency signal

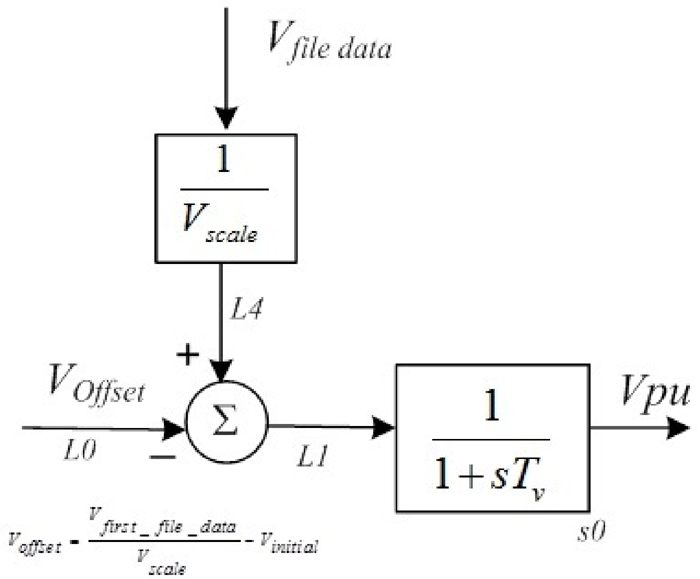
ICONs	Value	Description
M		Voltage playback flag (1: play voltage signal, else 0)
M+1		Frequency playback flag (1: play frequency signal, else 0)
M+2		Playback file name (in single quotes, without ".plb")

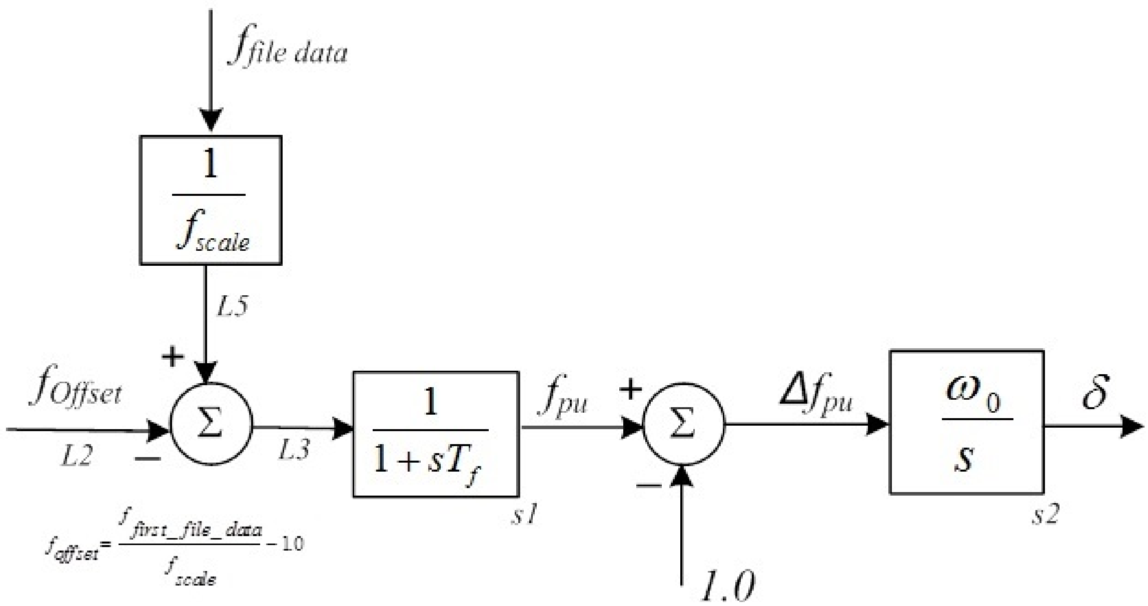
CONs	Value	Description
J		Vscale, voltage scaling factor (>0.0)
J+1		fscale, frequency scaling factor (>0.0)
J+2		Tv, filtering time constant for voltage signal (s)
J+3		Tf, filtering time constant for frequency signal (s)

STATEs	Description
K	Filtered voltage
K+1	Filtered Frequency
K+2	Angle (radians)

VARs	Description
L	Voffset
L+1	Input to voltage filter block
L+2	foffset
L+3	Input to frequency filter block
L+4	Scaled value of voltage signal
L+5	Scaled value of frequency signal

```
IBUS, 'USRMDL', ID, 'PLBVFU1', 1, 1, 3, 4, 3, 6, ICON(M) to
 ICON(M+2), CON(J) to CON(J+3) /
```





Notes:

1. This model plays back a known set of voltage and frequency signals.

2. The PLBVFU1 model acts as a generator model. In using this generator model, do not attach an AVR or governor model to the machine associated with the PLBVFU1 model.

3. To use the playback model PLBVFU1, a new machine has to be created in powerflow at the bus at which the voltage and frequency signals have to be played back. The PLBVFU1 model must be attached to this generator with the following conditions: Vscheduled = Vinitial of the bus, generator Pgen = 0.0, and generator QMAX=QMIN=0.0. When the powerflow is solved under such a condition, the bus voltage angle is expected to be the same as the initial bus voltage angle of that bus.

4. The played-in voltage and frequency signals must be described in a file as shown below, with each sample described in a separate record and the values in each line separated by spaces or commas:

   Time, voltage, frequency,

   where,

   Time: time of sample [s]

   Voltage: bus voltage magnitude at sample instant

   Frequency: bus frequency at sample instant

5. The samples need not be equally spaced in time. However, the value of time must appear in the file in increasing time sequence.

6. The sample values of voltage can be in units of volts or kV or in per unit. If the value of voltage sample is in units of volts or kV, then Vscale will be the base voltage value. Else, Vscale will have a value of 1.0.

   The sample values of frequency can be in units of Hz or in per unit. If the value of frequency sample is in Hz, then fscale value will be the base frequency value (50 or 60 Hz). Else, fscale will have a value of 1.0.

   The file containing the measurement has to be supplied in a file with an extension ".plb". The file name (without the ".plb" extension) has to be less than or equal to 12 characters long for version 34 and 2 characters long for version 33, and is to be input within single quotes in ICON(M+2). This file has to exist in the working folder. If the "plb" file is not found, the PLBVFU1 model will keep the internal voltage and frequency fixed at the initial value (i.e., the playback feature will be ignored).

   The "plb" file will have to contain the time values in the first column. The 2nd and 3rd columns will contain the voltage and frequency values respectively.

   To playback both the voltage and frequency signals, the ICON(M) and ICON(M+1) will have values of 1. To playback just the voltage signal but not the frequency signal, set ICON(M) to 1 and ICON(M+1) to 0. In this case, although the ".plb" file will contain the voltage and frequency points, only the voltage signal will be played back. Similarly, to playback just the frequency signal but not the voltage signal, set ICON(M) to -1 and ICON(M+1) to 0.

7. In the traditional GENCLS model, when operated as an infinite bus, the magnitude and phase of the internal voltage are given by the steady state value of Efd (field voltage) and the initial rotor angle (?). In the play-back model PLVFBU1, the magnitude of the internal voltage is given by Vpu, while the phase (?) of the internal voltage is obtained as the output of the integrator labeled s2 by integrating the frequency deviation signal.

8. The voltage signal which is played back is the internal (Thevenin) voltage of the playback generator. The ZSORCE of the generator used to represent the PLVFBU1 model should be non-zero. In case the voltage that is played back is a measurement of voltage at the generator terminals (rather than the internal voltage of a source), set the generator MVA to a very large value (e.g. 10,000 MVA) and a low ZSORCE

value (e.g. 0.01 pu). This will make the voltage drop across ZSORCE small such that the terminal voltage is the same as the played-in voltage.

9. In the ".plb" file, the first value of time need not necessarily be zero. However all values of time are stated relative to this first value of time, and must be in increasing order. The samples need not be equally spaced in time.

   The playback of the recorded voltage and frequency signal starts at or after the first time value (Tstart) in the ".plb" file.

   Prior to Tstart, the magnitude and frequency of the Thevenin voltage are held constant at their initial condition values. Once PSS®E simulation time becomes greater than or equal to the first time sample, the initial condition values are replaced by the values of the sample value. The effective sample value at each simulation time point is obtained by linear interpolation using the sample values immediately preceding and following the value of the present PSS®E simulation time.

   The values of voltage and frequency in the first sample need not be equal to the initial condition values of the Thevenin voltage and frequency. To deal with the difference between the initial sample values and the corresponding initial condition values, an off-set (Voffset and foffset) is calculated as the difference between the first sample and the corresponding simulation initial condition value.

10. The sampled voltage and frequency values may be smoothed via a first order block with time constants Tv (for voltage signal) and Tf (for frequency signal).

Chapter 2
Compensator Models

This chapter contains a collection of data sheets for the compensator models contained in the PSS®E dynamics model library.

Model	Description
CCOMP4U1	Cross-Current Compensation model with Reactive Current Feedback
COMP	Voltage regulator compensating model.
COMPCC	Cross compound compensating model.
IEEEVC	1981 IEEE voltage compensating model.
REMCMP	Remote bus voltage signal model.

2.1. CCOMP4U1

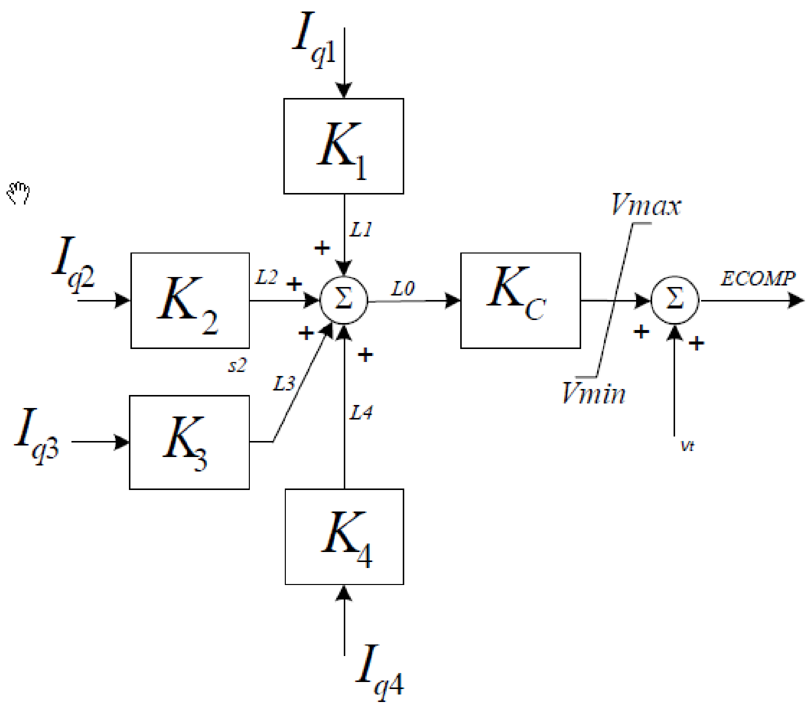
Cross-Current Compensation model with Reactive Current Feedback

ICONs	Value	Description
M		Bus number for unit 2
M+1		Machine id for Unit 2 (enter in single quotes)
M+2		Bus number for unit 3
M+3		Machine id for Unit 3 (enter in single quotes)
M+4		Bus number for unit 4
M+5		Machine id for Unit 4 (enter in single quotes)

CONs	Value	Description
J		K1, Compensation constant for unit 1 (pu of MBASE of unit 1)
J+1		K2, Compensation constant for unit 2 (pu of MBASE of unit 1)
J+2		K3, Compensation constant for unit 3 (pu of MBASE of unit 1)
J+3		K4, Compensation constant for unit 4 (pu of MBASE of unit 1)
J+4		Kc, Overall gain (pu of MBASE of unit 1)
J+5		Vmax, Maximum output (pu of MBASE of unit 1)
J+6		Vmin, Minimum output (pu of MBASE of unit 1)

VARs	Description
L	Input to Kc block
L+1	Output of K1 block
L+2	Output of K2 block
L+3	Output of K3 block
L+4	Output of K4 block

```
IBUS   'USRMDL'   ID   'CCOMP4U1'    2   0   6   7    0    5   ICONs from
 (M) to (M+5),  CONs from (J) to (J+6)      /
```



Notes:

1. This model allows for up to four machines to be linked by cross-current compensation.

2. The currents Iq1 through Iq4 are the reactive component of stator currents (i.e., the imaginary component of the total complex terminal current) of the respective generator.

3. The model is attached to the generator 1 (i.e., to the machine ID at bus IBUS in the DYR record). The bus number and the machine ID of the other three units are specified in ICON(M) through ICON(M+5).

4. All the four units can be on identical or different MVA bases. In PSS®E power flow, the XTRAN and RTRAN for these units should be set to zero (i.e., the GSU should not be modeled using the RTRAN and XTRAN).

5. To model line-drop compensation, specify the compensation constant as a negative value (which follows the IEEE 421.5 convention).

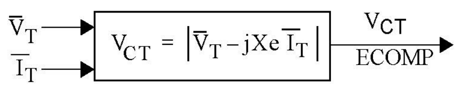
2.2. COMP

Voltage Regulator Current Compensating Model

CONs	Value	Description
J		X_e (machine base)

This model allows the voltage regulator of machine I to sense the voltage at a point separated from the machine terminals by an impedance of X_e.

```
IBUS, 'COMP', ID, CON(J)/
```



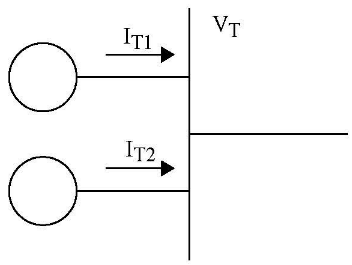
2.3. COMPCC

Voltage Regulator Current Compensating Model for Cross-Compound Units

CONs	Value	Description
J		R_1 (system base)
J+1		X_1 (system base)
J+2		R_2 (system base)
J+3		X_2 (system base)

This model allows the voltage regulators of machines I and M to sense the voltage separated from the machine terminals.

```
IBUS, 'COMPCC', ID, M, CON(J) to CON(J+3)   /
```



$$E_{COMP1} = V_T - \left(\frac{I_{T1} + I_{T2}}{2}\right)(R_1 + jX_1) + I_{T1}(R_2 + jX_2)$$

$$E_{COMP2} = V_T - \left(\frac{I_{T1} + I_{T2}}{2}\right)(R_1 + jX_1) + I_{T2}(R_2 + jX_2)$$

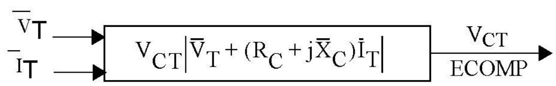
2.4. IEEEVC

Voltage Regulator Current Compensating Model

CONs	Value	Description
J		R_C (machine base)
J+1		X_C (machine base)

This model allows the voltage regulator of mMachine I to sense the voltage at a point separated from the machine terminals by an impedance of $R_C + jX_C$.

```
IBUS, 'IEEEVC', ID, CON(J) and CON(J+1)   /
```



2.5. REMCMP

Voltage Regulator Current Compensating Model

ICONs	Value	Description
M		Remote bus number, JBUS

This model allows the voltage regulator of machine ID to sense the voltage at a remote bus.

```
IBUS, 'REMCMP', ID, ICON(M)   /
```

Chapter 3
Stabilizer Models

This chapter contains a collection of data sheets for the stabilizer models contained in the PSS®E dynamics model library.

Model	Description
BEPSST	Transient excitation boosting stabilizer model
IEE2ST	Dual-input signal power system stabilizer model
IEEEST	1981 IEEE power system stabilizer model
IVOST	IVO stabilizer model
OSTB2T	Ontario Hydro delta-omega power system stabilizer
OSTB5T	Ontario Hydro delta-omega power system stabilizer
PSS1A	IEEE Std. 421.5-2005 PSS1A Single-Input Stabilizer model
PSS2A	1992 IEEE type PSS2A dual-input signal stabilizer model
PSS2B	IEEE 421.5 2005 PSS2B IEEE dual-input stabilizer model
PSS2CU1	IEEE 421.5 2016 PSS2C IEEE dual-input stabilizer model
PSS3B	IEEE Std. 421.5 2005 PSS3B IEEE dual-input stabilizer model
PSS4B	IEEE 421.5(2005) dual-input stabilizer model
PSS6CU1	IEEE 421.5(2016) dual-input stabilizer model
PSS7CU1	IEEE 421.5(2016) dual-input stabilizer model
PTIST1	PTI microprocessor-based stabilizer model
PTIST3	PTI microprocessor-based stabilizer model
ST2CUT	Dual-input signal power system stabilizer model
STAB1	Speed sensitive stabilizer model
STAB2A	ASEA power sensitive stabilizer model
STAB3	Power sensitive stabilizer model
STAB4	Power sensitive stabilizer model
STABNI	Power sensitive stabilizer model type NI (NVE)
STBSVC	WECC supplementary signal for static var system
SYNAXBU1	Synchronous Condenser Auxiliary Control Model

3.1. BEPSST

Transient Excitation Boosting PSS

ICONs	Value	Description
M		ICS_1, first stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+1		IB1, first remote bus number
M+2		IC2, second stabilizer input code
M+3		IB2, second remote bus number
M+4		ITS, trip signal; > 0 ≥ trip

CONs	Value	Description
J		K_1
J+1		K_2
J+2		T_1 (sec)
J+3		T_2 (sec)
J+4		T_3 (sec) [a]
J+5		T_4 (>0) (sec)
J+6		T_5 (sec)
J+7		T_6 (sec)
J+8		T_7 (sec)
J+9		T_8 (sec)
J+10		T_9 (sec)
J+11		T_{10} (sec)
J+12		L_{SMAX}
J+13		L_{SMIN}
J+14		V_{CU} (pu) (if equal zero, ignored)
J+15		V_{CL} (pu) (if equal zero, ignored)
J+16		K
J+17		T_{11} (sec)
J+18		T_{12} (sec)
J+19		C_{RT}
J+20		C_{LIM}

[a] If T_3 equals 0, sT_3 will equal 1.0.

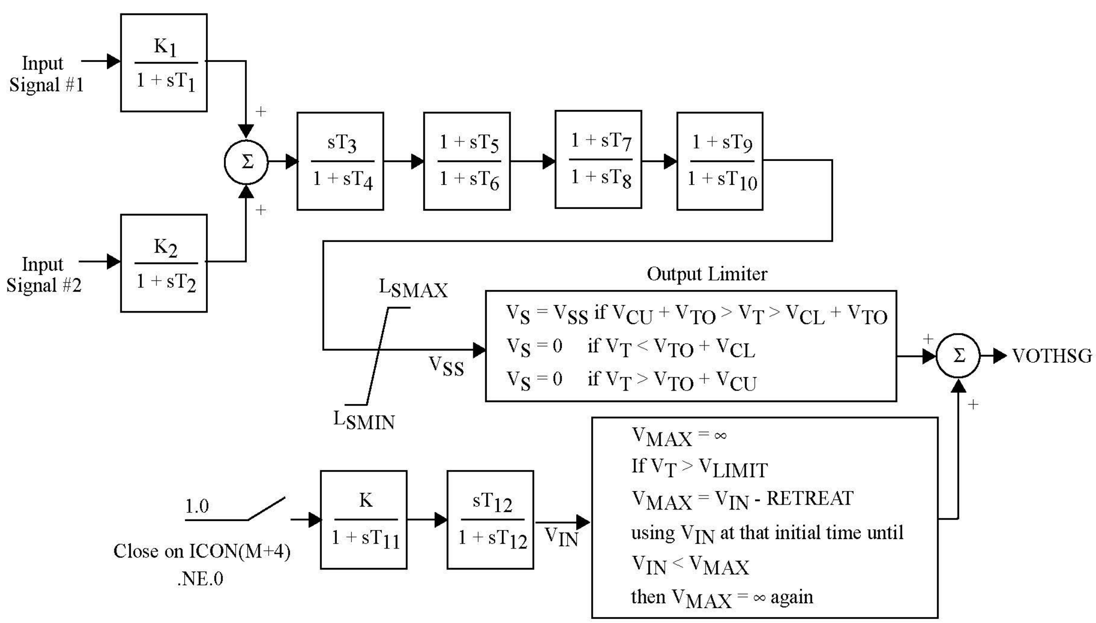
STATEs	Description
K	PSS state 1
K+1	PSS state 2
K+2	PSS state 3
K+3	PSS state 4
K+4	PSS state 5
K+5	PSS state 6
K+6	TEB state 1
K+7	TEB state 2

VARs	Description
L	Memory
L+1	Derivative of pu bus voltage (first bus)
L+2	Memory
L+3	Derivative of pu bus voltage (second bus)
L+4	Initial bus voltage (pu)
L+5	RETREAT
L+6	V_{MAX}

$$\mathrm{RETREAT} = C_{RT} \times \frac{T_{12}}{T_{12} - T_{11}}$$

$V_{Limit} = C_{LIM} * ETERM_{Initial}$

```
IBUS, 'BEPSST', ID, ICON(M) to ICON(M+4), CON(J) to CON(J+20)  /
```



V_T is the terminal voltage at bus IBUS.

V_{TO} is the initial terminal voltage at bus IBUS.

3.2. IEE2ST

IEEE Stabilizing Model With dual-input Signals

ICONs	Value	Description
M		ICS_1, first stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+1		IB1, first remote bus number
M+2		ICS2, second stabilizer input code
M+3		IB2, second remote bus number

CONs	Value	Description
J		K_1
J+1		K_2
J+2		T_1 (sec)
J+3		T_2 (sec)
J+4		T_3 (sec)[a]
J+5		T_4 (>0) (sec)
J+6		T_5 (sec)
J+7		T_6 (sec)
J+8		T_7 (sec)
J+9		T_8 (sec)
J+10		T_9 (sec)
J+11		T_{10} (sec)
J+12		L_{SMAX}
J+13		L_{SMIN}
J+14		V_{CU} (pu) (if equal zero, ignored.)
J+15		V_{CL} (pu) (if equal zero, ignored.)

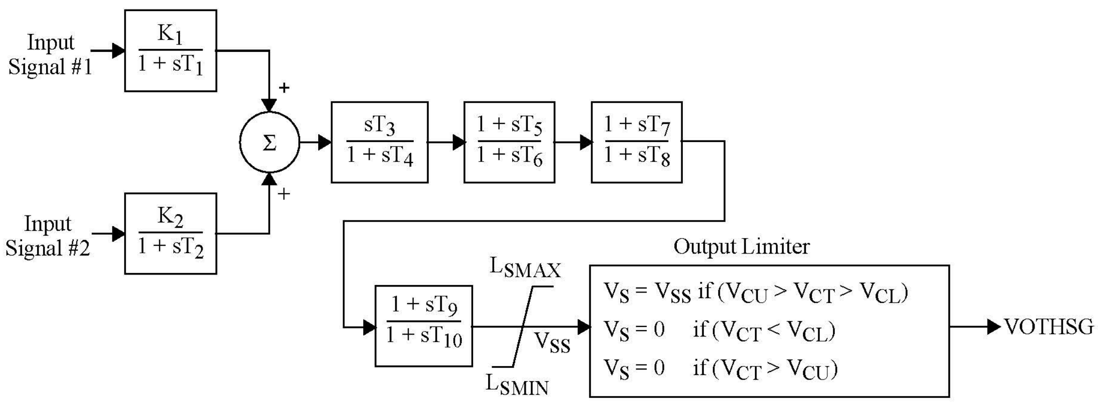
[a] If T_3 equals 0, sT_3 will equal 1.0.

STATEs	Description
K	First signal transducer
K+1	Second signal transducer
K+2	Washout
K+3	First lead-lag

STATEs	Description
K+4	Second lead-lag
K+5	Third lead-lag

VARs	Description
L	Memory
L+1	Derivative of pu bus voltage, first bus
L+2	Memory
L+3	Derivative of pu bus voltage, second bus

```
IBUS, 'IEE2ST', ID, ICON(M) to ICON(M+3), CON(J) to CON(J+15)   /
```



3.3. IEEEST

IEEE Stabilizing Model

ICONs	Value	Description
M		Stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage (pu) • 6 - Derivative of pu bus voltage
M+1		IB, remote bus number 2, 5, 6 [ab]

[a]ICON(M+1) may be nonzero only when ICON(M) is 2, 5, or 6.
[b]If ICON(M+1) is zero, the terminal quantity is used.

CONs	Value	Description
J		A_1
J+1		A_2
J+2		A_3
J+3		A_4
J+4		A_5
J+5		A_6
J+6		T_1 (sec)
J+7		T_2 (sec)
J+8		T_3 (sec)
J+9		T_4 (sec)
J+10		T_5 (sec) [a]
J+11		T_6 (>0) (sec)
J+12		K_S
J+13		L_{SMAX}
J+14		L_{SMIN}
J+15		V_{CU} (pu) (if equal zero, ignored)
J+16		V_{CL} (pu) (if equal zero, ignored.)

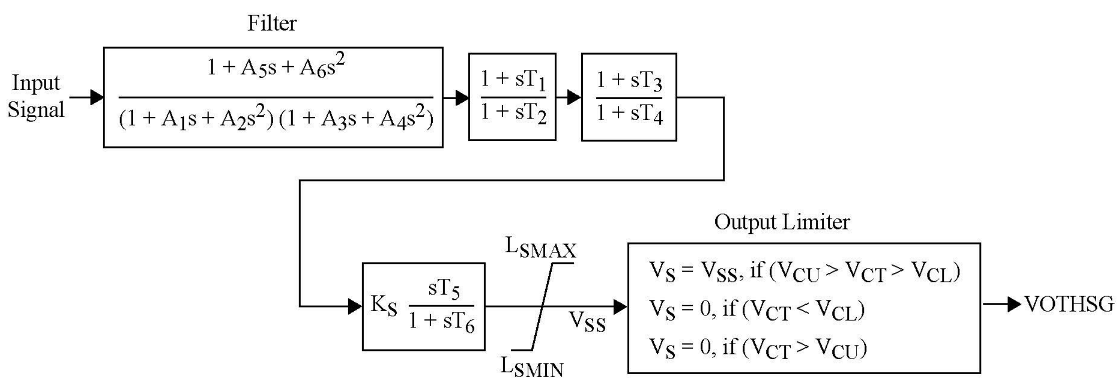
[a]If T_5equals 0, sT_5 will equal 1.0.

STATEs	Description
K	1st filter integration
K+1	2nd filter integration
K+2	3rd filter integration

STATEs	Description
K+3	4th filter integration
K+4	T_1/T_2 lead-lag integrator
K+5	T_3/T_4 lead-lag integrator
K+6	Last integer

VARs	Description
L	Memory
L+1	Derivative of pu bus voltage

```
IBUS, 'IEEEST', ID, ICON(M) and ICON(M+1), CON(J) to CON(J+16)   /
```



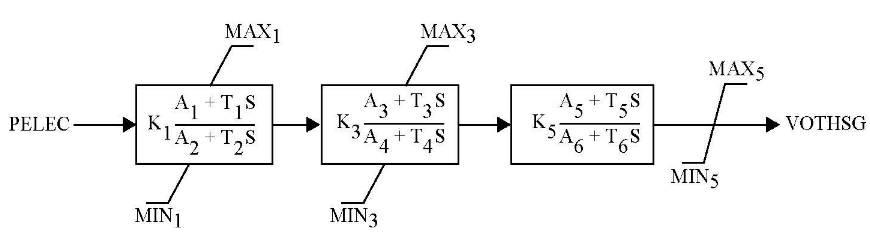
3.4. IVOST

IVO Stabilizer Model

CONs	Value	Description
J		K_1
J+1		A_1
J+2		A_2
J+3		T_1
J+4		T_2
J+5		MAX_1
J+6		MIN_1
J+7		K_3
J+8		A_3
J+9		A_4
J+10		T_3
J+11		T_4
J+12		MAX_3
J+13		MIN_3
J+14		K_5
J+15		A_5
J+16		A_6
J+17		T_5
J+18		T_6
J+19		MAX_5
J+20		MIN_5

STATEs	Description
K	Integrator 1
K+1	Integrator 2
K+2	Integrator 3

```
IBUS, 'IVOST', ID, CON(J) to CON(J+20)   /
```



3.5. OSTB2T

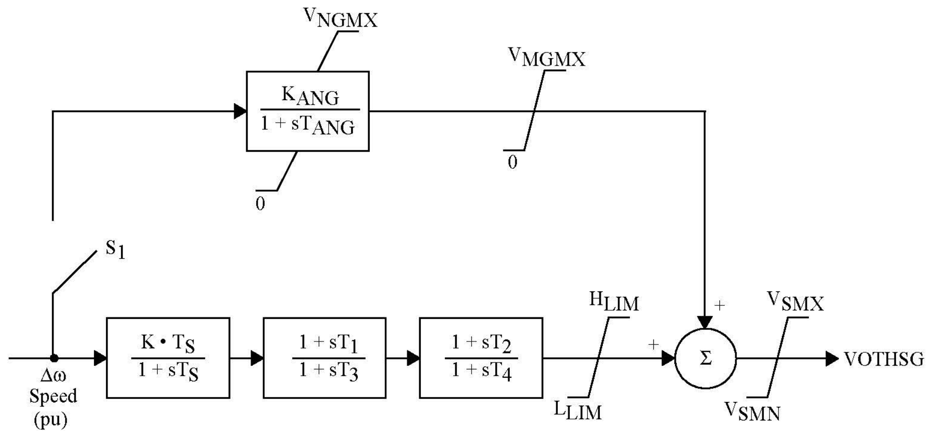
Ontario Hydro Delta-Omega Power System Stabilizer

CONs	Value	Description
J		K
J+1		T_S (>0) (sec)
J+2		T_1/T_3
J+3		T_3 (>0) (sec)
J+4		T_2/T_4
J+5		T_4 (>0) (sec)
J+6		H_{LIM}
J+7		L_{LIM}
J+8		K_{ANG} (>0)
J+9		T_{ANG}
J+10		V_{NGMX}
J+11		V_{MGMX}
J+12		T-ON
J+13		T-OFF
J+14		V_{SMX}
J+15		V_{SMN}
J+16		$\Delta\omega_{THR}$
J+17		E_{THR}
J+18		EFD_{THR}
J+19		T_{SEAL}

STATEs	Description
K	Washout T_S block
K+1	Lead-lag T_1/T_3 block
K+2	Lead-lag T_2/T_4 block
K+3	T_{ANG} block

VARs	Description
L	S_1
L+1	T_{SEC} duration
L+2	T_{SEAL} duration

```
IBUS, 'OSTB2T', ID, CON(J) to CON(J+19)   /
```



TSEC Switching Logic

Notes:

1. S_1 normally open.
2. S_1 closes if $E_t < E_{THR}$ and $\Delta\omega > \Delta\omega_{THR}$ or $\Delta\omega > \Delta\omega_{THR}$ within T_{SEAL} seconds of last time $E_t < E_{THR}$.
3. Once closed, S_1 remains closed for at least T-ON seconds.
4. S_1 opens if:
   a. $\Delta\omega < \Delta\omega_{THR}$, or
   b. $EFD < EFD_{THR}$, or
   c. after being closed for T-OFF seconds.
5. Once open, stays open.

3.6. OSTB5T

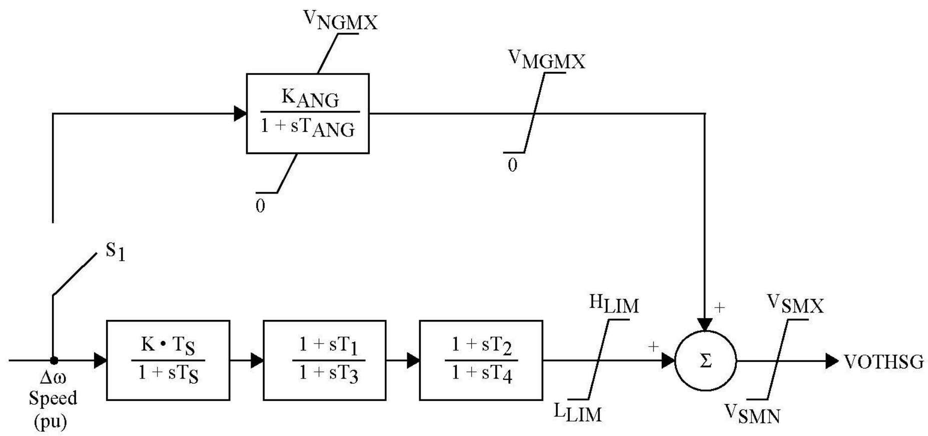
Ontario Hydro Delta-Omega Power System Stabilizer

CONs	Value	Description
J		K
J+1		T_S (>0) (sec)
J+2		T_1 (sec)
J+3		T_2(sec)
J+4		T_3/T_4
J+5		T_4 (>0) (sec)
J+6		H_{LIM}
J+7		L_{LIM}
J+8		K_{ANG} (>0)
J+9		T_{ANG}
J+10		V_{NGMX}
J+11		V_{MGMX}
J+12		T-ON
J+13		T-OFF
J+14		V_{SMX}
J+15		V_{SMN}
J+16		$\Delta\omega_{THR}$
J+17		E_{THR}
J+18		EFD_{THR}
J+19		T_{SEAL}

STATEs	Description
K	Washout T_S block
K+1	Quadratic lead-lag block
K+2	Quadratic lead-lag block
K+3	T_{ANG} block

VARs	Description
L	S_1
L+1	T_{SEC} duration
L+2	T_{SEAL} duration

```
IBUS, 'OSTB5T', ID, CON(J) to CON(J+19)   /
```



TSEC Switching Logic

1. S_1 normally open.
2. S_1 closes if $Et < E_{THR}$ and $\Delta\omega > \Delta\omega_{THR}$ or $\Delta\omega > \Delta\omega_{THR}$ within T_{SEAL} seconds of last time $Et < E_{THR}$.
3. Once closed, S_1 remains closed for at least T-ON seconds.
4. S_1 opens if:
   a. $\Delta\omega < \Delta\omega_{THR}$, or
   b. $EFD < EFD_{THR}$, or
   c. after being closed for T-OFF seconds.
5. Once open, stays open.

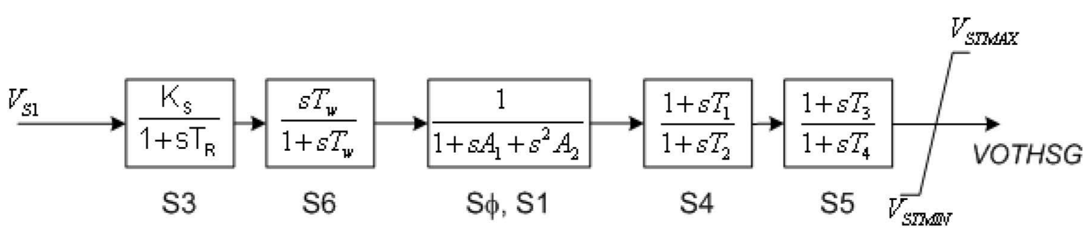
3.7. PSS1A

IEEE Std. 421.5-2005 PSS1A Single-Input Stabilizer Model

The PSS®E model IEEEST can be used to simulate the PSS1A model. The correspondence between the IEEEST model CONs and the PSS1A parameters (shown in the block) diagram are as given in the table below.

CONs	Value	Description
J	A_1	A_1
J+1	A_2	A_2
J+2	A_3	T_r
J+3	A_4	0.0
J+4	A_5	0.0
J+5	A_6	0.0
J+6	T_1	T_1
J+7	T_2	T_2
J+8	T_3	T_3
J+9	T_4	T_4
J+10	T_5	T_W
J+11	T_6	T_W
J+12	K_S	K_S
J+13	L_{SMAX}	V_{STMAX}
J+14	L_{SMIN}	V_{STMIN}
J+15	V_{CU}	0.0
J+16	V_{CL}	0.0

```
IBUS, 'IEEEST', ID, ICON(M), ICON(M+1), CON(J) to CON(J+16)   /
```



3.8. PSS2A

IEEE Dual-Input Stabilizer Model

ICONs	Value	Description
M		ICS_1, first stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+1		$REMBUS_1$, first remote bus number
M+2		ICS_2, second stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+3		REMBUS2, second remote bus number
M+4		M, ramp tracking filter
M+5		N, ramp tracking filter

CONs	Value	Description
J		T_{w1} (>0)
J+1		T_{w2}
J+2		T_6
J+3		T_{w3} (>0)
J+4		T_{w4}
J+5		T_7
J+6		K_{S2}
J+7		K_{S3}
J+8		T_8
J+9		T_9 (>0)
J+10		K_{S1}

CONs	Value	Description
J+11		T_1
J+12		T_2
J+13		T_3
J+14		T_4
J+15		V_{STMAX}
J+16		V_{STMIN}

STATEs	Description
K	Washout, first signal
K+1	Washout, first signal
K+2	Transducer, first signal
K+3	Washout, second signal
K+4	Washout, second signal
K+5	Transducer, second signal
K+6 . . . K +13	Ramp Tracking Filter
K+14	First lead-lag
K+15	Second lead-lag

VARs	Description
L	Memory
L+1	Derivative of pu bus voltage, first bus
L+2	Memory
L+3	Derivative of pu bus voltage, second bus

```
IBUS, 'PSS2A', ID, ICON(M) to ICON(M+5), CON(J) to CON(J+16)   /
```

Notes:

Ramp Tracking Filter

$M \geq 0$

$N \geq 0$

$M * N \leq 8$

If $M = 0$, then N is set equal to 0

To bypass: set $M = N = 0$

Washouts

To bypass second washout, first signal: set $T_{w2} = 0$

To bypass second washout, second signal: set $T_{w4} = 0$

Transducers

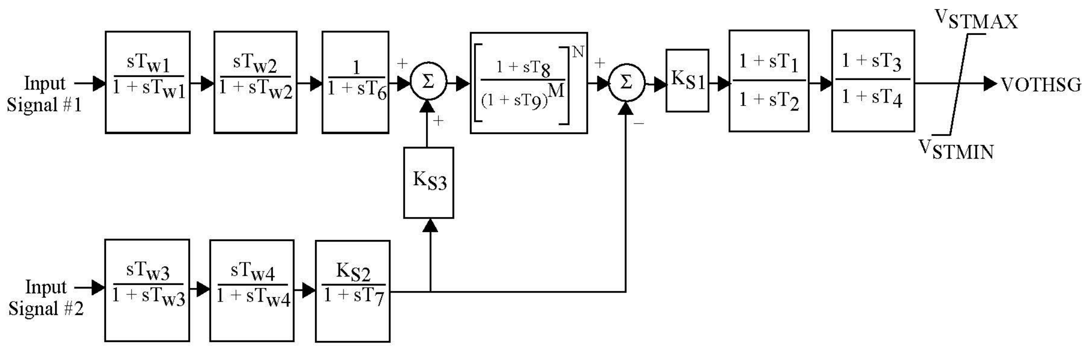
To bypass first signal transducer: set $T_6 = 0$

To bypass second signal transducer: set $T_7 = 0$

Lead-Lags

To bypass first lead-lag: set $T_1 = T_2 = 0$

To bypass second lead-lag: set $T_3 = T_4 = 0$



3.9. PSS2B

IEEE 421.5 2005 PSS2B IEEE Dual-Input Stabilizer Model

ICONs	Value	Description
M		ICS_1, first stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+1		$REMBUS_1$, first remote bus to be entered as 0 for input codes 1, 3, and 4.
M+2		ICS_2, second stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+3		REMBUS2, second remote bus to be entered as 0 for input codes 1, 3, and 4.
M+4		M, ramp tracking filter
M+5		N, ramp tracking filter

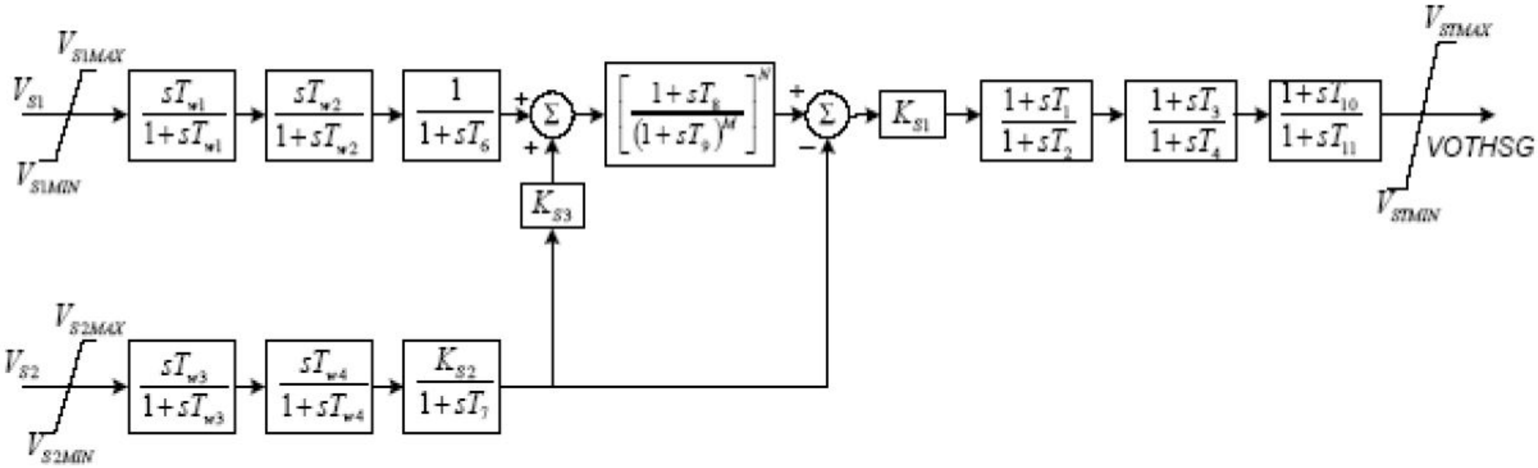
CONs	Value	Description
J		T_{w1} (> 0)
J+1		T_{w2}
J+2		T_6
J+3		T_{w3}
J+4		T_{w4}
J+5		T_7
J+6		K_{S2}
J+7		K_{S3}
J+8		T_8

CONs	Value	Description
J+9		T_9 (> 0)
J+10		K_{S1}
J+11		T_1
J+12		T_2
J+13		T_3
J+14		T_4
J+15		T_{10}
J+16		T_{11}
J+17		VS_1MAX
J+18		VS_1MIN
J+19		V_{S2MAX}
J+20		V_{S2MIN}
J+21		V_{STMAX}
J+22		V_{STMIN}

STATEs	Description
K	Washout-first signal
K+1	Washout-first signal
K+2	Transducer-first signal
K+3	Washout-second signal
K+4	Washout-second signal
K+5	Transducer-second signal
K+6 . . . K+13	Ramp tracking filter
K+14	First lead-lag
K+15	Second lead-lag
K+16	Third lead-lag

VARs	Description
L	Memory
L+1	Derivative of pu bus voltage-first bus
L+2	Memory
L+3	Derivative of pu bus voltage-second bus

```
IBUS, 'PSS2B', ID, ICON(M) to ICON(M+5), CON(J) to CON(J+22)   /
```


VOTHSG

3.10. PSS2CU1

IEEE 421.5 2016 PSS2CU1 IEEE Dual-Input Stabilizer Model

ICONs	Value	Description
M		ICS_1, first stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage • 7 - Compensated Frequency
M+1		REMBUS1, first remote bus number
M+2		ICS_2, second stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+3		REMBUS2, second remote bus number
M+4		M, ramp tracking filter
M+5		N, ramp tracking filter

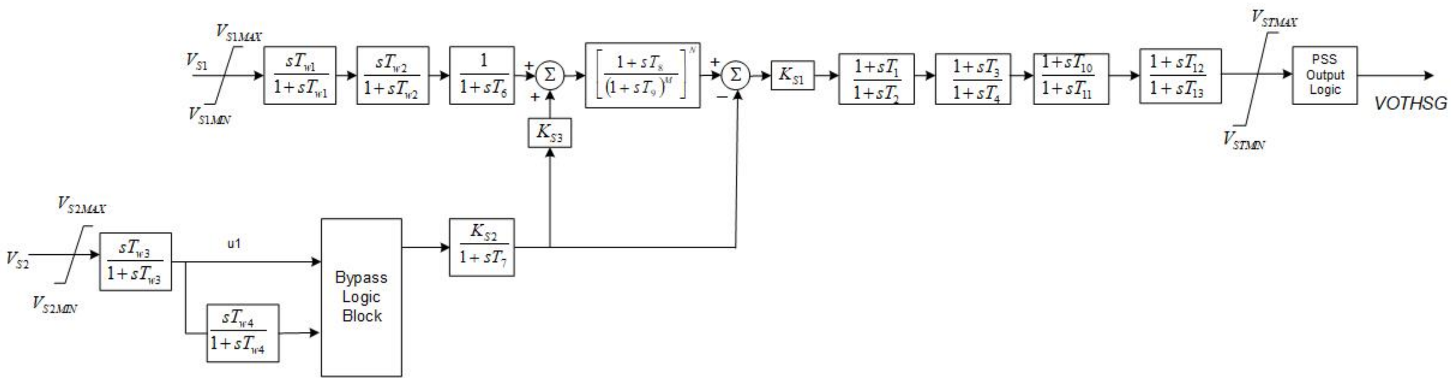
CONs	Value	Description
J		T_{w1}, First Washout Time constant - Signal 1
J+1		K_{w2}, Second Washout Time Constant - Signal 1
J+2		T_6, Lag Time Constant - Signal 1
J+3		T_{w3}, First Washout Time Constant - Signal 2
J+4		T_{w4}, Second Washout Time Constant - Signal 2
J+5		T_7, Lag Time Constant - Signal 2
J+6		K_{S2}, Gain for Signal 2
J+7		K_{S3}, Gain before Ramp Tracking Filter
J+8		T_8, Ramp Tracking Filter Lead Time Constant

CONs	Value	Description
J+9		T_9, Ramp Tracking Filter Lag Time Constant
J+10		K_{S1}, Stabilizer Gain
J+11		T_1, Lead Time Constant - Phase Comp. Block 1
J+12		T_2, Lag Time Constant - Phase Comp. Block 1
J+13		T_3, Lead Time Constant - Phase Comp. Block 2
J+14		T_4, Lag Time Constant - Phase Comp. Block 2
J+15		T_{10}, Lead Time Constant - Phase Comp. Block 3
J+16		T_{11}, Lag Time Constant - Phase Comp. Block
J+17		V_{S1MAX}, Stabilizer Input Maximum. Input 1
J+18		V_{S1MIN}, Stabilizer Input Minimum. Input 1
J+19		V_{S2MAX}, Stabilizer Input Maximum. Input 2
J+20		V_{S2MIN}, Stabilizer Input Maximum. Input 2
J+21		V_{STMAX}, Stabilizer Output Maximum Limit
J+22		V_{STMIN}, Stabilizer Output Minimum Limit
J+23		T_{12}, Lead Time Constant - Phase Comp. Block 4
J+24		T_{13}, Lag Time Constant - Phase Comp. Block 4
J+25		PSSON, Parameter for electrical signal - ON
J+26		PSSOFF, Parameter for electrical signal - OFF
J+27		Xcomp, reactance associated with compensated frequency
J+28		Tcomp, Time measured with compensated frequency (> 0)

STATEs	Description
K	First Washout - First Signal
K+1	Second Washout - First Signal
K+2	Transducer - First Signal
K+3	First Washout-second signal
K+4	Second Washout-second Signal
K+5	Transducer Second Signal
K+6 . . . K+13	Ramp tracking filter
K+14	First Lead-Lag Block
K+15	Second Lead-Lag Block
K+16	Third Lead-Lag Block
K+17	Fourth Lead-Lag Block
K+18	Washout Block for compensated frequency

VARs	Description
L	Memory
L+1	Derivative of pu bus voltage-first bus
L+2	Memory
L+3	Derivative of pu bus voltage-second bus
L+4	Compensated Frequency Signal

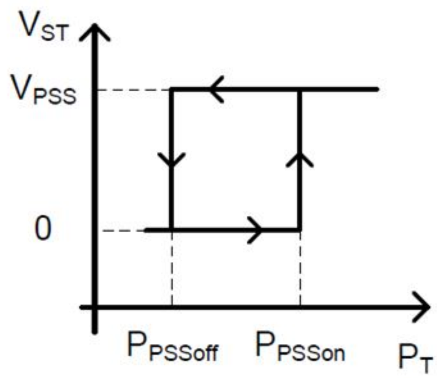
```
IBUS 'USRMDL' ID  'PSS2CU1' 3   0   6   29  19  5   ICON(M) to ICON(M+5),
 CON(J) to CON(J+28)   /
```



Notes:

1. Bypass Logic: The Washout Block is bypassed if associated Time constant is set to zero. If $T_{w4} = 0$, y = u1 ELSE y= u2

2. The PSS output logic: Uses user selected parameters P_{SSON} and P_{SSOFF}. It also uses V_{PSS} shown in the block diagram, and the generator electrical output P_T. The output logic implements the following hysteresis to define the output signal V_{ST}



- P_{SSON} and P_{SSOFF} are in pu of machine base
- To enable PSS output logic specify $P_{SSON} > 0$
- To disable PSS output logic specify $P_{SSON} < 0$

3. The first signal input ICS1 can be the compensated frequency.The signal is passed through a washout block and is fed into the stabilizer as the input signal. Reference regarding the compensated frequency can be found in this paper from Kestrel Power Engineering: "Accelerating-Power Based Power System Stabilizers"

3.11. PSS3B

IEEE 421.5 2005 PSS2B IEEE Dual Input Stabilizer Model

ICONs	Value	Description
M		ICS_1, code for first channel stabilizer input variable: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage
M+1		Remote bus number associated with input variable for channel 1
M+2		ICS_2, code for second channel stabilizer input variable: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage
M+3		Remote bus number associated with input variable for channel 2

CONs	Value	Description
J		K_{S1} (pu) (≠0), input channel #1 gain
J+1		T_1 input channel #1 transducer time constant (sec)
J+2		T_{w1} input channel #1 washout time constant (sec)
J+3		K_{S2} (pu) (≠0), input channel #2 gain
J+4		T_2 input channel #2 transducer time constant (sec)
J+5		T_{w2} input channel #2 washout time constant (sec)
J+6		T_{w3} (0), main washout time constant (sec)
J+7		A_1
J+8		A_2
J+9		A_3
J+10		A_4
J+11		A_5
J+12		A_6
J+13		A_7
J+14		A_8
J+15		V_{STMAX} (pu), stabilizer output maximum limit
J+16		V_{STMIN} (pu), stabilizer output minimum limit

STATEs	Description
K	Time lead block (first signal)
K+1	Time lead block (second signal)
K+2	First signal washout
K+3	Second signal washout
K+4	Washout block
K+5	First two-order block
K+6	First two-order block
K+7	Second two-order block
K+8	Second two-order block

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IBUS, 'PSS3B', ID, ICON(M) to ICON(M+3), CON(J) to CON(J+16)   /
```
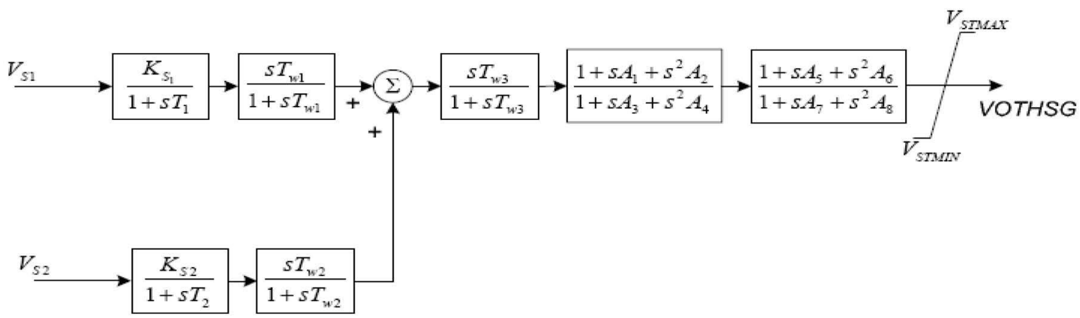



3.12. PSS4B

IEEE 421.5(2005) Dual-Input Stabilizer Model

CONs	Value	Description
J		C_{L-I}
J+1		D_{L-I}
J+2		A_{L-I} (>0)
J+3		B_{L-I}
J+4		$B\omega_{L-I1}$
J+5		ω_{L-I1}
J+6		$B\omega_{L-I2}$
J+7		ω_{L-I2}
J+8		T_H (>0)
J+9		AH (>0)
J+10		BH
J+11		M
J+12		$B\omega_{H1}$
J+13		ω_{H1}
J+14		$B\omega_{H2}$
J+15		ω_{H2}
J+16		K_{L1}
J+17		K_{L11}
J+18		T_{L1}
J+19		T_{L2}
J+20		T_{L3}
J+21		T_{L4}
J+22		T_{L5}
J+23		T_{L6}
J+24		K_L2
J+25		$K_{L1}7$
J+26		T_{L7}
J+27		T_{L8}
J+28		T_{L9}
J+29		T_{L10}
J+30		T_{L11}
J+31		T_{L12}
J+32		K_L
J+33		V_{Lmax}
J+34		V_{Lmin}
J+35		K_{I1}
J+36		K_{I11}

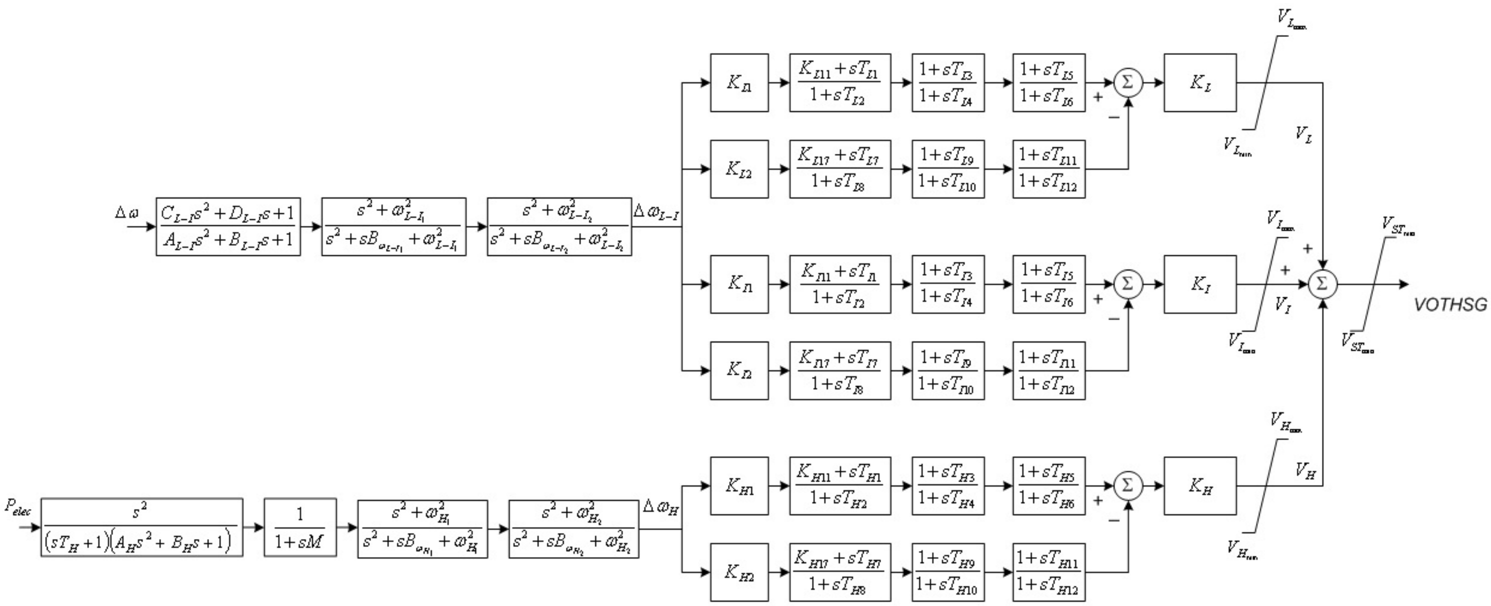
CONs	Value	Description
J+37		T_{I1}
J+38		T_{I2}
J+39		T_{I3}
J+40		T_{I4}
J+41		T_{I5}
J+42		T_{I6}
J+43		K_{I2}
J+44		K_{I17}
J+45		T_{I7}
J+46		T_{I8}
J+47		T_{I9}
J+48		T_{I10}
J+49		T_{I11}
J+50		T_{I12}
J+51		K_I
J+52		V_{IMAX}
J+53		V_{IMIN}
J+54		K_H1
J+55		K_{H11}
J+56		T_{H1}
J+57		T_{H2}
J+58		T_{H3}
J+59		T_{H4}
J+60		T_{H5}
J+61		T_{H6}
J+62		K_{H2}
J+63		K_{H17}
J+64		T_{H7}
J+65		T_{H8}
J+66		T_{H9}
J+67		T_{H10}
J+68		T_{H11}
J+69		$T_{H1}2$
J+70		K_H
J+71		V_{Hmax}
J+72		V_{Hmin}
J+73		V_{STMAX}
J+74		V_{STMIN}

STATEs	Description
K	First signal transducer

STATEs	Description
K+1	
K+2 K+3	First notch filter (first signal)
K+4 K+5	Second notch filter (first signal)
K+6 K+7 K+8	Second signal transducer
K+9	Time lag block (second signal)
K+10 K+11	First Notch filter (second signal)
K+12 K+13	Second notch filter (second signal)
K+14	Lead-lag (low frequency, part 1)
K+15	Lead-lag (low frequency, part 1)
K+16	Lead-lag (low frequency, part 1)
K+17	Lead-lag (low frequency, part 2)
K+18	Lead-lag (low frequency, part 2)
K+19	Lead-lag (low frequency, part 2)
K+20	Lead-lag (medium frequency, part 1)
K+21	Lead-lag (medium frequency, part 1)
K+22	Lead-lag (medium frequency, part 1)
K+23	Lead-lag (medium frequency, part 2)
K+24	Lead-lag (medium frequency, part 2)
K+25	Lead-lag (medium frequency, part 2)
K+26	Lead-lag (high frequency, part 1)
K+27	Lead-lag (high frequency, part 1)
K+28	Lead-lag (high frequency, part 1)
K+29	Lead-lag (high frequency, part 2)
K+30	Lead-lag (high frequency, part 2)
K+31	Lead-lag (high frequency, part 2)

VARs	Description
L	$\Delta\omega_{L-I}$
L+1	$\Delta\omega_H$
L+2	V_L
L+3	V_I
L+4	V_H

```
IBUS, 'PSS4B', ID, CON(J) to CON(J+74)   /
```



Δω
Δω_{L-I}
P_{elec}
Δω_H
K_L
K_I
K_H
V_L
V_I
V_H
VOTHSG

3.13. PSS6CU1

IEEE 421.5 2016 PSS6CU1 IEEE Dual-Input Stabilizer Model

ICONs	Value	Description
M		ICS_1, first stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage • 7 - Compensated Frequency Signal
M+1		REMBUS1, first remote bus number
M+2		ICS_2, second stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+3		REMBUS2, second remote bus number

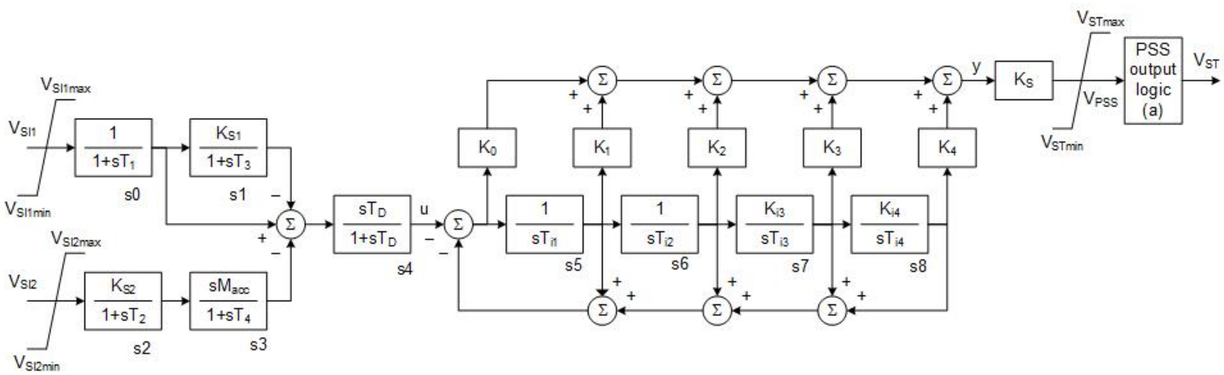
CONs	Value	Description
J		T_1, Lag Time Constant - Signal 1
J+1		K_{S2}, Gain for Signal 2
J+2		T_2, Lag Time Constant - Signal 2
J+3		K_{S1}, Gain for Signal 1
J+4		T_3, Lag Time Constant - Signal 1
J+5		M_{ACC}, PSS Washout Time constant for Signal 2
J+6		T_4, Washout Block Tiem Constant - Signal 2
J+7		T_D, PSS Washout Time constant
J+8		K_0, PSS Canonical Gain 0
J+9		K_1, PSS Canonical Gain 1

CONs	Value	Description
J+10		K_2, PSS Canonical Gain 2
J+11		K_3, PSS Canonical Gain 3
J+12		K_4, PSS Canonical Gain 4
J+13		T_{i1}, PSS Time Constant (First Block)
J+14		T_{i2}, PSS Time Constant (Second Block)
J+15		K_{i3}, PSS Third Block Gain
J+16		T_{i3}, PSS Time Constant (Third Block)
J+17		K_{i4}, PSS Fourth Block Gain
J+18		T_{i4}, PSS Time Constant (Fourth Block)
J+19		K_S, PSS Main gain
J+20		V_{SI1MAX}, Stabilizer Input Maximum Input 1
J+21		V_{SL1MIN}, Stabilizer Input Minimum Input 1
J+22		V_{SI2MAX}, Stabilizer Input Maximum Input 2
J+23		V_{SL2MIN}, Stabilizer Input Minimum Input 2
J+24		V_{STMAX}, Stabilizer Output Maximum Limit
J+25		V_{STMIN}, Stabilizer Output Minimum Limit
J+26		PSSON, Parameter for electrical signal - ON
J+27		PSSOFF, Parameter for electrical signal - OFF
J+28		Xcomp, reactance associated with compensated frequency
J+29		Tcomp, Time measured with compensated frequency (> 0)

STATEs	Description
K	First Transducer - First Signal
K+1	Second Transducer - First Signal
K+2	First Transducer - Second Signal
K+3	Washout-second signal
K+4	PSS Washout Signal
K+5	First Integrator
K+6	Second Integrator
K+7	Third Integrator
K+8	Fourth Integrator

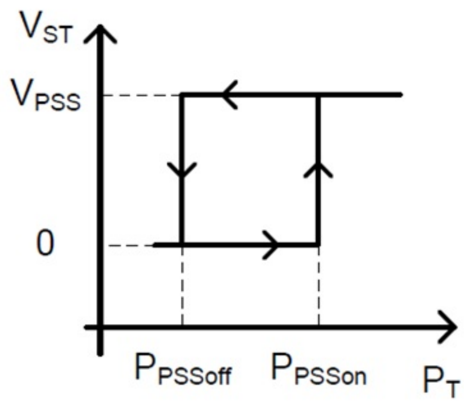
VARs	Description
L	Memory
L+1	Derivative of pu bus voltage-first bus
L+2	Memory
L+3	Derivative of pu bus voltage-second bus
L+4	Compensated Frequency Signal

```
IBUS 'USRMDL' ID  'PSS6CU1' 3   0   4   30  10  5   ICON(M) to ICON(M+3),
 CON(J) to CON(J+29)   /
```



Notes:

1. The PSS output logic: Uses user selected parameters P_{SSON} and P_{SSOFF}. It also uses V_{PSS} shown in the block diagram, and the generator electrical output P_T. The output logic implements the following hysteresis to define the output signal V_{ST}



a. P_{SSON} and P_{SSOFF} are in pu of machine base

b. To enable PSS output logic specify $P_{SSON} < 0$

c. To disable PSS output logic specify $P_{SSON} > 0$

3. The first signal input ICS1 can be the compensated frequency.The signal is passed through a washout block and is fed into the stabilizer as the input signal. Reference regarding the compensated frequency can be found in this paper from Kestrel Power Engineering: “Accelerating-Power Based Power System Stabilizers”

3.14. PSS7CU1

IEEE 421.5 2016 PSS7CU1 IEEE Dual-Input Stabilizer Model

ICONs	Value	Description
M		ICS_1, first stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage • 7 - Compensated Frequency Signal
M+1		REMBUS1, first remote bus number
M+2		ICS_2, second stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+3		REMBUS2, second remote bus number
M+4		M, ramp tracking filter
M+5		N, ramp tracking filter

CONs	Value	Description
J		T_{w1}, First Washout Time constant - Signal 1
J+1		K_{w2}, Second Washout Time Constant - Signal 1
J+2		T_6, Lag Time Constant - Signal 1
J+3		T_{w3}, First Washout Time Constant - Signal 2
J+4		T_{w4}, Second Washout Time Constant - Signal 2
J+5		T_7, Lag Time Constant - Signal 2
J+6		K_{S2}, Gain for Signal 2
J+7		K_{S3}, Gain before Ramp Tracking Filter
J+8		T_8, Ramp Tracking Filter Lead Time Constant
J+9		T_9, Ramp Tracking Filter Lag Time Constant

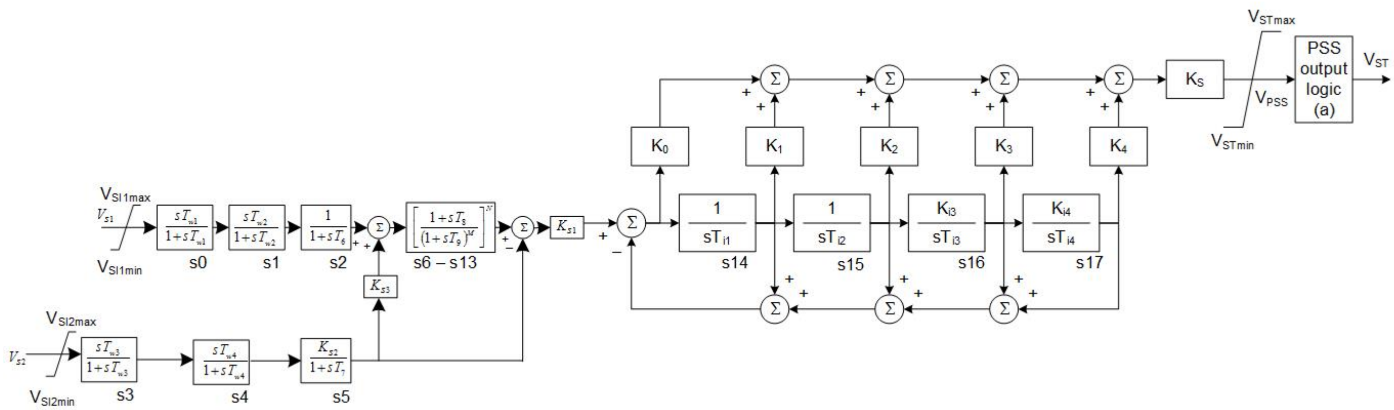
CONs	Value	Description
J+10		K_{S1}, Stabilizer Gain
J+11		K_0 PSS Canonical Gain 0
J+12		K_1 PSS Canonical Gain 1
J+13		K_2 PSS Canonical Gain 2
J+14		K_3 PSS Canonical Gain 3
J+15		K_4 PSS Canonical Gain 4
J+16		T_{i1} PSS Time Constant (First Block)
J+17		T_{i2} PSS Time Constant (Second Block)
J+18		K_{i3} PSS Canonical Gain 3
J+19		T_{i3} PSS Time Constant (Third Block)
J+20		K_{i4} PSS Fourth Block Gain
J+21		T_{i4} PSS Time Constant (Fourth Block)
J+22		V_{SL1MAX} Stabilizer Input Maximum Input 1
J+23		V_{SL1MIN} Stabilizer Input Minimum Input 1
J+24		V_{SL2MAX} Stabilizer Input Maximum Input 2
J+25		V_{SL2MIN} Stabilizer Input Minimum Input 2
J+26		V_{STMAX} Stabilizer Output Maximum Limit
J+27		V_{STMIN} Stabilizer Output Minimum Limit
J+28		PSSON Parameter for electrical signal - ON
J+29		PSSOFF Parameter for electrical signal - OFF
J+30		Xcomp, reactance associated with compensated frequency
J+31		Tcomp, Time measured with compensated frequency (> 0)

STATEs	Description
K	First Washout - First Signal
K+1	Second Washout - First Signal
K+2	Transducer - First Signal
K+3	First Washout-second signal
K+4	Second Washout-second Signal
K+5	Transducer Second Signal
K+6 . . . K+13	Ramp tracking filter
K+14	First Integrator
K+15	Second Integrator
K+16	Third Integrator
K+17	Fourth Integrator
K+18	Washout Block for compensated frequency

VARs	Description
L	Memory
L+1	Derivative of pu bus voltage-first bus
L+2	Memory

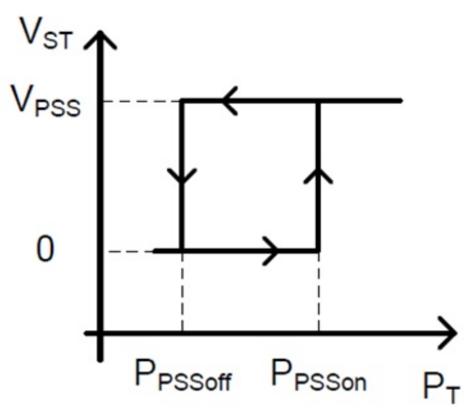
VARs	Description
L+3	Derivative of pu bus voltage-second bus
L+4	Compensated Frequency Signal

```
IBUS 'USRMDL' ID 'PSS7CU1' 3  0  6  32  19  5  ICON(M) to ICON(M+5),
 CON(J) to CON(J+31)  /
```



Notes:

1. The PSS output logic: Uses user selected parameters P_{SSON} and P_{SSOFF}. It also uses V_{PSS} shown in the block diagram, and the generator electrical output P_T. The output logic implements the following hysteresis to define the output signal V_{ST}



a. P_{SSON} and P_{SSOFF} are in pu of machine base

b. To enable PSS output logic specify $P_{SSON} > 0$

c. To disable PSS output logic specify $P_{SSON} < 0$

3. The first signal input ICS1 can be the compensated frequency.The signal is passed through a washout block and is fed into the stabilizer as the input signal. Reference regarding the compensated frequency can be found in this paper from Kestrel Power Engineering: "Accelerating-Power Based Power System Stabilizers"

3.15. PTIST1

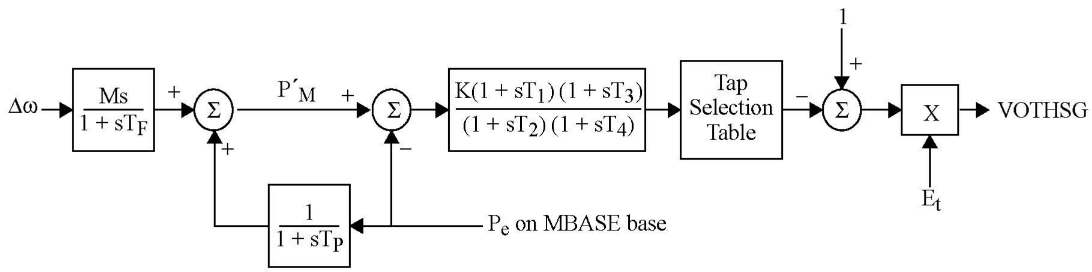
PTI Microprocessor-Based Stabilizer

ICONs	Values	Description
M		Number of time steps to activate frequency calculation
M+1		Number of time steps to activate power calculation
M+2		Number of time steps to activate controls

CONs	Value	Description
J		Δt_F
J+1		Δt_P
J+2		Δt_C
J+3		X_q
J+4		M
J+5		T_P
J+6		T_F
J+7		K
J+8		T_1
J+9		T_2
J+10		T_3
J+11		T_4

VARs	Description
L	$\Delta\omega$ from E_Q
L+1	P_e average
L+2	V_{dI}
L+3	V_{qI}
L+4	States for transfer
L+5	States for transfer
L+6	States for transfer
L+7	Function
L+8	T_ap setting
L+9	P_e last

```
IBUS, 'PTIST1', ID, CON(J) to CON(J+11)   /
```



Notes:

$M = 2. * H$

$T_F = TP \approx 0.2$ sec

K = 1 to 10, depends on tuning

T_1 = 0.1 to 0.5, depends on tuning

T_2 = 1 to 3 sec

T_3 = 0.1 to 0.5, depends on tuning

T_4 = 0.05 sec

$\Delta_{tF} = \Delta t_C$ = 0.025 sec

Δ_{tP} = 0.0125 sec

3.16. PTIST3

PTI Microprocessor-Based Stabilizer

ICONs	Value	Description
M		ISW, Digital/analog output switch (ISW = 0 or 1) (see Note 5)
M+1		NAV, Number of control outputs to average ($1 \le NAV \le 16$) (see Note 3)
M+2		NCL, Number of counts at limit to active limit function (NCL > 0) (see Note 4)
M+3		NCR, Number of counts until reset after limit function is triggered (see Note 4)
M+4 . . . M+8	X	ICONs reserved for internal logic

CONs	Value	Description
J		ΔtF
J+1		Δt_P
J+2		Δt_C
J+3		X'_q
J+4		M
J+5		$T_P > 0$
J+6		$T_F > 0$
J+7		K
J+8		T_1
J+9		$T_2 > 0$
J+10		T_3
J+11		$T_4 > 0$
J+12		T_5
J+13		T_6 (see Note 1)
J+14		A_0
J+15		A_1
J+16		A_2
J+17		B_0
J+18		B1
J+19		B_2 (see Note 2)
J+20		A_3
J+21		A_4
J+22		A_5
J+23		B_3
J+24		B_4
J+25		B_5 (see Note 2)

CONs	Value	Description
J+26		A_{THRES} (see Note 3)
J+27		D_L
J+28		A_L
J+29		L_{THRES} (see Note 4)
J+30		P_{MIN} (see Note 6)

VARs	Description
L	$\Delta\omega$ from E_Q
L+1	P_e average
L+2	V_{dl}
L+3	V_{ql}
L+4	Frequency filter state or store
L+5	Power filter state or store
L+6	1st lead/lag state or store
L+7	2nd lead/lag state or store
L+8	T_ap setting or analog output
L+9	PE_{LAST}
L+10	3rd lead/lag state or store
L+11	Torsional filter store
L+12	Torsional filter store
L+13	Torsional filter store
L+14	Torsional filter store
L+15	Frequency filter output
L+16	Power filter output
L+17	1st lead/lag output
L+18	2nd lead/lag output
L+19	3rd lead/lag output
L+20	1st stage torsional filter output
L+21	2nd stage torsional filter output
L+22 . . . L+37	Output averaging table
L+38	Output accumulator
L+39	Analog ramp

```
IBUS, 'PTIST3', ID, ICON(M) to ICON(M+3), CON(J) to CON(J+30)   /
```

Notes:

M = 2. * H

T_F = TP ≈ 0.2 sec

K = 1 to 10 (depends on tuning)

T_1 = 0.1 to 0.5 (depends on tuning)

T_2 = 1 to 3 sec

T_3 = 0.1 to 0.5 (depends on tuning)

T_4 = 0.05 sec

$\Delta t_F = \Delta t_C$ = 0.025 sec for 60 Hz

$\Delta t_F = \Delta t_C$ = 0.03 sec for 50 Hz

Δt_P = 0.0125 sec for 60 Hz

Δt_P = 0.015 sec for 50 Hz

Optional Features:

1. Third Lead/Lag

   To disable: set $T_6 = 0$

   If enabled: $T_6 > 0$

2. Torsional Filter

   To disable: set $B_2 = 0$ (both stages will be disabled)

   If enabled: $B_2 > 0$, $B_5 > 0$ (both stages are active)

3. Averaging Function

   To disable: set ICON(M+1) = 1

   Maximum number of outputs to average = 16

   CON(J+26) is the threshold value above which output averaging will be bypassed

   A recommended value for ICON(M+1) is 4

   A recommended default value for CON(J+26) is 0.005

4. Limit Function

   To disable: set ICON(M+2) = 9999 and CON(J+29) = 9999

   If enabled: ICON(M+3) is the number of counts to reset to normal operation after LIMIT function has activated

5. Analog Output

   To enable: set ICON(M) = 1

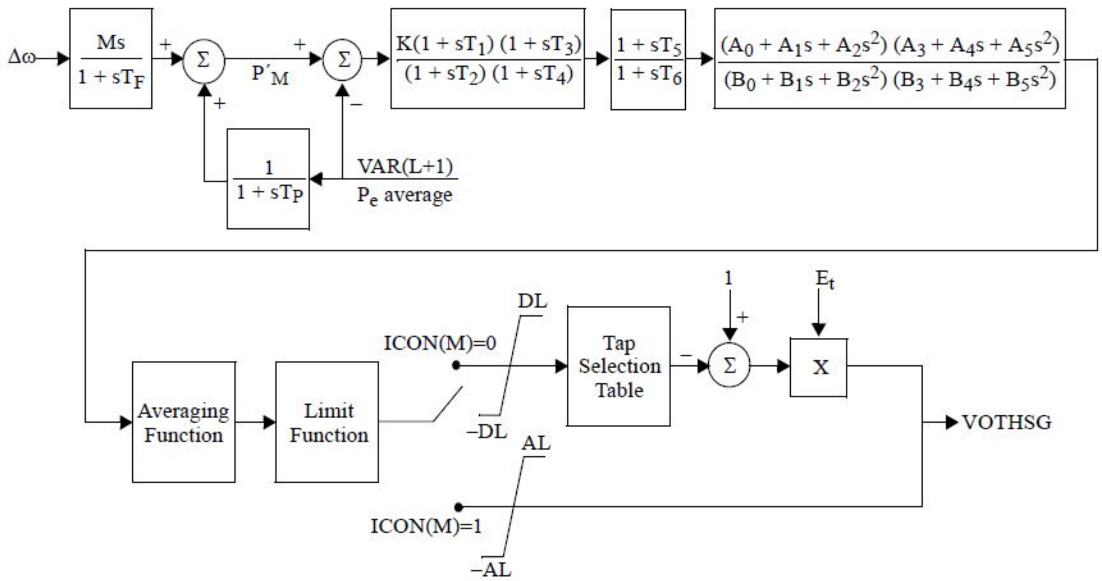
   For digital output: set ICON(M) = 0

6. Minimum Power

   CON(J+30) sets the minimum power output for stabilizer operation

In pu on MBASE

Unit operation below this threshold will force zero stabilizer output



3.17. ST2CUT

Stabilizing Model With Dual-Input Signals

ICONs	Value	Description
M		IC1, first stabilizer input code: • 1 - Rotor speed deviation (pu) • 2 - Bus frequency deviation (pu) • 3 - Generator electrical power on MBASE base (pu) • 4 - Generator accelerating power (pu) • 5 - Bus voltage • 6 - Derivative of pu bus voltage
M+1		IB1, first remote bus number
M+2		IC2, second stabilizer input code
M+3		IB2, second remote bus number

CONs	Value	Description
J		K_1
J+1		K_2
J+2		T_1 (sec)
J+3		T_2 (sec)
J+4		T_3 (sec) [a]
J+5		T_4 (>0) (sec)
J+6		T_5 (sec)
J+7		T_6 (sec)
J+8		T_7 (sec)
J+9		T_8 (sec)
J+10		T_9 (sec)
J+11		T_{10} (sec)
J+12		L_{SMAX}
J+13		L_{SMIN}
J+14		V_{CU} (pu) (if equal zero, ignored)
J+15		V_{CL} (pu) (if equal zero, ignored)

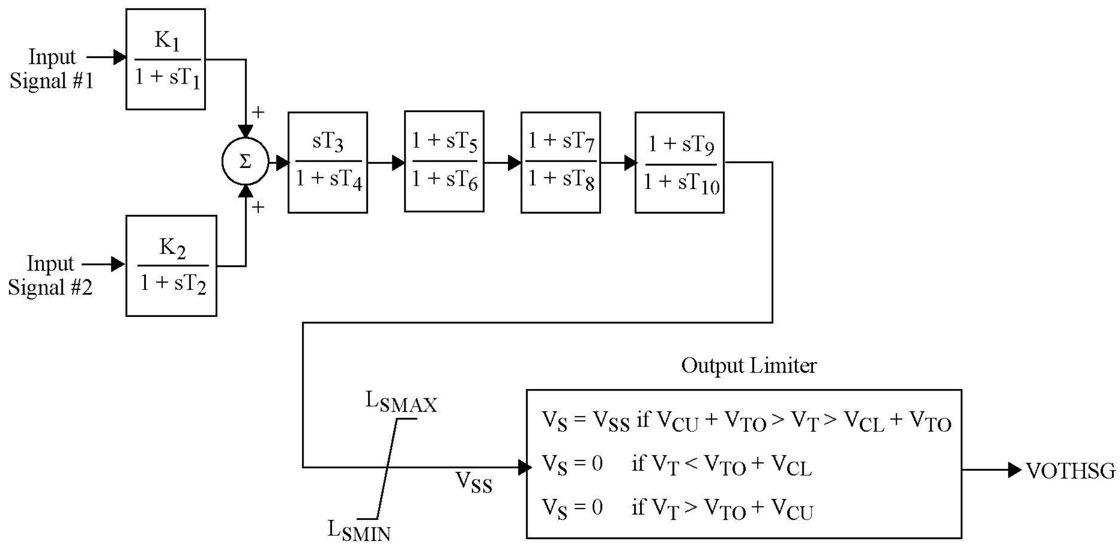
[a]If T_3 equals 0_1, sT_3 will equal 1.0

STATEs	Description
K	First signal transducer
K+1	Second signal transducer
K+2	Washout
K+3	First lead-lag

STATEs	Description
K+4	Second lead-lag
K+5	Third lead-lag

VARs	Description
L	Memory
L+1	Derivative of pu bus voltage, first bus
L+2	Memory
L+3	Derivative of pu bus voltage, second bus
L+4	Initial bus voltage (pu)

```
IBUS, 'ST2CUT', ID, ICON(M) to ICON(M+3), CON(J) to CON(J+15)   /
```



V_T is the terminal voltage at bus IBUS.

V_{TO} is the initial terminal voltage at bus IBUS.

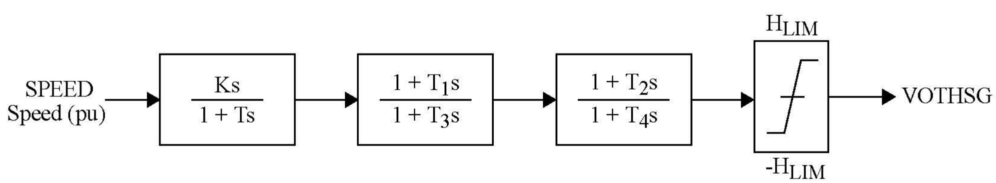
3.18. STAB1

Speed Sensitive Stabilizing Model

CONs	Value	Description
J		K/T (sec)$^{-1}$
J+1		T (sec) (>0)
J+2		T_1/T_3
J+3		T_3 (sec) (>0)
J+4		T_2/T_4
J+5		T_4 (sec) (>0)
J+6		H_{LIM}

STATEs	Description
K	Washout
K+1	First lead-lag
K+2	Second lead-lag

```
IBUS, 'STAB1', ID, CON(J) to CON(J+6)   /
```



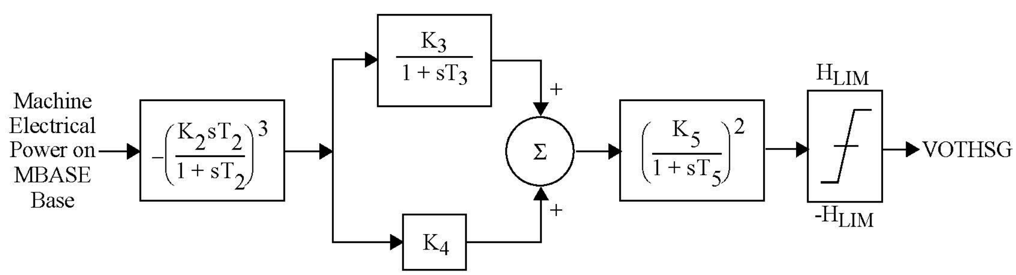
3.19. STAB2A

Power Sensitive Stabilizing Unit (ASEA)

CONs	Value	Description
J		K_2
J+1		T_2 (sec) (>0)
J+2		K_3
J+3		T_3 (sec) (>0)
J+4		K_4
J+5		K_5
J+6		T_5 (sec) (>0)
J+7		H_{LIM}

STATEs	Description
K	Implicit
K+1	Integration
K+2	State
K+3	Variables

```
IBUS, 'STAB2A', ID, CON(J) to CON(J+7)   /
```



3.20. STAB3

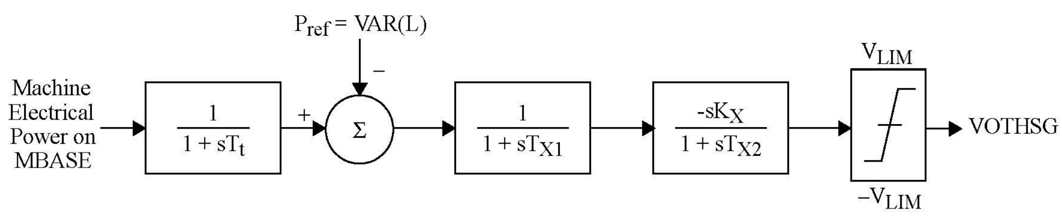
Stabilizing Model With Dual-Input Signals

CONs	Value	Description
J		T_t (sec)
J+1		T_{X1} (sec) (>0)
J+2		T_{X2} (sec) (>0)
J+3		K_X
J+4		V_{LIM}

STATEs	Description
K	First time constant output
K+1	Second time constant output
K+2	Unlimited signal

VARs	Description
L	Power reference signal

```
IBUS, 'STAB3', ID, CON(J) to CON(J+4)   /
```



3.21. STAB4

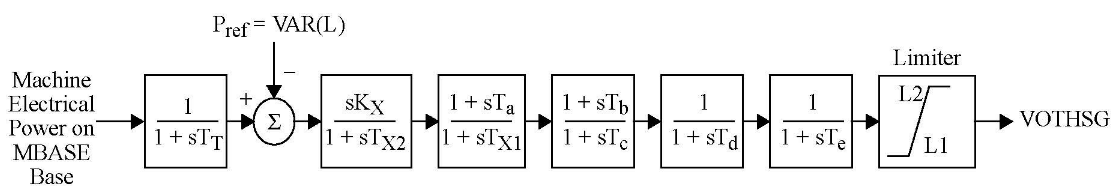
Power Sensitive Stabilizer

CONs	Value	Description
J		K_X (gain)
J+1		T_T, watt transducer time constant (sec)
J+2		T_{X1} (sec) (>0)
J+3		T_{X2}, reset time constant (sec) (>0)
J+4		T_a (sec)
J+5		T_b (sec)
J+6		T_c (sec) (>0)
J+7		T_d (sec)
J+8		T_e (sec)
J+9		L1 (pu) low limit
J+10		L2 (pu) high limit

STATEs	Description
K	Transducer output
K+1	Reset state
K+2	1st lead lag
K+3	2nd lead lag
K+4	5th state
K+5	Unlimited signal

VARs	Description
L	Initial electrical power

```
IBUS, 'STAB4', ID, CON(J) to CON(J+10)   /
```



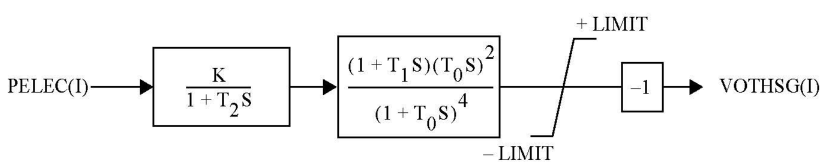
3.22. STABNI

Power Sensitive Stabilizer Model Type NI (NVE)

CONs	Value	Description
J		K (≥0)
J+1		T_1 (>0) (sec)
J+2		T_2 (≥0) (sec)
J+3		T0 (>0) (sec)
J+4		LIMIT (± pu)

STATEs	Description
K	Filter
K+1	Filter
K+2	Filter
K+3	Filter
K+4	Output

```
IBUS, 'STABNI', ID, CON(J) to CON(J+4)   /
```



3.23. STBSVC

WECC Supplementary Signal for Static var Compensator

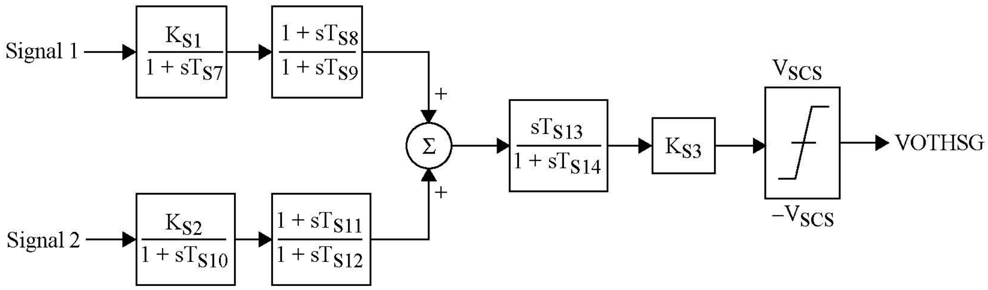
ICONs	Value	Description
M		IC1, signal 1 input code: • 1 - Accelerating power from remote machine (pu) • 2 - Electrical power from branch (pu) • 3 - Frequency deviation from remote bus (pu)
M+1		IC2, signal 2 input code: • 0 - No signal bus • 1 - Bus voltage (pu) • 2 - VARS from SVC to system (pu) • 3 - Current from SVC to system (pu)
M+2		IR1, remote machine bus number or from bus number for branch
M+3		IT, to bus number for branch
M+4		IR2, remote machine ID or circuit number for branch
M+5		IB, remote bus number for signal (2) = 1

CONs	Value	Description
J		K_{S1} (>0)
J+1		T_{S7} (sec)
J+2		T_{S8} (sec)
J+3		T_{S9} (>0) (sec)
J+4		T_{S13} (>0) (sec)
J+5		T_{S13} (>0) (sec)
J+6		K_{S3} (>0)
J+7		VSCS
J+8		K_{S2}
J+9		T_{S10} (sec)
J+10		T_{S11}1 (sec)
J+11		T_{S12} (>0, if $K_{S2} \neq 0$) sec

STATEs	Description
K	Filter for signal (1)
K+1	Lead-lag for signal (1)
K+2	Filter for signal (2)
K+3	Lead-lag for signal (2)
K+4	Wash out with time constant for both signals

VARs	Description
L	MW flow-through branch

```
IBUS, 'STBSVC', ID, ICON(M) to ICON(M+5), CON(J) to CON(J+11)   /
```



3.24. SYNAXBU1

Synchronous Condenser Auxiliary Control Model

ICONs	Value	Description
M		Bus Number at which the Plant controller Model is attached

CONs	Value	Description
J		Tw1 (s), Measurement time constant
J+1		Kw1 (pu on MBASE), Gain for signal in reactive path (Note 3)
J+2		Kp1 (pu on MBASE), Gain for signal in real path (Note 3)
J+3		Wmax (pu), Maximum value of W01

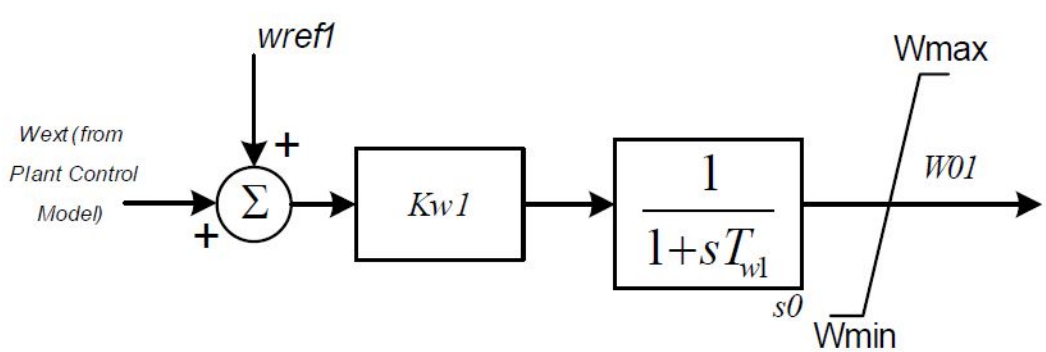
STATEs	Description
K	Measurement lag (reactive part)

VARs	Description
L	wref1 (pu on MBASE)

```
IBUS  'USRMDL'  ID  'SYNAXBU1'  3  0  1  4  1  1  ICON(M), CON
 (J) to CON(J+3)  /
```

Notes:

1. This model receives input from the plant control model which is connected at bus spec- ified in ICON(M). If there is no plant control model attached at the bus specified in ICON(M), then the input (Wext) to the SYNAXBU1model would be zero.
2. This model is treated as an auxiliary signal model for the synchronous condenser. The output of this model is stored in VOTHSG. In view of this, the excitation system model attached to the synchronous condenser should not have a power system stabilizer (PSS) model attached.
3. Model parameters should be in per unit of machine MVA base.



Chapter 4
Minimum Excitation Limiter Models

This chapter contains a collection of data sheets for the minimum excitation limiter models contained in the PSS®E dynamics model library.

Model	Description
MNLEX1	Minimum excitation limiter model
MNLEX2	Minimum excitation limiter model
MNLEX3	Minimum excitation limiter model
UEL1	IEEE 421.5 2005 UEL1 under-excitation limiter
UEL2	IEEE 421.5 2005 UEL2 minimum excitation limiter
UEL2CU1	IEEE 421.5 2016 UEL2C minimum excitation limiter

4.1. MNLEX1

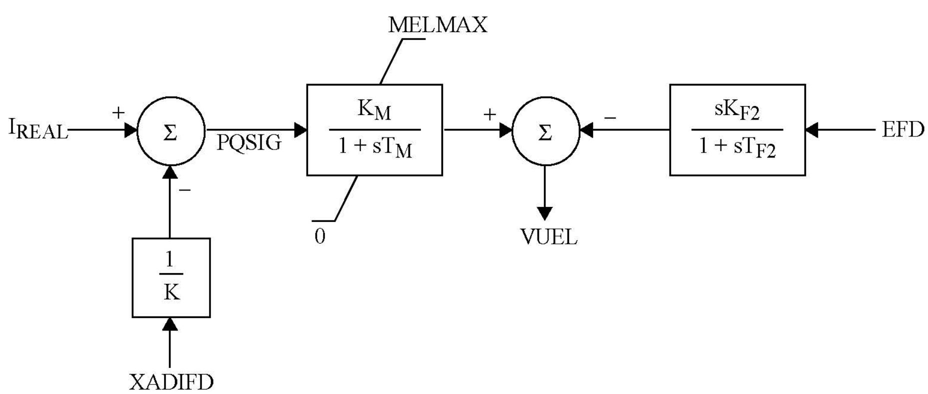
Minimum Excitation Limiter

CONs	Value	Description
J		K_{F2}
J+1		$T_{F2} > 0$ (sec)
J+2		K_M, MEL gain
J+3		T_M, MEL time constant (sec)
J+4		MELMAX
J+5		K, MEL slope (>0)

STATEs	Description
K	MEL feedback integrator
K+1	MEL

VARS	Description
L	PQSIG

```
IBUS, 'MNLEX1', ID, CON(J) to CON(J+5)   /
```



4.2. MNLEX2

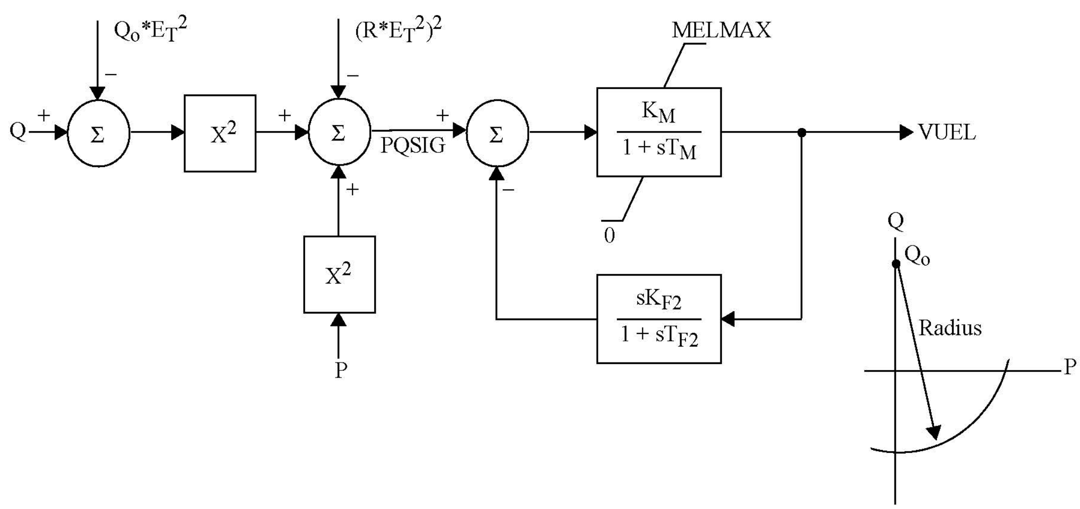
Minimum Excitation Limiter

CONs	Value	Description
J		K_{F2}
J+1		$T_{F2} > 0$ (sec)
J+2		K_M, MEL Gain
J+3		T_M, MEL time constant (sec)
J+4		MELMAX
J+5		Q_0 (pu on machine base)
J+6		Radius (pu on machine base)

STATEs	Description
K	MEL feedback integrator
K+1	MEL

VARS	Description
L	PQSIG

```
IBUS, 'MNLEX2', ID, CON(J) to CON(J+6)   /
```



4.3. MNLEX3

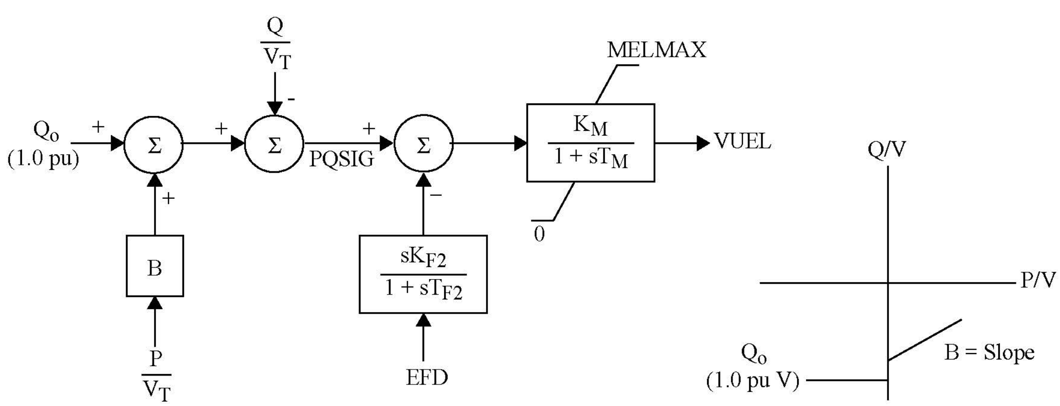
Minimum Excitation Limiter

CONs	Value	Description
J		K_{F2}
J+1		$T_{F2} > 0$ (sec)
J+2		K_M, MEL gain
J+3		T_M, MEL time constant (sec)
J+4		MELMAX
J+5		Q_0 (pu on machine base)<0
J+6		B, slope

STATEs	Description
K	MEL feedback integrator
K+1	MEL

VARs	Description
L	PQSIG

```
IBUS, 'MNLEX3', ID, CON(J) to CON(J+6)   /
```



4.4. UEL1

IEEE 421.5 2005 UEL1 Under-Excitation Limiter

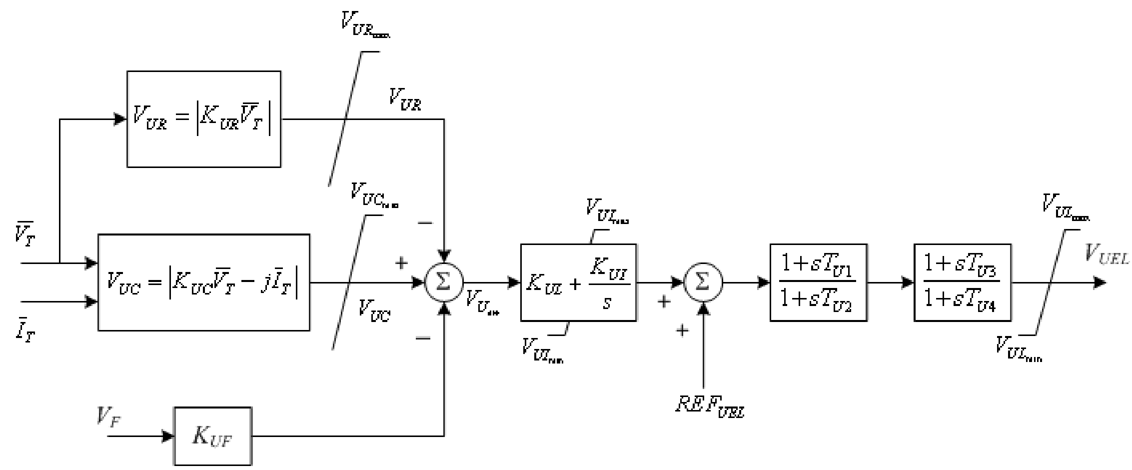
CONs	Value	Description
J		K_{UR}, UEL radius setting (pu)
J+1		K_{UC}, (pu) UEL center setting (pu)
J+2		K_{UF}, (pu) UEL excitation system stabilizer gain (pu)
J+3		V_{URMAX}, UEL maximum limit for radius phasor magnitude (pu)
J+4		V_{UCMAX}, UEL maximum limit for operating point phasor magnitude (pu)
J+5		K_{UI}, UEL integral gain (pu)
J+6		K_{UL}, UEL proportional gain (pu)
J+7		V_{UIMAX}, UEL integrator output maximum limit(pu)
J+8		V_{UIMIN}, UEL integrator output minimum limit (pu)[a]
J+9		T_{U1}, UEL lead time constant (sec)
J+10		T_{U2}, UEL lag time constant (sec)
J+11		T_{U3}, UEL lead time constant (sec)
J+12		T_{U4}, UEL lag time constant (sec)
J+13		V_{ULMAX}, UEL output maximum limit (pu)
J+14		V_{ULMIN}, UEL output minimum limit (pu) [a]

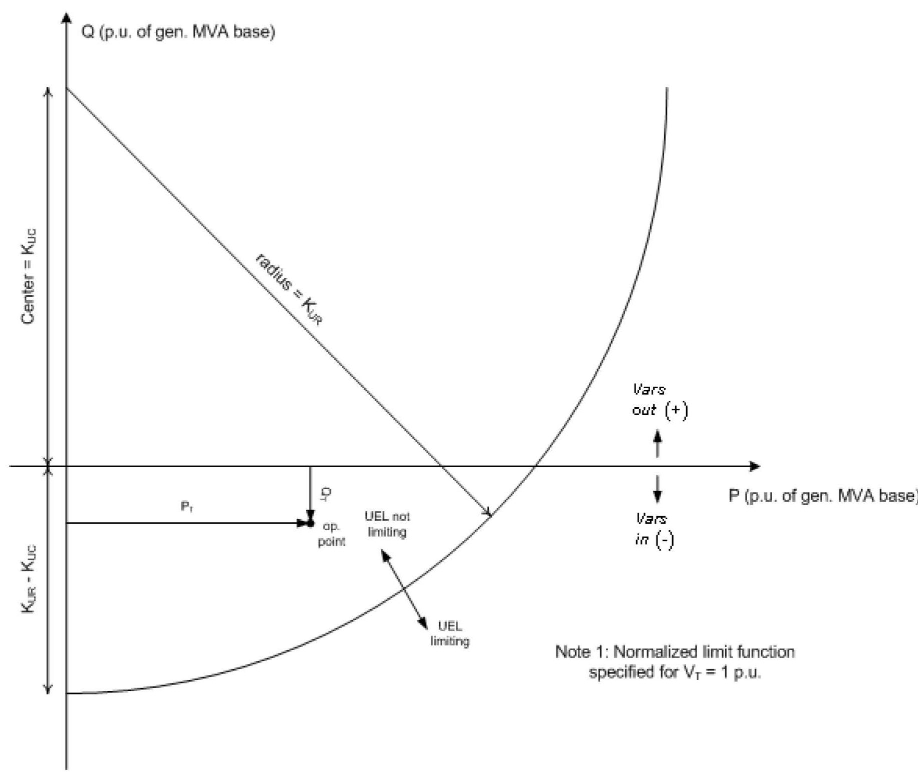
[a]V_{UIMIN} and V_{ULMIN} should be set to 0.0 for excitation systems where V_{UEL} is added to the summing junction of AVR reference, and should be set to a negative number of a relatively large magnitude if V_{UEL} enters the AVR through a HV (high value) gate.

STATEs	Description
K	Integrator
K+1	First lead-lag
K+2	Second lead-lag

VARs	Description
L	Reference input signal
L+1	V_{UC}
L+2	V_{UR}
L+3	V_{Uerr}

```
IBUS, 'UEL1', ID, CON(J) to CON(J+14)   /
```




Q (p.u. of gen. MVA base)
Center = KUC
radius = KUR
KUR - KUC
Vars out (+)
Vars in (-)
P (p.u. of gen. MVA base)
PT
QT
op. point
UEL not limiting
UEL limiting
Note 1: Normalized limit function specified for VT = 1 p.u.

4.5. UEL2

IEEE 421.5 2005 UEL2 Minimum Excitation Limiter

ICONs	Value	Description
M		k_1, exponent in function F1
M+1		k_2, exponent in function F2
M+2		0 for transient swings in MW that move to the third quadrant, MVAR curve interpreted as mirror image around MVAR axis 1 for transient swings in MW that move to the third quadrant, MVAR is found by linear extrapolation

CONs	Value	Description
J		T_{UV} (sec) voltage filter time constant
J+1		T_{UP} (sec) real power filter time constant
J+2		T_{UQ} (sec) reactive power filter time constant
J+3		K_{UI} (pu) UEL integral gain
J+4		K_{UL} (pu) UEL proportional gain
J+5		V_{UIMAX} (pu) UEL integrator output maximum limit
J+6		V_{UIMIN} (pu) UEL integrator output minimum limit
J+7		K_{UF} (pu) UEL excitation system stabilizer gain
J+8		K_{FB} (pu)
J+9		T_{UL} (sec)
J+10		T_{U1} UEL lead time constant (sec)
J+11		T_{U2} UEL lag time constant (sec)
J+12		T_{U3} UEL lead time constant (sec)
J+13		T_{U4} UEL lag time constant (sec)
J+14		P_0 (pu on gen. MVA base) [a]
J+15		Q_0 (pu on gen. MVA base) [a]
J+16		P_1 (pu on gen. MVA base)
J+17		Q_1 (pu on gen. MVA base)
J+18		P_2 (pu on gen. MVA base)
J+19		Q_2 (pu on gen. MVA base)
J+20		P_3 (pu on gen. MVA base)
J+21		Q_3 (pu on gen. MVA base)
J+22		P_4 (pu on gen. MVA base)
J+23		Q_4 (pu on gen. MVA base)
J+24		P_5 (pu on gen. MVA base)
J+25		Q_5 (pu on gen. MVA base)
J+26		P_6 (pu on gen. MVA base)
J+27		Q_6 (pu on gen. MVA base)
J+28		P_7 (pu on gen. MVA base)

CONs	Value	Description
J+29		Q_7 (pu on gen. MVA base)
J+30		P_8 (pu on gen. MVA base)
J+31		Q_8 (pu on gen. MVA base)
J+32		P_9 (pu on gen. MVA base)
J+33		Q_9 (pu on gen. MVA base)
J+34		P_{10} (pu on gen. MVA base)
J+35		Q_{10} (pu on gen. MVA base)
J+36		V_{ULMAX} (pu) UEL output maximum limit
J+37		V_{ULMIN} (pu) UEL output minimum limit[b]

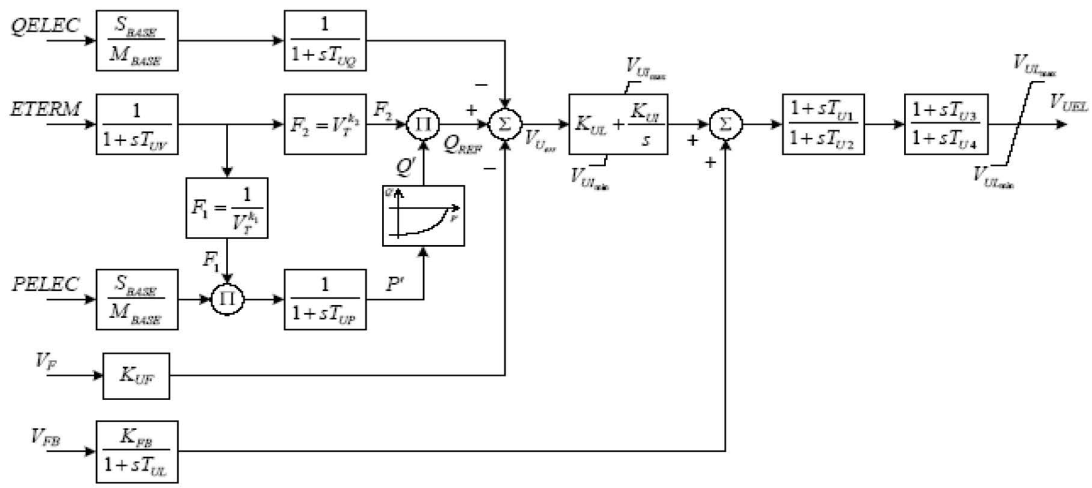
[a]A maximum if 11 pairs may be specified. The unused pairs should be entered as zero.

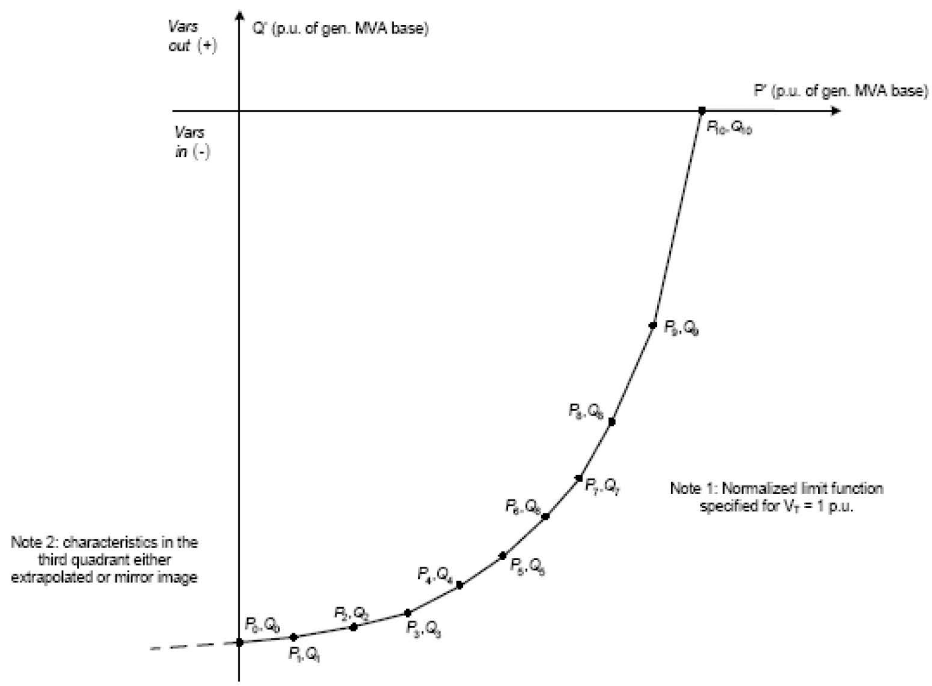
[b]V_{ULMIN} should be set to 0.0 for excitation systems where V_{UEL} is added to the reference.

STATEs	Description
K	Voltage filter output
K+1	Real power filter output
K+2	Reactive power filter output
K+3	Integrator
K+4	Reference feedback block
K+5	First lead-lag
K+6	Second lead-lag

VARs	Description
L	Reference input signal
L+1	Q´, normalized reactive power output for 1 pu voltage
L+2	Q_{REF}

```
IBUS, 'UEL2', ID, ICON(M) to ICON(M+2), CON(J) to CON(J+37)   /
```


QELEC
ETERM
PELEC
V_F
V_{FB}
$F_2 = V_T^{k_2}$
$F_1 = \frac{1}{V_T^{k_1}}$
Q_{REF}
Q'
P'
K_{UF}
$\frac{K_{FB}}{1+sT_{UL}}$
$K_{UL} + \frac{K_{UI}}{s}$
$\frac{1+sT_{U1}}{1+sT_{U2}}$
$\frac{1+sT_{U3}}{1+sT_{U4}}$
V_{UEL}


Vars out (+)
Q' (p.u. of gen. MVA base)
P' (p.u. of gen. MVA base)
Vars in (-)
Note 1: Normalized limit function specified for V_T = 1 p.u.
Note 2: characteristics in the third quadrant either extrapolated or mirror image

4.6. UEL2CU1

IEEE 421.5 2016 UEL2C Under Excitation Limiter

ICONs	Value	Description
M		K_1, exponent in function F1
M+1		K_2, exponent in function F2
M+2		0 for transient swings in MW that move to the third quadrant, MVAR curve interpreted as mirror image around MVAR axis 1 for transient swings in MW that move to the third quadrant, MVAR is found by linear extrapolation
M+3		Switch for adjustable gain reduction 1: Position A 2: Position B

CONs	Value	Description
J		T_{UV} (sec) voltage filter time constant
J+1		T_{UP} (sec) real power filter time constant
J+2		T_{UQ} (sec) reactive power filter time constant
J+3		K_{UI} (pu) UEL integral gain
J+4		K_{UL} (pu) UEL proportional gain
J+5		V_{UIMAX} (pu) UEL integrator output maximum limit
J+6		V_{UIMIN} (pu) UEL integrator output minimum limit
J+7		K_{UF} (pu) UEL excitation system stabilizer gain
J+8		K_{FB} (pu)
J+9		T_{UL} (sec)
J+10		T_{U1} UEL lead time constant (sec)
J+11		T_{U2} UEL lag time constant (sec)
J+12		T_{U3} UEL lead time constant (sec)
J+13		T_{U4} UEL lag time constant (sec)
J+14		P_0 (pu on gen. MVA base) [a]
J+15		Q_0 (pu on gen. MVA base) [a]
J+16		P_1 (pu on gen. MVA base)
J+17		Q_1 (pu on gen. MVA base)
J+18		P_2 (pu on gen. MVA base)
J+19		Q_2 (pu on gen. MVA base)
J+20		P_3 (pu on gen. MVA base)
J+21		Q_3 (pu on gen. MVA base)
J+22		P_4 (pu on gen. MVA base)
J+23		Q_4 (pu on gen. MVA base)
J+24		P_5 (pu on gen. MVA base)

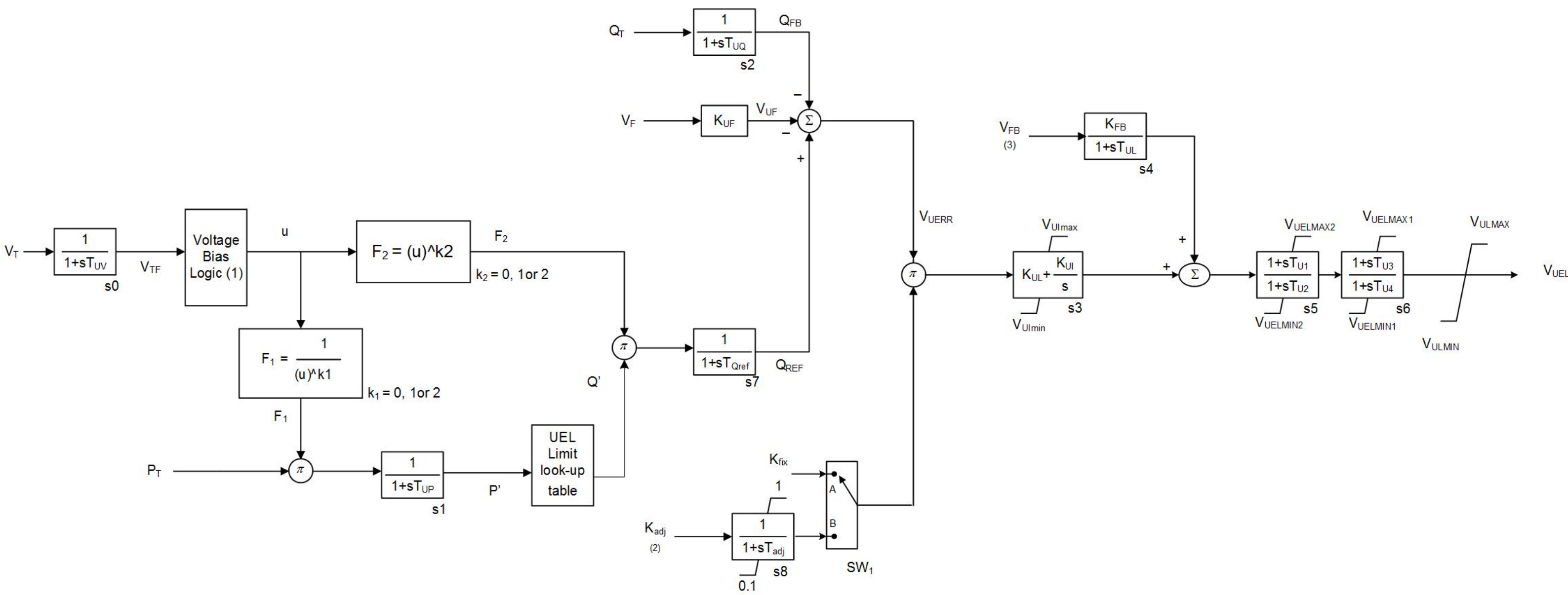
CONs	Value	Description
J+25		Q_5 (pu on gen. MVA base)
J+26		P_6 (pu on gen. MVA base)
J+27		Q_6 (pu on gen. MVA base)
J+28		P_7 (pu on gen. MVA base)
J+29		Q_7 (pu on gen. MVA base)
J+30		P_8 (pu on gen. MVA base)
J+31		Q_8 (pu on gen. MVA base)
J+32		P_9 (pu on gen. MVA base)
J+33		Q_9 (pu on gen. MVA base)
J+34		P_{10} (pu on gen. MVA base)
J+35		Q_{10} (pu on gen. MVA base)
J+36		V_{ULMAX} (pu) UEL output maximum limit
J+37		V_{ULMIN} (pu) UEL output minimum limit
J+38		V_{BIAS} (pu) UEL voltage bias
J+39		K_{FIX} (pu) UEL fixed gain reduction factor
J+40		T_{ADJ} UEL adjustable gain reduction time constant (s)
J+41		T_{QREF} UEL reactive power reference time constant(s)
J+42		$V_{UELMAX2}$ (pu) UEL maximum output
J+43		$V_{UELMIN2}$ (pu) UEL minimum output
J+44		$V_{UELMAX1}$ (pu) UEL maximum output
J+45		$V_{UELMIN1}$ (pu) UEL minimum output
J+46		X_Q (pu) Q axis reactance of the synchronous generator to which the exciter model is attached

[a]A maximum if 11 pairs may be specified. The unused pairs should be entered as zero.

STATEs	Description
K	Voltage filter output (s0)
K+1	Real power filter output (s1)
K+2	Reactive power filter output (s2)
K+3	Integrator (s3)
K+4	Reference feedback block (s4)
K+5	First lead-lag (s5)
K+6	Second lead-lag (s6)
K+7	Reactive power Reference lag block (s7)
K+8	Lag block associated with T_{adj} (s8)

VARs	Description
L	Reference input signal
L+1	Q´, normalized reactive power output for 1 pu voltage

```
IBUS ’USRMDL’ ID ’UEL2CU1’  9   0   4   47   9    2  ICON(M) to ICON(M+3),
 CON(J) to CON(J+46)   /
```



Notes:

1. The voltage bias logic uses parameters V_{BIAS} and also uses the signal V_{TF} as shown in the block diagram

   IF V_{TF} > 1.0 pu

   $u = V_{TF}$

   ELSE

   IF $V_{TF} > V_{BIAS}$

   u = 1

   ELSE

   $u = V_{TF} / V_{BIAS}$

   END

   END

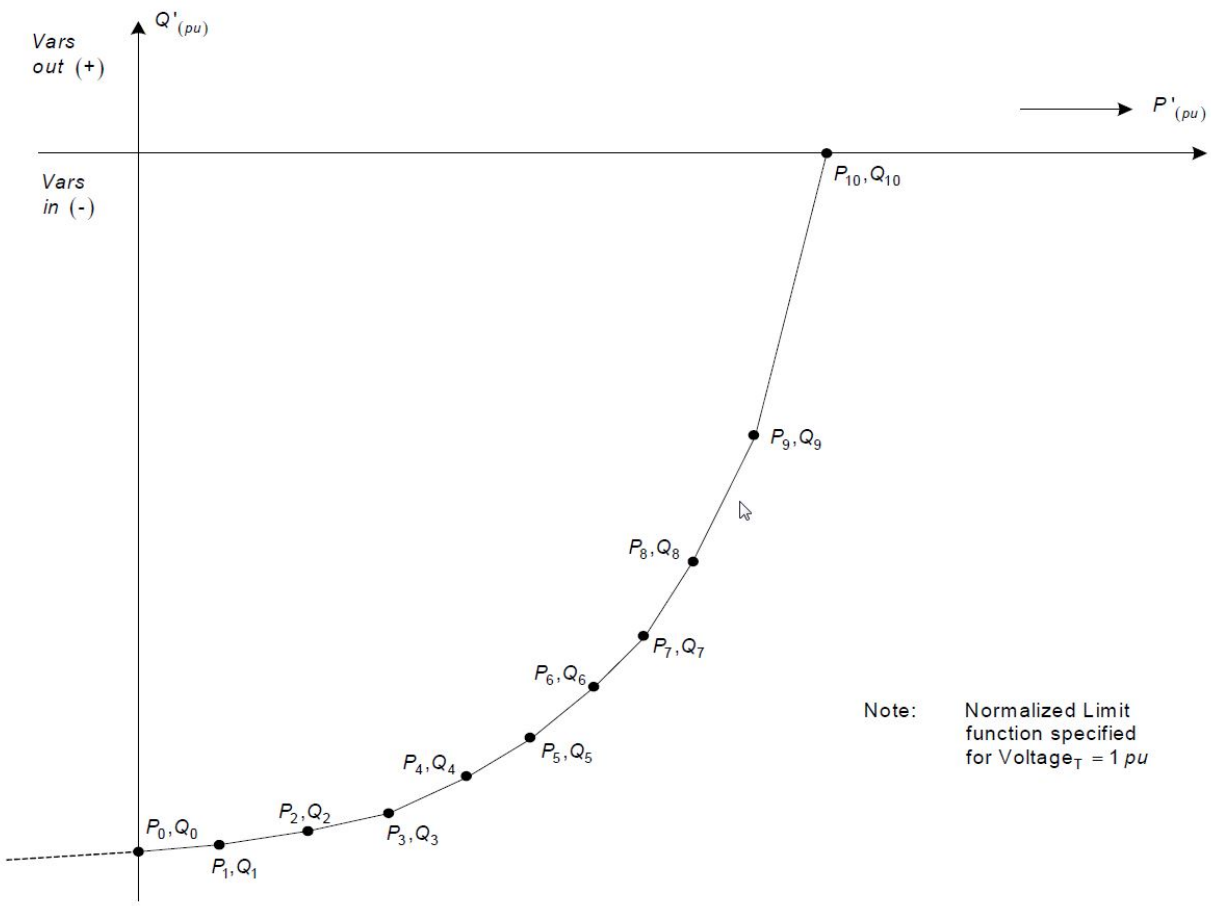
2. The value for $K_{ADJ}$is calculated as (Vt^2/xq + Qt) / sqrt ((Qt + Vt^2/Xq)^2 + Pt^2)

3. The input signal VFB is specific for the application of the UEL2C model in conjunction with the S T7C excitation system model as per the IEEE 421.5 2016 document.

4. The UEL Lookup table is represented by multi segment normalized characteristics as shown in the figure below. The P, Q values specify the UEL limit applicable to the machine terminal voltage of 1 p.u. The model can accept up to 11 pairs representing 10 segments of the P-Q points.

At least two pairs of P-Q points i.e. defining one segment is required to be provided as input by the user. Between any two segment endpoints, the UEL characteristic is defined by a straight line. For any value of P, the corresponding value of Q is obtained by linear interpolation.

To allow a general implementation of the model that allows the user to specify any number of points up to 11 (with a minimum of two pairs) the data requirements for the P-Q points are such that the first zero value for P would indicate the end of the P-Q characteristics. Thus, if the user specifies four pairs of P-Q points (i.e P0-Q0, P1-Q1, P2-Q2, P3-Q3), the user data from P4-Q4 onwards to P10-Q10 will have to be zero.



5. To simulate UEL2C, set CON(J+5) and CON(J+6) as 99.0 and -99.0 respectively.

6. To simulate UEL2 using the UEL2C model, set the ICONs and CONs as follows:

   ICON(M+3) = 1

   CON(J+41) = 0.0

   CON(J+38) = -1.0

CON(J+39) = 1.0

CON(J+42) and CON(J+44) = 99.0

CON(J+43) and CON(J+45) = -99.0

7. To bypass VBIAS logic, set CON(J+38) < 0.0

Chapter 5
Maximum Excitation Limiter Models

This chapter contains a collection of data sheets for the maximum excitation limiter models contained in the PSS®E dynamics model library.

Model	Description
BASOELU2	Basler DECS-250 OEL and V/Hz Limiter model
MAXEX1	Maximum excitation limiter model
MAXEX2	Maximum excitation limiter model
OEL2CU1	Overexictation Limiter
OEL5CU1	IEEE 421.5 2016 Overexictation Limiter

5.1. BASOELU2

Basler DECS-250 OEL and V/Hz Limiter

ICONs	Value	Description
M		OEL status: 0: disable; 1: enable
M+1		V/Hz limiter status: 0: disable; 1: enable
M+2		OEL input: 0: Efd; 1: Ifd; 2: Vfe
M+3		OET1 Delay Flag (to be entered as 0 by user)
M+4		OET1 Timeout Flag (to be entered as 0 by user)
M+5		OET1 Timer Status (to be entered as 0 by user)
M+6		OET1 Limit Status (to be entered as 0 by user)
M+7		OET2 Delay Flag (to be entered as 0 by user)
M+8		OET2 Timeout Flag (to be entered as 0 by user)
M+9		OET2 Timer Status (to be entered as 0 by user)
M+10		OET2 Limit Status (to be entered as 0 by user)
M+11		OET3 Delay Flag (to be entered as 0 by user)
M+12		OET3 Timeout Flag (to be entered as 0 by user)
M+13		OET3 Timer Status (to be entered as 0 by user)
M+14		OET3 Limit Status (to be entered as 0 by user)

CONs	Value	Description
J		TRoel (s), OEL regulator input filter time constant
J+1		KP (pu), OEL regulator proportional gain
J+2		KI (pu), OEL regulator integral gain
J+3		OEI1 (pu), Short-time allowed overload
J+4		OET1 (s), Short-time overload time (normally zero)
J+5		OEI2 (pu), Medium-time allowed overload
J+6		OET2 (s), Medium-time overload time
J+7		OEI3 (pu), Continuous limit
J+8		OET3 (s), Continuous limit time
J+9		TRVHz (s), V/Hz limiter regulator input filter time constant
J+10		KVHz (pu), V/Hz limiter gain
J+11		VHzmin (pu), V/Hz limiter minimum input

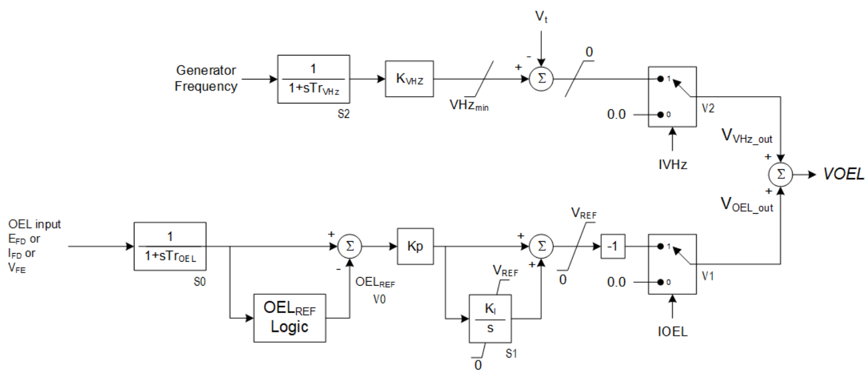
STATEs	Description
K	OEL Sensed field current
K+1	OEL Integral channel PI
K+2	V/Hz limiter sensed speed

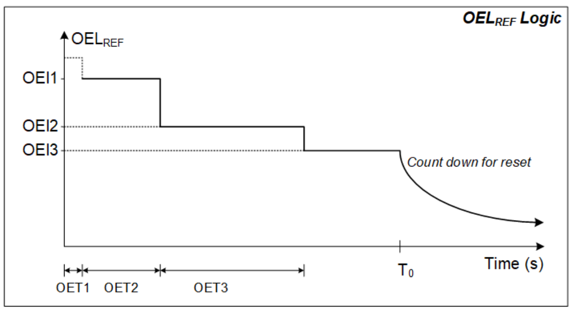
VARs	Description
L	OELref
L+1	OEL output

VARs	Description
L+2	V/Hz limiter output
L+3	OET1 Timer memory a
L+4	OET1 Timer memory b
L+5	OET2 Timer memory a
L+6	OET2 Timer memory b
L+7	OET3 Timer memory a
L+8	OET3 Timer memory b

DYR record:

```
IBUS 'USRMDL'  ID  'BASOELU2'  10   0  15  12  3  9  ICON(M) to ICON(M
+14), CON (J) to CON(J+11)    /
```





5.2. MAXEX1

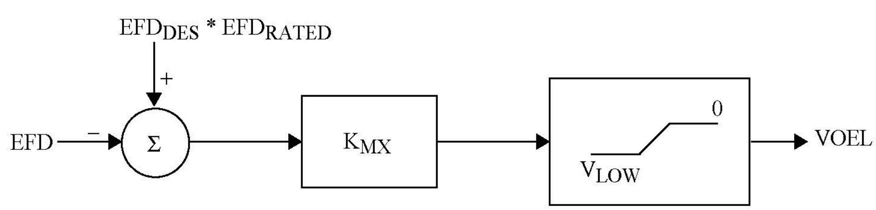
Maximum Excitation Limiter

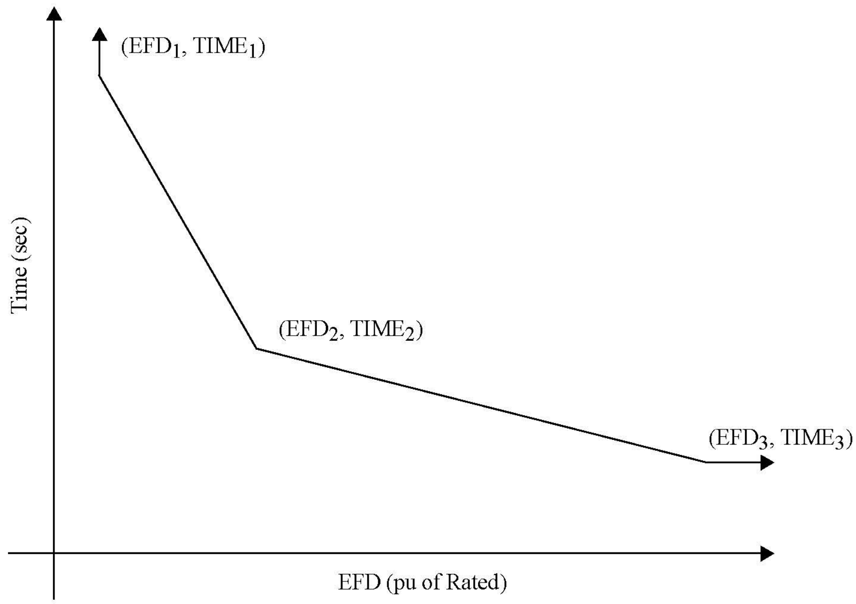
ICONs	Value	Description
M		Status

CONs	Value	Description
J		EFD_{RATED}
J+1		EFD_1 (pu of rated)
J+2		$TIME_1$
J+3		EFD_2 (pu of rated)
J+4		T_IME_2
J+5		EFD_3 (pu of rated)
J+6		$TIME_3$
J+7		EFD_{DES} (pu of rated)
J+8		K_{MX}
J+9		V_{LOW}

VARs	Description
K	Contact position

```
IBUS, 'MAXEX1', ID, CON(J) to CON(J+9)   /
```




(EFD1, TIME1)
(EFD2, TIME2)
(EFD3, TIME3)
Time (sec)
EFD (pu of Rated)

5.3. MAXEX2

Maximum Excitation Limiter

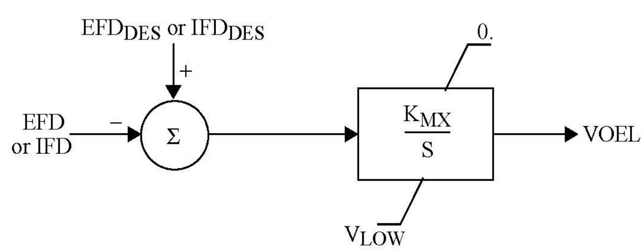
ICONs	Value	Description
M		0 for EFD limiting, 1 for IFD limiting

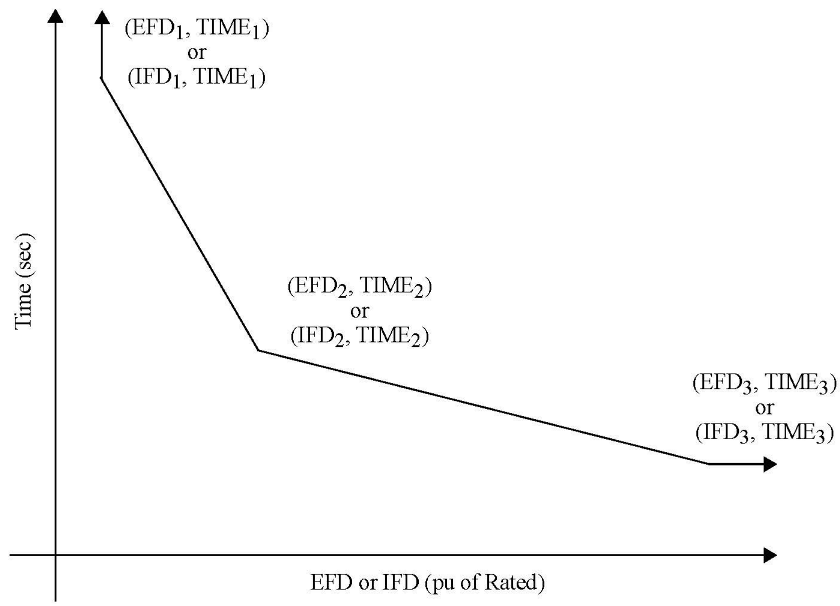
CONs	Value	Description
J		EFD_{RATED} or IFD_{RATED}
J+1		EFD_1 or IFD_1 (pu of rated)
J+2		$TIME_1$
J+3		EFD_2 or IFD_2 (pu of rated)
J+4		$TIME_2$
J+5		EFD_3 or IFD_3 (pu of rated)
J+6		T_IME_3
J+7		EFD_{DES} or IFD_{DES} (pu of rated)
J+8		K_{MX}
J+9		V_{LOW} (< 0)

STATEs	Description
K	Reset integrator

VARs	Description
L	Contact position

```
IBUS, 'MAXEX2', ID, ICON(M), CON(J) to CON(J+9)   /
```




(EFD1, TIME1)
or
(IFD1, TIME1)
(EFD2, TIME2)
or
(IFD2, TIME2)
(EFD3, TIME3)
or
(IFD3, TIME3)
Time (sec)
EFD or IFD (pu of Rated)

5.4. OEL2CU1

IEEE 421.5 2016 Overexictation Limiter

ICONs	Value	Description
M		Input flag:1=Efd 2=Ifd 3=VFE (Default = 1)
M+1		Logic switch(SW1) 1=Fixed Ramp rate 2=Inverse characteristics

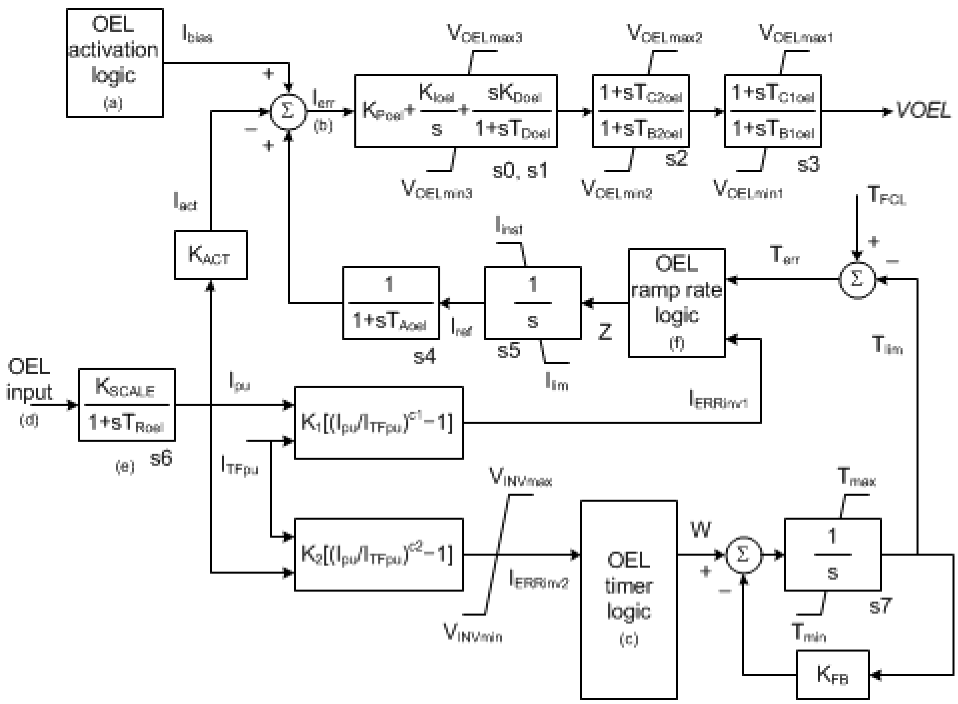
CONs	Value	Description
J		T_{C1OEL} (s) OEL Regulator lead time constant 1
J+1		T_{B1OEL} (s) OEL Regulator lag time constant 1
J+2		T_{C2OEL} (s) OEL Regulator lead time constant 2
J+3		T_{B2OEL} (s) OEL Regulator lag time constant 2
J+4		K_{POEL} (pu) OEL PID Regulator proportional gain
J+5		K_{IOEL} (pu) OEL PID Regulator integral gain
J+6		K_{DOEL} (pu) OEL PID Regulator differential gain
J+7		T_{DOEL} (s) OEL PID Regulator differential time constant
J+8		$V_{OELMAX3}$ (pu) maximum OEL PID output limit
J+9		$V_{OELMIN3}$ (pu) minimum OEL PID output limit
J+10		$V_{OELMAX2}$ (pu) maximum OEL lead-lag 1 output limit
J+11		$V_{OELMIN2}$ (pu) minimum OEL lead-lag 1 output limit
J+12		$V_{OELMAX1}$ (pu) maximum OEL output limit
J+13		$V_{OELMIN1}$ (pu) minimum OEL output limit
J+14		I_{RESET} (pu) OEL Reset reference if OEL is inactive
J+15		T_{EN} (s) OEL Activation delay time
J+16		T_{OFF} (s) OEL Reset delay time
J+17		I_{THOFF} (pu) OEL Reset threshold value
J+18		K_{SCALE} (pu) OEL input signal scaling factor
J+19		T_{ROEL} (s) Input signal filter time constant
J+20		K_{ACT} (pu) OEL Actual value scaling factor
J+21		I_{TFPU} (pu) OEL Reference for inverse time calculations
J+22		I_{INST} (pu) OEL Instantaneous field current limit
J+23		I_{LIM} (pu) OEL Thermal field current limit
J+24		T_{AOEL} (s) OEL Reference filter time constant
J+25		C_1 OEL Exponent for calculation of $I_{ERRinv1}$
J+26		K_1 OEL Gain for calculation of $I_{ERRinv1}$
J+27		C_2 OEL Exponent for calculation of $I_{ERRinv2}$
J+28		K_2 OEL Gain for calculation of $I_{ERRinv2}$
J+29		V_{INVMAX} (pu) OEL Maximum inverse time output
J+30		V_{INVMIN} (pu) OEL Minimum inverse time output

CONs	Value	Description
J+31		$Fixed_{RU}$ (pu) OEL Fixed delay time output
J+32		$Fixed_{RD}$ OEL Fixed cooling-down time output
J+33		T_{FCL} (pu) OEL timer reference
J+34		T_{MAX} (pu) OEL Timer maximum level
J+35		T_{MIN} (pu) OEL Timer minimum level
J+36		K_{FB} (pu) OEL Timer feedback gain
J+37		K_{RD} (pu/s) OEL Reference ramp-down rate
J+38		K_{RU} (pu/s) OEL Reference ramp-up rate
J+39		K_{ZRU} OEL thermal reference release threshold
J+40		$I_{FDRATED}$ (pu) Rated field current

STATEs	Description
K	OEL PID integrator
K+1	OEL PID derivative
K+2	OEL First lead-lag
K+3	OEL Second lead-lag
K+4	OEL Reference filter
K+5	OEL Current reference I_{ref}
K+6	OEL Sensed input
K+7	OEL Timer signal T_{lim}

VARs	Description
L	Z
L+1	I_{err}
L+2	I_{BIAS}
L+3	Contains TIME at which OEL "set" timer starts and then stops.
L+4	$I_{ERRINV1}$
L+5	$I_{ERRINV2}$
L+6	W
L+7	Contains TIME at which OEL "reset" timer starts and then stops.

```
IBUS, 'USRMDL', ID, 'OEL2CU1' 10 0 2 41 8 8 ICON(M) to ICON(M+1), CON(J)
 to CON(J+40)   /
```



Notes (taken from IEEE 421.5 2016 standard):

(a) OEL activation logic uses user-selected parameters T_{en}, T_{off}, I_{THoff}, I_{reset} and I_{inst}. It also uses the signals T_{err}, I_{act} and I_{ref} shown in the block diagram.

IF {($T_{err} \leq 0$) **or** [($I_{act} > I_{ref}$) for longer than T_{en}]} **or** (T_{en}=0)
    enable OEL → I_{bias} = 0
IF {($I_{ref} = I_{inst}$) **and** [($I_{ref} - I_{act}$) > I_{THoff}]} for longer than T_{off}
    reset OEL → $I_{bias} = I_{reset}$

(b) The OEL transfer function is either just the gain K_{Poel}, or the PID control, or the double lead-lag blocks. The parameters in the model should be set accordingly.

(c) OEL timer logic uses user-selected parameters $Fixed_{RU}$, $Fixed_{RD}$ and I_{TFpu}. It also uses the signals I_{pu} and $I_{ERRinv2}$, shown in the block diagram.

IF ($I_{TFpu} - I_{pu}$) ≥ 0
    W = $Fixed_{RU}$ + $I_{ERRinv2}$
ELSE
    W = $Fixed_{RD}$ + $I_{ERRinv2}$
ENDIF

(d) OEL input is user-selected. Could be generator field current I_{FD} or generator field voltage E_{FD} or exciter field current V_{FE}.

(e) Parameter K_{SCALE} should be calculated to convert from the per unit base used for the OEL input signal to a per unit base corresponding to the rated value for the selected OEL input signal. All other parameters in the model are expressed in per unit of rated value.

(f) OEL ramp rate logic uses user-selected parameters SW_1, K_{ZRU}, T_{FCL}, K_{RU} and K_{RD}. It also uses the signals T_{err} and $I_{ERRinv1}$, shown in the block diagram. The parameter SW_1 is a user-selected logic, which will select fixed ramp rates or a ramp rate function of the field current error.

IF SW_1 = 0 (fixed ramp rates)
    C = K_{RU}
    D = K_{RD}
ELSE
    C = $I_{ERRinv1}$
    D = $I_{ERRinv1}$
ENDIF
IF Terr ≥ K_{ZRU}*T_{FCL} (ramp I_{ref} up)
    Z = C
ELSEIF T_{err} ≤ 0 (ramp I_{ref} down)
    Z = D
ELSE
    Z = 0
ENDIF

Note(s) :

1. OEL input is user-selected. Could be generator field current I_{FD} or generator field voltage E_{FD} or exciter field current V_{FE}
2. The OEL Transfer function is either just the gain K_{POEL} or the PID control or the double lead-lag blocks. The parameters in the model should be set accordingly.
3. OEL timer-logic uses user pre-selected $Fixed_{RU}$, $Fixed_{RD}$ and I_{TFPU}. It also uses the signals I_{pu} and $I_{ERRinv1}$, shown in the block diagram.

```
IF(I_TFPU - I_PU) >=0
    W = Fixed_RU + I_ERRinv2
ELSE
    W = Fixed_RD + I_ERRinv2
END
```

4. Parameter K_{SCALE} should be calculated to convert from the per unit base used for the OEL input signal to a per unit base corresponding to the rated value for the selected OEL input signal. All other parameters in the model are expressed in per unit of rated value

5. OEL Ramp-rate logic uses user-selected parameters SW_1 , K_{ZRU}, T_{FCL} , K_{RU} and K_{RD}. It also uses the signals Y_{err} and $I_{ERRinv1}$, shown in the block diagram. The parameter SW_1 is a user-selected logic , which will select fixed ramp rates or ramp-rate function of the field current error

```
IF(SW_1 = 1) (fixed ramp rates)
    C=K_RU
    D=K_RD
ELSE
    C = I_ERRinv1
    D = I_ERRinv1
END

IF (T_err>=K_ZRU*T_FCL (ramp I_ref up)
    Z = C
ELSEIF T_err<=0 (ramp I_ref down)
    Z = D
ELSE
    Z = 0
END
```

6. I_{BIAS} calculation logic uses user-selected parameters T_{en}, T_{off}, I_{THoff}, I_{reset} and I_{inst}. It also uses the signals T_{err}, I_{act} and I_{ref}.

```
IF {(T_err <=0) or [(I_act > I_ref ) for longer than T_en]} or (T_en = 0)
    I_BIAS = 0 (i.e., OEL is set)
If the OEL is set
    IF {(I_ref = I_inst) and [(I_ref - I_act) > I_THoff ]} for longer than T_off
    I BIAS  = I_reset
```

7. If T_{en} is equal to zero , then I_{reset} is set to zero.

5.5. OEL5CU1

IEEE 421.5 2016 Overexcitation Limiter Model

ICON	Value	Description
M		OEL Input Flag: • 1 : Efd (field voltage) • 2 : Ifd (field current) • 3: Vfe (exciter filed current)
M+1		SW1 (OEL reference logic switch): • 0 : Position A • 1 : Position B
M+2		K1, Exponent for inverse time function (> 0)

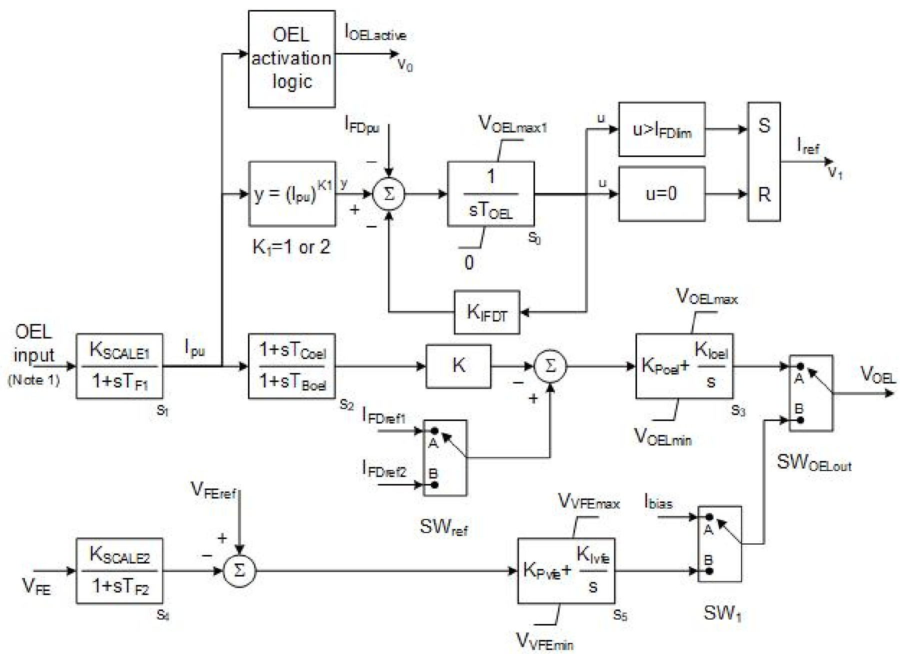
CONs	Value	Description
J		IFDpu (pu), OEL inverse time integrator pickup level
J+1		IFDlim (pu), OEL inverse time limit active level
J+2		VOELmax1 (pu), OEL inverse time integrator upper limit
J+3		TOEL (s), OEL inverse time integrator time constant (> 0)
J+4		KIFDT (pu), OEL inverse time lag gain
J+5		K (pu), OEL lead-lag gain
J+6		TCoel (s), OEL lead time constant
J+7		TBoel (s), OEL lag time constant
J+8		IFDpulev (pu), OEL activation logic pickup level
J+9		TIFDlev (s), OEL activation logic timer setpoint
J+10		IFDdolev (pu), OEL activation logic drop out level
J+11		IFDref1 (pu), OEL reference 1
J+12		IFDref2 (pu), OEL reference 2
J+13		KPoel (pu), OEL proportional gain
J+14		KIoel (pu/s), OEL integral gain
J+15		VOELmax (pu), OEL PI control upper limit
J+16		VOELmin (pu), OEL PI control lower limit
J+17		KPvfe (pu), Exciter field current regulator proportional gain
J+18		KIvfe (pu/s), Exciter field current regulator integral gain
J+19		VVFEmax (pu), Exciter field current regulator upper limit
J+20		VVFEmin (pu), Exciter field current regulator lower limit
J+21		KSCALE1, Scale factor for OEL input
J+22		TF1 (s), OEL input transducer time constant
J+23		KSCALE2, Scale factor IFEbase/IFErated
J+24		TF2 (s), Exciter field current transducer time constant

CONs	Value	Description
J+25		VFEref (pu), Exciter field current reference setpoint
J+26		Ibias (pu), OEL reference bias

STATEs	Description
K	Integrator
K+1	OEL Input
K+2	lead-lag
K+3	OEL PI block
K+4	VFE lag block
K+5	VFE PI block

VARs	Description
L	IOELactive
L+1	Iref
L+2	Timer for OEL activation logic

```
IBUS   'USRMDL'   ID   'OEL5CU1'    10    0    3    27    6    3
 ICON(M) to ICON(M+2)     CON(J) to CON(J+26)   /
```



Notes (some of the material below has ben taken from IEEE 421.5 2016):

1. SW1 is a user-selection option. Position A corresponds to the application to a static excitation system or a brushless system. Position B is used for rotating exciters with collector rings.

2. OEL input is user-selected. Could be generator field current IFD or generator field voltage EFD or exciter field current VFE.

3. Parameter KSCALE1 should be calculated to convert from the per unit base used for the OEL input signal to a per unit base corresponding to the rated value for the selected OEL input signal. All other parameters in the model are expressed in per unit of rated value.

4. Parameter KSCALE2 should be calculated to convert from the per unit base used for the VFE input signal to a per unit base corresponding to the rated value for the selected OEL input signal. All other parameters in the model are expressed in per unit of rated value.

5. The logical signal Iref is the output of the S-R flip-flop block shown in the diagram. The input signals for the S-R flip-flop block are the result of the logical tests indicated in the block diagram.

6. The logic switch SWref uses the signal Iref shown in the block diagram. SWref is in position “A” if Iref = 0 and in position “B” if Iref = 1.

7. The OEL activation logic uses the parameters IFDpulev, IFDdolev, and TIFDlev. It also uses the signal Ipu shown in the block diagram.

   The Activation Block has a setting for pickup when the input signal exceed IFDpulev and a timer is activated. The timer will proceed until the value of the input signal goes below the value of IFDdolev. When that occurs the Activation Block is reset.

   Note: The check of Ipu > IFDDOLEV is not shown in the IEEE 421.5 2016 OEL5C documentation. This was added into the PSS(R)E model after discussions with the equipment vendors and in consultation with IEEE 421.5 representatives.

```
IF (Ipu > IFDPULEV) for longer than TIFDlev
    enable OEL, i.e., set IOELactive = 1
ELSE IF ( Ipu < IFDDOLEV)
    block OEL, i.e., set IOELactive = 0
END
```

8. The logic switch SWOELout uses the logic signals IOELactive and Iref shown in the block diagram.

```
IF (Iref = 1) or (IOELactive = 1)
 enable OEL, i.e., set SWOELout in position “A”
ELSE
 block OEL, i.e., set SWOELout in position “B”
END
```

9. The output signal from OEL5C should be coordinated with the AVR output as these two signals are inputs to a low value gate. For brushless applications of one manufacturer, there was a scale factor for the output to reflect the scaling of the field quantities from a per unit system based on the generator air gap values for no load, nominal voltage condition to the per unit system at rated terminal conditions. With the present model, there is no scale factor for the output signal, and that scaling will need to be factored into the values for the IFDREF1, IFDREF2 and VFEREF.

Chapter 6
Excitation System Models

This chapter contains a collection of data sheets for the excitation system models contained in the PSS®E dynamics model library.

Model	Description
AC1C	IEEE AC1C excitation system model
AC2C	IEEE AC2C excitation system model
AC3C	IEEE AC3C excitation system model
AC4C	IEEE AC4C excitation system model
AC5C	IEEE AC5C excitation system model
AC6A	IEEE AC6A excitation system model
AC6C	IEEE AC6C excitation system model
AC6CU2	Modified AC6CU2 Excitation System Model
AC7B	IEEE 421.5 2005 AC7B excitation system
AC7CU1	IEEE 421.5 2016 AC7CU1 excitation system
AC8B	IEEE 421.5 2005 AC8B excitation system
AC8BBU2	Basler DECS-250 Excitation System
AC8CU1	IEEE 421.5 2016 AC8CU1 excitation system
AC8CU1	IEEE 421.5 2016 AC8CU1 excitation system
AC9CU1	IEEE 421.5 2016 AC9CU1 excitation system
AC11CU1	IEEE 421.5 2016 AC11CU1 excitation system
BBSEX1	Brown-Boveri static excitation system model
BUDCZT	Czech proportional/integral excitation system model
CELIN	ELIN brushless excitation system model
DC1C	IEEE DC1C excitation system model
DC2C	IEEE DC2C excitation system model
DC3A	IEEE 421.5 2005 DC3A excitation system
DC4B	IEEE 421.5 2005 DC4B excitation system
DC4CU1	IEEE 421.5 2016 DC4CU1 excitation system
EMAC1T	AEP Rockport excitation system model
ESAC1A	1992 IEEE type AC1A excitation system model
ESAC2A	1992 IEEE type AC2A excitation system model
ESAC3A	1992 IEEE type AC3A excitation system model
ESAC4A	1992 IEEE type AC4A excitation system model
ESAC5A	1992 IEEE type AC5A excitation system model
ESAC6A	1992 IEEE type AC6A excitation system model
ESAC8B	Basler DECS model
ESDC1A	1992 IEEE type DC1A excitation system model

Model	Description
ESDC2A	1992 IEEE type DC2A excitation system model
ESST1A	1992 IEEE type ST1A excitation system model
ESST2A	1992 IEEE type ST2A excitation system model
ESST3A	1992 IEEE type ST3A excitation system model
ESST4B	IEEE type ST4B potential or compounded source-controlled rectifier exciter
ESURRY	Modified IEEE Type AC1A excitation model
EX2000	EX2000 Excitation System
EXAC1	1981 IEEE type AC1 excitation system model
EXAC1A	Modified type AC1 excitation system model
EXAC2	1981 IEEE type AC2 excitation system model
EXAC3	1981 IEEE type AC3 excitation system model
EXAC4	1981 IEEE type AC4 excitation system model
EXBAS	Basler static voltage regulator feeding dc or ac rotating exciter model
EXDC2	1981 IEEE type DC2 excitation system model
EXELI	Static PI transformer fed excitation system model
EXNEBB	Bus or solid fed SCR bridge excitation system model type NEBB (NVE)
EXNI	Bus or solid fed SCR bridge excitation system model type NI (NVE)
EXPIC1	Proportional/integral excitation system model
EXST1	1981 IEEE type ST1 excitation system model
EXST2	1981 IEEE type ST2 excitation system model
EXST2A	Modified 1981 IEEE type ST2 excitation system model
EXST3	1981 IEEE type ST3 excitation system model
IEEET1	1968 IEEE type 1 excitation system model
IEEET2	1968 IEEE type 2 excitation system model
IEEET3	1968 IEEE type 3 excitation system model
IEEET4	1968 IEEE type 4 excitation system model
IEEET5	Modified 1968 IEEE type 4 excitation system model
IEEEX1	1979 IEEE type 1 excitation system model and 1981 IEEE type DC1 model
IEEEX2	1979 IEEE type 2 excitation system model
IEEEX3	1979 IEEE type 3 excitation system model
IEEEX4	1979 IEEE type 4 excitation system, 1981 IEEE type DC3 and 1992 IEEE type DC3A models
IEET1A	Modified 1968 IEEE type 1 excitation system model
IEET1B	Modified 1968 IEEE type 1 excitation system model
IEET5A	Modified 1968 IEEE type 4 excitation system model
IEEX2A	1979 IEEE type 2A excitation system model
IVOEX	IVO excitation system model
OEX12T	Ontario Hydro IEEE Type ST1 excitation system with continuous and bang bang terminal voltage limiter
OEX3T	Ontario Hydro IEEE Type ST1 excitation system with semicontinuous and acting terminal voltage limiter

Model	Description
REXSY1	General purpose rotating excitation system model
REXSYS	General purpose rotating excitation system model
SCRX	Bus or solid fed SCR bridge excitation system model
SEXS	Simplified excitation system model
ST1C	IEEE ST1C excitation system model
ST4CU1	IEEE ST4CU1 excitation system model
ST5B	IEEE 421.5 2005 ST5B excitation system
ST5C	IEEE ST5C excitation system model
ST7C	IEEE ST7C excitation system model
ST6B	IEEE 421.5 2005 ST6B excitation system
ST6CU1	IEEE 421.5 2016 ST6CU1 excitation system
ST7B	IEEE 421.5 2005 ST7B excitation system
ST8CU1	IEEE 421.5 2016 ST8CU1 excitation system
ST9CU1	IEEE 421.5 2016 ST9CU1 excitation system
ST10CU1	IEEE 421.5 2016 ST10CU1 excitation system
URHIDT	High dam excitation system model
URST5T	IEEE proposed type ST5B excitation system

6.1. AC1C

IEEE 421.5 Excitation System Model AC1C

ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

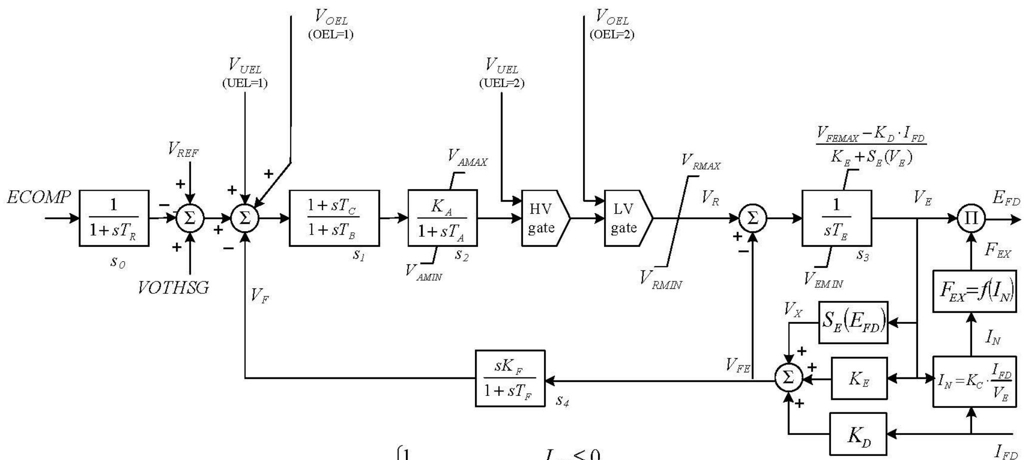
CONs	Value	Description
J		T_R (s), transducer time constant
J+1		T_B (s), lag time constant
J+2		T_C (s), lead time constant
J+3		K_A (pu), voltage regulator gain
J+4		T_A (s), voltage regulator time constant
J+5		V_{AMAX} (pu), maximum regulator output
J+6		V_{AMIN} (pu), minimum regulator output
J+7		T_E (>0) (s), exciter time constant
J+8		K_F (pu), rate feedback gain
J+9		T_F (>0) (s), rate feedback time constant
J+10		K_C (pu), function of commutating reactance
J+11		K_D (pu), function of the exciter alternator synchronous and transient reactance
J+12		K_E (pu), exciter constant related to self-excited field
J+13		E_1(pu), field voltage
J+14		$S_E(E_1)$ (pu), saturation factor at E_1
J+15		E_2(pu), field voltage
J+16		$SE(E_2)$ (pu), saturation factor at E_2
J+17		V_{RMAX} (pu), regulator output maximum limit
J+18		V_{RMIN} (pu), regulator output minimum limit
J+19		$V_{FE_{MAX}}$ (pu), maximum exciter field current limit reference
J+20		$V_{E_{MIN}}$ (pu), minimum exciter voltage output

STATEs	Description
K	Measurement lag
K+1	Lead-lag
K+2	Regulator
K+3	Exciter

STATEs	Description
K+4	Rate feedback

VARs	Description
L	Output of HV gate
L+1	Output of LV gate

```
IBUS, 'AC1C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+20) /
```



$$F_{EX}(I_N) = \begin{cases} 1 & I_N \le 0 \\ 1 - 0.577 I_N & 0 \le I_N \le 0.433 \\ \sqrt{0.75 - I_N^2} & 0.433 < I_N < 0.75 \\ 1.732(1 - I_N) & 0.75 \le I_N \le 1 \\ 0 & I_N > 1 \end{cases}$$

Notes:

1. For AC brushless exciters, VE_{MIN} has to be set to zero, and KC and KD have to be greater than zero.

6.2. AC2C

IEEE 421.5 Excitation System Model AC2C

ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

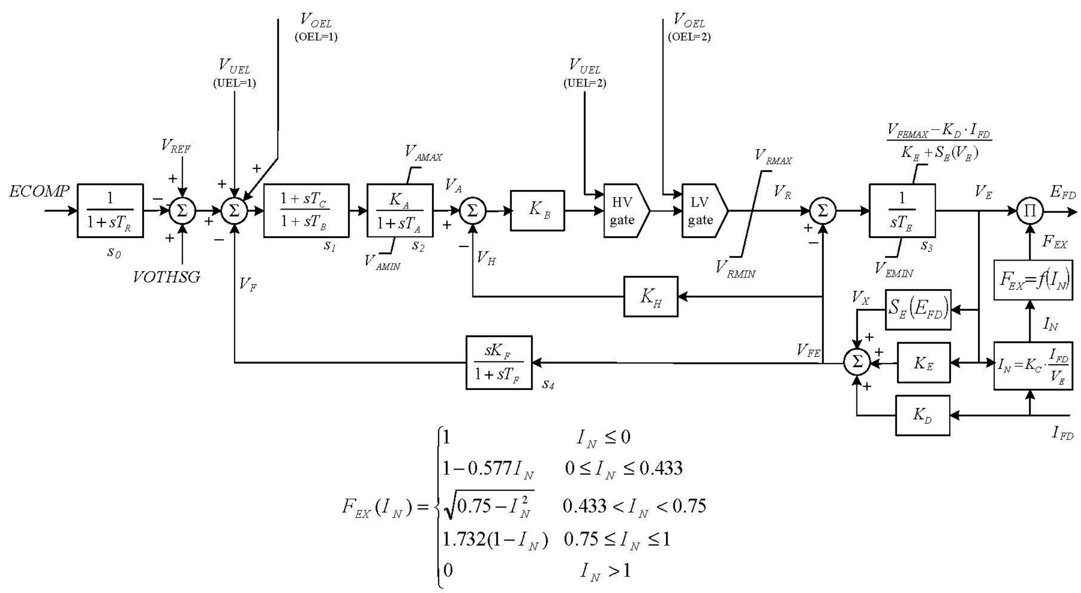
CONs	Value	Description
J		T_R (s), transducer time constant
J+1		T_B (s), lag time constant
J+2		T_C (s), lead time constant
J+3		K_A (pu), voltage regulator gain
J+4		T_A (s), voltage regulator time constant
J+5		V_{AMAX} (pu), maximum regulator output
J+6		V_{AMIN} (pu), minimum regulator output
J+7		K_B (pu), second stage regulator gain
J+8		V_{RMAX} (pu), regulator output maximum limit
J+9		V_{RMIN} (pu), regulator output minimum limit
J+10		T_E (>0) (s), exciter time constant
J+11		$V_{FE_{MAX}}$ (pu) , maximum exciter field current limit reference
J+12		K_H (pu), exciter field current regulator feedback gain
J+13		K_F (pu), rate feedback gain
J+14		T_F (>0) (s), rate feedback time constant
J+15		K_C (pu), function of commutating reactance
J+16		K_D (pu), function of the exciter alternator synchronous and transient reactance
J+17		K_E (pu), exciter constant related to self-excited field
J+18		E_1(pu), field voltage
J+19		$S_E(E_1)$ (pu), saturation factor at E_1
J+20		E_2(pu), field voltage
J+21		$SE(E_2)$ (pu), saturation factor at E_2
J+22		$V_{E_{MIN}}$ (pu)

STATEs	Description
K	Measurement lag
K+1	Lead-lag

STATEs	Description
K+2	Regulator output
K+3	Exciter
K+4	Feedback output

VARs	Description
L	Output of HV gate
L+1	Output of LV gate

```
IBUS, 'AC2C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+22) /
```



Notes:

1. For AC brushless exciters, VE_{MIN} has to be set to zero, and KC and KD have to be greater than zero.

6.3. AC3C

IEEE 421.5 Excitation System Model AC3C

ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

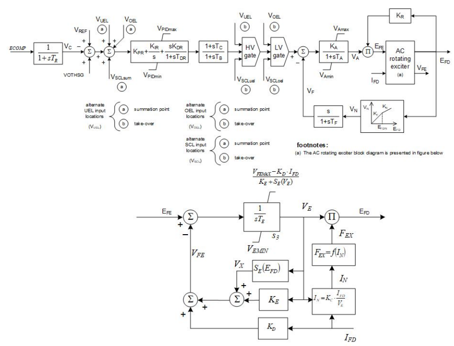
CONs	Value	Description
J		T_R (s), transducer time constant
J+1		T_B (s), lag time constant
J+2		T_C (s), lead time constant
J+3		K_A (pu), voltage regulator gain
J+4		T_A (s), voltage regulator time constant
J+5		V_{AMAX} (pu), maximum regulator output
J+6		V_{AMIN} (pu), minimum regulator output
J+7		T_E (>0) (s), exciter time constant
J+8		$V_{E_{MIN}}$ (pu), minimum exciter voltage output
J+9		K_R (>0) (pu), gain associated with regulator & alternator field power supply
J+10		K_F (pu), rate feedback gain
J+11		T_F (>0) (s), rate feedback time constant
J+12		K_N (pu), rate feedback excitation system stabilizer gain
J+13		E_{FDN} (pu), value of EFD at which feedback gain changes
J+14		K_C (pu), function of commutating reactance
J+15		K_D (pu), function of the exciter alternator synchronous and transient reactance
J+16		K_E (pu), exciter constant related to self-excited field
J+17		$V_{FE_{MAX}}$ (pu), maximum exciter field current limit reference
J+18		E_1(pu), field voltage
J+19		$S_E(E_1)$ (pu), saturation factor at E_1
J+20		E_2(pu), field voltage
J+21		$SE(E_2)$ (pu), saturation factor at E_2
J+22		K_{PA}, PID proportional gain (pu)
J+23		K_{IA}, PID integral gain (pu)
J+24		K_{DA}, PID derivative gain (pu)
J+25		T_{DA} (>0), PID derivative time constant (s)

CONs	Value	Description
J+26		V_{PIDMAX}, maximum PID output (pu)
J+27		V_{PIDMIN}, minimum PID output (pu)

STATEs	Description
K	Measurement lag
K+1	Lead-lag
K+2	Regulator output
K+3	Exciter
K+4	Feedback output

VARs	Description
L	Output of HV gate
L+1	Output of LV gate

```
IBUS, 'AC3C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+21) /
```



6.4. AC4C

IEEE 421.5 Excitation System Model AC4C

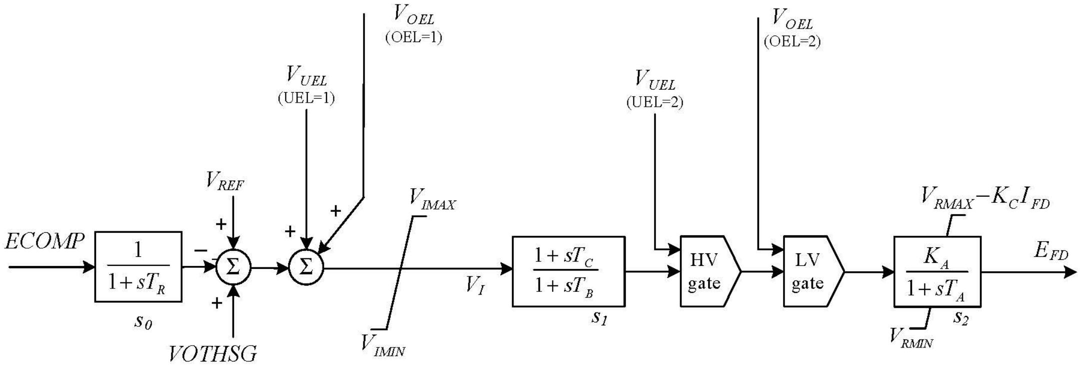
ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

CONs	Value	Description
J		T_R (s), transducer time constant
J+1		V_{IMAX} (pu), voltage regulator input (voltage error) maximum limit
J+2		V_{IMIN} (pu), voltage regulator input (voltage error) minimum limit
J+3		T_C (s), lead time constant
J+4		T_B (s), lag time constant
J+5		K_A (pu), voltage regulator gain
J+6		T_A (s), voltage regulator time constant
J+7		V_{RMAX} (pu), regulator output maximum limit
J+8		V_{RMIN} (pu), regulator output minimum limit
J+9		K_C (pu), Rectifier loading factor proportional to commutating reactance

STATEs	Description
K	Measurement lag
K+1	Lead-lag
K+2	Regulator

VARs	Description
L	Output of HV gate
L+1	Output of LV gate

```
IBUS, 'AC4C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+9) /
```


ECOMP
$\frac{1}{1+sT_R}$
s_0
V_{REF}
VOTHSG
V_{UEL}
(UEL=1)
V_{OEL}
(OEL=1)
V_{IMAX}
V_{IMIN}
V_I
$\frac{1+sT_C}{1+sT_B}$
s_1
V_{UEL}
(UEL=2)
HV gate
V_{OEL}
(OEL=2)
LV gate
$V_{RMAX}-K_C I_{FD}$
$\frac{K_A}{1+sT_A}$
s_2
V_{RMIN}
E_{FD}

6.5. AC5C

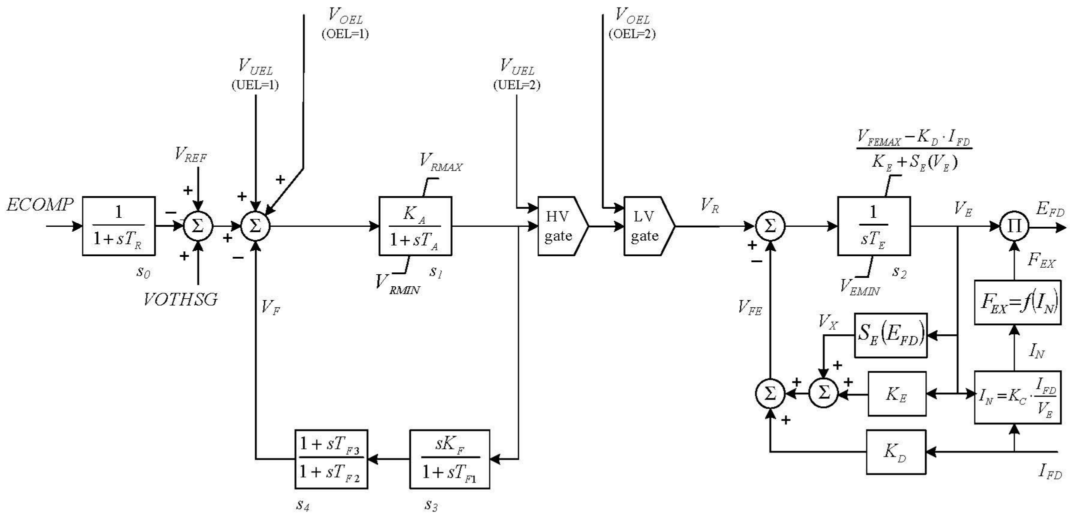
IEEE 421.5 Excitation System Model

ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

CONs	Value	Description
J		T_R (s), transducer time constant
J+1		K_A (pu), voltage regulator gain
J+2		T_A (s), voltage regulator time constant
J+3		V_{RMAX} (pu), regulator output maximum limit
J+4		V_{RMIN} (pu), regulator output minimum limit
J+5		K_E (pu), exciter constant related to self-excited field
J+6		T_E (>0) (s), exciter time constant
J+7		K_F (pu), rate feedback gain
J+8		T_{F1} (>0) (s), rate feedback excitation system stabilizer time constant
J+9		T_{F2} (>0) (s), rate feedback excitation system stabilizer time constant
J+10		T_F3 (>0) (s), rate feedback excitation system stabilizer time constant
J+11		E_1(pu), field voltage
J+12		$S_E(E_1)$ (pu), saturation factor at E_1
J+13		E_2(pu), field voltage
J+14		$SE(E_2)$ (pu), saturation factor at E_2
J+15		K_C (pu), function of commutating reactance
J+16		K_D (pu), function of the exciter alternator synchronous and transient reactance
J+17		$V_{FE_{MAX}}$ (pu), maximum exciter field current limit reference
J+18		$V_{E_{MIN}}$ (pu), minimum exciter voltage output

STATEs	Description
K	Measurement lag
K+1	Lead-lag
K+2	Exciter output
K+3	Washout
K+4	Feedback lead-lag

VARs	Description
L	K_E
L+1	Output of HV gate
L+2	Output of LV gate



$$F_{EX}(I_N)=\begin{cases}1 & I_N \le 0\\ 1-0.577I_N & 0\le I_N\le 0.433\\ \sqrt{0.75-I_N^2} & 0.433<I_N<0.75\\ 1.732(1-I_N) & 0.75\le I_N\le 1\\ 0 & I_N>1\end{cases}$$

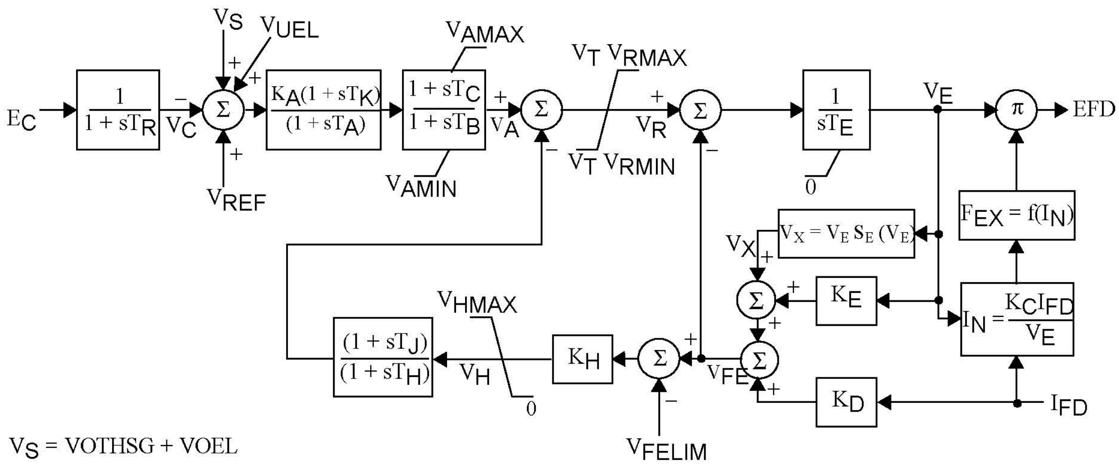
6.6. AC6A

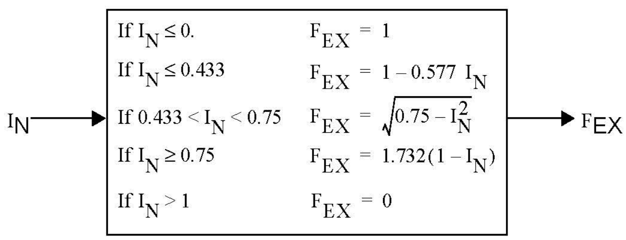
Modified ESAC6A Model

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		T_K (s)
J+4		T_B (s)
J+5		T_C (s)
J+6		V_{AMAX}
J+7		V_{AMIN}
J+8		V_{RMAX}
J+9		V_{RMIN}
J+10		T_E (>0) (s)
J+11		V_{FELIM}
J+12		K_H
J+13		V_{Hmax}
J+14		T_H (s)
J+15		T_J (s)
J+16		K_C
J+17		K_D
J+18		K_E
J+19		E_1
J+20		$S_E(E_1)$
J+21		E_2
J+22		$S_E(E_2)$

STATEs	Description
K	Sensed E_T
K+1	First block
K+2	Lead lag
K+3	V_E
K+4	Feedback

```
IBUS, 'AC6A', ID, CON(J) to CON(J+20)   /
```





Notes:

The ESAC6A model was the original implementation of the 1992 IEEE 421.5 AC6A model. The implementation of the non-windup limit applied to the lead-lag block in the ESAC6A model is not consistent with the implementation shown in the 2005 IEEE 421.5 Standard. The revised AC6A model strictly follows the 2005 IEEE 421.5 Standard and should be preferred if adherence to that Standard is required.

6.7. AC6C

IEEE 421.5 Excitation System Model AC6C

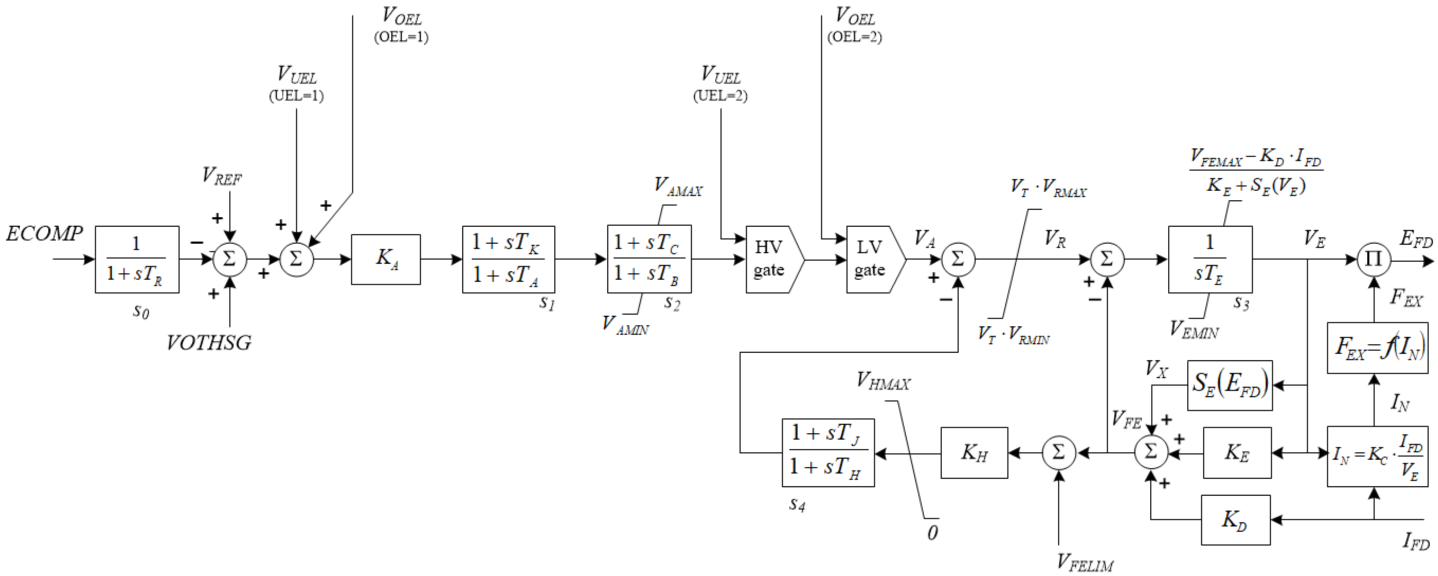
ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

CONs	Value	Description
J		T_R (s), transducer time constant
J+1		K_A (pu), voltage regulator gain
J+2		T_A (s), voltage regulator time constant
J+3		TK (s), regulator numerator (lead) time constant
J+4		T_B (s), lag time constant
J+5		T_C (s), lead time constant
J+6		V_{AMAX} (pu), maximum regulator output
J+7		V_{AMIN} (pu), minimum regulator output
J+8		V_{RMAX} (pu), regulator output maximum limit
J+9		V_{RMIN} (pu), regulator output minimum limit
J+10		T_E (>0) (s), exciter time constant
J+11		V_{FELIM} (pu), exciter field current limiter reference
J+12		K_H (pu), exciter field current limiter gain
J+13		V_{Hmax} (pu), exciter field current limiter maximum output
J+14		T_H (>0) (s), exciter field current limiter denominator (lag) time constant
J+15		T_J (>0) (s), exciter field current limiter numerator (lead) time constant
J+16		K_C (pu), function of commutating reactance
J+17		K_D (pu), function of the exciter alternator synchronous and transient reactance
J+18		K_E (pu), exciter constant related to self-excited field
J+19		E_1(pu), field voltage
J+20		$S_E(E_1)$ (pu), saturation factor at E_1
J+21		E_2(pu), field voltage
J+22		$SE(E_2)$ (pu), saturation factor at E_2
J+23		$V_{FE_{MAX}}$ (pu), maximum exciter field current limit reference
J+24		$V_{E_{MIN}}$ (pu), minimum exciter voltage output

STATEs	Description
K	Measurement lag
K+1	First lead-lag
K+2	Second lead-lag
K+3	Exciter output
K+4	Feedback

VARs	Description
L	Output of HV gate
L+1	Output of LV gate

```
IBUS, 'AC6C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+24) /
```



$$F_{EX}(I_N) = \begin{cases} 1 & I_N \le 0 \\ 1 - 0.577 I_N & 0 \le I_N \le 0.433 \\ \sqrt{0.75 - I_N^2} & 0.433 < I_N < 0.75 \\ 1.732(1 - I_N) & 0.75 \le I_N \le 1 \\ 0 & I_N > 1 \end{cases}$$

6.8. AC6CU2

Modified AC6C Excitation System Model

ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate
M+2		Regulator limit (VRMAX & VRMIN) voltage dependency flag • 1 - limits dependent on voltage • 0 - limits not dependent on voltage

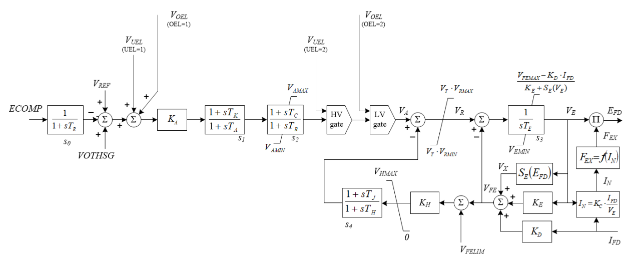
CONs	Value	Description
J		T_R (s), transducer time constant
J+1		K_A (pu), voltage regulator gain
J+2		T_A (s), voltage regulator time constant
J+3		TK (s), regulator numerator (lead) time constant
J+4		T_B (s), lag time constant
J+5		T_C (s), lead time constant
J+6		V_{AMAX} (pu), maximum regulator output
J+7		V_{AMIN} (pu), minimum regulator output
J+8		V_{RMAX} (pu), regulator output maximum limit
J+9		V_{RMIN} (pu), regulator output minimum limit
J+10		T_E (>0) (s), exciter time constant
J+11		V_{FELIM} (pu), exciter field current limiter reference
J+12		K_H (pu), exciter field current limiter gain
J+13		V_{Hmax} (pu), exciter field current limiter maximum output
J+14		T_H (>0) (s), exciter field current limiter denominator (lag) time constant
J+15		T_J (>0) (s), exciter field current limiter numerator (lead) time constant
J+16		K_C (pu), function of commutating reactance
J+17		K_D (pu), function of the exciter alternator synchronous and transient reactance
J+18		K_E (pu), exciter constant related to self-excited field
J+19		E_1(pu), field voltage
J+20		$S_E(E_1)$ (pu), saturation factor at E_1

CONs	Value	Description
J+21		E_2(pu), field voltage
J+22		$SE(E_2)$ (pu), saturation factor at E_2
J+23		$V_{FE_{MAX}}$ (pu), maximum exciter field current limit reference
J+24		$V_{E_{MIN}}$ (pu), minimum exciter voltage output

STATEs	Description
K	Measurement lag
K+1	First lead-lag
K+2	Second lead-lag
K+3	Exciter output
K+4	Feedback

VARs	Description
L	Output of HV gate
L+1	Output of LV gate

```
IBUS, 'USRMDL', ID, 'AC6CU2', 4, 0, 3, 25, 5, 2, ICON(M) to ICON(M+2),
 CON(J) to CON(J+24) /
```



$$F_{EX}(I_N)=\begin{cases}1 & I_N \le 0\\ 1-0.577I_N & 0 \le I_N \le 0.433\\ \sqrt{0.75-I_N^2} & 0.433 < I_N < 0.75\\ 1.732(1-I_N) & 0.75 \le I_N \le 1\\ 0 & I_N > 1\end{cases}$$

6.9. AC7B

IEEE 421.5 2016 AC7B Excitation System

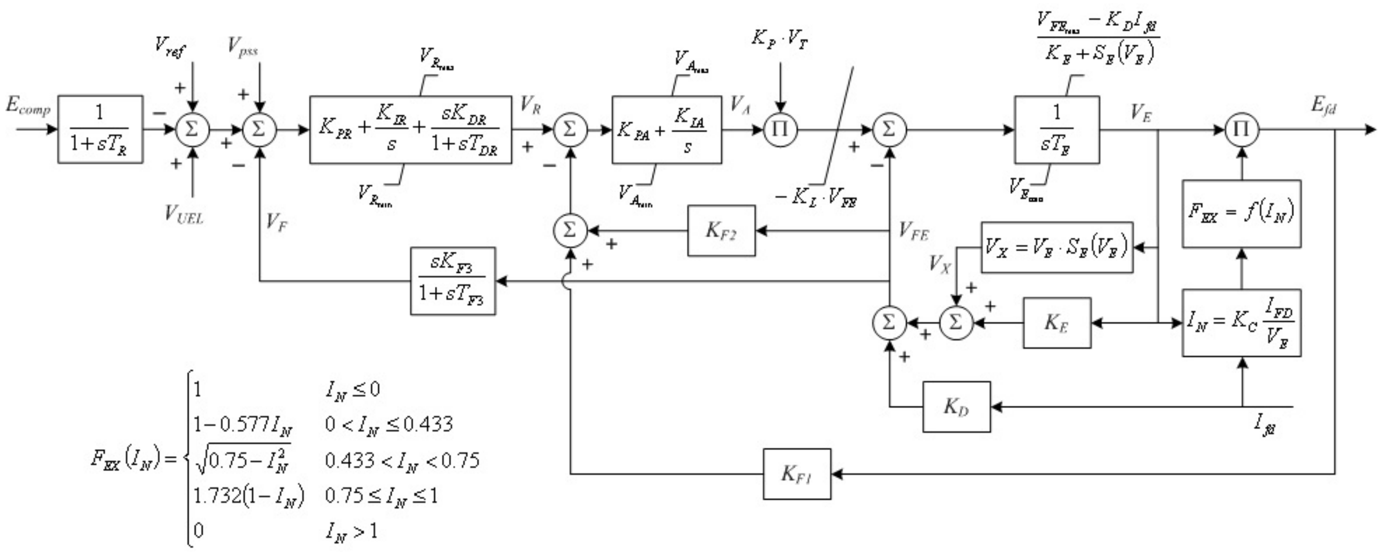
CONs	Value	Description
J		T_R (s) regulator input filter time constant
J+1		K_{PR} (pu) regulator proportional gain
J+2		K_{IR} (pu) regulator integral gain
J+3		K_{DR} (pu) regulator derivative gain
J+4		T_{DR} (s) regulator derivative block time constant
J+5		V_{RMAX} (pu) regulator output maximum limit
J+6		V_{RMIN} (pu) regulator output minimum limit
J+7		K_{PA} (pu) voltage regulator proportional gain
J+8		K_{IA} (pu) voltage regulator integral gain
J+9		V_{AMAX} (pu) regulator output maximum limit
J+10		V_{AMIN} (pu) regulator output minimum limit
J+11		K_P (pu) [a]
J+12		K_L (pu)
J+13		K_{F1} (pu)
J+14		K_{F2} (pu)
J+15		K_{F3} (pu)
J+16		T_{F3} (s) time constant (> 0)
J+17		K_C (pu) rectifier loading factor proportional to commutating reactance
J+18		K_D (pu) demagnetizing factor, function of AC exciter reactances
J+19		K_E (pu) exciter constant related fo self-excited field
J+20		T_E (pu) exciter time constant (>0)
J+21		$V_{FE_{MAX}}$ (pu) exciter field current limit (> 0)
J+22		$V_{E_{MIN}}$ (pu)
J+23		E_1
J+24		$S(E_1)$
J+25		E_2
J+26		$S(E_2)$

[a]Setting K_P = 0 eliminates the multiplication of VA by terminal voltage V_T

STATEs	Description
K	Sensed V_t
K+1	Integral channel 1
K+2	Derivative channel 1
K+3	Integral channel 2
K+4	V_E
K+5	Rate feedback

VARs	Description
L	V_R
L+1	V_A

```
IBUS, 'AC7B', ID, CON(J) to CON(J+26)   /
```



If K_p is zero, the factor K_p * V_t is ignored.

6.10. AC7CU1

IEEE 421.5 2016 AC7CU1 Excitation System

ICONs	Value	Description
M		OEL Flag (See notes)
M+1		UEL Flag (See notes)
M+2		SCL Flag (See notes)
M+3		PSS Flag (See notes)
M+4		SW1 Flag 1: Position A 2: Position B
M+5		SW2 Flag 1: Position A 2: Position B

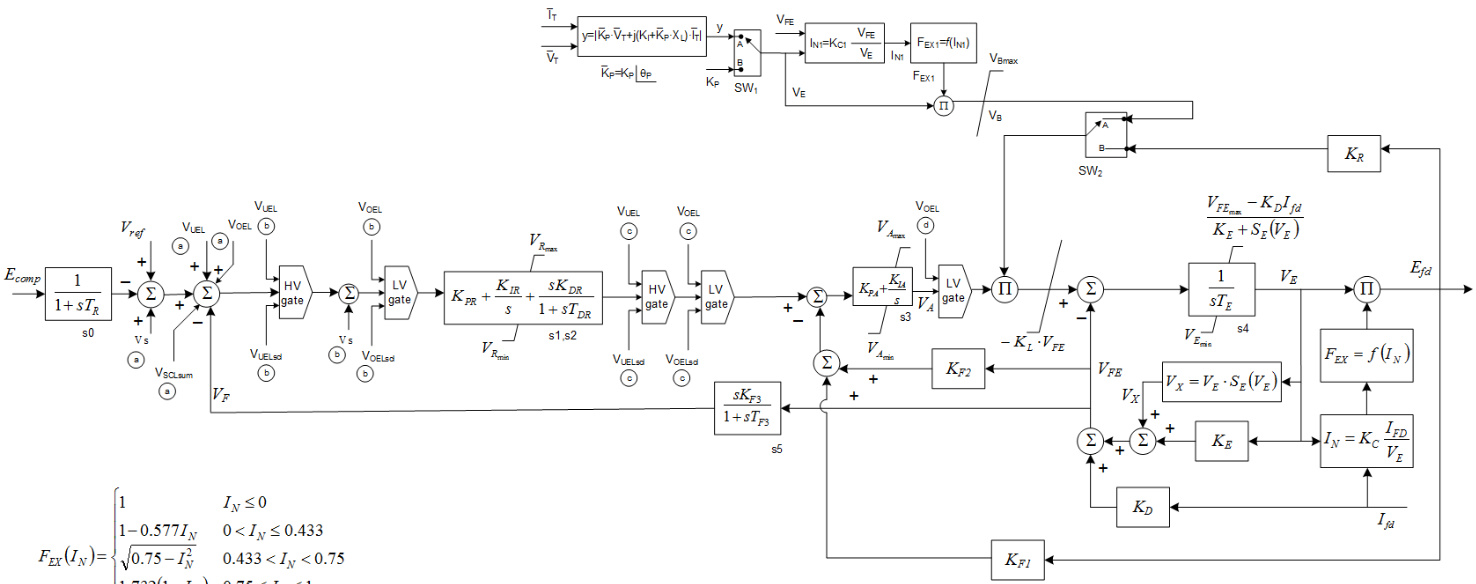
CONs	Value	Description
J		T_R (s) regulator input filter time constant
J+1		K_{PR} (pu) regulator proportional gain
J+2		K_{IR} (pu) regulator integral gain
J+3		K_{DR} (pu) regulator derivative gain
J+4		T_{DR} (s) regulator derivative block time constant
J+5		V_{RMAX} (pu) regulator output maximum limit
J+6		V_{RMIN} (pu) regulator output minimum limit
J+7		K_{PA} (pu) voltage regulator proportional gain
J+8		K_{IA} (pu) voltage regulator integral gain
J+9		V_{AMAX} (pu) regulator output maximum limit
J+10		V_{AMIN} (pu) regulator output minimum limit
J+11		K_P (pu)
J+12		K_L (pu)
J+13		K_{F1} (pu)
J+14		K_{F2} (pu)
J+15		K_{F3} (pu)
J+16		T_{F3} (s) time constant (> 0)
J+17		K_C (pu) rectifier loading factor proportional to commutating reactance
J+18		K_D (pu) demagnetizing factor, function of AC exciter reactances
J+19		K_E (pu) exciter constant related fo self-excited field
J+20		T_E (pu) exciter time constant (>0)
J+21		V_{FEMAX} (pu) exciter field current limit (> 0)

CONs	Value	Description
J+22		V_{EMIN} (pu)
J+23		E_1
J+24		$S(E_1)$
J+25		E_2
J+26		$S(E_2)$
J+27		K_I Potential circuit (current)
J+28		X_L Reactance associated with potential source
J+29		θ_P Potential circuit phase angle (degrees)
J+30		K_{C1} Rectifier loading factor proportional to commutating reactance
J+31		V_{BMAX} Maximum available exciter field voltage
J+32		K_R Regulator and alternator field power supply gain

STATEs	Description
K	Sensed V_t
K+1	Integral channel 1
K+2	Derivative channel 1
K+3	Integral channel 2
K+4	V_E
K+5	Rate feedback

VARs	Description
L	V_R
L+1	V_A
L+2	V_F
L+3	V_{FE}

```
IBUS  'USRMDL'  ID  'AC7CU1'   4   0   6   33    6    4   ICON (M) to
 ICON(M+5), CON(J) to CON(J+32)       /
```



$$F_{EX}(I_N)=\begin{cases}1 & I_N \le 0\\ 1-0.577 I_N & 0 < I_N \le 0.433\\ \sqrt{0.75-I_N^2} & 0.433 < I_N < 0.75\\ 1.732(1-I_N) & 0.75 \le I_N \le 1\\ 0 & I_N > 1\end{cases}$$

Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.
2. Setting K_P = 0 eliminates the multiplication of V_A by terminal voltage V_T
3. For UEL and SCL flag options, the ICON value can be 1 through 3 with description as follows:
   a. 1: Position (a)
   b. 2: Position (b)
   c. 3: Position (c)
4. For OEL flag options, the ICON value can be 1 through 4 with description as follows:
   a. 1: Position (a)
   b. 2: Position (b)
   c. 3: Position (c)
   d. 4: Position (d)
5. For PSS flag options, the ICON value can be 1 through 2 with description as follows:
   a. 1: Position (a)
   b. 2: Position (b)

6.11. AC8B

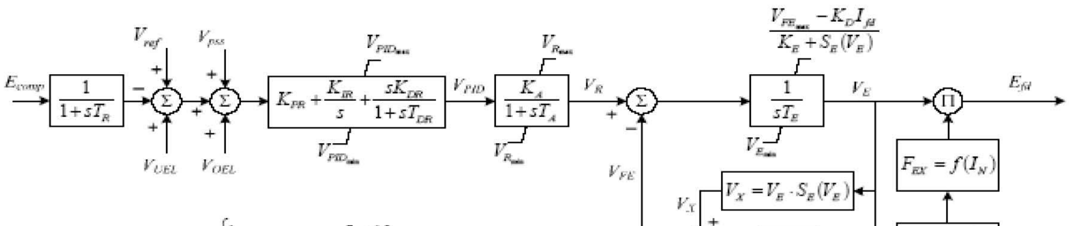
IEEE 421.5 2005 AC8B Excitation System

CONs	Value	Description
J		T_R (s) regulator input filter time constant
J+1		K_{PR} (pu) regulator proportional gain
J+2		K_{IR} (pu) regulator integral gain
J+3		K_{DR} (pu) regulator derivative gain
J+4		T_{DR} (s) regulator derivative block time constant
J+5		V_{PIDMAX} (pu) PID maximum limit
J+6		V_{PIDMIN} (pu) PID minimum limit
J+7		K_A (pu) voltage regulator proportional gain
J+8		T_A (s) voltage regulator time constant
J+9		V_{RMAX} (pu) regulator output maximum limit
J+10		V_{RMIN} (pu) regulator output minimum limit
J+11		K_C (pu) rectifier loading factor proportional to commutating reactance
J+12		K_D (pu) demagnetizing factor, function of AC exciter reactances
J+13		K_E (pu) exciter constant related fo self-excited field
J+14		T_E (pu) exciter time constant (>0)
J+15		$V_{FE_{MAX}}$ (pu) exciter field current limit (> 0)
J+16		$V_{E_{MIN}}$ (pu)
J+17		E_1
J+18		$S(E_1)$
J+19		E_2
J+20		$S(E_2)$

STATEs	Description
K	Sensed V_t
K+1	Integral channel PID
K+2	Derivative channel PID
K+3	V_R
K+4	V_E

VARs	Description
L	V_{PID}
L+1	FEX
L+2	$V_{E_{MAX}}$

```
IBUS, 'AC8B', ID, CON(J) to CON(J+20)   /
```



$$F_{EX}(I_N)=\begin{cases}1 & I_N \le 0\\ 1-0.577I_N & 0<I_N\le 0.433\\ \sqrt{0.75-I_N^2} & 0.433<I_N<0.75\\ 1.732(1-I_N) & 0.75\le I_N\le 1\\ 0 & I_N>1\end{cases}$$

6.12. AC8BBU2

Basler DECS-250 Excitation System

ICONs	Value	Description
M		PSS signal entry point 0 – at voltage error calculation (a) 1 – after take-over UEL (b)
M+1		UEL signal entry point 0 – at voltage error calculation (summation point) (a) 1 – at voltage error (take-over UEL) (b) 2 – at voltage regulator output (take-over UEL) (c)
M+2		OEL signal entry point 0 – at voltage error calculation (summation point) (a) 1 – at voltage error (take-over OEL) (b) 2 – at voltage regulator output (take-over OEL) (c)
M+3		SW1, excitation power source switch 0 – position (a) 1 – position (b)
M+4		Iouter, AVR outer loop control remote bus number 0 – disable bus number – enable

CONs	Value	Description
J		TR (s), regulator input filter time constant
J+1		KPR (pu), regulator proportional gain
J+2		KIR (pu), regulator integral gain
J+3		KDR (pu), regulator derivative gain
J+4		TDR (s), regulator derivative block time constant
J+5		VPIDmax (pu), PID maximum limit
J+6		VPIDmin (pu), PID minimum limit
J+7		KA (pu), voltage regulator proportional gain
J+8		TA (s), voltage regulator time constant
J+9		VRMAX (pu), regulator output maximum limit
J+10		VRMIN (pu), regulator output minimum limit
J+11		KC (pu), rectifier loading factor proportional to commutating reactance
J+12		KD (pu), demagnetizing factor, function of AC exciter reactances
J+13		KE (pu), exciter constant related to self-excited field
J+14		TE (s), exciter time constant
J+15		VFEMAX (pu), exciter field current maximum limit reference (> 0)
J+16		VEMIN (pu), exciter field current minimum limit
J+17		E1
J+18		S(E1)
J+19		E2
J+20		S(E2)
J+21		KP (pu), Potential circuit gain coefficient
J+22		03B8 P (degrees), Potential circuit phase angle
J+23		KI (pu), Potential circuit (current) gain coefficient
J+24		XL (pu), Reactance associated with potential source

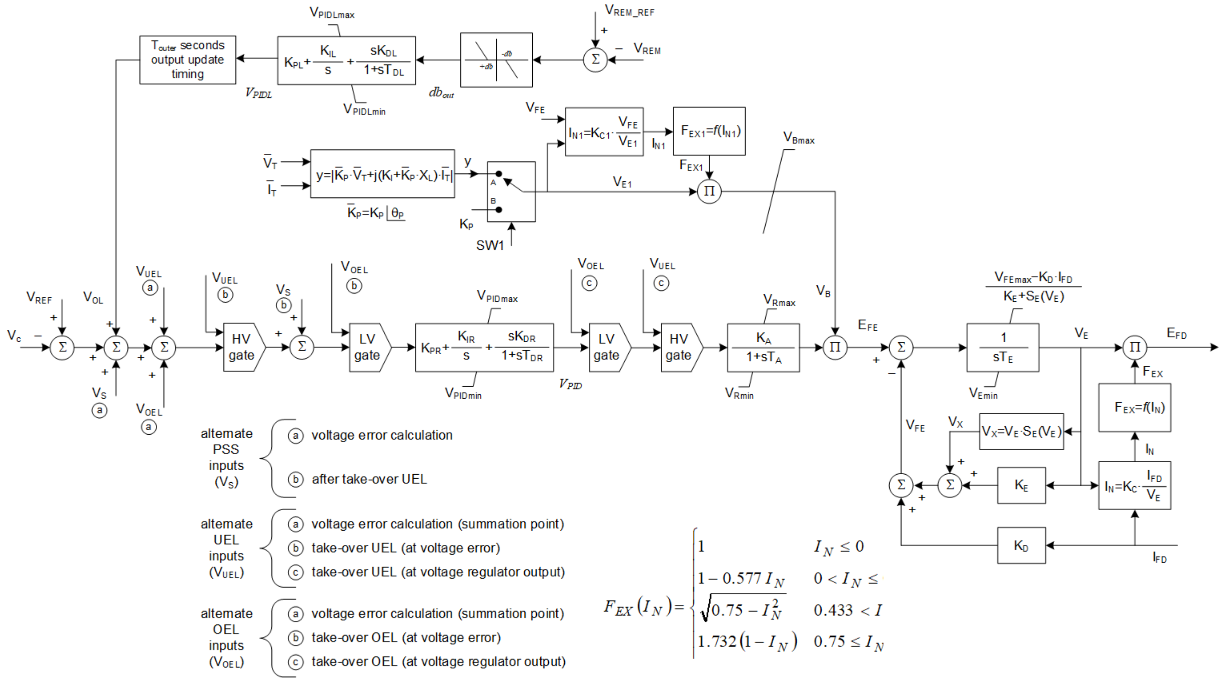
CONs	Value	Description
J+25		KC1 (pu), Rectifier loading factor proportional to commutating reactance
J+26		VBmax (pu), Maximum available exciter field voltage
J+27		db (>=0), AVR outer loop dead band
J+28		KPL (pu), AVR outer loop proportional gain
J+29		KIL (pu), AVR outer loop integral gain
J+30		KDL (pu), AVR outer loop derivative gain
J+31		TDL (s), AVR outer loop derivative block time constant
J+32		VPIDLmax (pu), AVR outer loop PID maximum limit
J+33		VPIDLmin (pu), AVR outer loop PID minimum limit
J+34		Touter (s), AVR outer loop output update timing

STATEs	Description
K	Sensed Voltage (to AVR)
K+1	AVR Integral channel PID
K+2	AVR Derivative channel PID
K+3	VR
K+4	VE
K+5	AVR outer loop Integral channel PID
K+6	AVR outer loop Derivative channel PID

VARs	Description
L	VPID
L+1	FEX
L+2	VEMAX
L+3	VB
L+4	Vref_rem
L+5	dbout
L+6	VPIDL
L+7	TOL
L+8	VOL

DYR record:

```
IBUS 'USRMDL'  ID  'AC8BBU2'  4  0 5 35 7 9 ICON(M) to ICON(M+4), CON (J)
 to CON(J+34)    /
```



alternate PSS inputs (V_S)
ⓐ voltage error calculation
ⓑ after take-over UEL
alternate UEL inputs (V_{UEL})
ⓐ voltage error calculation (summation point)
ⓑ take-over UEL (at voltage error)
ⓒ take-over UEL (at voltage regulator output)
alternate OEL inputs (V_{OEL})
ⓐ voltage error calculation (summation point)
ⓑ take-over OEL (at voltage error)
ⓒ take-over OEL (at voltage regulator output)
HV gate
LV gate
SW1

6.13. AC8CU1

IEEE 421.5 2016 AC8CU1 Excitation System

ICONs	Value	Description
M		OEL Flag (See notes)
M+1		UEL Flag (See notes)
M+2		SCL Flag (See notes)
M+3		PSS Flag (See notes)
M+4		SW1 Flag 1: Position A 2: Position B

CONs	Value	Description
J		T_R (s) regulator input filter time constant
J+1		K_{PR} (pu) regulator proportional gain
J+2		K_{IR} (pu) regulator integral gain
J+3		K_{DR} (pu) regulator derivative gain
J+4		T_{DR} (s) regulator derivative block time constant
J+5		V_{PIDMAX} (pu) PID maximum limit
J+6		V_{PIDMIN} (pu) regulator output minimum limit
J+7		K_A (pu) voltage regulator proportional gain
J+8		T_A (pu) voltage regulator integral gain
J+9		V_{RMAX} (pu) regulator output maximum limit
J+10		V_{RMIN} (pu) regulator output minimum limit
J+11		K_C (pu) rectifier loading factor proportional to commutating reactance
J+12		K_D (pu) demagnetizing factor, function of AC exciter reactance
J+13		K_E (pu) exciter constant related to self-excited field
J+14		T_E (pu) exciter time constant
J+15		V_{FEMAX} (pu) exciter field current limit (> 0)
J+16		V_{EMIN} (pu) (> 0)
J+17		E_1
J+18		S (E1)
J+19		E_2
J+20		S (E2)
J+21		$K_P$potential circuit gain Coefficient
J+22		K_I potential circuit (current) gain coefficient
J+23		$X_L$reactance associated with potential source
J+24		θ_P Potential circuit phase angle (degrees)
J+25		K_{C1} Rectifier loading factor proportional to commutating reactance
J+26		V_{BMAX} Maximum available exciter field voltage

STATEs	Description
K	Sensed V_t
K+1	PID Integrator
K+2	PID Derivator
K+3	V_R
K+4	V_E

VARs	Description
L	V_{PID}
L+1	FEX
L+2	V_{EMAX}

```
IBUS 'USRMDL' ID 'AC8CU1' 4 0 5 27 5 3 ICON (M) to
 ICON(M+4), CON(J) to CON(J+26) /
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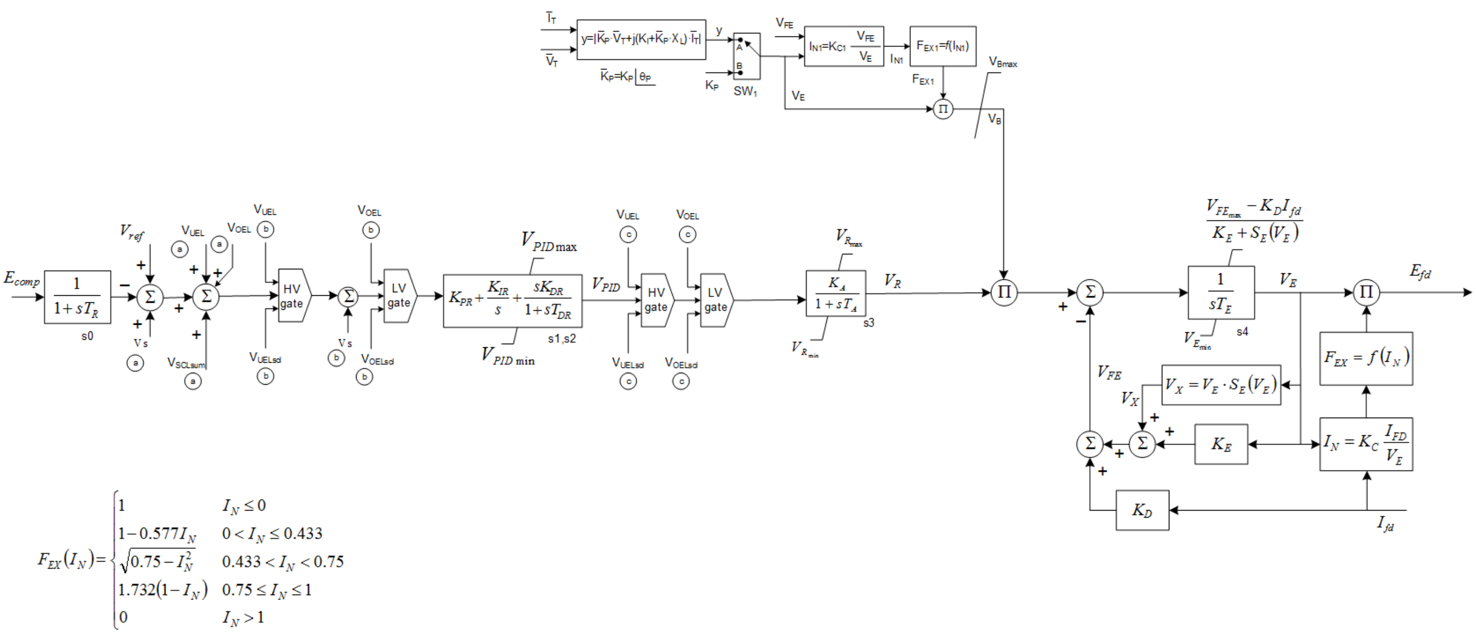


Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.
2. For OEL, UEL and SCL flag options, the ICON value can be 1 through 3 with description as follows:
   a. 1: Position (a)
   b. 2: Position (b)
   c. 3: Position (c)
3. For PSS flag options, the ICON value can be 1 or 2 with description as follows:

a. 1: Position (a)

b. 2: Position (b)

6.14. AC9CU1

IEEE 421.5 2016 AC9CU1 Excitation System

ICONs	Value	Description
M		OEL Flag (See notes)
M+1		UEL Flag (See notes)
M+2		SCL Flag (See notes)
M+3		SW1 Flag 1: Position A 2: Position B

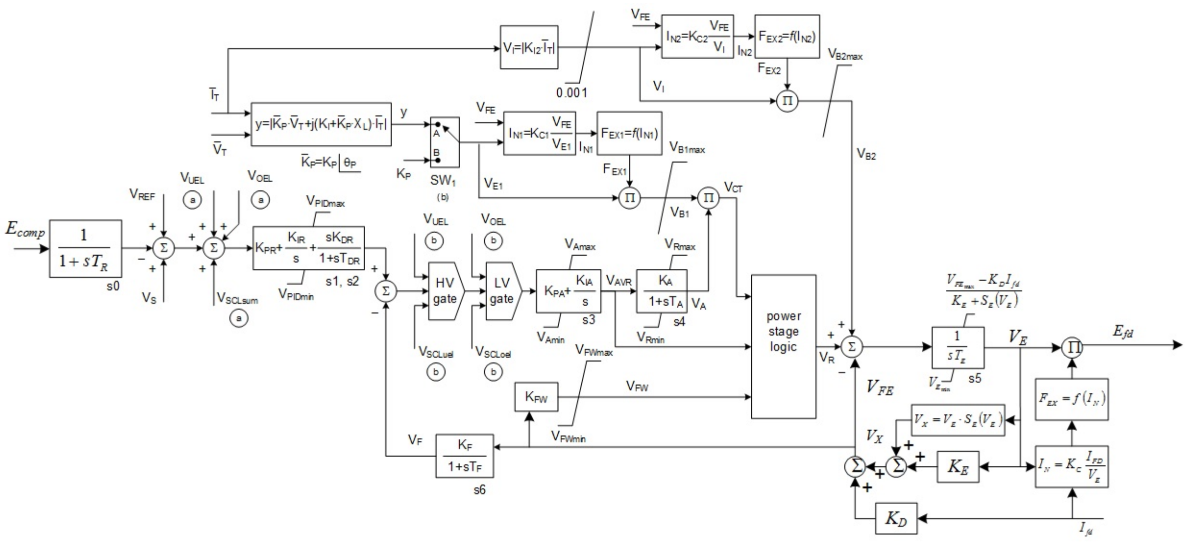
CONs	Value	Description
J		T_R (s) Regulator input filter time constant
J+1		K_{PR} (pu) Regulator proportional gain
J+2		K_{IR} (pu) Regulator integral gain
J+3		K_{DR} (pu) Regulator derivative gain
J+4		T_{DR} (s) Regulator derivative block time constant
J+5		V_{PIDMAX} (pu) PID maximum limit
J+6		V_{PIDMIN} (pu) PID minimum limit
J+7		K_{PA} (pu) Field current regulator proportional gain
J+8		K_{IA} (pu) Field current regulator integral gain
J+9		V_{AMAX} (pu) Maximum current regulator output
J+10		V_{AMIN} (pu) Minimum current regulator output
J+11		K_A (pu) Controlled rectifier bridge equivalent gain
J+12		T_A (s) Controlled rectifier bridge equivalent time constant
J+13		V_{RMAX} (pu) Maximum rectifier bridge output
J+14		V_{RMIN} (pu) Minimum rectifier bridge output
J+15		K_F (pu) Exciter field current feedback gain
J+16		T_F (s) Field current feedback time constant
J+17		K_{FW} (pu) Free wheel equivalent feedback gain
J+18		V_{FWMAX} (pu) Maximum free wheel feedback
J+19		K_E (pu) Minimum free wheel feedback
J+20		S_{CT} Power stage type selector
J+21		K_C(pu) Diode bridge loading factor proportional to commutating reactance
J+22		K_D(pu) Demagnetizing factor, function of exciter alternator reactance
J+23		K_E (pu) Exciter field proportional constant
J+24		T_E (pu) Exciter field time constant
J+25		V_{FEMAX} (pu) Exciter Field current limit
J+26		V_{EMIN} (pu) Minimum exciter output limit

CONs	Value	Description
J+27		E_1
J+28		S(E1)
J+29		E_2
J+30		S(E2)
J+31		K_P (pu) Potential current gain coefficient
J+32		K_{I1} (pu) Compound circuit (current) gain coefficient
J+33		K_{I2} (pu) Compound circuit (current) gain coefficient
J+34		K_{C1} (pu) Rectifier loading factor proportional to commutating reactance
J+35		K_{C2} (pu) Rectifier loading factor proportional to commutating reactance
J+36		X_L (pu) Reactance associated with potential source
J+37		Θ_P (degrees) Potential circuit phase angle
J+38		V_{B1MAX} (pu) Maximum available exciter field voltage
J+39		V_{B2MAX} (pu) Maximum available exciter field voltage
J+40		V_{LIM1} (pu) Limit1 for Power Stage Logic Block
J+41		V_{LIM2} (pu) Limit2 for Power Stage Logic Block

STATEs	Description
K	Sensed V_t
K+1	PID Integrator
K+2	PID Derivator
K+3	V_{AVR}
K+4	V_A
K+5	V_E
K+6	V_F

VARs	Description
L	V_{PID}
L+1	V_{FE}
L+2	V_{EMAX}

```
IBUS  'USRMDL'  ID  'AC9CU1'   4   0   4   42    7    3   ICON (M) to
 ICON(M+3), CON(J) to CON(J+41)       /
```



Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.

2. SW1 is a user-selected option. Position A corresponds to a power source from generator terminal voltage such as an excitation transformer. Position B corresponds to a power source independent of generator terminal conditions, such as pilot exciter.

3. For OEL, UEL and SCL flag options, the ICON value can be 1 through 3 with description as follows:

   a. 1: Position (a)

   b. 2: Position (b)

4. The Power stage logic uses user-selected parameters SCT, VLIM1, VLIM2 and the signals VCT, VFW and VAVR as shown in the model block diagram. The parameter VLIM1 should be greater than VLIM2. Typical values are VLIM1 = 0 and VLIM2 = -0.1 pu.

   IF SCT =/ 0 (this represents a thyristor bridge)

   VR = VCT

   ELSE (this represents a chopper converter)

   IF VAVR > VLIM1

   VR = VCT

   ELSE

   IF VAVR > VLIM2

   VR = 0

ELSE

VR = -VFW

ENDIF

ENDIF

ENDIF

6.15. AC11CU1

IEEE 421.5 2016 AC11CU1 Excitation System

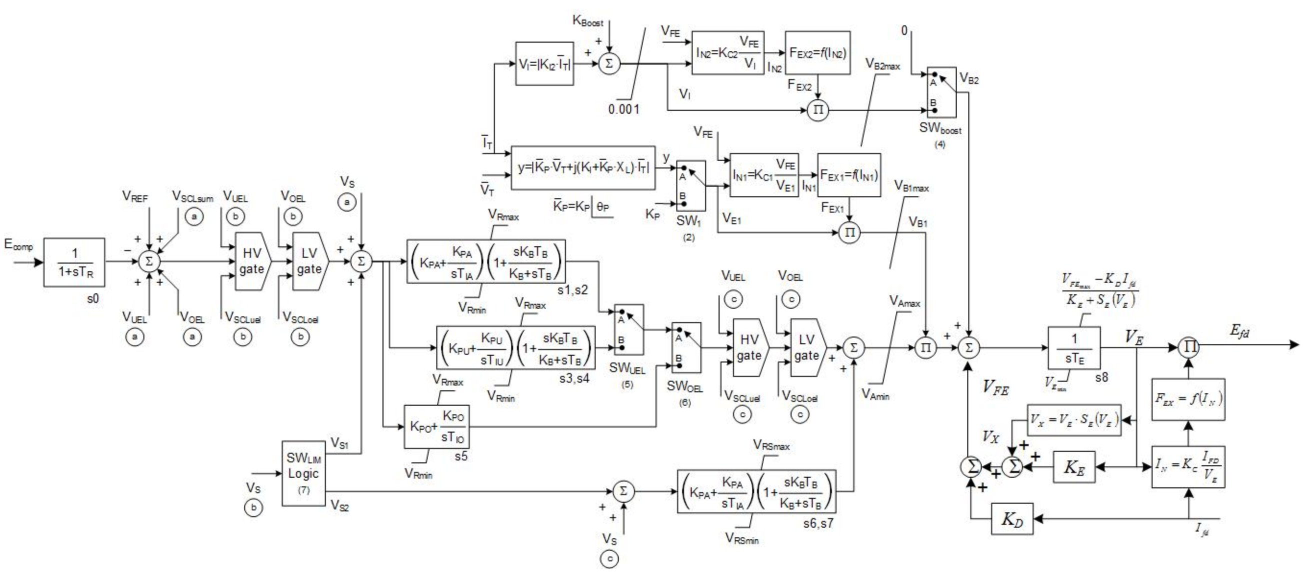
ICONs	Value	Description
M		PSS Flag (See notes)
M+1		OEL Flag (See notes)
M+2		UEL Flag (See notes)
M+3		SCL Flag (See notes)
M+4		SW1 Flag 1: Position A 2: Position B

CONs	Value	Description
J		T_R (s) Regulator input filter time constant
J+1		K_{PA} (pu) Voltage Regulator proportional gain
J+2		T_{IA} (s) Voltage Regulator Integral Time constant (>0)
J+3		K_{PU} (pu) UEL Regulator proportional gain
J+4		T_{IU} (s) UEL Regulator Integral Time constant (>0)
J+5		K_B (pu) Voltage and UEL Regulator derivative gain
J+6		T_B (s) UEL Regulator Integral Time constant (>0)
J+7		K_{PO} (pu) OEL regulator proportional gain
J+8		T_{IO} (s) OEL Regulator Integral Time constant (>0)
J+9		V_{RSMAX} (pu) Maximum PSS regulator output
J+10		V_{RSMIN} (pu) Minimum PSS regulator output
J+11		V_{RMAX} (pu) Maximum regulator output
J+11		V_{RMIN} (pu) Minimum regulator output
J+13		V_{AMAX} (pu) Maximum exciter output
J+14		V_{AMIN} (pu) Minimum exciter output
J+15		T_E (s) Exciter field time constant
J+16		K_C (pu) Rectifier loading factor proportional to commutating reactance
J+17		K_D (pu) Demagnetizing factor, function of exciter alternator reactance
J+18		K_E (pu) Exciter field proportional constant
J+19		V_{FEMAX} (pu) Exciter field current limit
J+20		V_{EMIN} (pu) Minimum exciter output limit
J+21		E1
J+22		S(E1)
J+23		E2
J+24		S(E2)
J+25		K_P (pu) Potential circuit (voltage) gain coefficient

CONs	Value	Description
J+26		K_{I1} (pu) Potential circuit (current) gain coefficient
J+27		X_L Reactance associated with potential source
J+28		θ_P (degrees) Potential circuit phase angle
J+29		K_{C1} (pu) Rectifier loading factor proportional to commutating reactance
J+30		V_{B1MAX} (pu) Maximum available exciter field voltage
J+31		K_{I2} (pu) Additive potential circuit (gain) coefficient
J+32		K_{C2} (pu) Rectifier loading factor proportional to commutating reactance
J+33		V_{B2MAX} (pu) Maximum available exciter field voltage
J+34		K_{BOOST} (pu) Additive independent source
J+35		V_{BOOST} (pu) Reference value for applying additive (boost) circuit (See Notes)

STATEs	Description
K	Sensed V_t (s0)
K+1	s1
K+2	s2
K+3	s3
K+4	s4
K+5	s5
K+6	s6
K+7	s7
K+8	V_E (s8)

```
IBUS 'USRMDL' ID 'AC11CU1' 4 0 5 36 9 0 ICON (M) to
 ICON(M+4), CON(J) to CON(J+35) /
```



Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.
2. SW1 is a user-selected option. Position A corresponds to a power source from generator terminal voltage such as an excitation transformer. Position B corresponds to a power source independent of generator terminal conditions, such as pilot exciter.
3. For OEL, UEL and SCL flag options, the ICON value can be 1 through 3 with description as follows:
   a. 1: Position (a)
   b. 2: Position (b)
   c. 3: Position (c)
4. The logic switch SWBOOST depends on the user selected parameter V_{BOOST}. SW_{BOOST} is in position A (boost source disabled) if $V_T > V_{BOOST}$. Otherwise in position B (boost source enabled). This voltage boost feature is disabled when V_{BOOST} is set less than zero.
5. Position (b) is active when UEL input location (b) is active and UEL is active. Position (a) is used otherwise
6. Position (b) is active when OEL input location (b) is active and OEL is active. Position (a) is used otherwise
7. The SWLIM logic, as described IEEE 421.5 document, applies only if the alternate PSS input location (b) is selected, otherwise $V_{S1} = V_{S2} = 0$.

   If OEL or UEL are active

   $V_{S1} = 0$

   $V_{S2} = V_S$

   ELSE

   $V_{S1} = V_S$

   $V_{S2} = 0$

   ENDIF

   where Vs is the stabilizer signal

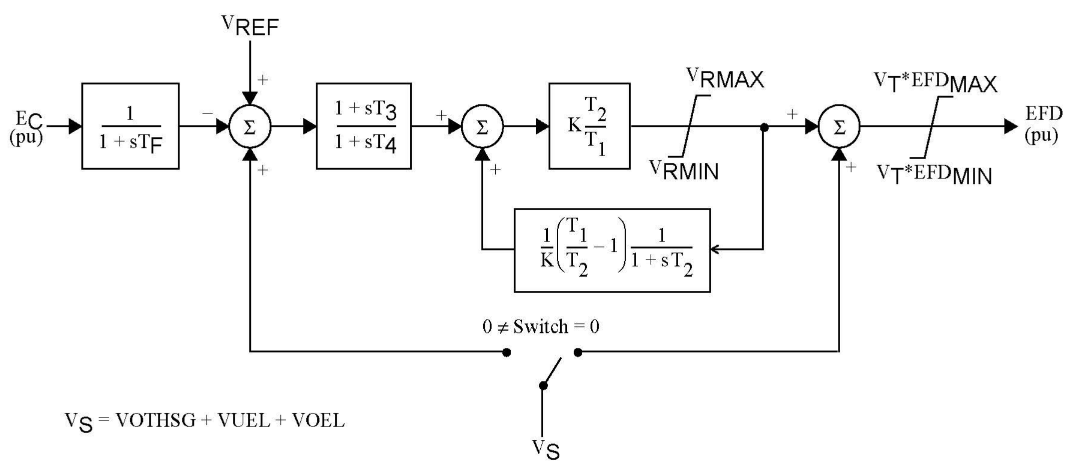
6.16. BBSEX1

Brown Boveri Static Exciter

CONs	Value	Description
J		T_F (s)
J+1		K
J+2		T_1 (>0) (s)
J+3		T_2 (>0) (s)
J+4		T_3 (s)
J+5		T_4 (s)
J+6		V_{RMAX}
J+7		V_{RMIN}
J+8		EFD_{MAX}
J+9		EFD_{MIN}
J+10		Switch

STATEs	Description
K	Sensed V_T
K+1	Lead lag
K+2	Regulator feedback

```
IBUS, 'BBSEX1', ID, CON(J) to CON(J+10)   /
```



6.17. BUDCZT

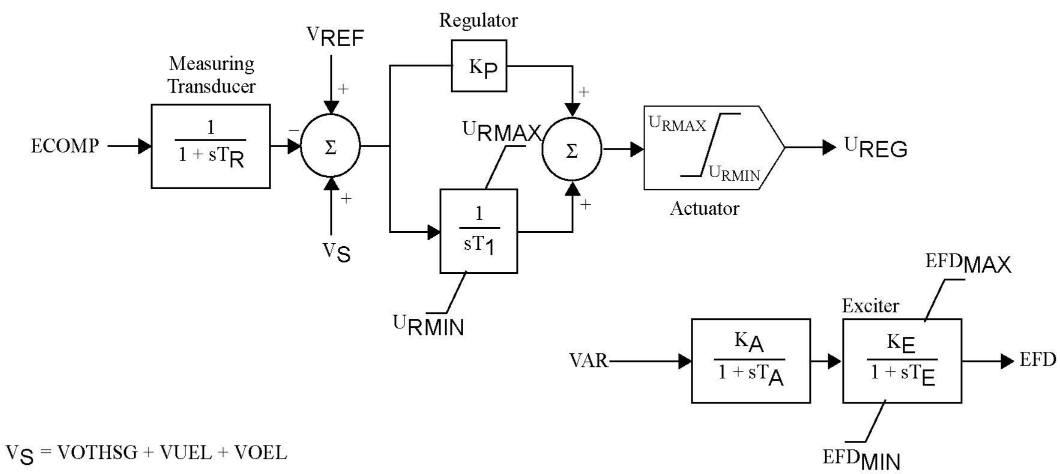
Czech Proportion/Integral Exciter

CONs	Value	Description
J		K_P (pu)
J+1		$K_A > 0$ (pu)
J+2		$K_E > 0$ (pu)
J+3		T_r (s)
J+4		$T_I > 0$ (s)
J+5		T_E (s)
J+6		T_A (s)
J+7		U_{RMAX} (pu)
J+8		UR_{MIN} (pu)
J+9		EFD_{MAX} (pu)
J+10		EFD_{MIN} (pu)

STATEs	Description
K	Transducer
K+1	PI regulator
K+2	Actuator
K+3	Exciter

VARs	Description
L	Actuator input UREG

```
IBUS, 'BUDCZT', ID, CON(J) to CON(J+10)   /
```



6.18. CELIN

ELIN Excitation System

CONs	Value	Description
J		T_{R1}
J+1		T_{R2}
J+2		T_{R3}
J+3		α
J+4		β
J+5		T_{E2}
J+6		Nominal full load EFD in IEEE pu [a]
J+7		K_{E2}
J+8		T_{R4}
J+9		T_1
J+10		T_2
J+11		T_3
J+12		T_4
J+13		T_5
J+14		T_6
J+15		K_{12}
J+16		K_2
J+17		p_PSS
J+18		a_PSS
J+19		PsS_{LIM}
J+20		K_1
J+21		K_IEC
J+22		K_{D1}
J+23		T_{B1} (>0)
J+24		T_{11}
J+25		LIMMAX_PID1
J+26		LIMMIN_PID1
J+27		K_21
J+28		Spare
J+29		U_p+
J+30		U_p-
J+31		K_3
J+32		T_{13}
J+33		K_4
J+34		T_{14}
J+35		K_ETB
J+36		T_E

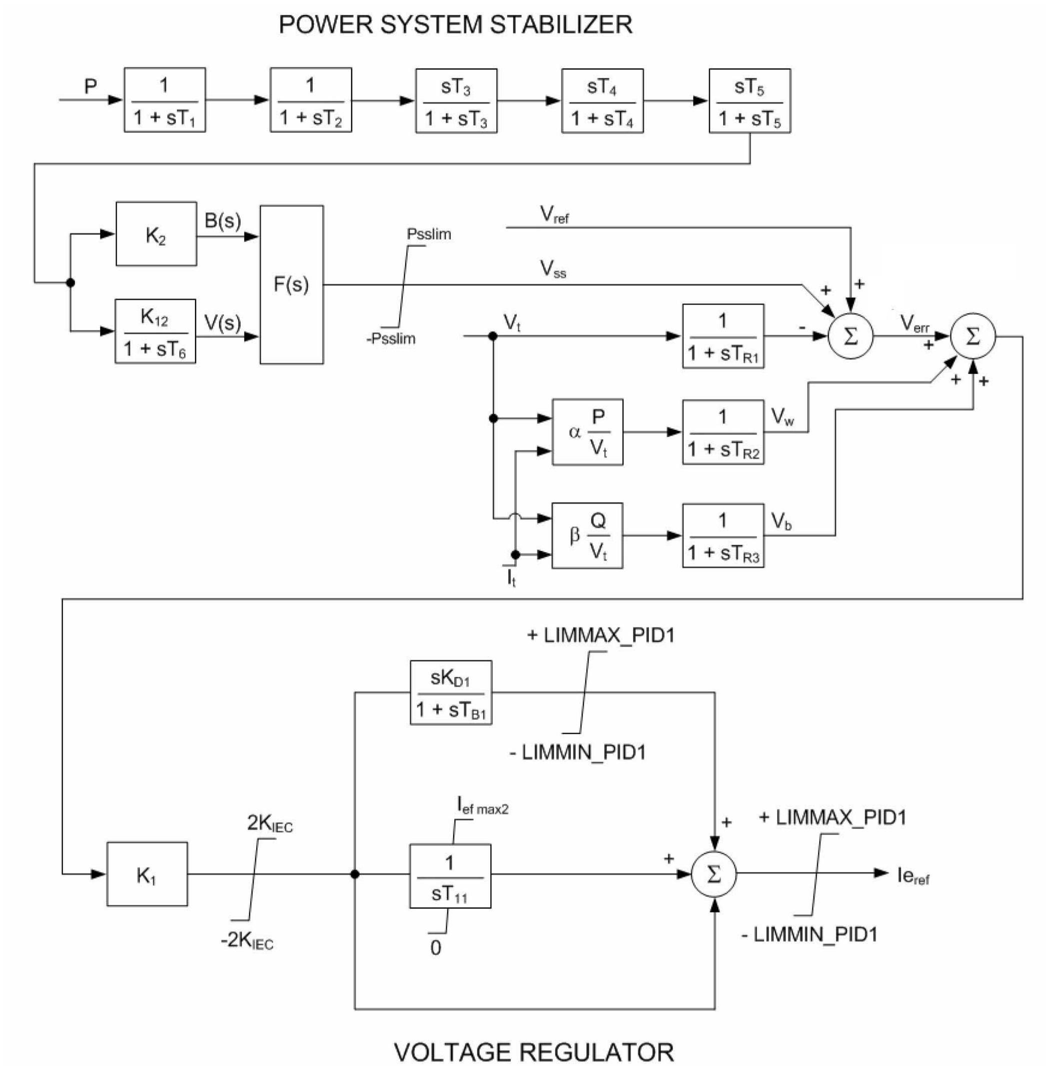
CONs	Value	Description
J+37		Xp
J+38		$I_{ef\ max1}$[b]
J+39		$I_{ef\ max2}$[c]
J+40		$I_{ef\ min}$
J+41		E_1
J+42		$S_E(E_1)$
J+43		E_2
J+44		$S_E(E_2)$

[a]Should be adjusted to the specific machine.
[b]Corresponds to the ceiling of 1.6 pu.
[c]This limit is actually disabled.

STATEs	Description
K	Sensed V_t
K+1	Uw
K+2	Ub
K+3	Efd
K+4	Sensed Ief
K+5	PSS_first lag
K+6	PSS_second lag
K+7	PSS_first washout
K+8	PSS_second washout
K+9	PSS_third washout
K+10	PSS_third lag
K+11	PID1_rate-lag
K+12	PID1_integrator
K+13	Spare
K+14	PID3_integrator
K+15	PID4_integrator
K+16	Converter_lag

VARs	Description
L	IEF, pu
L+1	IEF_REF, pu

```
IBUS, 'CELIN', ID, CON(J) to CON(J+44)   /
```



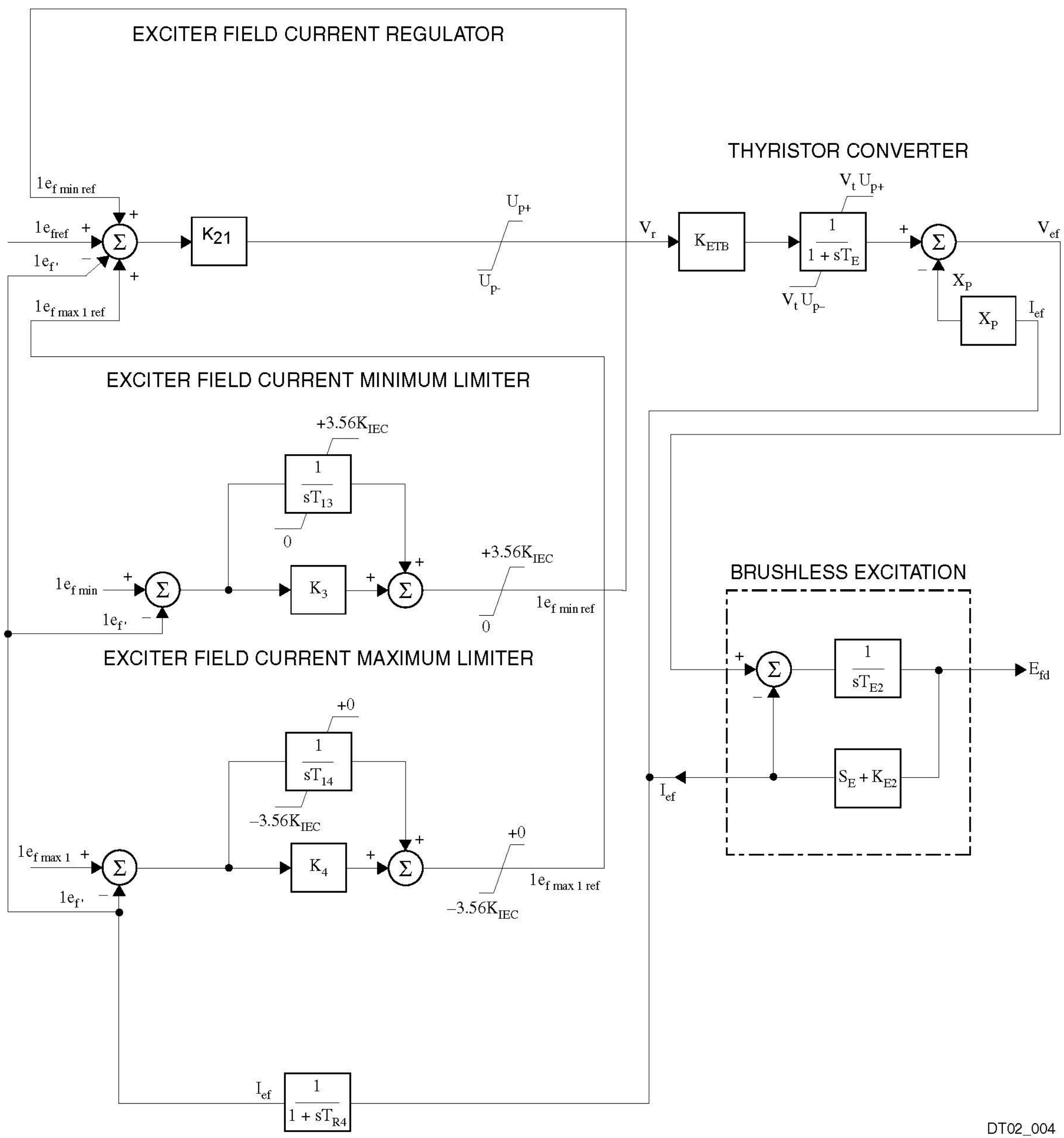
Notes:

$0 \leq p\_PSS \leq 2$

F(s) = a_PSS[B(s)(1 - p_PSS) + V(s)(1 - |p_PSS - 1|)]

$2 \leq p\_PSS \leq 4$

F(s) = a_PSS[B(s)(3 - p_PSS) + V(s)(1 - |p_PSS - 3|)]


EXCITER FIELD CURRENT REGULATOR
THYRISTOR CONVERTER
EXCITER FIELD CURRENT MINIMUM LIMITER
EXCITER FIELD CURRENT MAXIMUM LIMITER
BRUSHLESS EXCITATION
K21
KETB
Vr
Vef
Xp
Ief
Efd
SE + KE2
K3
K4
+3.56KIEC
−3.56KIEC
DT02_004

6.19. DC1C

IEEE 421.5 Excitation System DC1C

ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

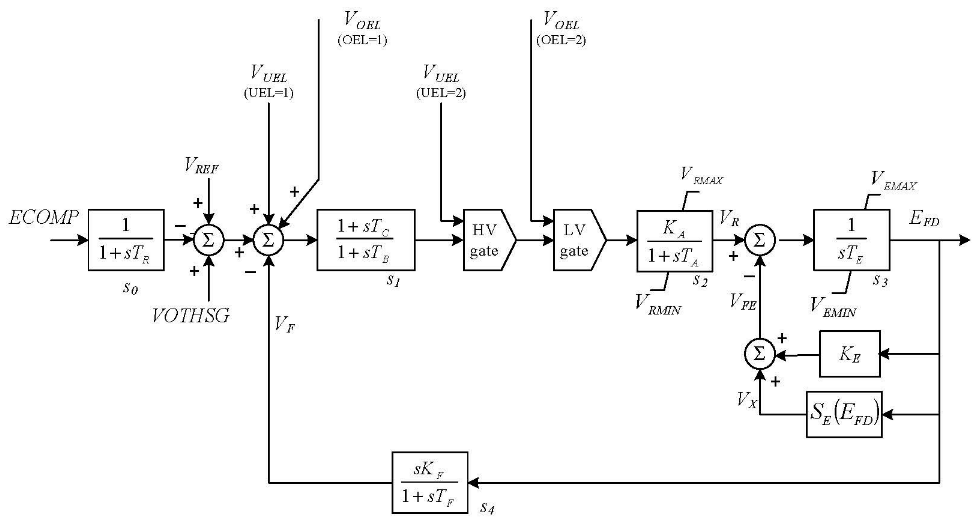
CONs	Value	Description
J		T_R (s), transducer time constant
J+1		K_A (pu), voltage regulator gain
J+2		T_A (s), voltage regulator time constant
J+3		T_B (s), lag time constant
J+4		T_C (s), lead time constant
J+5		V_{RMAX} (pu), regulator output maximum limit
J+6		V_{RMIN} (pu), regulator output minimum limit
J+7		K_E (pu), exciter constant related to self-excited field
J+8		T_E (>0) (s), exciter time constant
J+9		K_F (pu), rate feedback gain
J+10		T_F (>0) (s), rate feedback time constant
J+11		E_1(pu), field voltage
J+12		$S_E(E_1)$ (pu), saturation factor at E_1
J+13		E_2(pu), field voltage
J+14		$S_E(E_2)$ (pu), saturation factor at E_2
J+15		V_{EMAX} (pu), exciter output maximum limit
J+16		V_{EMIN} (pu), exciter output minimum limit

STATEs	Description
K	Measurement lag
K+1	Lead-lag
K+2	Regulator
K+3	Exciter
K+4	Rate feedback

VARs	Description
L	Output of HV gate
L+1	Output of LV gate

VARs	Description
L+2	Calculated KE IF CON(J+7) is entered as zero

IBUS, 'DC1C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+16) /



Notes:

1. If KE is entered as zero, the model calculates a value of KE and stores it in VAR(L+2), The zero value of KE (specified in CON(J+7)) is not changed, If KE is entered as non-zero, its value is used without change.
2. If VRMAX is specified as less than or equal to zero, a value of VRMAX is determined in the model.
3. Saturation parameters are specified using the points E_1, $SE(E_1)$, and E_2, $SE(E_2)$. Either points E_1, $SE(E_1)$ or E_2, $SE(E_2)$ may be the higher value and the other the lower value if the input value of VRMAX is greater than zero, else E_2 must be greater than E_1.
4. The IEEE standard does not specify the limits on the exciter output. To simulate the condition where the exciter output is unlimited, set $V_{E_{MAX}}$ = 999 and VE_{MIN} = -999

6.20. DC2C

IEEE 421.5 Excitation System DC2C

ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

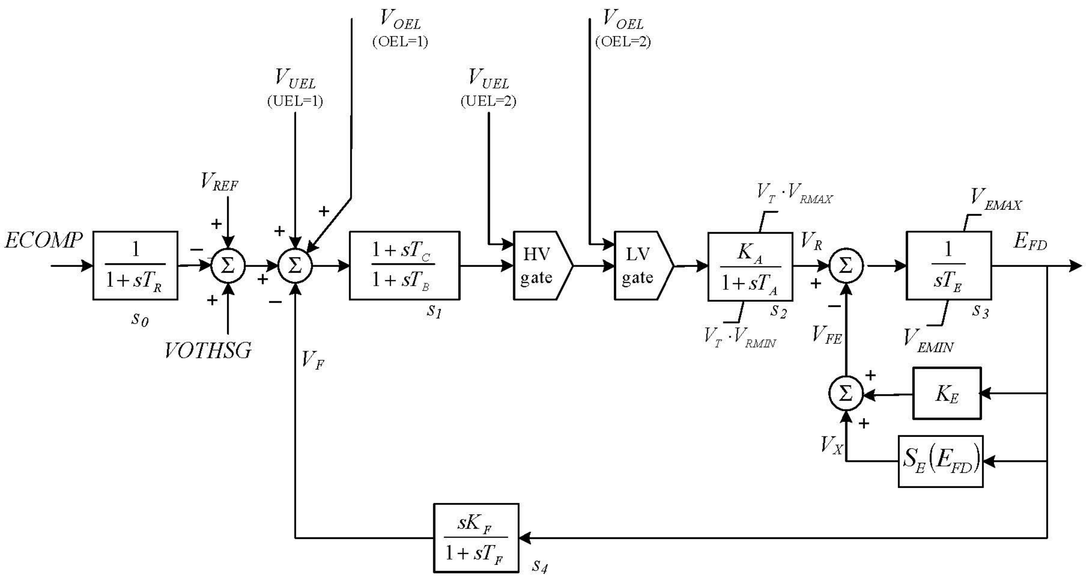
CONs	Value	Description
J		T_R (s), transducer time constant
J+1		K_A (pu), voltage regulator gain
J+2		T_A (s), voltage regulator time constant
J+3		T_B (s), lag time constant
J+4		T_C (s), lead time constant
J+5		V_{RMAX} (pu), regulator output maximum limit
J+6		V_{RMIN} (pu), regulator output minimum limit
J+7		K_E (pu), exciter constant related to self-excited field
J+8		T_E (>0) (s), exciter time constant
J+9		K_F (pu), rate feedback gain
J+10		T_F (>0) (s), rate feedback time constant
J+11		E_1(pu), field voltage
J+12		$S_E(E_1)$ (pu), saturation factor at E_1
J+13		E_2(pu), field voltage
J+14		$S_E(E_2)$ (pu), saturation factor at E_2
J+15		V_{EMAX} (pu), exciter output maximum limit
J+16		V_{EMIN} (pu), exciter output minimum limit

STATEs	Description
K	Measurement lag
K+1	Lead-lag
K+2	Regulator
K+3	Exciter
K+4	Rate feedback

VARs	Description
L	Output of HV gate
L+1	Output of LV gate

VARs	Description
L+2	Calculated KE IF COM(J+7) is entered as zero

```
IBUS, ' DC2C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+16)   /
```



Notes:

1. If KE is entered as zero, the model calculates a value of KE and stores it in VAR(L+2), The zero value of KE (specified in CON(J+7)) is not changed, If KE is entered as non-zero, its value is used without change.

2. If VRMAX is specified as less than or equal to zero, a value of VRMAX is determined in the model.

3. Saturation parameters are specified using the points E_1, SE(E_1), and E_2, SE(E_2). Either points E_1, SE(E_1) or E_2, SE(E_2) may be the higher value and the other the lower value if the input value of VRMAX is greater than zero, else E_2 must be greater than E_1.

4. The IEEE standard does not specify the limits on the exciter output. To simulate the condition where the exciter output is unlimited, set $V_{E_{MAX}}$ = 999 and VE_{MIN} = -999

6.21. DC3A

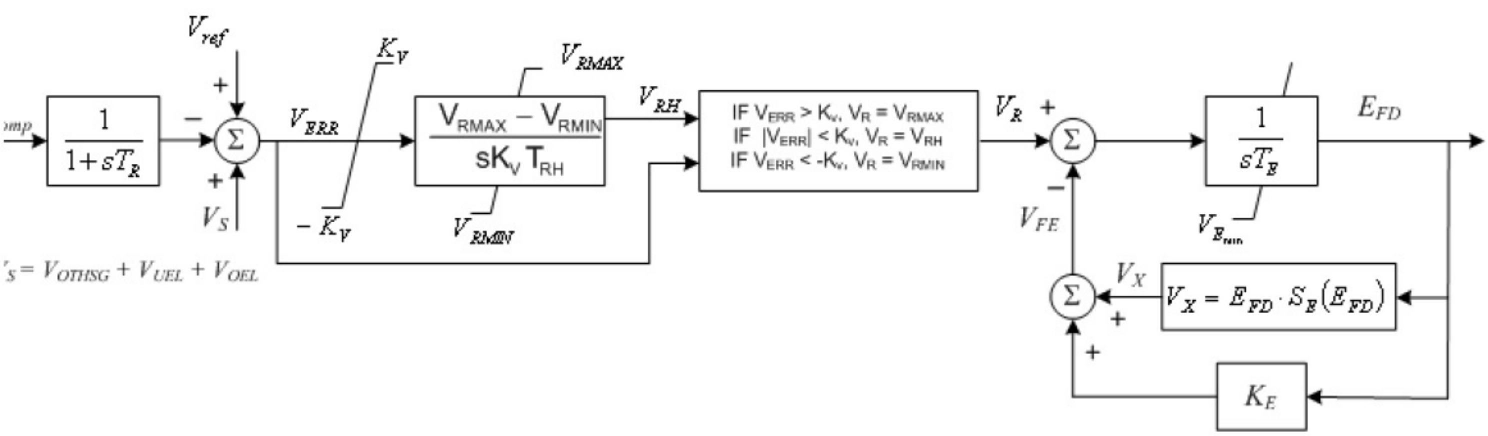
IEEE 421.5 2005 DC3A Excitation System

CONs	Value	Description
J		T_R Regulator input time constant (s)
J+1		K_V (pu) limit on fast raise/lower contact setting
J+2		V_{RMAX} (pu) regulator maximum limit
J+3		V_{RMIN} (pu) regulator minimum limit
J+4		T_{RH} (> 0) Rheostat motor travel time (s)
J+5		T_E (> 0) exciter time-constant (s)
J+6		K_E (pu) exciter constant related to self-excited field
J+7		$V_{E_{MIN}}$ (pu) exciter minimum limit
J+8		E_1
J+9		$S(E_1)$
J+10		E_2
J+11		$S(E_2)$

STATEs	Description
K	Sensed Ecomp
K+1	Rheostat setting
K+2	Exciter (EFD)

VARs	Description
L	V_ERR
L+1	V_R

```
IBUS, 'DC3A', ID, CON(J) to CON(J+11)   /
```



6.22. DC4B

IEEE 421.5 2005 DC4B Excitation System

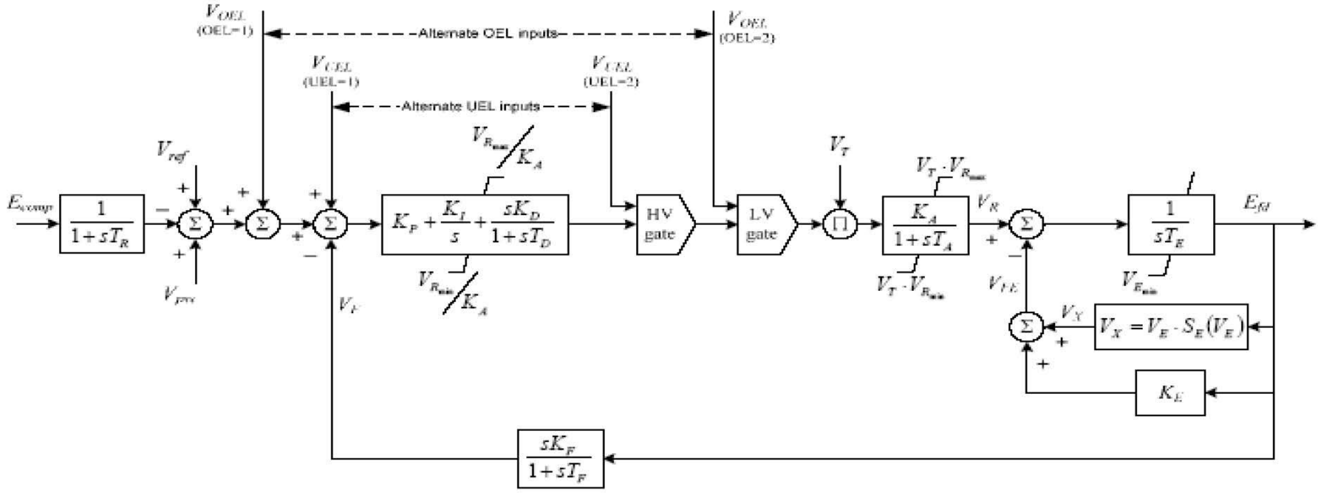
ICONs	Value	Description
M		OEL flag (1 or 2, default = 1)
M+1		UEL flag (1 or 2, default = 1

CONs	Value	Description
J		$T_R$regulator input filter time constant (s)
J+1		K_P (pu) (> 0) voltage regulator proportional gain
J+2		K_I (pu) voltage regulator integral gain
J+3		K_D (pu) voltage regulator derivative gain
J+4		TD voltage regulator derivative channel time constant (s)
J+5		V_{RMAX} (pu) regulator output maximum limit
J+6		V_{RMIN} (pu) regulator output minimum limit
J+7		K_A (> 0) (pu) voltage regulator gain
J+8		T_A voltage regulator time constant (s)
J+9		K_E (pu) exciter constant related to self-excited field
J+10		T_E (> 0) rotating exciter time constant (s)
J+11		K_F (pu) rate feedback gain
J+12		T_F (> 0) rate feedback time constant (s)
J+13		$V_{E_{MIN}}$ (pu) minimum exciter voltage output
J+14		E_1 (pu)
J+15		$S_E(E_1)$
J+16		E_2 (pu)
J+17		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Integral channel
K+2	Derivative Channel
K+3	V_R
K+4	EFD
K+5	Rate feedback

VARs	Description
L	V_{PID}
L+1	K_E

```
IBUS, 'DC4B', ID, ICON(M), ICON(M+1), CON(J) to CON(J+17)   /
```


V_{OEL}
(OEL=1)
Alternate OEL inputs
V_{OEL}
(OEL=2)
V_{UEL}
(UEL=1)
Alternate UEL inputs
V_{UEL}
(UEL=2)
V_{ref}
E_{comp}
$\frac{1}{1+sT_R}$
V_{pss}
$V_{R_{max}}/K_A$
$K_P + \frac{K_I}{s} + \frac{sK_D}{1+sT_D}$
$V_{R_{min}}/K_A$
HV gate
LV gate
V_T
$V_T \cdot V_{R_{max}}$
$\frac{K_A}{1+sT_A}$
$V_T \cdot V_{R_{min}}$
V_R
V_{FE}
$\frac{1}{sT_E}$
E_{fd}
$V_{E_{min}}$
V_X
$V_X = V_E \cdot S_E(V_E)$
K_E
V_F
$\frac{sK_F}{1+sT_F}$

6.23. DC4CU1

IEEE 421.5 2016 DC4CU1 Excitation System

ICONs	Value	Description
M		OEL flag 1: Summation point 2: LV gate
M+1		UEL flag 1: Summation point 2: LV gate
M+2		SCL flag 1: Summation point 2: Take-over
M+3		SW1 flag 1: Position A 2: Position B

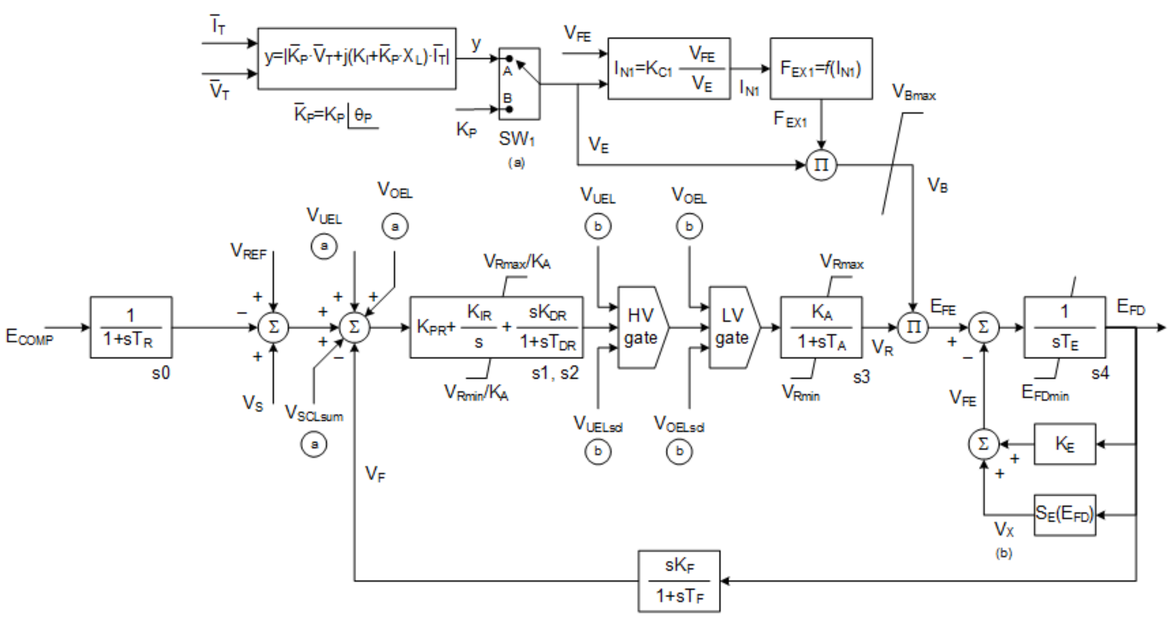
CONs	Value	Description
J		T_R(s) regulator input filter time constant
J+1		K_{PR} (pu) (> 0) regulator proportional gain
J+2		K_{JR} (pu) regulator integral gain
J+3		K_{DR} (pu) regulator derivative gain
J+4		T_{DR} (s) regulator derivative filter time constant
J+5		V_{RMAX} (pu) maximum controller output
J+6		V_{RMIN} (pu) minimum controller output
J+7		K_A (> 0) (pu) regulator output gain
J+8		T_A (> 0) (s) regulator output time constant
J+9		K_E (pu) exciter field proportional constant
J+10		T_E (> 0) (s) exciter field time constant
J+11		K_F (pu) rate feedback gain
J+12		T_F (> 0) (s) rate feedback time constant
J+13		V_{EMIN} (pu) exciter minimum voltage output
J+14		E_1 (pu) exciter output voltage for saturation factor
J+15		$S_E(E_1)$ (pu) exciter saturation factor at exciter output voltage
J+16		E_2 (pu) exciter output voltage for saturation factor
J+17		$S_E(E_2)$ (pu) exciter saturation factor at exciter output voltage
J+18		K_P (pu) potential circuit gain coefficient
J+19		K_I (pu) potential circuit (current) gain coefficient

CONs	Value	Description
J+20		X_L (pu) reactance associated with potential source
J+21		θ_P (degrees) potential circuit phase angle (degrees)
J+22		K_{C1} (pu) rectifier loading factor proportional to commutating reactance
J+23		V_{BMAX} (pu) maximum available exciter field voltage

STATEs	Description
K	Sensed V_T
K+1	Regulator integrator
K+2	Regulator derivator
K+3	V_R
K+4	E_{FD}
K+5	Rate feedback

VARs	Description
L	V_{PID}
L+1	Calculated K_E if CON(J+9) is entered as zero
L+2	Output of HV gate
L+3	Output of LV gate
L+4	E_{FE}
L+5	V_{FE}

```
IBUS, 'USRMDL', ID, 'DC4CU1', 4, 0, 4, 24, 6, 6, ICON(M) to ICON(M+3),
 CON(J) to CON(J+23)   /
```



Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.

2. SW_1 is a user-selected option. Position A corresponds to a power source from generator terminal voltage such as an excitation transformer. Position B corresponds to a power source independent of generator terminal conditions, such as pilot exciter.

3. $V_X = E_{FD} * S_E(E_{FD})$

6.24. EMAC1T

Modified IEEE Type AC1 Excitation System

(AEP Rockport Excitation Model)

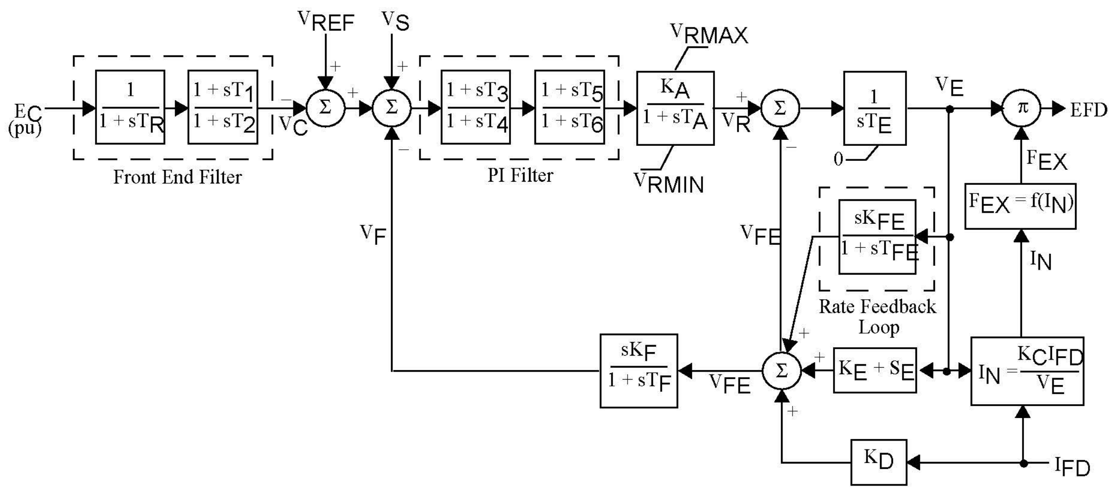
CONs	Value	Description
J		T_R (s)
J+1		T_4 (s)
J+2		T_3 (s)
J+3		K_A
J+4		T_A (s)
J+5		V_{RMAX}
J+6		V_{RMIN}
J+7		$T_E > 0$ (s)
J+8		K_F
J+9		$T_F > 0$ (s)
J+10		K_C
J+11		K_D
J+12		K_E
J+13		E_1
J+14		$S_E(E_1)$
J+15		E_2
J+16		$S_E(E_2)$
J+17		T_6 (s)
J+18		T_5 (s)
J+19		T_2 (s)
J+20		T_1 (s)
J+21		K_{FE}
J+22		T_{FE} (s)

STATEs	Description
K	Sensed E_T
K+1	2nd lead lag output
K+2	3rd lead lag output
K+3	Regulator output, V_R
K+4	V_E
K+5	Feedback output, V_F
K+6	1st lead lag output
K+7	Rate feedback output

VARs	Description
L	Feedback output, V_F

VARs	Description
L+1	2nd summer output
L+2	3rd lead lag output
L+3	V_{FE}
L+4	2nd lead lag output
L+5	1st lead lag output
L+6	Rate feedback output

```
IBUS, 'EMAC1T', ID, CON(J) to CON(J+22)   /
```



$I_N \rightarrow$
If $I_N \le 0.51$, $F_{EX} = 1 - 1.058\ I_N$
If $0.51 < I_N < 0.715$, $F_{EX} = -0.865\ (I_N + 0.00826)^2 + 0.93233$
If $I_N \ge 0.715$, $F_{EX} = -1.68 - 1.714\ I_N$
$\rightarrow F_{EX}$

$V_S = VOTHSG + VUEL + VOEL$

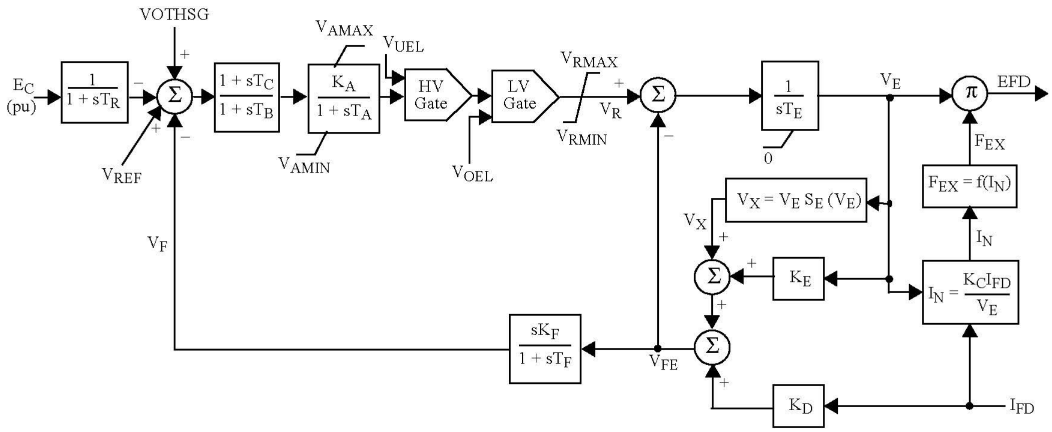
6.25. ESAC1A

IEEE Type AC1A Excitation System

CONs	Value	Description
J		T_R (s)
J+1		T_B (s)
J+2		T_C (s)
J+3		K_A
J+4		T_A (s)
J+5		V_{AMAX}
J+6		V_{AMIN}
J+7		$T_E > 0$ (s)
J+8		K_F
J+9		$T_F > 0$ (s)
J+10		K_C
J+11		K_D
J+12		K_E
J+13		E_1
J+14		$S_E(E_1)$
J+15		E_2
J+16		$S_E(E_2)$
J+17		V_{RMAX}
J+18		V_{RMIN}

STATEs	Description
K	Sensed E_T
K+1	Lead lag
K+2	Regulator output
K+3	V_E
K+4	Feedback output

```
IBUS, 'ESAC1A', ID, CON(J) to CON(J+18)   /
```



$I_N \rightarrow$

If $I_N \le 0$	$F_{EX} = 1$
If $I_N \le 0.433$	$F_{EX} = 1 - 0.577\ I_N$
If $0.433 < I_N < 0.75$	$F_{EX} = \sqrt{0.75 - I_N^2}$
If $I_N \ge 0.75$	$F_{EX} = 1.732(1 - I_N)$
If $I_N > 1$	$F_{EX} = 0$

$\rightarrow F_{EX}$

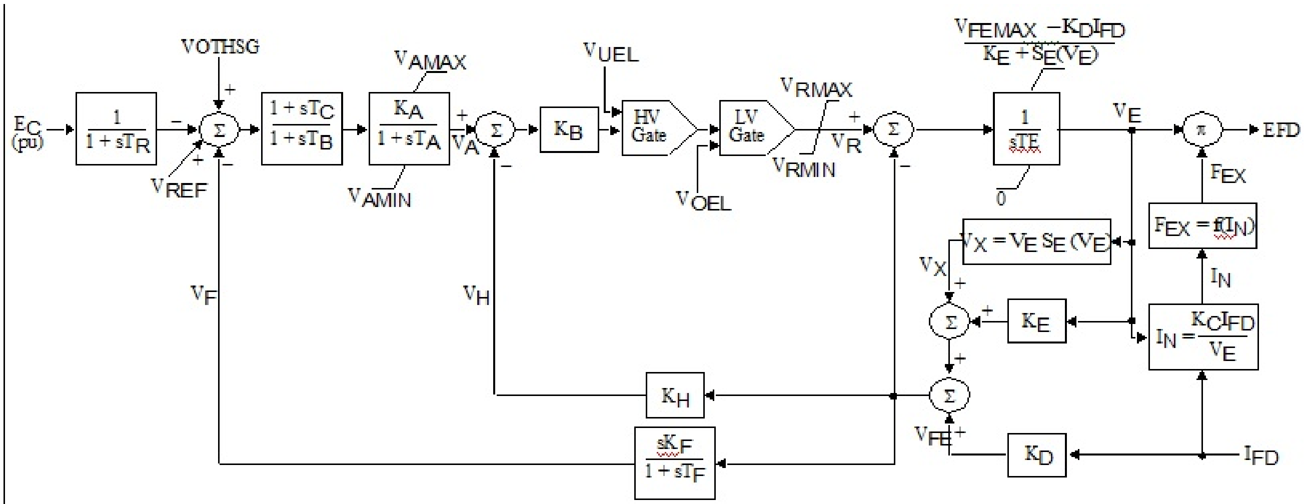
6.26. ESAC2A

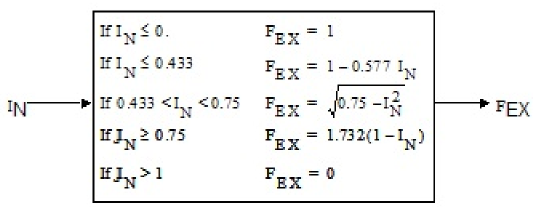
IEEE Type AC2A Excitation System

CONs	Value	Description
J		T_R (s)
J+1		T_B (s)
J+2		T_C (s)
J+3		K_A
J+4		T_A (s)
J+5		V_{AMAX}
J+6		V_{AMIN}
J+7		K_B
J+8		V_{RMAX}
J+9		V_{RMIN}
J+10		$T_E > 0$ (s)
J+11		$V_{FE_{MAX}}$
J+12		K_H
J+13		K_F
J+14		$T_F > 0$ (s)
J+15		K_C
J+16		K_D
J+17		K_E
J+18		E_1
J+19		$S_E(E_1)$
J+20		E_2
J+21		$S_E(E_2)$

STATEs	Description
K	Sensed E_T
K+1	Lead lag
K+2	Regulator output
K+3	V_E
K+4	Feedback output

```
IBUS, 'ESAC2A', ID, CON(J) to CON(J+21)   /
```


VOTHSG
VAMAX
VUEL
VFEMAX −KDIFD
KE + SE(VE)
VRMAX
EC
(pu)
1
1 + sTR
1 + sTC
1 + sTB
KA
1 + sTA
VA
KB
HV
Gate
LV
Gate
VR
1
sTE
VE
π
EFD
VREF
VAMIN
VOEL
VRMIN
0
FEX
FEX = f(IN)
VX = VE SE (VE)
VX
IN
KE
IN = KCIFD / VE
VF
VH
KH
VFE
sKF
1 + sTF
KD
IFD


IN
If IN ≤ 0.
FEX = 1
If IN ≤ 0.433
FEX = 1 − 0.577 IN
If 0.433 < IN < 0.75
FEX = √(0.75 − IN²)
If IN ≥ 0.75
FEX = 1.732(1 − IN)
If IN > 1
FEX = 0
FEX

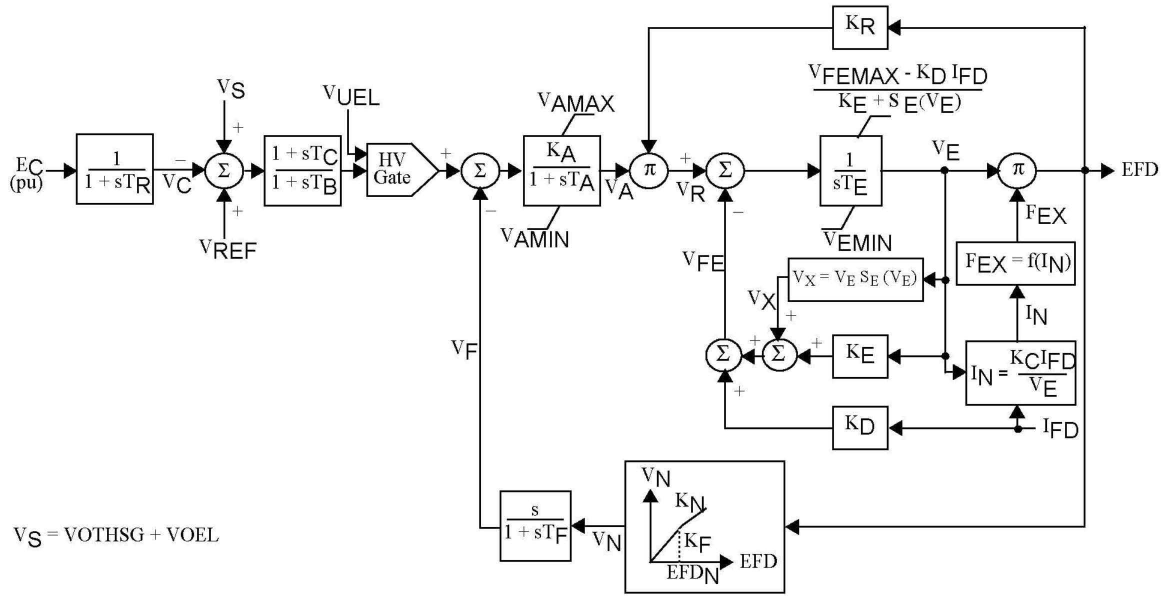
6.27. ESAC3A

IEEE Type AC3A Excitation System

CONs	Value	Description
J		T_R (s)
J+1		T_B (s)
J+2		T_C (s)
J+3		K_A
J+4		T_A (s)
J+5		V_{AMAX}
J+6		V_{AMIN}
J+7		$T_E > 0$ (s)
J+8		V_{EMIN}
J+9		K_R (>0)
J+10		K_F
J+11		$T_F > 0$ (s)
J+12		K_N
J+13		EFD_N
J+14		K_C
J+15		K_D
J+16		K_E
J+17		$V_{FE_{MAX}}$
J+18		E_1
J+19		$S_E(E_1)$
J+20		E_2
J+21		$S_E(E_2)$

STATEs	Description
K	Sensed E_T
K+1	Lead lag
K+2	Regulator output
K+3	V_E
K+4	Feedback output

```
IBUS, 'ESAC3A', ID, CON(J) to CON(J+21)   /
```



V_S = VOTHSG + VOEL

$I_N \rightarrow$

If $I_N \le 0.$	$F_{EX} = 1$
If $I_N \le 0.433$	$F_{EX} = 1 - 0.577\ I_N$
If $0.433 < I_N < 0.75$	$F_{EX} = \sqrt{0.75 - I_N^2}$
If $I_N \ge 0.75$	$F_{EX} = 1.732(1 - I_N)$
If $I_N > 1$	$F_{EX} = 0$

$\rightarrow F_{EX}$

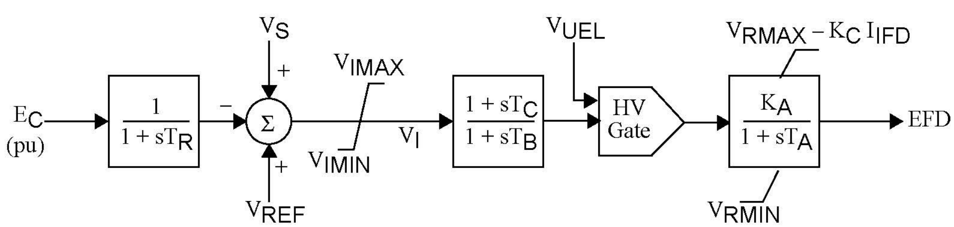
6.28. ESAC4A

IEEE Type AC4A Excitation System

CONs	Value	Description
J		T_R(s)
J+1		V_{IMAX}
J+2		V_{IMIN}
J+3		T_C
J+4		T_B (s)
J+5		K_A
J+6		T_A
J+7		V_{RMAX}
J+8		V_{RMIN}
J+9		K_C

STATEs	Description
K	$V_{measured}$
K+1	Lead lag
K+2	V_R

```
IBUS, 'ESAC4A', ID, CON(J) to CON(J+9)   /
```



V_S = VOTHSG + VOEL

6.29. ESAC5A

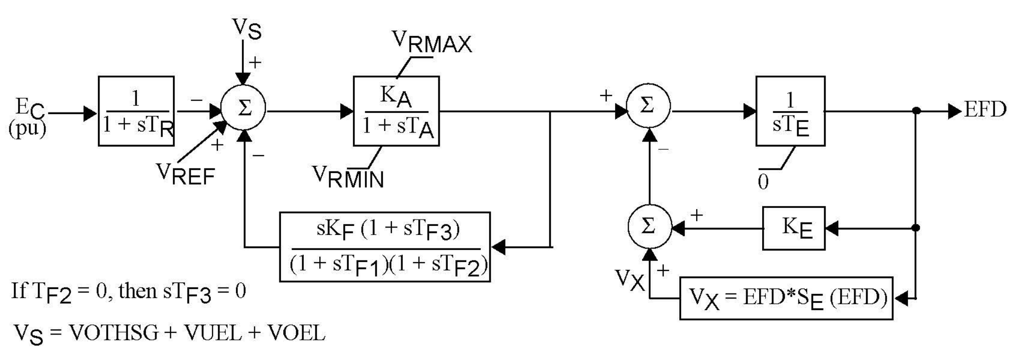
IEEE Type AC5A Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		V_{RMAX} or zero
J+4		V_{RMIN}
J+5		K_E or zero
J+6		$T_E > 0$ (s)
J+7		K_F
J+8		$T_{F1} > 0$ (s)
J+9		T_{F2} (s)
J+10		T_{F3} (s)
J+11		E_1
J+12		$S_E(E_1)$
J+13		E_2
J+14		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Regulator output, V_R
K+2	Exciter output, EFD
K+3	First feedback integrator
K+4	Second feedback integrator

VARs	Description
L	K_E

```
IBUS, 'ESAC5A', ID, CON(J) to CON(J+14)   /
```



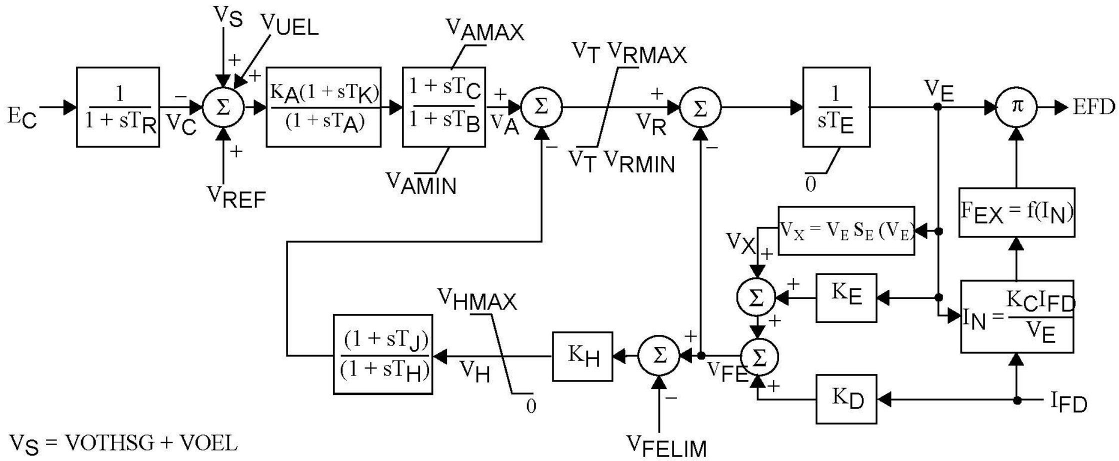
6.30. ESAC6A

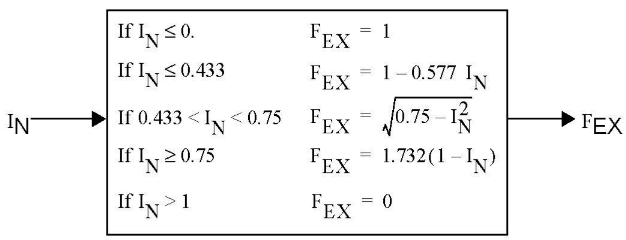
IEEE Type AC6A Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		T_K (s)
J+4		T_B (s)
J+5		T_C (s)
J+6		V_{AMAX}
J+7		V_{AMIN}
J+8		V_{RMAX}
J+9		V_{RMIN}
J+10		T_E (>0) (s)
J+11		V_{FELIM}
J+12		K_H
J+13		V_{Hmax}
J+14		T_H (s)
J+15		T_J (s)
J+16		K_C
J+17		K_D
J+18		K_E
J+19		E_1
J+20		$S_E(E_1)$
J+21		E_2
J+22		$S_E(E_2)$

STATEs	Description
K	Sensed E_T
K+1	First block
K+2	Lead lag
K+3	V_E
K+4	Feedback

```
IBUS, 'ESAC6A', ID, CON(J) to CON(J+22)   /
```





Notes:

AC6A is a modified version of ESAC6A. The difference between AC6A and ESAC6A is in the way the non-windup limit is applied on the lead-lag block (STATE(K+2)). In the AC6A model, the implementation of the non-windup limit on STATE(K+2) is consistent with the recommendation as given in the IEEE 421.5 2005 standard.

6.31. ESAC8B

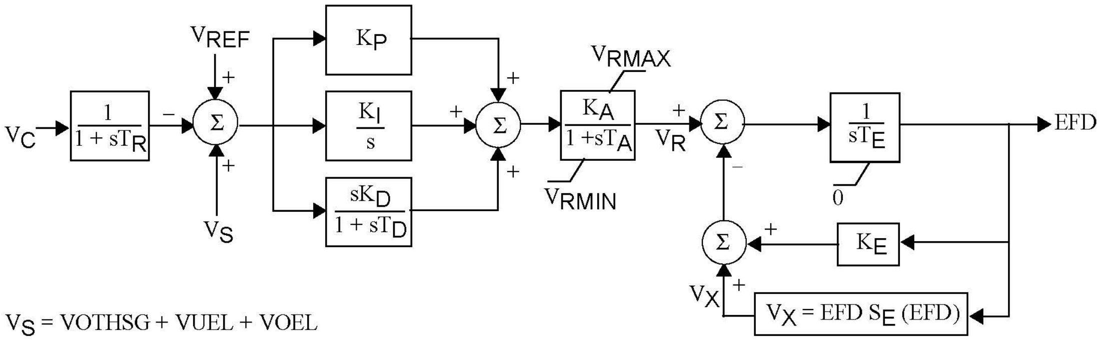
Basler DECS

CONs	Value	Description
J		T_R (s)
J+1		K_P
J+2		K_I
J+3		K_D
J+4		T_D (s)
J+5		K_A
J+6		T_A
J+7		V_{RMAX} or zero
J+8		V_{RMIN}
J+9		$T_E > 0$ (s)
J+10		K_E or zero
J+11		E_1
J+12		$S_E(E_1)$
J+13		E_2
J+14		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Integral controller
K+2	Derivative controller
K+3	Voltage regulator
K+4	Exciter output, EFD

VARs	Description
L	K_E

```
IBUS, 'ESAC8B', ID, CON(J) to CON(J+14)   /
```



6.32. ESDC1A

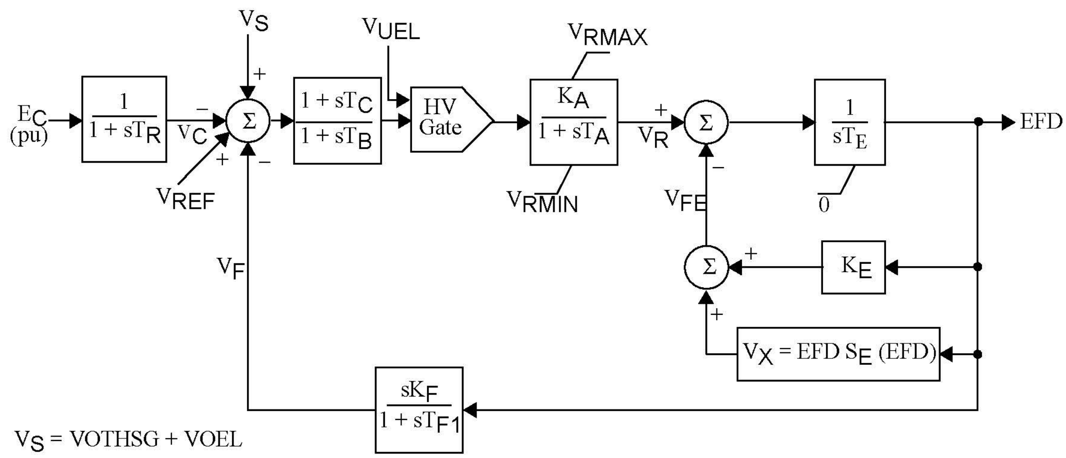
IEEE Type DC1A Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		T_B (s)
J+4		T_C (s)
J+5		V_{RMAX} or zero
J+6		V_{RMIN}
J+7		K_E or zero
J+8		T_E (>0) (s)
J+9		K_F
J+10		T_{F1} (>0) (s)
J+11		Switch
J+12		E_1
J+13		$S_E(E_1)$
J+14		E_2
J+15		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Lead lag
K+2	Regulator output, V_R
K+3	Exciter output, EFD
K+4	Rate feedback integrator

VARs	Description
L	K_E

```
IBUS, 'ESDC1A', ID, CON(J) to CON(J+15)   /
```



VS
VUEL
VRMAX
EC
(pu)
1
1 + sTR
VC
+
−
Σ
1 + sTC
1 + sTB
HV
Gate
KA
1 + sTA
+
VR
Σ
1
sTE
EFD
VREF
VRMIN
VFE
0
VF
Σ
KE
VX = EFD SE (EFD)
sKF
1 + sTF1
VS = VOTHSG + VOEL

6.33. ESDC2A

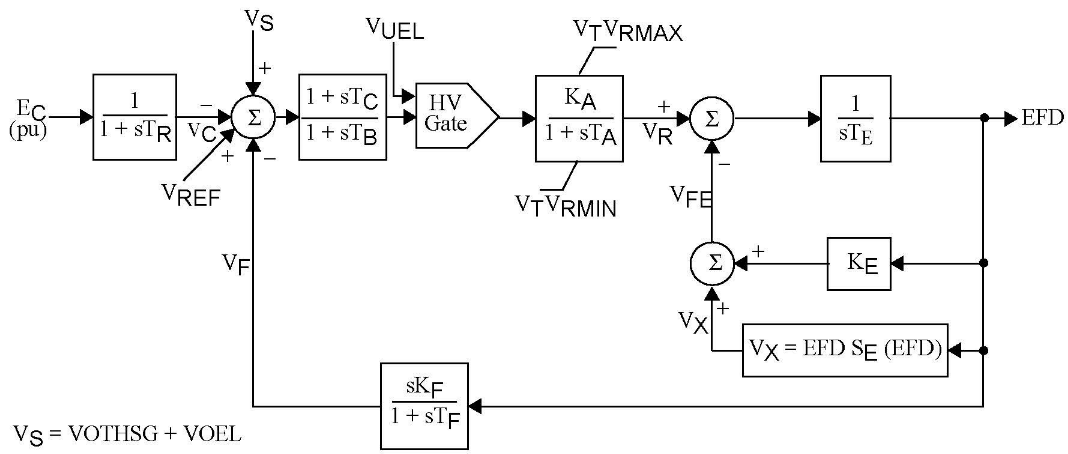
IEEE Type DC2A Excitation System

CONs	Value	Description
J		T_R (sec)
J+1		K_A
J+2		T_A (sec)
J+3		T_B (sec)
J+4		T_C (sec)
J+5		V_{RMAX} or zero
J+6		V_{RMIN}
J+7		K_E or zero
J+8		T_E (>0) (sec)
J+9		K_F
J+10		T_{F1} (>0) (sec)
J+11		Switch
J+12		E_1
J+13		$S_E(E_1)$
J+14		E_2
J+15		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Lead lag output
K+2	Regulator output, V_R
K+3	Exciter output, EFD
K+4	Rate feedback integrator

VARs	Description
L	K_E

```
IBUS, ’ESDC2A’, ID, CON(J) to CON(J+15)   /
```



VS
VUEL
VTVRMAX
EC
(pu)
1
1 + sTR
VC
VREF
1 + sTC
1 + sTB
HV
Gate
KA
1 + sTA
VR
1
sTE
EFD
VTVRMIN
VFE
VF
KE
VX
VX = EFD SE (EFD)
sKF
1 + sTF
VS = VOTHSG + VOEL

6.34. ESST1A

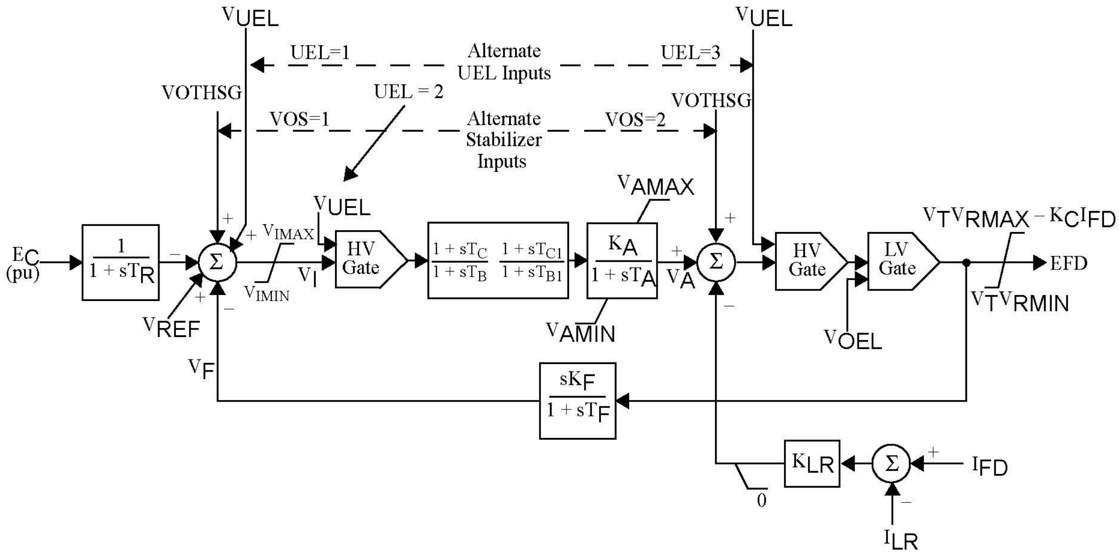
IEEE Type ST1A Excitation System

ICONs	Value	Description
M		UEL (1, 2, or 3)
M+1		VOS (1 or 2)

CONs	Value	Description
J		T_R (s)
J+1		V_{IMAX}
J+2		V_{IMIN}
J+3		T_C (s)
J+4		T_B (s)
J+5		T_{C1} (s)
J+6		T_{B1} (s)
J+7		K_A
J+8		T_A (s)
J+9		V_{AMAX}
J+10		V_{AMIN}
J+11		V_{RMAX}
J+12		V_{RMIN}
J+13		K_C
J+14		K_F
J+15		$T_F > 0$ (s)
J+16		K_{LR}
J+17		I_{LR}

STATEs	Description
K	$V_{measured}$
K+1	First lead lag
K+2	Second lead lag
K+3	V_A
K+4	Feedback

```
IBUS, 'ESST1A', ID, ICON(M), ICON(M+1), CON(J) to CON(J+17)   /
```


VUEL
VUEL
UEL=1
Alternate
UEL Inputs
UEL=3
VOTHSG
UEL = 2
VOTHSG
VOS=1
Alternate
Stabilizer
Inputs
VOS=2
VAMAX
VUEL
VTVRMAX – KCIFD
EC
(pu)
1
1 + sTR
VIMAX
HV
Gate
1 + sTC
1 + sTB
1 + sTC1
1 + sTB1
KA
1 + sTA
HV
Gate
LV
Gate
EFD
VI
VA
VIMIN
VTVRMIN
VREF
VAMIN
VOEL
VF
sKF
1 + sTF
KLR
IFD
0
ILR

6.35. ESST2A

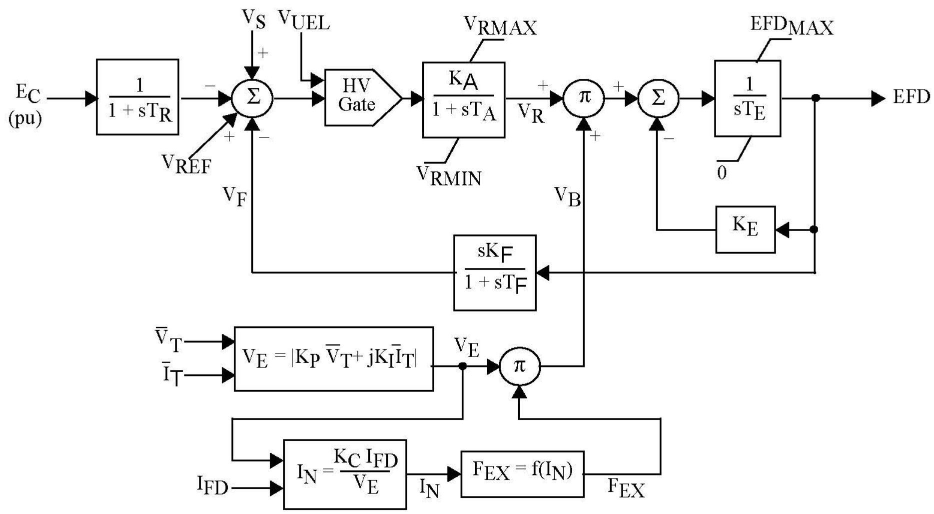
Modified IEEE Type ST2A Excitation System

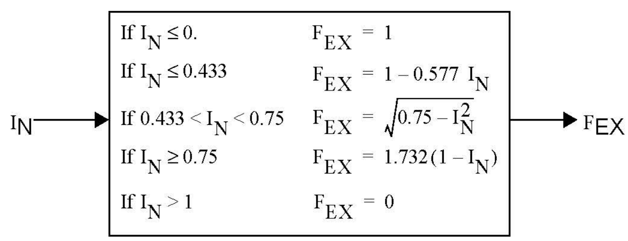
CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		K_E
J+6		T_E (>0) (s)
J+7		K_F
J+8		T_F (>0) (s)
J+9		K_P
J+10		K_I
J+11		K_C
J+12		EFD_{MAX}

STATEs	Description
K	Sensed V_T
K+1	Regulator output, V_R
K+2	Exciter output, EFD
K+3	Rate feedback integral

VARs	Description
L	K_I

```
IBUS, 'ESST2A', ID, CON(J) to CON(J+12)   /
```





V_S = VOTHSG + VOEL

If Kp = 0 and K_I = 0, V_B = 1

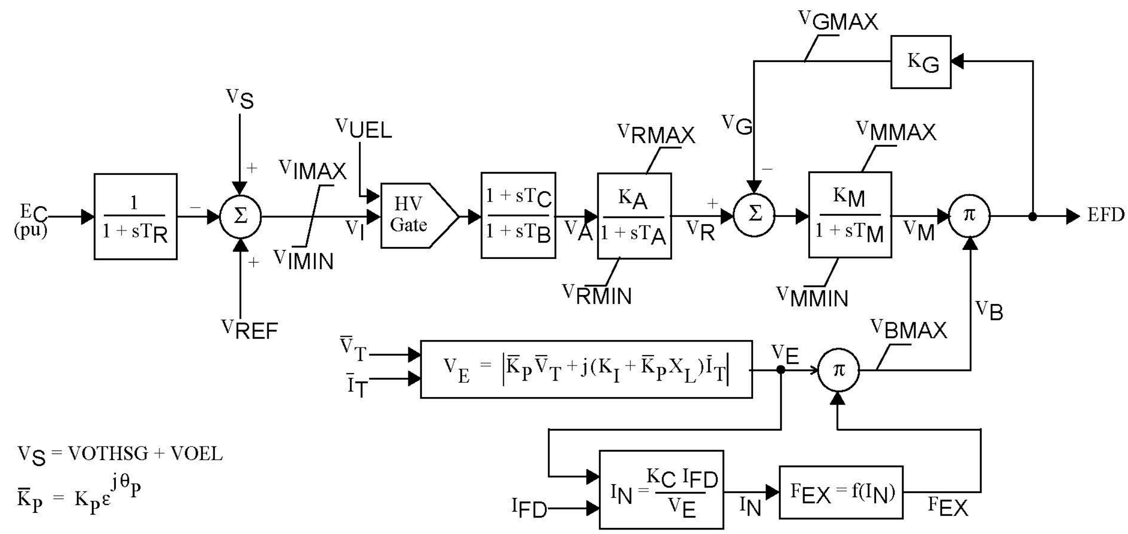
6.36. ESST3A

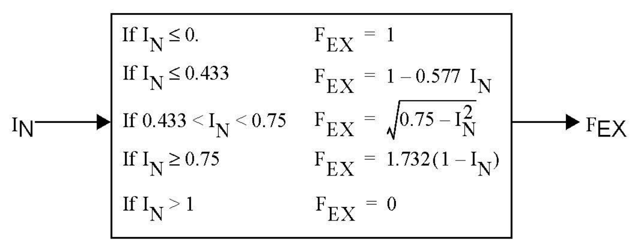
IEEE Type ST3A Excitation System

CONs	Value	Description
J		T_R (s)
J+1		V_{IMAX}
J+2		V_{IMIN}
J+3		K_M
J+4		T_C (s)
J+5		T_B (s)
J+6		K_A
J+7		T_A (s)
J+8		V_{RMAX}
J+9		V_{RMIN}
J+10		K_G
J+11		K_P
J+12		K_I
J+13		V_{BMAX}
J+14		K_C
J+15		X_I
J+16		V_{GMAX}
J+17		θ_P (degrees)
J+18		T_M (s)
J+19		V_{MMAX}
J+20		V_{MMIN}

STATEs	Description
K	Sensed V_T
K+1	V_A
K+2	V_R
K+3	V_M

```
IBUS, 'ESST3A', ID, CON(J) to CON(J+20)   /
```


VGMAX
KG
VS
VUEL
VRMAX
VG
VMMAX
+
VIMAX
HV Gate
1 + sTC / 1 + sTB
KA / 1 + sTA
KM / 1 + sTM
EC (pu)
1 / 1 + sTR
VI
VA
VR
VM
EFD
VIMIN
VRMIN
VMMIN
VREF
VB
VBMAX
VT
IT
VE = |KP VT + j(KI + KP XL) IT|
VE
π
VS = VOTHSG + VOEL
KP = KP e^(jθP)
IN = KC IFD / VE
IFD
IN
FEX = f(IN)
FEX


IN
If IN ≤ 0. FEX = 1
If IN ≤ 0.433 FEX = 1 – 0.577 IN
If 0.433 < IN < 0.75 FEX = √(0.75 – IN²)
If IN ≥ 0.75 FEX = 1.732(1 – IN)
If IN > 1 FEX = 0
FEX

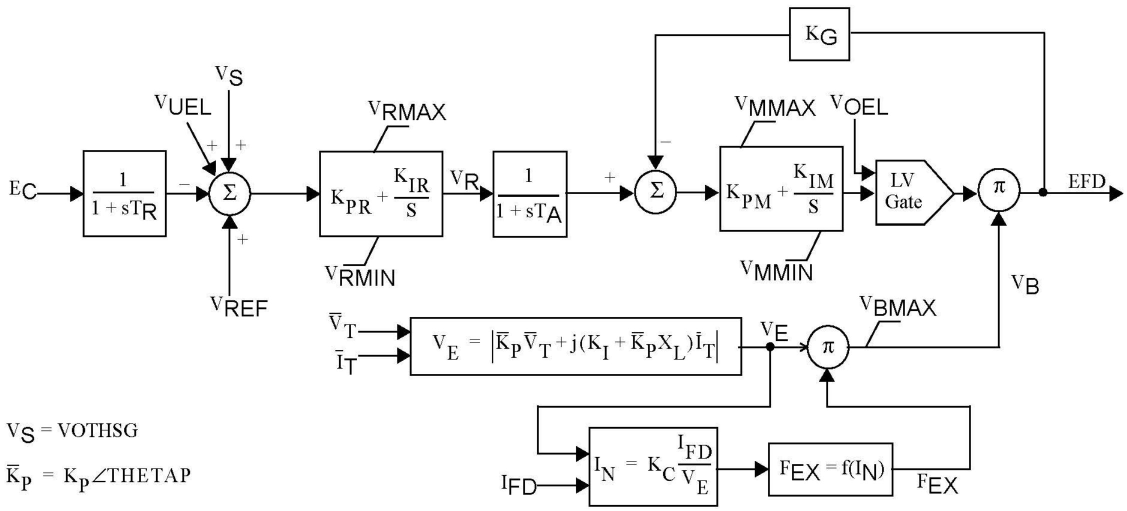
6.37. ESST4B

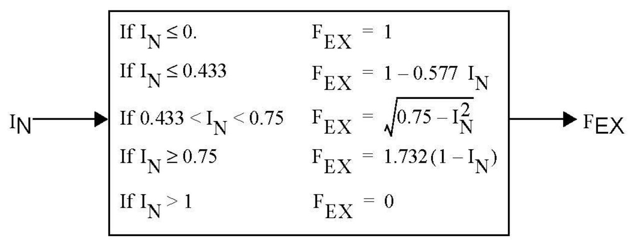
IEEE Type ST4B Potential or Compounded Source-Controlled Rectifier Exciter

CONs	Value	Description
J		T_R (s)
J+1		K_{PR}
J+2		K_{IR}
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		T_A (s)
J+6		K_PM
J+7		K_IM
J+8		VMMAX
J+9		VMMIN
J+10		K_G
J+11		K_P
J+12		K_I
J+13		V_{BMAX}
J+14		K_C
J+15		X_I
J+16		T_HETAP in degrees

STATEs	Description
K	Sensed V_T
K+1	Regulator integrator
K+2	Regulator output, V_R
K+3	V_M

```
IBUS, 'ESST4B', ID, CON(J) to CON(J+16)   /
```


KG
VS
VUEL
VRMAX
VMMAX
VOEL
EC
1 / (1 + sTR)
Σ
KPR + KIR/s
VR
1 / (1 + sTA)
Σ
KPM + KIM/s
LV Gate
π
EFD
VRMIN
VMMIN
VB
VREF
VBMAX
V̄T
ĪT
VE = |K̄P V̄T + j(KI + K̄P XL) ĪT|
VE
π
VS = VOTHSG
K̄P = KP∠THETAP
IN = KC IFD/VE
FEX = f(IN)
IFD
FEX


IN
If IN ≤ 0. FEX = 1
If IN ≤ 0.433 FEX = 1 – 0.577 IN
If 0.433 < IN < 0.75 FEX = √(0.75 – IN²)
If IN ≥ 0.75 FEX = 1.732(1 – IN)
If IN > 1 FEX = 0
FEX

6.38. ESURRY

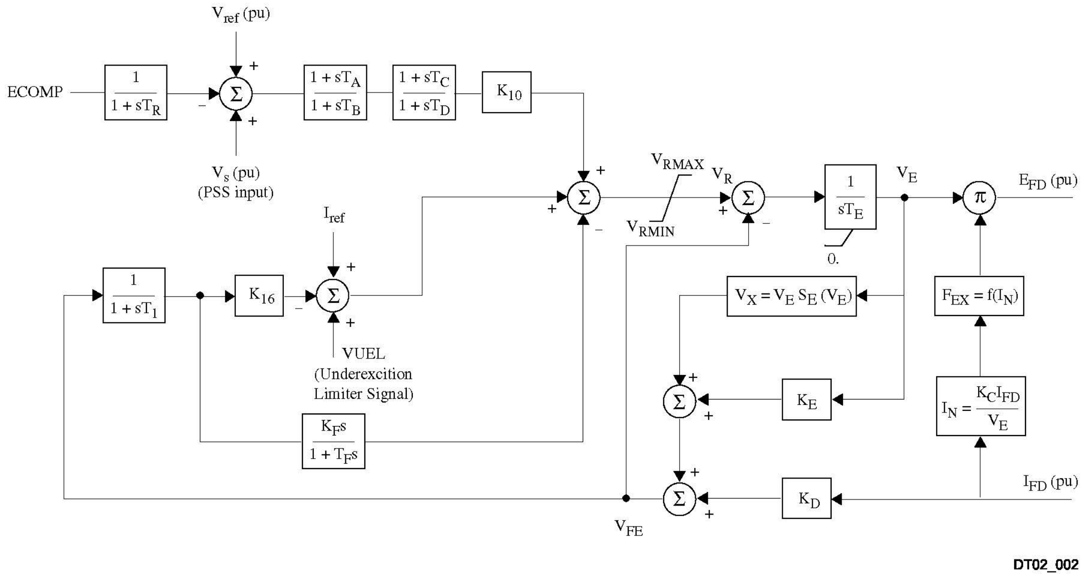
Modified IEEE Type AC1A Excitation System

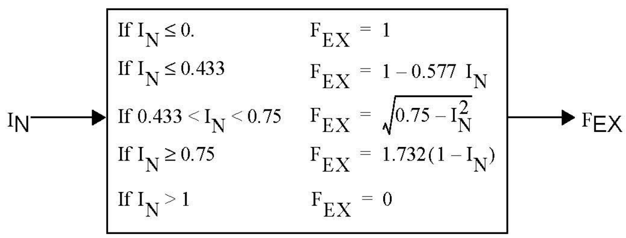
CONs	Value	Description
J		T_R (s)
J+1		T_A (s)
J+2		T_B (s)
J+3		T_C (s)
J+4		T_D (s)
J+5		$K_1$0
J+6		T_1 (s)
J+7		K_{16}
J+8		K_F
J+9		$T_F > 0$ (s)
J+10		V_{RMAX}
J+11		V_{RMIN}
J+12		$T_E > 0$ (s)
J+13		E_1
J+14		$S(E_1)$
J+15		E_2
J+16		$S(E_2)$
J+17		K_C (0<KC≤1)
J+18		K_D
J+19		K_E

STATEs	Description
K	Sensor
K+1	1st lead lag
K+2	2nd lead lag
K+3	Exciter field current sensor
K+4	Feed forward output
K+5	Exciter

VARs	Description
L	Exciter field current reference

```
IBUS, 'ESURRY', ID, CON(J) to CON(J+19)   /
```


Vref (pu)
ECOMP
1 / 1 + sTR
1 + sTA / 1 + sTB
1 + sTC / 1 + sTD
K10
Vs (pu)
(PSS input)
VRMAX
VR
VRMIN
1 / sTE
0.
VE
π
EFD (pu)
Iref
1 / 1 + sT1
K16
VUEL
(Underexcition
Limiter Signal)
KFs / 1 + TFs
VX = VE SE (VE)
FEX = f(IN)
KE
IN = KCIFD / VE
KD
IFD (pu)
VFE
DT02_002


IN
If IN ≤ 0. FEX = 1
If IN ≤ 0.433 FEX = 1 – 0.577 IN
If 0.433 < IN < 0.75 FEX = √(0.75 – IN²)
If IN ≥ 0.75 FEX = 1.732(1 – IN)
If IN > 1 FEX = 0
FEX

6.39. EX2000

EX2000 Excitation System

also represents

IEEE Type AC7B Alternator-Rectifier Excitation System

(Under Excitation Limiter is not included)

ICONs	Value	Description
M		• 0 - Field Current Limiter is excluded (and upper limit $V_{E_{MAX}}$ is on) • 1 - Field Current Limiter is included (and upper limit $V_{E_{MAX}}$ is off)
M+1		• 0 - Minimum Gate 2 is excluded • 1 - Minimum Gate 2 is included
M+2		Memory. Set to 0. • 0 - Latch Gate 1 signal is 0 • 1 - Latch Gate 1 signal is 1
M+3		Memory. Set to 0. • 0 - Field Current Limiter Timer is not active • 1 - Field Current Limiter Timer is active

CONs	Value	Description
J		K_{PR}, proportional gain
J+1		K_{IR}, integral gain
J+2		V_{RMAX}, maximum output
J+3		V_{RMIN}, minimum output
J+4		K_{PA}, proportional gain
J+5		K_{IA}, integral gain
J+6		V_{AMAX}, maximum output
J+7		V_{AMIN}, minimum output
J+8		K_P, constant
J+9		K_L, constant
J+10		T_E, exciter field time constant (s), (>0)
J+11		$V_{FE_{MAX}}$, parameter of $V_{E_{MAX}}$, exciter field maximum output
J+12		K_E, exciter field proportional constant
J+13		K_C, rectifier regulation factor
J+14		K_D, exciter regulation factor
J+15		K_{F1}
J+16		K_{F2}

CONs	Value	Description
J+17		E_1, exciter flux at knee of curve
J+18		$S(E_1)$, saturation factor at knee of curve
J+19		E_2, maximum exciter flux
J+20		$S(E_2)$, saturation factor at maximum exciter flux
J+21		KVHZ, Volt/Hz gain
J+22		K_RCC, Volt/reactive current gain
J+23		T_r, voltage transducer time constant (s)
J+24		IFDREF1, field current 1st reference
J+25		IFDFEF2, field current 2nd
J+26		IFDREF3, field current 3rd reference
J+27		IFDREF4, field current 4th reference
J+28		I1, inverse timing constant
J+29		T_1, inverse timing constant (s)
J+30		I2, inverse timing constant
J+31		T_2, inverse timing constant (s)
J+32		I3, inverse timing constant
J+33		T_3, inverse timing constant (s)
J+34		I_4, inverse timing constant
J+35		T_4, inverse timing constant (s)
J+36		TLEAD, field current limiter time constant (s)
J+37		TLAG, field current limiter time constant (s)
J+38		K_PIFD, proportional gain
J+39		K_{II}FD, integral gain
J+40		IFDLIMP, maximum output
J+41		IFDLIMN, minimum output
J+42		IFDADVLIM, advance field current limit
J+43		$V_{E_{MIN}}$, exciter field minimum output
J+44		REFLIMP, voltage reference signal limit

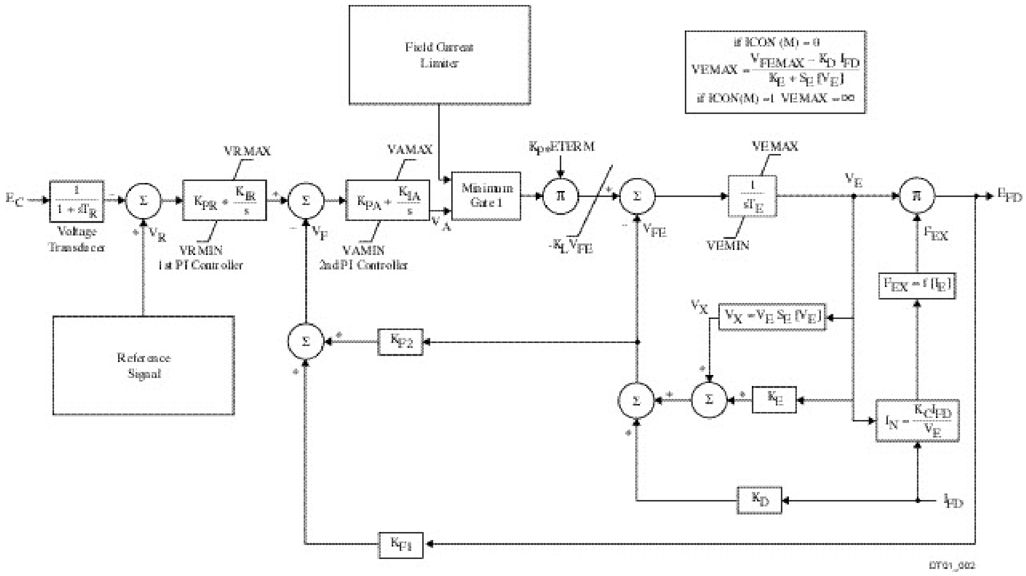
The values are given in per unit unless the unit is shown. For field current references and inverse timing constants the value of the current is in per unit of the generator Air Gap Line base.

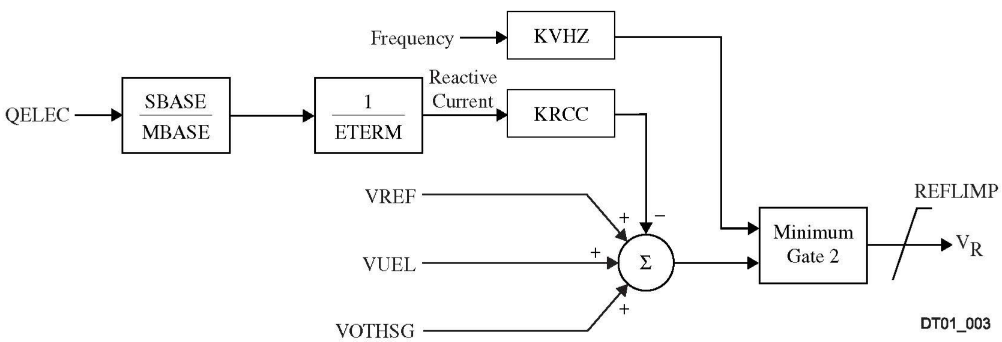
STATEs	Description
K	Voltage Transducer
K+1	1st PI controller
K+2	2nd PI controller
K+3	Exciter field voltage
K+4	3rd PI controller (Field Current Limiter)
K+5	Lead-lag element (Field Voltage Limiter)

VARs	Description
L	Inverse Timing Function Memory

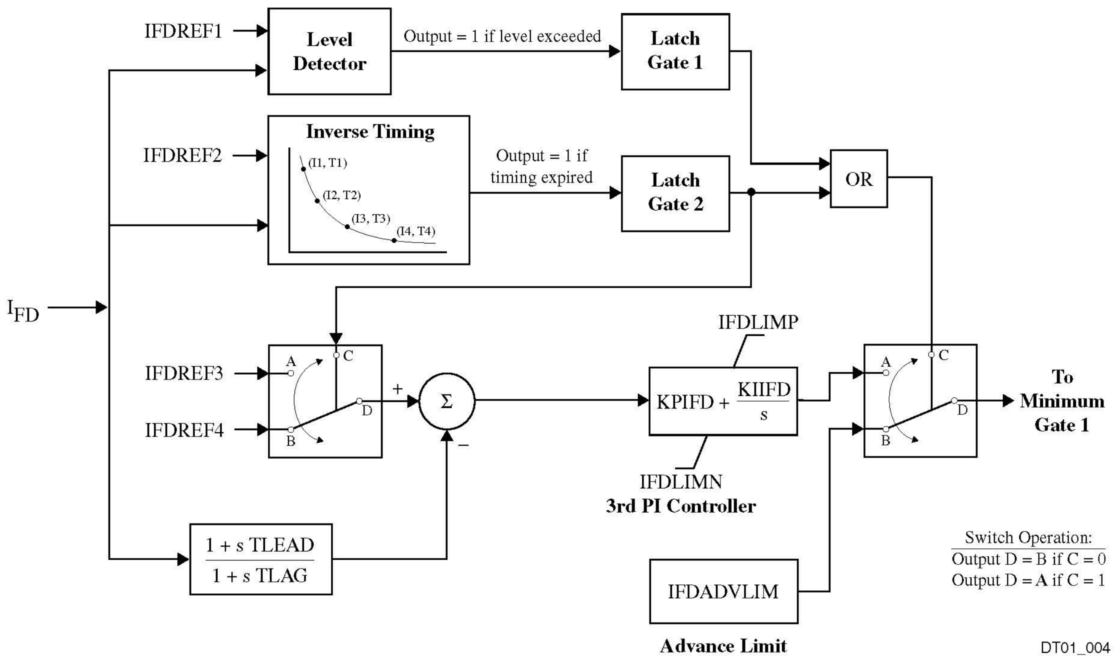
VARs	Description
	• <= 1 - Latch Gate 2 signal is 0 • >= 1 - Latch Gate 2 signal is 1

```
IBUS, 'EX2000', ID, ICON(M), ICON(M+1), CON(J) to CON(J+44)   /
```





Reference Signal



Field Current Limiter
(Over Excitation Limiter)

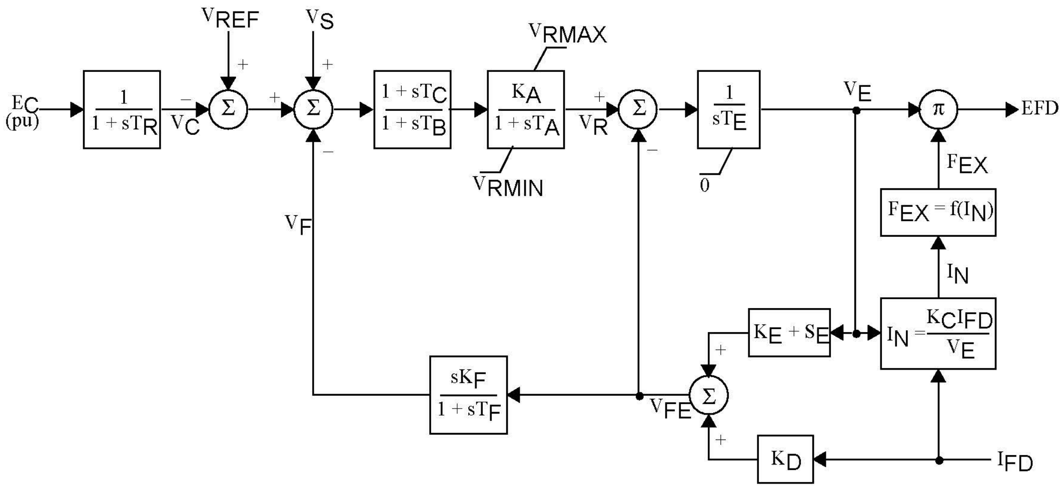
6.40. EXAC1

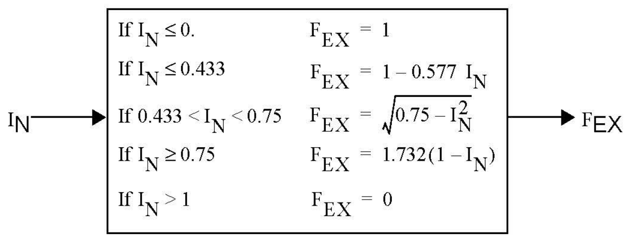
IEEE Type AC1 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		T_B (s)
J+2		T_C (s)
J+3		K_A
J+4		T_A (s)
J+5		V_{RMAX}
J+6		V_{RMIN}
J+7		$T_E > 0$ (s)
J+8		K_F
J+9		$T_F > 0$ (s)
J+10		K_C
J+11		K_D
J+12		K_E
J+13		E_1
J+14		$S_E(E_1)$
J+15		E_2
J+16		$S_E(E_2)$

STATEs	Description
K	Sensed E_T
K+1	Lead lag
K+2	Regulator output
K+3	V_E
K+4	Feedback output

```
IBUS, ’EXAC1’, ID, CON(J) to CON(J+16)   /
```





V_S = VOTHSG + VUEL + VOEL

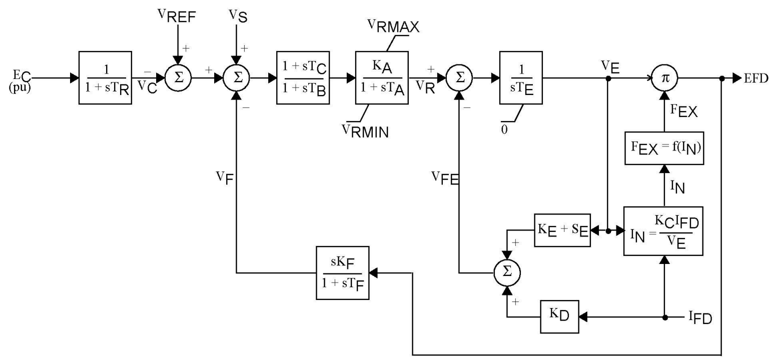
6.41. EXAC1A

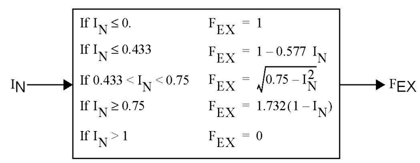
IEEE Modified Type AC1 Excitation System

CONs	Value	Description
J		T_r (sec)
J+1		T_B (sec)
J+2		T_C (sec)
J+3		K_A
J+4		T_A (sec)
J+5		V_{RMAX}
J+6		V_{RMIN}
J+7		$T_E > 0$ (sec)
J+8		K_F
J+9		$T_F > 0$ (sec)
J+10		K_C
J+11		K_D
J+12		K_E
J+13		E_1
J+14		$S_E(E_1)$
J+15		E_2
J+16		$S_E(E_2)$

STATEs	Description
K	Sensed E_T
K+1	Lead lag
K+2	Regulator output
K+3	V_E
K+4	Feedback output

```
IBUS, 'EXAC1A', ID, CON(J) to CON(J+16)   /
```





V_S = VOTHSG + VUEL + VOEL

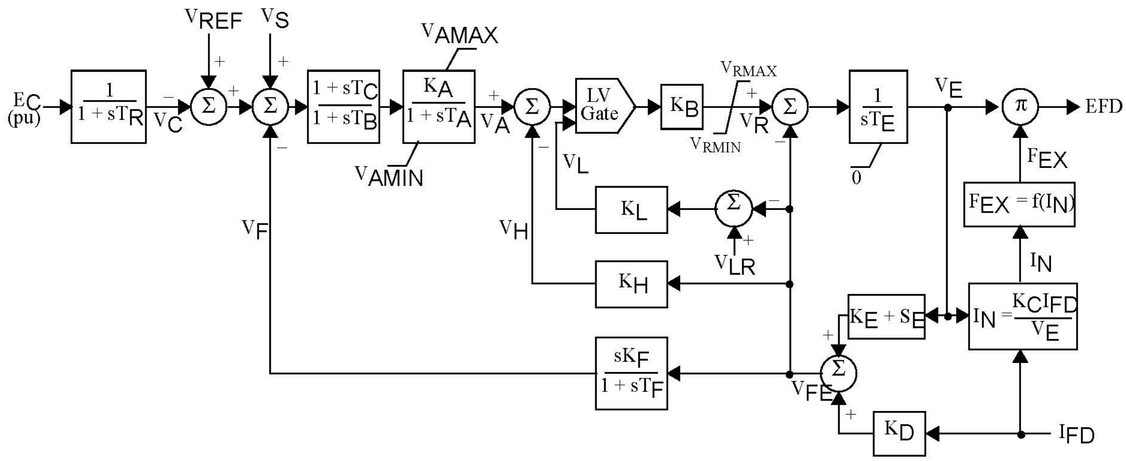
6.42. EXAC2

IEEE Type AC2 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		T_B (s)
J+2		T_C (s)
J+3		K_A
J+4		T_A (s)
J+5		V_{AMAX}
J+6		V_{AMIN}
J+7		K_B
J+8		V_{RMAX}
J+9		V_{RMIN}
J+10		$T_E > 0$ (s)
J+11		K_L
J+12		K_H
J+13		K_F
J+14		$T_F > 0$ (s)
J+15		K_C
J+16		K_D
J+17		K_E
J+18		V_{LR}
J+19		E_1
J+20		$S_E(E_1)$
J+21		E_2
J+22		$S_E(E_2)$

STATEs	Description
K	Sensed E_T
K+1	Lead lag
K+2	Regulator output
K+3	V_E
K+4	Feedback output

```
BUS, 'EXAC2', ID, CON(J) to CON(J+22)   /
```



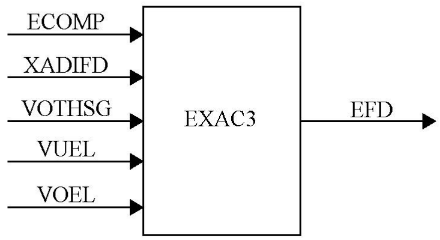
$I_N \rightarrow F_{EX}$:

$$
\begin{array}{ll}
\text{If } I_N \le 0. & F_{EX} = 1 \\
\text{If } I_N \le 0.433 & F_{EX} = 1 - 0.577\, I_N \\
\text{If } 0.433 < I_N < 0.75 & F_{EX} = \sqrt{0.75 - I_N^2} \\
\text{If } I_N \ge 0.75 & F_{EX} = 1.732(1 - I_N) \\
\text{If } I_N > 1 & F_{EX} = 0
\end{array}
$$

V_S = VOTHSG + VUEL + VOEL

6.43. EXAC3

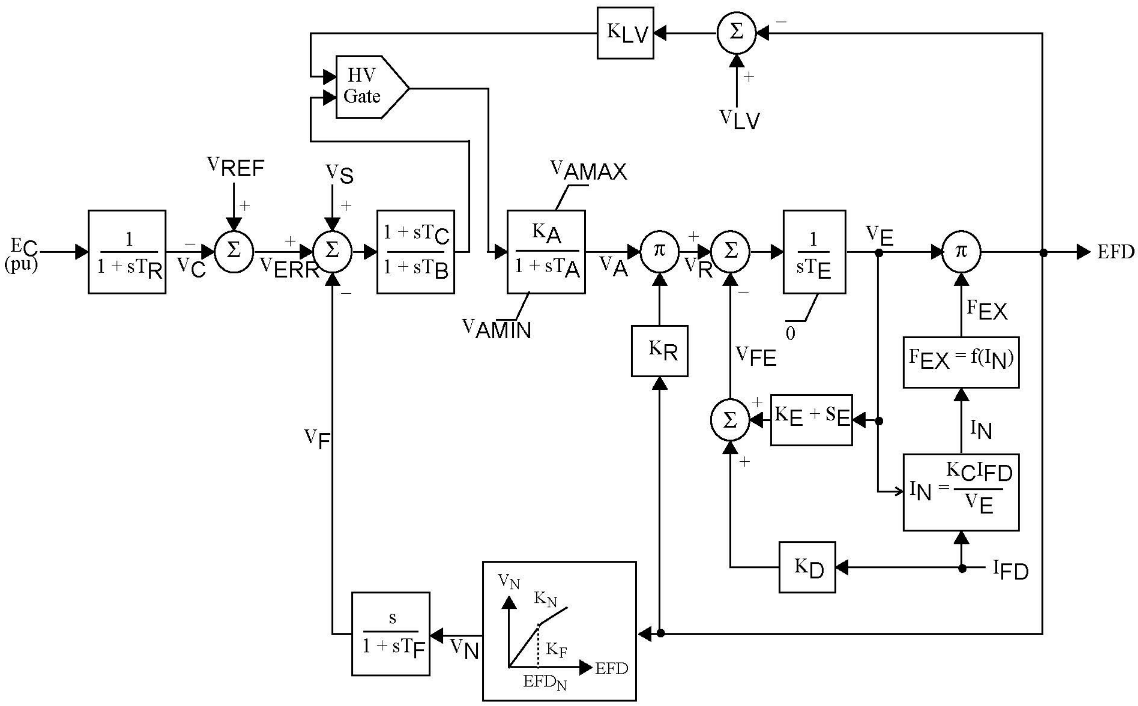
IEEE Type AC3 Excitation System

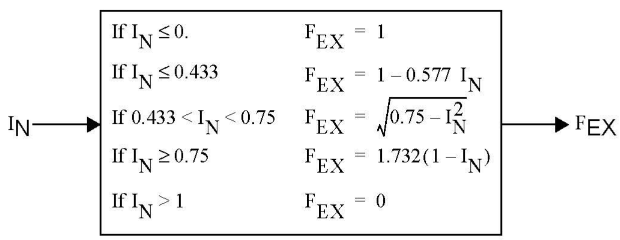


CONs	Value	Description
J		T_R (s)
J+1		T_B (s)
J+2		T_C (s)
J+3		K_A
J+4		T_A (s)
J+5		V_{AMAX}
J+6		V_{AMIN}
J+7		$T_E > 0$ (s)
J+8		K_LV
J+9		K_R (>0)
J+10		K_F
J+11		$T_F > 0$ (s)
J+12		K_N
J+13		EFDN
J+14		K_C
J+15		K_D
J+16		K_E
J+17		V_{LV}
J+18		E_1
J+19		$S_E(E_1)$
J+20		E_2
J+21		$S_E(E_2)$

STATEs	Description
K	Sensed E_T
K+1	Lead lag
K+2	Regulator output
K+3	V_E
K+4	Feedback output

```
IBUS, 'EXAC3', ID, CON(J) to CON(J+21)   /
```





V_S = VOTHSG + VUEL + VOEL

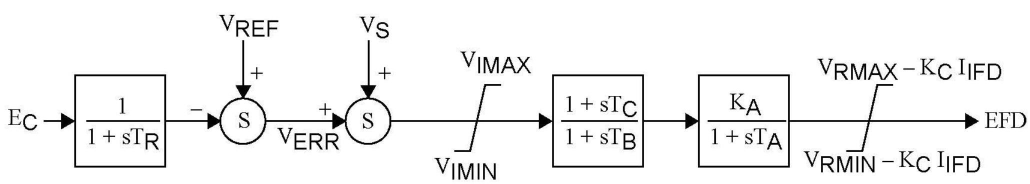
6.44. EXAC4

IEEE Type AC4 Excitation System

CONs	Value	Description
J		T_R
J+1		V_{IMAX}
J+2		V_{IMIN}
J+3		T_C
J+4		T_B (s)
J+5		K_A
J+6		T_A
J+7		V_{RMAX}
J+8		V_{RMIN}
J+9		K_C

STATEs	Description
K	$V_{measured}$
K+1	Lead lag
K+2	V_R

```
IBUS, 'EXAC4', ID, CON(J) to CON(J+9)   /
```



VS = VOTHSG + VUEL + VOEL

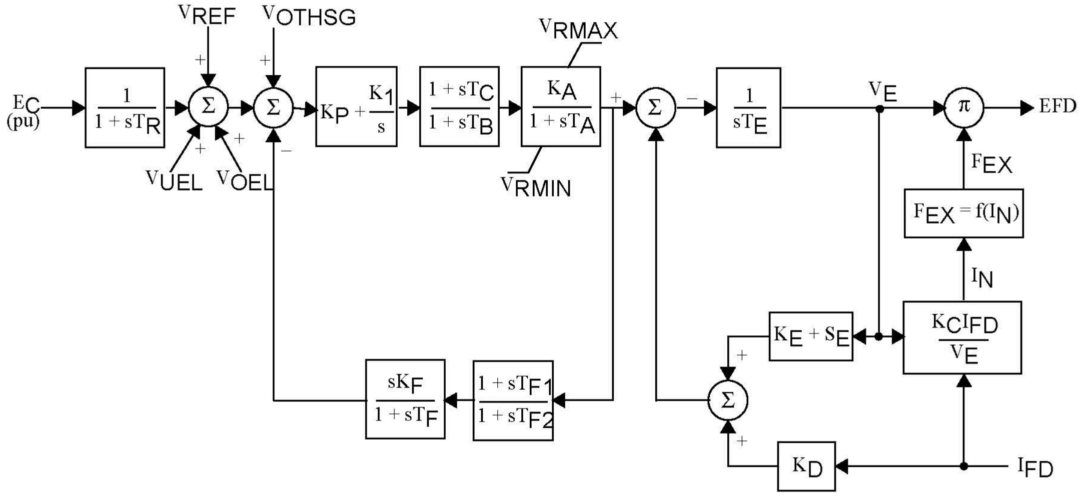
6.45. EXBAS

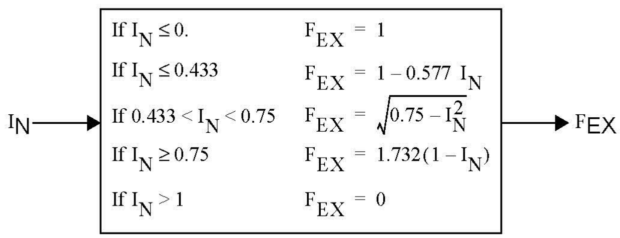
Basler Static Voltage Regulator Feeding dc or ac Rotating Exciter

CONs	Value	Description
J		T_R, voltage transducer time constant (s)
J+1		K_P, proportional gain
J+2		K_I, integral (reset) gain
J+3		K_A, gain
J+4		T_A, bridge time constant (s)
J+5		T_B, lag time constant (s)
J+6		TC, lead time constant (s)
J+7		V_{RMAX}, maximum control output (pu)
J+8		V_{RMIN}, minimum control output (pu)
J+9		K_F, rate feedback gain
J+10		T_F, rate feedback time constant (>0) (s)
J+11		T_{F1}, feedback lead time constant (s)
J+12		T_{F2}, feedback lag time constant (s)
J+13		K_E, exciter field proportional constant
J+14		T_E, exciter field time constant (>0) (s)
J+15		K_C, rectifier regulation factor (pu)
J+16		K_D, exciter regulation factor (pu)
J+17		E_1, exciter flux at knee of curve (pu)
J+18		$S_E(E_1)$, saturation factor at knee of curve
J+19		E_2, maximum exciter flux (pu)
J+20		$SE(E_2)$, saturation factor at maximum exciter flux (pu)

STATEs	Description
K	Sensed E_T
K+1	Integral gain
K+2	Lead lag
K+3	Regulator output
K+4	V_E
K+5	Feedback washout
K+6	Feedback lead lag

```
IBUS, 'EXBAS', ID, CON(J) to CON(J+20)  /
```


VREF
VOTHSG
VRMAX
EC
(pu)
1/(1 + sTR)
Σ
Σ
KP + K1/s
(1 + sTC)/(1 + sTB)
KA/(1 + sTA)
Σ
1/sTE
VE
π
EFD
VUEL
VOEL
VRMIN
FEX
FEX = f(IN)
IN
KE + SE
KCIFD/VE
sKF/(1 + sTF)
(1 + sTF1)/(1 + sTF2)
Σ
KD
IFD


IN
If IN ≤ 0. FEX = 1
If IN ≤ 0.433 FEX = 1 – 0.577 IN
If 0.433 < IN < 0.75 FEX = √(0.75 – IN²)
If IN ≥ 0.75 FEX = 1.732(1 – IN)
If IN > 1 FEX = 0
FEX

6.46. EXDC2

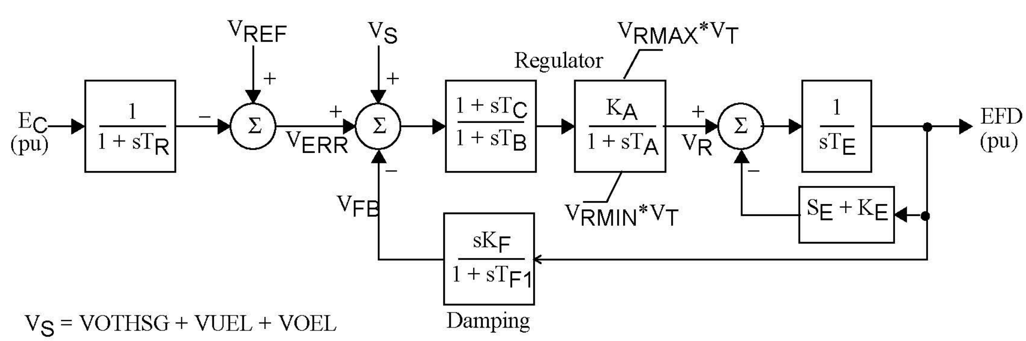
IEEE Type DC2 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		T_B (s)
J+4		T_C (s)
J+5		V_{RMAX} or zero
J+6		V_{RMIN}
J+7		K_E or zero
J+8		T_E (>0) (s)
J+9		K_F
J+10		T_{F1} (>0) (s)
J+11		Switch
J+12		E_1
J+13		$S_E(E_1)$
J+14		E_2
J+15		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Lead lag output
K+2	Regulator output, V_R
K+3	Exciter output, EFD
K+4	Rate feedback integrator

VARs	Description
L	K_E

```
IBUS, 'EXDC2', ID, CON(J) to CON(J+15)   /
```



6.47. EXELI

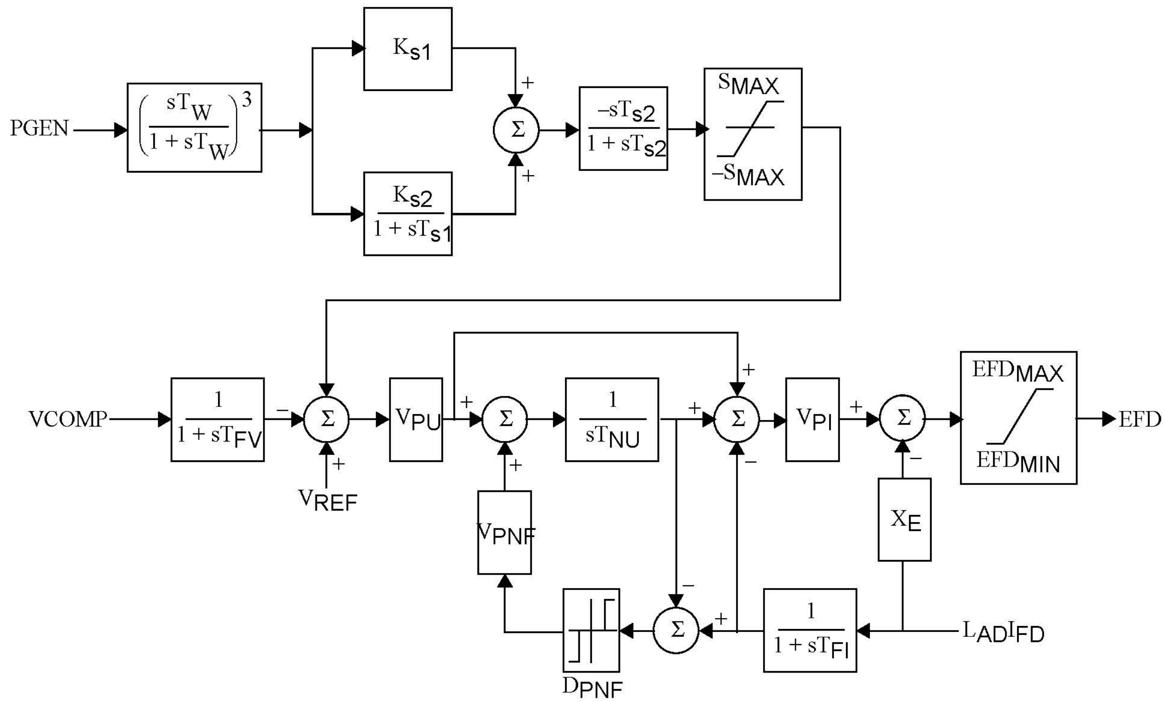
Static PI Transformer Fed Excitation System

CONs	Value	Description
J		$T_{FV} \geq 0$, voltage transducer time constant (s)
J+1		$T_{FI} \geq 0$, current transducer time constant (s)
J+2		$T_{NU} > 0$, controller reset time constant (s)
J+3		V_{PU}, voltage controller proportional gain
J+4		V_{PI}, current controller gain
J+5		$V_{PNF} \geq 0$, controller follow-up gain
J+6		$D_{PNF} \geq 0$, controller follow-up dead band (pu)
J+7		EFD_{MIN}, minimum open circuit excitation voltage (pu)
J+8		$EFD_{MAX} \geq EFD_{MIN}$, maximum open circuit excitation voltage (pu)
J+9		$X_E \geq 0$, excitation transformer effective reactance (pu)
J+10		$T_W \geq 0$, stabilizer feedback time constant (s)
J+11		K_{S1}, first stabilizer gain
J+12		K_{S2}, second stabilizer gain
J+13		$T_{S1} \geq 0$, first stabilizer time constant (s)
J+14		$T_{S2} \geq 0$, second stabilizer feedback time constant (s)
J+15		$S_{MAX} > 0$, stabilizer limit (pu)

STATEs	Description
K	First washout stabilizer state
K+1	Lag stabilizer state
K+2	Negative washout stabilizer state
K+3	Sensed voltage state
K+4	Sensed field current state
K+5	Controlled voltage state
K+6	Second washout stabilizer state
K+7	Third washout stabilizer state

VARs	Description
L	Stabilizer signal

```
IBUS, 'EXELI', ID, CON(J) to CON(J+15)   /
```


PGEN
$\left(\frac{sT_W}{1+sT_W}\right)^3$
K_{s1}
$\frac{K_{s2}}{1+sT_{s1}}$
$\frac{-sT_{s2}}{1+sT_{s2}}$
S_{MAX}
$-S_{MAX}$
VCOMP
$\frac{1}{1+sT_{FV}}$
V_{REF}
V_{PU}
$\frac{1}{sT_{NU}}$
V_{PI}
EFD_{MAX}
EFD_{MIN}
EFD
V_{PNF}
X_E
D_{PNF}
$\frac{1}{1+sT_{FI}}$
$L_{AD}I_{FD}$

6.48. EXNEBB

Bus or Solid Fed SCR Bridge Excitation System Model Type NEBB (NVE)

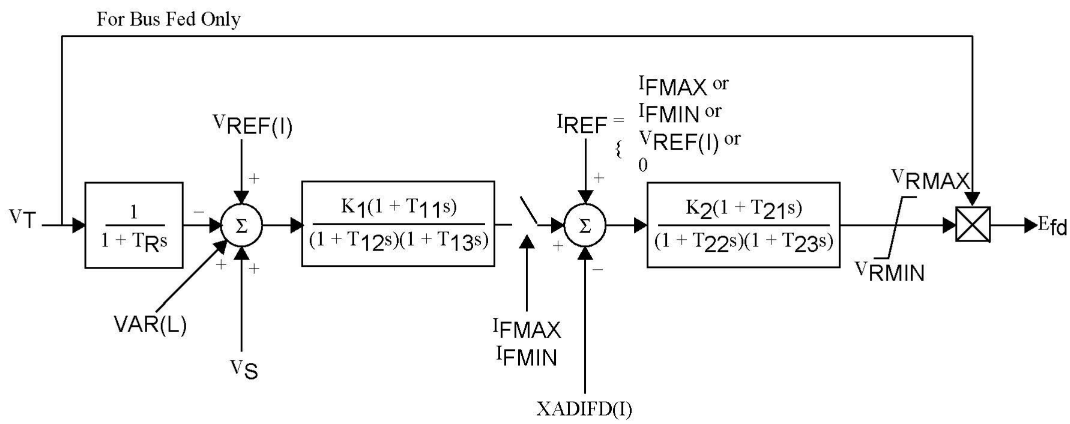
CONs	Value	Description
J		$T_R \geq 0$ (s)
J+1		$K_1 > 0$ (s)
J+2		$T_{11} \geq 0$ (s)
J+3		$T_{12} > 0$ (s)
J+4		$T_{13} > 0$ (s)
J+5		$K_2 > 0$
J+6		$T_{21} \geq 0$ (s)
J+7		$T_{22} > 0$ (s)
J+8		$T_{23} > 0$ (s)
J+9		V_{RMAX} pu
J+10		V_{RMIN} pu
J+11		I_{FMAX} (maximum field current) pu[a]
J+12		I_{FMIN} (minimum field current) pu
J+13		FLAG: 0 bus fed 1 solid fed

[a]If $I1_{FMAX} \leq I_{FMIN}$, only current regulation (IREF = V_{REF}(I))

STATEs	Description
K	Measuring circuit
K+1	1st amplifier
K+2	1st amplifier output
K+3	2nd amplifier
K+4	2nd amplifier output

VARs	Description
L	For tests
L+1	Field current limiter

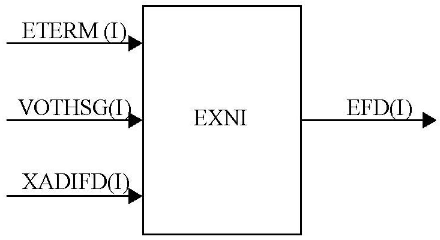
```
IBUS, 'EXNEBB', ID, CON(J) to CON(J+13)   /
```



V_S = VOTHSG + VUEL + VOEL

6.49. EXNI

Bus or Solid Fed SCR Bridge Excitation System Model Type NI (NVE)



CONs	Value	Description
J		$T_R \geq 0$ (s)
J+1		$K_A > 0$
J+2		$T_A > 0$ (s)
J+3		V_{RMAX} pu
J+4		V_{RMIN} pu
J+5		$K_F \geq 0$
J+6		$T_{F1} > 0$ (s)
J+7		$T_{F2} > 0$ (s)
J+8		SWITCH[a]
J+9		R = rc / rfd[b]

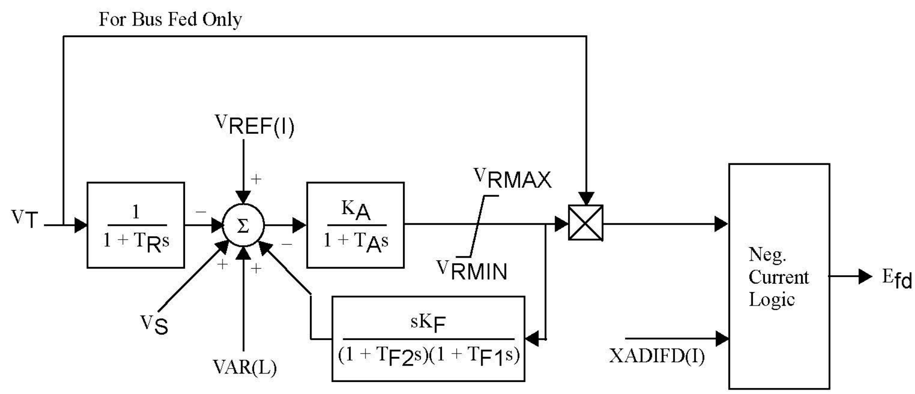
[a]SWITCH = 0 for bus fed, 1 for solid fed

[b]r2c / rfd = 0 for exciter with negative current capability > 0 without (typical = 10)

STATEs	Description
K	Measuring circuit
K+1	Amplifier
K+2	Feedback
K+3	Feedback output

VARs	Description
L	For tests

```
IBUS, 'EXNI', ID, CON(J) to CON(J+9)   /
```



V_S = VOTHSG + VUEL + VOEL

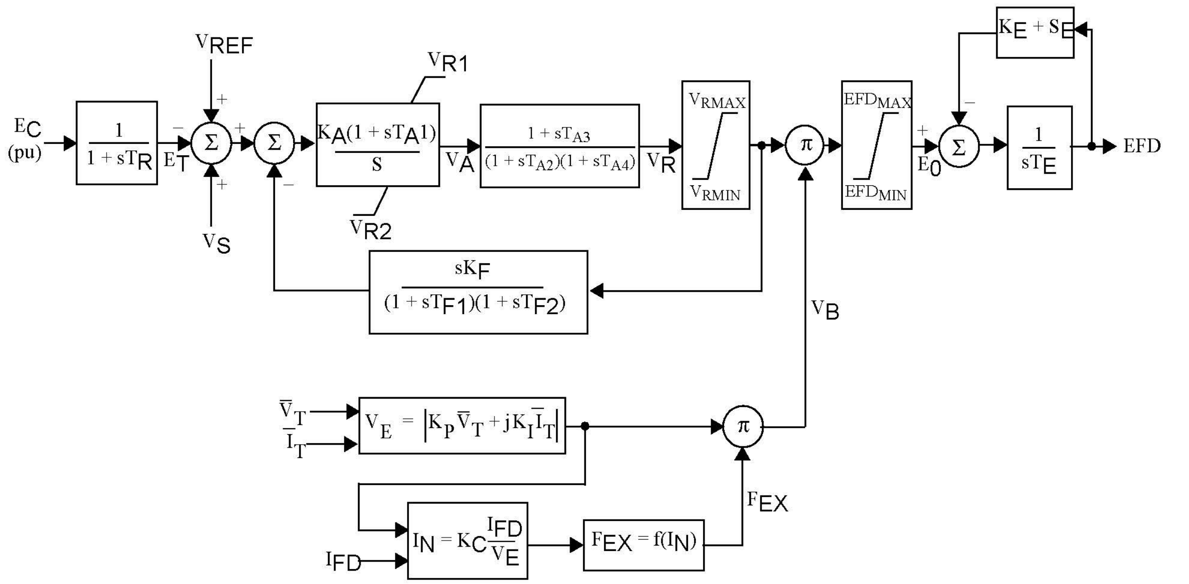
6.50. EXPIC1

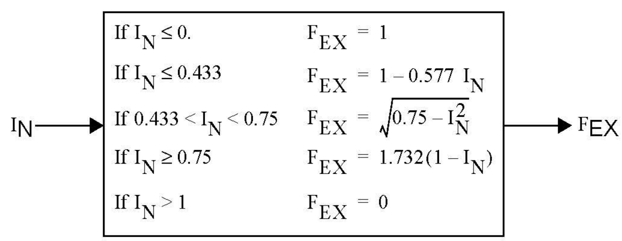
Proportional/Integral Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A1 (s)
J+3		V_R1
J+4		V_R2
J+5		T_{A2} (s)
J+6		T_{A3} (s)
J+7		T_{A4} (s)
J+8		V_{RMAX}
J+9		V_{RMIN}
J+10		K_F
J+11		T_{F1} (>0) (s)
J+12		T_{F2} (s)
J+13		EFD_{MAX}
J+14		EFD_{MIN}
J+15		K_E
J+16		T_E (s)
J+17		E_1
J+18		SE_1
J+19		E_2
J+20		SE_2
J+21		K_P
J+22		K_I
J+23		K_C

STATEs	Description
K	Sensed E_T
K+1	First regulator, VA
K+2	Second regulator
K+3	Third regulator, V_R
K+4	Exciter output, EFD
K+5	First feedback integrator
K+6	Second feedback integrator

```
IBUS, 'EXPIC1', ID, CON(J) to CON(J+23)   /
```





If ($K_P = 0$ and $K_I = 0$), then $V_B = 1$

If $T_E = 0$, then $EFD = E_0$

$V_S = VOTHSG + VUEL + VOEL$

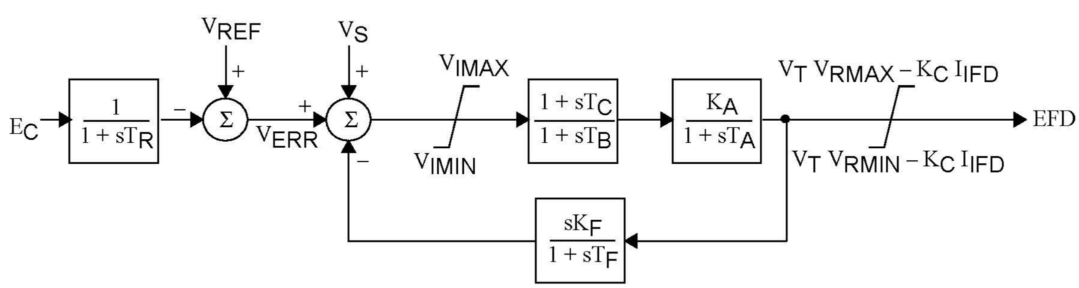
6.51. EXST1

IEEE Type ST1 Excitation System

CONs	Value	Description
J		T_R
J+1		V_{IMAX}
J+2		V_{IMIN}
J+3		T_C
J+4		T_B (s)
J+5		K_A
J+6		T_A (s)
J+7		V_{RMAX}
J+8		V_{RMIN}
J+9		K_C
J+10		K_F
J+11		T_F (> 0) (s)

STATEs	Description
K	$V_{measured}$
K+1	Lead lag
K+2	V_R
K+3	Feedback

```
IBUS, 'EXST1', ID, CON(J) to CON(J+11)   /
```



V_S = VOTHSG + VUEL + VOEL

6.52. EXST2

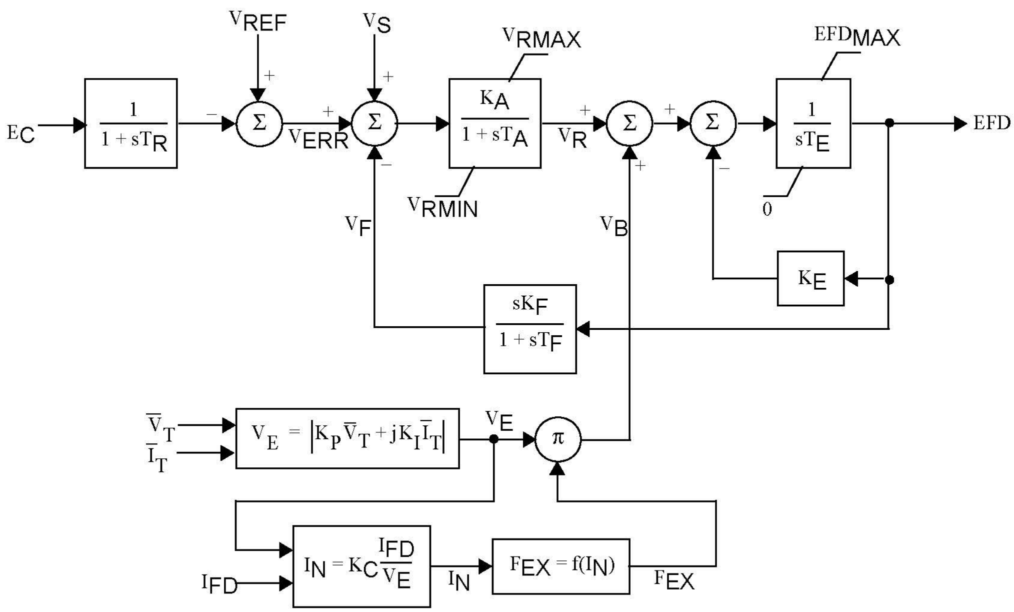
IEEE Type ST2 Excitation System

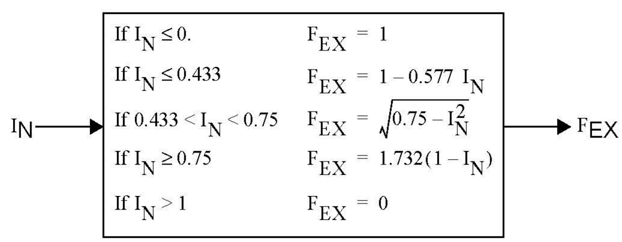
CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		K_E
J+6		T_E (>0) (s)
J+7		K_F
J+8		T_F (>0) (s)
J+9		K_P
J+10		K_I or zero
J+11		K_C
J+12		EFD_{MAX}

STATEs	Description
K	Sensed V_T
K+1	Regulator output, V_R
K+2	Exciter output, E_{FD}
K+3	Rate feedback integral

VARs	Description
L	K_I

```
IBUS, 'EXST2', ID, CON(J) to CON(J+12)   /
```





$V_S = VOTHSG + VUEL + VOEL$

If $K_P = 0$ and $K_I = 0$, $V_B = 1$

6.53. EXST2A

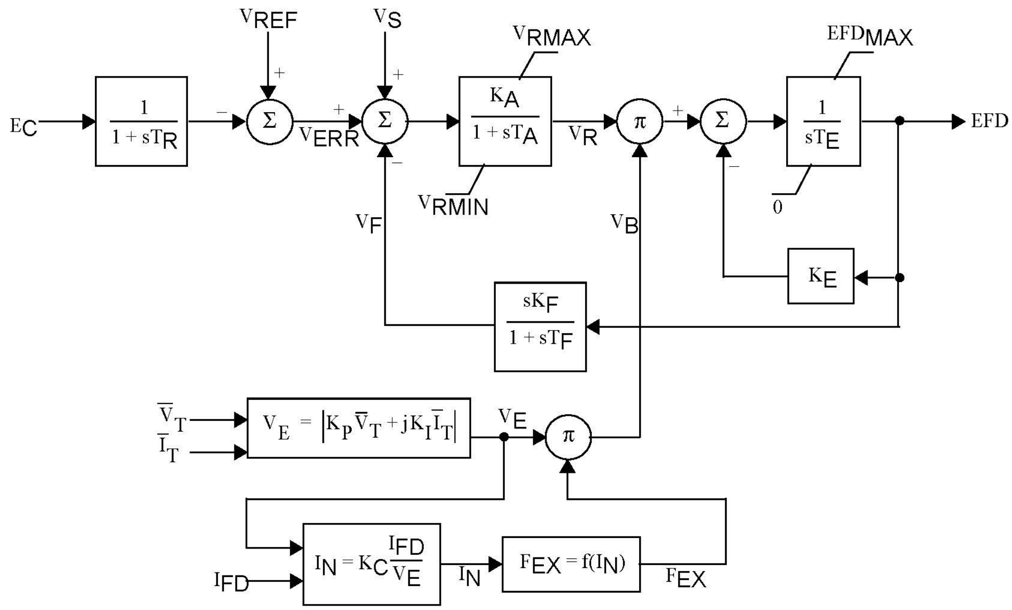
Modified IEEE Type ST2 Excitation System

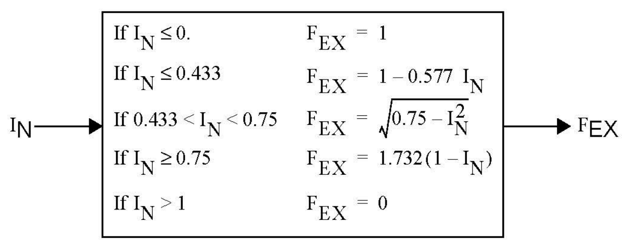
CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		K_E
J+6		T_E (>0) (s)
J+7		K_F
J+8		T_F (>0) (s)
J+9		K_P
J+10		K_I
J+11		K_C
J+12		EFD_{MAX}

STATEs	Description
K	Sensed V_T
K+1	Regulator output, V_R
K+2	Exciter output, E_{FD}
K+3	Rate feedback integral

VARs	Description
L	K_I

```
IBUS, 'EXST2A', ID, CON(J) to CON(J+12)   /
```





V_S = VOTHSG + VUEL + VOEL

If $K_P = 0$ and $K_I = 0$, $V_B = 1$

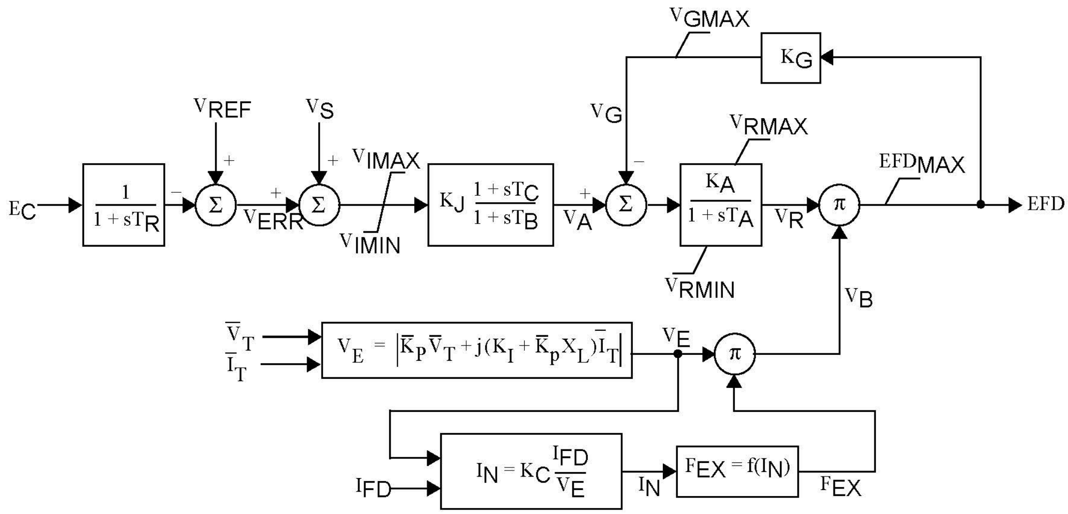
6.54. EXST3

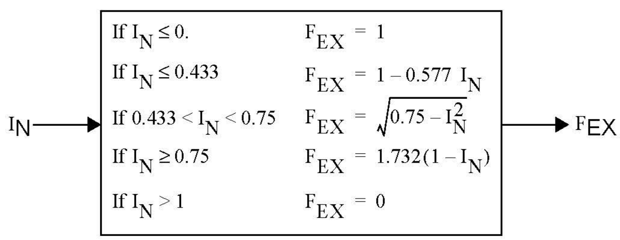
IEEE Type ST3 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		V_{IMAX}
J+2		V_{IMIN}
J+3		KJ
J+4		T_C (s)
J+5		T_B (s)
J+6		K_A
J+7		T_A (s)
J+8		V_{RMAX}
J+9		V_{RMIN}
J+10		K_G
J+11		K_P
J+12		K_I
J+13		EFD_{MAX}
J+14		K_C
J+15		X_I
J+16		V_{GMAX}
J+17		θ_P (degrees)

STATEs	Description
K	Sensed V_T
K+1	V_A
K+2	V_R

```
IBUS, 'EXST3', ID, CON(J) to CON(J+17)   /
```





$\bar{K}_P = K_P \varepsilon^{j\theta_P}$

V_S = VOTHSG + VUEL + VOEL

6.55. IEEET1

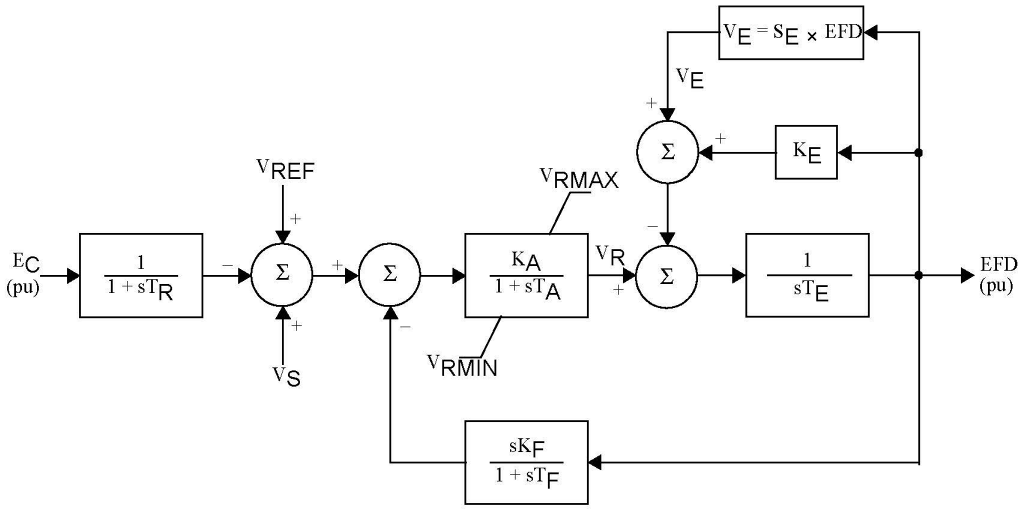
IEEE Type 1 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		V_{RMAX} or zero
J+4		V_{RMIN}
J+5		K_E or zero
J+6		T_E (>0) (s)
J+7		K_F
J+8		T_F (>0) (s)
J+9		Switch
J+10		E_1
J+11		$S_E(E_1)$
J+12		E_2
J+13		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Regulator output, V_R
K+2	Exciter output, EFD
K+3	Rate feedback integrator

VARs	Description
L	K_E

```
IBUS, 'IEEET1', ID, CON(J) to CON(J+13)   /
```



V_S = VOTHSG + VUEL + VOEL

Note: S_E is the saturation function.

6.56. IEEET2

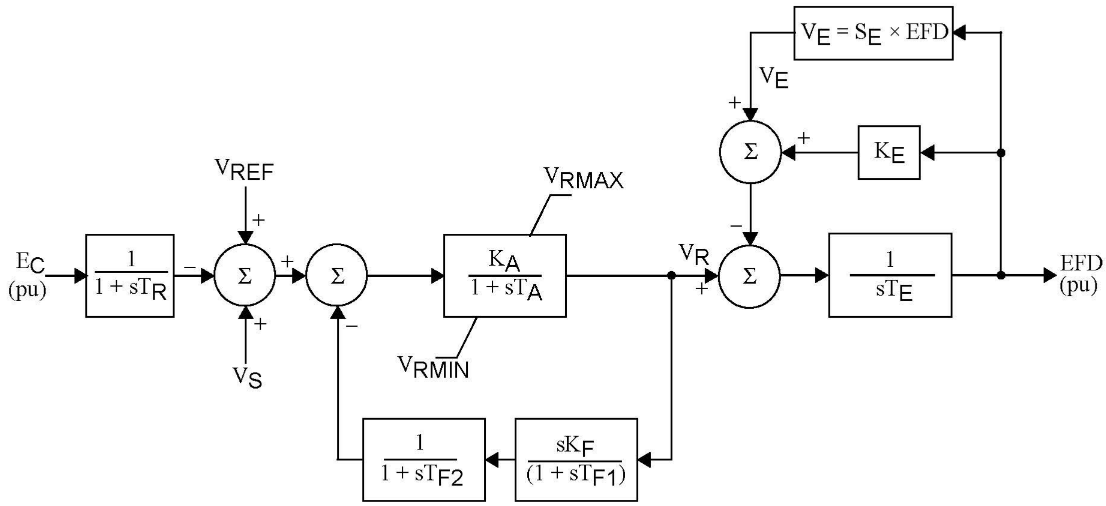
IEEE Type 2 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		V_{RMAX} or zero
J+4		V_{RMIN}
J+5		K_E
J+6		T_E (>0) (s)
J+7		K_F
J+8		T_{F1} (>0) (s)
J+9		T_{F2} (>0) (s)
J+10		E_1
J+11		$S_E(E_1)$
J+12		E_2
J+13		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Regulator output, V_R
K+2	Exciter output, EFD
K+3	First feedback integrator
K+4	Second feedback integrator

VARs	Description
L	K_E

```
IBUS, ’IEEET2’, ID, CON(J) to CON(J+13)   /
```



V_S = VOTHSG + VUEL + VOEL

Note: S_E is the saturation function.

6.57. IEEET3

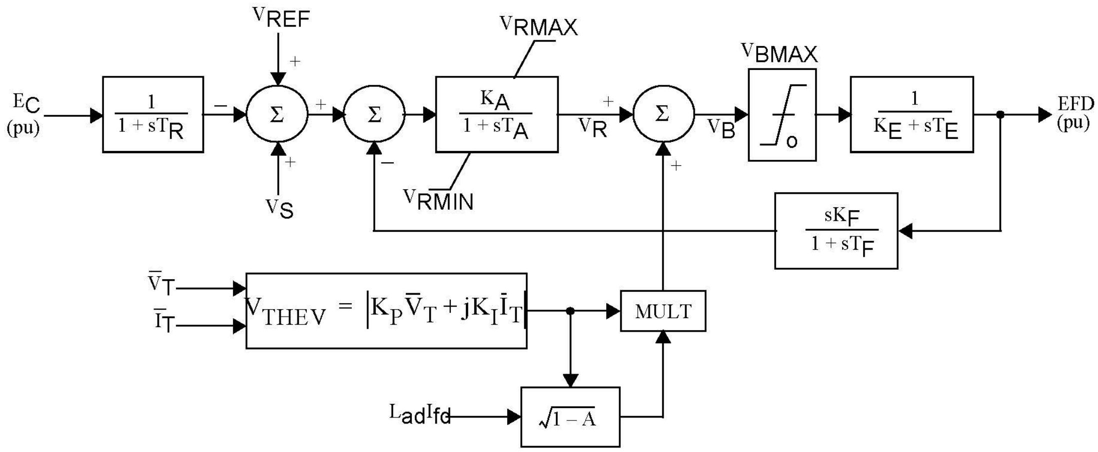
IEEE Type 3 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		T_E (>0) (s)
J+6		K_F
J+7		T_F (>0) (s)
J+8		K_P (>0)
J+9		K_I or zero
J+10		V_{BMAX} (pu voltage base)
J+11		K_E

STATEs	Description
K	Sensed V_T
K+1	Regulator output, V_R
K+2	Exciter output, EFD
K+3	Rate feedback internal

VARs	Description
L	K_I

```
IBUS, 'IEEET3', ID, CON(J) to CON(J+11)   /
```



$$A = \left(\frac{0.78 \times L_{ad}I_{fd}}{V_{THEV}}\right)^2$$

If $A > 1$, $V_B = 0$

V_S = VOTHSG + VUEL + VOEL

6.58. IEEET4

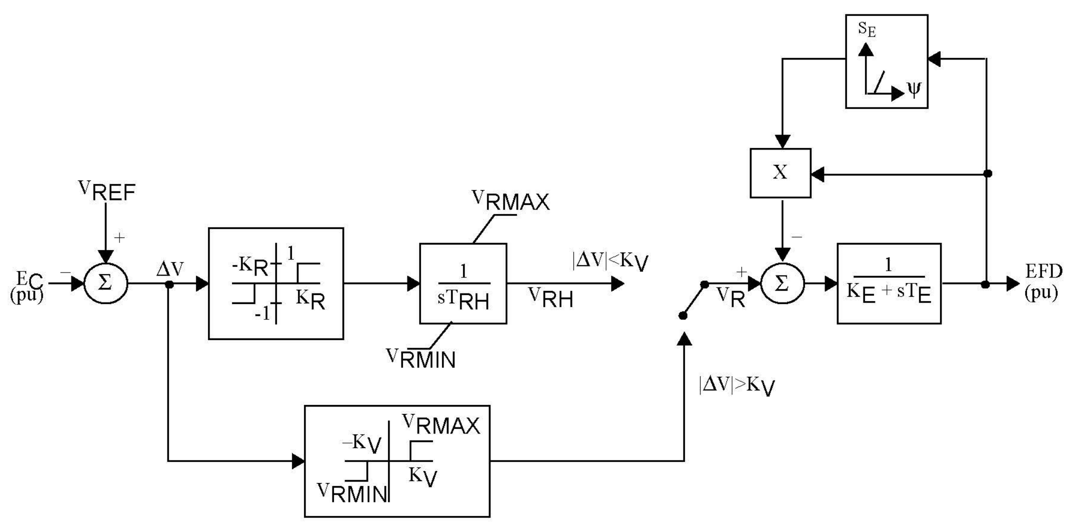
IEEE Type 4 Excitation System

CONs	Value	Description
J		K_R
J+1		T_{RH} (>0) (s)
J+2		K_V
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		T_E (>0) (s)
J+6		K_E
J+7		E_1
J+8		$S_E(E_1)$
J+9		E_2
J+10		$S_E(E_2)$

STATEs	Description
K	V_{RH}
K+1	EFD

VARs	Description
L	K_E

```
IBUS, 'IEEET4', ID, CON(J) to CON(J+10)   /
```



6.59. IEEET5

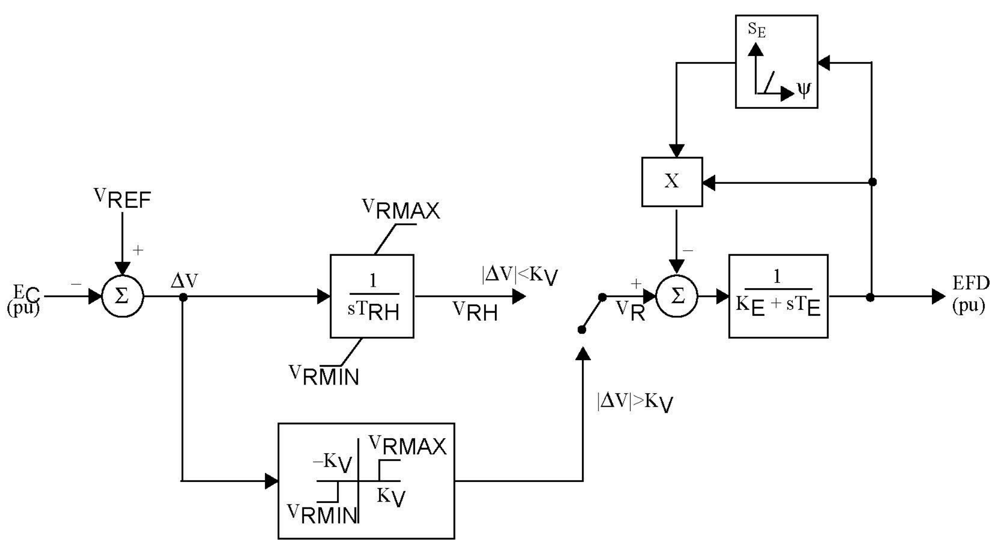
Modified IEEE Type 4 Excitation System

CONs	Value	Description
J		T_{RH} (>0) (s)
J+1		K_V
J+2		V_{RMAX}
J+3		V_{RMIN}
J+4		T_E (>0) (s)
J+5		K_E
J+6		E_1
J+7		$S_E(E_1)$
J+8		E_2
J+9		$S_E(E_2)$

STATEs	Description
K	V_{RH}
K+1	EFD

VARs	Description
L	K_E

```
IBUS, 'IEEET5', ID, CON(J) to CON(J+9)   /
```



6.60. IEEEX1

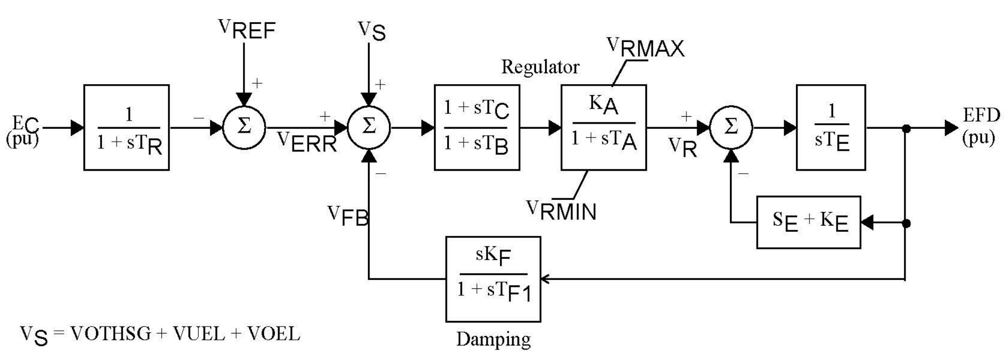
IEEE Type 1 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		T_B (s)
J+4		T_C (s)
J+5		V_{RMAX} or zero
J+6		V_{RMIN}
J+7		K_E or zero
J+8		T_E (>0) (s)
J+9		K_F
J+10		T_{F1} (>0) (s)
J+11		Switch
J+12		E_1
J+13		$S_E(E_1)$
J+14		E_2
J+15		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Lead lag
K+2	Regulator output, V_R
K+3	Exciter output, EFD
K+4	Rate feedback integrator

VARs	Description
L	K_E

```
IBUS, 'IEEEX1', ID, CON(J) to CON(J+15)   /
```



6.61. IEEEX2

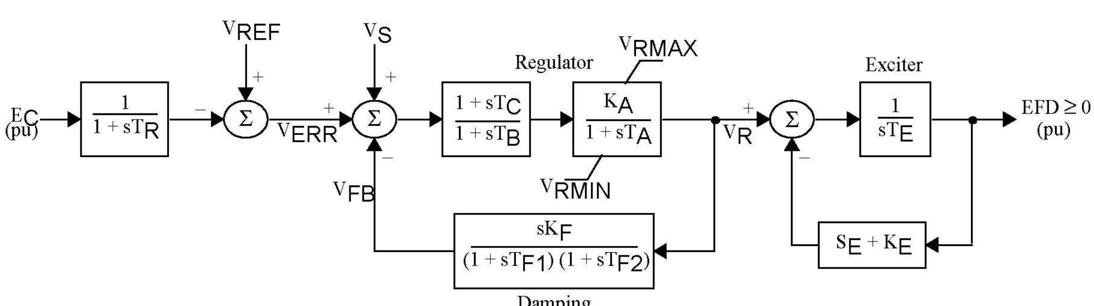
IEEE Type 2 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		T_B (s)
J+4		T_C (s)
J+5		V_{RMAX} or zero
J+6		V_{RMIN}
J+7		K_E or zero
J+8		T_E (>0) (s)
J+9		K_F
J+10		T_{F1} (>0) (s)
J+11		T_{F2} (>0) (s)
J+12		E_1
J+13		$S_E(E_1)$
J+14		E_2
J+15		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Lead lag
K+2	Regulator output, V_R
K+3	Exciter output, EFD
K+4	First feedback integrator
K+5	Second feedback integrator

VARs	Description
L	K_E

```
IBUS, 'IEEEX2', ID, CON(J) to CON(J+15)   /
```



V_S = VOTHSG + VUEL + VOEL

6.62. IEEEX3

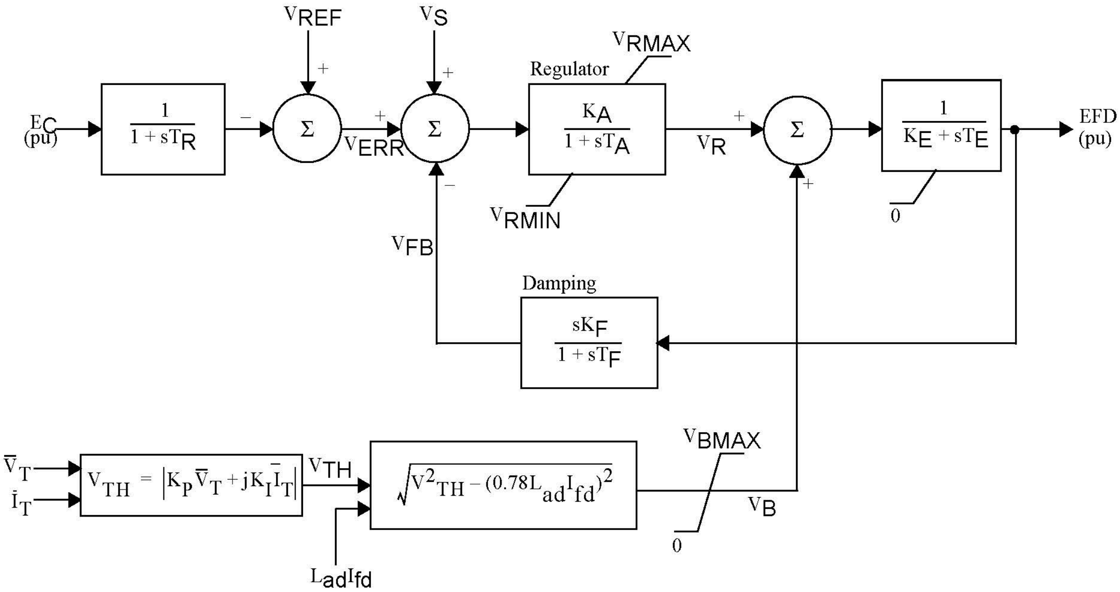
IEEE Type 3 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		T_E (>0) (s)
J+6		K_F
J+7		T_F (>0) (s)
J+8		K_P (>0)
J+9		K_I or zero
J+10		V_{BMAX} (pu voltage base)
J+11		K_E

STATEs	Description
K	Sensed V_T
K+1	Regulator output, V_R
K+2	Exciter output, EFD
K+3	Rate feedback integrator

VARs	Description
L	K_I

```
IBUS, 'IEEEX3', ID, CON(J) to CON(J+11)   /
```



V_S = VOTHSG + VUEL + VOEL

6.63. IEEEX4

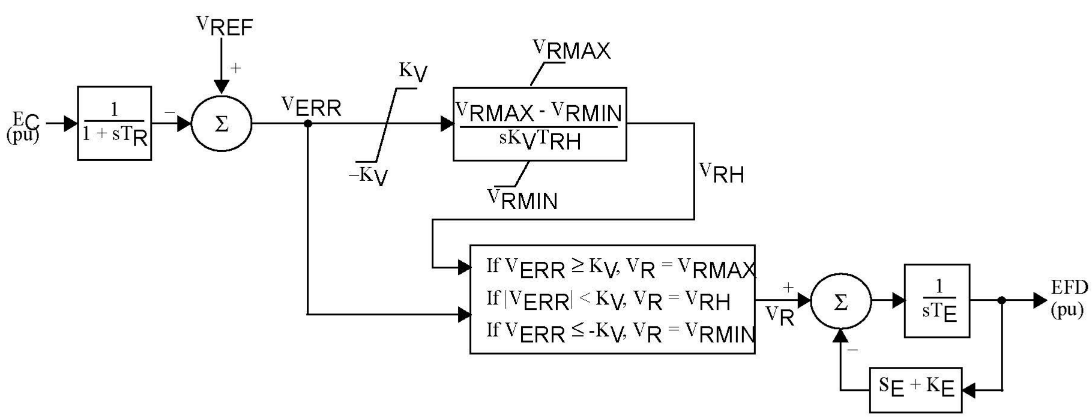
IEEE Type 4 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		T_{RH} (>0) (s)
J+2		K_V
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		T_E (>0) (s)
J+6		K_E
J+7		E_1
J+8		$S_E(E_1)$
J+9		E_2
J+10		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	V_{RH}
K+2	EFD

VARs	Description
L	K_E

```
IBUS, 'IEEEX4', ID, CON(J) to CON(J+10)   /
```



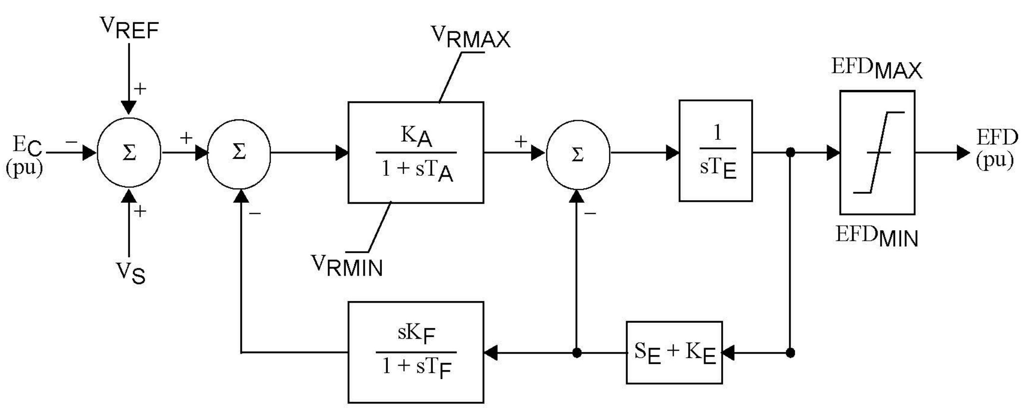
6.64. IEET1A

Modified IEEE Type 1 Excitation System

CONs	Value	Description
J		K_A
J+1		T_A (s)
J+2		V_{RMAX}
J+3		V_{RMIN}
J+4		K_E
J+5		T_E (>0) (s)
J+6		K_F
J+7		T_F (>0) (s)
J+8		EFD_{MIN}
J+9		E_1
J+10		$S_E(E_1)$
J+11		EFD_{MAX}
J+12		$S_E(EFD_{MAX})$

STATEs	Description
K	Regulator output
K+1	Exciter output, EFD
K+2	Rate feedback integrator

```
IBUS, 'IEET1A', ID, CON(J) to CON(J+12)   /
```



V_S = VOTHSG + VUEL + VOEL

6.65. IEET1B

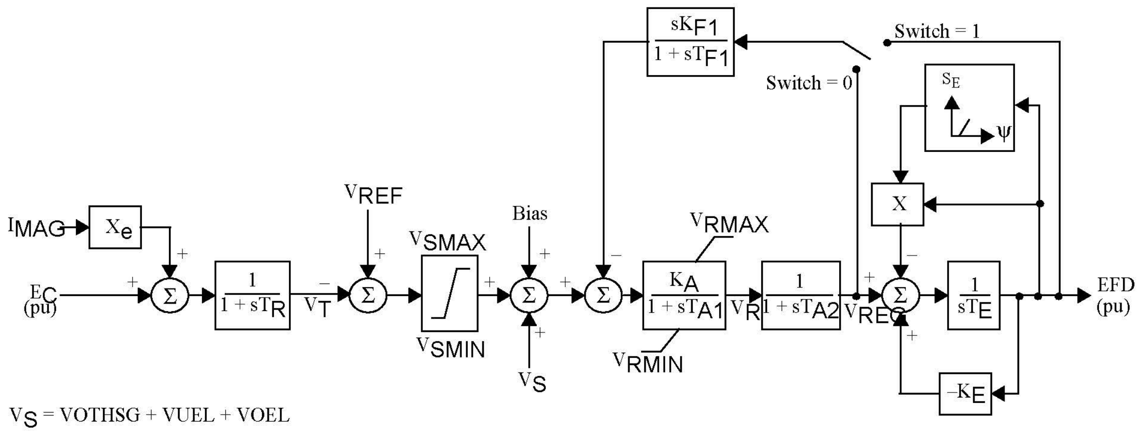
Modified Type 1 Excitation System

CONs	Value	Description
J		T_R (s)
J+1		V_{SMAX}
J+2		V_{SMIN}
J+3		K_A
J+4		T_A1 (s)
J+5		V_{RMAX} or zero
J+6		V_{RMIN}
J+7		T_{A2} (s)
J+8		K_{F1}
J+9		T_{F1}(>0) (s)
J+10		K_E or zero
J+11		T_E (>0) (s)
J+12		E_1
J+13		$S_E(E_1)$
J+14		E_2
J+15		$S_E(E_2)$
J+16		Switch
J+17		X_e, compensation

STATEs	Description
K	Sensed V_T
K+1	Amplified output, V_R
K+2	Regulator output, V_{REG}
K+3	Feedback integrator
K+4	Exciter output, EFD

VARs	Description
L	K_E
L+1	Bias

```
IBUS, 'IEET1B', ID, CON(J) to CON(J+17)   /
```


sKF1 / 1 + sTF1
Switch = 1
Switch = 0
SE
ψ
X
IMAG
Xe
EC (pu)
1 / 1 + sTR
VT
VREF
VSMAX
VSMIN
Bias
VS
KA / 1 + sTA1
VRMAX
VRMIN
VR
1 / 1 + sTA2
VREG
1 / sTE
−KE
EFD (pu)
VS = VOTHSG + VUEL + VOEL

6.66. IEET5A

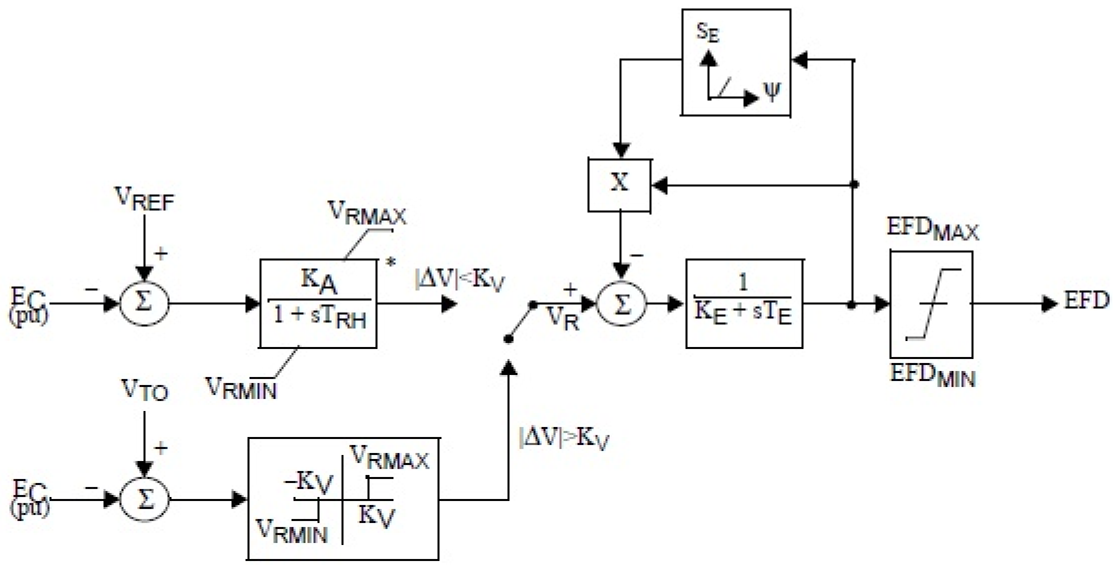
Modified IEEE Type 4 Excitation System

CONs	Value	Description
J		K_A
J+1		T_{RH} (s)
J+2		K_V
J+3		V_{RMAX}
J+4		V_{RMIN}
J+5		T_E (>0) (s)
J+6		K_E
J+7		E_1
J+8		$S_E(E_1)$
J+9		E_2
J+10		$S_E(E_2)$
J+11		EFD_{MAX}
J+12		EFD_{MIN}

STATEs	Description
K	V_{RH}
K+1	Exciter output

VARs	Description
L	K_E
L+1	VTO

```
IBUS, ’IEET5A’, ID, CON(J) to CON(J+12)   /
```



*If T_{RH} equals zero, block becomes $\frac{K_A}{s}$

6.67. IEEX2A

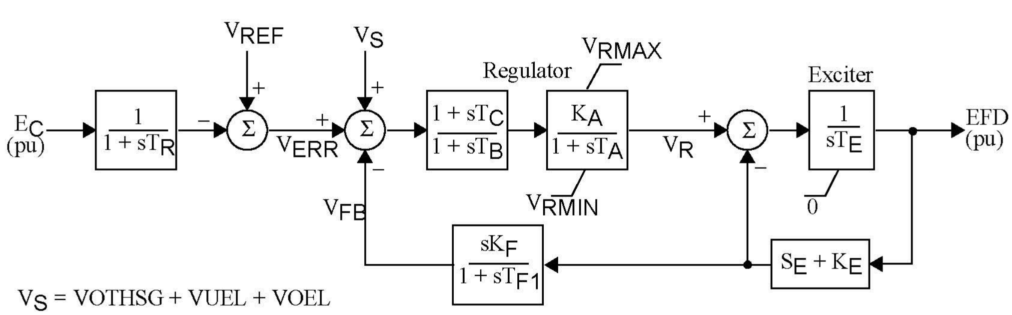
IEEE Type 2A Excitation System

CONs	Value	Description
J		T_R (s)
J+1		K_A
J+2		T_A (s)
J+3		T_B (s)
J+4		T_C (s)
J+5		V_{RMAX} or zero
J+6		V_{RMIN}
J+7		K_E or zero
J+8		T_E (>0) (s)
J+9		K_F
J+10		T_{F1} (>0) (s)
J+11		E_1
J+12		$S_E(E_1)$
J+13		E_2
J+14		$S_E(E_2)$

STATEs	Description
K	Sensed V_T
K+1	Lead lag
K+2	Regulator output, V_R
K+3	Exciter output, EFD
K+4	Rate feedback integrator

VARs	Description
L	K_E

```
IBUS, 'IEEX2A', ID, CON(J) to CON(J+14)   /
```



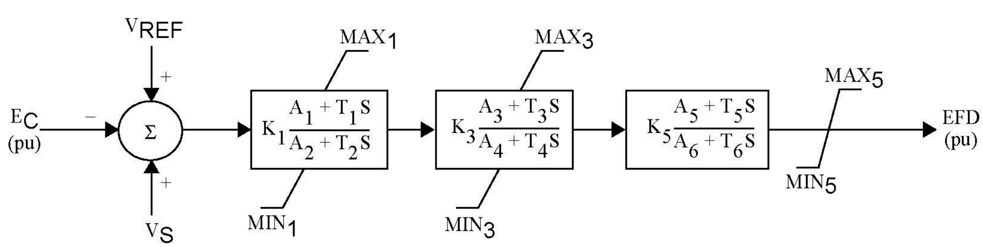
6.68. IVOEX

IVO Excitation Model

CONs	Value	Description
J		K_1
J+1		A_1
J+2		A2
J+3		T_1
J+4		T_2
J+5		MAX_1
J+6		MIN_1
J+7		K_3
J+8		A_3
J+9		A_4
J+10		T_3
J+11		T_4
J+12		MAX_3
J+13		MIN_3
J+14		K_5
J+15		A_5
J+16		A_6
J+17		T_5
J+18		T_6
J+19		MAX_5
J+20		MIN_5

STATEs	Description
K	Integrator 1
K+1	Integrator 2
K+2	Integrator 3

```
IBUS, 'IVOEX', ID, CON(J) to CON(J+20)   /
```



V_S = VOTHSG + VUEL + VOEL

6.69. OEX12T

Ontario Hydro IEEE Type ST1 Excitation System With Continuous and Bang Bang Terminal Voltage Limiter

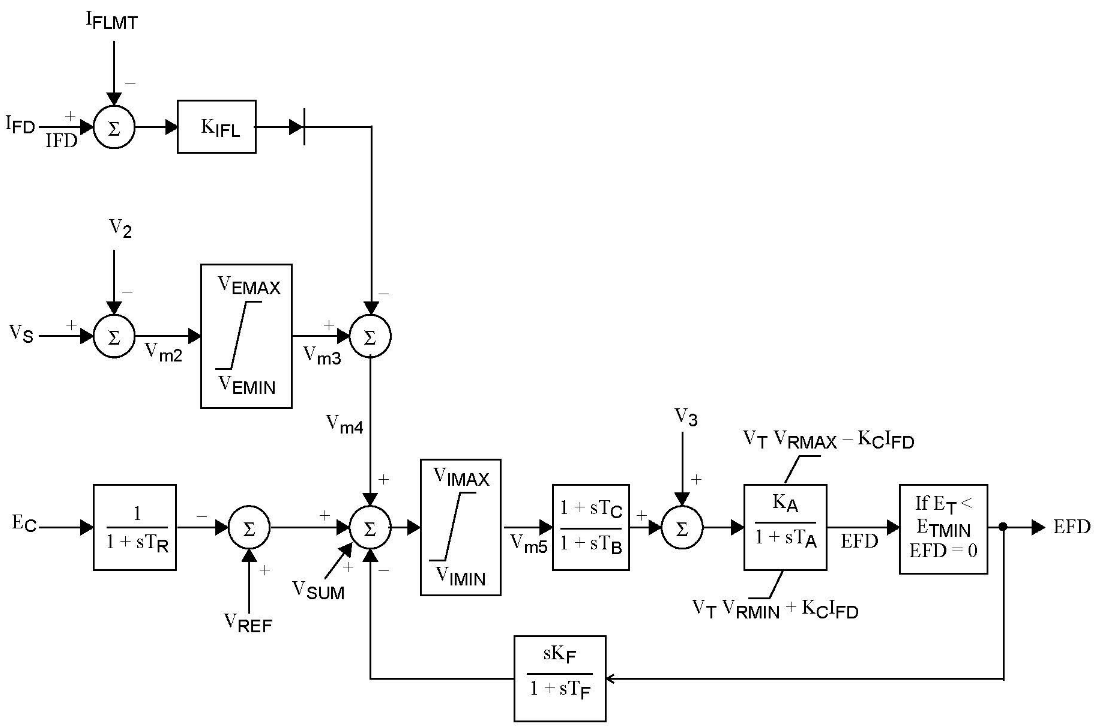
CONs	Value	Description
J		T_R
J+1		V_{IMAX}
J+2		V_{IMIN}
J+3		T_C
J+4		T_B (>0) (s)
J+5		K_A
J+6		T_A (s)
J+7		V_{RMAX}
J+8		V_{RMIN}
J+9		K_C
J+10		K_F
J+11		T_F (>0) (s)
J+12		E_{TMIN}
J+13		V_{TMAX}
J+14		V_{TMIN}
J+15		LIMOUT
J+16		ACON
J+17		BCON
J+18		$V_{E_{MAX}}$
J+19		$V_{E_{MIN}}$
J+20		I_{FLMT}
J+21		K_IFL
J+22		ETLMT
J+23		K_{ETL}
J+24		T_{L1} ($\leq T_{L2}$)
J+25		T_{L2}
J+26		V_{OMX}
J+27		$V_{OMN} \leq 0$

Note: Parameters (J+23) through (J+27) are for the continuous voltage limiter.

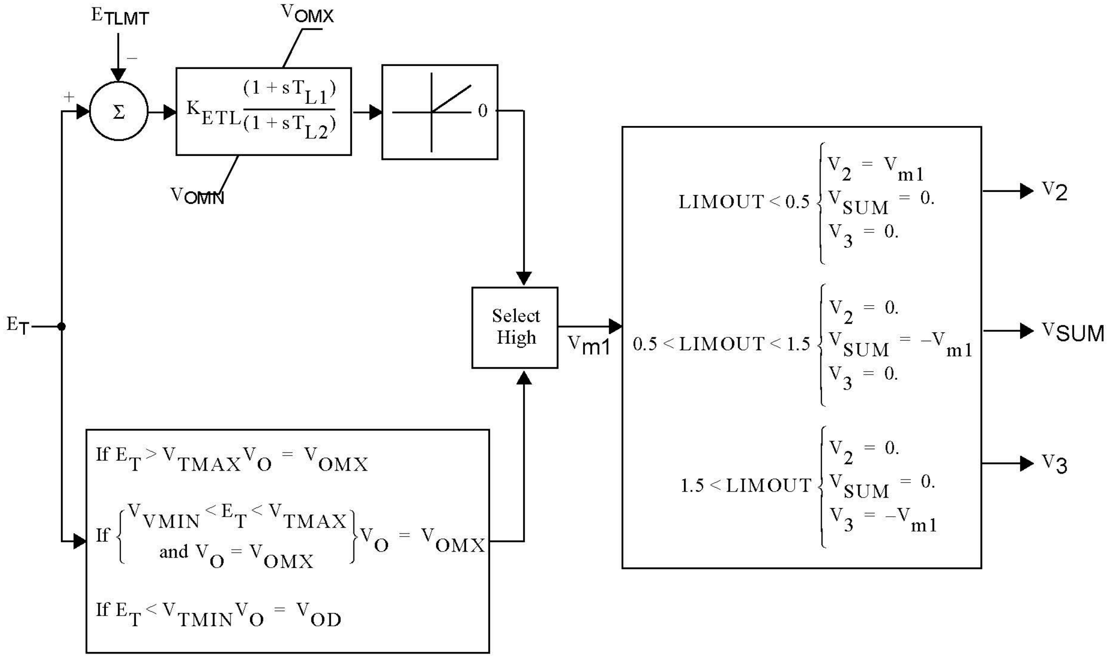
STATEs	Description
K	Voltage sensing block
K+1	Lead lag TC/TB block
K+2	Regulator TA block
K+3	T_F feedback block
K+4	Voltage limiter T_{L1}/T_{L2}

VARs	Description
L	Limiter status
L+1	Period of decay
L+2	Monitored voltage Vm1
L+3	Monitored voltage Vm2
L+4	Monitored voltage Vm3
L+5	Monitored voltage Vm4
L+6	Monitored voltage Vm5

```
IBUS, 'OEX12T', ID, CON(J) to CON(J+27)   /
```



V_S = VOTHSG + VUEL + VOEL



$$V_{OD} = V_{OMX} EXP[-ACON(t-t_2)] \text{ if } t < t_3$$
$$= 0 \qquad \text{if } t \geq t_3$$

$$t_3 = t_2 + \frac{B_{CON}}{A_{CON}}$$

t_2 = time at which E_T drops below V_{TMIN}

Voltage Limiter

6.70. OEX3T

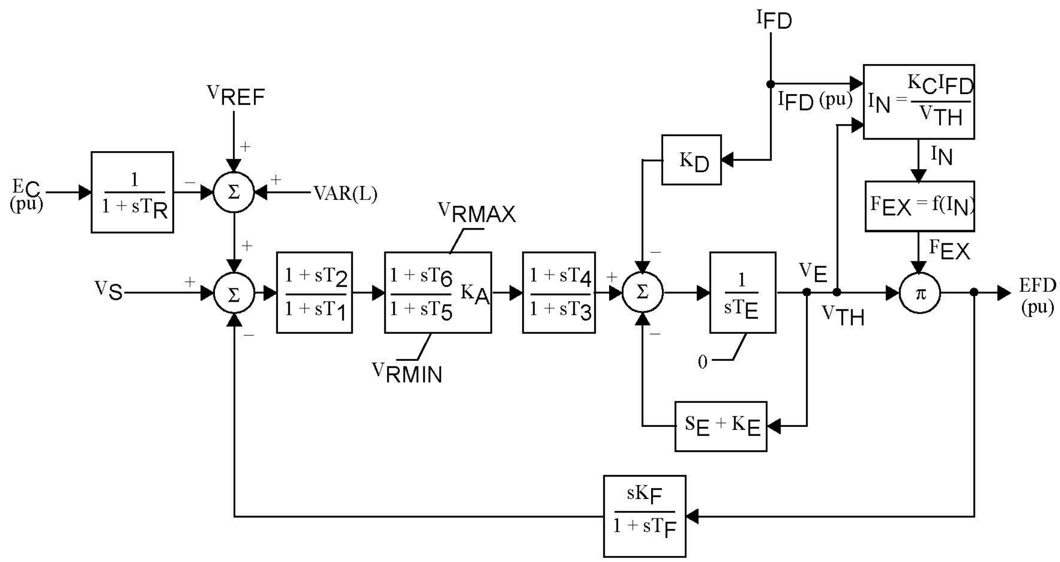
Ontario Hydro IEEE Type ST1 Excitation System With Semicontinuous and Acting Terminal Voltage Limiter

CONs	Value	Description
J		T_R
J+1		T_1 (s)
J+2		T_2 (s)
J+3		T_3 (s)
J+4		T_4 (s)
J+5		K_A
J+6		T_5 (s)
J+7		T_6 (s) (<T_5)
J+8		V_{RMAX}
J+9		V_{RMIN}
J+10		T_E (>0) (s)
J+11		K_F
J+12		T_F (>0) (s)
J+13		K_C
J+14		K_D
J+15		K_E
J+16		E_1
J+17		$S_E(E_1)$
J+18		E_2 ($E_2 > E_1$)
J+19		$S_E(E_2)$

STATEs	Description
K	Voltage sensing block
K+1	Lead lag T_2/T_1 block
K+2	Lead lag T_4/T_3 block
K+3	Regulator T_6/T_5 block
K+4	T_E block
K+5	T_F feedback block

VARs	Description
L	Input to V_{REF} junction

```
IBUS, 'OEX3T', ID, CON(J) to CON(J+19)   /
```



$F_{EX} = 1.0 - 0.58\ I_N$ for $I_N \le 0.433$ $\quad S_E = \dfrac{[A_{EX} EXP(B_{EX} V_E)]}{V_E}$

$F_{EX} = \sqrt{0.75 - (I_N)^2}$ for $0.433 < I_N < 0.75$ $\quad \dfrac{\text{Restrictions}}{T_E \ne 0}$

$F_{EX} = 1.732(1.0 - I_N)$ for $I_N > 0.75$ $\quad V_S = VOTHSG + VUEL + VOEL$

Alternator-Supplied Diode Exciter Type OEX3

6.71. REXSY1

General-Purpose Rotating Excitation System Model

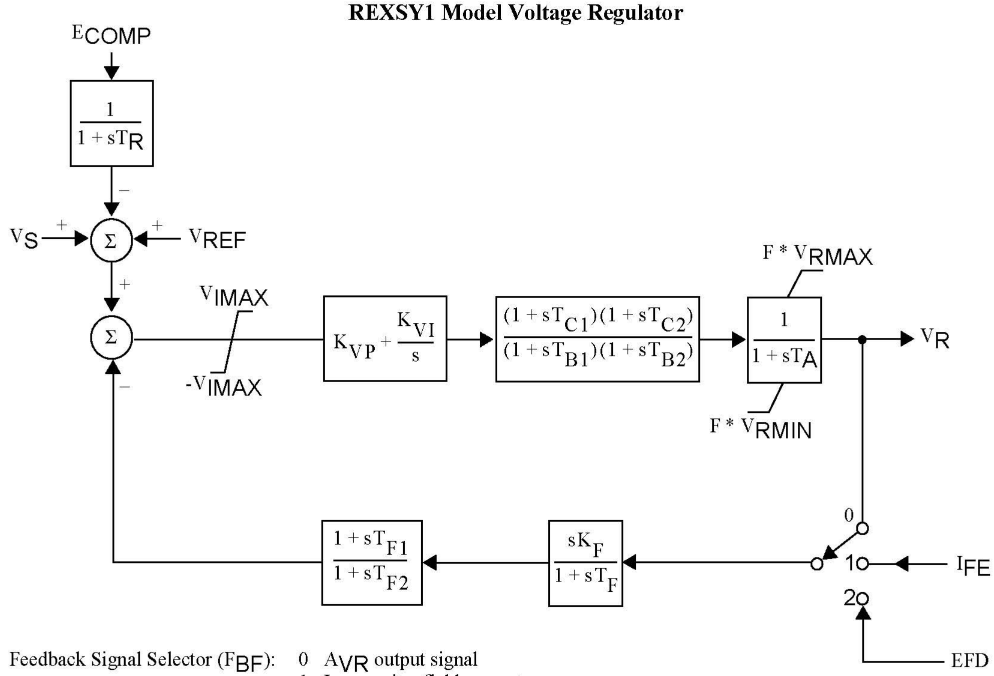
CONs	Value	Description
J		T_R, voltage transducer time constant (s)
J+1		K_{VP}, voltage regulator proportional gain
J+2		K_{VI}, voltage regulator integral gain
J+3		V_{IMAX}, voltage regulator input limit (pu)
J+4		T_A, voltage regulator time constant (s)
J+5		T_{B1}, lag-time constant (s)
J+6		T_{C1}, lead-time constant (s)
J+7		T_{B2}, lag-time constant (s)
J+8		T_{C2}, lead-time constant (s)
J+9		V_{RMAX}, maximum controller output (pu)
J+10		V_{RMIN}, minimum controller output (pu)
J+11		K_F, rate feedback gain
J+12		T_F, rate feedback >0 time constant (s)
J+13		T_{F1}, feedback lead-time constant (s)
J+14		T_{F2}, feedback lag-time constant (s)
J+15		F_{BF}, [0,1,2] rate feedback signal flag
J+16		K_{IP}, field current regulator proportional gain
J+17		K_{II}, field current regulator integral gain
J+18		T_P, field current bridge time constant (s)
J+19		V_{FMAX}, maximum exciter field current (pu)
J+20		V_{FMIN}, minimum exciter field current (pu)
J+21		K_H, field voltage controller feedback gain
J+22		K_E, exciter field proportional constant
J+23		T_E, exciter field time constant (sec >0)
J+24		K_C, rectifier regulation factor (pu)
J+25		K_D, exciter regulation factor (pu)
J+26		E_1, exciter flux at knee of curve (pu)
J+27		$S_E(E_1)$, saturation factor at knee
J+28		E_2, maximum exciter (pu)
J+29		$SE(E_2)$, saturation factor at maximum flux
J+30		F_{1IMF}, power supply limit factor
J+31		X_C, compounding resistance (pu)
J+32		V_{CMAX}, maximum compounding voltage

STATEs	Description
K	Sense voltage
K+1	Proportional voltage

STATEs	Description
K+2	Regulator lead-lag, first stage
K+3	Regulator output
K+4	Feedback lead-lag
K+5	Feedback state
K+6	Proportional field current
K+7	V_E
K+8	Regulator lead-lag, second state
K+9	Exciter field current regulator output

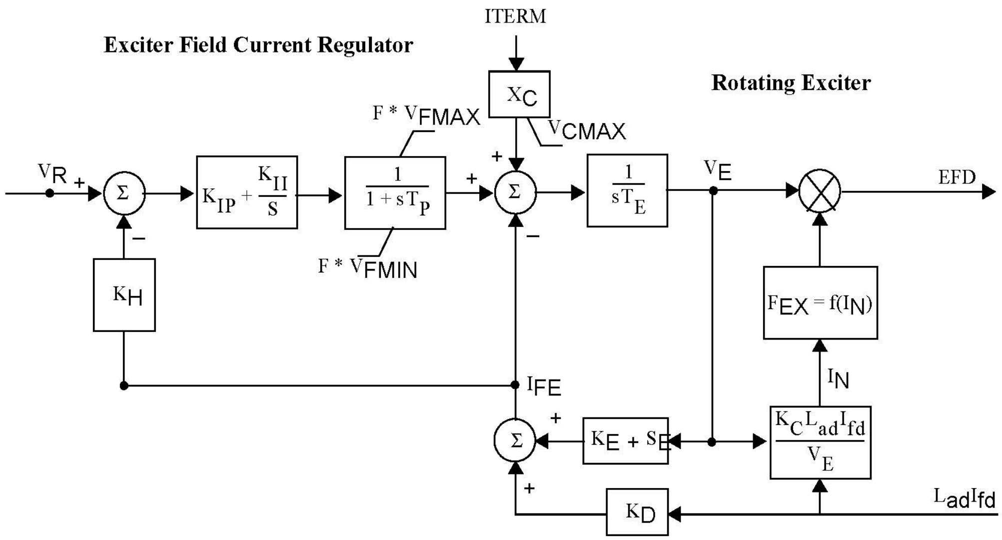
```
IBUS, 'REXSY1', ID, CON(J) to CON(J+32)   /
```

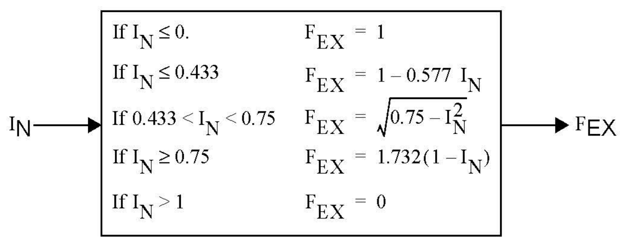
REXSY1 Model Voltage Regulator



Feedback Signal Selector (F_{BF}): 0 A_{VR} output signal
1 I_{FE} exciter field current
2 EFD exciter output voltage

V_S = VOTHSG + VUEL + VOEL
$F = [1.0 + F_{1IMF} (E_T - 1.0)]*(K_E + K_D + S_E)$


ITERM
Exciter Field Current Regulator
Rotating Exciter
F * VFMAX
VCMAX
XC
VR
KIP + KII/s
1/(1 + sTP)
1/(sTE)
VE
EFD
F * VFMIN
KH
FEX = f(IN)
IN
IFE
KE + SE
KC Lad Ifd / VE
KD
Lad Ifd


IN
If IN ≤ 0. FEX = 1
If IN ≤ 0.433 FEX = 1 – 0.577 IN
If 0.433 < IN < 0.75 FEX = √(0.75 – IN²)
If IN ≥ 0.75 FEX = 1.732(1 – IN)
If IN > 1 FEX = 0
FEX

6.72. REXSYS

General-Purpose Rotating Excitation System Model

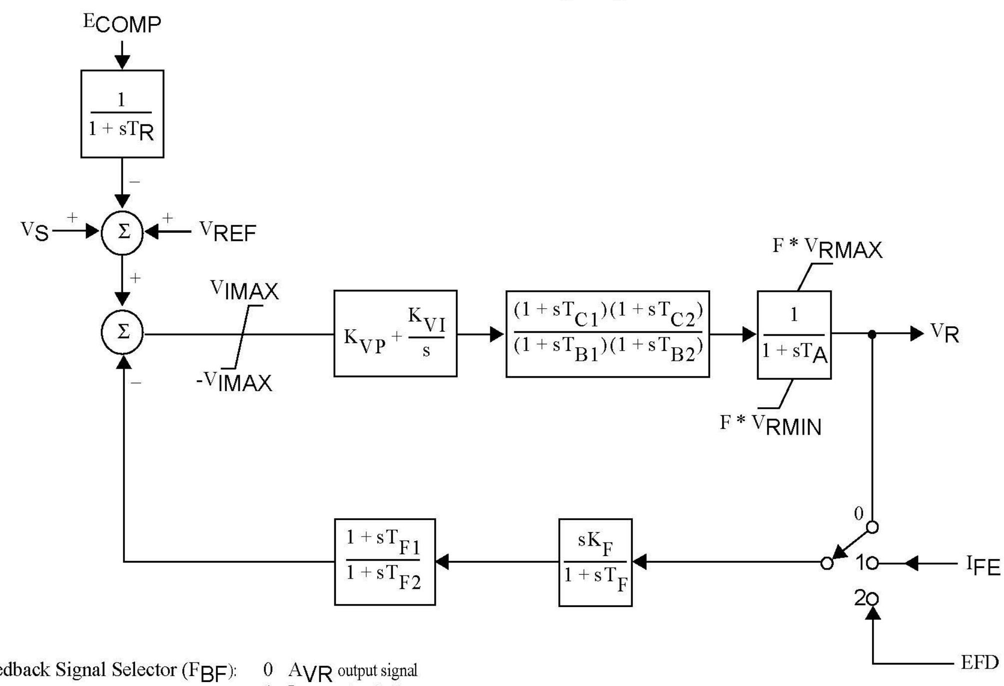
CONs	Value	Description
J		T_R, voltage transducer time constant (s)
J+1		K_{VP}, voltage regulator proportional gain
J+2		K_{VI}, voltage regulator integral gain
J+3		V_{IMAX}, voltage regulator input limit (pu)
J+4		T_A, voltage regulator time constant (s)
J+5		T_{B1}, lag-time constant (s)
J+6		T_{C1}, lead-time constant (s)
J+7		T_{B2}, lag-time constant (s)
J+8		T_{C2}, lead-time constant (s)
J+9		V_{RMAX}, maximum controller output (pu)
J+10		V_{RMIN}, minimum controller output (pu)
J+11		K_F, rate feedback gain
J+12		T_F, rate feedback >0 time constant (s)
J+13		T_{F1}, feedback lead-time constant (s)
J+14		T_{F2}, feedback lag-time constant (s)
J+15		F_{BF}, [0,1,2] rate feedback signal flag
J+16		K_{IP}, field current regulator proportional gain
J+17		K_{II}, field current regulator integral gain
J+18		TP, field current bridge time constant (s)
J+19		V_{FMAX}, maximum exciter field current (pu)
J+20		V_{FMIN}, minimum exciter field current (pu)
J+21		K_H, field voltage controller feedback gain
J+22		K_E, exciter field proportional constant
J+23		T_E, exciter field time constant (sec >0)
J+24		K_C, rectifier regulation factor (pu)
J+25		K_D, exciter regulation factor (pu)
J+26		E_1, exciter flux at knee of curve (pu)
J+27		$S_E(E_1)$, saturation factor at knee
J+28		E_2, maximum exciter (pu)
J+29		$SE(E_2)$, saturation factor at maximum flux
J+30		F_{1IMF}, power supply limit factor

STATEs	Description
K	Sense voltage
K+1	Proportional voltage
K+2	Regulator lead-lag, first stage
K+3	Regulator output

STATEs	Description
K+4	Feedback lead-lag
K+5	Feedback state
K+6	Proportional field current
K+7	V_E
K+8	Regulator lead-lag, second stage
K+9	Exciter field current regulator output

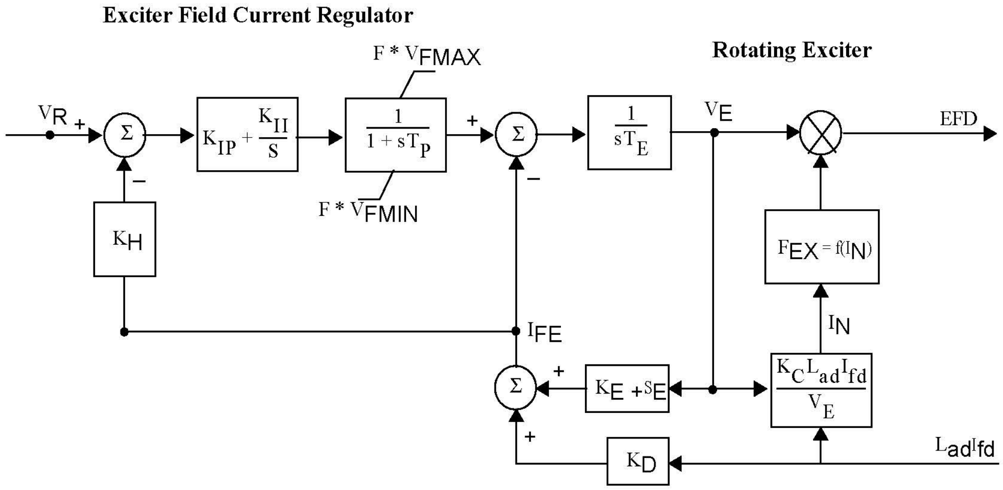
```
IBUS, 'REXSYS', ID, CON(J) to CON(J+30)   /
```

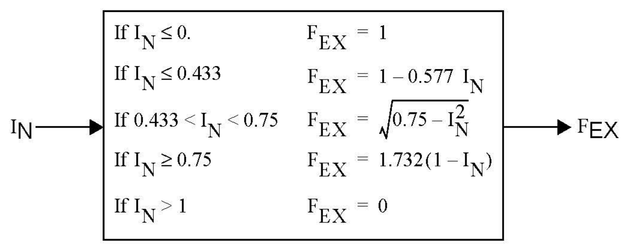
REXSYS Model Voltage Regulator



Feedback Signal Selector (F_{BF}): 0 A_{VR} output signal
1 I_{FE} exciter field current
2 EFD exciter output voltage

V_S = VOTHSG + VUEL + VOEL
$F = [1.0 + F_{IIMF}(E_T - 1.0)]*(K_E + K_D + S_E)$


Exciter Field Current Regulator
Rotating Exciter
F * VFMAX
F * VFMIN
VR
KIP + KII/S
1/(1 + sTP)
1/sTE
VE
EFD
KH
IFE
FEX = f(IN)
IN
KE + SE
KC Lad Ifd / VE
KD
Ladlfd


IN
If IN ≤ 0. FEX = 1
If IN ≤ 0.433 FEX = 1 – 0.577 IN
If 0.433 < IN < 0.75 FEX = √(0.75 – IN²)
If IN ≥ 0.75 FEX = 1.732(1 – IN)
If IN > 1 FEX = 0
FEX

6.73. SCRX

Bus Fed or Solid Fed Static Exciter

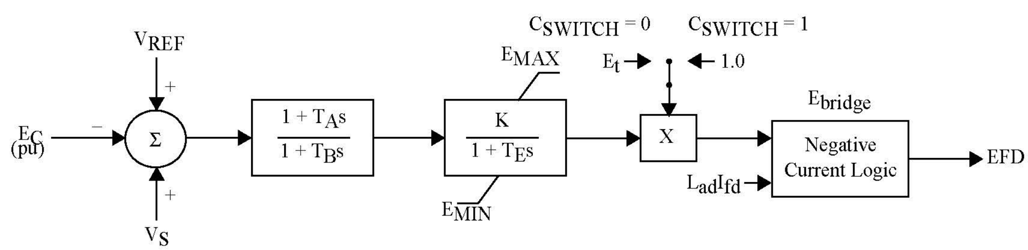
CONs	Value	Description
J		T_A/T_B
J+1		T_B (>0) (s)
J+2		K
J+3		T_E (s)
J+4		E_{MIN} (pu on EFD base)
J+5		E_{MAX} (pu on EFD base)
J+6		CSWITCH[a]
J+7		rc / r_{fd}[b]

[a]Set $C_{SWITCH}0$ = 0 for bus fed. Set C_{SWITCH} = 1 for solid fed.

[b]Set CON(J+7) = 0 for exciter with negative field current capability. Set CON(J+7) > 0 for exciter without negative field current capability. (Typical CON(J+7) = 10)Set CON(J+7) = 0 for exciter with negative field current capability. Set CON(J +7) > 0 for exciter without negative field current capability. (Typical CON(J+7) = 10)

STATEs	Description
K	First integrator
K+1	Second integrator

```
IBUS, 'SCRX', ID, CON(J) to CON(J+7)   /
```



V_S = VOTHSG + VUEL + VOEL

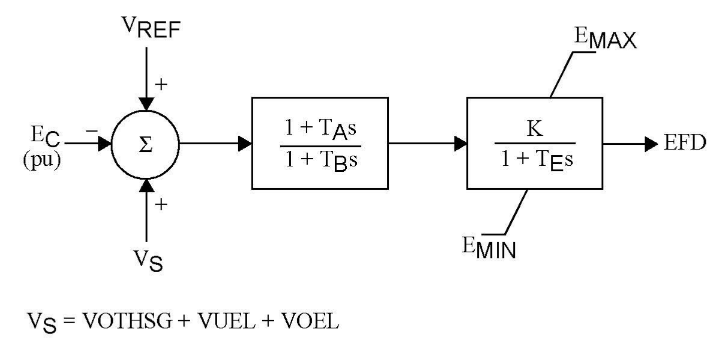
6.74. SEXS

Simplified Excitation System

CONs	Value	Description
J		T_A/TB
J+1		T_B (>0) (s)
J+2		K
J+3		T_E (s)
J+4		E_{MIN} (pu on EFD base)
J+5		E_{MAX} (pu on EFD base)

STATEs	Description
K	First integrator
K+1	Second integrator

```
IBUS, 'SEXS', ID, CON(J) to CON(J+5)   /
```



6.75. ST1C

IEEE 421.5 2005 ST1C Excitation System

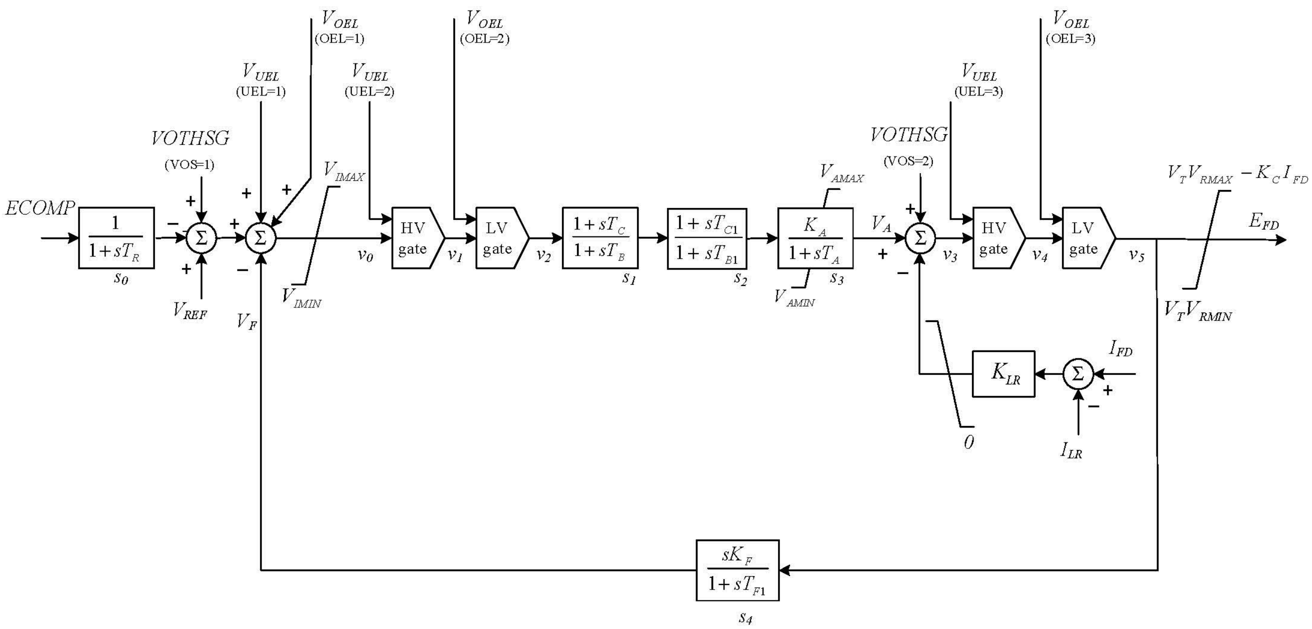
ICONs	Value	Description
M		UEL Flag • 1 - Summation point • 2 - HV Gate at voltage regulator input • 3 - HV Gate at voltage regulator output
M+1		VOS • 1 - Summation point at voltage regulator input • 2 - Summation point at voltage regulator output
M+2		OEL Flag • 1 - Summation point • 2 - LV Gate at voltage regulator input • 3 - LV Gate at voltage regulator output

CONs	Value	Description
J		T_R (s), regulator input filter time constant
J+1		V_IMAX (pu), maximum voltage error (regulator input)
J+2		V_IMIN (pu), minimum voltage error (regulator input)
J+3		TC (s), lead time constant of 1st lead-lag block
J+4		TB (s), lag time constant of 1st lead-lag block
J+5		TC1 (s), lead time constant of 2nd lead-lag block
J+6		TB1 (s), lag time constant of 2nd lead-lag block
J+7		KA (pu), voltage regulator gain
J+8		TA (s), voltage regulator time constant
J+9		VAMAX (pu), maximum regulator output
J+10		VAMIN (pu), minimum regulator output
J+11		VRMAX (pu), maximum exciter output
J+12		VRMIN (pu), minimum exciter output
J+13		KC (pu), rectifier loading factor proportional to commutating reactance
J+14		KF (pu), rate feedback gain
J+15		TF (s), rate feedback time constant
J+16		KLR (pu), exciter output current limiter gain
J+17		ILR (pu), exciter output current limit reference

VARs	Description
L	Input of HV gate at voltage regulator input

VARs	Description
L+1	Output of HV gate at voltage regulator input
L+2	Output of LV gate at voltage regulator input
L+3	Input of HV gate at voltage regulator output
L+4	Output of HV gate at voltage regulator output
L+5	Output of LV gate at voltage regulator output

IBUS, 'ST1C', ID, ICON(M) to ICON(M+2), CON(J) to CON(J+17) /



6.76. ST4CU1

IEEE 421.5 Excitation System Model

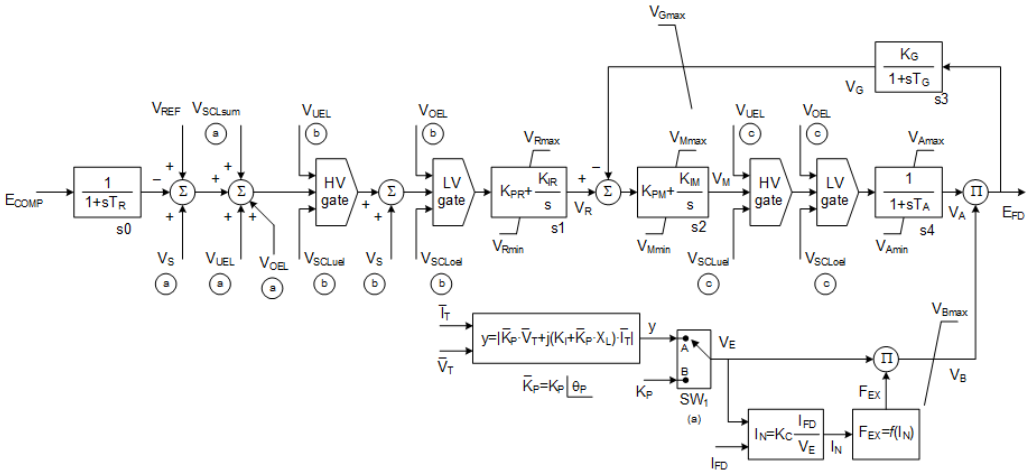
ICONs	Value	Description
M		PSS flag (See Notes)
M+1		OEL flag (See Notes)
M+2		UEL flag (See Notes)
M+3		SCL flag (See Notes)
M+4		SW1 flag 1: Position A 2: Position B

CONs	Value	Description
J		T_R (s) regulator input filter time constant
J+1		K_{PR} (pu) (>0) voltage regulator proportional gain
J+2		K_{IR} (pu) voltage regulator integral gain
J+3		V_{RMAX} (pu) maximum voltage regulator output
J+4		V_{RMIN} (pu) Minimum voltage regulator output
J+5		K_{PM} (pu) Proportional gain of inner loop field regulator
J+6		K_{IM} (pu) Integral gain of inner loop field regulator
J+7		V_{MMAX} (pu) voltage regulator output maximum limit
J+8		V_{MMIN} (pu) voltage regulator output minimum limit
J+9		T_A (s) Thyristor bridge firing control equivalent time constant
J+10		V_{AMAX} (pu) Maximum exciter output
J+11		V_{AMIN} (pu) Minimum exciter output
J+12		K_G (pu) feedback gain of the inner loop field voltage regulator
J+13		T_G (>0) feedback time constant of the inner loop field voltage regulator (s)
J+14		V_{GMAX} (pu) Maximum feedback voltage for field current regulator
J+15		K_P (pu) Potential circuit gain coefficient
J+16		K_I (pu) Potential circuit (current) gain coefficient
J+17		X_L (pu) Reactance associated with potential source
J+18		THETAP Potential circuit phase angle in degrees
J+19		K_C (pu) Rectifier loading factor proportional to commutating reactance
J+20		V_{BMAX} (pu) Maximum available exciter field voltage

STATEs	Description
K	Sensed V_T
K+1	Regulator integrator
K+2	Regulator output V_M

STATEs	Description
K+3	Feedback Loop V_G
K+4	V_A

```
IBUS, 'USRMDL', ID, 'ST4CU1', 4, 0, 5, 21, 5, 0, ICON(M) to ICON(M+4),
 CON(J) to CON(J+20)   /
```



Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.

2. SW_1 is a user-selected option. Position A corresponds to a power source from generator terminal voltage such as an excitation transformer. Position B corresponds to a power source independent of generator terminal conditions, such as pilot exciter.

3. For OEL, UEL and SCL flag options, the ICON value can be 1 through 3 with description as follows:

    a. 1: Position (a)

    b. 2: Position (b)

    c. 3: Position (c)

4. For PSS Flag options, the ICON value can be 1 or 2 with description as follows:

    a. 1: Position (a)

    b. 2: Position (b)

6.77. ST5B

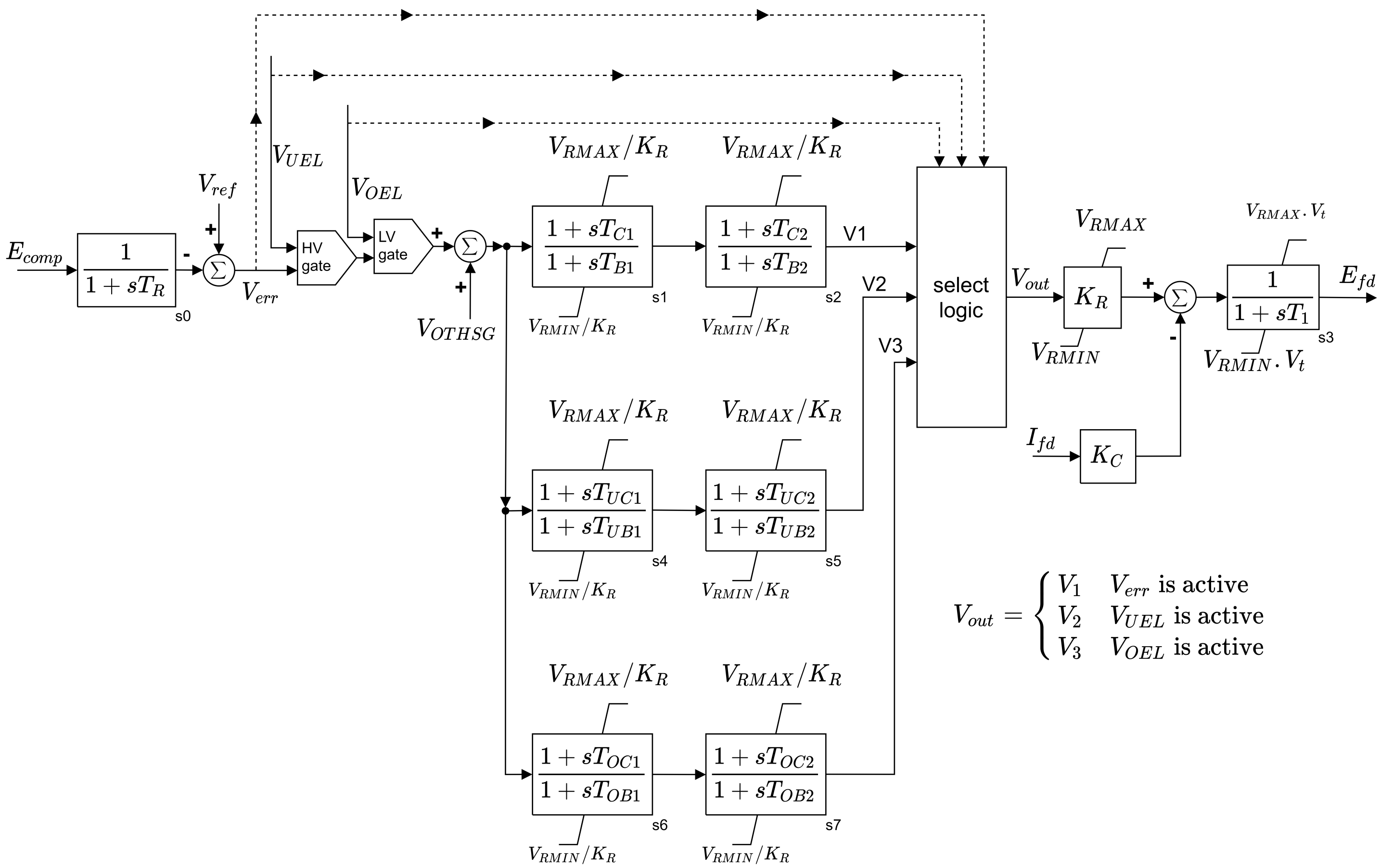
IEEE 421.5 2005 ST5B Excitation System

CONs	Value	Description
J		$T_R$regulator input filter time constant (s)
J+1		T_{C1} lead time constant of first lead-lag block (voltage regulator channel) (s)
J+2		T_{B1} lag time constant of first lead-lag block (voltage regulator channel) (s)
J+3		T_{C2} lead time constant of second lead-lag block (voltage regulator channel) (s)
J+4		T_{B2} lag time constant of second lead-lag block (voltage regulator channel) (s)
J+5		K_R (>0) (pu) voltage regulator gain
J+6		V_{RMAX} (pu) voltage regulator maximum limit
J+7		V_{RMIN} (pu) voltage regulator minimum limit
J+8		T_1 voltage regulator time constant (s)
J+9		K_C (pu)
J+10		T_{UC1} lead time constant of first lead-lag block (under-excitation channel) (s)
J+11		T_{UB1} lag time constant of first lead-lag block (under-excitation channel) (s)
J+12		T_{UC2} lead time constant of second lead-lag block (under-excitation channel) (s)
J+13		T_{UB2} lag time constant of second lead-lag block (under-excitation channel) (s)
J+14		T_{OC1} lead time constant of first lead-lag block (over-excitation channel) (s)
J+15		T_{OB1} lag time constant of first lead-lag block (over-excitation channel) (s)
J+16		T_{OC2} lead time constant of second lead-lag block (over-excitation channel) (s)
J+17		T_{OB2} lag time constant of second lead-lag block (over-excitation channel) (s)

STATEs	Description
K	Sensed V_T
K+1	First lead-lag (voltage regulator channel)
K+2	Second lead-lag (voltage regulator channel)
K+3	E_{FD}
K+4	First lead-lag (under-excitation channel)
K+5	Second lead-lag (under-excitation channel)
K+6	First lead-lag (over-excitation channel)
K+7	Second lead-lag (over-excitation channel)

VARs	Description
L	V_1
L+1	V_2
L+2	V_3

```
IBUS, 'ST5B', ID, CON(J) to CON(J+17)   /
```



$$V_{out} = \begin{cases} V_1 & V_{err} \text{ is active} \\ V_2 & V_{UEL} \text{ is active} \\ V_3 & V_{OEL} \text{ is active} \end{cases}$$

6.78. ST5C

IEEE 421.5 Excitation System ST5C

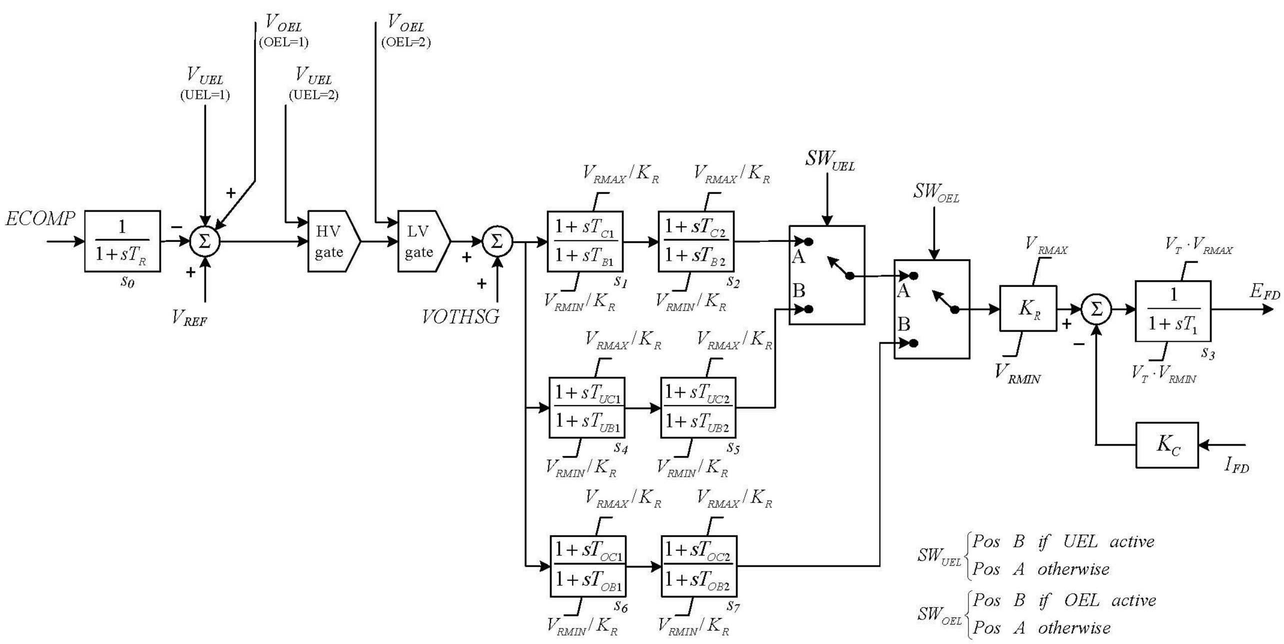
ICONs	Value	Description
M		OEL Flag • 1 - Summation point • 2 - LV Gate
M+1		UEL Flag • 1 - Summation point • 2 - HV Gate

CONs	Value	Description
J		T_R (s), regulator input filter time constant
J+1		TC1 (s), lead time constant of 1st lead-lag block (voltage regulator channel)
J+2		TB1 (s), lag time constant of 1st lead-lag block (voltage regulator channel)
J+3		TC2 (s), lead time constant of 2nd lead-lag block (voltage regulator channel)
J+4		TB2 (s), lag time constant of 2nd lead-lag block (voltage regulator channel)
J+5		KR (>0) (pu), voltage regulator gain
J+6		VRMAX (pu), voltage regulator maximum limit
J+7		VRMIN (pu), voltage regulator minimum limit
J+8		T1 (s), voltage regulator time constant
J+9		KC (pu)
J+10		TUC1 (s), lead time constant of 1st lead-lag block (underexcitation channel)
J+11		TUB1 (s), lag time constant of 1st lead-lag block (underexcitation channel)
J+12		TUC2 (s), lead time constant of 2nd lead-lag block (underexcitation channel)
J+13		TUB2 (s), lag time constant of 2nd lead-lag block (underexcitation channel)
J+14		TOC1 (s), lead time constant of 1st lead-lag block (overexcitation channel)
J+15		TOB1 (s), lag time constant of 1st lead-lag block (over - excitation channel)
J+16		TOC2 (s), lead time constant of 2nd lead-lag block (over - excitation channel)
J+17		TOB2 (s), lag time constant of 2nd lead-lag block (over - excitation channel)

STATEs	Description
K	Sensed VT
K+1	First lead-lag (voltage regulator channel)
K+2	Second lead-lag (voltage regulator channel)
K+3	EFD
K+4	First lead-lag (under-excitation channel)
K+5	Second lead-lag (under-excitation channel)
K+6	First lead-lag (over-excitation channel)
K+7	Second lead-lag (over-excitation channel)

VARs	Description
L	V1
L+1	V2
L+2	V3
L+3	Output of HV gate
L+4	Output of LV gate

IBUS, 'ST5C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+17) /



6.79. ST6B

IEEE 421.5 2005 ST6B Excitation System

ICONs	Value	Description
M		OEL flag (1 or 2, default = 1)

CONs	Value	Description
J		$T_R$regulator input filter time constant (s)
J+1		K_{PA} (pu) (> 0) voltage regulator proportional gain
J+2		K_{IA} (pu) voltage regulator integral gain
J+3		K_{DA} (pu) voltage regulator derivative gain
J+4		T_{DA} voltage regulator derivative channel time constant (s)
J+5		V_{AMAX} (pu) regulator output maximum limit
J+6		V_{AMIN} (pu) regulator output minimum limit
J+7		K_{FF} (pu) pre-control gain of the inner loop field regulator
J+8		K_M (pu) forward gain of the inner loop field regulator
J+9		K_{CI} (pu) exciter output current limit adjustment gain
J+10		K_{LR} (pu) exciter output current limiter gain
J+11		I_{LR} (pu) exciter current limit reference
J+12		V_{RMAX} (pu) voltage regulator output maximum limit
J+13		V_{RMIN} (pu) voltage regulator output minimum limit
J+14		K_G (pu) feedback gain of the inner loop field voltage regulator
J+15		T_G (> 0) feedback time constant of the inner loop field voltage regulator (s)

STATEs	Description
K	Sensed V_T
K+1	Integral channel
K+2	Derivative channel
K+3	V_G

VARs	Description
L	V_A
L+1	V_R
L+2	V_I

```
IBUS, 'ST6B', ID, ICON(M), CON(J) to CON(J+15)   /
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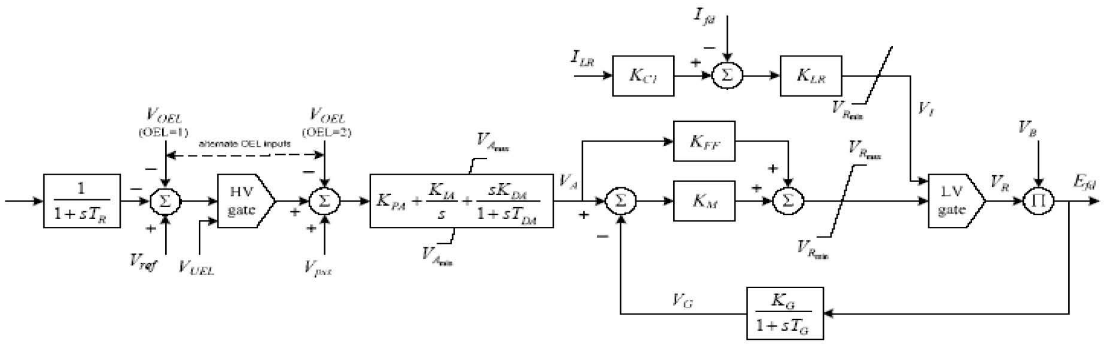

V_{OEL} (OEL=1)
alternate OEL inputs
V_{OEL} (OEL=2)
$\frac{1}{1+sT_R}$
HV gate
V_{ref}
V_{UEL}
V_{pss}
$K_{PA} + \frac{K_{IA}}{s} + \frac{sK_{DA}}{1+sT_{DA}}$
$V_{A_{max}}$
$V_{A_{min}}$
V_A
I_{LR}
K_{CI}
I_{fd}
K_{LR}
$V_{R_{min}}$
V_I
K_{FF}
K_M
$V_{R_{max}}$
$V_{R_{min}}$
LV gate
V_R
V_B
E_{fd}
V_G
$\frac{K_G}{1+sT_G}$

6.80. ST6CU1

IEEE 421.5 2016 ST6CU1 Excitation System

ICONs	Value	Description
M		OEL flag (See Notes)
M+1		UEL flag (See Notes)
M+2		SCL flag (See Notes)
M+3		SW1 flag 1: Position A 2: Position B

CONs	Value	Description
J		T_R (s) regulator input filter time constant
J+1		K_{PA} (pu) (> 0) voltage regulator proportional gain
J+2		K_{IA} (pu) voltage regulator integral gain
J+3		K_{DA} (pu) voltage regulator derivative gain
J+4		T_{DA} (s) voltage regulator derivative channel time constant
J+5		V_{AMAX} (pu) regulator output maximum limit
J+6		V_{AMIN} (pu) regulator output minimum limit (<= V_{RMIN})
J+7		K_{FF} (pu) pre-control gain of the inner loop field regulator
J+8		K_M (pu) forward gain of the inner loop field regulator
J+9		K_{CI} (pu) exciter output current limit adjustment gain
J+10		K_{LR} (pu) exciter output current limiter gain
J+11		I_{LR} (pu) exciter current limit reference
J+12		V_{RMAX} (pu) voltage regulator output maximum limit
J+13		V_{RMIN} (pu) voltage regulator output minimum limit
J+14		K_G (pu) feedback gain of the inner loop field voltage regulator
J+15		T_G (> 0) (s) feedback time constant of the inner loop field voltage regulator
J+16		V_{MMAX} maximum rectifier output limit
J+17		V_{MMAX} minimum rectifier output limit
J+18		T_A (s) thyristor bridge firing control equivalent time constant
J+19		K_P potential circuit gain coefficient
J+20		K_I (current) potential circuit gain coefficient
J+21		X_L reactance associated with potential source
J+22		θ_P (degrees) potential circuit phase angle
J+23		K_C rectifier loading factor proportional to commutating reactance
J+24		V_{BMAX} maximum available exciter field voltage

STATEs	Description
K	Sensed V_T

STATEs	Description
K+1	Regulator integrator
K+2	Regulator derivative
K+3	V_G Feedback loop
K+4	V_M

VARs	Description
L	V_A
L+1	V_R
L+2	V_I

```
IBUS, 'USRMDL', ID, 'ST6CU1', 4, 0, 4, 25, 5, 3, ICON(M) to ICON(M+3),
 CON(J) to CON(J+24)   /
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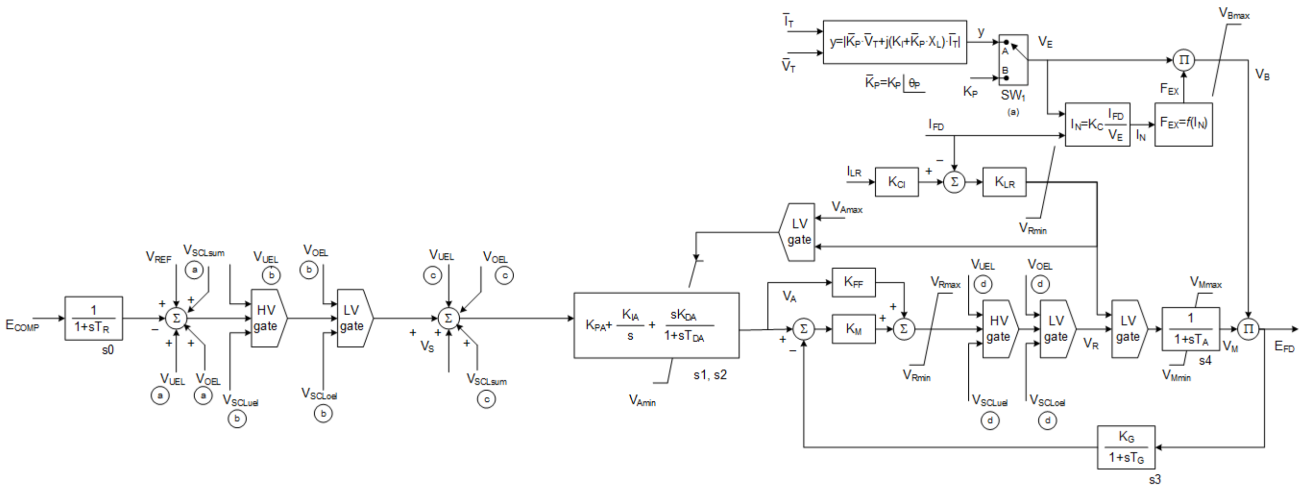


Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.

2. SW_1 is a user-selected option. Position A corresponds to a power source from generator terminal voltage such as an excitation transformer. Position B corresponds to a power source independent of generator terminal conditions, such as pilot exciter.

3. For OEL, UEL and SCL flag options, the ICON value can be 1 through 4 with description as follows:

    a. 1: Position (a)

    b. 2: Position (b)

    c. 3: Position (c)

    d. 4: Position (d)

6.81. ST7B

IEEE 421.5 2005 ST7B Excitation System

ICONs	Value	Description
M		OEL flag (1, 2 or 3, default = 1)
13M+1		UEL flag (1, 2 or 3, default = 1)

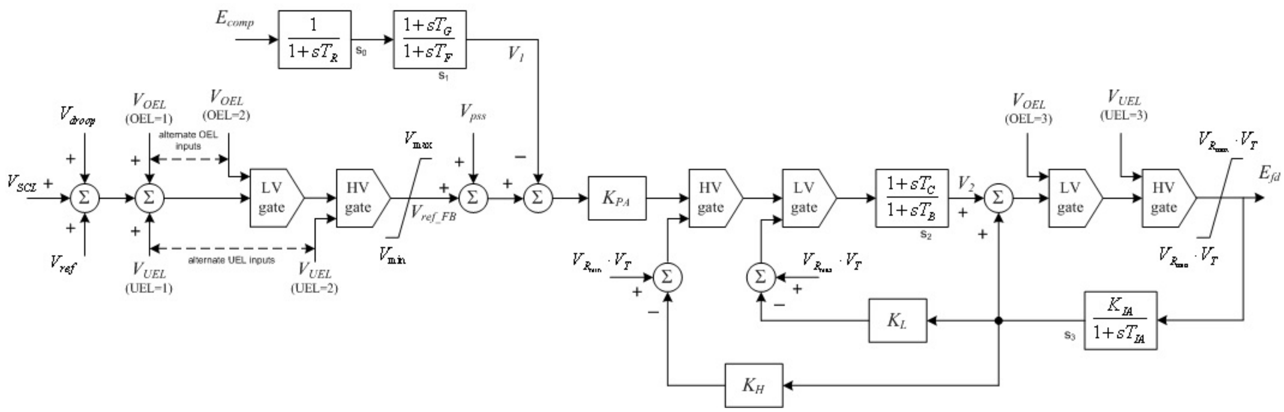
CONs	Value	Description
J		T_R regulator input filter time constant (s)
J+1		T_G lead time constant of voltage input (s)
J+2		T_F lag time constant of voltage input (s)
J+3		V_{MAX} (pu) voltage reference maximum limit
J+4		V_{MIN} (pu) voltage reference minimum limit
J+5		K_{PA} (pu) (>0) voltage regulator gain
J+6		V_{RMAX} (pu) voltage regulator output maximum limit
J+7		V_{RMIN} (pu) voltage regulator output minimum limit
J+8		K_H (pu) feedback gain
J+9		K_L (pu) feedback gain
J+10		T_C lead time constant of voltage regulator (s)
J+11		T_B lag time constant of voltage regulator (s)
J+12		K_{IA} (pu) (>0) gain of the first order feedback block
J+13		T_{IA} (>0) time constant of the first order feedback block (s)

STATEs	Description
K	Sensed V_T
K+1	Lead-lag block 1
K+2	Lead-lag block 2
K+3	First order feedback block

VARs	Description
L	V_1
L+1	V_2
L+2	V_{ref_FB}

```
IBUS, 'ST7B', ID, ICON(M) and ICON(M+1), CON(J) to CON(J+13)   /
```

Note: V_{droop} and V_{SCL} are related to the reactive current droop and the stator current limiter, respectively. These are not available in PSS®E and hence these variables are considered constant during the simulation and lumped into the array V_{REF}.



E_{comp}
$\frac{1}{1+sT_R}$
$\frac{1+sT_G}{1+sT_F}$
V_l
V_{droop}
V_{OEL} (OEL=1)
V_{OEL} (OEL=2)
alternate OEL inputs
V_{SCL}
V_{ref}
LV gate
HV gate
V_{max}
V_{min}
V_{ref_FB}
V_{pss}
V_{UEL} (UEL=1)
alternate UEL inputs
V_{UEL} (UEL=2)
K_{PA}
K_L
K_H
$\frac{1+sT_C}{1+sT_B}$
V_2
V_{OEL} (OEL=3)
V_{UEL} (UEL=3)
E_{fd}
$\frac{K_{IA}}{1+sT_{IA}}$

6.82. ST7C

IEEE 421.5 ST7C Excitation System

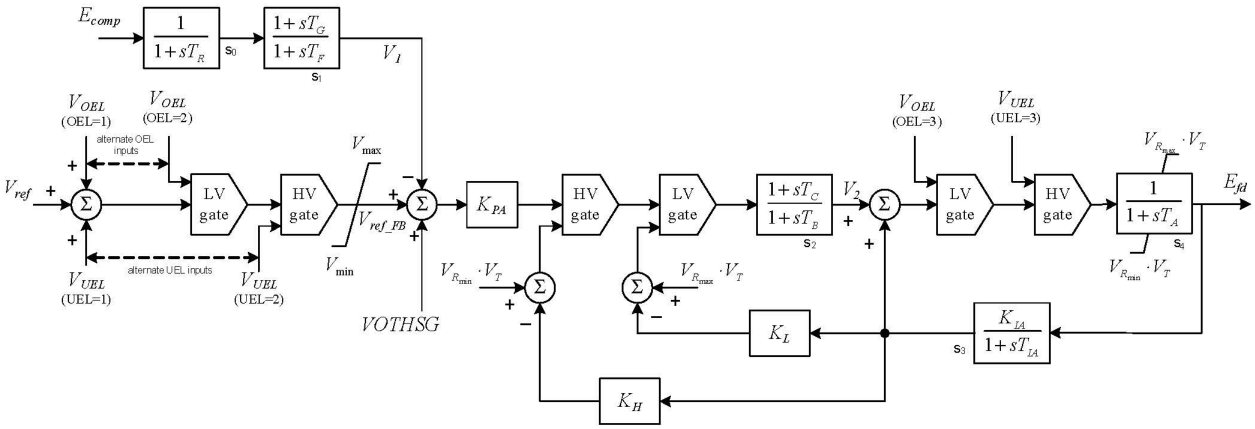
ICONs	Value	Description
M		OEL flag (1, 2 or 3, default = 1)
12M+1		UEL flag (1, 2 or 3, default = 1)

CONs	Value	Description
J		T_R (s) regulator input filter time constant
J+1		T_G (s) lead time constant of voltage input
J+2		TF (s) lag time constant of voltage input
J+3		Vmax (pu) voltage reference maximum limit
J+4		Vmin (pu) voltage reference minimum limit
J+5		K_PA (pu) (>0) voltage regulator gain
J+6		VRMAX (pu) voltage regulator output maximum limit
J+7		VRMIN (pu) voltage regulator output minimum limit
J+8		KH (pu) feedback gain
J+9		KL (pu) feedback gain
J+10		TC (s) lead time constant of voltage regulator
J+11		TB (s) lag time constant of voltage regulator
J+12		KIA (pu) (>0) gain of the first order feedback block
J+13		T_IA (s) (>0) time constant of the first order feedback block
J+14		TA (s) (>0) thyristor bridge firing control time constant

STATEs	Description
K	Sensed VT
K+1	Lead-lag block 1
K+2	Lead-lag block 2
K+3	First order feedback block
K+4	Thyristor bridge time constant

VARs	Description
L	V1
L+1	V2
L+2	Vref_FBs

```
IBUS, 'ST7C', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+14)   /
```



Ecomp
1
1+sTR
s0
1+sTG
1+sTF
s1
VI
VOEL
(OEL=1)
VOEL
(OEL=2)
alternate OEL inputs
Vref
LV gate
HV gate
Vmax
Vmin
Vref_FB
VOTHSG
KPA
HV gate
LV gate
1+sTC
1+sTB
s2
V2
VOEL
(OEL=3)
VUEL
(UEL=3)
LV gate
HV gate
1
1+sTA
s4
Efd
VUEL
(UEL=1)
alternate UEL inputs
VUEL
(UEL=2)
KL
KIA
1+sTIA
s3
KH

6.83. ST8CU1

IEEE 421.5 Excitation System Model

ICONs	Value	Description
M		OEL flag (See Notes)
M+1		UEL flag (See Notes)
M+2		SCL flag (See Notes)
M+3		SW1 flag (Power Source Selector) 1: Position A 2: Position B

CONs	Value	Description
J		T_R (s) regulator input filter time constant
J+1		K_{PR} (pu) (>0) voltage regulator proportional gain
J+2		K_{IR} (pu) voltage regulator integral gain
J+3		V_{PIMAX} (pu) maximum Voltage regulator input
J+4		V_{PIMIN} (pu) minimum Voltage regulator input
J+5		K_{PA} (pu) Field current regulator proportional gain
J+6		K_{IA} (pu) Field current regulator integral gain
J+7		V_{AMAX} (pu) maximum field current regulator output
J+8		V_{AMIN} (pu) minimum field current regulator output
J+9		K_A (s) field current regulator proportional gain
J+10		T_A (s) controlled rectifier bridge equivalent time constant
J+11		V_{RMAX} (pu) maximum field current regulator output
J+12		V_{RMIN} (pu) minimum field current regulator output
J+13		K_F exciter field current feedback gain
J+14		T_F (s) field current feedback time constant
J+15		K_{C1} (pu) rectifier loading factor proportional to commutating reactance
J+16		K_P (pu) potential circuit (voltage) gain coefficient
J+17		K_{I1} (pu) potential circuit (current) gain coefficient
J+18		X_L (pu) reactance associated with potential source
J+19		THETAP potential circuit phase angle in degrees
J+20		V_{B1MAX} (pu) maximum available exciter voltage
J+21		K_{C2} (pu) rectifier loading factor proportional to commutating reactance
J+22		K_{I2} (pu) potential circuit (current) gain coefficient
J+23		V_{B2MAX} (pu) maximum available exciter voltage

STATEs	Description
K	Sensed V_T

STATEs	Description
K+1	Regulator integrator
K+2	Field Current Regulator
K+3	Controlled Rectifier Bridge
K+4	Feedback Gain K_F

VARs	Description
L	IFDREF

```
IBUS, 'USRMDL', ID, 'ST8CU1', 4, 0, 4, 24, 5, 1, ICON(M) to ICON(M+4),
 CON(J) to CON(J+23)   /
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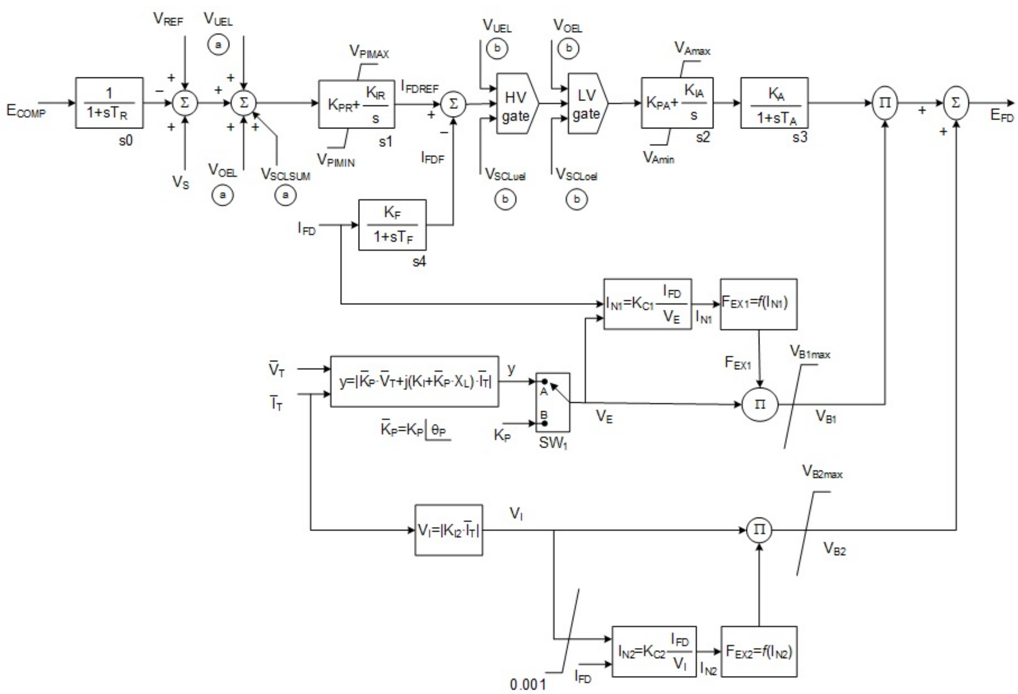

Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.

2. SW_1 is a user-selected option. Position A corresponds to a power source from generator terminal voltage such as an excitation transformer. Position B corresponds to a power source independent of generator terminal conditions, such as pilot exciter.

3. For OEL, UEL and SCL flag options, the ICON value can be 1 through 3 with description as follows:

   a. 1: Position (a)

   b. 2: Position (b)

6.84. ST9CU1

IEEE 421.5 Excitation System Model

ICONs	Value	Description
M		OEL flag (See Notes)
M+1		UEL flag (See Notes)
M+2		SCL flag (See Notes)
M+3		SW1 flag (Power Source Selector) 1: Position A 2: Position B

CONs	Value	Description
J		T_R (s) Regulator input filter time constant
J+1		T_{CD} (s) Time constant of differential part of AVR
J+2		T_{BD} (s)Filter time constant of differential part of AVR (>0)
J+3		Z_A Dead-band for differential part influence on AVR
J+4		K_A (pu) AVR Gain
J+5		K_U (pu) Gain associated with activation of takeover UEL
J+6		T_A (s) Time constant of AVR (>0)
J+7		T_{AUEL} (s) Time constant of underexcitation limiter (>0)
J+8		V_{RMAX} (pu) Maximum regulator output
J+9		V_{RMIN} (pu) Minimum regulator output
J+10		K_{AS} (pu) Power converter gain (proportional to supply voltage)
J+11		T_{AS} (s) Equivalent time constant of power converter firing control
J+12		K_P (pu) Potential circuit (voltage) gain coefficient
J+13		THETAP potential circuit phase angle in degrees
J+14		K_I (pu) Potential circuit (current) gain coefficient
J+15		X_L (pu) Reactance associated with the compound source
J+16		K_C (pu) Rectifier loading factor proportional to commutating reactance
J+17		V_{BMAX} (pu) Maximum limit on exciter voltage based on supply condition

STATEs	Description
K	Sensed V_T
K+1	AVR Differential Washout
K+2	Power Converter Filter
K+3	Integrator

```
IBUS, 'USRMDL', ID, 'ST9CU1', 4, 0, 4, 18, 4, 0, ICON(M) to ICON(M+3),
 CON(J) to CON(J+17)   /
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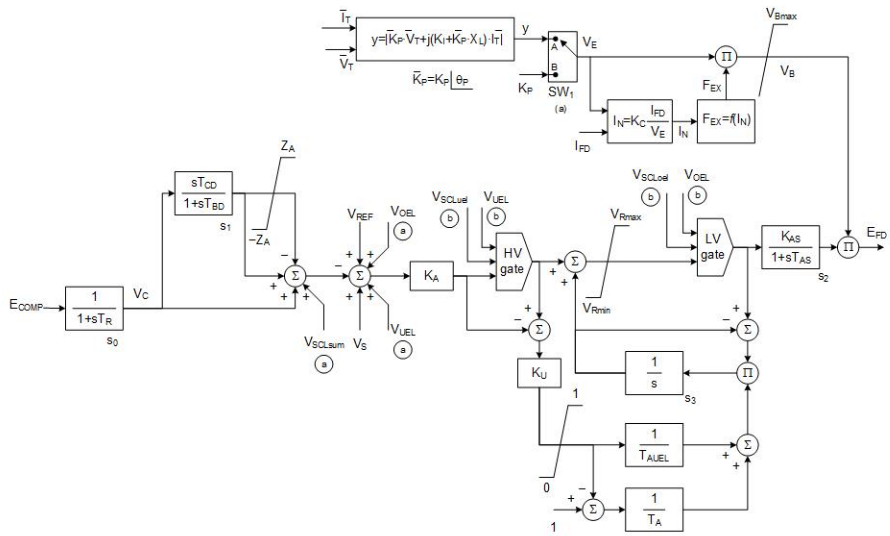

Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.

2. SW_1 is a user-selected option. Position A corresponds to a power source from generator terminal voltage such as an excitation transformer. Position B corresponds to a power source independent of generator terminal conditions, such as pilot exciter.

3. For OEL, UEL and SCL flag options, the ICON value can be 1 through 3 with description as follows:

   a. 1: Position (a)

   b. 2: Position (b)

6.85. ST10CU1

IEEE 421.5 Excitation System Model

ICONs	Value	Description
M		PSS Flag (See Notes)
M+1		OEL Flag (See Notes)
M+2		UEL Flag (See Notes)
M+3		SCL Flag (See Notes)
M+4		SW1 flag (Power Source Selector) 1: Position A 2: Position B

CONs	Value	Description
J		T_R (s) Regulator input filter time constant
J+1		K_R (pu) Regulator gain
J+2		T_{C1} (s)
J+3		T_{B1} (s)
J+4		T_{C2} (s)
J+5		T_{B2} (s)
J+6		T_{UC1} (s)
J+7		T_{UB1} (s)
J+8		T_{UC2} (s)
J+9		T_{UB2} (s)
J+10		T_{OC1} (s)
J+11		T_{OB1} (s)
J+12		T_{OC2} (s)
J+13		T_{OB2} (s)
J+14		V_{RSMAX} (pu)
J+15		V_{RSMIN} (pu)
J+16		V_{RMAX} (pu)
J+17		V_{RMIN} (pu)
J+18		T_1 (pu)
J+19		K_P (pu) Potential circuit (voltage) gain coefficient
J+20		K_C (pu) Rectifier Loading Factor proportional to commutating reactance
J+21		K_I (pu) Potential circuit (current) gain coefficient
J+22		X_L (pu) Reactance associated with potential source
J+23		THETAP Potential circuit phase angle (degrees)

CONs	Value	Description
J+24		V_{BMAX} (pu) Maximum available exciter field voltage

STATEs	Description
K	Sensed V_T (s0)
K+1	s1
K+2	s2
K+3	s3
K+4	s4
K+5	s5
K+6	s6
K+7	s7
K+8	s8
K+9	Power Source Selector Lag Block

VARs	Description
L	MAX1
L+1	MAX2
L+2	MAX3
L+3	MAX4
L+4	V_{RSMAX} / K_R
L+4	V_{RSMIN} / K_R

```
IBUS, 'USRMDL', ID, 'ST10CU1', 4, 0, 5, 25, 10, 6, ICON(M) to ICON(M+4),
 CON(J) to CON(J+24)   /
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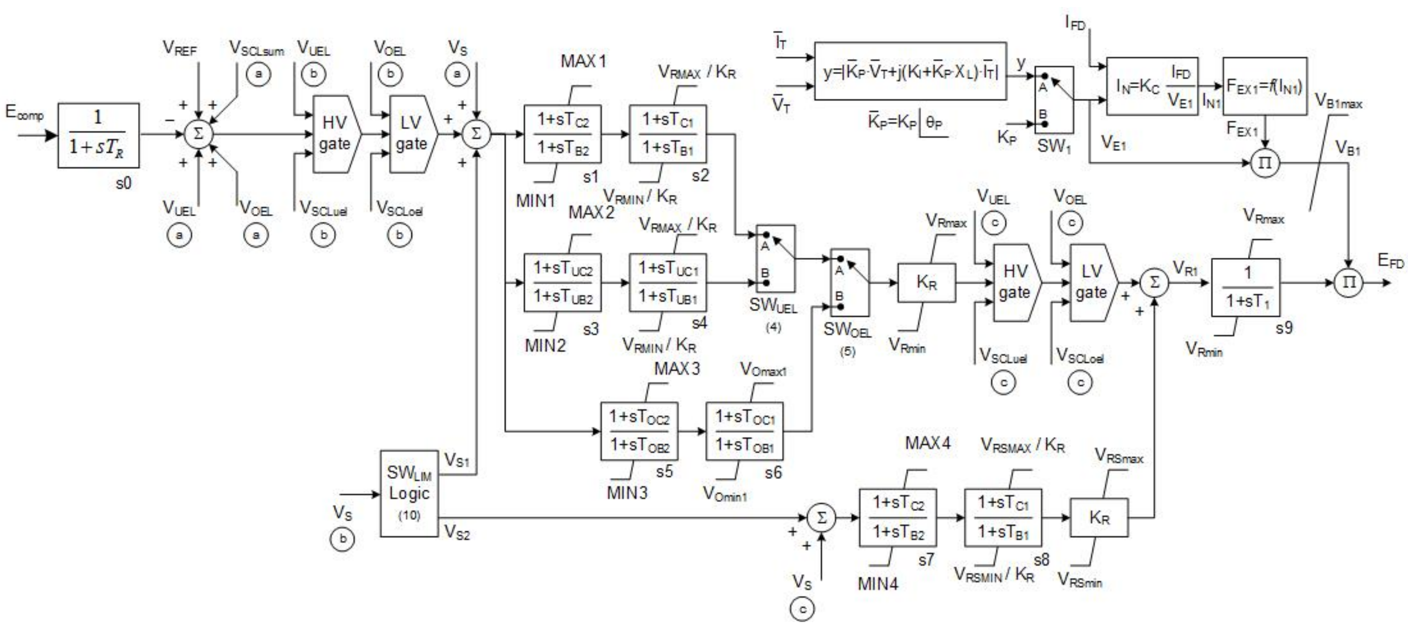


Notes:

1. V_{SCLCUM}, V_{UELSCL}, V_{OELSCL}, although shown in the model diagram as per IEEE 421.5 standard, these are currently not used in the model.

2. SW_1 is a user-selected option. Position A corresponds to a power source from generator terminal voltage such as an excitation transformer. Position B corresponds to a power source independent of generator terminal conditions, such as pilot exciter.

3. For OEL, UEL and SCL flag options, the ICON value can be 1 through 3 with description as follows:

   a. 1: Position (a)

   b. 2: Position (b)

   c. 3: Position (c)

4. Position (b) is active when UEL input location (b) is active and UEL is active. Position (a) is used otherwise

5. Position (b) is active when OEL input location (b) is active and OEL is active. Position (a) is used otherwise

6. As per the IEEE 421.5 2016 documentation, the limits MAX1, MIN1, MAX2, MIN2, MAX3, MIN3, MAX4, MIN4 are calculated as follows:

   $MAX1 = (V_{RMAX} - V_{RMIN}) * T_{B1} / (K_R * T_{C1})$

   $MIN1 = - MAX1$

   $MAX2 = (V_{RMAX} - V_{RMIN}) * T_{UB1} / (K_R * T_{UC1})$

   $MIN2 = - MAX2$

   $MAX3 = (V_{RMAX} - V_{RMIN}) * T_{OB1} / (K_R * T_{OC1})$

   $MIN3 = - MAX3$

   $MAX4 = (V_{RSMAX} - V_{RSMIN}) * T_{B1} / (K_R * T_{C1})$

   $MIN4 = - MAX4$

7. The SWLIM logic, as described IEEE 421.5 document, applies only if the alternate PSS input location (b) is selected, otherwise $V_{S1} = V_{S2} = 0$.

   If OEL or UEL are active

   $V_{S1} = 0$

   $V_{S2} = V_S$

   ELSE

$V_{S1} = V_S$

$V_{S2} = 0$

ENDIF

where Vs is the stabilizer signal

6.86. URHIDT

High Dam Excitation Model

ICONs	Value	Description
M		IF, from bus for current input
M+1		IT, to bus
M+2		CKT, circuit ID
M+3		FF, forcing flag

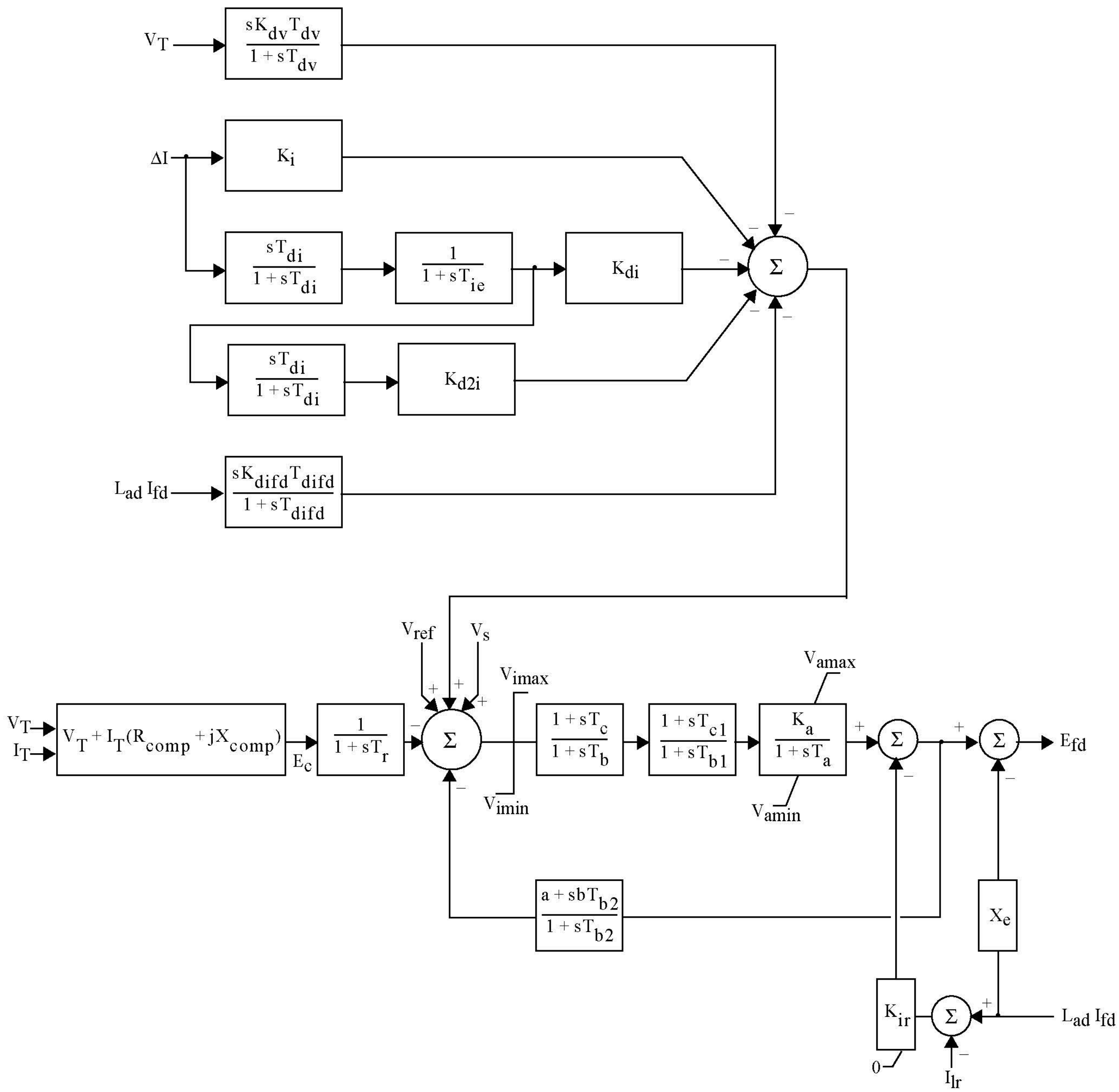
CONs	Value	Description
J		K_{dv}
J+1		T_{DV}
J+2		K_I
J+3		T_{di} (> 0)
J+4		T_{ie}
J+5		K_{di}
J+6		K_{d2i}
J+7		K_{difd}
J+8		T_{di}fd (> 0)
J+9		T_r
J+10		V_{IMAX}
J+11		V_{IMIN}
J+12		T_b
J+13		T_c
J+14		T_{b1}
J+15		T_{c1}
J+16		K_a
J+17		T_{aw} (> 0)
J+18		V_{amax}
J+19		V_{amin}
J+20		a
J+21		T_{b2} (> 0)
J+22		K_Ir
J+23		I_{lr}
J+24		X_e
J+25		$V_{lothrsh}$
J+26		$T_{lodelay}$
J+27		T_{af}
J+28		$V_{hithrsh}$
J+29		b

STATEs	Description
K	Compensating voltage

STATEs	Description
K+1	First exciter stabilizing
K+2	Second exciter stabilizing
K+3	Regulator
K+4	Feedback
K+5	Voltage stabilizer
K+6	First current
K+7	Current filter
K+8	Second current
K+9	Field current stabilization

VARs	Description
L	Initial current
L+1	Current flow
L+2	Timer

```
IBUS, 'URHIDT', ID, ICON(M) to ICON(M+3), CON(J) to CON(J+29)   /
```



Working Bridge Operation:

$T_a = T_{aw}$

Forcing Before Operation:

$V_{terr} = V_{ref} - E_c$

If $V_{terr} > V_{lothrsh}$, start low-voltage timer

If timer > $T_{lodelay}$,

T_a = forcing bridge time constant (T_{af})

Input of regulator (ds2) = V_{amax}/T_a

Reset to normal regulator when $V_{terr} > V_{hithrsh}$ for $T_{lodelay}$

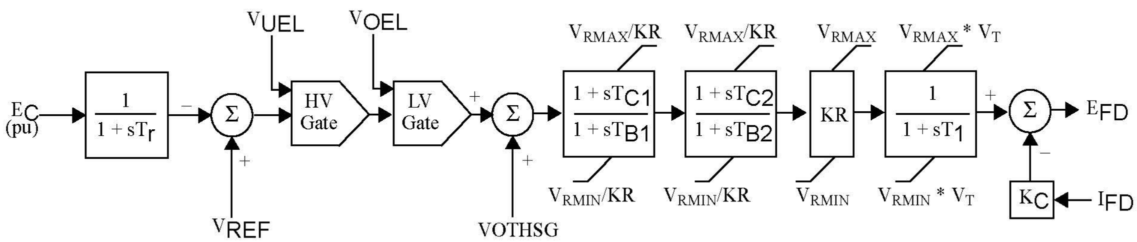
6.87. URST5T

IEEE Proposed Type ST5B Excitation System

CONs	Value	Description
J		T_R (s)
J+1		T_{C1} (s)
J+2		T_{B1} (s)
J+3		T_{C2} (s)
J+4		T_{B2} (s)
J+5		K_R
J+6		V_{RMAX}
J+7		V_{RMIN}
J+8		T_1
J+9		K_C

STATEs	Description
K	Sensed V_T
K+1	First lead lag
K+2	Second lead lag
K+3	Final filter

```
IBUS, 'URST5T', ID, CON(J) to CON(J+9)   /
```



Chapter 7
Turbine-Governor Models

This chapter contains a collection of data sheets for the turbine-governor models contained in the PSS®E dynamics model library.

Model	Description
BBGOV1	Brown-Boveri turbine-governor model
BBGOV1	Brown-Boveri turbine-governor model
CRCMGV	Cross compound turbine-governor model
DEGOV	Woodward diesel governor model
DEGOV1	Woodward diesel governor model
DEGOV1DU	Woodward diesel governor model with speed deadband
GAST	Gas turbine-governor model
GAST2A	Gas turbine-governor model
GAST2ADU	Gas turbine model with speed deadband
GASTDU	Gas turbine-governor with speed deadband
GASTWD	Gas turbine-governor model
GASTWDDU	Woodward gas turbine-governor model with speed deadband
GGOV1	GE general purpose turbine-governor model
GGOV1DU	GE general governor/turbine model with speed deadband
GOVSTEAMEUU	Simplified Boiler and Steam Turbine with PID governor
HYGOV	Hydro turbine-governor model
HYGOVDU	Hydro turbine-governor model with speed deadband
HYGOV2	Hydro turbine-governor model
HYGOV2DU	HYdro turbine-governor model with speed deadband
HYGOVM	Hydro turbine-governor lumped parameter model
HYGOVR1	Fourth order lead-lag governor and hydro turbine
HYGOVT	Hydro turbine-governor traveling wave model
HYG3U1	WECC GP Governor, WECC G2 Governor plus Turbine Model
H6EU1	Hydro Turbine with American Governor Company Controller
IEEEG1	1981 IEEE type 1 turbine-governor model
IEEEG1SDU	IEEE type 1 speed-governing model with speed deadband
IEEEG2	1981 IEEE type 2 turbine-governor model
IEEEG3	1981 IEEE type 3 turbine-governor model
IEEEG3DU	IEEE type 3 speed-governing model with speed deadband
IEESGO	1973 IEEE standard turbine-governor model
IEESGODU	IEEE standard model with speed deadband
IVOGO	IVO turbine-governor model
PIDGOV	Hydro turbine and governor model

Model	Description
PIDGOVDU	Hydro turbine-governor model with speed deadband
PWTBD1	Pratt & Whitney Turboden turbine-governor Model
SGT8HMU1	Siemens SGT6-8000H Turbine Model (Multi Shaft)
SGT8HSU1	Siemens SGT6-8000H Turbine Model (Single Shaft)
SGT2EU1	Siemens SGT-2000E Turbine Model
SITGTU1	Siemens SGT-A65 Gas Turbine Model
SHAF25	Torsional-elastic shaft model for 25 masses
TGOV1	Steam turbine-governor model
TGOV1DU	Steam turbine-governor model with speed deadband
TGOV2	Steam turbine-governor model with fast valving
TGOV3	Modified IEEE type 1 turbine-governor model with fast valving
TGOV3DU	Modified IEEE type 1 speed-governing model with fast valving with speed deadband
TGOV4	Modified IEEE type 1 speed governing model with PLU and EVA
TGOV5	Modified IEEE type 1 turbine-governor model with boiler controls
TURCZT	Czech hydro or steam turbine-governor model
TWDM1T	Tail water depression hydro governor model 1
TWDM2T	Tail water depression hydro governor model 2
URCSCT	Combined cycle, single shaft turbine-governor model
URGS3T	WECC gas turbine governor model
WEHGOV	Woodward electronic hydro governor model
WESGOV	Westinghouse digital governor for gas turbine
WESGOVDU	Westinghouse digital governor for gas turbine model with speed deadband
WPIDHY	Woodward PID hydro governor model
WPIDHYDU	Woodward PID hydro governor model with speed deadband
WSHYDD	WECC double derivative hydro governor model
WSHYGP	WECC GP hydro governor plus turbine model
WSIEG1	WECC modified 1981 IEEE type 1 turbine-governor model

7.1. BBGOV1

European Governor Model

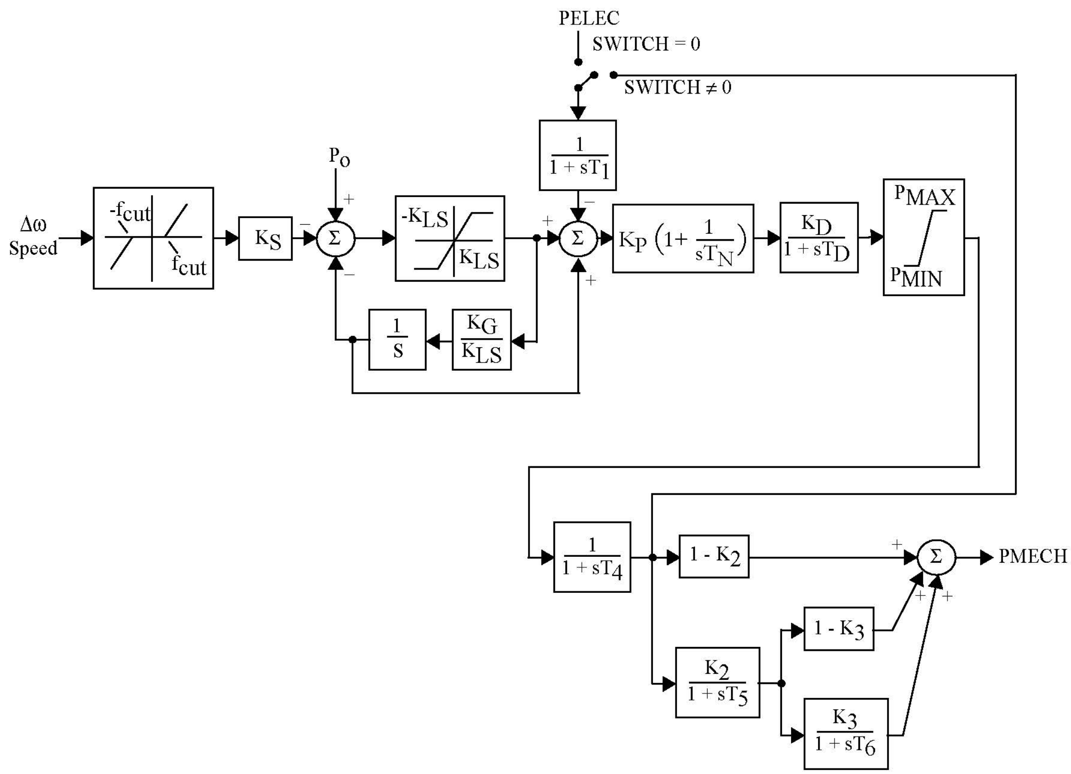
CONs	Value	Description
J		f_{cut} (≥ 0) (pu)
J+1		K_S
J+2		K_{LS} (> 0)
J+3		K_G
J+4		K_P
J+5		T_N (sec) (> 0)
J+6		K_D
J+7		T_D (sec) (> 0)
J+8		T_4 (sec)
J+9		K_2
J+10		T_5 (sec)
J+11		K_3
J+12		T_6 (sec)
J+13		T_1 (sec)
J+14		SWITCH
J+15		P_{MAX}
J+16		P_{MIN}

STATEs	Description
K	Step and gradient limiter
K+1	PI controller
K+2	Valve output
K+3	Steam output
K+4	Turbine power
K+5	Turbine power
K+6	Electrical damping feedback

VARs	Description
L	Reference, P_o

Govenor gain K_S =1/R, P_{MAX} and P_{MIN} are in pu on generator MVA base.

```
IBUS,'BBGOV1', ID, CON(J) to CON(J+16)   /
```


PELEC
SWITCH = 0
SWITCH ≠ 0
Δω
Speed
-fcut
fcut
KS
PO
-KLS
KLS
1/(1 + sT1)
Kp (1+ 1/sTN)
KD/(1 + sTD)
PMAX
PMIN
1/s
KG/KLS
1/(1 + sT4)
1 - K2
K2/(1 + sT5)
1 - K3
K3/(1 + sT6)
PMECH

7.2. CRCMGV

Cross Compound Turbine-Governor

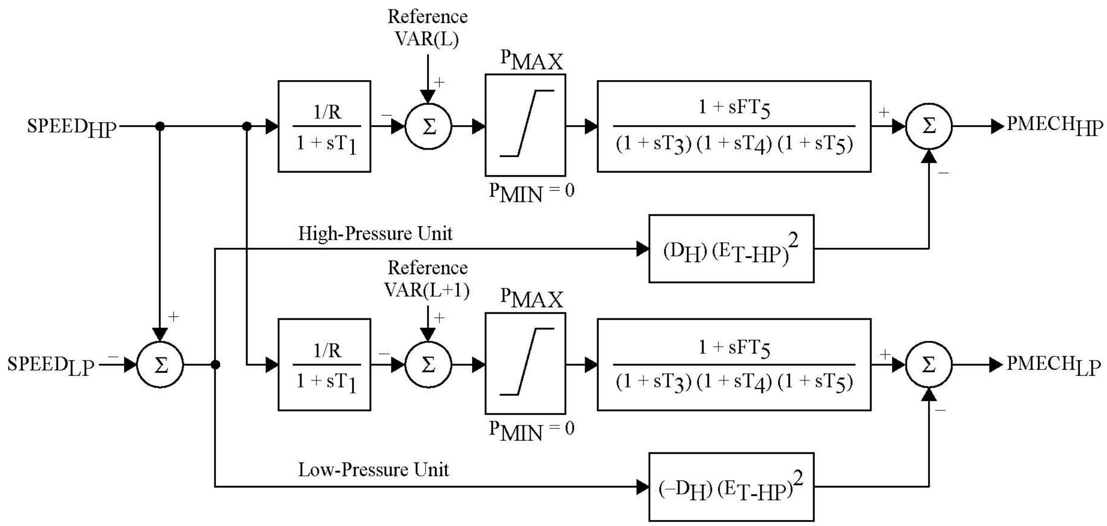
CONs	Value	Description
J		P_{MAX} (HP)[a]
J+1		R (HP)
J+2		T_1 (HP) (>0)
J+3		T_3 (HP) (>0)
J+4		T_4 (HP) (>0)
J+5		T_5 (HP) (>0)
J+6		F (HP)
J+7		D_H (HP)[a]
J+8		P_{MAX} (LP)
J+9		R (LP)
J+10		T_1 (LP) (>0)
J+11		T_3 (LP) (>0)
J+12		T_4 (LP) (>0)
J+13		T_5 (LP) (>0)
J+14		F (LP)
J+15		D_H (LP)

[a]P_{MAX} and D_H Ri are mpu on generator MVA base. P_{MAX}, D_H, and R are in pu on generator MWA base.

STATEs	Description
K	High-pressure unit
K+1	
K+2	
K+3	
K+4	Low-pressure unit
K+5	
K+6	
K+7	

VARs	Description
L	$PMECH_1$ REF
L+1	$PMECH_2$ REF

```
IBUS, 'CRCMGV', ID, JBUS, M, CON(J) to CON(J+15)   /
```


Reference
VAR(L)
PMAX
SPEEDHP
1/R
1 + sT1
1 + sFT5
(1 + sT3) (1 + sT4) (1 + sT5)
PMECHHP
PMIN = 0
High-Pressure Unit
(DH) (ET-HP)2
Reference
VAR(L+1)
PMAX
SPEEDLP
1/R
1 + sT1
1 + sFT5
(1 + sT3) (1 + sT4) (1 + sT5)
PMECHLP
PMIN = 0
Low-Pressure Unit
(–DH) (ET-HP)2

7.3. DEGOV

Woodward Diesel Governor

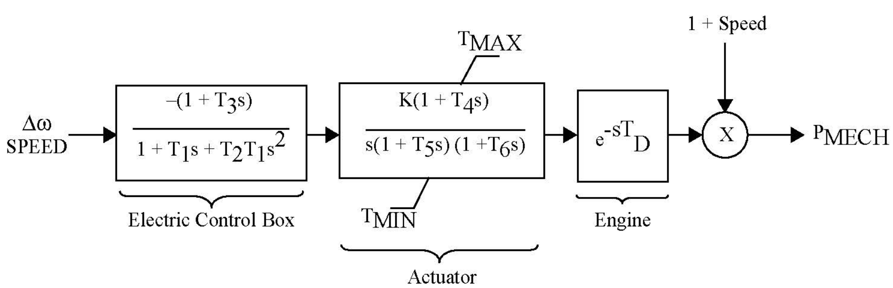
CONs	Value	Description
J		T_1 (sec)
J+1		T_2 (sec)
J+2		T_3 (sec)
J+3		K (pu)
J+4		T_4 (sec)
J+5		T_5 (sec)
J+6		T_6 (sec)
J+7		T_D ($0 < T_D$ * 12 # DELT) (sec)
J+8		T_{MAX}
J+9		T_{MIN}

STATEs	Description
K	Electric control box 1
K+1	Electric control box 2
K+2	Actuator 1
K+3	Actuator 2
K+4	Actuator 3

VARs	Description
L	Delay table
L+1	
...	
L+11	
L+12	

Governor gain K=1/R is in pu on generator MVA base.

```
IBUS, 'DEGOV', ID, CON(J) to CON(J+9)   /
```



7.4. DEGOV1

Woodward Diesel Governor

ICON	Value	Description
M		Droop control: 0 Throttle feedback 1 Electric power feedback

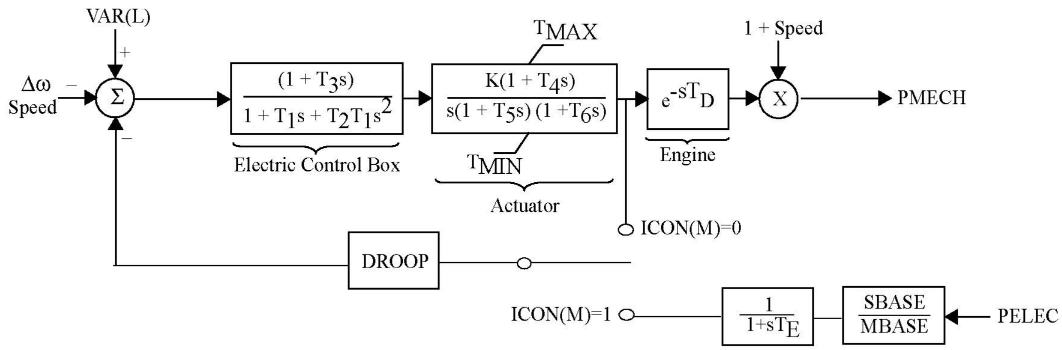
CONs	Value	Description
J		T_1 (sec)
J+1		T_2 (sec)
J+2		T_3 (sec)
J+3		K
J+4		T_4 (sec)
J+5		T_5 (sec)
J+6		T_6 (sec)
J+7		T_D ($0 < T_D$ 12 * DELT) (sec)
J+8		T_{MAX}
J+9		T_{MIN}
J+10		DROOP
J+11		T_E

STATEs	Description
K	Electric control box 1
K+1	Electric control box 2
K+2	Actuator 1
K+3	Actuator 2
K+4	Actuator 3
K+5	Power transducer

Governor gain K=1/R is in pu on generator MVA base.

VARs	Description
L	Reference
L+1	
...	Delay table
L+13	

```
IBUS, 'DEGOV1', ID, ICON(M), CON(J) to CON(J+11)   /
```


VAR(L)
Δω
Speed
Σ
(1 + T3s)
1 + T1s + T2T1s2
Electric Control Box
TMAX
K(1 + T4s)
s(1 + T5s) (1 +T6s)
TMIN
Actuator
e-sTD
Engine
1 + Speed
X
PMECH
ICON(M)=0
DROOP
ICON(M)=1
1
1+sTE
SBASE
MBASE
PELEC

7.5. DEGOV1DU

Woodward Diesel Governor

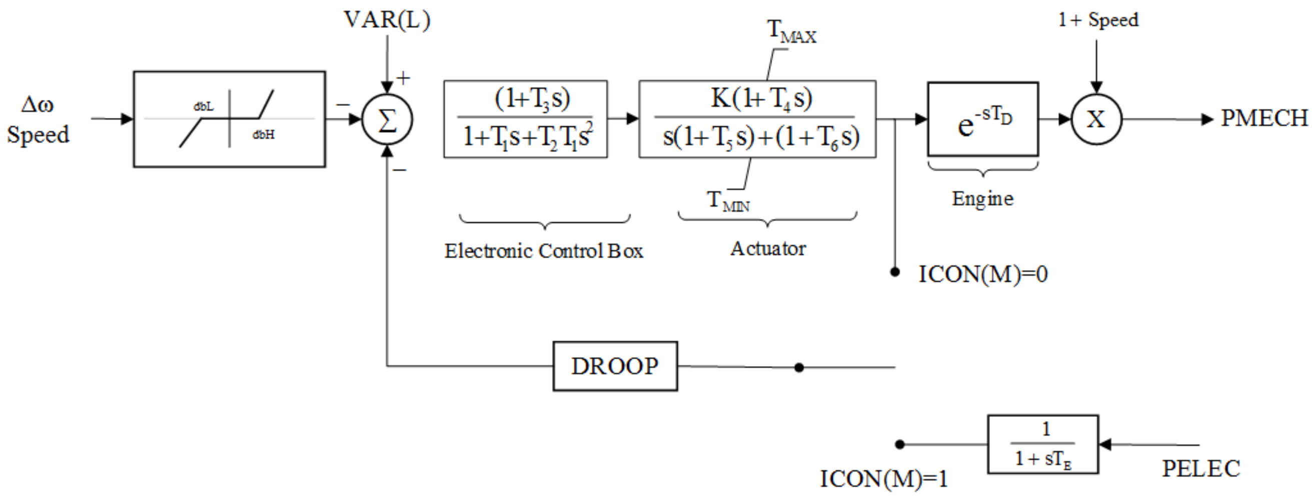
ICONs	Value	Description
M		Droop control: 0 Throttle feedback 1 Electric power feedback

CONs	Value	Description
J		T_1 (sec)
J+1		T_2 (sec)
J+2		T_3 (sec)
J+3		K
J+4		T_4 (sec)
J+5		T_5 (sec)
J+6		T_6 (sec)
J+7		T_D ($0 < T_D \leq 12$ * DELT) (sec)
J+8		T_{MAX}
J+9		T_{MIN}
J+10		DROOP
J+11		T_E
J+12		DBH (pu), deadband for overspeed, (≥ 0)
J+13		DBL (pu), deadband for underspeed, (≤ 0)
J+14		T_{Rate} (MW), Turbine rating, if zero, then MBASE used

STATEs	Description
K	Electric control box 1
K+1	Electric control box 2
K+2	Actuator 1
K+3	Actuator 2
K+4	Actuator 3
K+5	Power transducer

VAR	Description
L	Reference
L+1	Delay table
...	
L+13	
L+14	Deadband output

```
IBUS, 'USRMDL', ID, 'DEGOV1DU'   5   0   1   15   6   15   ICON(M), CON(J)
 to CON(J+14)   /
```


Δω
Speed
dbL
dbH
VAR(L)
+
−
Σ
−
(1+T3s)
1+T1s+T2T1s2
Electronic Control Box
TMAX
K(1+T4s)
s(1+T5s)+(1+T6s)
TMIN
Actuator
e-sTD
Engine
1+ Speed
X
PMECH
ICON(M)=0
DROOP
1
1 + sTE
ICON(M)=1
PELEC

7.6. GAST

Gas Turbine-Governor

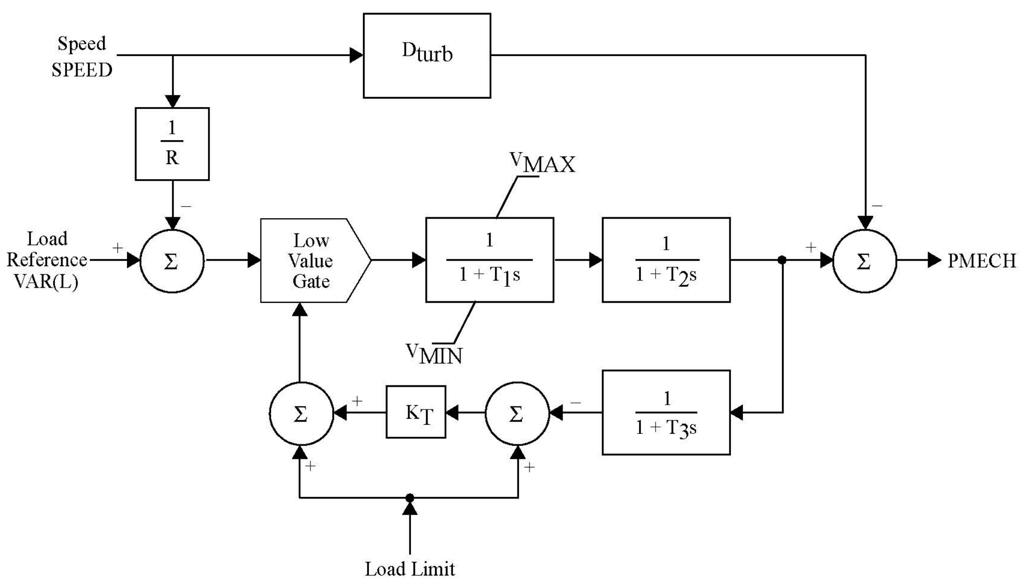
CONs	Value	Description
J		R (speed droop)
J+1		T_1 (>0) (sec)
J+2		T_2 (>0) (sec)
J+3		T_3 (>0) (sec)
J+4		Ambient temperature load limit, AT
J+5		K_T
J+6		V_{MAX}
J+7		V_{MIN}
J+8		D_{turb}

STATEs	Description
K	Fuel valve
K+1	Fuel flow
K+2	Exhaust temperature

VAR	Description
L	Load reference

V_{MAX}, V_{MIN}, D_{turb} and R are in pu on generator MVA base.

```
IBUS, 'GAST', ID, CON(J) to CON(J+8)   /
```



7.7. GAST2A

Gas Turbine Model

CONs	Value	Description
J		W, governor gain (1/droop) (on turbine rating)
J+1		X (sec) governor lead time constant
J+2		Y (sec) (> 0) governor lag time constant
J+3		Z, governor mode: 1 Droop 0 ISO
J+4		E_{TD} (sec)
J+5		T_{CD} (sec)
J+6		T_{RATE} turbine rating (MW)
J+7		T (sec)
J+8		MAX (pu) limit (on turbine rating)
J+9		MIN (pu) limit (on turbine rating)
J+10		E_{CR} (sec)
J+11		K_3
J+12		a (> 0) valve positioner
J+13		b (sec) (> 0) valve positioner
J+14		c valve positioner
J+15		τ_f (sec) (> 0)
J+16		Kf
J+17		K_5
J+18		K_4
J+19		T_3 (sec) (> 0)
J+20		T_4 (sec) (> 0)
J+21		τ_t (> 0)
J+22		T_5 (sec) (> 0)
J+23		a_{f1}
J+24		b_{f1}
J+25		a_{f2}
J+26		b_{f2}
J+27		c_{f2}
J+28		T_r(degree), Rated temperature[a]
J+29		K_6 (pu), Minimum fuel flow
J+30		T_C (degree), Temperature control [a]

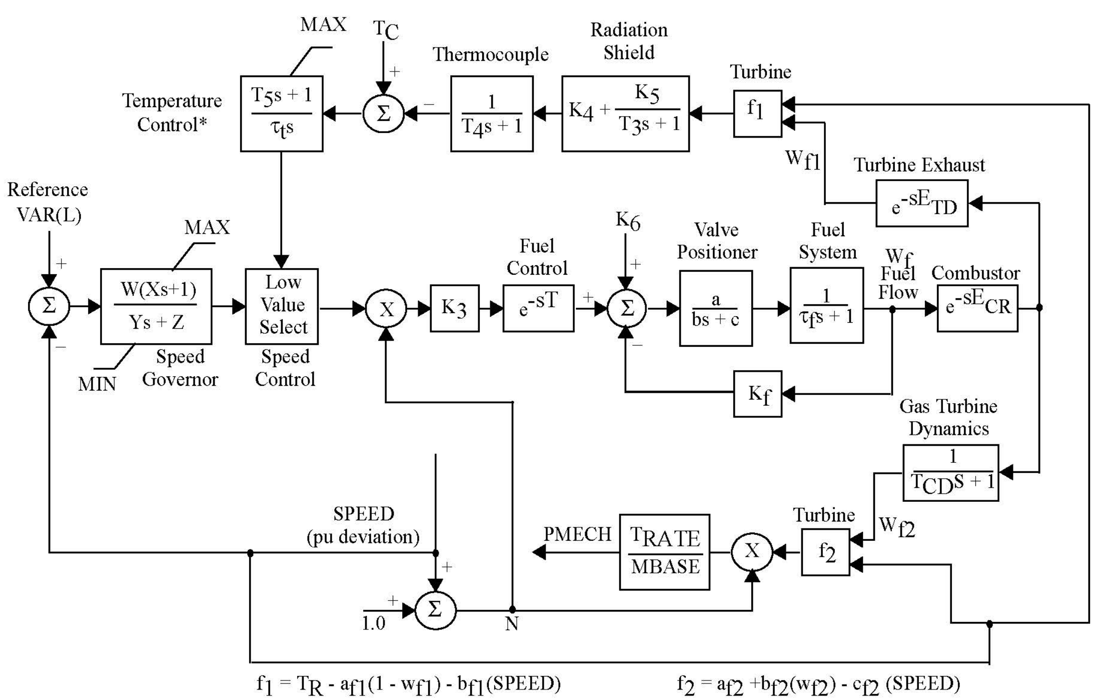
[a]Units can be °F or °C depending on constants a_{f1} and b_{f1}.

STATEs	Description
K	Speed governor

STATEs	Description
K+1	Valve positioner
K+2	Fuel system
K+3	Radiation shield
K+4	Thermocouple
K+5	Temperature control
K+6	Gas turbine dynamics
K+7	Combustor
K+8	Combustor
K+9	Turbine/exhaust
K+10	Turbine/exhaust
K+11	Fuel controller delay
K+12	Fuel controller delay

VARs	Description
L	Governor reference
L+1	Temperature reference flag
L+2	Low value select output
L+3	Output of temperature control

```
IBUS, 'GAST2A', ID, CON(J) to CON(J+30)   /
```



*Temperature control output is set to output of speed governor when temperature control input changes from positive to negative.

7.8. GAST2ADU

Gas Turbine Model

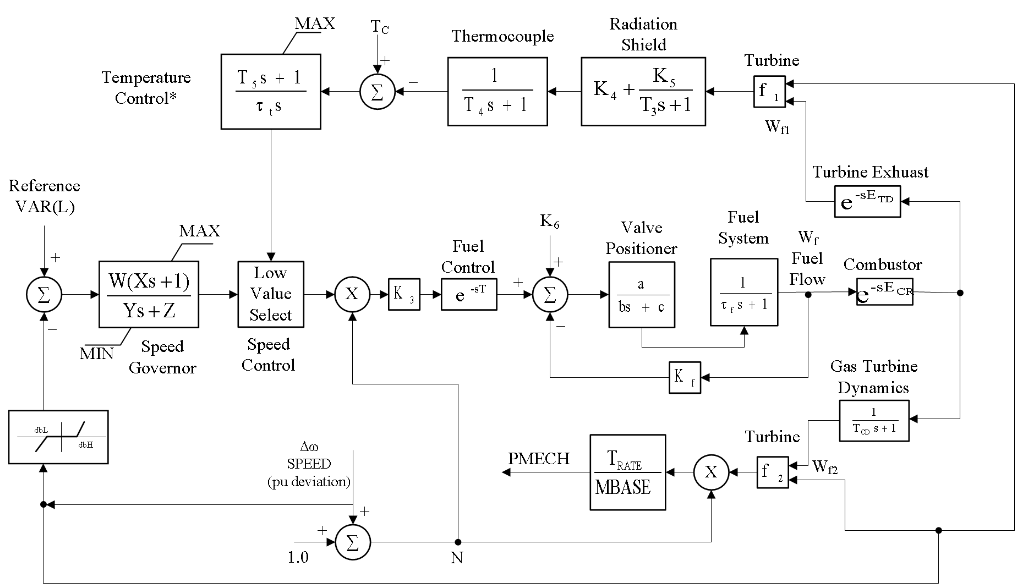
CONs	Value	Description
J		W, governor gain (1/droop) (on turbine rating)
J+1		X (sec) governor lead time constant
J+2		Y (sec) (> 0) governor lag time constant
J+3		Z, governor mode: 1 Droop 0 ISO
J+4		E_{TD} (sec)
J+5		T_{CD} (sec)
J+6		T_{RATE} turbine rating (MW)
J+7		T (sec)
J+8		MAX (pu) limit (on turbine rating)
J+9		MIN (pu) limit (on turbine rating)
J+10		E_{CR} (sec)
J+11		K_3
J+12		a (> 0) valve positioner
J+13		b (sec) (> 0) valve positioner
J+14		c valve positioner
J+15		τ_f (sec) (> 0)
J+16		Kf
J+17		K_5
J+18		K_4
J+19		T_3 (sec) (> 0)
J+20		T_4 (sec) (> 0)
J+21		τ_t (> 0)
J+22		T_5 (sec) (> 0)
J+23		a_{f1}
J+24		b_{f1}
J+25		a_{f2}
J+26		b_{f2}
J+27		c_{f2}
J+28		T_R(degree), Rated temperature[a]
J+29		K_6 (pu), Minimum fuel flow
J+30		T_C (degree), Temperature control [a]
J+31		DBH (pu), deadband for overspeed, (≥ 0)
J+32		DBL (pu), deadband for underspeed, (≤ 0)

[a]Units can be °F or °C depending on constants a_{f1} and b_{f1}.

STATEs	Description
K	Speed governor
K+1	Valve positioner
K+2	Fuel system
K+3	Radiation shield
K+4	Thermocouple
K+5	Temperature control
K+6	Gas turbine dynamics
K+7	Combustor
K+8	Combustor
K+9	Turbine/exhaust
K+10	Turbine/exhaust
K+11	Fuel controller delay
K+12	Fuel controller delay

VAR	Description
L	Governor reference
L+1	Temperature reference flag
L+2	Low value select output
L+3	Output of temperature control
L+4	Deadband output

```
IBUS, 'USRMDL', ID, 'GAST2ADU'   5   0   0   33   13   5   CON(J) to CON(J
+32)   /
```



f_1 = TR -af1(1-wf1)-bf1(SPEED)

$f_2 = a_{f2}+b_{f2}(w_{f2})-c_{f2}$ (SPEED)

*Temperature control output is set to output of speed governor when temperature control input changes from positive to negative.

7.9. GASTDU

Gas Turbine Model

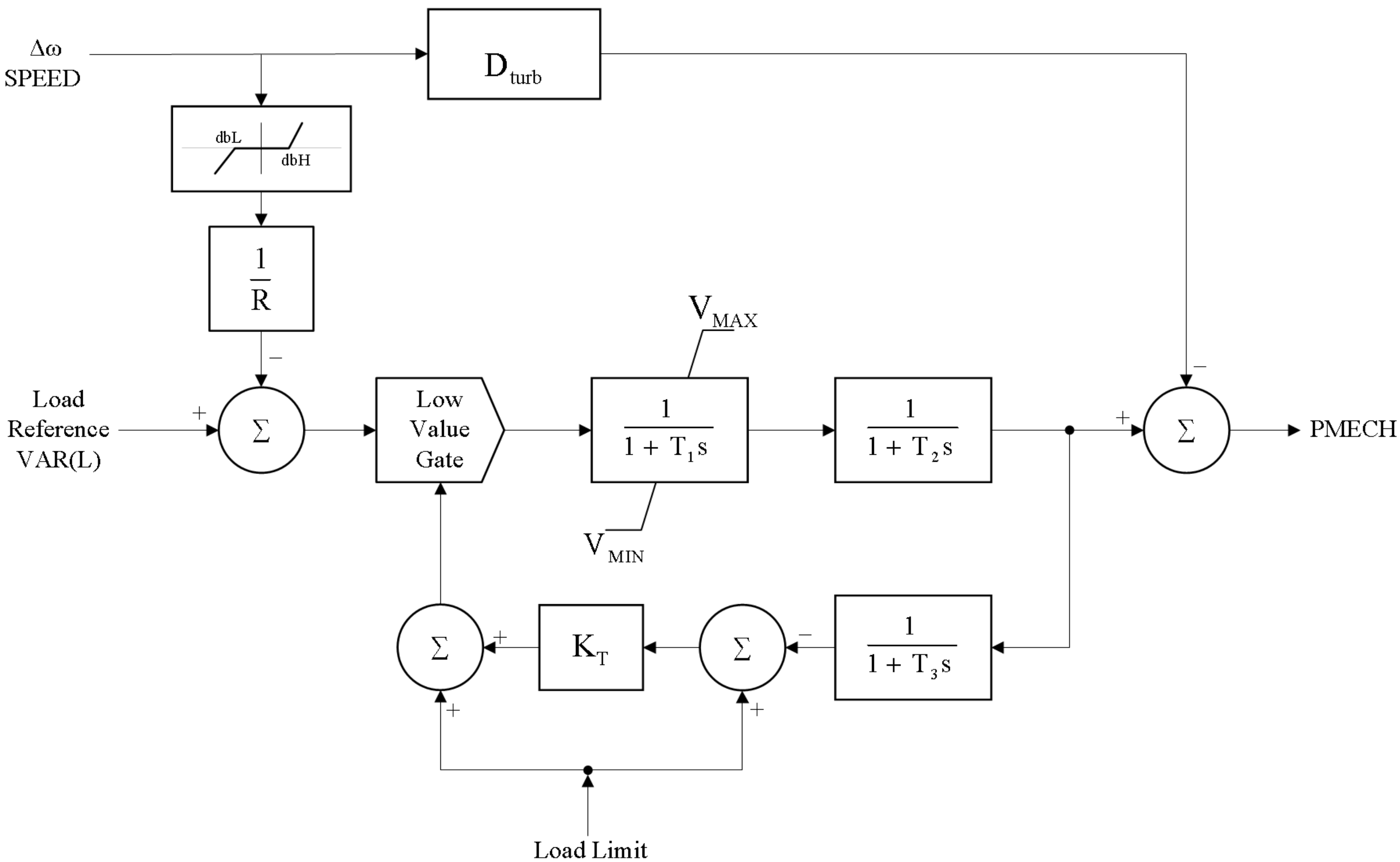
CONs	Value	Description
J		R (speed droop)
J+1		T_1 (>0) (sec)
J+2		T_2 (>0) (sec)
J+3		T_3 (>0) (sec)
J+4		Ambient temperature load limit, AT
J+5		K_T
J+6		V_{MAX}
J+7		V_{MIN}
J+8		D_{turb}
J+9		DBH (pu), deadband for overspeed, (≥ 0)
J+10		DBL (pu), deadband for underspeed, (≤ 0)
J+11		T_{Rate} (MW), Turbine rating, if zero, then MBASE used

STATEs	Description
K	Fuel valve
K+1	Fuel flow
K+2	Exhaust temperature

VAR	Description	
L	Governor reference	
L+1	Deadband output	

V_{max}, V_{min}, D_{turb} and R are in pu on T_{Rate} if T_{Rate} > 0, else in pu on generator MVA base.

```
IBUS, ’USRMDL’, ID, ’GASTDU’   5   0   0   12   3   2   CON(J) to CON(J
+11)   /
```


Δω
SPEED
D turb
dbL
dbH
1
R
Load
Reference
VAR(L)
Σ
Low
Value
Gate
V MAX
1
1 + T1s
V MIN
1
1 + T2s
Σ
PMECH
Σ
K T
Σ
1
1 + T3s
Load Limit

7.10. GASTWD

Woodward Gas Turbine-Governor Model

CONs	Value	Description
J		K_{DROOP} (on turbine rating)
J+1		K_P
J+2		K_I
J+3		K_D
J+4		E_{TD} (sec)
J+5		T_{CD} (sec)
J+6		T_{RATE} turbine rating (MW)
J+7		T (sec)
J+8		MAX (pu) limit (on turbine rating)
J+9		MIN (pu) limit (on turbine rating)
J+10		E_{CR} (sec)
J+11		K_3
J+12		a (> 0) valve positioner
J+13		b (sec) (> 0) valve positioner
J+14		c valve positioner
J+15		τ_f (sec) (> 0)
J+16		Kf
J+17		K_5
J+18		K_4
J+19		T_3 (sec) (> 0)
J+20		T_4 (sec) (> 0)
J+21		τ_t (> 0)
J+22		T_5 (sec) (> 0)
J+23		a_{f1}
J+24		b_{f1}
J+25		a_{f2}
J+26		bf2 (>0)
J+27		c_{f2}
J+28		T_r(degree), Rated temperature[a]
J+29		K_6 (pu), Minimum fuel flow
J+30		T_C (degree), Temperature control
J+31		T_D (sec) (> 0), Power transducer

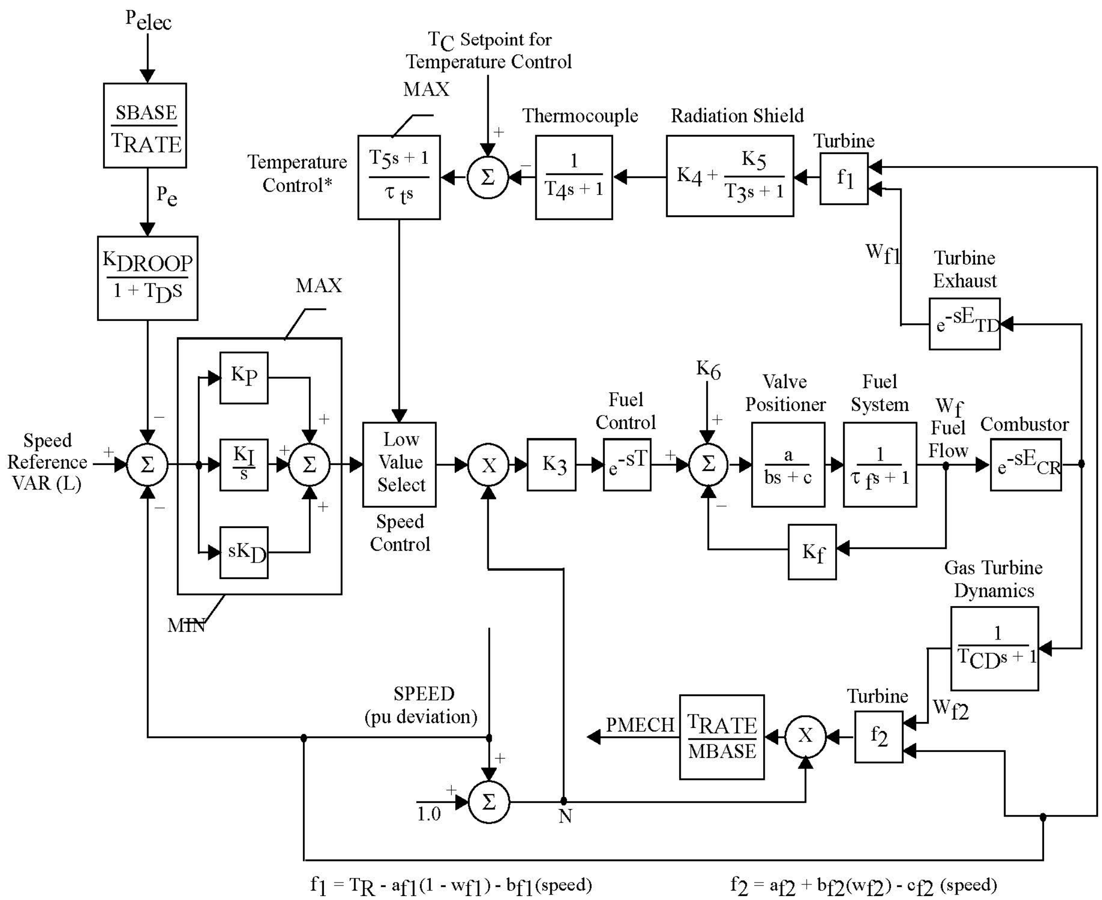
[a]Units can be °F or °C depending on constants a_{f1} and b_{f1}.

STATEs	Description
K	Speed governor
K+1	Valve positioner

STATEs	Description
K+2	Fuel system
K+3	Radiation shield
K+4	Thermocouple
K+5	Temperature control
K+6	Gas turbine dynamics
K+7	Combustor
K+8	Combustor
K+9	Turbine/exhaust
K+10	Turbine/exhaust
K+11	Fuel controller delay
K+12	Fuel controller delay
K+13	Power transducer

VARs	Description
L	Governor reference
L+1	Temperature reference flag
L+2	Low value select output
L+3	Output of temperature control
L+4	Derivative control

```
IBUS, 'GASTWD', ID, CON(J) to CON(J+31)   /
```



*Temperature control output is set to output of speed governor when temperature control input changes from positive to negative.

7.11. GASTWDDU

Woodward Gas Turbine-Governor Model

CONs	Value	Description
J		K_{DROOP} (on turbine rating)
J+1		K_P
J+2		K_I
J+3		K_D
J+4		E_{TD} (sec)
J+5		T_{CD} (sec)
J+6		T_{RATE} turbine rating (MW)
J+7		T (sec)
J+8		MAX (pu) limit (on turbine rating)
J+9		MIN (pu) limit (on turbine rating)
J+10		E_{CR} (sec)
J+11		K_3
J+12		a (> 0) valve positioner
J+13		b (sec) (> 0) valve positioner
J+14		c valve positioner
J+15		τ_f (sec) (> 0)
J+16		Kf
J+17		K_5
J+18		K_4
J+19		T_3 (sec) (> 0)
J+20		T_4 (sec) (> 0)
J+21		τ_t (> 0)
J+22		T_5 (sec) (> 0)
J+23		a_{f1}
J+24		b_{f1}
J+25		a_{f2}
J+26		b_{f2} (>0)
J+27		c_{f2}
J+28		T_r(degree), Rated temperature[a]
J+29		K_6 (pu), Minimum fuel flow
J+30		T_C (degree), Temperature control
J+31		T_D (sec) (> 0), Power transducer
J+32		DBH (pu), deadband for overspeed, (≥ 0)
J+33		DBL (pu), deadband for underspeed, (≤ 0)

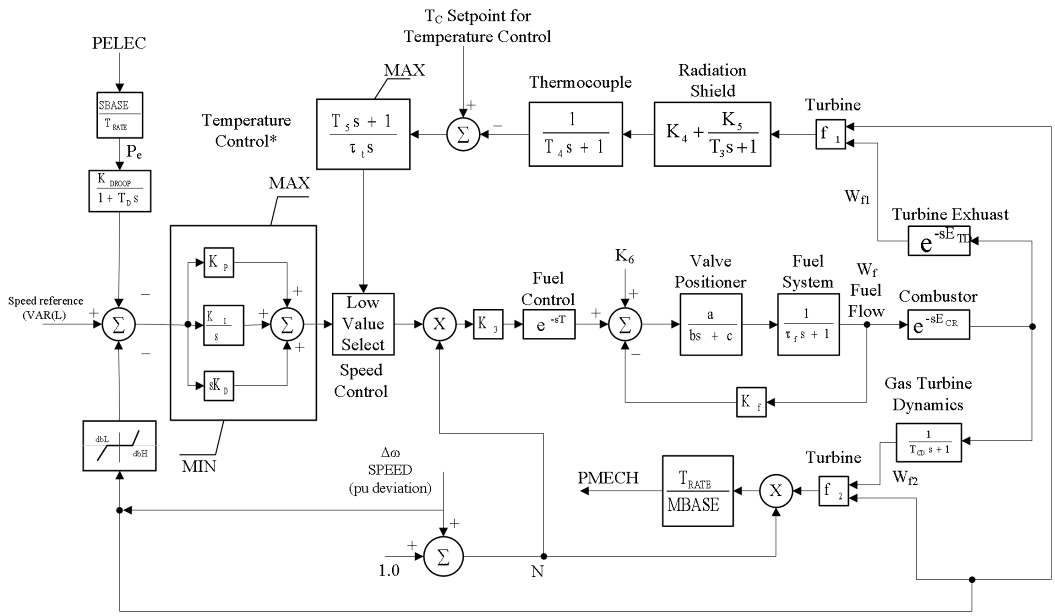
[a]Units can be °F or °C depending on constants a_{f1} and b_{f1}.

STATEs	Description
K	Speed governor

STATEs	Description
K+1	Valve positioner
K+2	Fuel system
K+3	Radiation shield
K+4	Thermocouple
K+5	Temperature control
K+6	Gas turbine dynamics
K+7	Combustor
K+8	Combustor
K+9	Turbine/exhaust
K+10	Turbine/exhaust
K+11	Fuel controller delay
K+12	Fuel controller delay
K+13	Power transducer

VARs	Description
L	Governor reference
L+1	Temperature reference flag
L+2	Low value select output
L+3	Output of temperature control
L+4	Derivative control
L+5	Deadband output

```
IBUS, 'USRMDL', ID, 'GASTWDDU'   5   0   0   34   14   6 CON(J) to CON(J
+33)   /
```



$f_1 = T_R - a_{f1}(1-w_{f1}) - b_{f1}(SPEED)$

$f_2 = a_{f2} + b_{f2}(w_{f2}) - c_{f2}\,(SPEED)$

*Temperature control output is set to output of speed governor when temperature control input changes from positive to negative.

7.12. GGOV1

GE General Governor/Turbine Model

ICONs	Value	Description
M	1	Rselect, Feedback signal for governor droop: 1 electrical power 0 none (isochronous governor) -1 fuel valve stroke (true stroke) -2 governor output (requested stroke)
M+1	0	Flag Switch for fuel source characteristic: 0 fuel flow independent of speed 1 fuel flow proportional to speed

CONs	Value	Description
J		R, Permanent droop, pu
J+1		Tpelec, Electrical power transducer time constant, sec
J+2		maxerr, Maximum value for speed error signal
J+3		minerr, Minimum value for speed error signal
J+4		K_{pgov}, Governor proportional gain
J+5		K_{Igov}, Governor integral gain
J+6		K_{dgov}, Governor derivative gain
J+7		T_{dgov}, Governor derivative controller time constant, sec
J+8		V_{MAX}, Maximum valve position limit
J+9		V_{MIN}, Minimum valve position limit
J+10		T_{act}, Actuator time constant, sec
J+11		Kturb, Turbine gain
J+12		Wfnl, No load fuel flow, pu
J+13		T_b, Turbine lag time constant, sec
J+14		Tc, Turbine lead time constant, sec
J+15		Teng, Transport lag time constant for diesel engine, sec
J+16		T_{fload}, Load Limiter time constant, sec
J+17		K_{pload}, Load limiter proportional gain for PI controller
J+18		K_{Iload}, Load limiter integral gain for PI controller
J+19		Ldref, Load limiter reference value pu
J+20		Dm, Mechanical damping coefficient, pu
J+21		Ropen, Maximum valve opening rate, pu/sec
J+22		Rclose, Maximum valve closing rate, pu/sec
J+23		$K_I$mw, Power controller (reset) gain

CONs	Value	Description
J+24		Aset, Acceleration limiter setpoint, pu/sec
J+25		Ka, Acceleration limiter gain
J+26		T_a, Acceleration limiter time constant, sec (> 0)
J+27		T_{rate}, Turbine rating (MW)[a]
J+28		db, Speed governor deadband
J+29		Tsa, Temperature detection lead time constant, sec
J+30		Tsb, Temperature detection lag time constant, sec
J+31		Rup, Maximum rate of load limit increase
J+32		Rdown, Maximum rate of load limit decrease

[a]If the turbine rating [CON(J+27)] is greater than zero, the input P_{ELEC} is converted in the model to per unit on turbine rating base, else P_{ELEC} is converted to per unit on machine base.

STATEs	Description
K	Machine Electrical Power Measurement
K+1	Governor Differential Control
K+2	Governor Integral Control
K+3	Turbine Actuator
K+4	Turbine Lead-Lag
K+5	Turbine load limiter measurement
K+6	Turbine Load Limiter Integral Control
K+7	Supervisory Load Control
K+8	Acceleration Control
K+9	Temperature Detection Lead-Lag

VARs	Description
L	Load Reference
L+1	Output of Load Limiter PI Control
L+2	Output of Governor PID Control
L+3	Low Value Select Output
L+4	Output of Turbine Actuator
L+5	Output of Turbine Lead-Lag
L+6	Supervisory Load Controller Setpoint, Pmwset
L+7	Delay table
...	
L+19	
L+20	Dead Band

R and DM in pu on Turbine MW base when Trate is specified and in pu on generator MVA base when Trate is not entered.

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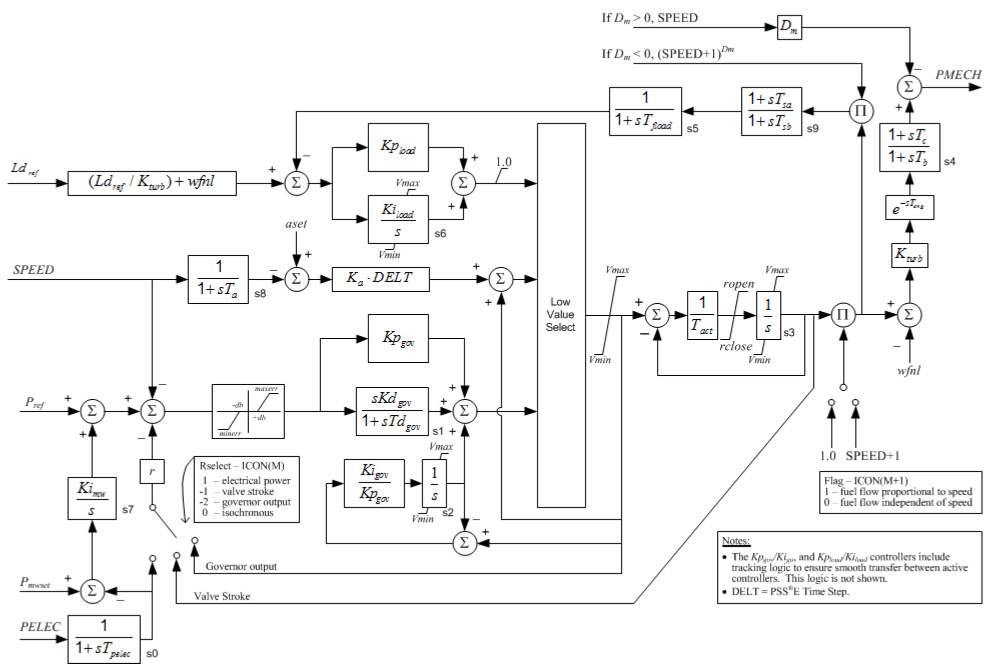
IBUS, 'GGOV1', ID, ICON(M) to ICON(M+1), CON(J) to CON(J+32)   /
```



Notes:

a. This model can be used to represent a variety of prime movers controlled by PID governors. It is suitable, for example, for representation of:

- gas turbine and single shaft combined cycle turbines
- diesel engines with modern electronic or digital governors
- steam turbines where steam is supplied from a large boiler drum or a large header whose pressure is substantially constant over the period under study simple hydro turbines in dam configurations where the water column length is short and water inertia effects are minimal

b. Per unit parameters are on base of the turbine MW base (T_{rate}). If no value is entered for T_{rate}, parameters are specified on generator MVA base.

c. The range of fuel valve travel and of fuel flow is unity. Thus the largest possible value of V_{MAX} is 1.0 and the smallest possible value of V_{MIN} is zero. V_{MAX} may, however, be reduced below unity to represent a loading limit that may be imposed by the operator or a supervisory control system. For gas turbines V_{MIN} should normally be greater than zero and less than w_{fnl} to represent a minimum firing limit. The value of fuel flow at maximum output must be less than, or equal to unity, depending on the value of k_{turb}.

d. The parameter T_{eng} is provided for use in representing diesel engines where there is a small but measurable transport delay between a change in fuel flow setting and the development of torque. In the majority of cases T_{eng} should be zero.

e. The parameter Flag is provided to recognize that fuel flow, for a given fuel valve stroke, can be proportional to engine speed. This is the case for GE gas turbines and for diesel engines with positive displacement fuel injectors. Flag should be set to unity for all GE gas turbines and most diesel engines. Flag should be set to zero where it is known that the fuel control system keeps fuel flow independent of engine speed.

f. The load limiter module may be used to impose a maximum output limit such as an exhaust temperature limit. To do this the time constant T_{fload} should be set to represent the time constant in the measurement of temperature (or other signal), and the gains of the limiter, K_{pload}, K_{iload}, should be set to give prompt stable control when on limit. The load limit can be deactivated by setting the parameter L_{dref} to a high value.

g. The parameter D_m can represent either the variation of engine power with shaft speed or the variation of maximum power capability with shaft speed.

- If Dm is positive it describes the falling slope of the engine speed versus power characteristic as speed increases. A slightly falling characteristic is typical for reciprocating engines and some aeroderivative turbines.
- If Dm is negative the engine power is assumed to be unaffected by shaft speed, but the maximum permissible fuel flow is taken to fall with falling shaft speed. This is characteristic of single shaft industrial gas turbines.

h. This model includes a simple representation of a supervisory load controller. This controller is active if the parameter K_{imw} is non-zero. The load controller is a slow acting reset loop that adjusts the speed/load reference of the turbine governor to hold the electrical power output of the unit at its initial condition value P_{mwset}. P_{mwset} is given a value automatically when the model is initialized and stored in VAR(L+6), and can be changed thereafter. The load controller must be adjusted to respond gently relative to the speed governor. A typical value for K_{imw} is 0.01, corresponding to a reset time of 100 seconds. Setting K_{imw} to 0.001 corresponds to a relatively slow acting load controller.

i. The parameters A_{set}, K_a, and T_a describe an acceleration limiter. These parameters may be set to zero if the limiter is not active.

j. The parameter db is the speed governor dead band. This parameter is in terms of per unit speed.

k. Tsa and Tsb are provided to augment the exhaust gas temperature measurement subsystem in gas turbines.

l. R_{up} and R_{down} specify the maximum rate of increase and decrease of the output of the load limit controller (K_{pload}/K_{iload}).

7.13. GGOV1DU

GE General Governor/Turbine Model

ICONs	Value	Description
M	1	Rselect, Feedback signal for governor droop: 1 electrical power 0 none (isochronous governor) -1 fuel valve stroke (true stroke) -2 governor output (requested stroke)
M+1	0	Flag Switch for fuel source characteristic: 0 fuel flow independent of speed 1 fuel flow proportional to speed

CONs	Value	Description
J		R, Permanent droop, pu
J+1		Tpelec, Electrical power transducer time constant, sec
J+2		maxerr, Maximum value for speed error signal
J+3		minerr, Minimum value for speed error signal
J+4		K_{pgov}, Governor proportional gain
J+5		K_{igov}, Governor integral gain
J+6		K_{dgov}, Governor derivative gain
J+7		T_{dgov}, Governor derivative controller time constant, sec
J+8		V_{MAX}, Maximum valve position limit
J+9		V_{MIN}, Minimum valve position limit
J+10		T_{act}, Actuator time constant, sec
J+11		Kturb, Turbine gain
J+12		Wfnl, No load fuel flow, pu
J+13		T_b, Turbine lag time constant, sec
J+14		Tc, Turbine lead time constant, sec
J+15		Teng, Transport lag time constant for diesel engine, sec
J+16		T_{fload}, Load Limiter time constant, sec
J+17		K_{pload}, Load limiter proportional gain for PI controller
J+18		K_{Iload}, Load limiter integral gain for PI controller
J+19		L_{dref}, Load limiter reference value pu
J+20		Dm, Mechanical damping coefficient, pu
J+21		Ropen, Maximum valve opening rate, pu/sec
J+22		Rclose, Maximum valve closing rate, pu/sec
J+23		$K_I$mw, Power controller (reset) gain
J+24		Aset, Acceleration limiter setpoint, pu/sec

CONs	Value	Description
J+25		K_a, Acceleration limiter gain
J+26		T_a, Acceleration limiter time constant, sec (> 0)
J+27		T_{rate}, Turbine rating (MW)[a]
J+28		db, Speed governor deadband
J+29		Tsa, Temperature detection lead time constant, sec
J+30		Tsb, Temperature detection lag time constant, sec
J+31		Rup, Maximum rate of load limit increase
J+32		Rdown, Maximum rate of load limit decrease
J+33		DBH (pu), deadband for overspeed, (≥ 0)
J+34		DBL (pu), deadband for underspeed, (≤ 0)

[a]If the turbine rating [CON(J+27)] is greater than zero, the input P_{ELEC} is converted in the model to per unit on turbine rating base, else P_{ELEC} is converted to per unit on machine base.

STATEs	Description
K	Machine Electrical Power Measurement
K+1	Governor Differential Control
K+2	Governor Integral Control
K+3	Turbine Actuator
K+4	Turbine Lead-Lag
K+5	Turbine load limiter measurement
K+6	Turbine Load Limiter Integral Control
K+7	Supervisory Load Control
K+8	Acceleration Control
K+9	Temperature Detection Lead-Lag

VARs	Description
L	Load Reference
L+1	Output of Load Limiter PI Control
L+2	Output of Governor PID Control
L+3	Low Value Select Output
L+4	Output of Turbine Actuator
L+5	Output of Turbine Lead-Lag
L+6	Supervisory Load Controller Setpoint, Pmwset
L+7 . . . L +19	Delay Table
L+20	Dead Band
L+21	Speed Deadband output

R and DM in pu on Turbine MW base when T_{rate} is specified and in pu on generator MVA base when T_{rate} is not entered.

```
IBUS, 'USRMDL', ID, 'GGOV1DU'   5   0   2   35   10   22   ICON(M) and
 ICON(M+1), CON(J) to CON(J+34)   /
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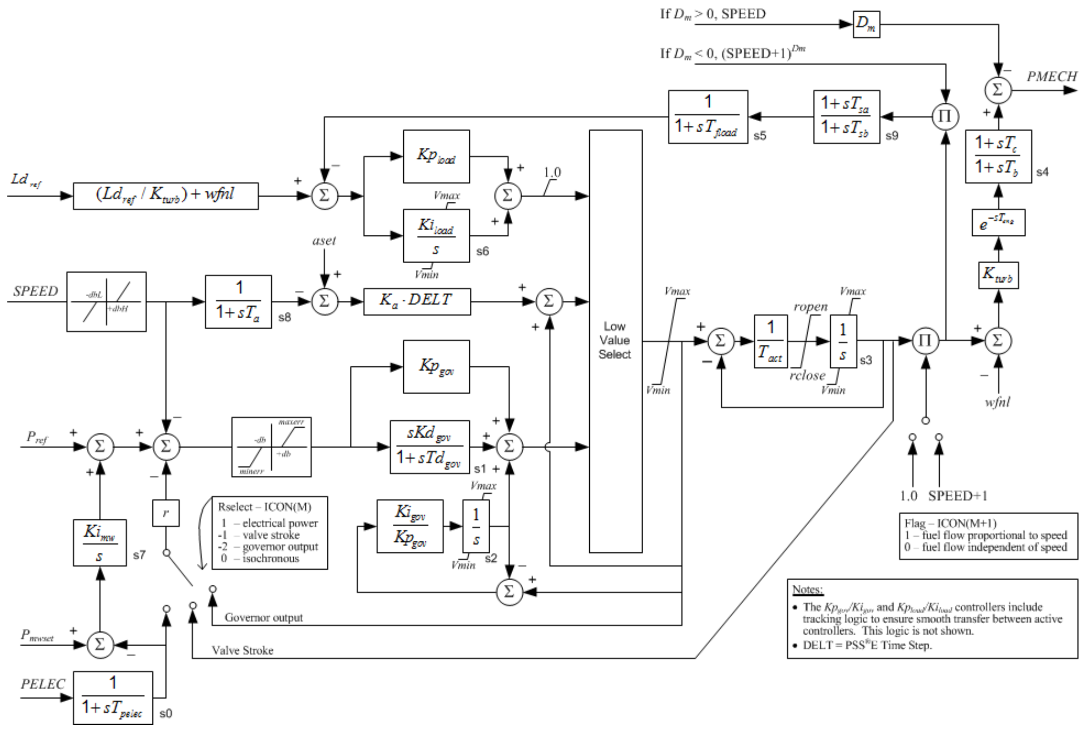


Notes:

a. This model can be used to represent a variety of prime movers controlled by PID governors. It is suitable, for example, for representation of:

- gas turbine and single shaft combined cycle turbines
- diesel engines with modern electronic or digital governors
- steam turbines where steam is supplied from a large boiler drum or a large header whose pressure is substantially constant over the period under study simple hydro turbines in dam configurations where the water column length is short and water inertia effects are minimal

b. Per unit parameters are on base of the turbine MW base (T_{rate}). If no value is entered for T_{rate}, parameters are specified on generator MVA base.

c. The range of fuel valve travel and of fuel flow is unity. Thus the largest possible value of V_{MAX} is 1.0 and the smallest possible value of V_{MIN} is zero. V_{MAX} may, however, be reduced below unity to represent a loading limit that may be imposed by the operator or a supervisory control system. For gas turbines V_{MIN} should normally be greater than zero and less than w_{fnl} to represent a minimum firing limit. The value of fuel flow at maximum output must be less than, or equal to unity, depending on the value of k_{turb}.

d. The parameter T_{eng} is provided for use in representing diesel engines where there is a small but measurable transport delay between a change in fuel flow setting and the development of torque. In the majority of cases T_{eng} should be zero.

e. The parameter Flag is provided to recognize that fuel flow, for a given fuel valve stroke, can be proportional to engine speed. This is the case for GE gas turbines and for diesel engines with positive displacement fuel injectors. Flag should be set to unity for all GE gas turbines and most diesel engines. Flag should be set to zero where it is known that the fuel control system keeps fuel flow independent of engine speed.

f. The load limiter module may be used to impose a maximum output limit such as an exhaust temperature limit. To do this the time constant T_{fload} should be set to represent the time constant in the measurement of temperature (or other signal), and the gains of the limiter, K_{pload}, K_{iload}, should be set to give prompt stable control when on limit. The load limit can be deactivated by setting the parameter L_{dref} to a high value.

g. The parameter D_m can represent either the variation of engine power with shaft speed or the variation of maximum power capability with shaft speed.

- If Dm is positive it describes the falling slope of the engine speed versus power characteristic as speed increases. A slightly falling characteristic is typical for reciprocating engines and some aeroderivative turbines.
- If Dm is negative the engine power is assumed to be unaffected by shaft speed, but the maximum permissible fuel flow is taken to fall with falling shaft speed. This is characteristic of single shaft industrial gas turbines.

h. This model includes a simple representation of a supervisory load controller. This controller is active if the parameter K_{imw} is non-zero. The load controller is a slow acting reset loop that adjusts the speed/load reference of the turbine governor to hold the electrical power output of the unit at its initial condition value P_{mwset}. P_{mwset} is given a value automatically when the model is initialized and stored in VAR(L+6), and can be changed thereafter. The load controller must be adjusted to respond gently relative to the speed governor. A typical value for K_{imw} is 0.01, corresponding to a reset time of 100 seconds. Setting K_{imw} to 0.001 corresponds to a relatively slow acting load controller.

i. The parameters A_{set}, K_a, and T_a describe an acceleration limiter. These parameters may be set to zero if the limiter is not active.

j. The parameter db is the speed governor dead band. This parameter is in terms of per unit speed.

k. Tsa and Tsb are provided to augment the exhaust gas temperature measurement subsystem in gas turbines.

l. R_{up} and R_{down} specify the maximum rate of increase and decrease of the output of the load limit controller (K_{pload}/K_{iload}).

7.14. GOVSTEAMEUU

Simplified Boiler and Steam Turbine with PID governor

CON	Value	Description
J		Trate (MW), Turbine rating
J+1		Tp (s), Power transducer time constant
J+2		Ke (pu), Power controller gain
J+3		Tip (s), Power controller integral time constant (> 0)
J+4		Tdp (s), Power controller derivative time constant
J+5		Tfp (s), Power controller time constant
J+6		Tf (s), Frequency transducer time constant
J+7		kfcor (pu), Frequency corrector gain
J+8		db11 (pu), Frequency corrector deadband upper limit (≥ 0)
J+9		db12 (pu), Frequency corrector deadband lower limit (≤ 0)
J+10		wfmax (pu), Frequency correction upper limit
J+11		wfmin (pu), Frequency correction lower limit
J+12		Pmax (pu), Turbine maximum power
J+13		Ten (s), Hydraulic transducer time constant
J+14		Tw (s), Speed transducer time constant
J+15		Kwcor (pu), Speed-governor gain
J+16		db21 (pu), Speed governor deadband upper limit (≥ 0)
J+17		db22 (pu), Speed governor deadband lower limit (≤ 0)
J+18		wwmax (pu), Speed governor upper limit
J+19		wwmin (pu), Speed governor lower limit
J+20		wmax1 (pu), Emergency Speed Control lower limit (entered as pu speed) (wmax1 < wmax2)
J+21		wmax2 (pu), Emergency Speed Control upper limit (entered as pu speed)
J+22		Tvhp (s), Control valves servo time constant (> 0)
J+23		Cho (pu/s), Control valves opening rate limit (> 0)
J+24		Chc (pu/s), Control valves closing rate limit (< 0)
J+25		Hhpmax (pu), Maximum control valve position
J+26		Tvip (s), Intercept valve servo time constant (> 0)
J+27		Cio (pu/s), Intercept valves opening rate limit (> 0)
J+28		Cic (pu/s), Intercept valves closing rate limit (< 0)
J+29		Simx (pu), Intercept valve transfer limit (> 0)
J+30		Trh (s), Reheater time constant
J+31		Prhmax (pu), Maximum limit of low-pressure turbine
J+32		Thp (s), High pressure turbine time constant
J+33		Khp, Fraction of total turbine output generated by HP turbine (0 ≤ Khp ≤ 1)
J+34		Tlp (s), Low pressure turbine time constant

CON	Value	Description
J+35		Klp, Fraction of total turbine output generated by LP turbine (0 ≤ Klp ≤ 1)
J+36		Tb (s), Boiler time constant (> 0)

STATE	Description
K	Frequency transducer
K+1	Power transducer
K+2	Power controller integrator
K+3	Power controller derivative
K+4	Hydraulic transducer
K+5	Speed transducer
K+6	Boiler
K+7	HP turbine
K+8	Reheater
K+9	Low pressure turbine
K+10	Servo control valve
K+11	Servo intercept valve

VAR	Description
L	Fref, Frequency reference
L+1	Wref, Speed reference
L+2	Output of frequency error deadband
L+3	Output of speed error deadband

DYR Syntax:

```
IBUS    'USRMDL'    ID    'GOVSTEAMEUU'    5     0        0      37      12
   4       CON(J) to CON(J+36)    /
```

Note(s):

This model represents the GovSteamEU model configuration given in IEC 61970-302, Edition 1.0 2018-04. The model block diagram, the parameter names shown in the model block diagram, and some of the model details given below are from this document

1. Parameters are in per unit of Turbine MW base.
2. To represent a non-reheat turbine, set Trh (i.e., CON(J+31))=0 and Tlp (i.e., CON(J+32)) to about 0.5.
3. F(v) is the minimum value selection.
4. Frequency (f) is the per unit bus frequency.

PSS®E Specific Model notes:

1. Per discussions in CGMES (The **Common Grid Model Exchange Specification**, which is an IEC technical specification based on the IEC Common Information Model), in using this model, the present structure

of the model requires that the machine Pelec (electrical power output) be equal to Pmech (turbine mechanical power output). This means that the stator resistance as well as the resistance of the implicit transformer (in power flow generator record) has to be set to zero. If this is not done, the model may not initialize correctly.

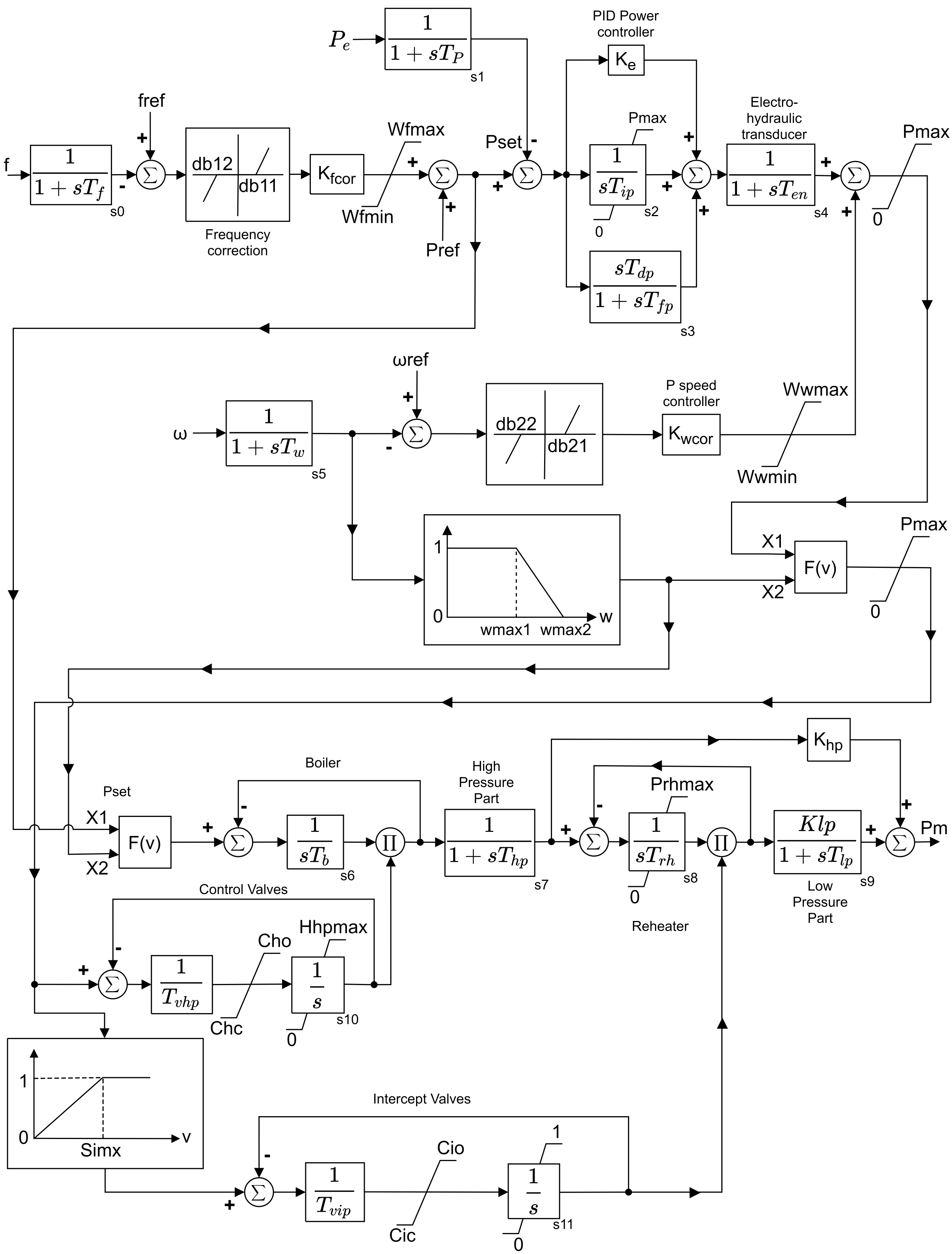
2. The Turbine MW base is specified in CON(J). If this is zero, then the turbine parameters are assumed to be in per unit of the machine MVA base.

3. If wmax1 is set equal to wmax2 (i.e., CON(J+20) is equal to CON(J+21)), the output of that block will be assumed equal to zero if the input (w) is greater than wmax1.

4. wmax1 and wmax2 are entered as per unit speed (and not as per unit speed deviation).

5. If Trh (i.e., CON(J+31)) is set equal to zero, then state s8 is completely ignored. This means that the input to the block s9 will be equal to output of block s7. This means that the intercept valve dynamics (represented by CONs J+26 through J+28) will be used only if Trh > 0.

6. Sum of Khp and Klp (HP and LP turbine fractions) cannot be greater than 1.0.



PID Power controller
Ke
Pe
s1
fref
f
s0
db12
db11
Frequency correction
Kfcor
Wfmax
Wfmin
Pref
Pset
Pmax
s2
0
s3
Electro-hydraulic transducer
s4
Pmax
0
ωref
ω
s5
db22
db21
P speed controller
Kwcor
Wwmax
Wwmin
1
0
w
wmax1 wmax2
X1
F(v)
X2
Pmax
0
Khp
Boiler
Pset
X1
F(v)
X2
s6
High Pressure Part
s7
Prhmax
s8
0
Reheater
s9
Low Pressure Part
Pm
Control Valves
Cho
Hhpmax
Chc
s10
0
1
0
Simx
v
Intercept Valves
Cio
1
Cic
s11
0

7.15. HYGOV

Hydro Turbine-Governor

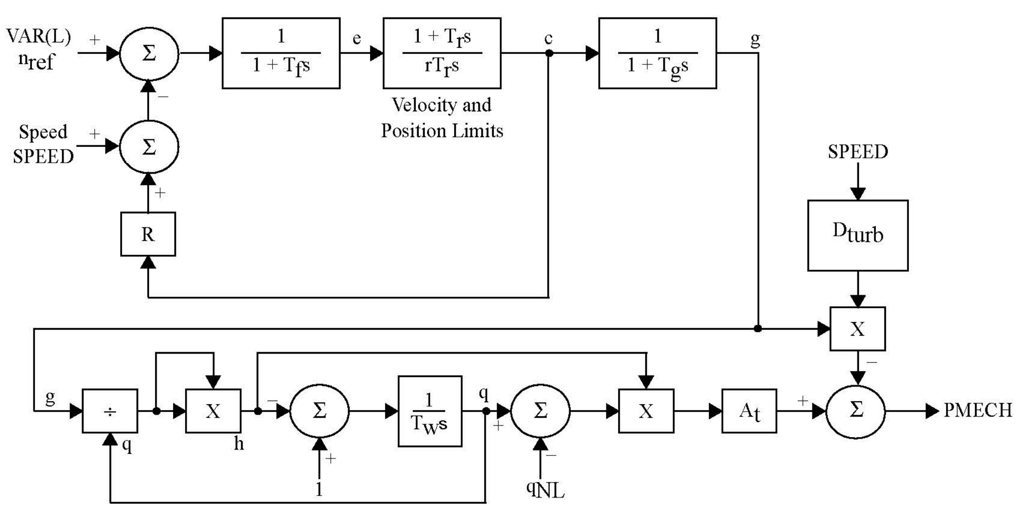
CONs	Value	Description
J		R, permanent droop
J+1		r, temporary droop
J+2		T_r (>0) governor time constant
J+3		T_f (>0) filter time constant
J+4		T_g (>0) servo time constant
J+5		± VELM, gate velocity limit
J+6		G_{MAX}, maximum gate limit
J+7		G_{MIN}, minimum gate limit
J+8		T_W (>0) water time constant
J+9		A_t, turbine gain
J+10		D_{turb}, turbine damping
J+11		q_{NL}, no power flow

STATEs	Description
K	e, filter output
K+1	c, desired gate
K+2	g, gate opening
K+3	q, turbine flow

VARs	Description
L	Speed reference
L+1	h, turbine head

R, r, and D_{turb} are in pu on generator MVA base.

```
IBUS, 'HYGOV', ID, CON(J) to CON(J+11)   /
```



7.16. HYGOV2

Hydro Turbine-Governor

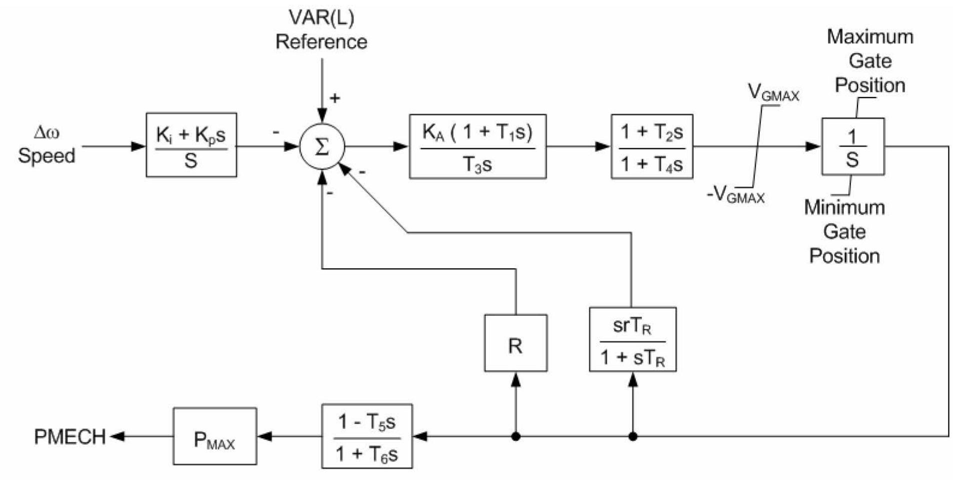
CONs	Value	Description
J		K_p
J+1		K_I
J+2		K_A
J+3		T_1
J+4		T_2
J+5		T_3 (> 0)
J+6		T_4 (> 0)
J+7		T_5
J+8		T_6 (> 0)
J+9		T_r(> 0)
J+10		r, temporary droop
J+11		R, permanent droop
J+12		$\pm V_{GMAX}$
J+13		Maximum gate position, $_{GMAX}$
J+14		Minimum gate position, $_{GMIN}$
J+15		P_{MAX}

STATEs	Description
K	Filter
K+1	Governor
K+2	Governor speed
K+3	Droop
K+4	Gate position
K+5	Penstock

VAR	Description
L	Reference

R. r, and P_{MAX} are in pu on generator MVA base.

```
IBUS, 'HYGOV2', ID, CON(J) to CON(J+15)   /
```


VAR(L)
Reference
Maximum
Gate
Position
Δω
Speed
$\frac{K_i + K_p s}{S}$
Σ
$\frac{K_A(1 + T_1 s)}{T_3 s}$
$\frac{1 + T_2 s}{1 + T_4 s}$
V_{GMAX}
$-V_{GMAX}$
$\frac{1}{S}$
Minimum
Gate
Position
R
$\frac{s r T_R}{1 + s T_R}$
PMECH
P_{MAX}
$\frac{1 - T_5 s}{1 + T_6 s}$

7.17. HYGOV2DU

Hydro Turbine-Governor

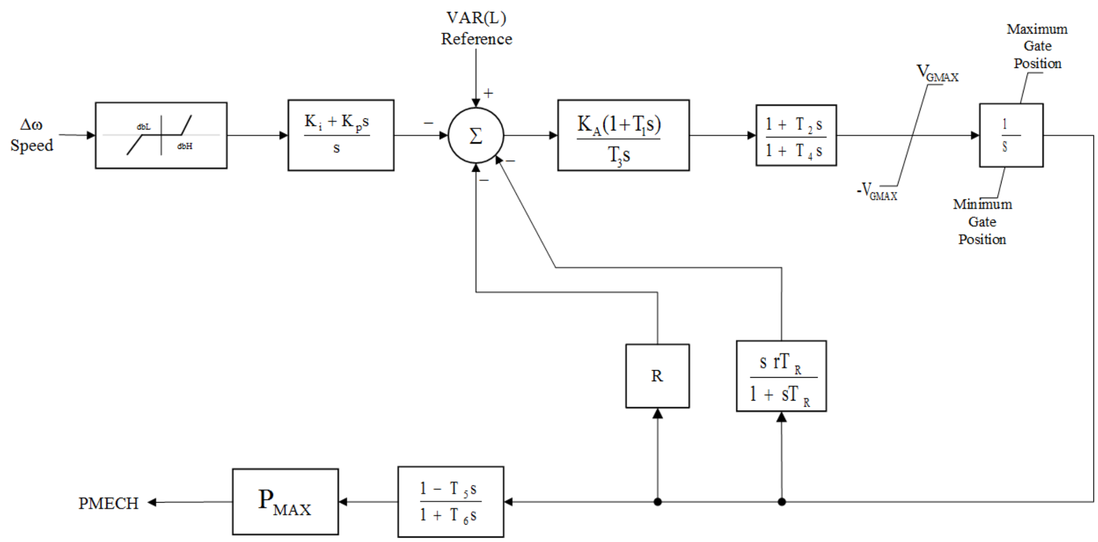
CONs	Value	Description
J		K_p
J+1		K_I
J+2		K_A
J+3		T_1
J+4		T_2
J+5		T_3 (> 0)
J+6		T_4 (> 0)
J+7		T_5
J+8		T_6 (> 0)
J+9		T_R(> 0)
J+10		r, temporary droop
J+11		R, permanent droop
J+12		$\pm V_{GMAX}$
J+13		Maximum gate position, G_{MAX}
J+14		Minimum gate position, G_{MIN}
J+15		P_{MAX}
J+16		DBH (pu), deadband for overspeed, (≥ 0)
J+17		DBL (pu), deadband for underspeed, (≤ 0)
J+18		T_{Rate} (MW), turbine rating, if zero, then MBASE used

STATEs	Description
K	Filter
K+1	Governor
K+2	Governor speed
K+3	Droop
K+4	Gate position
K+5	Penstock

VAR	Description
L	Reference
L+1	Deadband output

R, r, and P_{MAX} are in pu on generator MVA base.

```
IBUS, 'USRMDL', ID, 'HYGOV2DU'   5   0   0   19   6   2   CON(J) to
 CON(J+18)   /
```


VAR(L)
Reference
Δω
Speed
dbL
dbH
$\frac{K_i + K_p s}{s}$
Σ
$\frac{K_A(1+T_1 s)}{T_3 s}$
$\frac{1 + T_2 s}{1 + T_4 s}$
V_{GMAX}
$-V_{GMAX}$
Maximum
Gate
Position
$\frac{1}{s}$
Minimum
Gate
Position
R
$\frac{s\, rT_R}{1 + sT_R}$
PMECH
P_{MAX}
$\frac{1 - T_5 s}{1 + T_6 s}$

7.18. HYGOVDU

Hydro Turbine-Governor

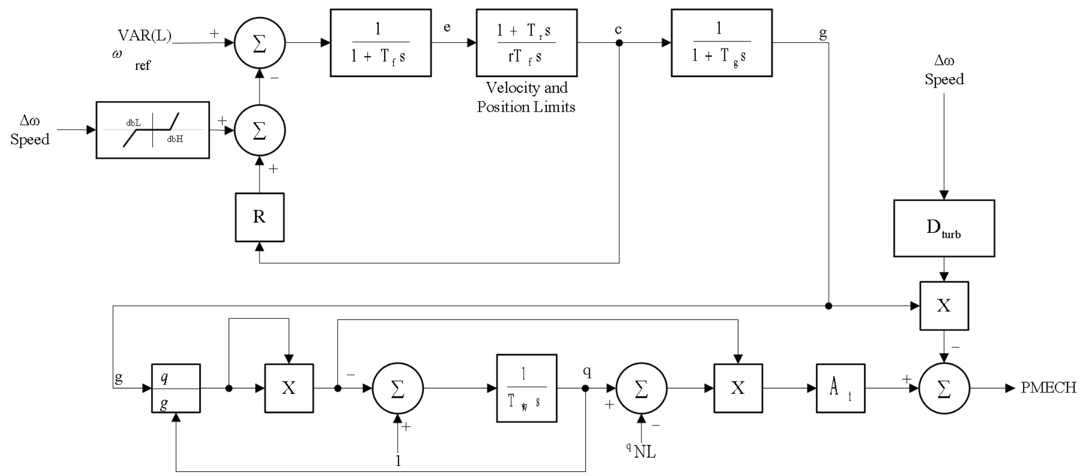
CONs	Value	Description
J		R, permanent droop
J+1		r, temporary droop
J+2		T_r (>0) governor time constant
J+3		T_f (>0) filter time constant
J+4		T_g (>0) servo time constant
J+5		± VELM, gate velocity limit
J+6		G_{MAX}, maximum gate limit
J+7		G_{MIN}, minimum gate limit
J+8		T_W (>0) water time constant
J+9		A_t, turbine gain
J+10		D_{turb}, turbine damping
J+11		q_{NL}, no power flow
J+12		DBH (pu), deadband for overspeed, (≥ 0)
J+13		DBL (pu), deadband for underspeed, (≤ 0)
J+14		T_{Rate} (MW), turbine rating, if zero, then MBASE used

STATEs	Description
K	e, filter output
K+1	c, desired gate
K+2	g, gate opening
K+3	q, turbine flow

VARs	Description
L	Speed reference
L+1	h, turbine head
L+2	Deadband output

R, r, and D_{turb} are in pu on generator MVA base.

```
IBUS, 'USRMDL', ID, 'HYDGOVDU'   5   0   0   15   4   3   CON(J) to CON(J
+14)   /
```


VAR(L)
ω ref
Δω
Speed
dbL
dbH
R
e
Velocity and
Position Limits
c
g
Δω
Speed
D turb
X
q
g
X
1
q NL
X
A t
PMECH

7.19. HYGOVM

Hydro Turbine-Governor Lumped Parameter Model

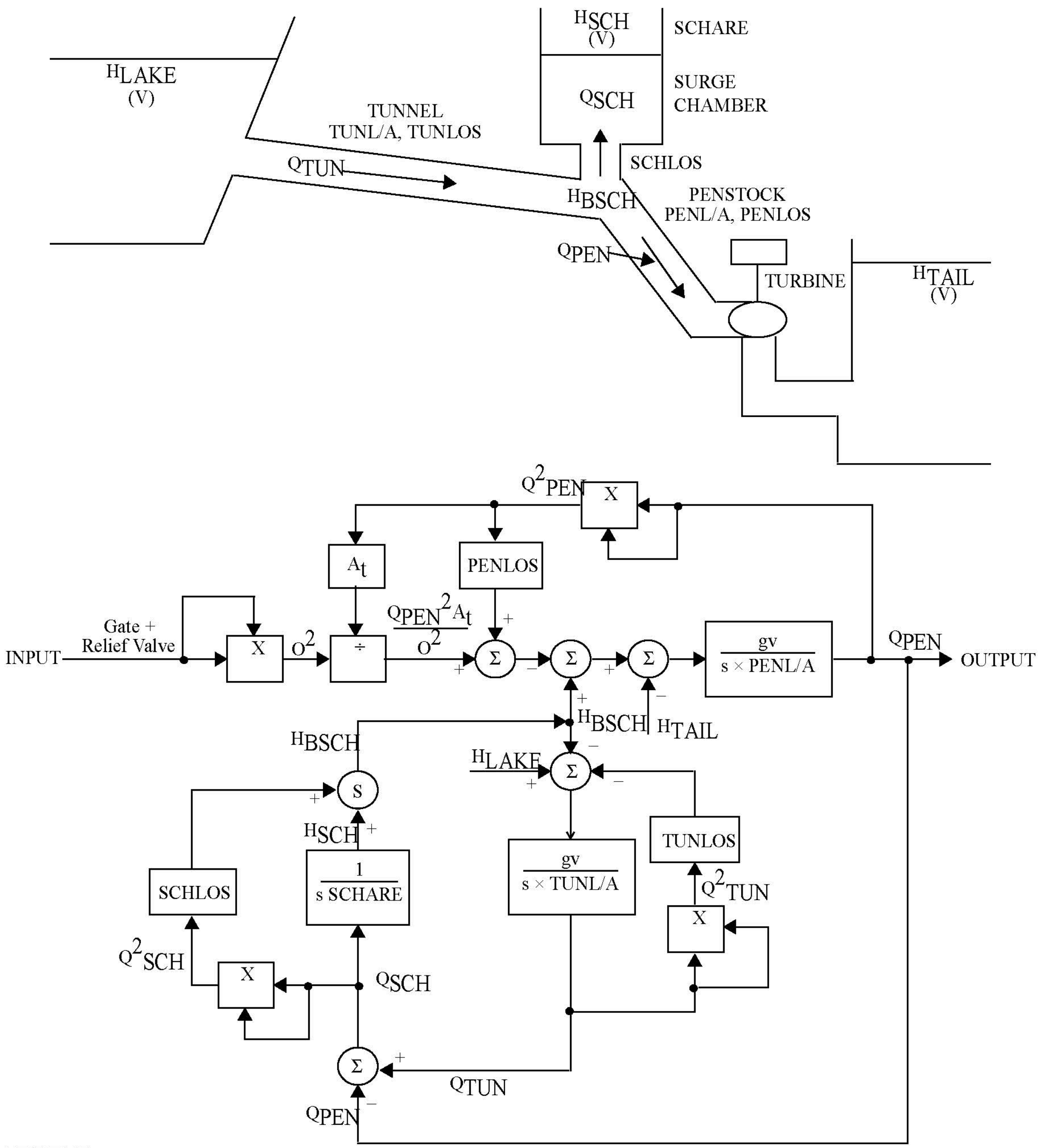
CONs	Value	Description
J		OPTIONS: 0 English units, relief valve 1 Metric units, relief valve 10 English units, jet deflector 11 Metric units, jet deflector
J+1		P_{rated}, rated turbine power (MW)
J+2		Q_{rated}, rated turbine flow (cfs or cms)
J+3		H_{rated}, rated turbine head (ft or m)
J+4		G_{rated}, gate position at rated conditions (pu)
J+5		QNL, no power flow (pu of Q_{rated})
J+6		R, permanent droop (pu)
J+7		r, temporary droop (pu)
J+8		T_r, governor time constant (> 0) (sec)
J+9		T_f, filter time constant (> 0) (sec)
J+10		T_G, servo time constant (> 0) (sec)
J+11		MXGTOR, maximum gate opening rate (pu/sec)
J+12		MXGTCR, maximum gate closing rate (< 0) (pu/sec)
J+13		MXBGOR, maximum buffered gate opening rate (pu/sec)
J+14		MXBGCR, maximum buffered gate closing rate (< 0) (pu/sec)
J+15		BUFLIM, buffer upper limit (pu)
J+16		G_{MAX}, maximum gate limit (pu)
J+17		G_{MIN}, minimum gate limit (pu)
J+18		RVLVCR, relief valve closing rate (< 0) (pu/sec) or MXJDOR, maximum jet deflector opening rate (pu/sec)
J+19		RVLMAX, maximum relief valve limit (pu) or MXJDCR, maximum jet deflector closing rate (< 0) (pu/sec)
J+20		H_{LAKE}, lake head (ft or m)
J+21		H_{TAIL}, tail head (ft or m)
J+22		PENL/A, summation of penstock, scroll case and draft tube lengths/ cross sections (> 0) (1/ft or 1/m)
J+23		PENLOS, penstock head loss coefficient (ft/cfs^2 or m/cms^2)
J+24		TUNL/A, summation of tunnel lengths/cross sections (>0) (1/ft or 1/ m)
J+25		TUNLOS, tunnel head loss coefficient (ft/cfs^2 or m/cms^2)
J+26		SCHARE, surge chamber effective cross section (>0) (fT^2 or m^2)
J+27		SCHMAX, maximum water level in surge chamber (ft or m)

CONs	Value	Description
J+28		SCHMIN, minimum water level in surge chamber (ft or m)
J+29		SCHLOS, surge chamber orifice head loss coefficient (ft/cfs^2 or m/cms^2)
J+30		DAMP1, turbine damping under RPM1
J+31		RPM1, overspeed (pu)
J+32		DAMP2, turbine damping above RPM2
J+33		RPM2, overspeed (pu)

STATEs	Description
K	e, filter output
K+1	c, desired gate
K+2	g, gate opening
K+3	Relief valve opening or jet deflector position
K+4	Q_{PEN}, penstock flow (cfs or cms)
K+5	Q_{TUN}, tunnel flow (cfs or cms)
K+6	H_{SCH}, surge chamber head (ft or m)

VARs	Description
L	Speed reference
L+1	Turbine head (ft or m)
L+2	Turbine flow (cfs or cms)
L+3	Relieve valve flow or deflected jet flow (cfs or cms)
L+4	Head at surge chamber base (ft or m)
L+5	Internal memory

```
IBUS, 'HYGOVM', ID, CON(J) to CON(J+33)   /
```

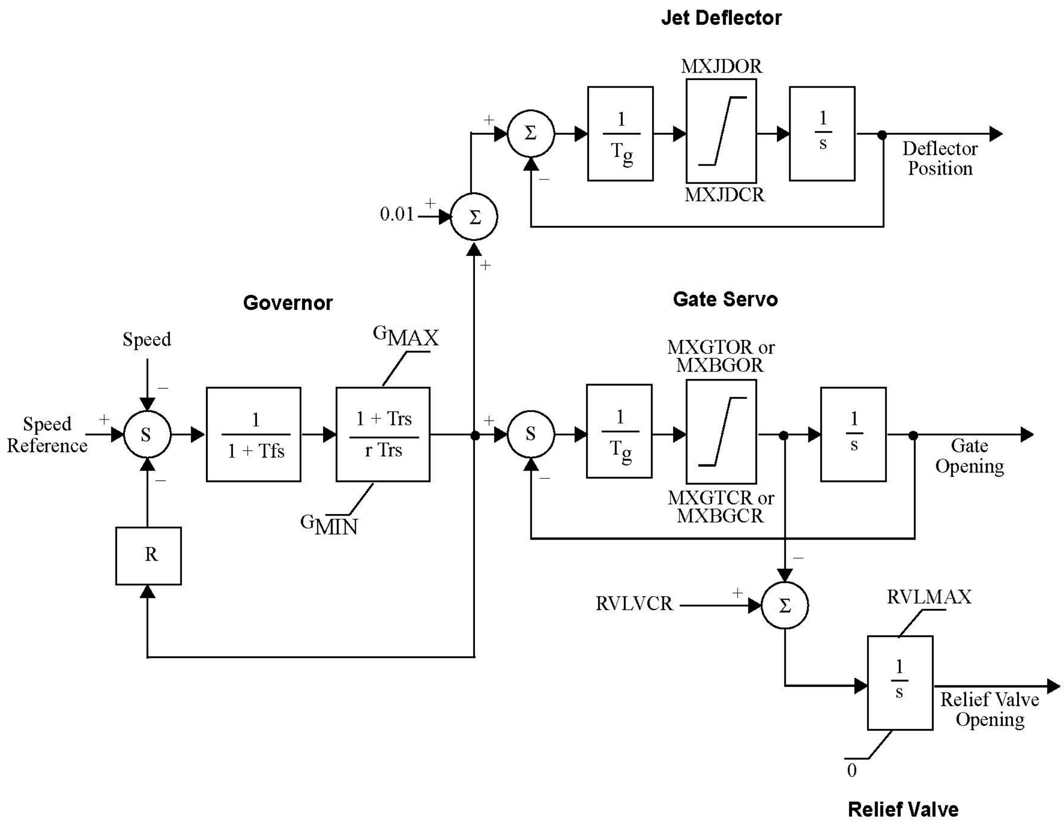


LEGEND

gv	Gravitational acceleration	At	Turbine flow gain
TUNL/A	Summation of length/cross section of tunnel	O	Gate + relief valve opening
SCHARE	Surge chamber cross section	H^{SCH}	Water level in surge chamber
PENLOS	Penstock head loss coefficient	Q^{PEN}	Penstock flow
TUNLOS	Tunnel head loss coefficient	Q_{TUN}	Tunnel flow

FSCH	Surge chamber orifice head loss coefficient	QSCH	Surge chamber flow
PENL/A	Summation of length/cross section of penstock,scroll case and draft tube		

Hydro Turbine Governor Lumped Parameter Model



LEGEND

R	Permanent droop	MXBGCR	Maximum buffered gate closing rate
r	Temporary droop	GMAX	Maximum gate limit
T_r			
T_f			
T_G			
MXGTOR	Maximum gate opening rate	MXJDOR	Maximum jet deflector opening rate
MXGTCR	Maximum gate closing rate	MXJDCR	Maximum jet deflector closing rate

MXBGOR	Maximum buffered gate opening rate

7.20. HYGOVR1

Fourth order lead-lag hydro-turbine

CONs	Value	Description
J		db_1
J+1		err
J+2		T_d (sec)
J+3		T_1 (sec)
J+4		T_2 (sec) q
J+5		T_3 (sec)
J+6		T_4 (sec)
J+7		T_5 (sec)
J+8		T_6 (sec)
J+9		T_7 (sec)
J+10		T_8 (sec)
J+11		K_P
J+12		R
J+13		T_t
J+14		K_G
J+15		T_P (sec)
J+16		VEL_{OPEN}
J+17		VEL_{CLOSE}
J+18		P_{MAX}
J+19		P_{MIN}
J+20		db_2
J+21		T_W (>0) water time constant
J+22		A_t, turbine gain
J+23		D_{turb}, turbine damping
J+24		q_{NL}, no power flow
J+25		T_{rate} (Turbine MW rating)

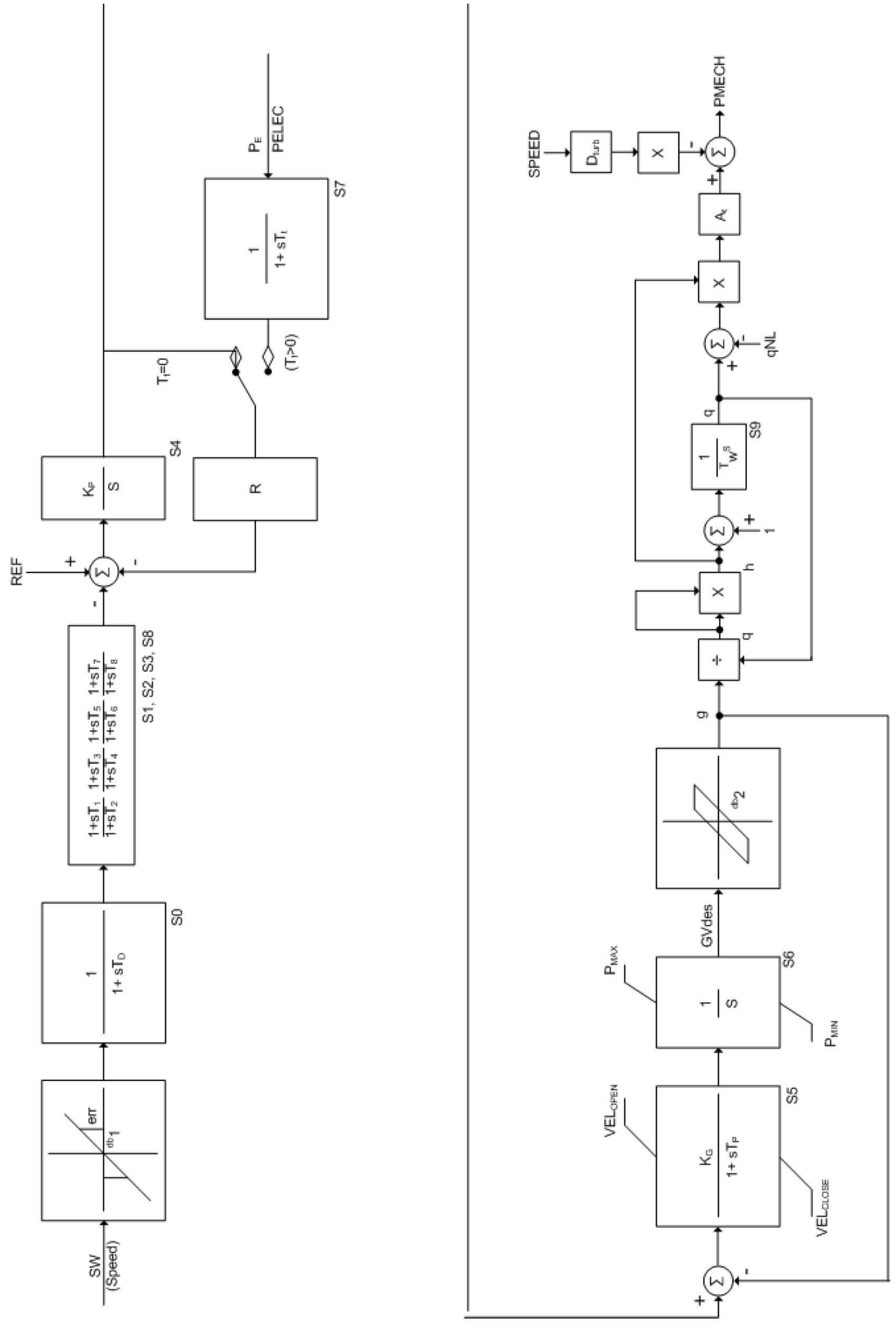
STATEs	Description
K	Output, T_d
K+1	Lead-lag T_1
K+2	Lead-lag T_2
K+3	Lead-lag T_3
K+4	Integrator K_p
K+5	Valve speed
K+6	Gate position
K+7	Generator power
K+8	Lead-lag T_3

STATEs	Description
K+9	q, turbine flow

VARs	Description
L	Reference
L+1	$Deadband_1$ In
L+2	$Deadband_1$ Out
L+3	$Deadband_2$ In
L+4	$Deadband_2$ Out
L+5	h, turbine head

R, P_{MAX}, and P_{MIN} are in pu on turbine MW base if T_{rate} is > 0, else in pu of generator MVA

```
IBUS, 'HYGOVR1', ID, CON(J) to CON(J+25)   /
```


SW
(Speed)
err
db1
1
1+ sT_D
S0
S1, S2, S3, S8
REF
K_P
s
S4
R
T_t=0
(T_t>0)
P_E
PELEC
1
1+ sT_t
S7
VEL_OPEN
VEL_CLOSE
K_G
1+ sT_P
S5
P_MAX
P_MIN
1
s
S6
GVdes
db2
g
q
h
S9
qNL
SPEED
D_turb
A_t
PMECH

7.21. HYGOVT

Hydro Turbine-Governor Traveling Wave Model

ICONs	Value	Description
M1[a]		Number of VARs representing the penstock
M+1		Travel time between VARs at the penstock, in time steps
M+2		Number of VARs representing the tunnel
M+3		Travel time between VARs at the tunnel, in time steps
M+4		Number of time steps since the last penstock update
M+5		Number of time steps since the last tunnel update

[a]ICON(M) through ICON(M+5) are internal ICONs. Users need not input any values for these ICONs in the DYR record.

CONs	Value	Description
J		OPTIONS: 0 English units, relief valve 1 Metric units, relief valve 10 English units, jet deflector 11 Metric units, jet deflector
J+1		P_{rated}, rated turbine power (MW)
J+2		Q_{rated}, rated turbine flow (cfs or cms)
J+3		H_{rated}, rated turbine head (ft or m)
J+4		G_{rated}, gate position at rated conditions (pu)
J+5		QNL, no power flow (pu of Q_{rated})
J+6		R, permanent droop
J+7		r, temporary droop (pu)
J+8		T_r, governor time constant (> 0) (sec)
J+9		T_f, filter time constant (> 0) (sec)
J+10		T_G, servo time constant (> 0) (sec)
J+11		MXGTOR, maximum gate opening rate (pu/sec)
J+12		MXGTCR, maximum gate closing rate (< 0) (pu/sec)
J+13		MXBGOR, maximum buffered gate opening rate (pu/sec)
J+14		MXBGCR, maximum buffered gate closing rate (< 0) (pu/sec)
J+15		BUFLIM, buffer upper limit (pu)
J+16		G_{MAX}, maximum gate limit (pu)
J+17		G_{MIN}, minimum gate limit (pu)
J+18		RVLVCR, relief valve closing rate (< 0) (pu/sec) or MXJDOR, maximum jet deflector opening rate (pu/sec)
J+19		RV_{Lmax}, maximum relief valve limit (pu) or MXJDCR, maximum jet deflector closing rate (< 0) (pu/sec)

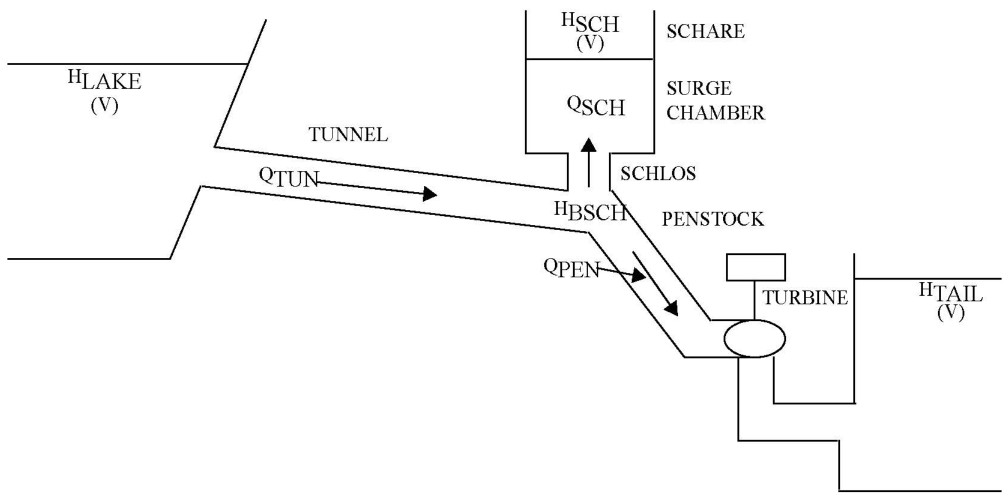
CONs	Value	Description
J+20		H_{LAKE}, lake head (ft or m)
J+21		H_{TAIL}, tail head (ft or m)
J+22		PENLGTH, penstock length (ft or m)
J+23		PENLOS, penstock head loss coefficient (ft/cfs^2 or m/cms^2)
J+24		TUNLGTH, tunnel length (ft or m)
J+25		TUNLOS, tunnel head loss coefficient (ft/cfs^2 or m/cms^2)
J+26		SCHARE, surge chamber effective cross section (>0) (fT^2 or m^2)
J+27		SCHMAX, maximum water level in surge chamber (ft or m)
J+28		SCHMIN, minimum water level in surge chamber (ft or m)
J+29		SCHLOS, surge chamber orifice head loss coefficient (ft/cfs^2 or m/cms^2)
J+30		DAMP1, turbine damping under RPM1
J+31		RPM1, overspeed (pu)
J+32		DAMP2, turbine damping above RPm^2
J+33		RPm^2, overspeed (pu)
J+34		PENSPD, penstock wave velocity (>0) (ft/sec or m/sec)
J+35		PENARE, penstock cross section (>0) (fT$_2$ or m^2)
J+36		TUNSPD, tunnel wave velocity (>0) (ft/sec or m/sec)
J+37		TUNARE, tunnel cross section (>0) (fT$_2$ or m^2)

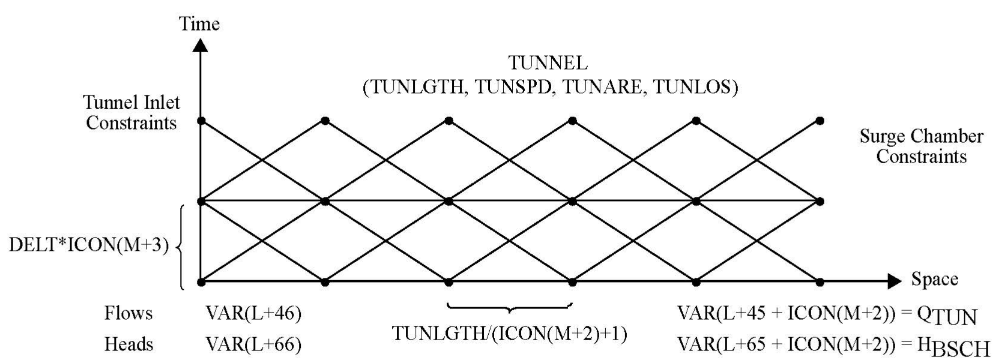
STATEs	Description
K	e, filter output
K+1	c, desired gate
K+2	g, gate opening
K+3	Relief valve opening or jet deflector position
K+4	Q_{PEN}, Penstock flow at the surge chamber end
K+5	Q_{TUN}, Tunnel flow at the surge chamber end
K+6	H_{SCH}, surge chamber head (ft or m)

VARs	Description
L	Speed reference
L+1	Turbine head (ft or m)
L+2	Turbine flow (cfs or cms)
L+3	Relieve valve flow or deflected jet flow (cfs or cms)
L+4	Head at surge chamber base (ft or m)
L+5	Internal memory
L+6	Penstock flow at surge chamber ends (cfs or cms)
L+7	Flows along the penstock (cfs or cms)
...	
L+25	
L+26	

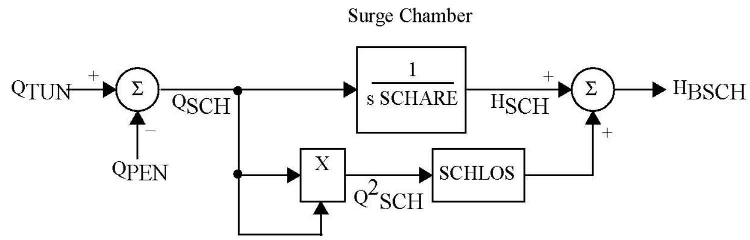
VARs	Description
...	Heads along the penstock (ft or m)
L+45	
L+46	Penstock head at surge chamber end (ft or m)
L+47	Flows along the tunnel (cfs or cms)
...	
L+65	
L+66	Tunnel head at lake end (ft or m)
L+67	Heads along the tunnel (ft or m)
...	
L+85	

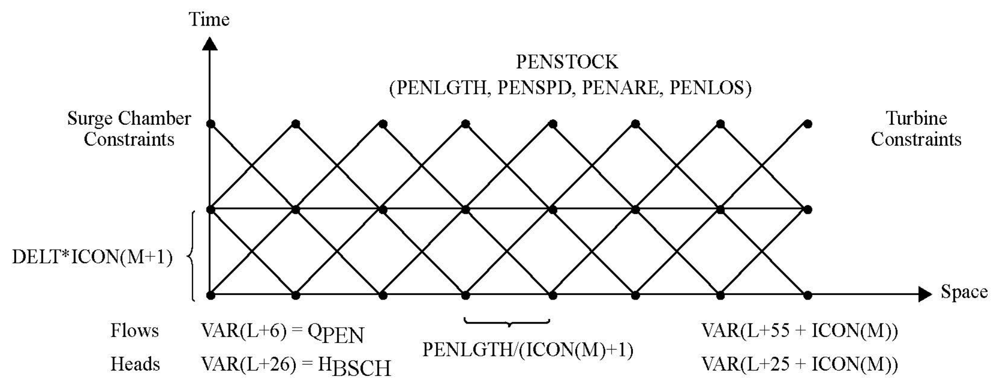
```
IBUS, 'HYGOVT', ID, CON(J) to CON(J+37)   /
```



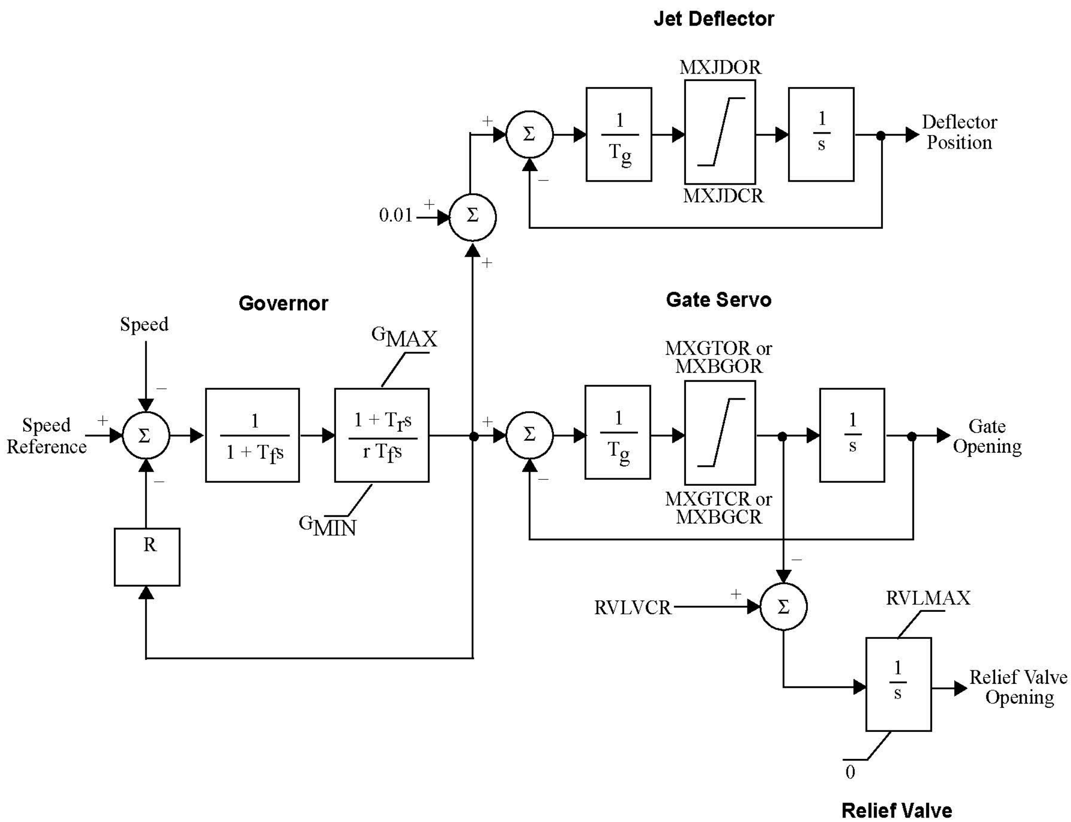


Hydro Turbine-Governor Traveling Wave Model





Hydro Turbine-Governor Traveling Wave Model



LEGEND:

R	Permanent droop	MXBGCR	Maximum buffered gate closing rate
r	Temporary droop	GMAX	Maximum gate limit
Tr	Governor time constant	GMIN	Minimum gate limit
Tf	Filter time constant	RVLVCR	Relief valve closing rate
Tg	Servo time constant	RVLMAX	Maximum relief valve limit
MXGTOR	Maximum gate opening rate	MXJDOR	Maximum jet deflector opening rate
MXGTCR	Maximum gate closing rate	MXJDCR	Maximum jet deflector closing rate
MXBGOR	Maximum buffered gate opening rate		

Hydro Turbine-Governor Traveling Wave Model

7.22. HYG3U1

WECC GP Governor, WECC G2 Governor plus Turbine Model

ICON	Value	Description
M		cflag 1: PID Control 0: Double Derivative
M+1		For internal use (input as 0)

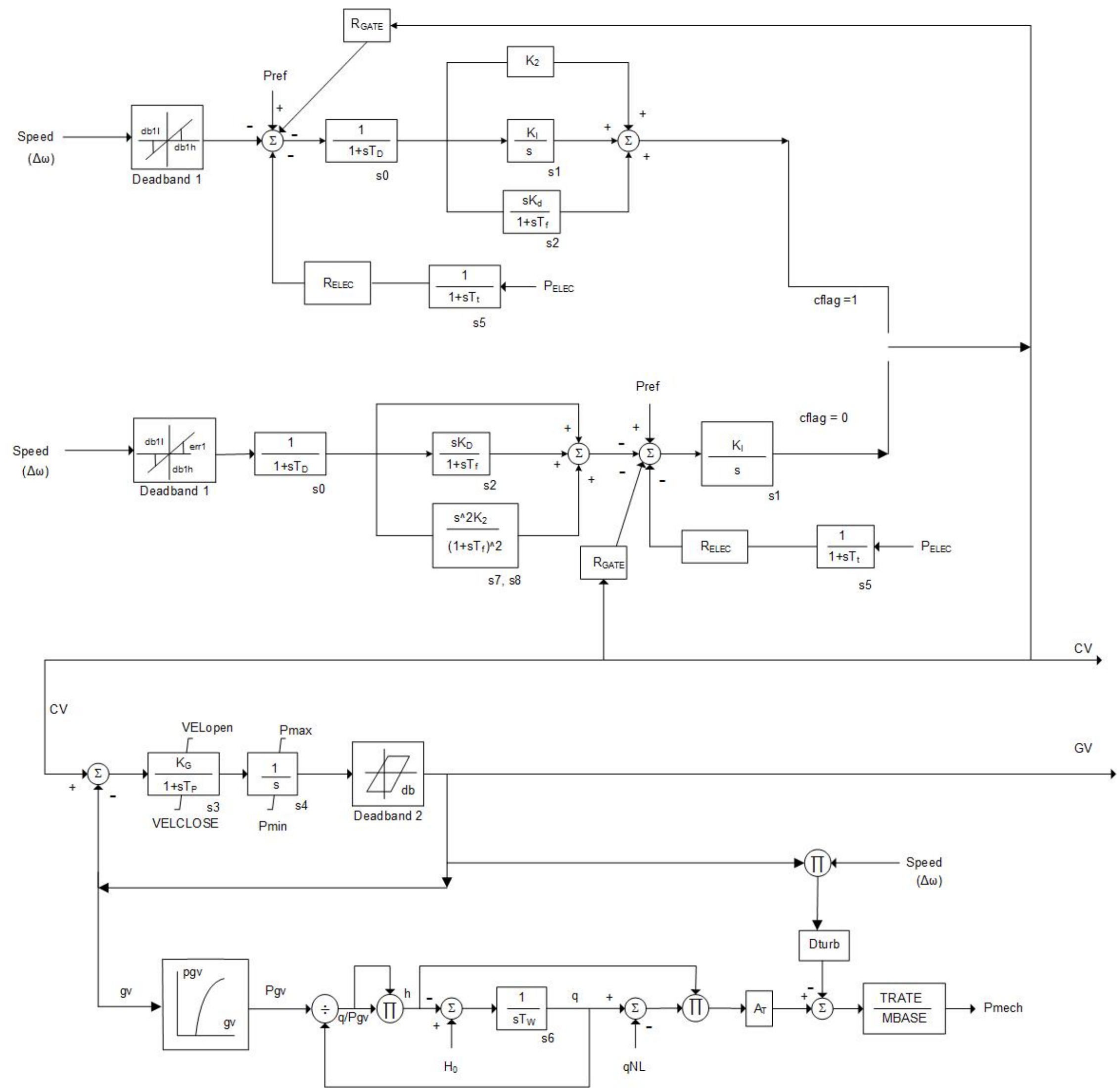
CONs	Value	Description
J		Rgate, steady state droop for governor output feedback
J+1		Relec, steady state droop for electrical power feedback
J+2		T_t Time constant for electrical power(s)
J+3		T_D Input filter time constant(s)
J+4		K_2 (proportional Gain when cflag = 1, gain of double derivative block when cflag = 0)
J+5		K_I Integral Gain
J+6		K_D Derivative gain
J+7		T_F Washout time constant (> 0)(s)
J+8		K_G Gate servo gain
J+9		T_P Gate servo time constant(s)
J+10		VEL_{OPEN} Maximum velocity for gate opening, pu/s (> 0)
J+11		VEL_{CLOSE} Minimum velocity for gate closing, pu/s (< 0)
J+12		P_{MAX} Maximum gate opening
J+13		P_{MIN} Minimum gate opening
J+14		db
J+15		gv1
J+16		pgv1
J+17		gv2
J+18		pgv2
J+19		gv3
J+20		pgv3
J+21		gv4
J+22		pgv4
J+23		gv5
J+24		pgv5
J+25		gv6
J+26		pgv6
J+27		H_0 Turbine nominal head (> 0)
J+28		qnl, no load turbine flow at nominal head

CONs	Value	Description
J+29		T_w, Water Inertia time constant
J+30		A_T
J+31		Dturb, Turbine damping factor
J+32		TRATE, Turbine rating in MW
J+33		db1h, Intentional deadband width high (> 0), (pu frequency deviation)
J+34		err1, Intentional deadband hysteresis (> 0), (pu frequency deviation)
J+35		db1l, Intentional deadband width low (< 0), (pu frequency deviation)

STATEs	Description
K	T_d block, s0
K+1	Integral block, s1
K+2	Derivative block, s2
K+3	Valve, s3
K+4	Integrator, s4
K+5	Pelec measured, s5
K+6	Water inertia, s6
K+7	Double derivative first state, s7
K+8	Double derivative second state, s8

VARs	Description
L	CV
L+1	Deadband_1 Output
L+2	Deadband_2 Input
L+3	Deadband_2 Output = GV
L+4	h

```
IBUS, 'USRMDL'  ID 'HYG3U1', 5  0  2  36  9  5, ICON(M) to ICON(M+1)
 CON(J) to CON(J+35)   /
```



Notes:

1. Per unit parameters are on the base of turbine MW capability as given by the parameter TRATE . If TRATE is specified as zero, then the parameters are assumed to be in per unit of machine MVA rating (MBASE) .
2. db1h, err1 and db2h are per unit frequency deviation.
3. Unintentional deadband (deadband 2) width (db) is per unit power.
4. The curve of gate position versus power (ie. CON(J+15) through CON(J+26)) may be input up to 6 points. The (0.0,0.0) and (1.0,1.0) points are assumed and need not be input. The output is not allowed to go beyond 0.0 and 1.0. However, if Pmax > 1.0, the specified G and P values are scaled by Pmax

7.23. H6EU1

Hydro Turbine with American Governor Company Controller

ICON	Value	Description
M		Flag 0: Speed Mode 1: Load Mode

CONs	Value	Description
J		Re , droop – electrical power
J+1		Rg , droop – gate command
J+2		Tpe , power transducer time constant(s)
J+3		Tsp , speed transducer time constant (s)
J+4		Kp , governor proportional gain (pu)
J+5		Ki , governor integral gain (pu)
J+6		K_D Derivative gain (pu)
J+7		Td , derivative filter time constant (s)
J+8		velm , maximum gate velocity
J+9		gmax , gate opening upper limit
J+10		gmin , gate opening lower limit
J+11		buf , top of gate buffer range
J+12		buv , gate buffer velocity
J+13		Kg , pilot servovavle gain (pu)
J+14		Tg , pilot servovalve time constant (s)
J+15		blg , gate linkage backlash
J+16		dbbd , blade command deadband (> = 0.0)
J+17		tbd , time constant for blade command deadband (s)
J+18		blb , blade servo backlash
J+19		dbbs , blade servo deadband (> = 0.0)
J+20		tbs , time constant for blade servo deadband (s)
J+21		bgvmin , blade flow coefficient at minimum position (< 1.0)
J+22		blv , maximum blade servo velocity
J+23		dturb , turbine speed / power coefficient
J+24		pgc, gate stroke at no load rated head
J+25		deff , turbine off-cam efficiency coefficient
J+26		hdam , operating head in per unit of rated head
J+27		gv0 , wicket gate turbine curve point
J+28		gv1 , wicket gate turbine curve point
J+29		gv2 , wicket gate turbine curve point
J+30		gv3 , wicket gate turbine curve point

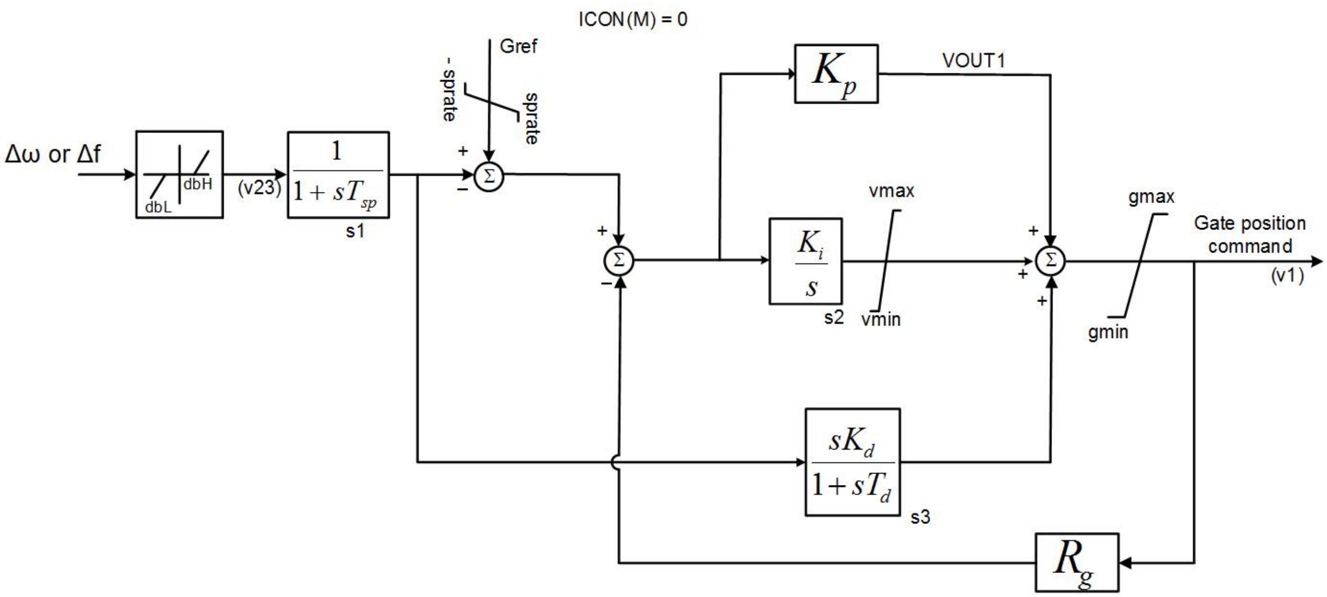
CONs	Value	Description
J+31		gv4 , wicket gate turbine curve point
J+32		gv5 , wicket gate turbine curve point
J+33		gv6 , wicket gate turbine curve point
J+34		gv7 , wicket gate turbine curve point
J+35		gv8 , wicket gate turbine curve point
J+36		gv9 , wicket gate turbine curve point
J+37		pgv0 , wicket gate flow area curve
J+38		pgv1 , wicket gate flow area curve
J+39		pgv2 , wicket gate flow area curve
J+40		pgv3 , wicket gate flow area curve
J+41		pgv4 , wicket gate flow area curve
J+42		pgv5 , wicket gate flow area curve
J+43		pgv6 , wicket gate flow area curve
J+44		pgv7 , wicket gate flow area curve
J+45		pgv8 , wicket gate flow area curve
J+46		pgv9 , wicket gate flow area curve
J+47		bgv0 , blade flow area curve
J+48		bgv1 , blade flow area curve
J+49		bgv2 , blade flow area curve
J+50		bgv3 , blade flow area curve
J+51		bgv4 , blade flow area curve
J+52		bgv5 , blade flow area curve
J+53		bgv6 , blade flow area curve
J+54		bgv7 , blade flow area curve
J+55		bgv8 , blade flow area curve
J+56		bgv9 , blade flow area curve
J+57		tw , water column inertia constant (s)
J+58		sprate , speed/load set-point adjustment rate
J+59		dbH (pu), deadband for overspeed, (> = 0, specified as frequency deviation)
J+60		dbL (pu), deadband for underspeed, (< = 0, specified as frequency deviation)
J+61		Trate, Turbine rating (MW)

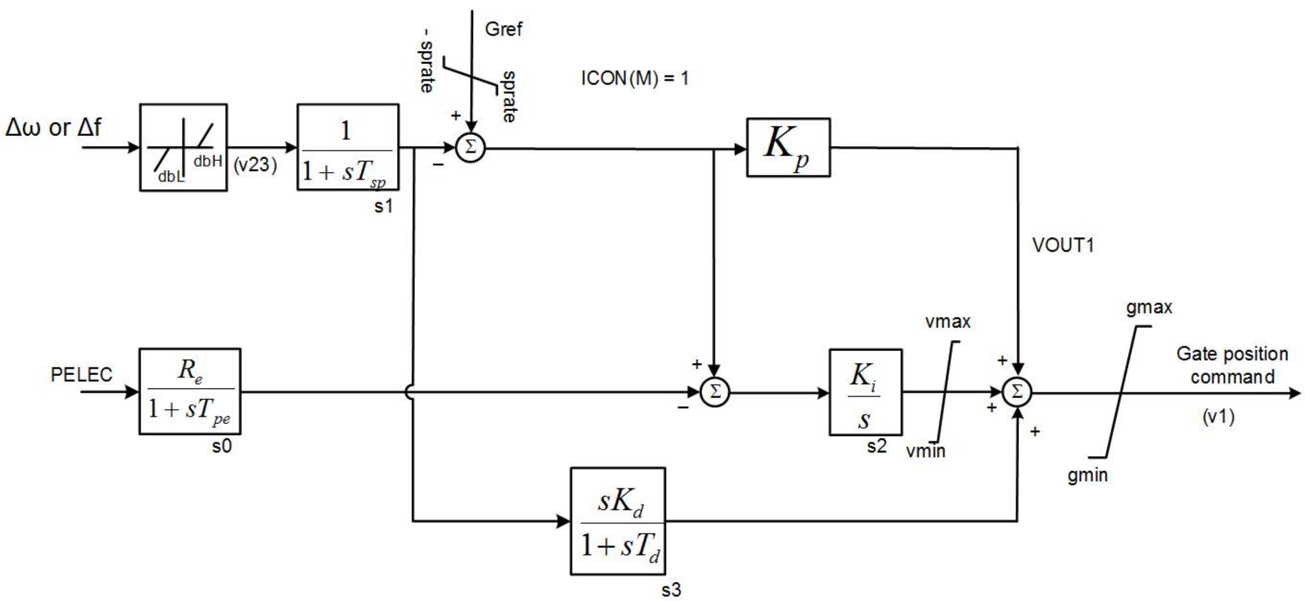
STATEs	Description
K	Measured electrical Power, s0
K+1	Measured speed, s1
K+2	Governor Integrator, s2
K+3	Governor Derivator, s3
K+4	Measured Gate Velocity, s4
K+5	Gate, s5
K+6	Gate Deadband, s6, s6

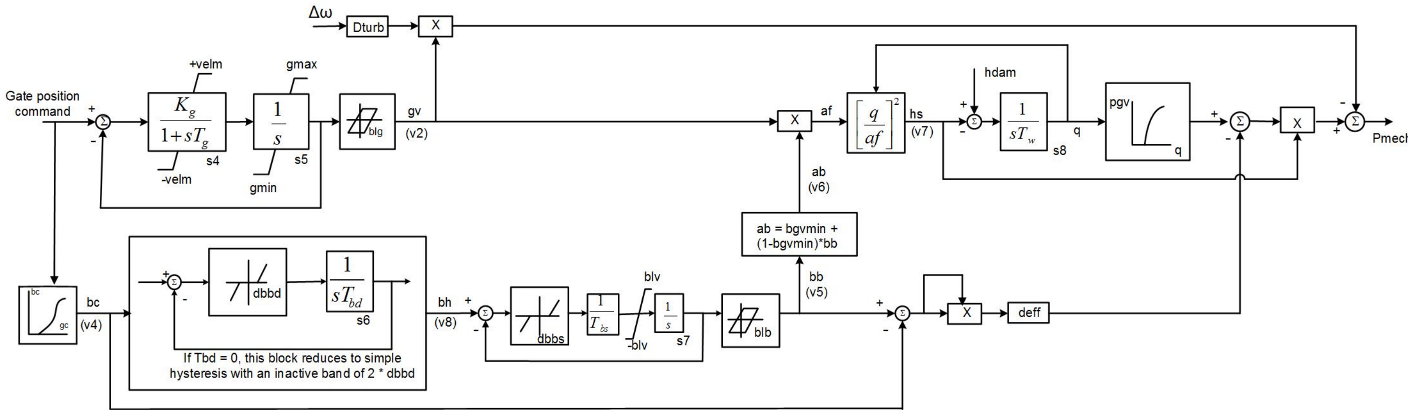
STATEs	Description
K+7	Blade, s7
K+8	Turbine Flow Integrator, s8

VARs	Description
L	Gref
L+1	Gout (v1)
L+2	gv
L+3	ag
L+4	bc
L+5	bb
L+6	ab
L+7	hscroll
L+8	bh
L+9	qgv0
L+10	qgv1
L+11	qgv2
L+12	qgv3
L+13	qgv4
L+14	qgv5
L+15	qgv6
L+16	qgv7
L+17	qgv8
L+18	qgv9
L+19	blg input
L+20	blg output
L+21	blb input
L+22	blb output
L+23	Speed Deadband Output

```
IBUS, 'USRMDL'  ID 'H6EU1', 5  0  1  62  9  24, ICON(M), CON(J) to CON(J
+61)   /
```


ICON(M) = 0
Gref
- sprate
sprate
Δω or Δf
dbL
dbH
(v23)
1
1 + sTsp
s1
Kp
VOUT1
vmax
Ki
s
s2
vmin
gmax
Gate position
command
(v1)
gmin
sKd
1+sTd
s3
Rg


Gref
- sprate
sprate
ICON(M) = 1
Δω or Δf
dbL
dbH
(v23)
1
1 + sTsp
s1
Kp
VOUT1
PELEC
Re
1 + sTpe
s0
vmax
Ki
s
s2
vmin
gmax
Gate position
command
(v1)
gmin
sKd
1+sTd
s3



Notes:

1. Turbine parameters are in per unit of Turbine rating (TRATE) if TRATE > 0. If TRATE is specified as zero, the parameters are assumed to be in per unit of MBASE (Machine MVA Base).

2. The configuration of the governor is determined by ICON(M) which is the speed/load flag F_D. If $F_D = 0$, then $R_E = 0$, while if $F_D = 1$, $R_G = 0$

3. The vmax and vmin as shown in the governor model are calculated as follows:

   vmax = gmax – VOUT1

   vmin = gmin – VOUT1

4. The gates travel over a range of 1.0 pu from fully closed to fully opened. The gates are at a position greater than zero when the turbine real power output is zero. Gmax and Gmin are the operating limits

5. Tpe, Td, Tg must be greater than zero. If Tsp < 0, then input is per unit bus frequency instead of rotor speed. In this case abs(Tsp) is used.

6. Dturb has the dimension of power/speed

7. The turbine is described by two curves as follows:

   pgv: turbine power in per unit base versus gate servomotor stroke

   bgv: blade servo stroke versus gate servomotor stroke

8. Each curve is specified by ten points (0-9) corresponding to ten values of gate servomotor stroke which are given as gv0-gv9. The same set of servo stroke is used for both curves. Gv0 should be greater than zero and the value of gv9 should normally be 1.0. pgv9 need not be equal to unity.

7.24. IEEEG1

IEEE Type 1 Speed-Governing Model

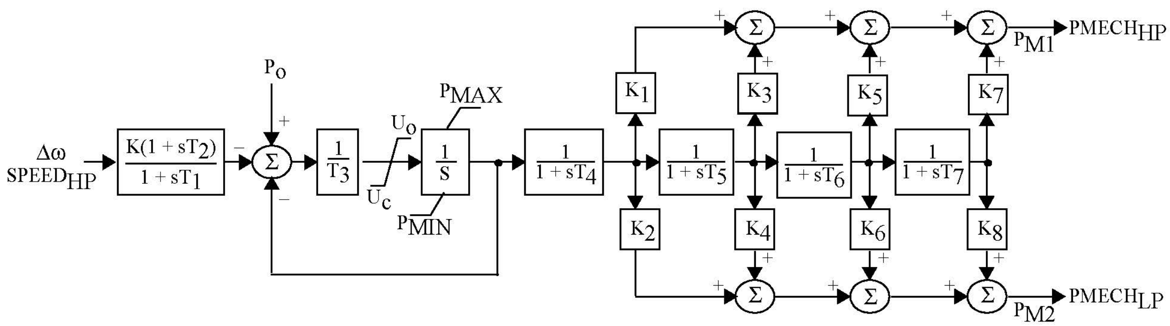
CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3 (> 0) (sec)
J+4		U_o (pu/sec)
J+5		U_c (< 0) (pu/sec)
J+6		P_{MAX} (pu on machine MVA rating)
J+7		P_{MIN} (pu on machine MVA rating)
J+8		T_4 (sec)
J+9		K_1
J+10		K_2
J+11		T_5 (sec)
J+12		K_3
J+13		K_4
J+14		T_6 (sec)
J+15		K_5
J+16		K_6
J+17		T_7 (sec)
J+18		K_7
J+19		K_8

STATEs	Description
K	First governor integrator
K+1	Governor output
K+2	First turbine integrator
K+3	Second turbine integrator
K+4	Third turbine integrator
K+5	Fourth turbine integrator

VARs	Description
L	Reference, P_0
L+1	Internal memory

Govenor gain K = 1/R is in pu on generator MVA base

```
IBUS, 'IEEEG1', ID, JBUS, M, CON(J) to CON(J+19)   /
```


Δω
SPEEDHP
K(1 + sT2) / 1 + sT1
Po
Σ
1/T3
Uo
Uc
PMAX
PMIN
1/s
1/(1 + sT4)
1/(1 + sT5)
1/(1 + sT6)
1/(1 + sT7)
K1
K2
K3
K4
K5
K6
K7
K8
PM1
PM2
PMECHHP
PMECHLP

7.25. IEEEG1SDU

IEEE Type 1 Speed-Governing Model

CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3 (> 0) (sec)
J+4		U_o (pu/sec)
J+5		U_c (< 0) (pu/sec)
J+6		P_{MAX} (pu rating)
J+7		P_{MIN} (pu rating)
J+8		T_4 (sec)
J+9		K_1
J+10		K_2
J+11		T_5 (sec)
J+12		K_3
J+13		K_4
J+14		T_6 (sec)
J+15		K_5
J+16		K_6
J+17		T_7 (sec)
J+18		K_7
J+19		K_8
J+20		DBH (pu), deadband for overspeed, (≥ 0)
J+21		DBL (pu), deadband for underspeed, (≤ 0)
J+22		T_{Rate} (MW), turbine rating, if zero, then MBASE used

STATEs	Description
K	First governor integrator
K+1	Governor output
K+2	First turbine integrator
K+3	Second turbine integrator
K+4	Third turbine integrator
K+5	Fourth turbine integrator

VARs	Description
L	Reference, P_0
L+1	Internal memory
L+2	Deadband output

All parameters are in pu on T_{Rate}. If T_{Rate} > 0, else in pu on generator MVA base

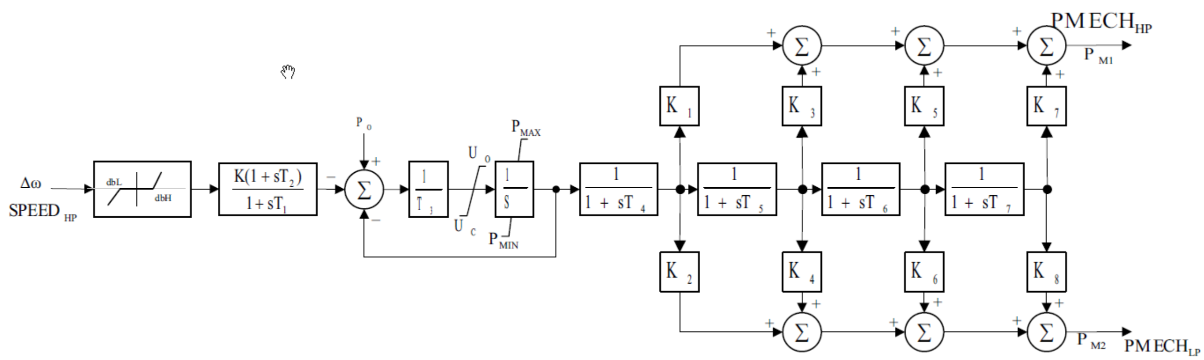
Governor gain K = 1/R is in pu on T_{Rate}. If $T_{Rate} > 0$, else in pu on generator MVA base

```
IBUS, 'USRMDL', ID, 'IEEEG1SDU'   5   0   0   23   6   3   CON(J) to CON(J
+22)   /
```

DYR Data record when governor is used for cross-compound machines

```
IBUS, 'USRMDL', ID, 'IEEEG1CDU'  11   0   0   23   6   3   JBUS  JD  CON
 (J) to CON(J+22)  /
```

For cross-compound units, IBUS and ID are the bus number and machine identifier of the high-pressure unit, while JBUS and JD are the bus number and machine identifier of the low pressure unit.



7.26. IEEEG2

IEEE Type 2 Speed-Governing Model

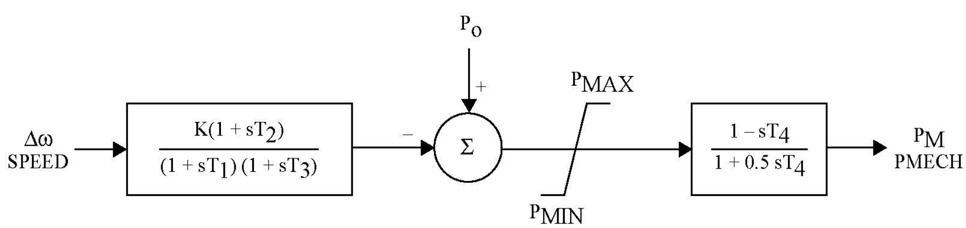
CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3 (>0) (sec)
J+4		P_{MAX} (pu on machine MVA rating)
J+5		P_{MIN} (pu on machine MVA rating)
J+6		T_4 (>0) (sec), water starting time

STATEs	Description
K	First integrator
K+1	Second integrator
K+2	Hydro turbine

VAR	Description
L	Reference, P_0

Govenor gain K = 1/R is in pu on generator MVA base

```
IBUS, 'IEEEG2', ID, CON(J) to CON(J+6)   /
```



7.27. IEEEG3

IEEE Type 3 Speed-Governing Model

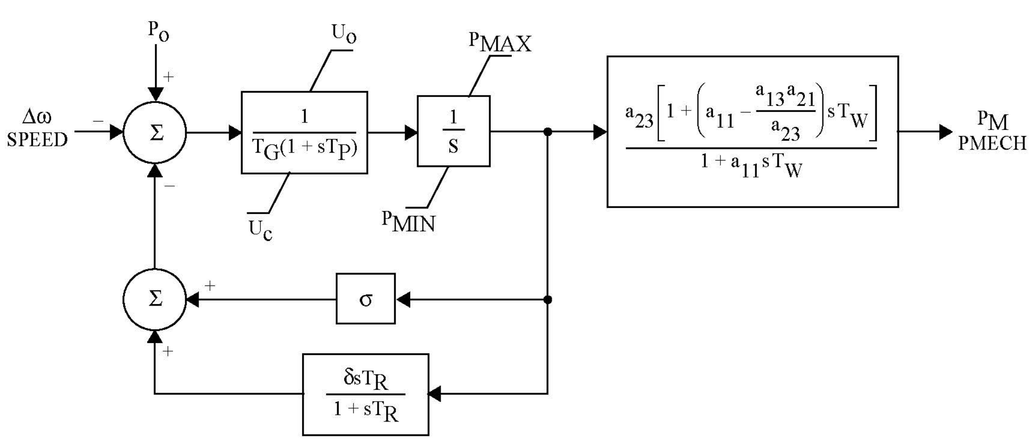
CONs	Value	Description
J		T_G, (>0) (sec), gate servomotor time constant
J+1		T_P (>0) (sec), pilot value time constant
J+2		U_o (pu per sec), opening gate rate limit
J+3		U_c (pu per sec), closing gate rate limit (< 0)
J+4		P_{MAX} maximum gate position (pu on machine MVA rating)
J+5		P_{MIN} minimum gate position (pu on machine MVA rating)
J+6		σ, permanent speed droop coefficient
J+7		δ, transient speed droop coefficient
J+8		T_r, (>0) (sec)
J+9		T_W (>0) (sec), water starting time
J+10		a_{11} (>0)
J+11		a_{13}
J+12		a_{21}
J+13		a_{23} (>0)

STATEs	Description
K	Servomotor position
K+1	Gate position
K+2	Transient droop compensation
K+3	Hydroturbine

VAR	Description
L	Reference, P_0

σ and δ are in pu on generator MVA base.

```
IBUS, 'IEEEG3', ID, CON(J) to CON(J+13)   /
```



7.28. IEEEG3DU

IEEE Type 3 Speed-Governing Model

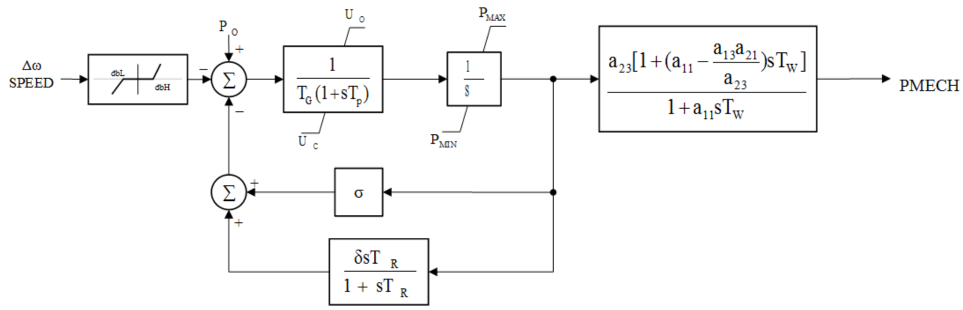
CONs	Value	Description
J		T_G, (>0) (sec), gate servomotor time constant
J+1		T_P (>0) (sec), pilot value time constant
J+2		U_o (pu per sec), opening gate rate limit
J+3		U_c (pu per sec), closing gate rate limit (< 0)
J+4		P_{MAX} maximum gate position (pu on machine MVA rating if T_{RATE} is zero)
J+5		P_{MIN} minimum gate position (pu on machine MVA rating if T_{RATE} is zero)
J+6		σ, permanent speed droop coefficient
J+7		δ, transient speed droop coefficient
J+8		T_r, (>0) (sec)
J+9		T_W (>0) (sec), water starting time
J+10		a_{11} (>0)
J+11		a_{13}
J+12		a_{21}
J+13		a_{23} (>0)
J+14		DBH (pu), deadband for overspeed, (≥ 0)
J+15		DBL (pu), deadband for underspeed, (≤ 0)
J+16		T_{Rate} (MW), turbine rating, if zero, then MBASE used

STATEs	Description
K	Servomotor position
K+1	Gate position
K+2	Transient droop compensation
K+3	Hydroturbine

VAR	Description
L	Reference, P_0
L+1	Deadband output

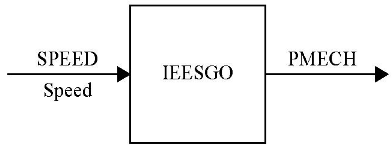
σ and δ are in pu on T_{Rate}. If $T_{Rate} > 0$, else in pu on generator MVA base.

```
IBUS, 'USRMDL', ID, 'IEEEG3DU'   5   0   0   17   4    2    CON(J) to
 CON(J+16)   /
```


Δω
SPEED
dbL
dbH
P O
U O
U C
P MAX
P MIN
σ
PMECH

7.29. IEESGO

IEEE Standard Model



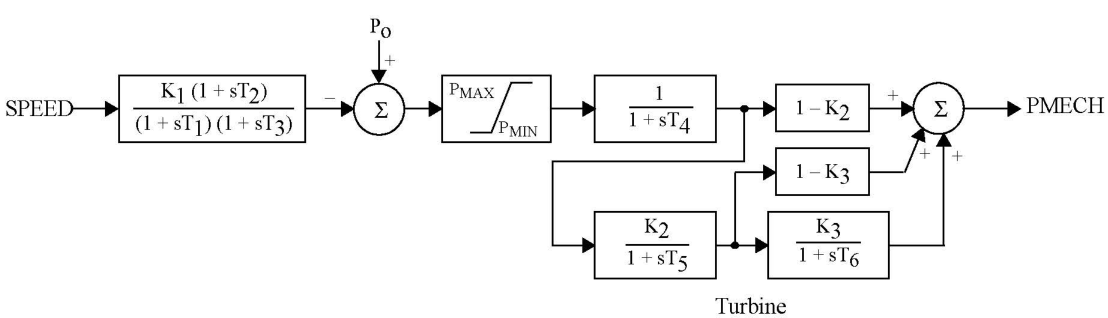
CONs	Value	Description
J		T_1, controller lag (sec)
J+1		T_2, controller lead compensation (sec)
J+2		T_3, governor lag (>0) (sec)
J+3		T_4, delay due to steam inlet volumes associated with steam chest and inlet piping (sec)
J+4		T_5, reheater delay including hot and cold leads (sec)
J+5		T_6, delay due to IP-LP turbine, crossover pipes, and LP end hoods (sec)
J+6		K_1, 1/per unit regulation
J+7		K_2, fraction
J+8		K3, fraction
J+9		P_{MAX}, upper power limit
J+10		P_{MIN}, lower power limit

STATEs	Description
K	Filter output
K+1	Valve or gate servo output
K+2	Turbine powers
K+3	Turbine powers
K+4	Turbine powers

VAR	Description
L	Reference, P_o

Govenor gain K1 = 1/R, P_{MAX} and P_{MIN} are in pu on generator MVA base.

```
IBUS, 'IEESGO', ID, CON(J) to CON(J+10)   /
```



7.30. IEESGODU

IEEE Standard Model

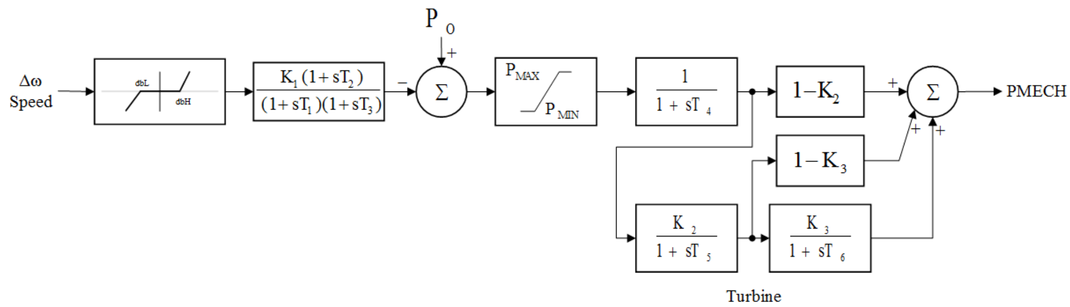
CONs	Value	Description
J		T_1, controller lag (sec)
J+1		T_2, controller lead compensation (sec)
J+2		T_3, governor lag (>0) (sec)
J+3		T_4, delay due to steam inlet volumes associated with steam chest and inlet piping (sec)
J+4		T_5, reheater delay including hot and cold leads (sec)
J+5		T_6, delay due to IP-LP turbine, crossover pipes, and LP end hoods (sec)
J+6		K_1, 1/per unit regulation
J+7		K_2, fraction
J+8		K3, fraction
J+9		P_{MAX}, upper power limit
J+10		P_{MIN}, lower power limit
J+11		DBH (pu), deadband for overspeed, (≥ 0)
J+12		DBL (pu), deadband for underspeed, (≤ 0)
J+13		T_{Rate} (MW), turbine rating, if zero, then MBASE used

STATEs	Description
K	Filter output
K+1	Valve or gate servo output
K+2	Turbine powers
K+3	Turbine powers
K+4	Turbine powers

VARs	Description
L	Reference, P_o
L+1	Deadband output

Govenor gain K1 = 1/R, P_{MAX} and P_{MIN} are in pu on T_{Rate} if $T_{Rate} > 0$, else in pu on generator MVA base.

```
IBUS, 'USRMDL', ID, 'IEESGODU'   5   0   0   14   5   2   CON(J) to CON(J
+13)   /
```



7.31. IVOGO

IVO Governor Model

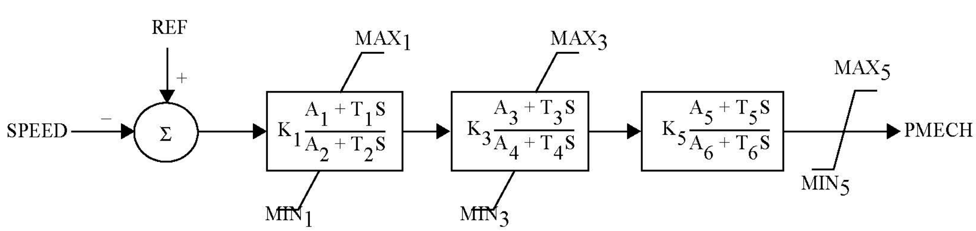
CONs	Value	Description
J		K_1
J+1		A_1
J+2		A2
J+3		T_1
J+4		T_2
J+5		MAX_1
J+6		MIN_1
J+7		K_3
J+8		A_3
J+9		A_4
J+10		T_3
J+11		T_4
J+12		MAX_3
J+13		MIN_3
J+14		K_5
J+15		A_5
J+16		A_6
J+17		T_5
J+18		T_6
J+19		MAX_5
J+20		MIN_5

STATEs	Description
K	Integrator 1
K+1	Integrator 2
K+2	Integrator 3

VARs	Description
L	Reference

Govenor gain K1 = 1/R, MAX_5 and MIN_5 are in pu on generator MVA base.

```
IBUS, 'IVOGO', ID, CON(J) to CON(J+20)   /
```



7.32. PIDGOV

Hydro Turbine-Governor

ICON	Value	Description
M		Feedback signal: • 0 - Electrical power feedback • 1 Gate position

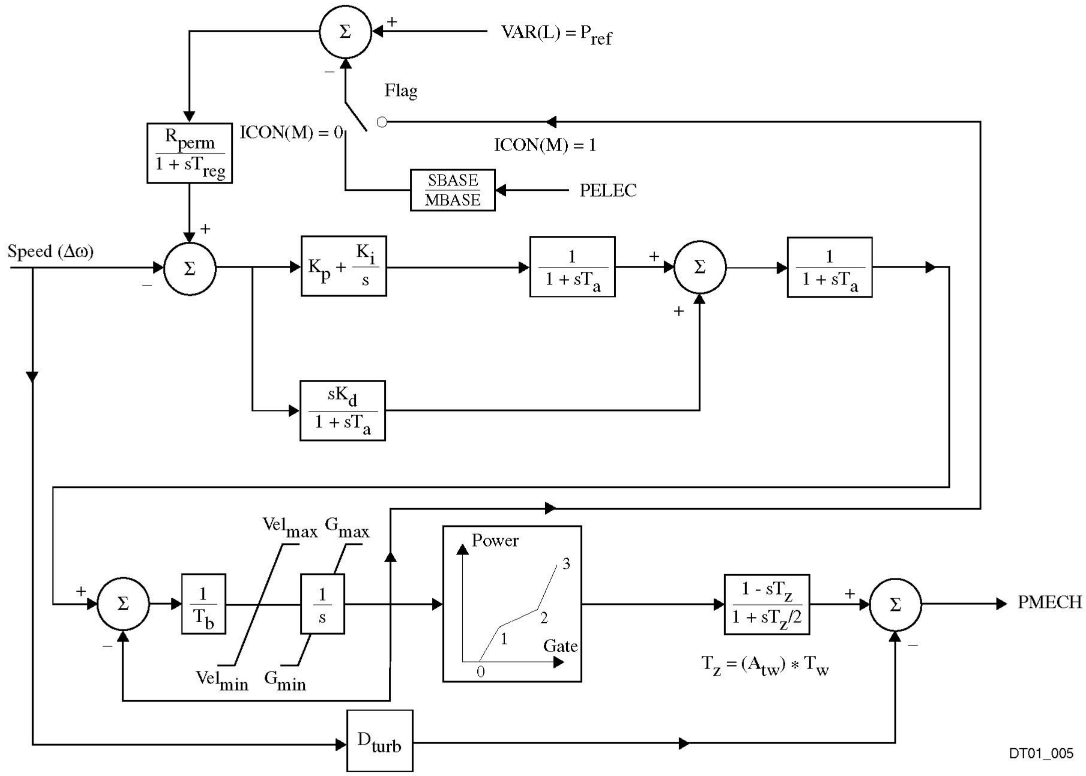
CONs	Value	Description
J		Rperm, permanent drop, pu
J+1		T_{reg} (sec), speed detector time constant
J+2		K_p, proportional gain, pu/sec
J+3		K_I, reset gain, pu/sec
J+4		K_d, derivative gain, pu
J+5		T_a (sec) > 0, controller time constant
J+6		T_b (sec) > 0, gate servo time constant
J+7		D_{turb}, turbine damping factor, pu
J+8		G_0, gate opening at speed no load, pu
J+9		G_1, intermediate gate opening, pu
J+10		P_1, power at gate opening G1, pu
J+11		G_2, intermediate gate opening, pu
J+12		P_2, power at gate opening G2, pu
J+13		P_3, power at full opened gate, pu
J+14		G_{MAX}, maximum gate opening, pu
J+15		G_{MIN}, minimum gate opening, pu
J+16		A_{tw} > 0, factor multiplying Tw, pu
J+17		T_W (sec) > 0, water inertia time constant
J+18		V_{elmax}, minimum gate opening velocity, pu/sec
J+19		V_{elmin} < 0, minimum gate closing velocity, pu/sec

STATEs	Description
K	Input sensor
K+1	PI controller
K+2	First regulator
K+3	Derivative controller
K+4	Second regulator
K+5	Gate position
K+6	Water inertia

VARs	Description
L	Reference

Rperm and D_{turb} are in pu on generator MVA base.

```
IBUS, 'PIDGOV', ID, ICON(M), CON(J) to CON(J+19)   /
```



7.33. PIDGOVDU

Hydro Turbine-Governor

ICON	Value	Description
M		Feedback signal: • 0 - Electrical power feedback • 1 - Gate position

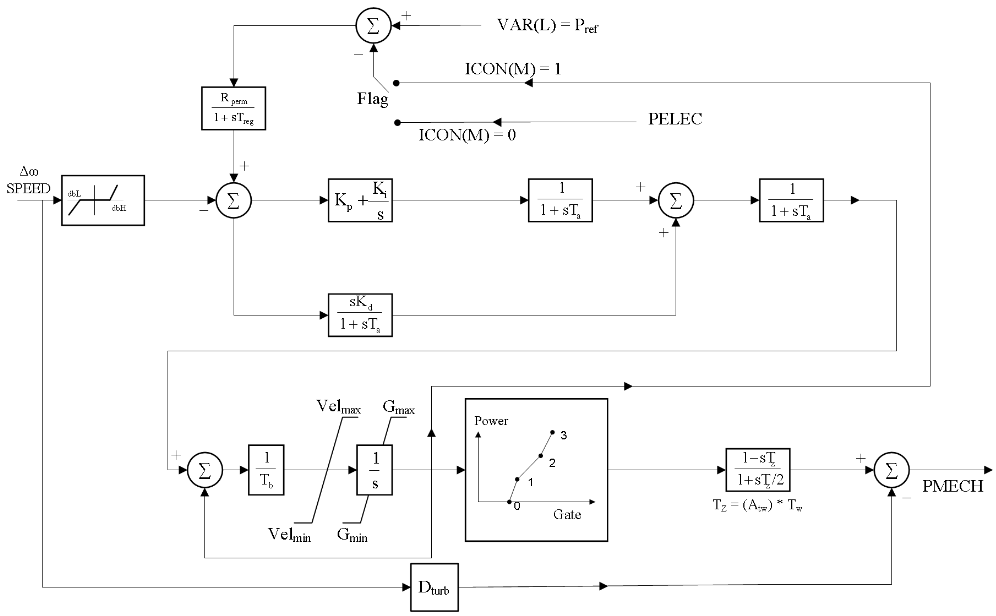
CONs	Value	Description
J		Rperm, permanent drop, pu
J+1		T_{reg} (sec), speed detector time constant
J+2		K_p, proportional gain, pu/sec
J+3		K_I, reset gain, pu/sec
J+4		K_d, derivative gain, pu
J+5		T_a (sec) > 0, controller time constant
J+6		T_b (sec) > 0, gate servo time constant
J+7		D_{turb}, turbine damping factor, pu
J+8		G_0, gate opening at speed no load, pu
J+9		G_1, intermediate gate opening, pu
J+10		P_1, power at gate opening G1, pu
J+11		G_2, intermediate gate opening, pu
J+12		P_2, power at gate opening G2, pu
J+13		P_3, power at full opened gate, pu
J+14		G_{MAX}, maximum gate opening, pu
J+15		G_{MIN}, minimum gate opening, pu
J+16		A_{tw} > 0, factor multiplying Tw, pu
J+17		T_W (sec) > 0, water inertia time constant
J+18		V_{elmax}, minimum gate opening velocity, pu/sec
J+19		V_{elmin} < 0, minimum gate closing velocity, pu/sec
J+20		DBH (pu), deadband for overspeed, (≥ 0)
J+21		DBL (pu), deadband for underspeed, (≤ 0)
J+22		T_{Rate} (MW), turbine rating, if zero, then MBASE used

STATEs	Description
K	Input sensor
K+1	PI controller
K+2	First regulator
K+3	Derivative controller
K+4	Second regulator
K+5	Gate position
K+6	Water inertia

VARs	Description
L	Reference
L+1	Deadband output

Rperm and D_{turb} are in pu on T_{Rate} if T_{Rate} >0. else in pu on generator MVA base.

```
IBUS, 'USRMDL', ID, 'PIDGOVDU'   5   0   1   23   7   2   ICON(M), CON(J)
 to CON(J+22)   /
```



7.34. PWTBD1

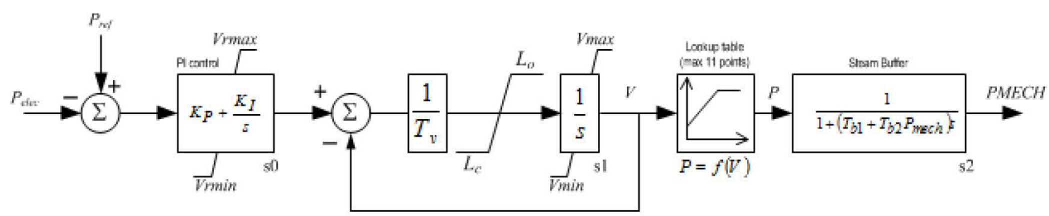
Pratt & Whitney Turboden Turbine-Governor Model

ICONs	Description
M	Internal Memory (no input data required for this ICON)

CONs	Value	Description
J		T_{rate} (MW), Turbine rating (MW)
J+1		K (pu), Proportional gain
J+2		K_I (pu), Integral gain
J+3		Vr_{max} (pu), Upper Limit of PI controller
J+4		Vr_{min} (pu), Lower Limit of PI controller
J+5		T_v (s) (>0), Control valve Time Constant
J+6		L_o (pu/sec) (>0), Control valve open rate limit
J+7		L_c (pu/sec) (>0), Control valve close rate limit
J+8		V_{MAX} (pu), Maximum valve position
J+9		V_{MIN} (pu), Minimum valve position
J+10		T_{b1} (s), steam buffer time constant
J+11		T_{b2} (s), steam buffer time constant
J+12		V_1 (pu), valve position 1
J+13		p_1 (pu), power output for valve position V_1
J+14		V_2 (pu), valve position 2
J+15		p_2 (pu), power output for valve position V_2
J+16		V_3 (pu), valve position 3
J+17		p_3 (pu), power output for valve position V_3
J+18		V_4 (pu), valve position 4
J+19		p_4 (pu), power output for valve position V_4
J+20		v_5 (pu), valve position 5
J+21		p_5 (pu), power output for valve position v5
J+22		v_6 (pu), valve position 6
J+23		p_6 (pu), power output for valve position v6
J+24		v_7 (pu), valve position 7
J+25		p_7 (pu), power output for valve position v7
J+26		v_8 (pu), valve position 8
J+27		p_8 (pu), power output for valve position v8
J+28		v_9 (pu), valve position 9
J+29		p_9 (pu), power output for valve position v9
J+30		V_{10} (pu), valve position 10
J+31		p_{11} (pu), power output for valve position $V_1$1
J+32		V_{11} (pu), valve position 11
J+33		p_{11} (pu), power output for valve position $V_1$1

STATEs	Description
K	PI controller
K+1	Valve opening
K+2	Turbine power

```
IBUS 'PWTBD1' ID CON (J) to CON(J+33) /
```



Notes:

1. Trate (CON(J) - Turbine MW rating) can be specified as zero or can be greater than zero. If Trate is greater than zero, the governor model parameters have to be specified in per unit of Trate, else the parameters are assumed to be in per unit of machine MVA base.

2. The valve position (V) versus power output (P) curve is specified as a series of the maximum of 11 pairs of V-P points with the V-values assumed to be along the x-axis, and the P-values along the y-axis. The V-P pairs of points should have values such that $V_1$1>$V_1$0>....>V_1, and P11 ? P10 ?...? P1. Unused pairs must be entered as zero. The power output (P) is limited to the P-value of the first and the last valid points. If none or only one valid pair of P-V points is entered the output is considered equal to the input.

7.35. SGT2EU1

Siemens SGT-2000E Turbine Model

ICON	Value	Description
M		Flag: • 1 : load shedding logic active • 0 : no load shedding logic

CONs	Value	Description
J		BLA
J+1		BLB
J+2		Kl)
J+3		Ks
J+4		Kp
J+5		Drl
J+6		Drs
J+7		Tlt
J+8		Tls
J+9		Tdt
J+10		Pls
J+11		Tn
J+12		Ppr
J+13		Ylo
J+14		Fa
J+15		Kcc
J+16		Tcc (≥ 2×DELT)
J+17		PGB
J+18		Pup
J+19		Plo
J+20		Pgs
J+21		Pgfup
J+22		Pgfdown
J+23		PGTA (>0)
J+24		PGTB
J+25		T_{RATE} (MW)
J+26		dbu (≥ 0)
J+27		dbo (≤ 0)
J+28		PSu (>0)
J+29		PSo (<0)

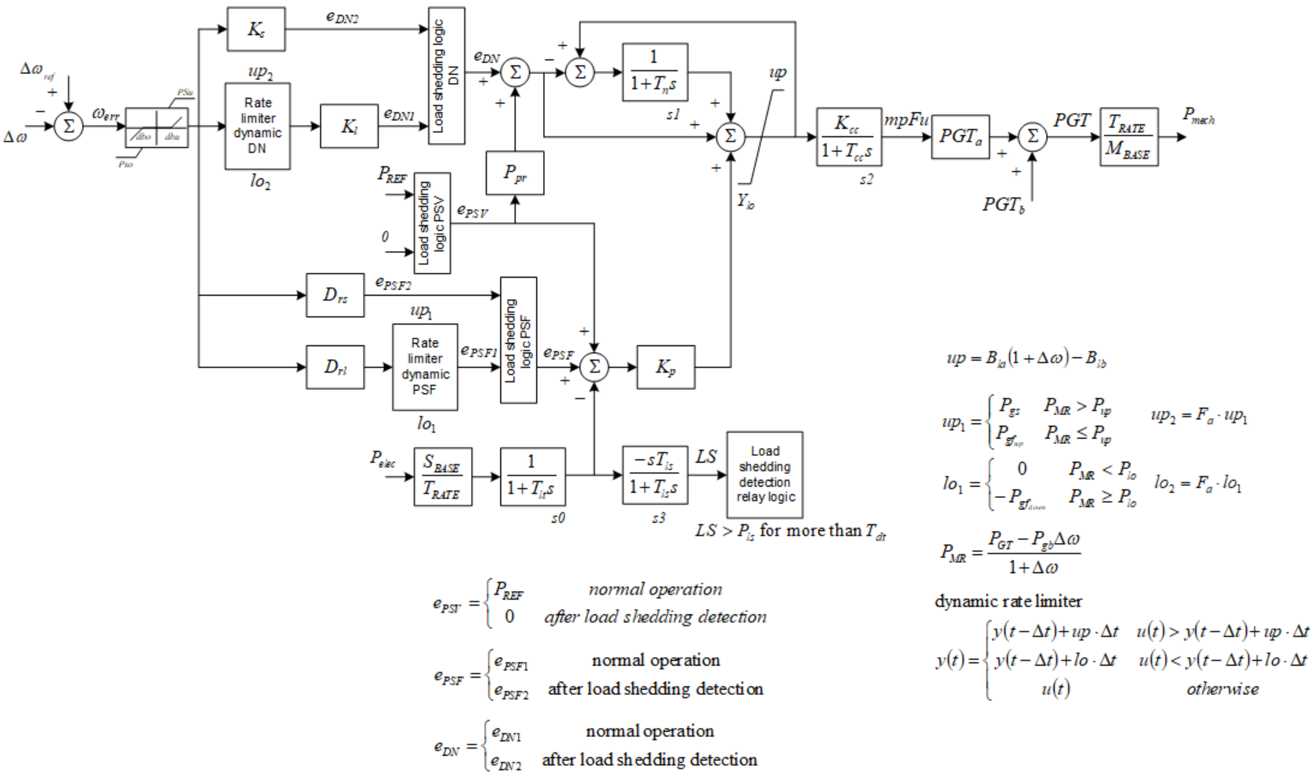
STATEs	Description
K	Sensed P_{gen}

STATEs	Description
K+1	Lag block
K+2	mPF
K+3	Load Detection

VARs	Description
L	Speed Deadband Output
L+1	Up1
L+2	Lo1
L+3	PMR
L+4	Rate limiter DN
L+5	Rate limiter PSF
L+6	ePSF
L+7	eDN
L+8	LS
L+9	Speed reference, $\Delta \omega_{ref}$
L+10	Timer for LDSH
L+11	Rate limiter PSF (t–Δt)
L+12	Rate limiter DN (t–Δt)
L+13	Output of limit block

```
IBUS   'USRMDL'   ID   'SGT2EU1'    5     0    1    30    4     14
 ICON(M)     CON(J) to CON(J+29)   /
```

Notes:



1. T_{RATE} is the turbine rating in MW. If T_{RATE} is is set to zero, then the model parameters are assumed to be in per unit of generator MVA.

2. dbu (≥ 0) is the deadband for under-frequency conditions (i.e., ωerr is greater than 0). dbu is specified as the per unit frequency deviation.

3. dbo (≤ 0) is the deadband for over-frequency conditions (i.e., ωerr is less than 0). dbo is specified as the per unit frequency deviation.

4. Psu (> 0) is the limit on speed deviation error (ωerr) for under-frequency condition.

5. Pso (< 0) is the limit on speed deviation error (ωerr) for over-frequency condition.

7.36. SGT8HMU1

Siemens SGT6-8000H Turbine Model (Multi Shaft)

ICON	Value	Description
M		Flag: • 1 : load shedding logic active • 0 : no load shedding logic
M+1		Internal (to be input as 0)
M+2		Internal (to be input as 0)

CONs	Value	Description
J		BLA
J+1		BLB
J+2		Kl)
J+3		Ks
J+4		Kp
J+5		Drl
J+6		Drs
J+7		Tlt
J+8		Kpsh
J+9		Tdt
J+10		Pls
J+11		Tn
J+12		Ppr
J+13		Ylo
J+14		Fa
J+15		Kcc
J+16		Tcc (≥ 2×DELT)
J+17		PGB
J+18		Pup
J+19		Plo
J+20		Pgs
J+21		Pgfup
J+22		Pgfdown
J+23		PGTA (>0)
J+24		PGTB
J+25		T_{RATE} (MW)
J+26		Dup
J+27		Dlo
J+28		Pgup
J+29		Pglo

CONs	Value	Description
J+30		Plsm
J+31		TdP
J+32		Tdel
J+33		Slaw
J+34		PSF0lim
J+35		DN0lim
J+36		KDNlim
J+37		TDNlim
J+38		XDK
J+39		dbu (≥ 0)
J+40		dbo (≤ 0)
J+41		PSu (>0)
J+42		PSo (< 0)

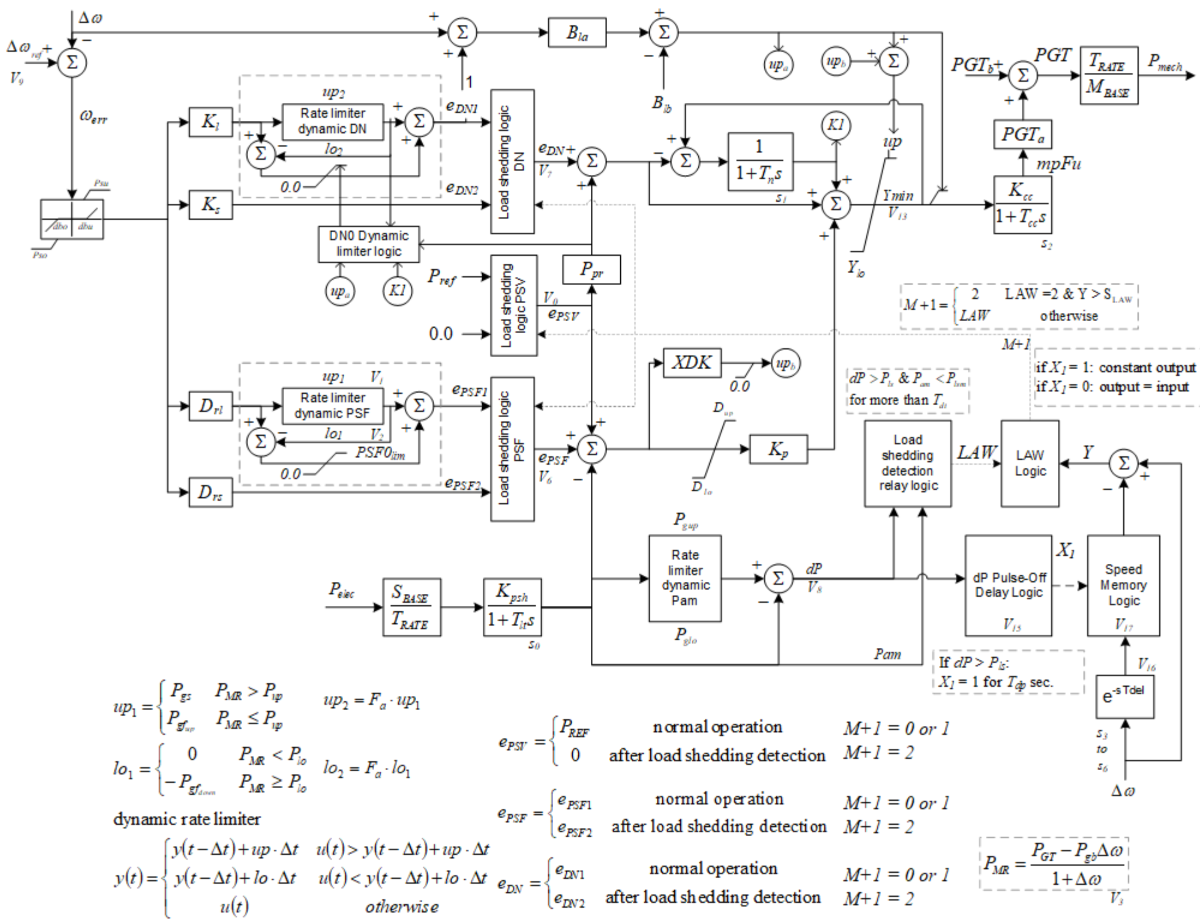
STATEs	Description
K	Sensed P_{gen}
K+1	Load/Speed Control
K+2	Combustion Dynamics
K+3	Transport Delay
K+4	Transport Delay
K+5	Transport Delay
K+6	Transport Delay
K+7	DN limit

VARs	Description
L	Speed Deadband Output
L+1	Up1
L+2	Lo1
L+3	PMR
L+4	Rate limiter DN
L+5	Rate limiter PSF
L+6	ePSF
L+7	eDN
L+8	LS
L+9	Speed reference, $\Delta\omega_{ref}$
L+10	Initial time for load shedding
L+11	Rate limiter PSF (t–Δt)
L+12	Rate limiter DN (t–Δt)
L+13	Output of Fuel Limiter
L+14	Rate Limiter Pam: y (t–Δt)
L+15	Timer of dP Pulse off delay logic
L+16	Output of Pade transport delay

VARs	Description
L+17	Speed Memory Logic

```
IBUS   'USRMDL'   ID   'SGT8HMU1'    5     0    3    43    8     18
  ICON(M)  0  0  CON(J) to CON(J+42)   /
```

Notes:



1. T_{RATE} is the turbine rating in MW. If T_{RATE} is is set to zero, then the model parameters are assumed to be in per unit of generator MVA.

2. dbu (≥ 0) is the deadband for under-frequency conditions (i.e., ωerr is greater than 0). dbu is specified as the per unit frequency deviation.

3. dbo (≤ 0) is the deadband for over-frequency conditions (i.e., ωerr is less than 0). dbo is specified as the per unit frequency deviation.

4. Psu (> 0) is the limit on speed deviation error (ωerr) for under-frequency condition.

5. Pso (< 0) is the limit on speed deviation error (ωerr) for over-frequency condition.

7.37. SGT8HSU1

Siemens SGT6-8000H Turbine Model (Single Shaft)

ICON	Value	Description
M		Flag: • 1 : load shedding logic active • 0 : no load shedding logic
M+1		Internal (to be input as 0)
M+2		Internal (to be input as 0)

CONs	Value	Description
J		BLA
J+1		BLB
J+2		Kl)
J+3		Ks
J+4		Kp
J+5		Drl
J+6		Drs
J+7		Tlt
J+8		Kpsh
J+9		Tdt
J+10		Pls
J+11		Tn
J+12		Ppr
J+13		Ylo
J+14		Fa
J+15		Kcc
J+16		Tcc (≥ 2×DELT)
J+17		PGB
J+18		Pup
J+19		Plo
J+20		Pgs
J+21		Pgfup
J+22		Pgfdown
J+23		PGTA (>0)
J+24		PGTB
J+25		GTRATE (gas turbine rating, MW)
J+26		Dup
J+27		Dlo
J+28		Pgup

CONs	Value	Description
J+29		Pglo
J+30		Plsm
J+31		TdP
J+32		Tdel
J+33		Slaw
J+34		PSF0lim
J+35		DN0lim
J+36		KDNlim
J+37		TDNlim
J+38		XDK
J+39		dbu (≥ 0)
J+40		dbo (≤ 0)
J+41		PSu (>0)
J+42		PSo (< 0)
J+43		STRATE (steam turbine rating, MW)
J+44		x1, pu on total rate (see Note1)
J+45		y1, pu on ST rate (see Note2)
J+46		x2, pu on total rate (see Note1)
J+47		y2, pu on ST rate (see Note2)
J+48		x3, pu on total rate (see Note1)
J+49		y3, pu on ST rate (see Note2)
J+50		x4, pu on total rate (see Note1)
J+51		y4, pu on ST rate (see Note2)
J+52		x5, pu on total rate (see Note1)
J+53		y5, pu on ST rate (see Note2)

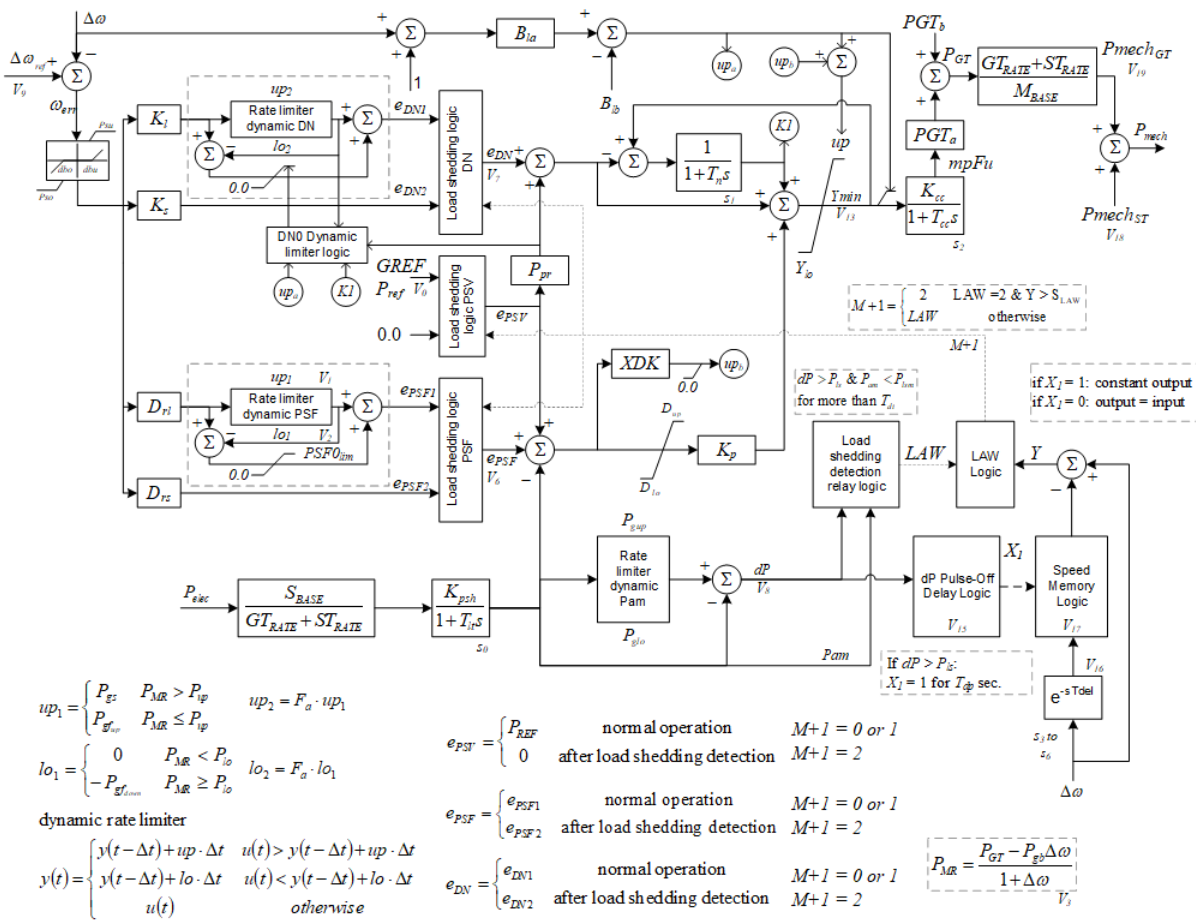
STATEs	Description
K	Sensed P_{gen}
K+1	Load/Speed Control
K+2	Combustion Dynamics
K+3	Transport Delay
K+4	Transport Delay
K+5	Transport Delay
K+6	Transport Delay
K+7	DN limit

VARs	Description
L	Speed Deadband Output
L+1	Up1
L+2	Lo1
L+3	PMR

VARs	Description
L+4	Rate limiter DN
L+5	Rate limiter PSF
L+6	ePSF
L+7	eDN
L+8	LS
L+9	Speed reference, $\Delta\ \omega_{ref}$
L+10	Initial time for load shedding
L+11	Rate limiter PSF (t–Δt)
L+12	Rate limiter DN (t–Δt)
L+13	Output of Fuel Limiter
L+14	Rate Limiter Pam: y (t–Δt)
L+15	Timer of dP Pulse off delay logic
L+16	Output of Pade transport delay
L+17	Speed Memory Logic
L+18	Pst, pu on MBase
L+19	Pgt, pu on MBase

```
IBUS   'USRMDL'   ID   'SGT8HSU1'    5     0    3    54    8     20
 ICON(M)  0  0  CON(J) to CON(J+53)   /
```

Notes:



1. 1. in per unit of total rate ($GT_{RATE} + ST_{RATE}$).
2. 2. in per unit of ST_{RATE}.
3. GT_{RATE} is equal to zero, then it assumed to be equal to generator MVA*2/3.
4. ST_{RATE} is equal to zero, then it assumed to be equal to $GT_{RATE}/2$.
5. P_{ref} is defined as the total electrical power output in pu of total rating corrected by K_{psh}.
6. The initialization follows the logic presented in the figure below representing the relationship between the GT and ST units power outputs through a 5-point lookup table.
7. If less than 5 points are required in the lookup table, the remaining data points should be set to [0.0, 0.0].
8. The abscissa points must be entered in ascending order.
9. The lookup table output values are limited by the minimum and maximum ordinate input values; that is, the lookup table does not extrapolate outside the defined range of the ordinate.
10. Normally, for the last point x=y=1.0, indicating that the ST power reaches its rating when the total output equals the total rating ($GT_{RATE}+ST_{RATE}$).

11. Normally, for the first point y1=0.0, indicating there is no supplemental firing and a minimum GT output is required to guarantee ST power.

12. dbu (≥ 0) is the deadband for under-frequency conditions (i.e., ωerr is greater than 0). dbu is specified as the per unit frequency deviation.

13. dbo (≤ 0) is the deadband for over-frequency conditions (i.e., ωerr is less than 0). dbo is specified as the per unit frequency deviation.

14. Psu (> 0) is the limit on speed deviation error (ωerr) for under-frequency condition.

15. Pso (< 0) is the limit on speed deviation error (ωerr) for over-frequency condition.

7.38. SITGTU1

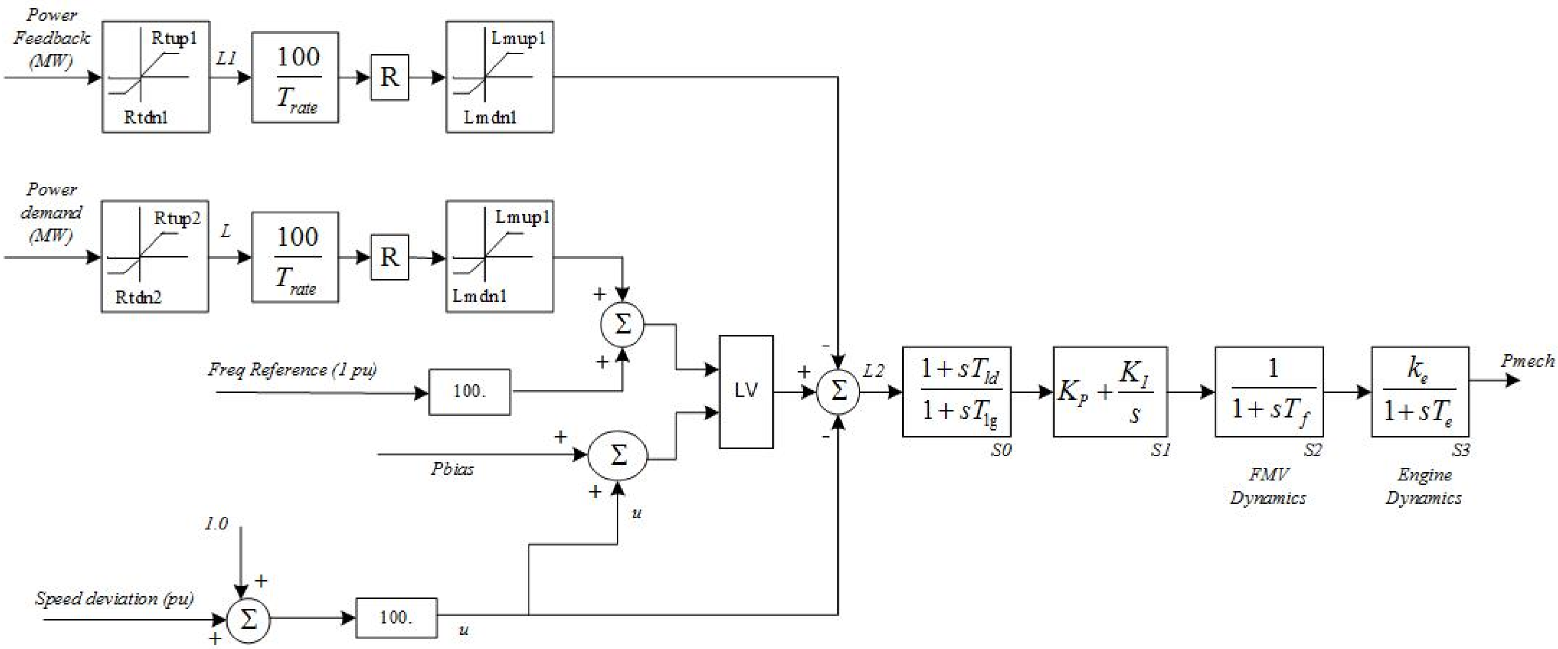
Siemens SGT-A65 Gas Turbine Model

CONs	Value	Description
J		R, Governor Droop(pu) (> 0)
J+1		Rtup1, Maximum power feedback loading rate limit (MW/s)
J+2		Rtdn1, Maximum power feedback unloading rate limit (MW/s)
J+3		Rtup2, Maximum power demand loading rate limit (MW/s)
J+4		Rtdn2, Maximum power demand unloading rate limit (MW/s)
J+5		Lmup1, Maximum bias due to droop (%)
J+6		Lmdn1, Minimum bias due to droop (%)
J+7		Tld, Lead compensation time constant (s)
J+8		Tlg, Lag compensation time constant (s)
J+9		Kp, PI proportional gain (>0) (%/%)
J+10		Ki, PI integral gain (%/s)
J+11		Tf, FMV dynamics time constant (s)
J+12		Ke, Engine dynamics (>0) (MW/%)
J+13		Te, Engine dynamics time constant (sec)
J+14		Pbias, Bias for power limit (%)
J+15		Trate, Turbine rating (MW), (Note 1)

STATEs	Description
K	Lead Lag
K+1	PI controller
K+2	FMV dynamics
K+3	Engine dynamics

VARs	Description
L	Rate-limited power demand (MW)
L+1	Rate-limited power feedback (MW)
L+2	Turbine Dynamics input

```
IBUS   'USRMDL'   ID   'SITGTU1'   5    0    0    16    4    3
 CON(J) to CON(J+15)   /
```



Notes:

1. If Trate is zero, turbine rating parameters are assumed to be in per unit of machine MVA base..

7.39. SHAF25

Torsional Shaft Model for 25 Masses

This model must be used in conjunction with the GENDCO generator model.

ICONs	Value	Description
M		STATE number containing Δ speed from GENDCO
M+1		VAR number containing electrical torque (from GENDCO)

CONs	Value	Description
J		X_d - X'_d
J+1		T'_{do}
J+2		Mass number for exciter
J+3		Mass number for generator
J+4		H of mass 1
J+5		H of mass 2
J+6		H of mass 3
J+7		H of mass 4
J+8		H of mass 5
J+9		H of mass 6
J+10		H of mass 7
J+11		H of mass 8
J+12		H of mass 9
J+13		H of mass 10
J+14		H of mass 11
J+15		H of mass 12
J+16		H of mass 13
J+17		H of mass 14
J+18		H of mass 15
J+19		H of mass 16
J+20		H of mass 17
J+21		H of mass 18
J+22		H of mass 19
J+23		H of mass 20
J+24		H of mass 21
J+25		H of mass 22
J+26		H of mass 23
J+27		H of mass 24
J+28		H of mass 25
J+29		Power fraction of 1
J+30		Power fraction of 2
J+31		Power fraction of 3
J+32		Power fraction of 4

CONs	Value	Description
J+33		Power fraction of 5
J+34		Power fraction of 6
J+35		Power fraction of 7
J+36		Power fraction of 8
J+37		Power fraction of 9
J+38		Power fraction of 10
J+39		Power fraction of 11
J+40		Power fraction of 12
J+41		Power fraction of 13
J+42		Power fraction of 14
J+43		Power fraction of 15
J+44		Power fraction of 16
J+45		Power fraction of 17
J+46		Power fraction of 18
J+47		Power fraction of 19
J+48		Power fraction of 20
J+49		Power fraction of 21
J+50		Power fraction of 22
J+51		Power fraction of 23
J+52		Power fraction of 24
J+53		Power fraction of 25
J+54		D of mass 1
J+55		D of mass 2
J+56		D of mass 3
J+57		D of mass 4
J+58		D of mass 5
J+59		D of mass 6
J+60		D of mass 7
J+61		D of mass 8
J+62		D of mass 9
J+63		D of mass 10
J+64		D of mass 11
J+65		D of mass 12
J+66		D of mass 13
J+67		D of mass 14
J+68		D of mass 15
J+69		D of mass 16
J+70		D of mass 17
J+71		D of mass 18
J+72		D of mass 19
J+73		D of mass 20

CONs	Value	Description
J+74		D of mass 21
J+75		D of mass 22
J+76		D of mass 23
J+77		D of mass 24
J+78		D of mass 25
J+79		K shaft mass 1-2
J+80		K shaft mass 2-3
J+81		K shaft mass 3-4
J+82		K shaft mass 4-5
J+83		K shaft mass 5-6
J+84		K shaft mass 6-7
J+85		K shaft mass 7-8
J+86		K shaft mass 8-9
J+87		K shaft mass 9-10
J+88		K shaft mass 10-11
J+89		K shaft mass 11-12
J+90		K shaft mass 12-13
J+91		K shaft mass 13-14
J+92		K shaft mass 14-15
J+93		K shaft mass 15-16
J+94		K shaft mass 16-17
J+95		K shaft mass 17-18
J+96		K shaft mass 18-19
J+97		K shaft mass 19-20
J+98		K shaft mass 20-21
J+99		K shaft mass 21-22
J+100		K shaft mass 22-23
J+101		K shaft mass 23-24
J+102		K shaft mass 24-25

STATEs	Description
K	Slip at mass 1
K+1	Slip at mass 2
K+2	Slip at mass 3
K+3	Slip at mass 4
K+4	Slip at mass 5
K+5	Slip at mass 6
K+6	Slip at mass 7
K+7	Slip at mass 8
K+8	Slip at mass 9
K+9	Slip at mass 10

STATEs	Description
K+10	Slip at mass 11
K+11	Slip at mass 12
K+12	Slip at mass 13
K+13	Slip at mass 14
K+14	Slip at mass 15
K+15	Slip at mass 16
K+16	Slip at mass 17
K+17	Slip at mass 18
K+18	Slip at mass 19
K+19	Slip at mass 20
K+20	Slip at mass 21
K+21	Slip at mass 22
K+22	Slip at mass 23
K+23	Slip at mass 24
K+24	Slip at mass 25

VARs	Description
L	T electrical of exciter
L+1	T shaft 1-2
L+2	T shaft 2-3
L+3	T shaft 3-4
L+4	T shaft 4-5
L+5	T shaft 5-6
L+6	T shaft 6-7
L+7	T shaft 7-8
L+8	T shaft 8-9
L+9	T shaft 9-10
L+10	T shaft 10-11
L+11	T shaft 11-12
L+12	T shaft 12-13
L+13	T shaft 13-14
L+14	T shaft 14-15
L+15	T shaft 15-16
L+16	T shaft 16-17
L+17	T shaft 17-18
L+18	T shaft 18-19
L+19	T shaft 19-20
L+20	T shaft 20-21
L+21	T shaft 21-22
L+22	T shaft 22-23
L+23	T shaft 23-24

VARs	Description
L+24	T shaft 24-25
L+25	Angle at mass 1
L+26	Angle at mass 2
L+27	Angle at mass 3
L+28	Angle at mass 4
L+29	Angle at mass 5
L+30	Angle at mass 6
L+31	Angle at mass 7
L+32	Angle at mass 8
L+33	Angle at mass 9
L+34	Angle at mass 10
L+35	Angle at mass 11
L+36	Angle at mass 12
L+37	Angle at mass 13
L+38	Angle at mass 14
L+39	Angle at mass 15
L+40	Angle at mass 16
L+41	Angle at mass 17
L+42	Angle at mass 18
L+43	Angle at mass 19
L+44	Angle at mass 20
L+45	Angle at mass 21
L+46	Angle at mass 22
L+47	Angle at mass 23
L+48	Angle at mass 24
L+49	Angle at mass 25
L+50	Working storage locations
L+51	
L+52	
.	
.	
.	
L+74	

```
IBUS, 'SHAF25', ID, CON(J) to CON(J+102)   /
```

7.40. TGOV1

Steam Turbine-Governor

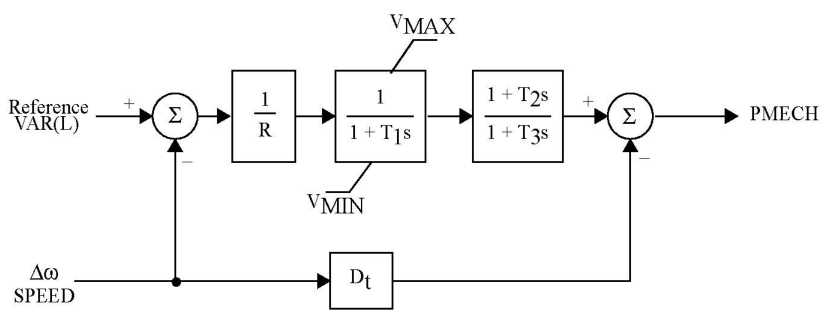
CONs	Value	Description
J		R
J+1		T_1 (>0) (sec)
J+2		V_{MAX} [a]
J+3		$V_{MIN}1$ [a]
J+4		T_2 (sec) [b]
J+5		T_3 (>0) (sec)[c]
J+6		D_T1

[a]V_1MAX, V_{MIN}, D_T and R are in per unit on generator MVA base.
[b]T_2/T_3 = high-pressure fraction.
[c]T_3 = reheater time constant.

STATEs	Description
K	Valve opening
K+1	Turbine power

VARs	Description
L	Reference

```
IBUS, 'TGOV1', ID, CON(J) to CON(J+6)   /
```



7.41. TGOV1DU

Steam Turbine-Governor

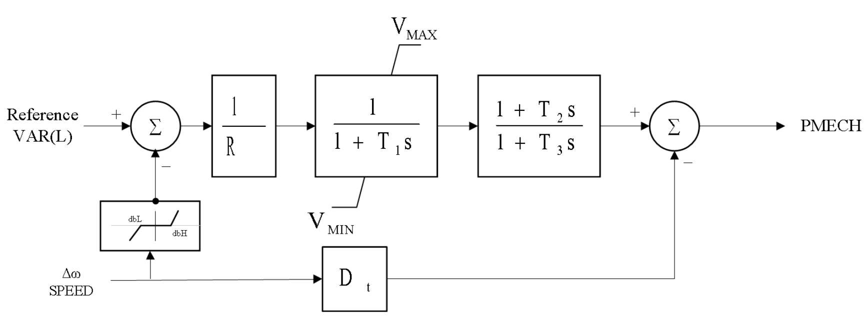
CONs	Value	Description
J		R
J+1		T_1 (>0) (sec)
J+2		V_{MAX} [a]
J+3		V_{MIN} [a]
J+4		T_2 (sec) [b]
J+5		T_3 (>0) (sec)[c]
J+6		D_Ta
J+7		DBH (pu), deadband for overspeed, (≥ 0)
J+8		DBL (pu), deadband for underspeed, (≤ 0)
J+9		T_{Rate} (MW), turbine rating, if zero, then MBASE used

[a]V_{MAX}, V_{MIN}, D_T and R are in per unit on generator MVA base.
[b]T_2/T_3 = high-pressure fraction.
[c]$T_3$3 = reheater time constant.

STATEs	Description
K	Valve opening
K+1	Turbine power

VARs	Description
L	Reference
L+1	Deadband output

```
IBUS, 'USRMDL', ID, 'TGOV1DU'   5   0   0   10   2   2   CON(J) to CON(J
+9)   /
```



7.42. TGOV2

Steam Turbine-Governor With Fast Valving

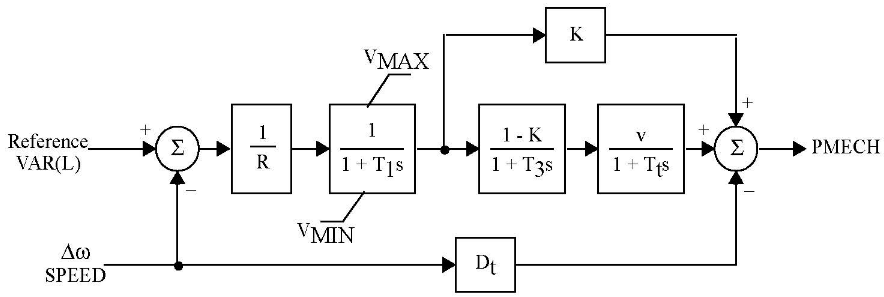
CONs	Value	Description
J		R (pu)
J+1		T_1 (>0) (sec)
J+2		V_{MAX} (pu)
J+3		V_{MIN} (pu)
J+4		K (pu)
J+5		T_3 (>0) (sec)
J+6		D_t (pu)
J+7		T_t (>0) (sec)
J+8		T_A
J+9		T_B
J+10		T_C

STATEs	Description
K	Throttle
K+1	Reheat pressure
K+2	Reheat power
K+3	Intercept valve position, V

VARs	Description
L	Speed reference
L+1	Fast valving initial time, T_I

V_{MAX}, V_{MIN} and R are in pu on generator MVA base.

```
IBUS, 'TGOV2', ID, CON(J) to CON(J+10)   /
```

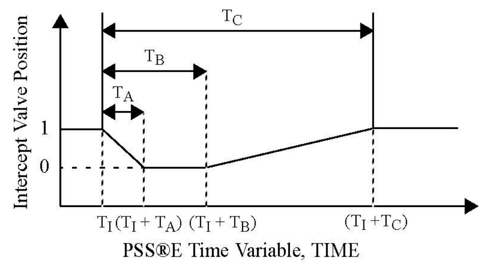


T_I [VAR(L+1)]: TIME to initiate fast valving.

T_A [CON(J+8)]: Intercept valve, v, fully closed T_A seconds after fast valving initiation.

T_B [CON(J+9)]: Intercept valve starts to reopen T_B seconds after fast valving initiation.

T_C [CON(J+10)]: Intercept valve again fully open T_C seconds after fast valving initiation.



7.43. TGOV3

Modified IEEE Type 1 Speed-Governing Model With Fast Valving

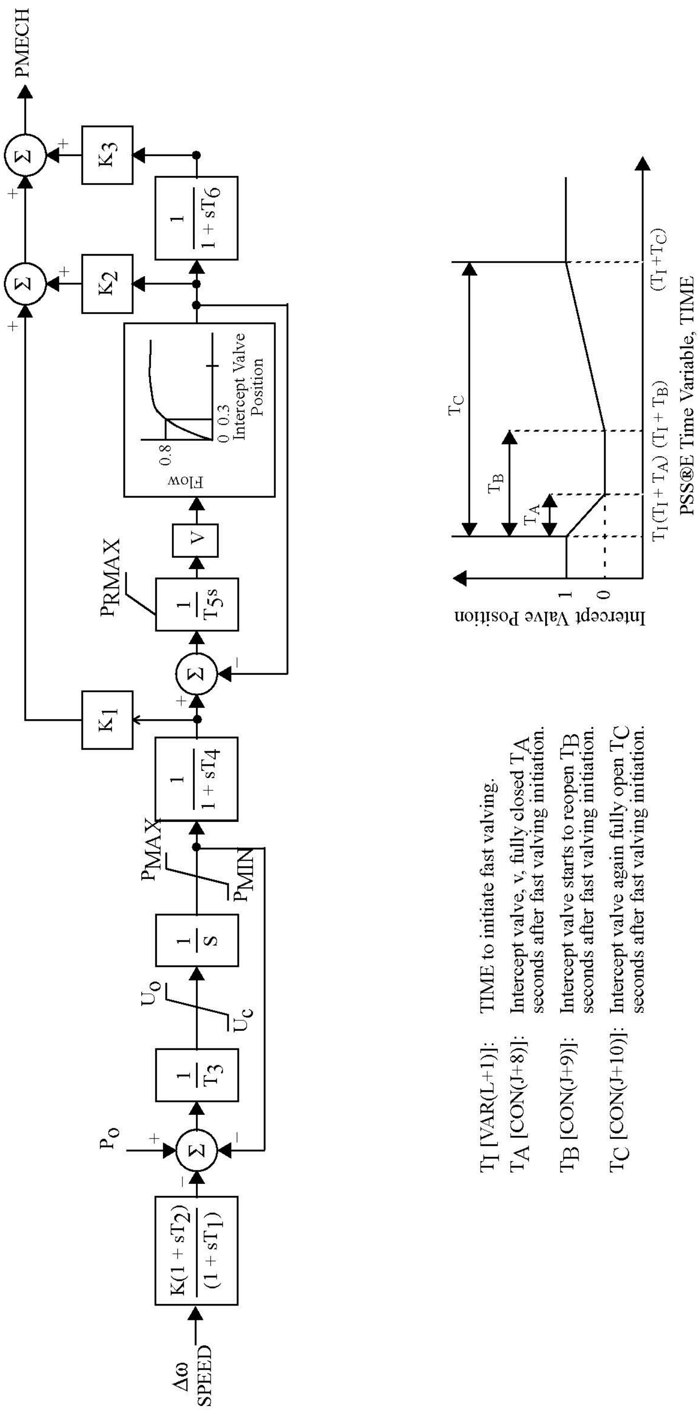
CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3 (>0) (sec)
J+4		U_o
J+5		U_c (< 0)
J+6		P_{MAX}
J+7		P_{MIN}
J+8		T_4 (sec)
J+9		K_1
J+10		T_5 (> 0) (sec)
J+11		K_2
J+12		T_6 (sec)
J+13		K_3
J+14		T_A (sec)
J+15		T_B (sec)
J+16		T_C (sec)
J+17		P_{RMAX} (pu)

STATEs	Description
K	First governor integrator
K+1	Governor output
K+2	First turbine integrator
K+3	Second turbine integrator
K+4	Third turbine integrator
K+5	Intercept valve position, v

VARs	Description
L	Reference
L+1	Fast valving initial time, T_I

Govenor gain K = 1/R, P_{MAX} and P_{MIN} are in pu on generator MVA base.

```
IBUS, 'TGOV3', ID, CON(J) to CON(J+17)   /
```


PMECH
K3
K2
K1
1 / (1 + sT6)
Flow
0.8
0 0.3
Intercept Valve Position
V
1 / T5s
PRMAX
1 / (1 + sT4)
PMAX
PMIN
1 / s
UO
UC
1 / T3
PO
K(1 + sT2) / (1 + sT1)
Δω SPEED
Intercept Valve Position
1
0
TC
TB
TA
TI (TI + TA) (TI + TB) (TI + TC)
PSS®E Time Variable, TIME
TI [VAR(L+1)]: TIME to initiate fast valving.
TA [CON(J+8)]: Intercept valve, v, fully closed TA seconds after fast valving initiation.
TB [CON(J+9)]: Intercept valve starts to reopen TB seconds after fast valving initiation.
TC [CON(J+10)]: Intercept valve again fully open TC seconds after fast valving initiation.

7.44. TGOV3DU

Modified IEEE Type 1 Speed-Governing Model With Fast Valving

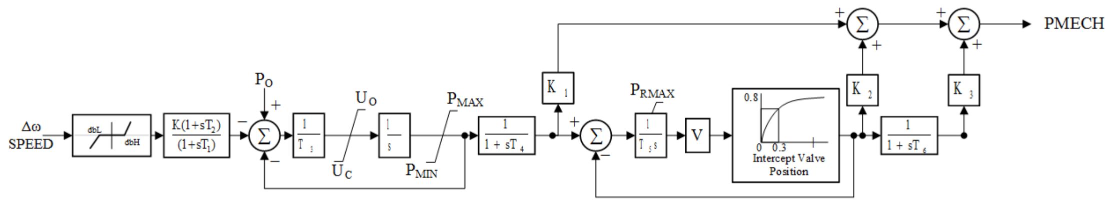
CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3 (>0) (sec)
J+4		U_o
J+5		U_c (< 0)
J+6		P_{MAX}
J+7		P_{MIN}
J+8		T_4 (sec)
J+9		K_1
J+10		T_5 (> 0) (sec)
J+11		K_2
J+12		T_6 (sec)
J+13		K_3
J+14		T_A (sec)
J+15		T_B (sec)
J+16		T_C (sec)
J+17		P_{RMAX} (pu)
J+18		DBH (pu), deadband for overspeed, (≥ 0)
J+19		DBL (pu), deadband for underspeed, (≤ 0)
J+20		T_{Rate} (MW), turbine rating, if zero, then MBASE used

STATEs	Description
K	First governor integrator
K+1	Governor output
K+2	First turbine integrator
K+3	Second turbine integrator
K+4	Third turbine integrator
K+5	Intercept valve position, v

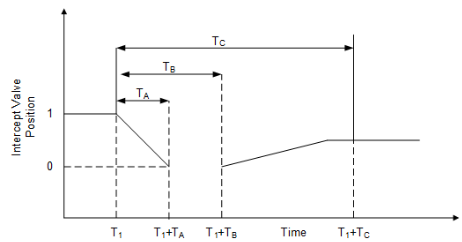
VARs	Description
L	Reference
L+1	Fast valving initial time, T_I
L+2	Deadband output

Govenor gain K = 1/R, P_{MAX} and P_{MIN} are in pu on T_{Rate} if T_{Rate} > 0, else in pu on generator MVA base.

```
IBUS, 'USRMDL', ID, 'TGOV3DU'   5   0   0   21   6   3   CON(J) to CON(J
+20)   /
```



T_1 [VAR(L+1)]:	TIME to initiate fast valving.
T_A [CON(J+8)]:	Intercept valve, v, fully closed T_A seconds after fast valving initiation.
T_B [CON(J+9)]:	Intercept valve starts to reopen T_B seconds after fast valving initiation.
T_C [CON(J+10)]:	Intercept valve again fully open T_C seconds after fast valving initiation.



7.45. TGOV4

Modified IEEE Type 1 Speed-Governing Model With PLU and EVA

ICONs	Value	Description
M		NCV, Number of control valves
M+1		NIV, Number of intercept valves
M+2		MODE, Control mode: • 0 - No PLU or EVA • 1 - User-controlled PLU/EVA • 2 - PLU • 3 - PLU and EVA
M+3	X	Internal (CV status)
M+4	X	Internal (IV status)
M+5	X	Internal (PLU or EVA switch)
M+6	X	Internal (latch/unlatch switch)

CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3 (> 0) (sec)
J+4		U_o
J+5		U_c (< 0)
J+6		K_{CAL}
J+7		T_4 (sec)
J+8		K_1
J+9		T_5 (> 0) (sec)
J+10		K_2
J+11		T_6 (sec)
J+12		PRMAX
J+13		K_P
J+14		K_I
J+15		T_{Fuel} (sec)
J+16		T_{FD1} (sec)
J+17		T_{FD2} (sec)
J+18		K_b
J+19		C_b (> 0) (sec)
J+20		T_{IV} (> 0) (sec)
J+21		U_{OIV}
J+22		U_{CIV}

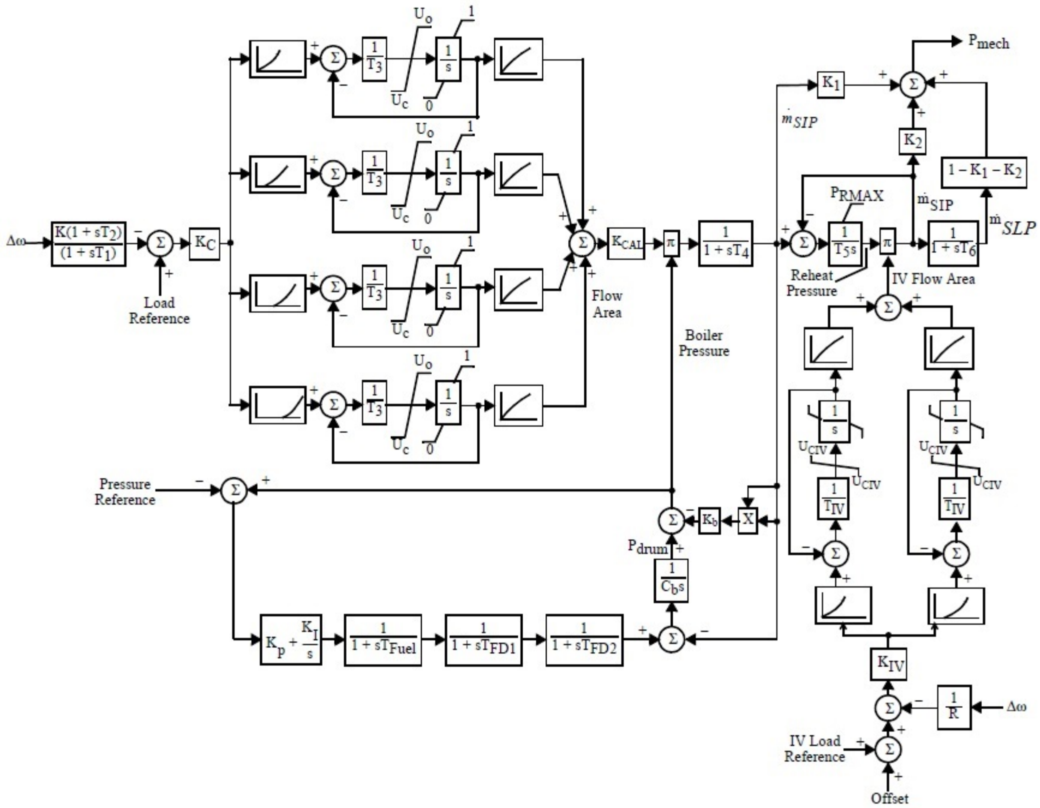
CONs	Value	Description
J+23		R (>0)
J+24		Offset
J+25		CV position demand characteristic
J+26		CV #2 offset
J+27		CV #3 offset
J+28		CV #4 offset
J+29		IV position demand characteristic
J+30		IV #2 offset
J+31		CV valve characteristic
J+32		IV valve characteristic
J+33		CV starting time for valve closing (sec)
J+34		CV closing rate (pu/sec)
J+35		Time closed for CV #1 (sec)
J+36		Time closed for CV #2
J+37		Time closed for CV #3
J+38		Time closed for CV #4
J+39		IV starting time for valve closing (sec)
J+40		IV closing rate (pu/sec)
J+41		Time closed for IV #1 (sec)
J+42		Time closed for IV #2 (sec)
J+43		T_rPLU (>0) (sec)
J+44		PLU rate level
J+45		Timer
J+46		PLU unbalance level
J+47		T_rEVA (>0) (sec)
J+48		EVA rate level
J+49		EVA unbalance level
J+50		Minimum load reference (pu)
J+51		Load reference ramp rate (pu/sec)

STATEs	Description
K	CV speed controller integrator
K+1	CV #1 valve position
K+2	CV #2 valve position
K+3	CV #3 valve position
K+4	CV #4 valve position
K+5	HP steam flow ($\dot{m}_{SHP}$)
K+6	Reheat pressure
K+7	LP steam flow ($\dot{m}_{SLP}$)
K+8	IV #1 valve position
K+9	IV #2 valve position

STATEs	Description
K+10	Boiler pressure controller integrator
K+11	Fuel integrator
K+12	Fuel delay #1 integrator
K+13	Fuel delay #2 integrator
K+14	Drum pressure
K+15	PLU rate integrator
K+16	EVA rate integrator

VARs	Description
L	Load reference
L+1	Boiler pressure reference
L+2	IV load reference
L+3	Boiler pressure
L+4	CV flow area
L+5	IV flow area
L+6	K_{CV}
L+7	K_{IV}
L+8	CV position demand characteristic, K
L+9	CV position demand characteristic, A
L+10	IV position demand characteristic, K
L+11	IV position demand characteristic, A
L+12	CV valve characteristic, K
L+13	CV valve characteristic, A
L+14	IV valve characteristic, K
L+15	IV valve characteristic, A
L+16	Generator current (pu on machine base)
L+17	PLU rate output signal
L+18	Time when TIMER initialized
L+19	PLU unbalance signal
L+20	EVA unbalance signal
L+21	EVA rate output signal
L+22	Time of CV signal to close
L+23	Time of IV signal to close
L+24	Time when CVs closed
L+25	Time when IVs closed

```
IBUS, 'TGOV4', ID, ICON(M) to ICON(M+2), CON(J) to CON(J+51)   /
```


Δω
K(1 + sT2) / (1 + sT1)
Load Reference
KC
1/T3
1/s
Uo
Uc
1
0
KCAL
π
1/(1 + sT4)
Flow Area
Boiler Pressure
Pmech
K1
K2
1 − K1 − K2
ṁSIP
ṁSLP
PRMAX
1/(T5s)
1/(1 + sT6)
Reheat Pressure
IV Flow Area
UCIV
1/TIV
Pressure Reference
Pdrum
Kb
X
1/(Cbs)
Kp + KI/s
1/(1 + sTFuel)
1/(1 + sTFD1)
1/(1 + sTFD2)
KIV
1/R
IV Load Reference
Offset

7.46. TGOV5

IEEE Type 1 Speed-Governing Model Modified to Include Boiler Controls

CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3 (>0) (sec)
J+4		U_o
J+5		U_c (<0)
J+6		V_{MAX}
J+7		V_{MIN}
J+8		T_4 (sec)
J+9		K_1
J+10		K_2
J+11		T_5 (sec)
J+12		K_3
J+13		K_4
J+14		T_6 (sec)
J+15		K_5
J+16		K_6
J+17		T_7 (sec)
J+18		K_7
J+19		K_8
J+20		K9
J+21		K_{10}
J+22		K_{11}
J+23		K_{12}
J+24		K_{13}
J+25		K_{14}
J+26		R_{MX}
J+27		R_{MIN}
J+28		L_{MAX}
J+29		L_{MIN}
J+30		C1
J+31		C2
J+32		C3
J+33		B
J+34		$C_{B,}$ (>0) (sec)
J+35		K_I
J+36		T_I (sec)

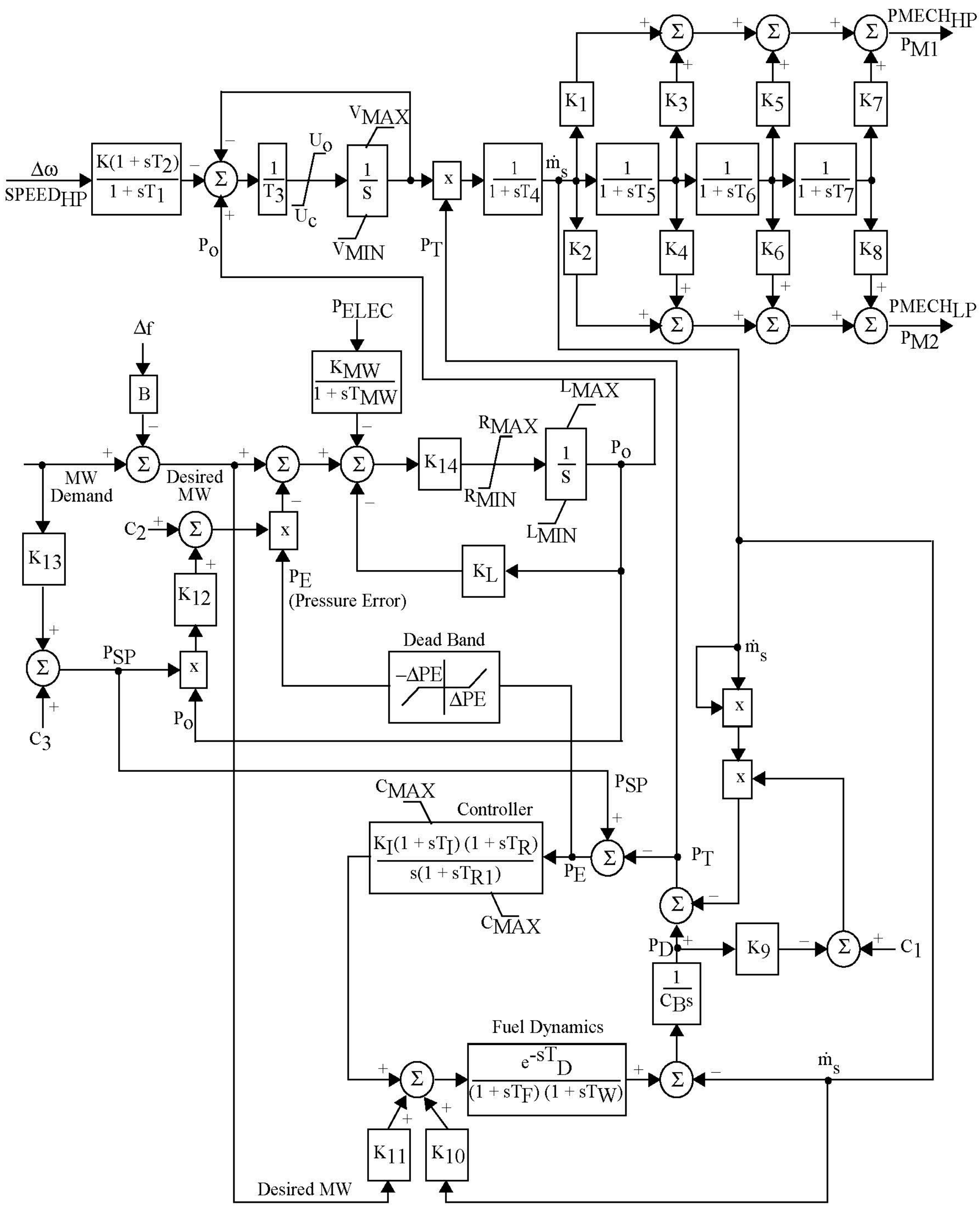
CONs	Value	Description
J+37		T_r (sec)
J+38		T_{R1} (sec)
J+39		C_{MAX}
J+40		C_{MIN}
J+41		T_D (sec)
J+42		T_F (sec)
J+43		T_W (sec)
J+44		P_{sp} (initial) (>0)
J+45		T_{MW} (sec)
J+46		K_L (0.0 or 1.0)
J+47		K_{MW} (0.0 or 1.0)
J+48		Δ_{PE} (pu pressure)

STATEs	Description
K	First governor integrator
K+1	Valve area
K+2	First turbine integrator, $\dot{m}_s$
K+3	Second turbine integrator
K+4	Third turbine integrator
K+5	Fourth turbine integrator
K+6	Po
K+7	Drum pressure, P_D
K+8	First controller integrator
K+9	Second controller integrator
K+10	Fuel
K+11	Water walls
K+12	First delay integrator
K+13	Second delay integrator
K+14	Third delay integrator
K+14	Fourth delay integrator
K+16	Measured MW

VARs	Description
L	Internal memory
L+1	Pressure setpoint, P_{sp}
L+2	MW demand
L+3	Pressure error, P_E
L+4	Throttle pressure, P_T
L+5	C_2 VAR
L+6	C_3 VAR

Govenor gain K-1/R, L_{MAX} and L_{MIN} in pu on generator MVA base.

```
IBUS, 'TGOV5', ID, JBUS, M, CON(J) to CON(J+48)   /
```



7.47. TURCZT

Czech Hydro and Steam Governor

CONs	Value	Description
J		f_{DEAD} (pu)
J+1		f_{MIN} (pu)
J+2		f_{MAX} (pu)
J+3		K_{KOR} (pu)
J+4		$K_M > 0$ (pu)
J+5		K_P (pu)
J+6		SDEAD (pu)
J+7		K_{STAT} (pu)
J+8		K_{HP} (pu)
J+9		T_C (sec)
J+10		T_I (sec) [a]
J+11		T_{EHP} (sec)
J+12		TV > 0 (sec)
J+13		T_{HP} (sec)
J+14		T_R (sec)
J+15		T_W (sec)
J+16		N_{TMAX} (pu)
J+17		N_{TMIN} (pu)
J+18		G_{MAX} (pu)
J+19		G_{MIN} (pu)
J+20		V_{MIN} (pu/sec)
J+21		V_{MAX} (pu/sec)

[a]For $T_{I1} = 0$, STATE(K) and STATE(K+1) are both zero and K_P must be greater than zero.

STATEs	Description
K	Transducer
K+1	PI regulator
K+2	Hydro converter
K+3	Regulation valves
K+4	Hydro unit/HP part
K+5	Reheater

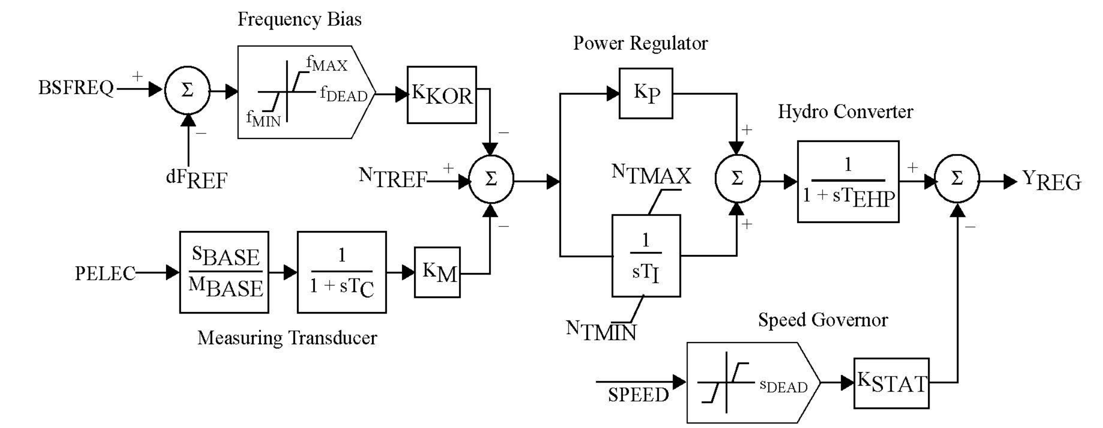
VARs	Description
L	NTREF
L+1	dFREF
L+2	YREG

ICON	Value	Description
M		SWITCH:

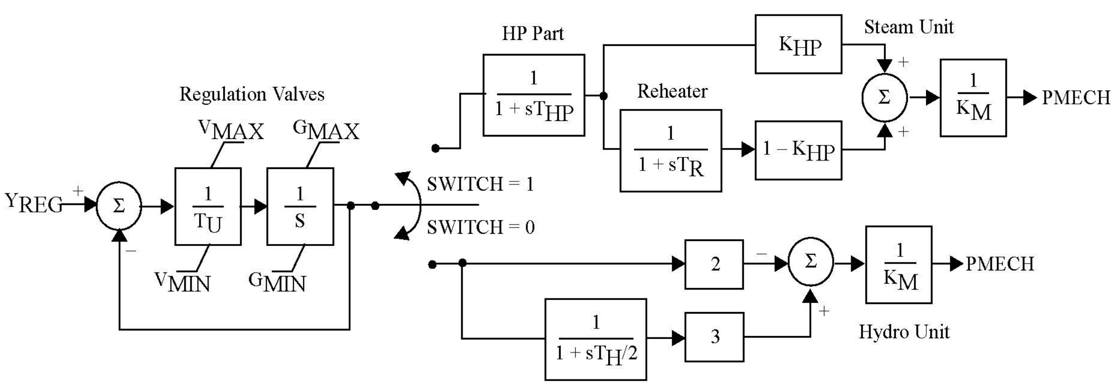
ICON	Value	Description
		• 0 - Hydro • 1 - Steam

Govenor gain K_{KOR} = 1/R is in pu on generator MVA base.

```
IBUS, 'TURCZT', ID, ICON (M), CON(J) to CON(J+21)   /
```



Governor



Turbine

7.48. TWDM1T

Tail Water Depression Hydro Governor Model 1

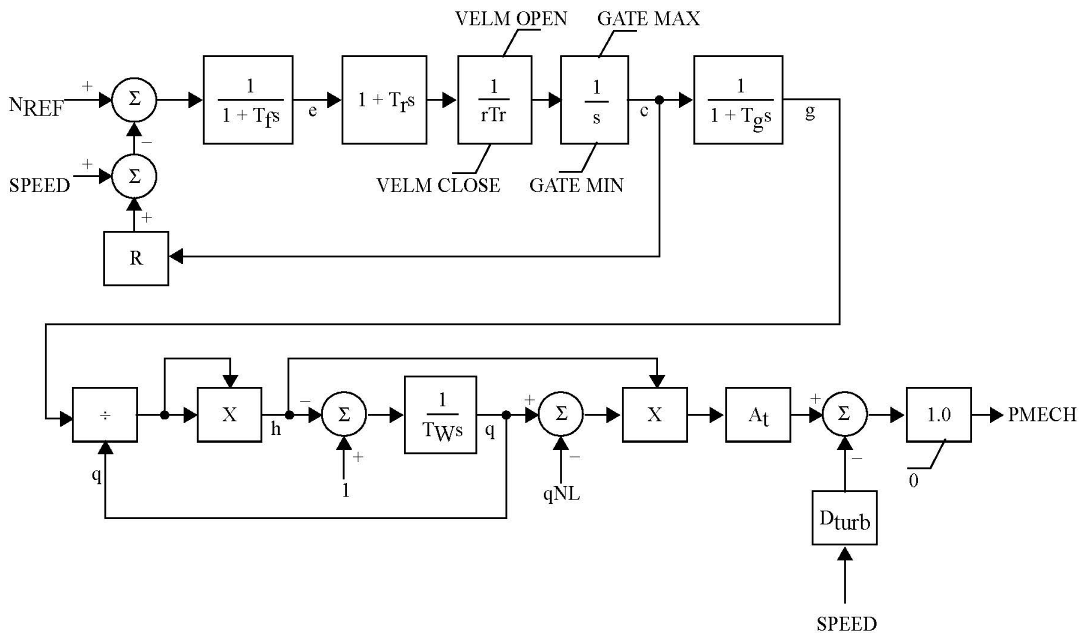
ICONs	Value	Description
M		• 0 - TWD has not tripped • 1 - TWD has tripped
M+1		• = 0 - calculate N_{REF} • ≠ 0 - N_{REF} = CON(J+19)

CONs	Value	Description
J		R, permanent droop
J+1		r, temporary droop
J+2		T_r, governor time constant (>0)
J+3		T_f, filter time constant (>0)
J+4		T_G, servo time constant (>0)
J+5		V_{ELMX}, open gate velocity limit (pu/sec)
J+6		V_{ELMN}, close gate velocity limit (pu/sec) (<0)
J+7		G_{MAX}, maximum gate limit
J+8		G_{MIN}, minimum gate limit
J+9		T_W, water time constant (sec) (>0)
J+10		A_t, turbine gain
J+11		D_{turb}, turbine damping
J+12		q_{NL}, no power flow
J+13		F1, frequency deviation (pu)
J+14		T_{F1}, time delay (sec)
J+15		F_2, frequency deviation (pu)
J+16		s_{F2}, frequency (pu/sec)
J+17		T_{F2}, time delay (sec)
J+18		GMXRT, rate with which GMAX changes when TWD is tripped (pu/sec)
J+19		N_{REF}, setpoint frequency deviation (pu)
J+20		T_{ft}, frequency filter time constant (>0

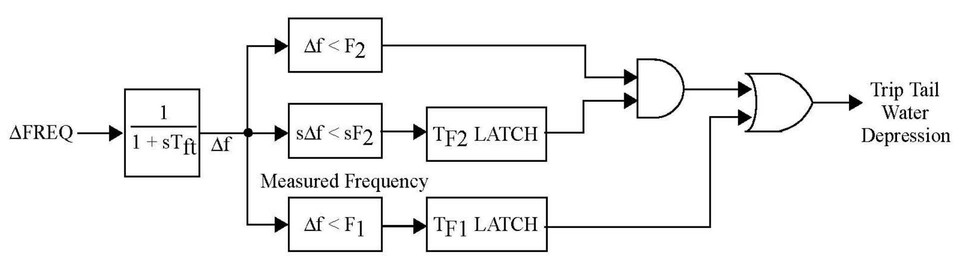
STATEs	Description
K	e, filter output
K+1	e, filter output
K+2	c, desired Gate
K+3	g, gate opening
K+4	q, turbine flow
K+5	G_{MAX} state

VARs	Description
L	N_{REF}, speed reference
L+1	h, turbine head
L+2	Internal memory
L+3	Internal memory
L+4	Measured frequency rate

```
IBUS,'TWDM1T', ID, ICON (M) and ICON (M+1), CON(J) to CON(J+20)   /
```



Tail Water Depression Model 1



Tail Water Depression Trip Model

7.49. TWDM2T

Tail Water Depression Hydro Governor Model 2

ICONs	Value	Description
M		• 0 - TWD has not tripped • 1 - TWD has tripped
M+1		• = 0 - Calculate P_{REF} • ≠ 0 - P_{REF} = CON(J+20)

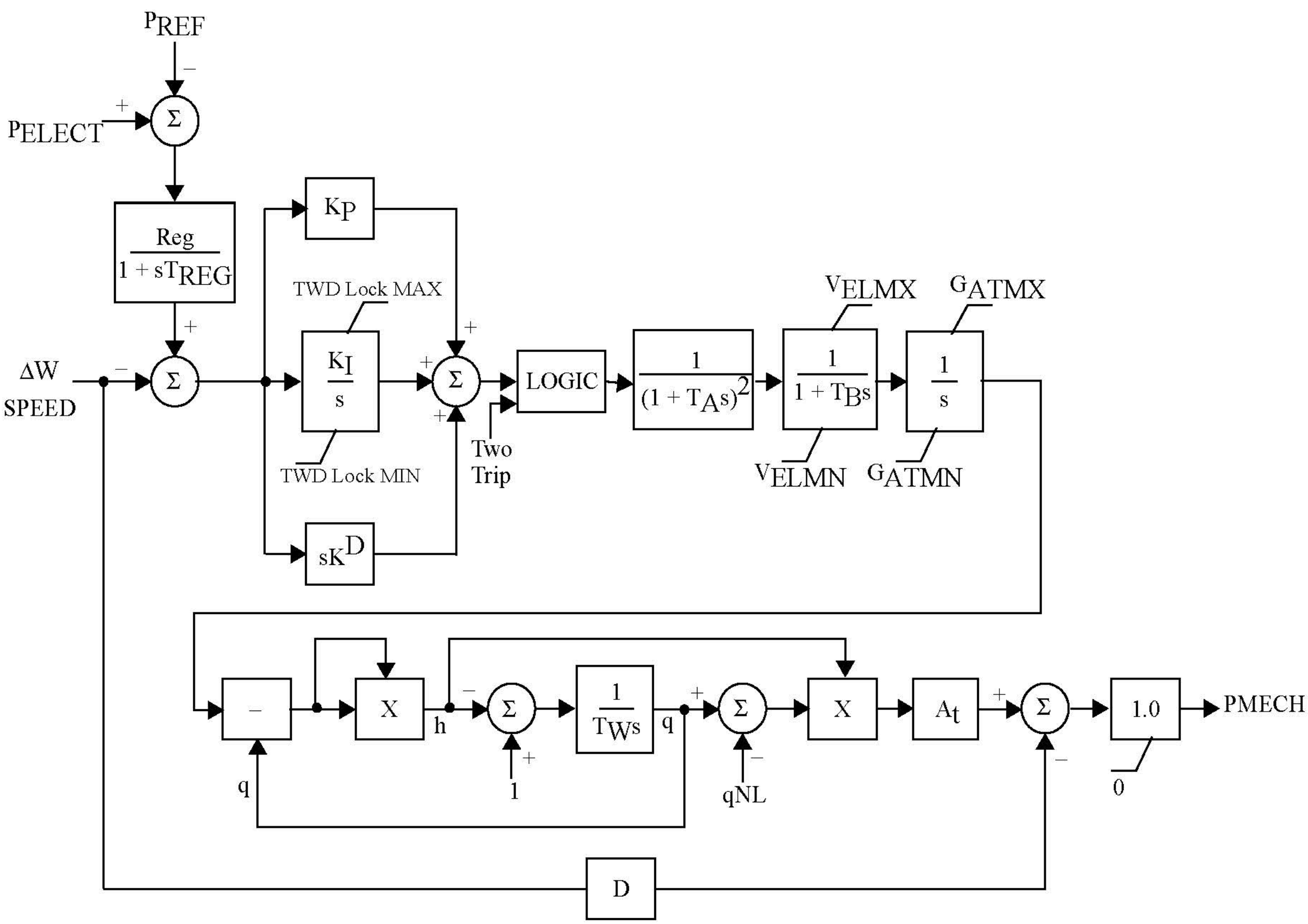
CONs	Value	Description
J		T_{REG} (sec)
J+1		Reg
J+2		K_P
J+3		K_I
J+4		K_D
J+5		T_A (sec) (> 0)
J+6		T_B (sec) (> 0)
J+7		V_{ELMX} (pu/sec)
J+8		V_{ELMN} (pu/sec) (> 0)
J+9		GATMX (pu)
J+10		GATMN (pu)
J+11		T_W (sec) (> 0)
J+12		A_t, turbine gain
J+13		q_{NL}, no power flow
J+14		D_{turb}, turbine damping
J+15		F_1, frequency deviation (pu)
J+16		T_{F1}, time delay (sec)
J+17		F_2, frequency deviation (pu)
J+18		sF2, frequency (pu/sec)
J+19		T_{F2}, time delay (sec)
J+20		P_{REF}, power reference (pu)
J+21		T_{ft}, frequency filter time constant (sec) (>0)

STATEs	Description
K	Measured electrical power deviation
K+1	PID controller
K+2	First lag
K+3	Second lag
K+4	Rate

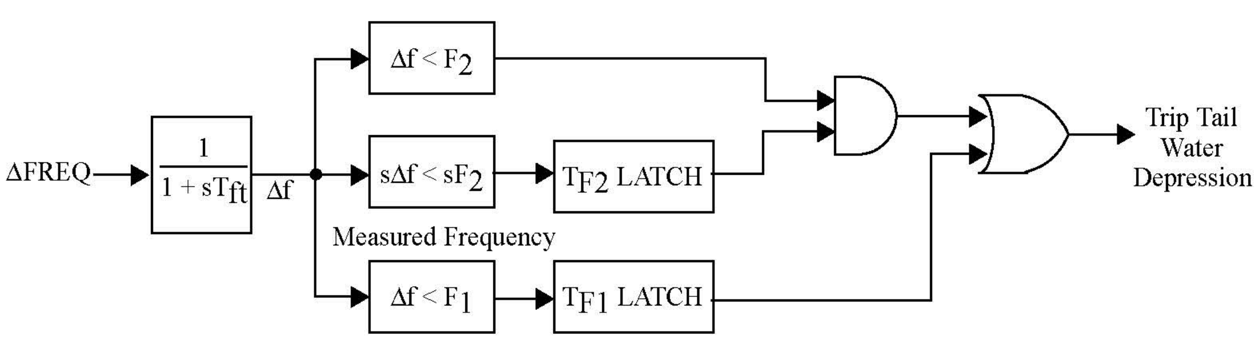
STATEs	Description
K+5	Rate
K+6	q, turbine flow
K+7	Measured frequency

VARs	Description
L	P_{REF}, electrical power reference
L+1	h, turbine head
L+2	Internal memory
L+3	Internal memory
L+4	Measured frequency rate

```
IBUS, 'TWDM2T', ID, ICON (M) and ICON (M+1), CON(J) to CON(J+21)   /
```



Tail Water Depression Model 2



Tail Water Depression Trip Model

7.50. URCSCT

Combined Cycle on Single Shaft

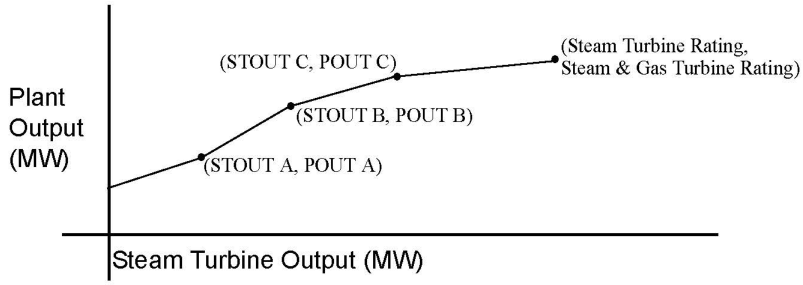
CONs	Value	Description
J		Refer to model GAST2A CONs
...		
J+30		
J+31		Refer to model IEEEG1 CONs
...		
J+50		
J+51		ST Rating, Steam turbine rating (MW)
J+52		POUTA, Plant total, point A (MW)
J+53		STOUT A, Steam turbine output, point A (MW)
J+54		POUTB, Plant total, point B (MW)
J+55		STOUT B, Steam turbine output, point B (MW)
J+56		POUT C, Plant total, point C (MW)
J+57		STOUT C, Steam turbine output, point C (MW)

Note: CON(J+37) and CON(J+38) of the URCST model (which are P_{MAX} and P_{MIN} values corresponding to the IEEEG1 model) are the pu on steam turbine MW rating specified in CON(J+51).

STATEs	Description
K	Refer to model GAST2A STATEs
...	
K+12	
K+13	Refer to model IEEEG1 STATEs
...	
K+18	

VARs	Description
L	Refer to model GAST2A VARs
...	
L+3	
L+4	Refer to model IEEEG1 VARs
L+5	

```
IBUS, 'URCSCT', ID, GAST2A CONs, IEEEG1 CONs, CON(J+51) to
     CON(J+57)   /
```


Plant
Output
(MW)
(STOUT C, POUT C)
(Steam Turbine Rating,
Steam & Gas Turbine Rating)
(STOUT B, POUT B)
(STOUT A, POUT A)
Steam Turbine Output (MW)

7.51. URGS3T

WECC Gas Turbine Model

CONs	Value	Description
J		R
J+1		T_1 (> 0) (sec)
J+2		T_2 (> 0) (sec)
J+3		T_3 (> 0) (sec)
J+4		Lmax
J+5		Kt
J+6		V_{MAX}
J+7		V_{MIN}
J+8		D_{turb}
J+9		Fidle
J+10		Rmax
J+11		Linc (> 0)
J+12		T_{ltr} (>0) (sec)
J+13		Ltrat
J+14		a
J+15		b (> 0)
J+16		db_1
J+17		err
J+18		db_2
J+19		GV_1
J+20		P_{GV1}
J+21		GV_2
J+22		P_{GV2}
J+23		GV_3
J+24		P_{GV3}
J+25		GV_4
J+26		P_{GV4}
J+27		GV_5
J+28		P_{GV5}
J+29		Ka
J+30		T_4
J+31		T_5
J+32		MWCAP

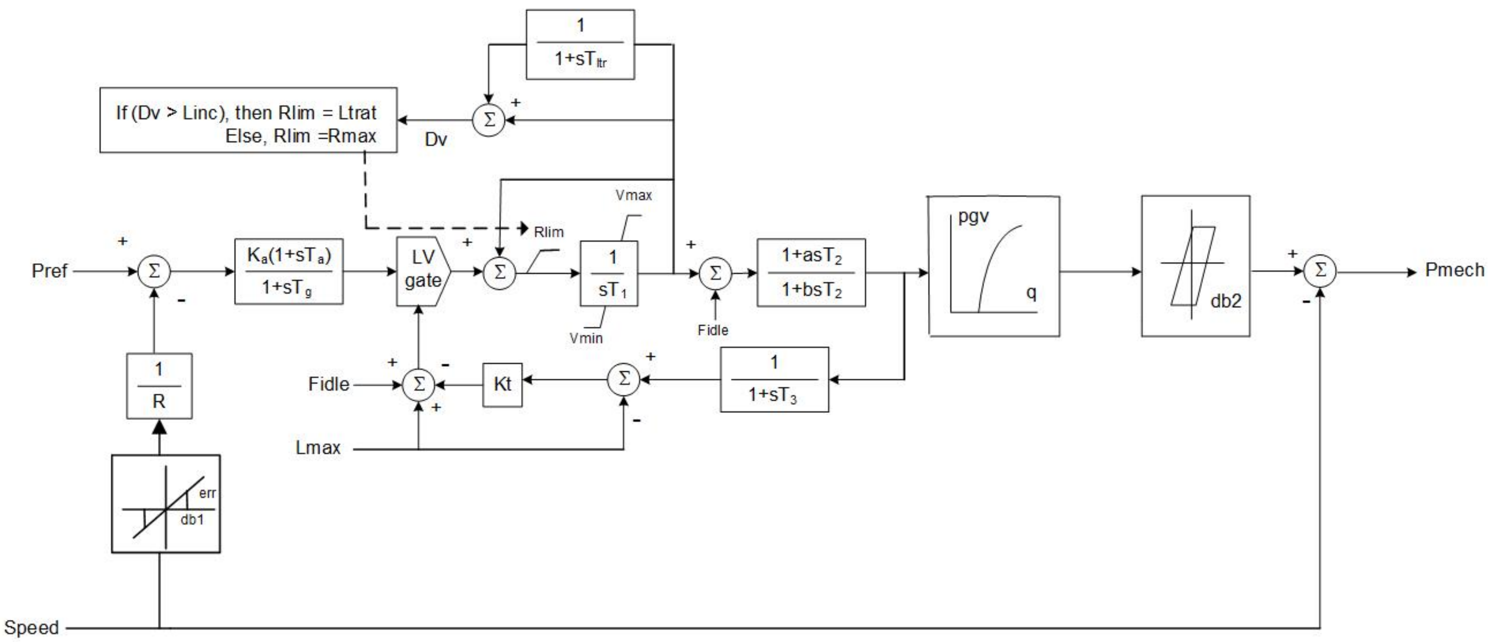
STATEs	Description
K	Governor output
K+1	Engine output
K+2	Exhaust temperature delay

STATEs	Description
K+3	Load limit
K+4	Governor lead/lag

VARs	Description
L	Reference
L+1	Deadband, In
L+2	Deadband, Out
L+3	Deadband_2, In
L+4	Deadband_2, Out

R and D_{turb} are in pu on generator MVAbase.

```
IBUS, 'URGS3T', ID, CON(J) to CON(J+32)   /
```



7.52. WEHGOV

Woodward Electric Hydro Governor Model

CONs	Value	Description
J		R-PERM-GATE[a]
J+1		R-PERM-PE[b]
J+2		T_{PE} (sec)
J+3		K_p
J+4		K_I
J+5		K_D
J+6		T_D (sec)
J+7		T_P (sec)
J+8		T_{DV} (sec)
J+9		T_G (sec)
J+10		GTMXOP (>0)
J+11		GTMXCL (<0)
J+12		G_{MAX}
J+13		G_{MIN}
J+14		D_{turb}
J+15		T_W (sec)
J+16		Speed Dead Band (DBAND)
J+17		DPV
J+18		DICN
J+19		GATE 1
J+20		GATE 2
J+21		GATE 3
J+22		GATE 4
J+23		GATE 5
J+24		FLOW G1
J+25		FLOW G2
J+26		FLOW G3
J+27		FLOW G4
J+28		FLOW G5
J+29		FLOW P1
J+30		FLOW P2
J+31		FLOW P3
J+32		FLOW P4
J+33		FLOW P5
J+34		FLOW P6
J+35		FLOW P7
J+36		FLOW P8

CONs	Value	Description
J+37		FLOW P9
J+38		FLOW P10
J+39		PMECH 1
J+40		PMECH 2
J+41		PMECH 3
J+42		PMECH 4
J+43		PMECH 5
J+44		PMECH 6
J+45		PMECH 7
J+46		PMECH 8
J+47		PMECH 9
J+48		PMECH 10

[a]Feedback settings.

[b]Feedback settings.

STATEs	Description
K	Pilot valve position
K+1	Distribution valve position
K+2	Gate position
K+3	Turbine flow
K+4	Derivative controller
K+5	Integral controller
K+6	PE transducer output

VARs	Description
L	Reference
L+1	Turbine head
L+2	Controller output
L+3	Gate position

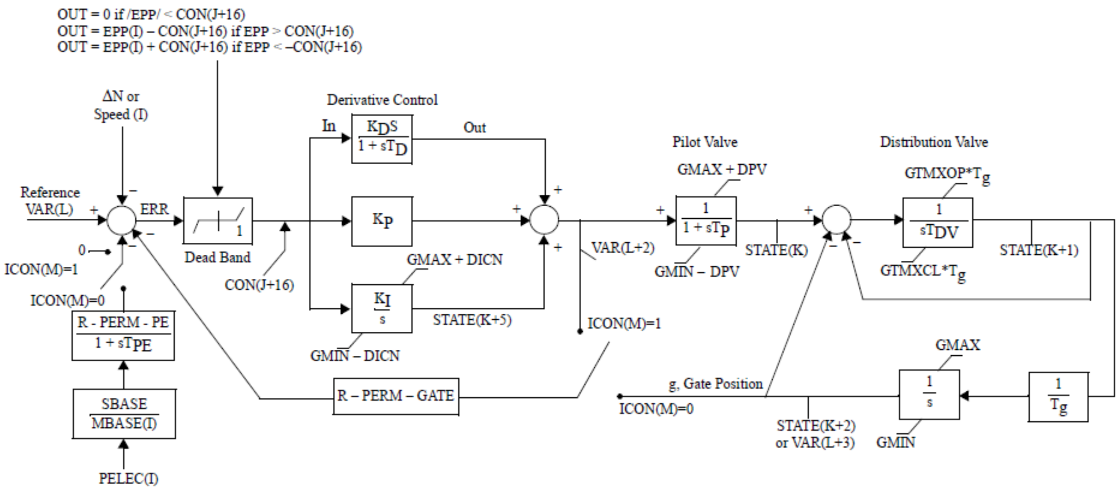
ICON	Value	Description
M		Feedback signal switch[a] (0 or 1)

[a]Feedback settings.

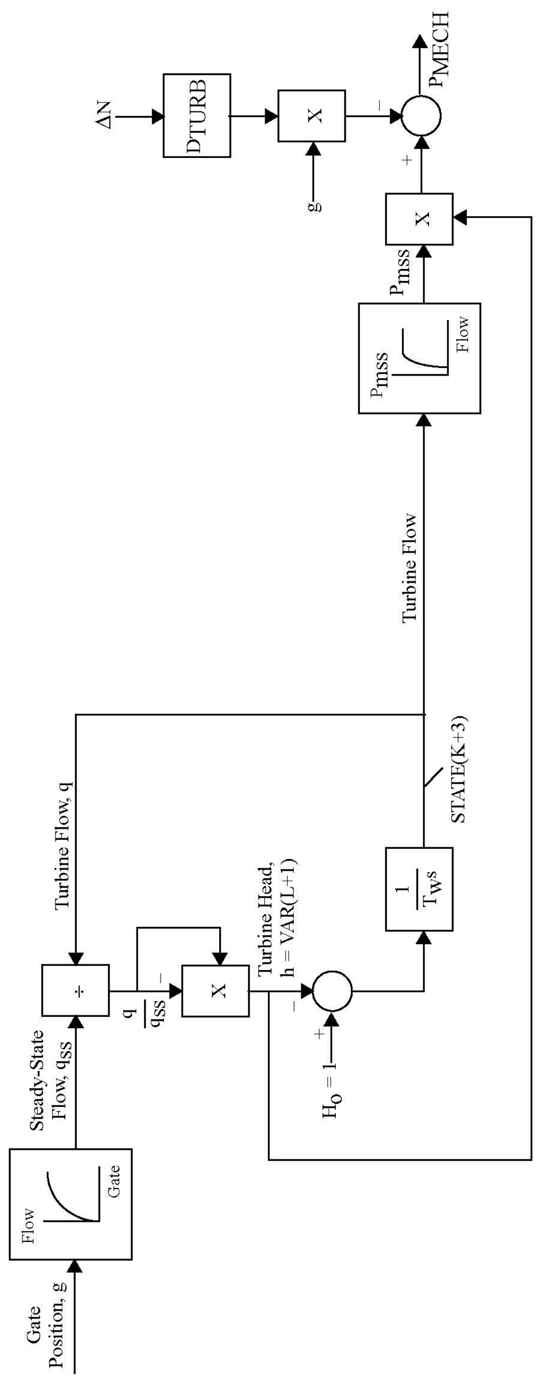
Feedback Signal	CON(J)	CON(J+1)	ICON(M)
Electrical Power	0	Droop	0
Gate Position	Droop	0	0
PID Output	Droop	0	1

R-PERM-GATE, R-PERM-PE and D_{turb} are i n pu on generator MVA base.

```
IBUS, 'WEHGOV', ID, ICON(M), CON(J) to CON(J+48)   /
```



Governor and Hydraulic Actuators



Turbine Dynamics

7.53. WESGOV

Westinghouse Digital Governor for Gas Turbine

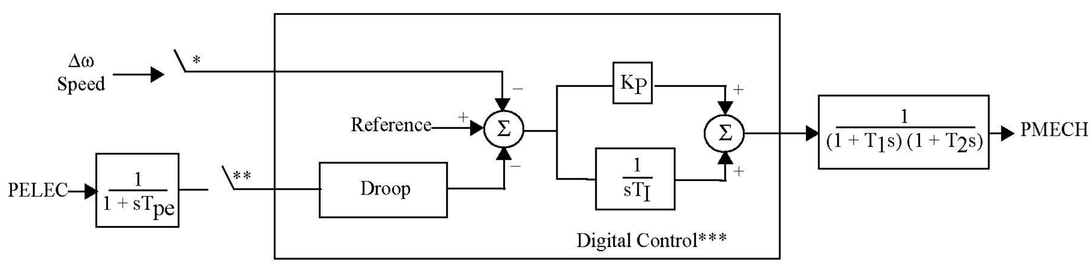
CONs	Value	Description
J		ΔTC (sec), Δt sample for controls
J+1		ΔT_P (sec), Δt sample for PE
J+2		Droop
J+3		K_p
J+4		T_I (> 0) (sec)
J+5		T_1 (sec)
J+6		T_2 (sec)
J+7		A_{LIM}
J+8		T_{pe} (sec)

STATEs	Description
K	PE transducer
K+1	Valve position
K+2	PMECH

VARs	Description
L	References
L+1	PI output
L+2	Integration for PI
L+3	Integration for PI
L+4	PE transducer output
L+5	Speed measurement

Droop is in pu on generator MVA base.

```
IBUS, 'WESGOV', ID, CON(J) to CON(J+8)   /
```



*Sample hold with sample period defined by ΔTC.
**Sample hold with sample period defined by ΔTP.
***Maximum change is limited to A_{LIM} between sampling times.

7.54. WESGOVDU

Westinghouse Digital Governor for Gas Turbine

ICONs	Value	Description
M		Internal (to be entered as 0)
M+1		Internal (to be entered as 0)

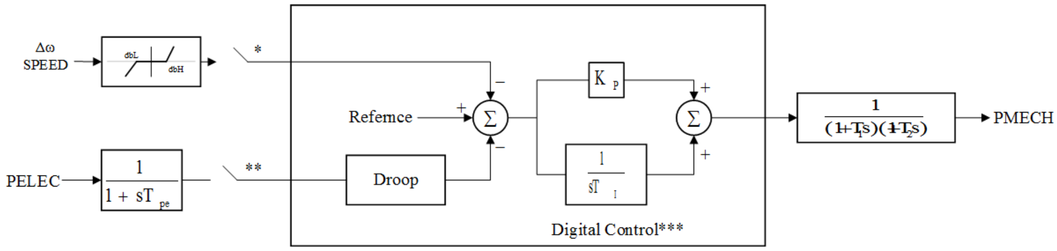
CONs	Value	Description
J		ΔTC (sec), Δt sample for controls
J+1		ΔT_P (sec), Δt sample for PE
J+2		Droop
J+3		K_p
J+4		T_I (> 0) (sec)
J+5		T_1 (sec)
J+6		T_2 (sec)
J+7		A_{LIM}
J+8		Tpe (sec)
J+9		DBH (pu), deadband for overspeed, (≥ 0)
J+10		DBL (pu), deadband for underspeed, (≤ 0)
J+11		T_{Rate} (MW), turbine rating, if zero, then MBASE used

STATEs	Description
K	PE transducer
K+1	Valve position
K+2	PMECH

VARs	Description
L	References
L+1	PI output
L+2	Integration for PI
L+3	Integration for PI
L+4	PE transducer output
L+5	Speed measurement
L+6	Deadband output

Droop is in pu T_{Rate} if T_{Rate} > 0, else in pu on generator MVA base.

```
IBUS, 'USRMDL', ID, 'WESGOVDU'   5   0   2   12   3   7   0   0   CON(J)
 to CON(J+11)   /
```



*Sample hold with sample period defined by ΔTC.
**Sample hold with sample period defined by ΔTP.
***Maximum change is limited to A_{LIM} between sampling times.

7.55. WPIDHY

Woodward PID Hydro Governor

CONs	Value	Description
J		T_{REG} (sec)
J+1		REG[a]
J+2		K_P
J+3		K_I
J+4		K_D
J+5		T_A (>0) (sec)
J+6		T_B (>0) (sec)
J+7		V_{ELMX} (>0)
J+8		V_{ELMN} (<0)
J+9		GATMX
J+10		GATMN
J+11		T_W (>0) (sec)
J+12		P_{MAX}
J+13		P_{MIN}
J+14		D
J+15		G_0
J+16		G_1
J+17		P_1
J+18		G_2
J+19		P_2
J+20		P_3

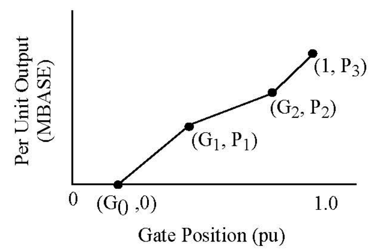
[a]REG has to be input as a negative value because the input to REG block is P1ELEC - P_{REF} instead of P_{REF} - P_{ELEC}.

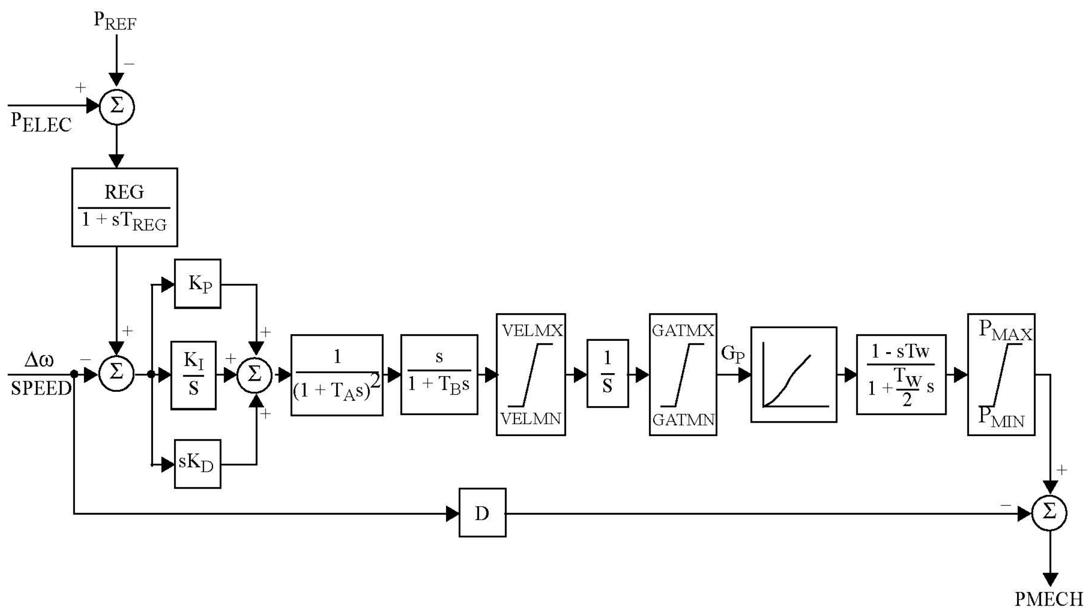
STATEs	Description
K	Measured electrical power deviation
K+1	PID controller
K+2	First lag
K+3	Second lag
K+4	Rate
K+5	Gate
K+6	Mechanical power

VARs	Description
L	Electrical power reference

REG, P_{MAX}, P_{MIN}, and D are in pu on generator MVA base.

```
IBUS, 'WPIDHY', ID, CON(J) to CON(J+20)   /
```


Per Unit Output
(MBASE)
(1, P3)
(G2, P2)
(G1, P1)
0
(G0 ,0)
1.0
Gate Position (pu)


PREF
PELEC
REG
1 + sTREG
KP
KI
S
sKD
Δω
SPEED
1
(1 + TAs)^2
s
1 + TBs
VELMX
VELMN
1
S
GATMX
GATMN
GP
1 - sTw
1 + Tw/2 s
PMAX
PMIN
D
PMECH

7.56. WPIDHYDU

Woodward PID Hydro Governor

CONs	Value	Description
J		T_{REG} (sec)
J+1		REG[a]
J+2		K_P
J+3		K_I
J+4		K_D
J+5		T_A (>0) (sec)
J+6		T_B (>0) (sec)
J+7		V_{ELMX} (>0)
J+8		V_{ELMN} (<0)
J+9		GATMX
J+10		GATMN
J+11		T_W (>0) (sec)
J+12		P_{MAX}
J+13		P_{MIN}
J+14		D
J+15		G_0
J+16		G_1
J+17		P_1
J+18		G_2
J+19		P_2
J+20		P_3
J+21		DBH (pu), deadband for overspeed, (≥ 0)
J+22		DBL (pu), deadband for underspeed, (≤ 0)
J+23		T_{Rate} (MW), turbine rating, if zero, then MBASE used

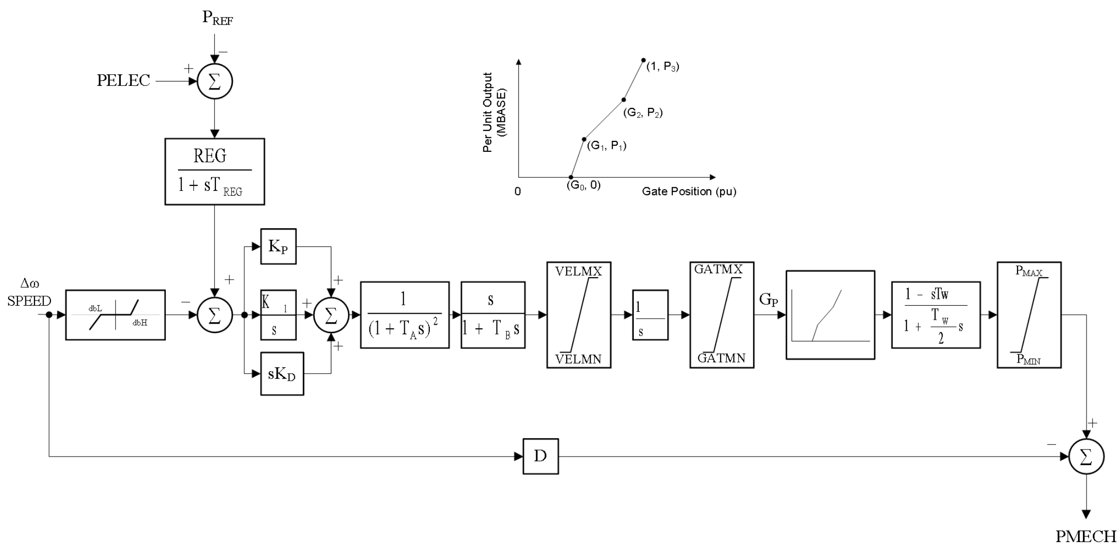
[a]REG has to be input as a negative value because the input to REG block is P1ELEC - P_{REF} instead of P_{REF} - P_{ELEC}.

STATEs	Description
K	Measured electrical power deviation
K+1	PID controller
K+2	First lag
K+3	Second lag
K+4	Rate
K+5	Gate
K+6	Mechanical power

VARs	Description
L	Electrical power reference
L+1	Deadband output

REG, P_{MAX}, P_{MIN}, and D are in pu on T_{Rate} if T_{Rate} >0, else in pu on generator MVA base.

```
IBUS, 'USRMDL', ID, 'WPIDHYDU'   5   0   0   24   7   2   CON(J) to CON(J
+23)   /
```



7.57. WSHYDD

WECC Double-Derivative Hydro Governor

CONs	Value	Description
J		db_1
J+1		err
J+2		T_d (sec)
J+3		K_1
J+4		T_f (sec)
J+5		K_D
J+6		K_P
J+7		R
J+8		T_t
J+9		K_G
J+10		T_P (sec)
J+11		VEL_{OPEN} (>0)
J+12		VEL_{CLOSE} (>0)
J+13		P_{MAX}
J+14		P_{MIN}
J+15		db_2
J+16		GV_1
J+17		P_{GV1}
J+18		GV_2
J+19		P_{GV2}
J+20		GV_3
J+21		P_{GV3}
J+22		GV_4
J+23		P_{GV4}
J+24		GV_5
J+25		P_{GV5}
J+26		A_turb
J+27		B_{turb} (> 0)
J+28		T_{turb} (> 0) (sec)
J+29		T_{rate}

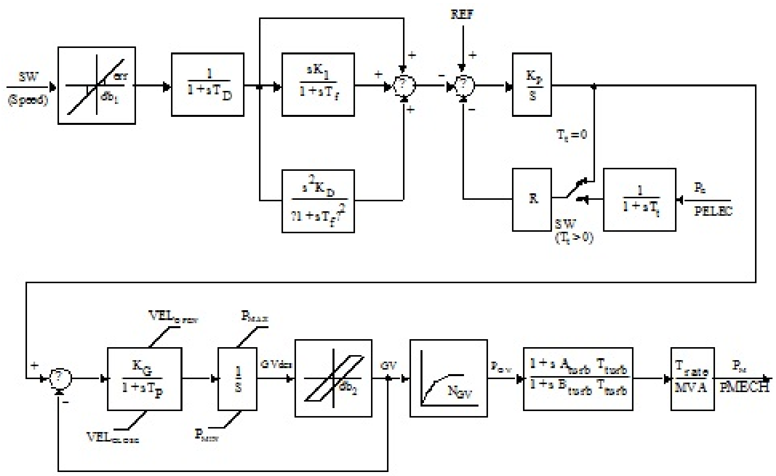
STATEs	Description
K	Output, T_d
K+1	K_1 state
K+2	K_D first
K+3	K_D second
K+4	CV
K+5	Valve speed

STATEs	Description
K+6	Gate position
K+7	Generator power
K+8	Turbine

VARs	Description
L	Reference
L+1	Deadband_1 In
L+2	Deadband_1 Out
L+3	P_{MAX}
L+4	P_{MIN}
L+5	Deadband_2 In
L+6	Deadband_2 Out

R1, P_{MAX}, and P_{MIN} are in pu on turbine MW base.

```
IBUS, 'WSHYDD', ID, CON(J) to CON(J+29)   /
```



7.58. WSHYGP

WECC GP Hydro Governor Plus Turbine

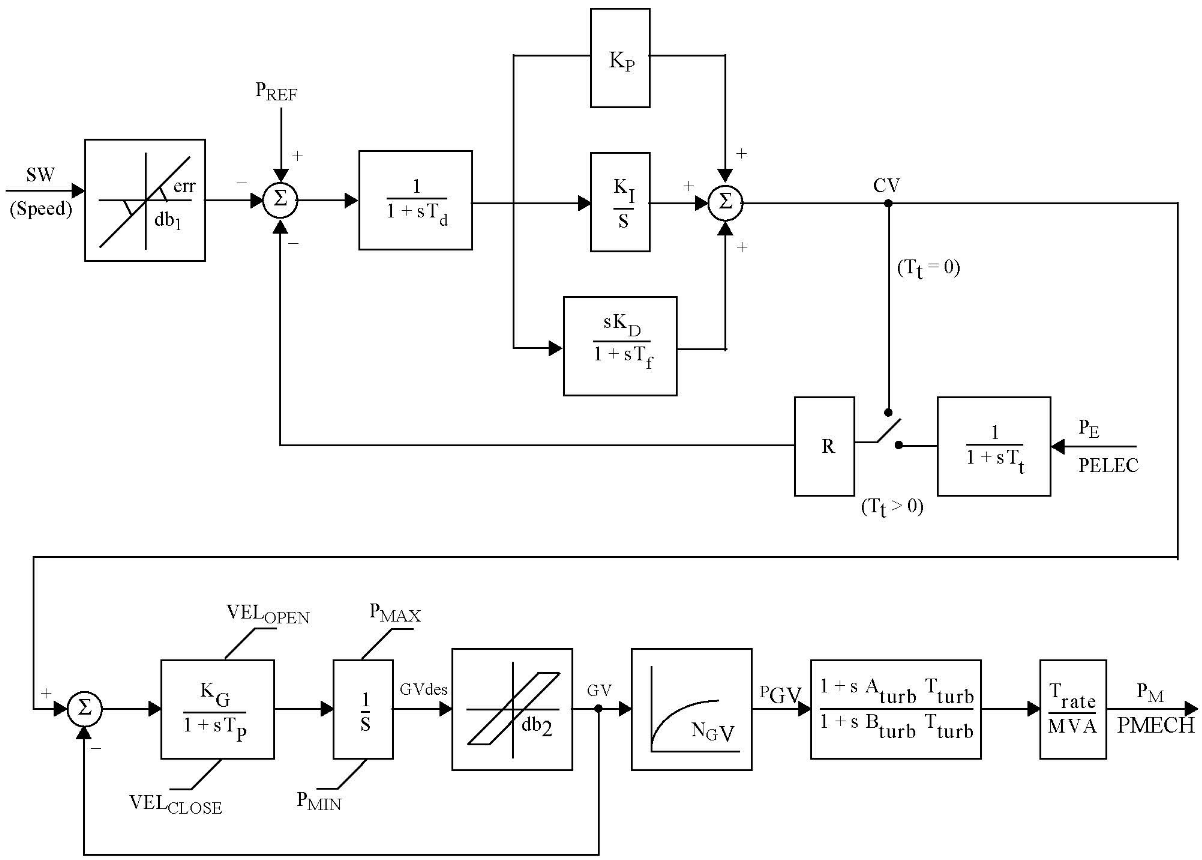
CONs	Value	Description
J		db_1
J+1		err
J+2		T_D (sec)
J+3		K_I
J+4		T_f (sec)
J+5		K_D
J+6		K_P
J+7		R
J+8		Tt
J+9		K_G
J+10		T_P (sec)
J+11		VEL_{OPEN} (>0)
J+12		VEL_{CLOSE} (>0)
J+13		P_{MAX}
J+14		P_{MIN}
J+15		db_2
J+16		GV_1
J+17		P_{GV1}
J+18		GV_2
J+19		P_{GV2}
J+20		GV_3
J+21		P_{GV3}
J+22		GV_4
J+23		P_{GV4}
J+24		GV_5
J+25		P_{GV5}
J+26		A_{turb}
J+27		B_{turb} (> 0)
J+28		T_{turb} (sec)
J+29		T_{rate}

STATEs	Description
K	Output, T_d
K+1	Integrator state
K+2	Derivative state
K+3	Valve speed
K+4	Gate position
K+5	Generator power

STATEs	Description
K+6	Turbine

VARs	Description
L	Reference
L+1	$Deadband_1$ In
L+2	$Deadband_1$ Out
L+3	P_{MAX}
L+4	P_{MIN}
L+5	$Deadband_2$ In
L+6	$Deadband_2$ Out

```
IBUS, 'WSHYGP', ID, CON(J) to CON(J+29)   /
```



7.59. WSIEG1

WECC Modified IEEE Type 1 Speed-Governing Model

CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3(> 0) (sec)
J+4		U_o
J+5		U_c (< 0)
J+6		P_{MAX}
J+7		P_{MIN}
J+8		T_4 (sec)
J+9		K_1
J+10		K_2
J+11		T_5 (sec)
J+12		K_3
J+13		K_4
J+14		T_6 (sec)
J+15		K_5
J+16		K_6
J+17		T_7 (sec)
J+18		K_7
J+19		K_8
J+20		db_1
J+21		err
J+22		db_2
J+23		GV_1
J+24		P_{GV1}
J+25		GV_2
J+26		P_{GV2}
J+27		GV_3
J+28		P_{GV3}
J+29		GV_4
J+30		P_{GV4}
J+31		GV_5
J+32		P_{GV5}
J+33		IBLOCK

STATEs	Description
K	1st governor integrator

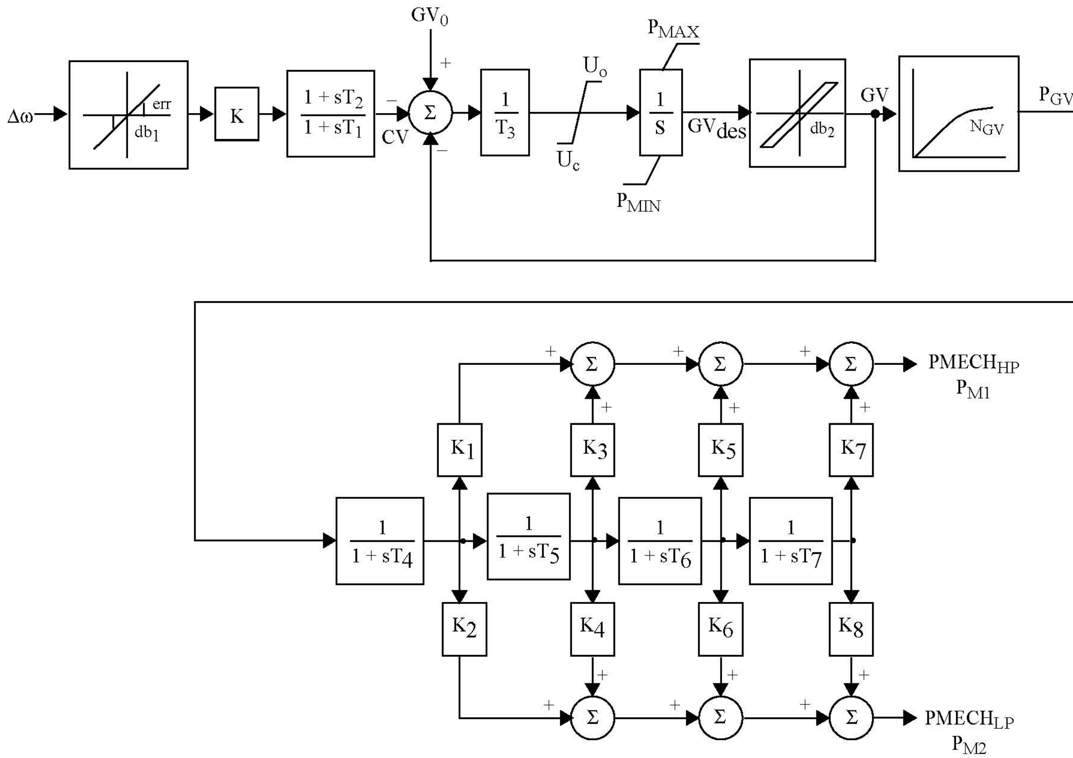
STATEs	Description
K+1	Governor output
K+2	1st turbine integrator
K+3	2nd turbine integrator
K+4	3rd turbine integrator
K+5	4th turbine integrator

VARs	Description
L	Reference
L+1	Internal memory
L+2	Deadband_1 in
L+3	Deadband_1 out
L+4	P´MAX
L+5	P'_{MIN}
L+6	Deadband_2 in
L+7	Deadband_2 out

```
IBUS, 'WSIEG1', ID, JBUS, M, CON(J) to CON(J+33)   /
```

At initialization:

IBLOCK = 0	$P'MAX = P_{MAX}$	$P'_{MIN} = P_{MIN}$
IBLOCK = 1	If $P_{MIN} = 0$	$P'_{MIN} = P_{INITIAL}$
IBLOCK = 2	If $P_{MAX} = 0$	$P'MAX = P_{INITIAL}$
IBLOCK = 3	If $P_{MIN} = 0$ If $P_{MAX} = 0$	$P'_{MIN} = P_{INITIAL}$ $P'MAX = P_{INITIAL}$


Δω
err
db1
K
1 + sT2
1 + sT1
CV
GV0
Σ
1
T3
Uo
Uc
PMAX
PMIN
1
s
GVdes
db2
GV
NGV
PGV
1
1 + sT4
1
1 + sT5
1
1 + sT6
1
1 + sT7
K1
K2
K3
K4
K5
K6
K7
K8
PMECHHP
PM1
PMECHLP
PM2

Chapter 8
Turbine Load Controller Models

This chapter contains a collection of data sheets for the turbine-load controller models contained in the PSS®E dynamics model library.

Model	Description
LCFB1	Turbine load controller model

8.1. LCFB1

Turbine Load Controller Model

CONs	Value	Description
J		Fb
J+1		Tpelec
J+2		db
J+3		emax
J+4		K_p
J+5		K_I
J+6		Irmax

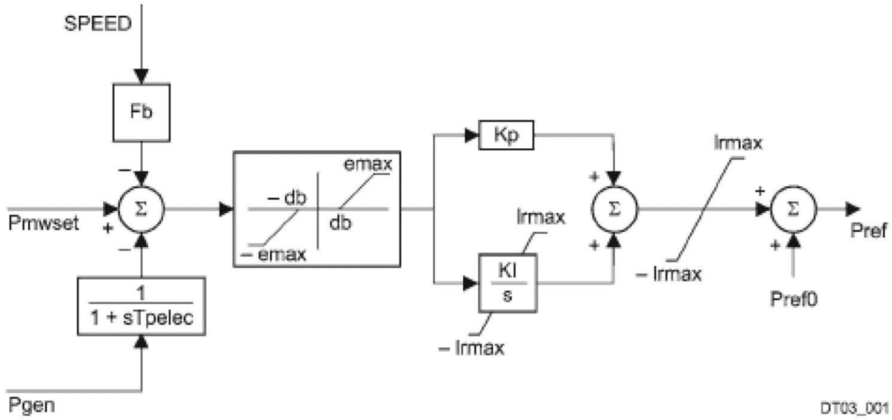
STATEs	Description
K	Measured power
K+1	Integrator

VARs	Description
L	Deadband input
L+1	Deadband output
L+2	Pref 0

```
IBUS, 'LCFB1', ID, ICON(M), ICON(M+1), CON(J) to CON(J+6)    /
```

This model can be used with the following turbine governor models.

DEGOV1	PIDGOV	HYGOVM	WSHYGP
GAST	TGOV1	HYGOVT	WSIEG1
GAST2A	TGOV2	IVOGO	TGOV5
GASTWD	TGOV3	TGOV4	
HYGOV	WEHGOV	TURGZT	
IEEEG1	WESGOV	TWDM1T	
IEEEG2	WPIDHY	TWDM2T	
IEEEG3	BBGOV1	URGS3T	
IEESGO	HYGOV2	WSHYDD	


SPEED
Fb
Pmwset
1
1 + sTpelec
Pgen
emax
– db
db
– emax
Kp
KI
s
Irmax
– Irmax
Irmax
– Irmax
Pref
Pref0
DT03_001

Chapter 9
Load Characteristic Models

This chapter contains a collection of data sheets for the load characteristic models contained in the PSS®E dynamics model library.

Model	Description
ACMTBLU1, ACMTOWU1, ACMTZNU1, ACMTARU1, ACMTALU1	User written performance based model of single phase air conditioner motor
CIM5BL, CIM5OW, CIM5ZN, CIM5AR, CIM5AL	Induction motor model
CIM6BL, CIM6OW, CIM6ZN, CIM6AR, CIM6AL	Induction motor model
CIMWBL, CIMWOW, CIMWZN, CIMWAR, CIMWAL	Induction motor model (WECC)
CLODBL, CLODOW, CLODZN, CLODAR, CLODAL	Complex load model
CMLDBLU2, CMLDOWU2, CMLDZNU2, CMLDARU2, CMLDALU2	Composite load model
CMLDBLDGU2, CMLDOWDGU2, CMLDZNDGU2, CMLDARDGU2, CMLDALDGU2	Composite load model with DER included
EXTLBL, EXTLOW, EXTLZN, EXTLAR, EXTLAL	Extended-term load reset model
IEELBL, IEELOW, IEELZN, IEELAR, IEELAL	IEEE load model
LDFRBL, LDFROW, LDFRZN, LDFRAR, LDFRAL	Load frequency model

9.1. ACMTBLU1, ACMTOWU1, ACMTZNU1, ACMTARU1, ACMTALU1

Single-phase Air Conditioner Motor Model

CONs	Value	Description
J		T_{stall}, Stall Delay (sec)
J+1		$T_{restart}$, Restart Delay (sec)
J+2		T_v, Voltage Input time constant (sec)
J+3		T_f, Frequency Input time constant (sec)
J+4		$Comp_{LF}$, Compressor Load Factor[a]
J+5		$Comp_{PF}$, Compressor Power Factor
J+6		V_{stall}, compressor stall voltage at base condition (pu)
J+7		R_{stall}, compressor motor resistance with 1.0 pu current [b]
J+8		X_{stall}, compressor motor stall reactance - unsaturated (at 1.0 pu current)
J+9		LF_{adj}, adjustment to the stall voltage proportional to compressor LF[c]
J+10		K_{p1}, real power constant for running state 1, pu W/ pu V[d]
J+11		N_{p1}, real power exponent for running state 1[d]
J+12		K_{q1}, reactive power constant for running state 1, pu VAR/ pu V[d]
J+13		N_{q1}, reactive power exponent for running state 1[d]
J+14		K_{p2}, real power constant for running state 2, pu W/ pu V[d]
J+15		N_{p2}, real power exponent for running state 2[d]
J+16		K_{q2}, reactive power constant for running state 2, pu VAR/ pu V[d]
J+17		N_{q2}, reactive power exponent for running state 2[d]
J+18		V_{brk}, compressor motor "break-down" voltage (pu)
J+19		F_{rst}, fraction of motors that are capable of restart[e]
J+20		V_{rst}, voltage at which motors can restart (pu)[f]
J+21		$CmpK_{pf}$, real power constant for frequency dependency[f]
J+22		$CmpK_{qf}$, reactive power constant for frequency dependency[f]
J+23		Vc_{1off}, Control voltage 1 at which contactors start dropping out (pu)
J+24		Vc_{2off}, Control voltage 2 at which all contactors drop out (pu)
J+25		Vc_{1on}, Control voltage 1 at which all contactors reclose (pu)

CONs	Value	Description
J+26		Vc_{2on}, Control voltage 2 at which contactors start reclosing (pu)
J+27		T_{th}, Compressor motor heating time constant (sec)[g]
J+28		Th_{1t}, Temperature at which compressor motor begin tripping[g]
J+29		Th_{2t}, Temperature at which all compressor motors are tripped[g]
J+30		F_{uvr}, fraction of compressor motors with Under Voltage relays
J+31		UV_{tr1}, 1st voltage pick-up (pu)
J+32		T_{tr1}, 1st definite time voltage pick-up (sec)
J+33		UV_{tr2}, 2nd voltage pick-up (pu)
J+34		T_{tr2}, 2nd definite time voltage pick-up (sec)

[a]If "CompLF" is zero, it is initialized to 1.If "CompLF" is greater than zero, motor MVA base is adjusted.Load Factor is defined as initial kW loading / kW rated.

[b]Stall state is characterized by an equivalent impedance, (Rstall + j Xstall).

[c]LF_{adj} factor is used to update the V_{stall} and V_{brk} as defined below:

$V_{stall}(adj)=V_{stall}*(1+LF_{adj}*(CompLF-1))$

$V_{brk}(adj)=V_{brk}*(1+LF_{adj}*(CompLF-1))$

[d]The motor run state is characterized by an exponential characteristic. The run characteristic is divided into two states as a function of bus voltage, State 1 for Bus voltage V_{brk}, and State 2 for V_{stall} < Bus Voltage < V_{brk}. State 0, corresponds to 1.0 pu Bus voltage

$P_0=1-K_{p1}*(1-V_{brk})**N_{p1}$

$Q_0=(\sqrt{}(1-CompPF**2)/CompPF)-Kq1*(1-V_{brk})**Nq1$

State 1 for Bus voltage V_{brk}

$P=P_0+K_{p1}*(V-V_{brk})**N_{p1}$

$Q=Q_0+Kq1*(V-V_{brk})**Nq1$

State 2 for V_{stall} < Bus Voltage < V_{brk}

$P=P_0+K_{p2}*(V_{brk}-V)**Np2$

$Q=Q_0+Kq2*(V_{brk}-V)**N_{q2}$

[e] See Compressor Unit Model Structure, below. Motor A once stalled remains stalled. Motor B can restart if the voltage recovers above Vrst level. Frst is the fraction of motors that are capable of restart.

[f]Frequency dependency of the load is defined by following characteristics: $P(f)=P*(1+CmpK_{pf}* \Delta f)$
$Q(f)=Q*(1+CmpK_{qf}* \Delta f/\sqrt{}(1-CompPF**2))$

[g]See Thermal Relay Model, below. Thermal relay is modelled by the following characteristics: If Th_{2t} is equal to zero or if Th_{1t} is greater than or equal to Th_{2t}, all motors are tripped instantaneously when temperature reaches Th_{1t}.

STATEs	Description
K	Bus Voltage (pu)
K+1	Bus Frequency (pu)
K+2	Compressor Motor A Temperature
K+3	Compressor Motor B Temperature
K+4	U/V Relay Timer 1
K+5	U/V Relay Timer 2
K+6	Motor A Stall Timer
K+7	Motor B Stall Timer
K+8	Motor B Restart Timer

VARs	Description
L	Bus Voltage (pu)
L+1	Bus Frequency (pu)
L+2	Aggregated AC unit real power (MW)
L+3	Aggregated AC unit reactive power (MVAr)
L+4	Aggregated AC unit current (pu on system MVA base)
L+5	Terminal current component in phase with voltage (in pu on Motor MVA Base)
L+6	Terminal current component lagging voltage (in pu on Motor MVA Base)
L+7	Terminal current comp on network real axis on system MVA base (pu)
L+8	Terminal current comp on network imag axis on system MVA base (pu)
L+9	Motor A and B Initial Temperature
L+10	Fraction of motors not tripped by U/V Relay - gain K_{uv}
L+11	Fraction of motors not tripped by contactors - gain K_{con}
L+12	Contactor status for compressor voltage calculation 0=off, 1=on
L+13	Input voltage from a previous step (pu)
L+14	K_{thA} compressor motor A fraction not tripped by thermal protection
L+15	Shunt admittance (in pu on Motor MVA Base), computed during the initialization
L+16	Motor A run / stall state (run=1/stall=0)
L+17	Motor B run / stall state (run=1/stall=0)
L+18	K_{thB} compressor motor B fraction not tripped by thermal protection
L+19	Internal variable used for determining Motor A Temperature
L+20	Internal variable used for determining Motor B Temperature
L+21	Real component of voltage at pervious time step (pu)
L+22	Reactive component of voltage at previous time step (pu)
L+23	Time instant at which the model was called previous time
L+24	Internal variable, P_0 for active power at 1.0 pu voltage4
L+25	Internal variable, Q_0 for reactive power at 1.0 pu voltage4
L+26	Computed Motor MVA base
L+27	Adjusted V_{stall} based on load factor (pu)
L+28	Adjusted V_{brk} based on load factor (pu)

Reserved ICONs	Value	Description
N		Motor A Run/Stall Status, Run=1, Stall=0
N+1		Motor B Run, Restart, Stall Status, Run=1, Restart=2, Stall=0
N+2		Under Voltage Relay Trip Status, Non-Trip=1, Trip=0
N+3		Under Voltage Relay First Pick Up Flag, Becomes 0 on Pick Up
N+4		Under Voltage Relay Second Pick Up Flag, Becomes 0 on Pick Up
N+5		Thermal Relay Trip 1 Status for Motor A, Non-trip=1. Trip=0
N+6		Thermal Relay Trip 2 Status for Motor A, Non-trip=1. Trip=0
N+7		Thermal Relay Trip 1 Status for Motor B, Non-trip=1. Trip=0
N+8		Thermal Relay Trip 2 Status for Motor B, Non-trip=1. Trip=0
N+9		Contactors Started to Drop Out Flag, Not Started to Drop Out=1, Started to Drop Out=0
N+10		All Contactors Dropped out Flag, All Not Dropped Out=1, All Dropped Out=0
N+11		Contactors Started to Reclose Flag, Not Started to Reclose=1, Started to Reclose=0
N+12		All Contactors Reclosed Flag, All Not Reclosed=1, All Reclosed=0
N+13		Motor A Stall Relay Pick Up Flag, Becomes 0 on Pick Up
N+14		Motor B Stall Relay Pick Up Flag, Becomes 0 on Pick Up
N+15		Motor B Restart Relay Pick Up Flag, Becomes 0 on Pick Up

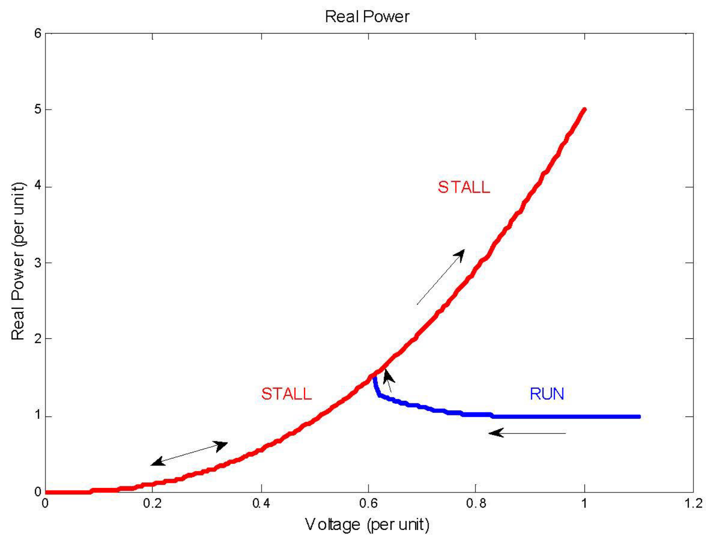
```
 I, 'USRLOD', LID, 'ACMTxxU1', 12, IT, 0, 35, 9, 29, 16, CON(J) to CON(J
+34)   /
```

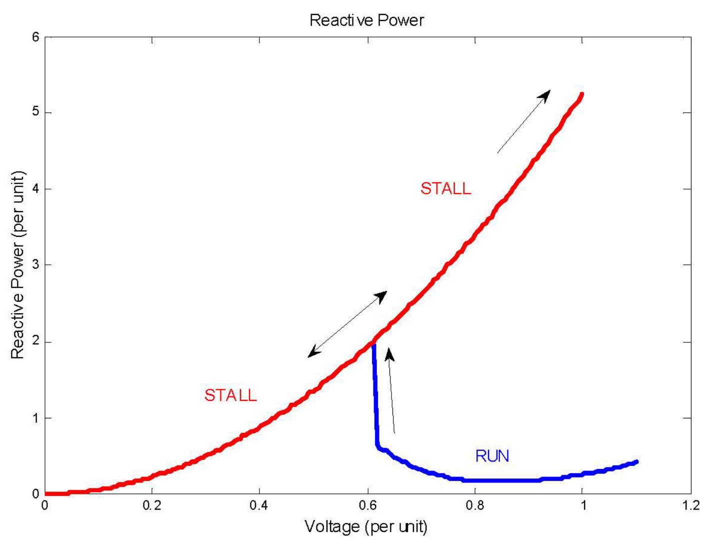
LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix xx	IT Description	"I" Description
BL	1	Bus number
OW	2	Owner number
ZN	3	Zone number
AR	4	Area number
AL	5	0

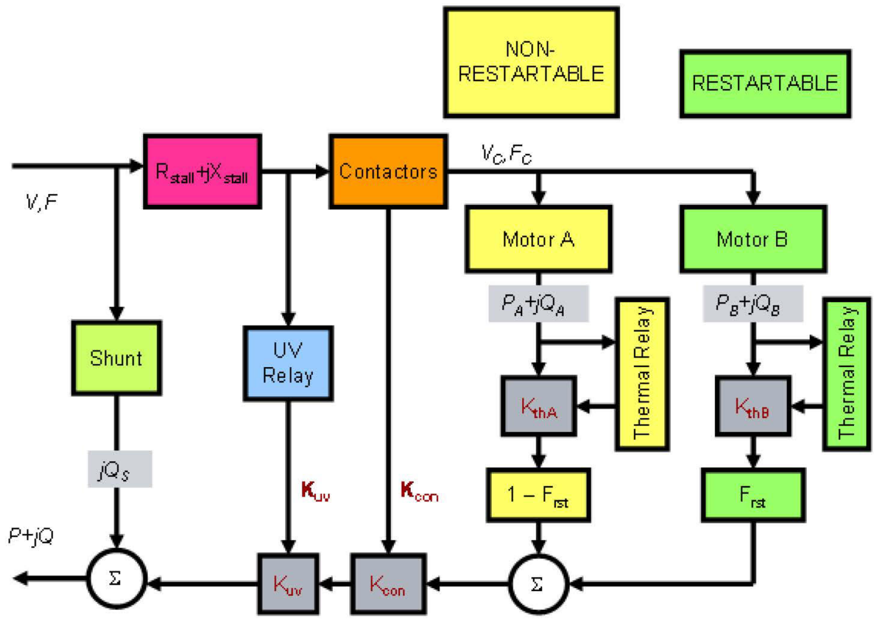
"Run" and "Stall" Characteristics of Compressor Motor[1]

"Run" and "Stall" Characteristics of Compressor Motor[1]

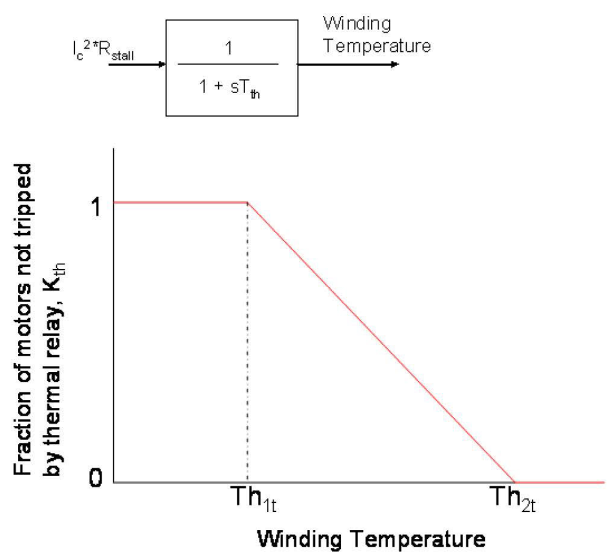




Compressor Unit Model Structure[1]



Thermal Relay Model[1]



[1] AC Unit Model specifications", WECC Load Modeling task Force, April 2008

9.2. CIM5BL, CIM5OW, CIM5ZN, CIM5AR, CIM5AL

CONs	Value	Description
J		R_A
J+1		X_A
J+2		$X_m > 0$
J+3		$R_1 > 0$
J+4		$X_1 > 0$
J+5		R_2 (0 for single cage)[a]
J+6		X_2 (0 for single cage)
J+7		$E_1 \geq 0$
J+8		$S(E_1)$
J+9		E_2
J+10		$S(E_2)$
J+11		MBASE[b]
J+12		PMULT
J+13		H (inertia, per unit motor base)
J+14		V_I (pu)[c]
J+15		T_I (cycles)[d]
J+16		T_B (cycles)
J+17		D (load damping factor)
J+18		T_{nom}, Load torque at 1 pu speed (used for motor starting only) (≥ 0)

[a]To model single cage motor: set $R_2 = X_2 = 0$.

[b]When MBASE = 0, motor MVA base = PMULT x MW load. When MBASE > 0, motor MVA base = MBASE.

[c]V_I is the per unit voltage level below which the relay to trip the motor will begin timing. To disable relay, set $V_I = 0$.

[d]T_I is the time in cycles for which the voltage must remain below the threshold for the relay to trip. T_B is the breaker delay time cycles.

STATEs	Description
K	E'_q
K+1	E'_d
K+2	E''_q
K+3	E#$_d$
K+4	#speed (pu)
K+5	Angle deviation

VARs	Description
L	Admittance of initial condition Mvar difference
L+1	Motor Q
L+2	T_{elec} (pu motor base)
L+3	$\Delta\omega$
L+4	T (pu on motor base)[a b]
L+5	I_Q

VARs	Description
L+6	ID
L+7	Motor current (pu motor base)
L+8	Relay trip time
L+9	Breaker trip time
L+10	MVA rating

[a]Load torque, $T_L L = T\,(1 + \Delta\,\omega\,)^D$

[b]For motor starting, T=T_{nom} is specified by the user in CON (J+18). For motor online studies, T=To is calculated in the code during initialization and stored in VAR (L+4).

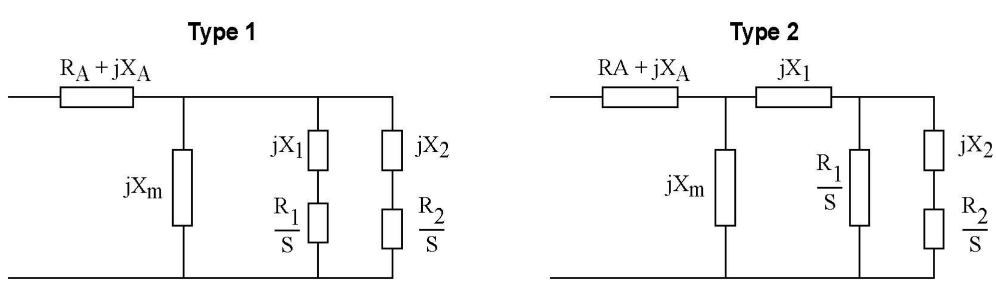
ICONs	Value	Description
M		IT, motor type (1 or 2)

Reserved ICONs	Value	Description
N		Relay action code
N+1		Relay trip flag
N+2		Breaker action code
N+3		Breaker trip flag

```
I, 'CIM5xx', LID, ICON(M), CON(J) to CON(J+18)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0



Impedances on Motor MVA Base

9.3. CIM6BL, CIM6OW, CIM6ZN, CIM6AR, CIM6AL

Induction Motor Load Model

CONs	Value	Description
J		R_A
J+1		X_A
J+2		$X_m > 0$
J+3		$R_1 > 0$
J+4		$X_1 > 0$
J+5		R_2 (0 for single cage)[a]
J+6		X_2 (0 for single cage)
J+7		$E_1 \geq 0$
J+8		$S(E_1)$
J+9		E_2
J+10		$S(E_2)$
J+11		MBASE[b]
J+12		PMULT
J+13		H (inertia, per unit motor base)
J+14		V_I (pu)[c]
J+15		T_I (cycles)[d]
J+16		T_B (cycles)
J+17		A
J+18		B
J+19		D
J+20		E
J+21		C_0
J+22		T_{nom}, Load torque at 1 pu speed (used for motor starting only) (≥ 0)

[a]To model single cage motor: set $R_2 = X_2 = 0$.
[b]When MBASE = 0, motor MVA base = PMULT x MW load. When MBASE > 0, motor MVA base = MBASE.
[c]V_I is the per unit voltage level below which the relay to trip the motor will begin timing. To disable relay, set $V_I = 0$.
[d]T_I is the time in cycles for which the voltage must remain below the threshold for the relay to trip. T_B is the breaker delay time cycles.

STATEs	Description
K+1	E'_d
K+2	E''_q
K+3	E''_d
K+4	Δ speed (pu)
K+5	Angle deviation

VARs	Description
L	Admittance of initial condition Mvar difference
L+1	Motor Q

VARs	Description
L+2	T_{elec} (pu motor base)
L+3	$\Delta\ \omega$
L+4	T (pu on motor base)[ab]
L+5	I_Q
L+6	ID
L+7	Motor current (pu motor base)
L+8	Relay trip time
L+9	Breaker trip time
L+10	MVA rating
L+11	TL (pu load torque)

[a]Load torque, $T_1L = T\ (A\ \omega^{2} + B\ \omega + C_o + D\ \omega^{E})$

[b]For motor starting, $T{=}T_{nom}$ is specified by the user in CON (J+22). For motor online studies, $T{=}T_o$ is calculated in the code during initialization and stored in VAR (L+4).

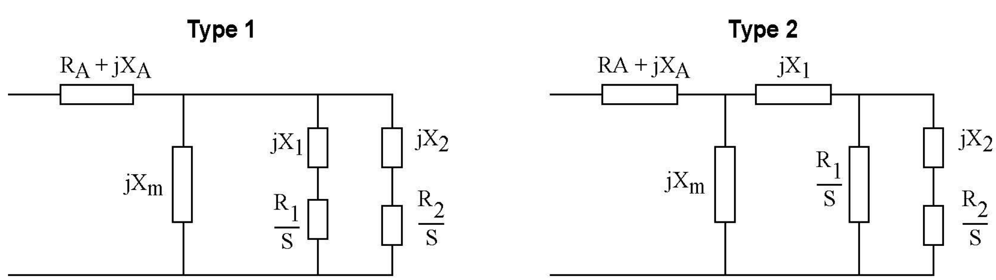
ICONs	Value	Description
M		IT, motor type

Reserved ICONs	Value	Description
N		Relay action code
N+1		Relay trip flag
N+2		Breaker action code
N+3		Breaker trip flag

```
I, 'CIM6xx', LID, ICON(M), CON(J) to CON(J+22)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0



Impedances on Motor MVA Base

9.4. CIMWBL, CIMWOW, CIMWZN, CIMWAR, CIMWAL

Induction Motor Load Model (WECC)

CONs	Value	Description
J		R_A
J+1		X_A
J+2		$X_m > 0$
J+3		$R_1 > 0$
J+4		$X_1 > 0$
J+5		R_2 (0 for single cage)[a]
J+6		X_2 (0 for single cage)
J+7		$E_1 \geq 0$
J+8		$S(E_1)$
J+9		E_2
J+10		$S(E_2)$
J+11		MBASE[b]
J+12		PMULT
J+13		H (inertia, per unit motor base)
J+14		V_I (pu)[c]
J+15		T_I (cycles)[d]
J+16		T_B (cycles)
J+17		A
J+18		B
J+19		D
J+20		E

[a]To model single cage motor: set $R_2 = X_2 = 0$.

[b]When MBASE = 0, motor MVA base = PMULT x MW load. When MBASE > 0, motor MVA base = MBASE.

[c]V_I is the per unit voltage level below which the relay to trip the motor will begin timing. To disable relay, set $V_I = 0$.

[d]T_I is the time in cycles for which the voltage must remain below the threshold for the relay to trip. T_B is the breaker delay time cycles.

STATEs	Description
K	E'_q
K+1	E'_d
K+2	E''_q
K+3	E''_d
K+4	Δ speed (pu)
K+5	Angle deviation

VARs	Description
L	Admittance of initial condition Mvar difference
L+1	Motor Q
L+2	T_{elec} (pu motor base)

VARs	Description
L+3	$\Delta\ \omega$
L+4	To (pu motor base), initial load torque [ab]
L+5	I_Q
L+6	ID
L+7	Motor current (pu motor base)
L+8	Relay trip time
L+9	Breaker trip time
L+10	MVA rating
L+11	Co

[a]Load torque T_L = To (A ω^2 +B ω + Co + D ω^E) where $C_o = 1 - A\ \omega_o^2 - B\ \omega_o - D\ \omega_o^E$.
[b]This model cannot be used for motor starting studies. T_2o is calculated in the code during initialization and stored in VAR (L+4).

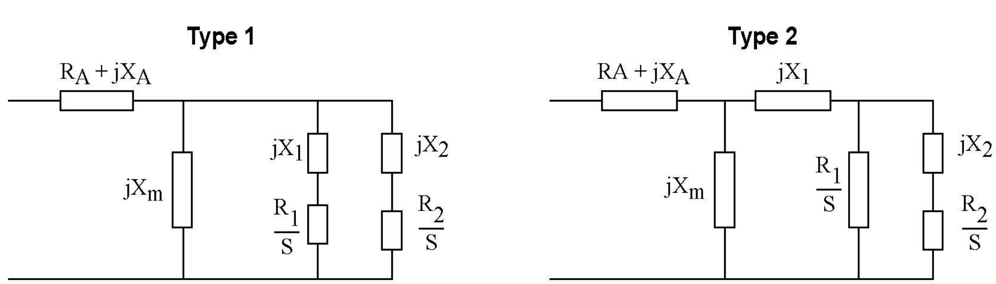
ICONs	Value	Description
M		IT, motor type

Reserved ICONs	Value	Description
N		Relay action code
N+1		Relay trip flag
N+2		Breaker action code
N+3		Breaker trip flag

```
I, 'CIMWxx', LID, ICON(M), CON(J) to CON(J+20)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0



Impedances on Motor MVA Base

9.5. CLODBL, CLODOW, CLODZN, CLODAR, CLODAL

CONs	Value	Description
J		% large motor
J+1		% small motor
J+2		% transformer exciting current
J+3		% discharge lighting
J+4		% constant power
J+5		K_P of remaining
J+6		Branch R (pu on load MW base)
J+7		Branch X (pu on load MW base)

STATEs	Description
K	Speed deviation of large motor
K+1	Speed deviation of small motor

VARs	Description
L	Branch R (pu on system base)
L+1	Branch X (pu on system base)
L+2	Tap
L+3	Large motor MVA base
L+4	Large motor old speed
L+5	Large motor present speed
L+6	Large motor, P
L+7	Large motor, Q
L+8	Small motor MVA base
L+9	Small motor old speed
L+10	Small motor present speed
L+11	Small motor, P
L+12	Small motor, Q
L+13	Memory of transformer exciting current
L+14	Transformer MVA base
L+15	Magnitude of low voltage
L+16	Discharge lighting
L+17	Discharge memory
L+18	Constant power
L+19	Constant reactive power
L+20	Remaining power storage
L+21	Remaining reactive storage
L+22	Local bus frequency deviation
L+23	Memory of frequency deviation
L+24	Discharge reactive

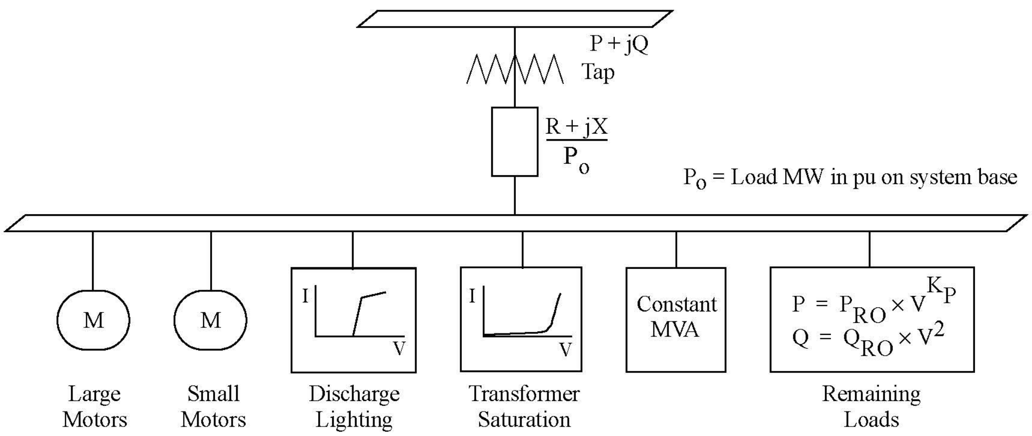
VARs	Description
L+25	Discharge reactive memory
L+26	REAL (V_{LOW})
L+27	AIMAG (V_{LOW})

Reserved ICONs	Value	Description
N		Service status memory

```
I, 'CLODxx', LID, CON(J) to CON(J+7)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0



9.6. CMLDBLU2, CMLDOWU2, CMLDZNU2, CMLDARU2, CMLDALU2

Composite Load Model

CONs	Value	Description
J		Load MVA base[a]
J+1		Substation shunt B (pu on Load MVA base)
J+2		Rfdr - Feeder R (pu on Load MVA base)
J+3		Xfdr - Feeder X (pu on Load MVA base)[b]
J+4		Fb - Fraction of Feeder Compensation at substation end
J+5		Xxf - Transformer Reactance - pu on load MVA base[c]
J+6		Tfixhs - High side fixed transformer tap
J+7		Tfixls - Low side fixed transformer tap
J+8		LTC - LTC flag (1 active, 0 inactive)
J+9		Tmin - LTC min tap (on low side)
J+10		Tmax - LTC max tap (on low side)
J+11		Step - LTC Tstep (on low side)
J+12		Vmin - LTC Vmin tap (low side pu)
J+13		Vmax - LTC Vmax tap (low side pu)
J+14		TD - LTC Control time delay (sec)
J+15		TC - LTC Tap adJustment time delay (sec)
J+16		Rcmp - LTC Rcomp (pu on load MVA base)
J+17		Xcmp - LTC Xcomp (pu on load MVA base)
J+18		FmA - Motor A Fraction
J+19		FmB - Motor B Fraction
J+20		FmC - Motor C Fraction
J+21		FmD - Motor D Fraction
J+22		Fel - Electronic Load Fraction[d]
J+23		PFel - PF of Electronic Loads
J+24		Vd1 - Voltage at which elect. loads start to drop
J+25		Vd2 - Voltage at which all elect.load have dropped
J+26		PFs - Static Load Power Factor
J+27		P1e - P1 exponent[e]
J+28		P1c - P1 coefficient
J+29		P2e - P2 exponent
J+30		P2c - P2 coefficient
J+31		Pfrq - Frequency sensitivity
J+32		Q1e - Q1 exponent
J+33		Q1c - Q1 coefficient
J+34		Q2e - Q2 exponent

CONs	Value	Description
J+35		Q2c - Q2 coefficient
J+36		Qfrq - Frequency sensitivity
J+37		MtypA - Motor type[f]
J+38		LFmA - Loading factor (MW/MVA rating)
J+39		RaA - Stator resistance
J+40		LsA - Synchronous reactance
J+41		LpA - Transient reactance
J+42		LppA - Sub-transient reactance
J+43		TpoA - Transient open circuit time constant
J+44		TppoA - Sub-transient open circuit time constant
J+45		HA - Inertia constant
J+46		etrqA - Torque speed exponent
J+47		Vtr1A - U/V Trip1 V (pu)
J+48		Ttr1A - U/V Trip1 Time (sec)
J+49		Ftr1A - U/V Trip1 fraction
J+50		Vrc1A - U/V Trip1 reclose V (pu)
J+51		Trc1A - U/V Trip1 reclose Time (sec)
J+52		Vtr2A - U/V Trip2 V (pu)
J+53		Ttr2A - U/V Trip2 Time (sec)
J+54		Ftr2A - U/V Trip2 fraction
J+55		Vrc2A - U/V Trip2 reclose V (pu)
J+56		Trc2A - U/V Trip2 reclose Time (sec)
J+57		MtypB - Motor type
J+58		LFmB - Loading factor (MW/MVA rating)
J+59		RaB - Stator resistance
J+60		LsB - Synchronous reactance
J+61		LpB - Transient reactance
J+62		LppB - Sub-transient reactance
J+63		TpoB - Transient open circuit time constant
J+64		TppoB - Sub-transient open circuit time constant
J+65		HB - Inertia constant
J+66		etrqB - Torque speed exponent
J+67		Vtr1B - U/V Trip1 V (pu)
J+68		Ttr1B - U/V Trip1 Time (sec)
J+69		Ftr1B - U/V Trip1 fraction
J+70		Vrc1B - U/V Trip1 reclose V (pu)
J+71		Trc1B - U/V Trip1 reclose Time (sec)
J+72		Vtr2B - U/V Trip2 V (pu)
J+73		Ttr2B - U/V Trip2 Time (sec)
J+74		Ftr2B - U/V Trip2 fraction
J+75		Vrc2B - U/V Trip2 reclose V (pu)

CONs	Value	Description
J+76		Trc2B - U/V Trip2 reclose Time (sec)
J+77		MtypC - Motor type
J+78		LFmC - Loading factor (MW/MVA rating)
J+79		RaC - Stator resistance
J+80		LsC - Synchronous reactance
J+81		LpC - Transient reactance
J+82		LppC - Sub-transient reactance
J+83		TpoC - Transient open circuit time constant
J+84		TppoC - Sub-transient open circuit time constant
J+85		HC - Inertia constant
J+86		etrqC - Torque speed exponent
J+87		Vtr1C - U/V Trip1 V (pu)
J+88		Ttr1C - U/V Trip1 Time (sec)
J+89		Ftr1C - U/V Trip1 fraction
J+90		Vrc1C - U/V Trip1 reclose V (pu)
J+91		Trc1C - U/V Trip1 reclose Time (sec)
J+92		Vtr2C - U/V Trip2 V (pu)
J+93		Ttr2C - U/V Trip2 Time (sec)
J+94		Ftr2C - U/V Trip2 fraction
J+95		Vrc2C - U/V Trip2 reclose V (pu)
J+96		Trc2C - U/V Trip2 reclose Time (sec)
J+97		Tstall - stall delay (sec)[g]
J+98		Trestart - restart delay (sec)
J+99		Tv - voltage input time constant(sec)
J+100		Tf - frequency input time constant(sec)
J+101		CompLF - compressor load factor, pu of rated power[h]
J+102		CompPF - compressor power factor at 1.0 pu voltage
J+103		Vstall - compressor stall voltage at base condition (pu)
J+104		Rstall - compressor motor res. with 1.0 pu current[i]
J+105		Xstall - compressor motor stall reactance - unsat.
J+106		LFadJ - Load factor adjustment to the stall voltage[j]
J+107		Kp1 - real power constant for running state 1[k]
J+108		Np1 - real power exponent for running state 1
J+109		Kq1 - reactive power constant for running state 1
J+110		Nq1 - reactive power exponent for running state 1
J+111		Kp2 - real power constant for running state 2
J+112		Np2 - real power exponent for running state 2
J+113		Kq2 - reactive power constant for running state 2
J+114		Nq2 - reactive power exponent for running state 2
J+115		Vbrk - compressor motor "breakdown" voltage (pu)
J+116		Frst - fraction of motors capable of restart

CONs	Value	Description
J+117		Vrst - voltage at which motors can restart (pu)
J+118		CmpKpf - real power constant for freq dependency[l]
J+119		CmpKqf - reactive power constnt for freq dependency
J+120		Vc1of f - Voltage 1 at which contactors start dropping out (pu)
J+121		Vc2off - Voltage 2 at which all contactors drop out (pu)
J+122		Vc1on - Voltage 1 at which all contactors reclose (pu)
J+123		Vc2on - Voltage 2 at which contactors start reclosing (pu)
J+124		Tth - compressor motor heating time constant(sec)[m]
J+125		Th1t - temp at which comp. motor begin tripping
J+126		Th2t - temp at which comp. all motors are tripped
J+127		Fuvr - fraction of comp. motors with U/V relays
J+128		UVtr1 - 1st voltage pick-up (pu)
J+129		Ttr1 - 1st definite time voltage pickup (sec)
J+130		UVtr2 - 2nd voltage pick-up (pu)
J+131		Ttr2 - 2nd definite time voltage
J+132		Fraction of eletronic load that can restart

[a] X = Load MVA base. If X>0., Load MVA base = X. If X<0, Loading factor = abs (X) = load MW/MVA base. If X=0, loading factor = default value(0.8). When model is applied on a subsystem basis (OW, ZN, AR, AL), CON(J) has to be less than or equal to 0

[b]If Xfdr<= jumper threshold, feeder is omitted from the model

[c]If Xxfr<=jumper threshold, transformer is omitted from the model

[d]If sum of load fractions FmA, FmB, FmC, FmD, Fel is <1, remainder is static load; If sum of fractions FmA, FmB, FmC, FmD, Fel is >1, fractions are normalized to 1 and there will be no static load

[e]The static load model uses the following equations;

P=P0*(P1c*V/V0P1e+P2c*V/V0P2e+P3)*(1+Pf#f)

Q=Q0*(Q1c*V/V0Q1e+Q2c*V/V0Q2e+Q3)*(1+Qf#f)

P0=Pload*(1.-FmA-FmB-FmC-FmD-Fel)

Q0=P0* tan(acos(PFs))

P3=1.-P1c-P2c

Q3=1-Q1c-Q2c

[f]Motor A, Motor B, and Motor C are 3-phase motors. MtypA (CON(J+37)), MtypB (CON(j+57)), and MtypC (CON(J+77)) =3 to represent three phase motor. These motors use the induction motor model CIM6BL from PSSE standard model library. The load torque is computed as TL=T0* ω^{Etrq}

[g]CON(J+99) to CON(J+131) are the parameters of Motor D. Motor D is single phase air conditioner. This model uses the user-defined ACMTBL model.

[h]If "CompLF" is zero, it is computed during the initialization. If "CompLF" is greater than zero, motor MVA base is adjusted. Load Factor is defined as initial kW loading / kW rated.

[i]Stall state is characterized by an equivalent impedance, (Rstall + j Xstall).

[j]Lfadj factor is used to update the Vstall and Vbrk as defined below:

Vstall(adj)=Vstall*(1+Lfadj*(CompLF-1))

Vbrk(adj)=Vbrk*(1+Lfadj*(CompLF-1))

[k] The motor run state is characterized by an exponential characteristic. The run characteristic is divided into two states as a function of bus voltage, State 1 for Bus voltage Vbrk, and State 2 for Vstall < Bus Voltage < Vbrk.

State 0, corresponds to 1.0 pu Bus voltage

P0=1-KP1*(1-Vbrk)**NP1

Q0=(√(1-CompPF**2)/CompPF)-KQ1*(1-Vbrk)**NQ1

State 1 for Bus voltage Vbrk

P=P0+KP1*(V-Vbrk)**NP1

Q=Q0+KQ1*(V-Vbrk)**NQ1

State 2 for Vstall < Bus Voltage $lt; Vbrk

P=P0+KP2*(Vbrk-V)**NP2

Q=Q0+KQ2*(Vbrk-V)**NQ2

[l]Frequency dependency of the load is defined by following characteristics:

P(f)=P*(1+CmpKpf*df)

Q(f)=Q*(1+CmpKqf*df/√(1-CompPF**2))

[m]Thermal relay is modelled by the following characteristics:If Th2t is equal to zero or if Th1t is greater than or equal to Th2t, all motors are tripped instantaneously when temperature reaches Th1t.

K	Motor A: E'q
K+1	Motor A: E'd
K+2	Motor A: E"q
K+3	Motor A: E"d
K+4	Motor A: speed deviation (pu)
K+5	Motor A: angle deviation
K+6	Motor B: E'q
K+7	Motor B: E'd
K+8	Motor B: E"q
K+9	Motor B: E"d
K+10	Motor B: speed deviation (pu)
K+11	Motor B: angle deviation
K+12	Motor C:: E'q
K+13	Motor C:: E'd
K+14	Motor C:: E"q
K+15	Motor C:: E"d
K+16	Motor C:: speed deviation (pu)
K+17	Motor C: angle deviation
K+18	Motor D: bus voltage (pu)

K+19	Motor D: bus frequency (pu)
K+20	Motor D: non-restartable compressor motor A temperature
K+21	Motor D: restartable compressor motor B temperature
K+22	Motor D: U/V relay timer 1
K+23	Motor D: U/V relay timer 2
K+24	Motor D: non-restartable motor A stall timer
K+25	Motor D: restartable Motor B stall timer
K+26	Motor D: restartable Motor B restart timer

VARs	Description
L	Load MVA base
L+1	Motor A fraction
L+2	Motor B fraction
L+3	Motor C fraction
L+4	Motor D: fraction
L+5	Electronic load fraction
L+6	Static load fraction
L+7	Initial value of static load real part (pu on system MVA base)
L+8	Initial value of static load reactive part (pu on system MVA base)
L+9	P3 component of static load
L+10	Q3 component of static load
L+11	Calculated substation shunt compensation (pu on system MVA base)
L+12	Transformer tap
L+13	Transformer low side voltage real part
L+14	Transformer low side voltage imaginary part
L+15	Load bus voltage real part
L+16	Load bus voltage imaginary part
L+17	Initial value of load bus voltage magnitude
L+18	Feeder resistance (pu on system MVA base)
L+19	Feeder reactance (pu on system MVA base)
L+20	Sum of substation shunt admittance and feeder compensation admittance at substation end
L+21	Substation shunt admittance
L+22	Initial value of electronic load real part (pu on system MVA base)
L+23	Initial value of electronic load reactive part (pu on system MVA base)
L+24	Transformer reactance (pu on system MVA base)
L+25	Static load real part (pu on system MVA base)
L+26	Static load reactive part (pu on system MVA base)
L+27	Electronic load real part (pu on system MVA base)
L+28	Electronic load reactive part (pu on system MVA base)
L+29	Load bus voltage magnitude

VARs	Description
L+30	Low side bus voltage magnitude
L+31	Motor A P (pu on system MVA base)
L+32	Motor A Q (pu on system MVA base)
L+33	Motor B P (pu on system MVA base)
L+34	Motor B Q (pu on system MVA base)
L+35	Motor C P (pu on system MVA base)
L+36	Motor C Q (pu on system MVA base)
L+37	Motor D P (pu on system MVA base)
L+38	Motor D Q (pu on system MVA base)
L+39	Transformer controlled bus voltage
L+40	Initial value of feeder resistance (pu on system MVA base)
L+41	Initial value of feeder reactance (pu on system MVA base)
L+42	Composite load real before load shed (pu on system MVA base)
L+43	Real part of composite load shed in a particular stage (pu on system MVA base)
L+44	Real part of composite load shed upto a particular stage (pu on system MVA base)
L+45	LTC control time delay counter
L+46	T_ap changer timer
L+47	Initial value of Motor A P (pu on system MVA base)
L+48	Initial value of Motor A Q (pu on system MVA base)
L+49	Initial value of Motor B P (pu on system MVA base)
L+50	Initial value of Motor B Q (pu on system MVA base)
L+51	Initial value of Motor C P (pu on system MVA base)
L+52	Initial value of Motor C Q (pu on system MVA base)
L+53	Initial value of Motor D P (pu on system MVA base)
L+54	Initial value of Motor D Q (pu on system MVA base)
L+55	Feeder compensation admittance at substation end
L+56	Feeder compensation admittance at far end
L+57	Static load conductance
L+58	Static load susceptance
L+59	Spare
L+60	Calculated Vstallbrk
L+61	Real component of current injection at system load bus
L+62	Reactive component of current injection at system load bus
L+63	Initial value of Motor A MVA base
L+64	Initial value of Motor B MVA base
L+65	Initial value of Motor C MVA base
L+66	Initial value of Motor D MVA base
L+67	Initial value of feeder compensation admittance at substation end

VARs	Description
L+68	Initial value of feeder compensation admittance at far end
L+69	Motor A: Admittance of initial condition MVAr difference
L+70	Motor A: Q
L+71	Motor A: Tele (pu on motor MVA base)
L+72	Motor A: Speed deviation
L+73	Motor A: Initial load torque (pu on motor MVA base)
L+74	Motor A: I_Q
L+75	Motor A: Id
L+76	Motor A: Current (pu on motor MVA base)
L+77	Motor A: UV relay1 trip time
L+78	Motor A: UV relay2 trip time
L+79	Motor A: MVA base
L+80	Motor A: TL - Load torque (pu)
L+81	Motor A: UV relay1 reclose time
L+82	Motor A: UV relay2 reclose time
L+83	Motor A: Trip-reclose factor
L+84	Motor A: Nominal load torque
L+85	Motor B: Admittance of initial condition MVAr difference
L+86	Motor B: Q
L+87	Motor B: Tele (pu on motor MVA base)
L+88	Motor B: Speed deviation
L+89	Motor B: Initial load torque (pu on motor MVA base)
L+90	Motor B: I_Q
L+91	Motor B: Id
L+92	Motor B: Current (pu on motor MVA base)
L+93	Motor B: UV relay1 trip time
L+94	Motor B: UV relay2 trip time
L+95	Motor B: MVA base
L+96	Motor B: TL - Load torque (pu)
L+97	Motor B: UV relay1 reclose time
L+98	Motor B: UV relay2 reclose time
L+99	Motor B: Trip-reclose factor
L+100	Motor B: Nominal load torque
L+101	Motor C: Admittance of initial condition MVAr difference
L+102	Motor C: Q
L+103	Motor C: Tele (pu on motor MVA base)
L+104	Motor C: Speed deviation
L+105	Motor C: Initial load torque (pu on motor MVA base)
L+106	Motor C: I_Q
L+107	Motor C: Id
L+108	Motor C: Current (pu on motor MVA base)

VARs	Description
L+109	Motor C: UV relay1 trip time
L+110	Motor C: UV relay2 trip time
L+111	Motor C: MVA base
L+112	Motor C: TL - Load torque (pu)
L+113	Motor C: UV relay1 reclose time
L+114	Motor C: UV relay2 reclose time
L+115	Motor C: Trip-reclose factor
L+116	Motor C: Nominal load torque
L+117	Motor D: Bus voltage (pu)
L+118	Motor D: Bus frequency (pu)
L+119	Motor D: Aggregated AC unit real power (MW)
L+120	Motor D: Aggregated AC unit reactive power (MVAr)
L+121	Motor D: Aggregated AC unit current (pu on system MVA base)
L+122	Motor D: Terminal current component in phase with voltage (in pu on motor MVA base)
L+123	Motor D: Terminal current component lagging voltage (in pu on motor MVA base)
L+124	Motor D: Terminal current component on network real axis on system MVA base (pu)
L+125	Motor D: Terminal current comp on network imaginary axis on system MVA base (pu)
L+126	Motor D: non-restartable motor A and restartable motor B Initial Temperature
L+127	Motor D: Fraction of motors not tripped by U/V relay - gain K_{uv}
L+128	Motor D: Fraction of motors not tripped by contactors - gain K_{con}
L+129	Motor D: Contactor status for compressor voltage calculation 0=off, 1=on
L+130	Motor D: Input voltage from a previous step (pu)
L+131	Motor D: K_{thA} non-restartable compressor motor A fraction not tripped by thermal protection
L+132	Motor D: Shunt admittance (in pu on motor MVA base), computed during the initialization
L+133	Motor D: non-restartable Motor A run / stall state (run=1/stall=0)
L+134	Motor D: restartable Motor B run / stall state (run=1/stall=0)
L+135	Motor D: K_{thB} restartable compressor motor B fraction not tripped by thermal protection
L+136	Motor D: Internal variable used for determining non-restartable motor A temperature
L+137	Motor D: Internal variable used for determining restartable motor B temperature
L+138	Motor D: Real component of voltage at pervious time step (pu)
L+139	Motor D: Reactive component of voltage at previous time step (pu)

VARs	Description
L+140	Motor D: Time instant at which the model was called previous time
L+141	Motor D: Internal variable, P0 for active power at 1.0 pu voltage4
L+142	Motor D: Internal variable, Q0 for reactive power at 1.0 pu voltage4
L+143	Motor D: Computed motor MVA base
L+144	Motor D: Adjusted V_{stall} based on load factor (pu)
L+145	Motor D: Adjusted V_{brk} based on load factor (pu)

ICONs	Value	Description
M		To be input as 0 by user (for internal storage)
M+1		To be input as 0 by user (for internal storage)

Reserved ICONs	Description
N+1	LTC control delay flag
N+2	LTC control timeout flag
N+3	Tap adjustment timer status flag
N+4	Static load admittance storage status flag
N+5	Motor A: UV trip relay1 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+6	Motor A: UV trip relay1 status (1=Delay complete, motor should be tripped)
N+7	Motor A: UV trip relay2 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+8	Motor A: UV trip relay2 status (1=Delay complete, motor should be tripped)
N+9	Motor A: UV reclose relay1 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+10	Motor A: UV reclose relay1 status (1=Delay complete, motor should be reclosed)
N+11	Motor A: UV reclose relay2 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+12	Motor A: UV reclose relay2 status (1=Delay complete, motor should be reclosed)
N+13	Motor A: starting status (1=starting phase, 0=already started)
N+14	Motor B: UV trip relay1 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+15	Motor B: UV trip relay1 status (1=Delay complete, motor should be tripped)
N+16	Motor B: UV trip relay2 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+17	Motor B: UV trip relay2 status (1=Delay complete, motor should be tripped)

Reserved ICONs	Description
N+18	Motor B: UV reclose relay1 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+19	Motor B: UV reclose relay1 status (1=Delay complete, motor should be reclosed)
N+20	Motor B: UV reclose relay2 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+21	Motor B: UV reclose relay2 status (1=Delay complete, motor should be reclosed)
N+22	Motor B: starting status (1=starting phase, 0=already started)
N+23	Motor C: UV trip relay1 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+24	Motor C: UV trip relay1 status (1=Delay complete, motor should be tripped)
N+25	Motor C: UV trip relay2 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+26	Motor C: UV trip relay2 status (1=Delay complete, motor should be tripped)
N+27	Motor C: UV reclose relay1 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+28	Motor C: UV reclose relay1 status (1=Delay complete, motor should be reclosed)
N+29	Motor C: UV reclose relay2 flag (0=Reset timer, 1=Start timer, 2=Test timer)
N+30	Motor C: UV reclose relay2 status (1=Delay complete, motor should be reclosed)
N+31	Motor C: starting status (1=starting phase, 0=already started)
N+32	Motor D: non-restartable Motor A Run/Stall status, Run=1, Stall=0
N+33	Motor D: restartable Motor B Run, Restart, Stall status, Run=1, Restart=2, Stall=0
N+34	Motor D: Under voltage relay trip status, Non-Trip=1, Trip=0
N+35	Motor D: Under voltage relay first pick up flag, becomes 0 on Pick Up
N+36	Motor D: Under voltage relay second pick up flag, becomes 0 on Pick Up
N+37	Motor D: Thermal relay trip 1 status for non-restartable motor A, Non-trip=1. Trip=0
N+38	Motor D: Thermal relay trip 2 status for non-restartable motor A, Non-trip=1. Trip=0
N+39	Motor D: Thermal relay trip 1 status for restartable motor B, Non-trip=1. Trip=0
N+40	Motor D: Thermal relay Trip 2 status for restartable motor B, Non-trip=1. Trip=0

Reserved ICONs	Description
N+41	Motor D: Contactors sarted to drop out flag, Not started to drop out=1, Started to drop out=0
N+42	Motor D: All contactors dropped out flag, All not dropped out=1, All dropped out=0
N+43	Motor D: Contactors started to reclose flag, Not started to re-close=1, Started to reclose=0
N+44	Motor D: All Contactors reclosed flag, All not reclosed=1, All re-closed=0
N+45	Motor D: non-restartable motor A stall relay pick up flag, be-comes 0 on pick up
N+46	Motor D: restartable motor B stall relay pick up flag, becomes 0 on pick up
N+47	Motor D: restartable motor B restart relay pick up flag, becomes 0 on pick up

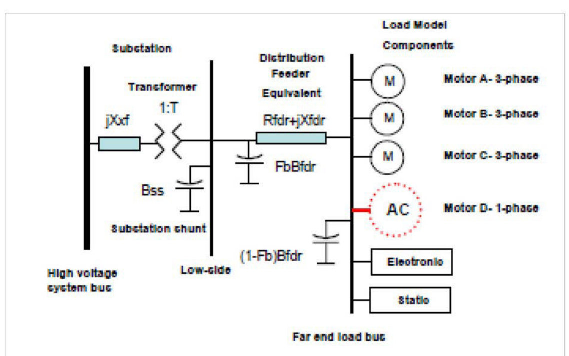
DYRE Data Record:

```
I, 'USRLOD', LID, 'CMLDxxU2', 12, IT, 2, 133, 27, 146, 48,  0,  0,
 CON(J) to CON(J+132)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix "xx"	"IT" Description	"I" Description
BL	1	Bus number
OW	2	Owner number
ZN	3	Zone number
AR	4	Area number
AL	5	0

Note: CMLDBL internally uses induction motor model to simulate three phase motors. In case of non-conver-gence, number of iterations may be increased and time step may be reduced.



Composite load model structure[1]

[1] "Load modeling", MMWG report to TSS, August 2009

9.7. CMLDBLDGU2, CMLDOWU2, CMLDZNDGU2, CMLDARDGU2, CMLDALDGU2

Composite Load Model

CONs	Value	Description
J		Load MVA base[a]
J+1		Substation shunt B (pu on Load MVA base)
J+2		Rfdr, Feeder R (pu on Load MVA base)
J+3		Xfdr, Feeder X (pu on Load MVA base)[b]
J+4		Xxf, Transformer Reactance - pu on load MVA base[c]
J+5		Tfixhs, High side fixed transformer tap
J+6		Tfixls, Low side fixed transformer tap
J+7		LTC flag (1: active during simulation, 0: inactive, -1: active during initialization, but inactive during simulation)
J+8		Tmin, LTC min tap (on low side)
J+9		Tmax, LTC max tap (on low side)
J+10		Tstep, LTC Tstep (on low side)
J+11		Vmin (pu), LTC Vmin tap (low side)
J+12		Vmax (pu), LTC Vmax tap (low side)
J+13		TD (s), LTC Control time delay
J+14		TC (s), LTC Tap adJustment time delay
J+15		Rcmp, LTC Rcomp (pu on load MVA base)
J+16		Xcmp, LTC Xcomp (pu on load MVA base)
J+17		FmA, Motor A Fraction
J+18		FmB, Motor B Fraction
J+19		FmC, Motor C Fraction
J+20		FmD, Motor D Fraction
J+21		Fel, Electronic Load Fraction[d]
J+22		PFel, PF of Electronic Loads
J+23		Vd1 (pu), Voltage at which electronic loads start to drop
J+24		Vd2 (pu), Voltage at which all electronic loads have dropped
J+25		frecel, fraction of electronic load that can restart
J+26		PFs, Power factor of static load
J+27		P1e, P1 exponent[e]
J+28		P1c, P1 coefficient
J+29		P2e, P2 exponent
J+30		P2c, P2 coefficient
J+31		Pfrq, Frequency sensitivity coefficient for real part of static load
J+32		Q1e, Q1 exponent
J+33		Q1c, Q1 coefficient

CONs	Value	Description
J+34		Q2e, Q2 exponent
J+35		Q2c, Q2 coefficient
J+36		Qfrq, Frequency sensitivity coefficient for reactive part of static loady
J+37		LFmA, Motor A Loading factor (MW/MVA rating)
J+38		RaA (pu), Motor A Stator resistance
J+39		LA (pu), Motor A leakage reactance
J+40		LsA (pu) - Motor A Synchronous reactance
J+41		LpA (pu), Motor A Transient reactance
J+42		LppA (pu), Motor A Sub-transient reactance
J+43		TpoA (s), Motor A Transient open circuit time constant
J+44		TppoA (s), Motor A Sub-transient open circuit time constant
J+45		HA (s), Motor A Inertia constant
J+46		etrqA, Motor A Load Torque exponent for speed
J+47		Vtr1A (pu), Motor A first undervoltage trip voltage
J+48		Ttr1A (s), Motor A first undervoltage trip delay
J+49		Ftr1A, Motor A first undervoltage trip fraction
J+50		Vrc1A (pu), Motor A first undervoltage reclose voltage
J+51		Trc1A (s), Motor A first undervoltage reclose delay
J+52		Vtr2A (pu), Motor A second undervoltage trip voltage
J+53		Ttr2A (s), Motor A second undervoltage trip delay
J+54		Ftr2A, Motor A second undervoltage trip fraction
J+55		Vrc2A (pu), Motor A second undervoltage reclose voltage
J+56		Trc2A (s), Motor A second undervoltage reclose delay
J+57		LFmB, Motor B Loading factor (MW/MVA rating)
J+58		RaB (pu), Motor B Stator resistance
J+59		LB (pu), Motor B leakage reactance
J+60		LsB (pu), Motor B Synchronous reactance
J+61		LpB (pu), Motor B Transient reactance
J+62		LppB (pu), Motor B Sub-transient reactance
J+63		TpoB (s), Motor B Transient open circuit time constant
J+64		TppoB (s), Motor B Sub-transient open circuit time constant
J+65		HB (s), Motor B Inertia constant
J+66		etrqB, Motor B Load Torque exponent for speed
J+67		Vtr1B (pu), Motor B first undervoltage trip voltage
J+68		Ttr1B (s), Motor B first undervoltage trip delay
J+69		Ftr1B, Motor B first undervoltage trip fraction
J+70		Vrc1B (pu), Motor B first undervoltage reclose voltage
J+71		Trc1B (s), Motor B first undervoltage reclose delay
J+72		Vtr2B (pu), Motor B second undervoltage trip voltage
J+73		Ttr2B (s) Motor B second undervoltage trip delay
J+74		Ftr2B, Motor B second undervoltage trip fraction

CONs	Value	Description
J+75		Vrc2B (pu), Motor B second undervoltage reclose voltage
J+76		Trc2B (s), Motor B second undervoltage reclose delay
J+77		LFmC, Motor C Loading factor (MW/MVA rating)
J+78		RaC (pu), Motor C Stator resistance
J+79		LC (pu), Motor C leakage reactance
J+80		LsC (pu) Motor C Synchronous reactance
J+81		LpC (pu) Motor C Transient reactance
J+82		LppC (pu), Motor C Sub-transient reactance
J+83		TpoC (s), Motor C Transient open circuit time constant
J+84		TppoC (s), Motor C Sub-transient open circuit time constant
J+85		HC (s), Motor C Inertia constant
J+86		etrqC, Motor C Load Torque exponent for speed
J+87		Vtr1C (pu), Motor C first undervoltage trip voltage
J+88		Ttr1C (s), Motor C first undervoltage trip delay
J+89		Ftr1C, Motor C first undervoltage trip fraction
J+90		Vrc1C (pu), Motor C first undervoltage reclose voltage
J+91		Trc1C (s), Motor C first undervoltage reclose delay
J+92		Vtr2C (pu), Motor C second undervoltage trip voltage
J+93		Ttr2C (s), Motor C second undervoltage trip delay
J+94		Ftr2C, Motor C second undervoltage trip fraction
J+95		Vrc2C (pu), Motor C second undervoltage reclose voltage
J+96		Trc2C (s), Motor C second undervoltage reclose delay
J+97		Tstall (s), Motr D (compressor motor) stall delay
J+98		Trestart (s), Motor D restart (after stall) delay
J+99		Tv (s), Motor D voltage measurement time constant
J+100		Tf (s), Motor D frequency measurement time constant
J+101		LFmD, Motor D load factor, pu of rated power[f]
J+102		PFmD, Motor D power factor
J+103		Vstall (pu), Motor D stall voltage at base condition
J+104		Rstall (pu), Motor D stall resistance[g]
J+105		Xstall (pu), Motor D stall reactance
J+106		LFadJ, Load factor adjustment to the stall voltage[h]
J+107		Kp1 (pu), Motor D real power constant for running state 1[i]
J+108		Np1, Motor D real power exponent for running state 1
J+109		Kq1, Motor D reactive power constant for running state 1
J+110		Nq1, Motor D reactive power exponent for running state 1
J+111		Kp2, Motor D real power constant for running state 2
J+112		Np2, Motor D real power exponent for running state 2
J+113		Kq2, Motor D reactive power constant for running state 2
J+114		Nq2, Motor D reactive power exponent for running state 2
J+115		Vbrk, Motor D "breakdown" voltage (pu)

CONs	Value	Description
J+116		Frst, fraction of motor D capable of restart
J+117		Vrst (pu), voltage at which motor D can restart after stall
J+118		CmpKpf, Motor D real power constant for frequency dependency[j]
J+119		CmpKqf, Motor D reactive power constnt for frequency dependency
J+120		Vc1off (pu), Motor D voltage 1 at which contactors start dropping out
J+121		Vc2off (pu), Motor D voltage 2 at which all contactors drop out
J+122		Vc1on (pu), Motor D Voltage 1 at which all contactors reclose
J+123		Vc2on (pu), Voltage 2 at which contactors start reclosing
J+124		Tth (s), Motor D heating time constant[k]
J+125		Th1t, temperature at which Motor D begins tripping
J+126		Th2t, temperature at which all of motor D are tripped
J+127		Fuvr, fraction of Motor D with underboltage relays
J+128		UVtr1 (pu), Motor D 1st undervoltage pick-up
J+129		Ttr1 (s), Motor D 1st undervoltage trip delay
J+130		UVtr2 (pu), Motor D 2nd undervoltage pick-up
J+131		Ttr2 (s), Motor D 2nd undervoltage trip delay
J+132		T_{rv} (s), DER voltage measurement transducer time constant
J+133		Trf (s), DER frequency measurement transducer time constant
J+134		dbd1 (pu), DER lower voltage deadband (< 0)
J+135		dbd2 (pu), DER upper voltage deadband (> 0)
J+136		Kqv (pu), DER proportional voltage control gain
J+137		Vref0 (pu), DER user specified voltage set-point (Note 2)
J+138		Tp (s), DER power measurement transducer time constant
J+139		Tiq (s), DER Q-control time constant
J+140		Ddn (pu), DER reciprocal of droop for over-frequency conditions (> 0)
J+141		Dup (pu), DER reciprocal of droop for under-frequency conditions (> 0)
J+142		fdbd1 (pu), DER deadband for frequency control, lower threshold (<= 0)
J+143		fdbd2 (pu), DER deadband for frequency control, upper threshold (>= 0)
J+144		femax (pu), DER frequency error upper limit
J+145		femin (pu), DER frequency error lower limit
J+146		PMAX (pu), DER Maximum power limit
J+147		PMIN (pu), DER Minimum power limit
J+148		dPmax (pu/s), DER Power reference maximum ramp rate (> 0)
J+149		dPmin (pu/s), DER Power reference minimum ramp rate (< 0)
J+150		Tpord (s), DER Power filter time constant
J+151		Kpg (pu), DER PI controller proportional gain
J+152		Kig (pu), DER PI controller integral gain

CONs	Value	Description
J+153		Imax (pu), DER Maximum converter current
J+154		vl0 (pu), DER voltage break-point for low voltage cut-out
J+155		vl1 (pu), DER voltage break-point for low voltage cut-out (vl1 > vl0)
J+156		vh0 (pu), DER voltage break-point for high voltage cut-out
J+157		vh1 (pu), DER voltage break-point for high voltage cut-out (vh1 < vh0)
J+158		tv10 (s), DER low voltage cut-out timer corresponding to voltage vl0
J+159		tvl1 (s), DER low voltage cut-out timer corresponding to voltage vl1
J+160		tvh0 (s), DER high voltage cut-out timer corresponding to voltage vh0
J+161		tvh1 (s), DER high voltage cut-out timer corresponding to voltage vh1
J+162		Vrfrac, DER fraction of device that recovers after voltage comes back to within vl1 < V < vh1 (0 <= Vrfrac <= 1)
J+163		fl (Hz), DER frequency break-point for low frequency cut-out
J+164		fh (Hz), DER frequency break-point for high frequency cut-out (Note 5)
J+165		tfl (s), DER low frequency cut-out timer corresponding to frequency fl
J+166		tfh (s), DER high frequency cut-out timer corresponding to frequency fh
J+167		Tg (s), DER current control time constant (to represent behavior of inner control loops) (> 0)
J+168		rrpwr (pu/s), DER ramp rate for real power increase following a fault
J+169		Tv (s), DER time constant on the output of the multiplier
J+170		Vpr (pu), DER voltage below which frequency tripping is disabled
J+171		Iqhl (pu), DER Upper limit on reactive current injection Iqinj
J+172		Iqll (pu), DER Lower limit on reactive current injection Iqinj
J+173		LfDER, DER Load factor (ratio of DER power to rating)
J+174		Xe (pu), DER output reactance

[a] X = Load MVA base. If X>0., Load MVA base = X. If X<0, Loading factor = abs (X) = load MW/MVA base. If X=0, loading factor = default value(0.8). When model is applied on a subsystem basis (OW, ZN, AR, AL), CON(J) has to be less than or equal to 0

[b]If Xfdr<= jumper threshold, feeder is omitted from the model

[c]If Xxfr<=jumper threshold, transformer is omitted from the model

[d]If sum of load fractions FmA, FmB, FmC, FmD, Fel is <1, remainder is static load; If sum of fractions FmA, FmB, FmC, FmD, Fel is >1, fractions are normalized to 1 and there will be no static load

[e]The static load model uses the following equations;

P=P0*(P1c*V/V0P1e+P2c*V/V0P2e+P3)*(1+Pf#f)

Q=Q0*(Q1c*V/V0Q1e+Q2c*V/V0Q2e+Q3)*(1+Qf#f)

P0=Pload*(1.-FmA-FmB-FmC-FmD-Fel)

Q0=P0* tan(acos(PFs))

P3=1.-P1c-P2c

Q3=1-Q1c-Q2c

[f]If "LFmD" is zero, it is computed during the initialization. If "LFmD" is greater than zero, motor MVA base is adjusted. Load Factor is defined as initial kW loading / kW rated.

[g]Stall state is characterized by an equivalent impedance, (Rstall + j Xstall).

[h]Lfadj factor is used to update the Vstall and Vbrk as defined below:

Vstall(adj)=Vstall*(1+Lfadj*(CompLF-1))

Vbrk(adj)=Vbrk*(1+Lfadj*(CompLF-1))

[i] The motor D run state is characterized by an exponential characteristic. The run characteristic is divided into two states as a function of bus voltage, State 1 for Bus voltage > Vbrk, and State 2 for Vstall < Bus Voltage < Vbrk.

State 0, corresponds to 1.0 pu Bus voltage

P0=1-KP1*(1-Vbrk)**NP1

Q0=(√(1-CompPF**2)/CompPF)-KQ1*(1-Vbrk)**NQ1

State 1 for Bus voltage Vbrk

P=P0+KP1*(V-Vbrk)**NP1

Q=Q0+KQ1*(V-Vbrk)**NQ1

State 2 for Vstall < Bus Voltage $lt; Vbrk

P=P0+KP2*(Vbrk-V)**NP2

Q=Q0+KQ2*(Vbrk-V)**NQ2

[j]Frequency dependency of the load is defined by following characteristics:

P(f)=P*(1+CmpKpf*#f)

Q(f)=Q*(1+CmpKqf*#f/√(1-CompPF**2))

[k]Thermal relay is modelled by the following characteristics:If Th2t is equal to zero or if Th1t is greater than or equal to Th2t, all motors are tripped instantaneously when temperature reaches Th1t.

K	Motor A: E'q
K+1	Motor A: E'd
K+2	Motor A: E"q
K+3	Motor A: E"d
K+4	Motor A: speed deviation (pu)
K+5	Motor A: angle deviation
K+6	Motor B: E'q
K+7	Motor B: E'd
K+8	Motor B: E"q
K+9	Motor B: E"d

K+10	Motor B: speed deviation (pu)
K+11	Motor B: angle deviation
K+12	Motor C: E'q
K+13	Motor C: E'd
K+14	Motor C: E"q
K+15	Motor C: E"d
K+16	Motor C:: speed deviation (pu)
K+17	Motor C: angle deviation
K+18	Motor D: bus voltage (pu)
K+19	Motor D: bus frequency (pu)
K+20	Motor D: non-restartable compressor motor temperature
K+21	Motor D: restartable compressor motor temperature
K+22	voltage measurement lag
K+23	DER power measurement lag
K+24	DER first order lag for reactive current
K+25	DER lag block representing inner current loop for iq
K+26	DER lag block for output of multiplier block
K+27	DER frequency measurement lag
K+28	DER PI controller for real power path
K+29	DER first order lag for dpmax and dpmin
K+30	DER first order lag for Pord
K+31	DER lag block representing inner current loop for id

VARs	Description
L	Load MVA base
L+1	Motor A fraction
L+2	Motor B fraction
L+3	Motor C fraction
L+4	Motor D: fraction
L+5	Electronic load fraction
L+6	Static load fraction
L+7	Initial value of static load real part (pu on system MVA base)
L+8	Initial value of static load reactive part (pu on system MVA base)
L+9	P3 component of static load
L+10	Q3 component of static load
L+11	Transformer tap
L+12	Transformer low side voltage real part
L+13	Transformer low side voltage imaginary part
L+14	Load bus voltage real part
L+15	Load bus voltage imaginary part
L+16	Initial value of load bus voltage magnitude
L+17	Feeder resistance (pu on system MVA base)

VARs	Description
L+18	Feeder reactance (pu on system MVA base)
L+19	Sum of substation shunt admittance and feeder compensation admittance at substation end
L+20	Initial value of electronic load real part (pu on system MVA base)
L+21	Initial value of electronic load reactive part (pu on system MVA base)
L+22	Transformer reactance (pu on system MVA base)
L+23	Static load real part (pu on system MVA base)
L+24	Static load reactive part (pu on system MVA base)
L+25	Electronic load real part (pu on system MVA base)
L+26	Electronic load reactive part (pu on system MVA base)
L+27	Load bus voltage magnitude
L+28	Low side bus voltage magnitude
L+29	Motor A P (pu on system MVA base)
L+30	Motor A Q (pu on system MVA base)
L+31	Motor B P (pu on system MVA base)
L+32	Motor B Q (pu on system MVA base)
L+33	Motor C P (pu on system MVA base)
L+34	Motor C Q (pu on system MVA base)
L+35	Motor D P (pu on system MVA base)
L+36	Motor D Q (pu on system MVA base)
L+37	Transformer controlled bus voltage
L+38	Initial value of feeder resistance (pu on system MVA base)
L+39	Initial value of feeder reactance (pu on system MVA base)
L+40	Composite load real before load shed (pu on system MVA base)
L+41	Real part of composite load shed in a particular stage (pu on system MVA base)
L+42	Reactive part of composite load shed upto a particular stage (pu on system MVA base)
L+43	LTC control time delay counter
L+44	Tap changer timer
L+45	Timer used internally for tap changing
L+46	Feeder compensation admittance at far end
L+47	Ratchet used for electronic load
L+48	Calculated Vstallbrk
L+49	Real component of current injection at system load bus
L+50	Reactive component of current injection at system load bus
L+51	Initial value of feeder compensation admittance at far end
L+52	Motor A: Telec (pu on motor MVA base)
L+53	Motor A: Speed deviation
L+54	Motor A: Initial load torque (pu on motor MVA base)

VARs	Description
L+55	Motor A: I_Q
L+56	Motor A: Id
L+57	Motor A: Current (pu on motor MVA base)
L+58	Motor A: Under voltage relay1 trip time
L+59	Motor A: Under voltage relay2 trip time
L+60	Motor A: MVA base
L+61	Motor A: TL - Load torque (pu)
L+62	Motor A: Under voltage relay1 reclose time
L+63	Motor A: Under voltage relay2 reclose time
L+64	Motor A: Trip-reclose factor
L+65	Motor B: Telec (pu on motor MVA base)
L+66	Motor B: Speed deviation
L+67	Motor B: Initial load torque (pu on motor MVA base)
L+68	Motor B: I_Q
L+69	Motor B: Id
L+70	Motor B: Current (pu on motor MVA base)
L+71	Motor B: Under voltage relay1 trip time
L+72	Motor B: Under voltage relay2 trip time
L+73	Motor B: MVA base
L+74	Motor B: TL - Load torque (pu)
L+75	Motor B: Under voltage relay1 reclose time
L+76	Motor B: Under voltage relay2 reclose time
L+77	Motor B: Trip-reclose factor
L+78	Motor C: Tele (pu on motor MVA base)
L+79	Motor C: Speed deviation
L+80	Motor C: Initial load torque (pu on motor MVA base)
L+81	Motor C: I_Q
L+82	Motor C: Id
L+83	Motor C: Current (pu on motor MVA base)
L+84	Motor C: Under voltage relay1 trip time
L+85	Motor C: Under voltage relay2 trip time
L+86	Motor C: MVA base
L+87	Motor C: TL - Load torque (pu)
L+88	Motor C: Under voltage relay1 reclose time
L+89	Motor C: Under voltage relay2 reclose time
L+90	Motor C: Trip-reclose factor
L+91	Motor D: Bus voltage (pu)
L+92	Motor D: Bus frequency (pu)
L+93	Motor D: Aggregated AC unit real power (MW)
L+94	Motor D: Aggregated AC unit reactive power (MVAr)
L+95	Motor D: Aggregated AC unit current (pu on system MVA base)

VARs	Description
L+96	Motor D: Used in delay calculation for 1st under voltage relay
L+97	Motor D: Used in delay calculation for 2nd under voltage relay
L+98	Motor D: Contactor status for compressor voltage calculation 0=off, 1=on
L+99	Motor D: stall time for non-restart fraction
L+100	Motor D: non-restartable motor A and restratable motor B initial temperature
L+101	Motor D: Fraction of motors not tripped by U/V relay - gain K_{uv}
L+102	Motor D: Fraction of motors not tripped by contactors - gain K_{con}
L+103	Motor D: Contactor status for compressor voltage calculation 0=off, 1=on
L+104	Motor D: filtered voltage for contactors
L+105	Motor D: K_{thA} non-restartable compressor motor A fraction not tripped by thermal protection
L+106	Motor D: stall time for restart fraction
L+107	Motor D: restart time for restart fraction
L+108	Motor D: K_{thB} restartable compressor motor B fraction not tripped by thermal protection
L+109	Motor D: non-restartable current, pu on motor base
L+110	Motor D: restartable current, pu on motor bas
L+111	Motor D: Real component of voltage at pervious time step (pu)
L+112	Motor D: Reactive component of voltage at previous time step (pu)
L+113	Motor D: Internal variable, time instant at which the model was called previous time
L+114	Motor D: Internal variable, P0 for active power at 1.0 pu voltage in pu
L+115	Motor D: Internal variable, Q0 for reactive power at 1.0 pu voltage
L+116	Motor D: Computed motor MVA base
L+117	Motor D: Adjusted V_{stall} based on load factor (pu)
L+118	Motor D: Adjusted V_{brk} based on load factor (pu)
L+119	Initial DER real power supplied, pu on system base
L+120	Initial DER reactive power supplied, pu on system base
L+121	DER real power, pu on system base
L+122	DER reactive power, pu on system base
L+123	DER Vref
L+124	DER powerfactor angle reference (radians)
L+125	DER reference frequency deviation
L+126	DER active power reference (Pref)
L+127	DER reactive power reference (Qref)
L+128	DER output of voltage deadband
L+129	DER output of frequency deadband

VARs	Description
L+130	DER Ipcmd
L+131	DER Iqcmd
L+132	DER Vmin
L+133	DER Vmax
L+134	DER output of undervoltage voltage multiplier block
L+135	DER output of overvoltage voltage multiplier block
L+136	DER output of frequency multiplier block
L+137	DER timer for vl0
L+138	DER timer for vl1
L+139	DER timer for vh0
L+140	DER timer for vh1
L+141	DER timer for fl
L+142	DER timer for fh
L+143	DER voltage from previous time step
L+144	DER voltage angle from previous time step
L+145	DER Iqinj
L+146	DER power base, MW
L+147	DER output current

ICONs	Value	Description
M		To be input as 0 by user (for internal storage)
M+1		To be input as 0 by user (for internal storage)
M+2		PfFlag: • 1 : constant power factor • 0 : constant Q control
M+3		FreqFlag: • 1 : frequency control enabled • 0 : frequency control disabled
M+4		PQFlag: • 1 : priority for current limit • 0 : Q priority
M+5		GenFlag: • 1 : unit is a generator • 0 : unit is a storage device (Note 6)
M+6		VtripFlag (flag to enable/disable voltage trip logic): • 1 : enable

ICONs	Value	Description
		• 0 : disable
M+7		FtripFlag (flag to enable/disable frequency trip logic): • 1 : enable • 0 : disable

DYRE Data Record:

```
I, 'USRLOD', LID, 'CMLDxxDGU2', 12, IT, 8, 175, 32, 148, 48,  0,  0,
 ICON(M+2) to ICON(M+7), CON(J) to CON(J+174)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix "xx"	"IT" Description	"I" Description
BL	1	Bus number
OW	2	Owner number
ZN	3	Zone number
AR	4	Area number
AL	5	0

9.8. EXTLBL, EXTLOW, EXTLZN, EXTLAR, EXTLAL

Extended-Term Load Reset Model

CONs	Value	Description
J		K_P
J+1		PMLTMX
J+2		PMLTMN
J+3		K_Q
J+4		QMLTMX
J+5		QMLTMN

STATEs	Value	Description
K		P_{MULT}
K+1		Q_{MULT}

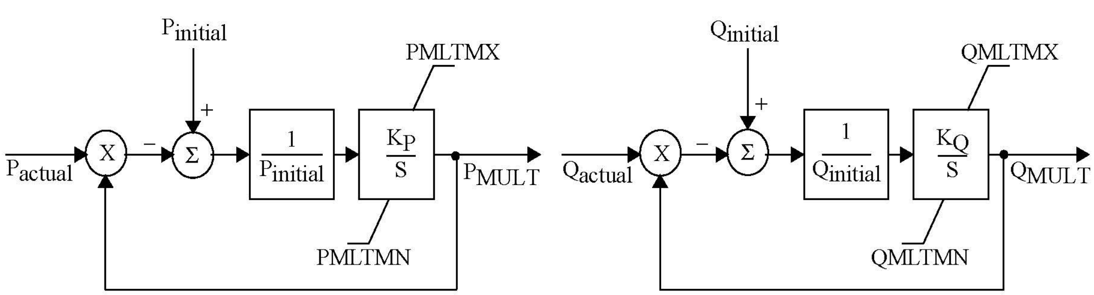
VAR	Value	Description
L		$V_{initial}$

Reserved ICON	Value	Description
N		Service status memory

```
I, 'EXTLxx', LID, CON(J) to CON(J+5)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0



9.9. IEELBL, IEELOW, IEELZN, IEELAR, IEELAL

IEEE Load Model

CONs	Value	Description
J		a_1
J+1		a_2
J+2		a_3
J+3		a_4
J+4		a_5
J+5		a_6
J+6		a_7
J+7		a_8
J+8		n_1
J+9		n_2
J+10		n_3
J+11		n_4
J+12		n_5
J+13		n_6

```
I, 'IEELxx', LID, CON(J) to CON(J+13)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0

$$P = P_{load}\left(a_1 v^{n_1} + a_2 v^{n_2} + a_3 v^{n_3}\right)(1 + a_7 \Delta f)$$

$$Q = Q_{load}\left(a_4 v^{n_4} + a_5 v^{n_5} + a_6 v^{n_6}\right)(1 + a_8 \Delta f)$$

9.10. LDFRBL, LDFROW, LDFRZN, LDFRAR, LDFRAL

Load Frequency Model

CONs	Value	Description
J		m, real power load exponent
J+1		n, reactive power load exponent
J+2		r, real current load exponent
J+3		s, reactive current load exponent

```
I, 'LDFRxx', LID, CON(J) to CON(J+3)   /
```

LID is an explicit load identifier or may be '*'; for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0

The constant power and constant current load components are made sensitive to bus frequency according to:

$$P = P_o\left(\frac{\omega}{\omega_o}\right)^m$$

$$Q = Q_o\left(\frac{\omega}{\omega_o}\right)^n$$

$$I_p = I_{po}\left(\frac{\omega}{\omega_o}\right)^r$$

$$I_q = I_{qo}\left(\frac{\omega}{\omega_o}\right)^s$$

Chapter 10
Load Relay Models

This chapter contains a collection of data sheets for the load relay models contained in the PSS®E dynamics model library.

Model	Description
DLSHBL, DLSHOW, DLSHZN, DLSHAR, DLSHAL	Rate of frequency load shedding mode
LDS3BL, LDS3OW, LDS3ZN, LDS3AR, LDS3AL	Underfrequency load shedding model with transfer trip
LDSHBL, LDSHOW, LDSHZN, LDSHAR, LDSHAL	Underfrequency load shedding model
LDSTBL, LDSTOW, LDSTZN, LDSTAR, LDSTAL	Time underfrequency load shedding model
LVS3BL, LVS3OW, LVS3ZN, LVS3AR, LVS3AL	Undervoltage load shedding model with transfer trip
LVSHBL, LVSHOW, LVSHZN, LVSHAR, LVSHAL	Undervoltage load shedding model
UVUFBLU1, UVUFOWU1, UVUFZNU1, UVUFARU1, UVUFALU1	User written under-voltage and under-frequency load shedding model

10.1. DLSHBL, DLSHOW, DLSHZN, DLSHAR, DLSHAL

Rate of Frequency Load Shedding Model

CONs	Value	Description
J		f_1, first load shedding point (Hz)
J+1		t_1, first point pickup time (sec)
J+2		$frac_1$, first fraction of load to be shed
J+3		f_2, second load shedding point (Hz)
J+4		t_2, second point pickup time (sec)
J+5		$frac_2$, second fraction of load to be shed
J+6		f_3, third load shedding point (Hz)
J+7		t_3, third point pickup time (sec)
J+8		$frac_3$, third fraction of load to be shed
J+9		T_B, breaker time (sec)
J+10		df_1, first rate of frequency shedding point (Hz/sec)
J+11		df_2, second rate of frequency shedding point (Hz/sec)
J+12		df_3, third rate of frequency shedding point (Hz/sec)

VARs	Description
L	First timer memory
L+1	Second timer memory
L+2	Third timer memory
L+3	Memory for derivative of bus frequency
L+4	Bus frequency derivative

Reserved ICONs	Value	Description
N		First point delay flag
N+1		First point timeout flag
N+2		First timer status
N+3		Second point delay flag
N+4		Second point timeout flag
N+5		Second timer status
N+6		Third point delay flag
N+7		Third point timeout flag
N+8		Third timer status

```
I, 'DLSHxx', LID, CON(J) to CON(J+12)   /
```

LID is an explicit load identifier or may be * for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number

Model suffix xx	I Description
OW	Owner number
ZN	Zone number
AR	Area number
AL	0

10.2. LDS3BL, LDS3OW, LDS3ZN, LDS3AR, LDS3AL

Underfrequency Load Shedding Model With Transfer Trip

ICONs	Value	Description
M		GBUS, bus number of transfer trip generator
M+1		GID, machine ID of transfer trip, -1 if plant
M+2		SC: 0 Do not shed shunt 1 Shed shunt with same fraction as load

Reserved ICONs	Value	Description
N		First point delay flag
N+1		First point timeout flag
N+2		First point timer status
N+3		Second point delay flag
N+4		Second point timeout flag
N+5		Second point timer status
N+6		Third point delay flag
N+7		Third point timeout flag
N+8		Third point timer status
N+9		Fourth point delay flag
N+10		Fourth point timeout flag
N+11		Fourth point timer status
N+12		Fifth point delay flag
N+13		Fifth point timeout flag
N+14		Fifth point timer status
N+15		Transfer trip breaker status
N+16		Transfer trip timer status

CONs	Value	Description
J		f_1, first load shedding point (Hz)
J+1		t_1, first point pickup time (sec)
J+2		tb_1, first breaker time (sec)
J+3		$frac_1$, first fraction of load to be shed
J+4		f_2, second load shedding point (Hz)
J+5		t_2, second point pickup time (sec)
J+6		tb_2, second breaker time (sec)
J+7		$frac_2$, second fraction of load to be shed
J+8		f_3, third load shedding point (Hz)
J+9		t_3, third point pickup time (sec)

CONs	Value	Description
J+10		tb_3, third breaker time (sec)
J+11		$frac_3$, third fraction of load to be shed
J+12		f_4, fourth load shedding point (Hz)
J+13		t_4, fourth point pickup time (sec)
J+14		tb_4, fourth breaker time (sec)
J+15		$frac_4$, fourth fraction of load to be shed
J+16		f_5, fifth load shedding point (Hz)
J+17		t_5, fifth point pickup time (sec)
J+18		tb_5, fifth breaker time (sec)
J+19		$frac_5$, fifth fraction of load to be shed
J+20		ttb, transfer trip breaker time (sec)

VARs	Description
L	First timer memory
L+1	Second timer memory
L+2	Third timer memory
L+3	Fourth timer memory
L+4	Fifth timer memory
L+5	Transfer trip timer

```
I, 'LDS3xx', LID, ICON(M) to ICON(M+2), CON(J) to CON(J+20)   /
```

LID is an explicit load identifier or may be # for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0

10.3. LDSHBL, LDSHOW, LDSHZN, LDSHAR, LDSHAL

Underfrequency Load Shedding Model

Reserved ICONs	Value	Description
N		First point delay flag
N+1		First point timeout flag
N+2		First timer status
N+3		Second point delay flag
N+4		Second point timeout flag
N+5		Second timer status
N+6		Third point delay flag
N+7		Third point timeout flag
N+8		Third timer status

CONs	Value	Description
J		f_1, first load shedding point (Hz)
J+1		t_1, first point pickup time (sec)
J+2		$frac_1$, first fraction of load to be shed
J+3		f_2, second load shedding point (Hz)
J+4		t_2, second fraction pickup time (sec)
J+5		$frac_2$, second fraction of load to be shed
J+6		f_3, third load shedding point (Hz)
J+7		t_3, third point pickup time (sec)
J+8		$frac_3$, third fraction of load to be shed
J+9		t_b, breaker time (sec)

VARs	Description
L	First timer memory
L+1	Second timer memory
L+2	Third timer memory

```
I, 'LDSHxx', LID, CON(J) to CON(J+9)   /
```

LID is an explicit load identifier or may be # for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0

10.4. LDSTBL, LDSTOW, LDSTZN, LDSTAR, LDSTAL

Time Underfrequency Load Shedding Model

Reserved ICONs	Value	Description
N		Relay status
N+1		Breaker timer flag
N+2		Breaker timeout flag

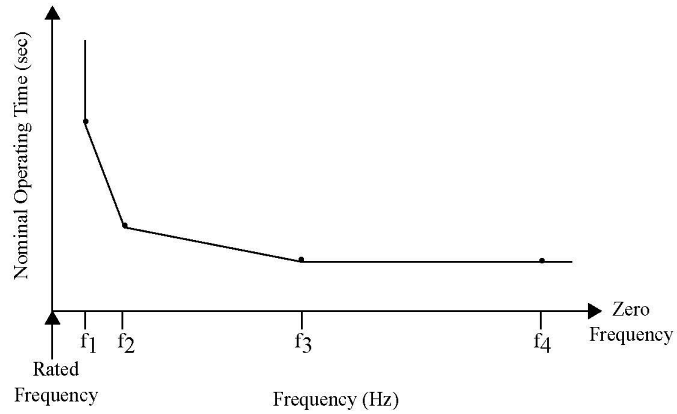
```
I, 'LDSTxx', LID, CON(J) to CON(J+11)   /
```

LID is an explicit load identifier or may be * for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0

CONs	Value	Description
J		f_1, pickup frequency (Hz)
J+1		z_1, nominal operating time (sec)
J+2		f_2, second frequency point (Hz)
J+3		z_2, nominal operating time (sec)
J+4		f_3, third frequency point (Hz)
J+5		z_3, nominal operating time (sec)
J+6		f_4, fourth frequency point (Hz)
J+7		z_4, nominal operating time (sec)
J+8		T_B, breaker time (sec)
J+9		frac, fraction of load to be shed
J+10		f_{reset}, reset frequency (Hz)
J+11		t_{res}, resetting time (sec)

VARs	Description
L	Frequency (Hz)
L+1	Relay trip contact position
L+2	Breaker timer memory


Nominal Operating Time (sec)
Zero Frequency
f1
f2
f3
f4
Rated Frequency
Frequency (Hz)

10.5. LVS3BL, LVS3OW, LVS3ZN, LVS3AR, LVS3AL

Undervoltage Load Shedding Model With Transfer Trip

ICONs	Value	Description	
M		FBUS1, from bus number First transfer trip	First transfer trip
M+1		TBUS1, to bus number First transfer trip	
M+2		ID1, Circuit ID First transfer trip	
M+3		FBUS2, from bus number Second transfer trip	Second Transfer trip
M+4		TBUS2, to bus number Second transfer trip	
M+5		ID2, Circuit ID	
M+6		SC: 0 Do not shed shunt 1 Shed shunt with same fraction as load	

Reserved ICONs	Value	Description
N		First point delay flag
N+1		First point timeout flag
N+2		First point timer status
N+3		Second point delay flag
N+4		Second point timeout flag
N+5		Second point timer status
N+6		Third point delay flag
N+7		Third point timeout flag
N+8		Third point timer status
N+9		Fourth point delay flag
N+10		Fourth point timeout flag
N+11		Fourth point timer status
N+12		Fifth point delay flag
N+13		Fifth point timeout flag
N+14		Fifth point timer status
N+15		First transfer trip breaker status
N+16		First transfer trip timer status
N+17		Second transfer trip breaker status
N+18		Second transfer trip timer status

CONs	Value	Description
J		f_1, first load shedding point (pu)
J+1		T_1, first point pickup time (sec)
J+2		tb_1, first breaker time (sec)
J+3		$frac_1$, first fraction of load to be shed

CONs	Value	Description
J+4		f_2, second load shedding point (pu)
J+5		T_2, second point pickup time (sec)
J+6		tb_2, second breaker time (sec)
J+7		$frac_2$, second fraction of load to be shed
J+8		f_3, third load shedding point (pu)
J+9		T_3, third point pickup time (sec)
J+10		tb_3, third breaker time (sec)
J+11		$frac_3$, third fraction of load to be shed
J+12		f_4, fourth load shedding point (pu)
J+13		T_4, fourth point pickup time (sec)
J+14		tb_4, fourth breaker time (sec)
J+15		$frac_4$, fourth fraction of load to be shed
J+16		f_5, fifth load shedding point (pu)
J+17		T_5, fifth point pickup time (sec)
J+18		tb_5, fifth breaker time (sec)
J+19		$frac_5$, fifth fraction of load to be shed
J+20		ttb_1, first transfer trip breaker time (sec)
J+21		ttb_2, second transfer trip breaker time (sec)

VARs	Description
L	First timer memory
L+1	Second timer memory
L+2	Third timer memory
L+3	Fourth timer memory
L+4	Fifth timer memory
L+5	First transfer trip timer
L+6	Second transfer trip timer

```
I, 'LVS3xx', LID, ICON(M) to ICON(M+6), CON(J) to CON(J+21)   /
```

LID is an explicit load identifier or may be * for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number
ZN	Zone number
AR	Area number
AL	0

10.6. LVSHBL, LVSHOW, LVSHZN, LVSHAR, LVSHAL

Undervoltage Load Shedding Model

CONs	Value	Description
J		V_1, first load shedding point (pu)
J+1		T_1, first point pickup time (sec)
J+2		F1, first fraction of load to be shed
J+3		V_2, second load shedding point (pu)
J+4		T_2, second fraction pickup time (sec)
J+5		F_2, second fraction of load to be shed
J+6		V_3, third load shedding point (pu)
J+7		T_3, third point pickup time (sec)
J+8		F3, third fraction of load to be shed
J+9		T_B, breaker time (sec)

VARs	Description
L	First timer memory
L+1	Second timer memory
L+2	Third timer memory

ICON	Value	Description
M		JBUS, remote bus number where voltage is measured [a]

[a]Set JBUS = 0, if remote bus is same as the local bus to which the load is connected.

Reserved ICONs	Value	Description
N		First point delay flag
N+1		First point timeout flag
N+2		First timer status
N+3		Second point delay flag
N+4		Second point timeout flag
N+5		Second timer status
N+6		Third point delay flag
N+7		Third point timeout flag
N+8		Third point status

```
I, 'LVSHxx', LID, ICON(M), CON(J) to CON(J+9)   /
```

LID is an explicit load identifier or may be # for application to loads of any ID associated with the subsystem type.

Model suffix xx	I Description
BL	Bus number
OW	Owner number

Model suffix xx	I Description
ZN	Zone number
AR	Area number
AL	0

10.7. UVUFBLU1, UVUFOWU1, UVUFZNU1, UVUFARU1, UVUFALU1

Undervoltage and Underfrequency Load Shedding Model

CONs	Value	Description
J		V1, first voltage-based load shedding point (pu)
J+1		TV1, first voltage-based point pickup time (sec)
J+2		FV1, first voltage-based fraction of load to be shed
J+3		V2, second voltage-based load shedding point (pu)
J+4		TV2, second voltage-based point pickup time (sec)
J+5		FV2, second voltage-based fraction of load to be shed
J+6		V3, third voltage-based load shedding point (pu)
J+7		TV3, third voltage-based point pickup time (sec)
J+8		FV3, third voltage-based fraction of load to be shed
J+9		TVB, voltage-based breaker time (sec)
J+10		F1, first frequency-based load shedding point (Hz)
J+11		TF1, first frequency-based point pickup time (sec)
J+12		FF1, first frequency-based fraction of load to be shed
J+13		F2,second frequency-based load shedding point (Hz)
J+14		TF2, second frequency-based point pickup time (sec)
J+15		FF2, second frequency-based fraction of load to be shed
J+16		F3, third frequency-based load shedding point (Hz)
J+17		TF3, third frequency-based point pickup time (sec)
J+18		FF3, third frequency-based fraction of load to be shed
J+19		TFB, frequency-based breaker time (sec)

VARs	Description
L	First voltage-based timer memory
L+1	Second voltage-based timer memory (pu)
L+2	Third voltage-based timer memory
L+3	First frequncy-based timer memory
L+4	Second frequncy-based timer memory
L+5	Third frequncy-based timer memory
L+6	Load fractions already shed in previous stages

ICON	Value	Description
M		JBUS, remote bus number where voltage is measured [a]

[a]Set JBUS = 0, if remote bus is same as the local bus to which the load is connected.

Reserved ICONs	Value	Description
N		First voltage-based point delay flag

Reserved ICONs	Value	Description
N+1		First voltage-based point timeout flag
N+2		First voltage-based timer status
N+3		Second voltage-based point delay flag
N+4		Second voltage-based point timeout flag
N+5		Second voltage-based timer status
N+6		Third voltage-based point delay flag
N+7		Third voltage-based point timeout flag
N+8		Third voltage-based timer status
N+9		First frequncy-based point delay flag
N+10		First frequncy-based point timeout flag
N+11		First frequncy-based timer status
N+12		Second frequncy-based point delay flag
N+13		Second frequncy-based point timeout flag
N+14		Second frequncy-based timer status
N+15		Third frequncy-based point delay flag
N+16		Third frequncy-based point timeout flag
N+17		Third frequncy-based timer status

DYRE Data Record:

```
I, 'USRLOD', LID, 'UVUFxxU1', 13, IT, 1, 20, 0, 7, 18, JBUS, CON(J) to
CON(J+19)
              /
```

LID is an explicit load identifier or may be * for application to loads of any ID associated with the subsystem type.

Model suffix "xx"	"IT" Description	"I" Description
BL	1	Bus number
OW	2	Owner number
ZN	3	Zone number
AR	4	Area number
AL	5	0

Chapter 11
Line Relay Model

This chapter contains a collection of data sheets for the line relay models contained in the PSS®E dynamics model library.

Model	Description
CIROS1	Double circle or lens out-of-step tripping or blocking relay
DISTR1	mho, impedance, or reactance distance relay
DPDTR1	Rate of change of power relay
RXR1	RXR distance relay
SCGAP2	Series capacitor gap relay
SLLP1	SLLP tripping relay
SLNOS1	Straight line blinder out-of-step relay
SLYPN1	G.E. directional comparison and overcurrent relay
TIOCR1	Time inverse overcurrent relay

11.1. CIROS1

Double Circle or Lens Out-of-Step Tripping or Blocking Relay

ICONs	Value	Description	
M		• 1 - Double circle tripping • -1 - Double circle blocking • +2 - Lens type tripping • -2 - Lens type blocking	
M+1		Operation mode: • 0 - Monitor • 1 - Monitor and operate	
M+2		From bus number	First transfer trip
M+3		To bus number	
M+4		Circuit ID	
M+5		From bus number trip	Second transfer
M+6		To bus number	
M+7		Circuit ID	
M+8		From bus number	Third transfer trip
M+9		To bus number	
M+10		Circuit ID	
M+11		Supervisory ICON (permissive flag ICON of another model)	
M+12	X	Permissive flag for self trip[a]	
M+13	X	Permissive flag for transfer trip[b]	
M+14	X	ICONs required for internal program logic	
...	X		
M+20	X		

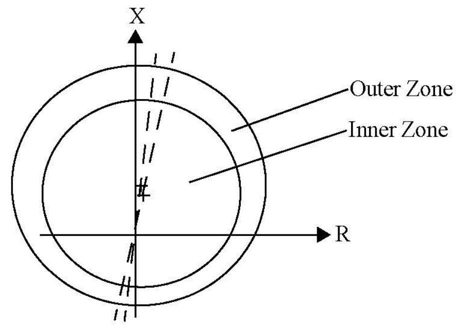
[a]Set to 1 and -1 by supervisory relay to block trip and force trip, respectively.
[b]Set to 1 by supervissory relay to block trip.

CONs	Value	Description
J		Interzone travel time (cycles)
J+1		Zone 1 (inner zone) diameter (pu)
J+2		Centerline angle (degrees)
J+3		Centerline distance (pu)
J+4		Zone 2 (outer zone) diameter
J+5		Centerline angle (degrees)
J+6		Centerline distance (pu)
J+7		Threshold current (pu)

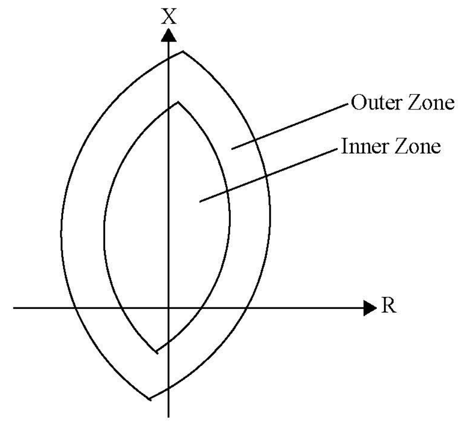
CONs	Value	Description
J+8		Self trip breaker time (cycles)
J+9		Transfer trip breaker and delay time
J+10		First blinder type (±1 or ±2)
J+11		First blinder intercept (pu)
J+12		First blinder rotation (degrees)
J+13		Second blinder type
J+14		Second blinder intercept (pu)
J+15		Second blinder rotation (degrees)

VARs	Description
L	Apparent R
L+1	Apparent X
L+2	Current
L+3	VARs required for internal program logic
L+4	
L+5	

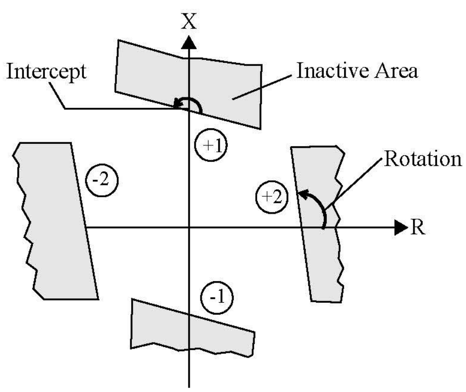
```
IBUS, ’CIROS1’, JBUS, ID, RS, ICON(M) to ICON(M+11), CON(J) to CON(J+15)
  /
```



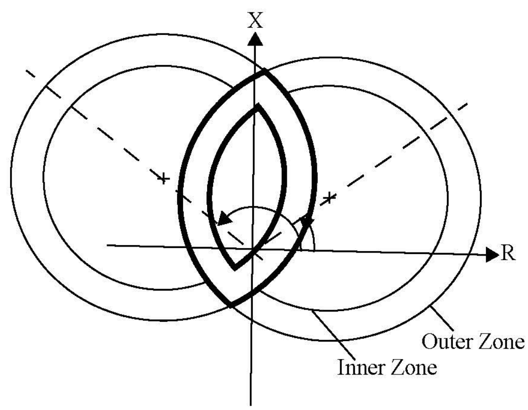
Double Circle



Lens Type



Blinder Types



Specification of Lens

Double Circle or Lens Out-of-Step Tripping or Blocking Relay

11.2. DISTR1

mho, Impedance, or Reactance Distance Relay

ICONs	Value	Description	
M		• 1 - mho distance • 2 - Impedance distance • 3 - Reactance distance	
M+1		• 0 - Monitor • 1 - Monitor and operate	
M+2		From bus number	First transfer trip
M+3		To bus number	
M+4		Circuit ID	
M+5		From bus number	Second transfer
M+6		To bus number	
M+7		Circuit ID	
M+8		From bus number	Third transfer trip
M+9		To bus number	
M+10		Circuit ID	
M+11	X	Permissive flag for self trip [a]	
M+12	X	Permissive flag for transfer trip[b]	
M+13	X	ICONs required for internal program logic	
...	X		
M+28	X		

[a]Set to 1 and -1 by supervisory relay to block trip and force trip, respectively.

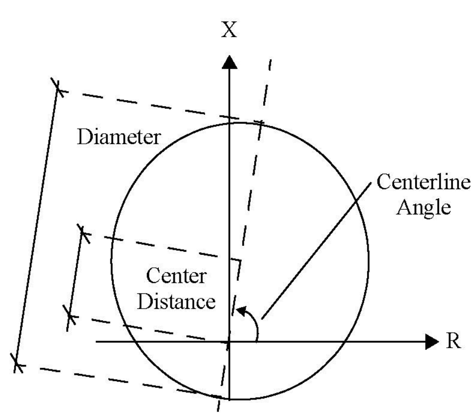
[b]Set to 1 by supervisory relay to block trip.

CONs	Value	Description
J		Zone 1 operating time (cycles)
J+1		Zone 1 reach (diameter or reactance) (pu)
J+2		Zone 1 centerline angle in degrees (0 for reactance relay)
J+3		Zone 1 center distance (0 for reactance relay)
J+4		Zone 2 pickup time (cycles)
J+5		Zone 2 reach (diameter or reactance) (pu)
J+6		Zone 2 centerline angle (0 for reactance relay)
J+7		Zone 2 center distance (0 for reactance relay)
J+8		Zone 3 pickup time (cycles)
J+9		Zone 3 reach (diameter)
J+10		Zone 3 centerline angle (degrees)
J+11		Zone 3 center distance (pu)

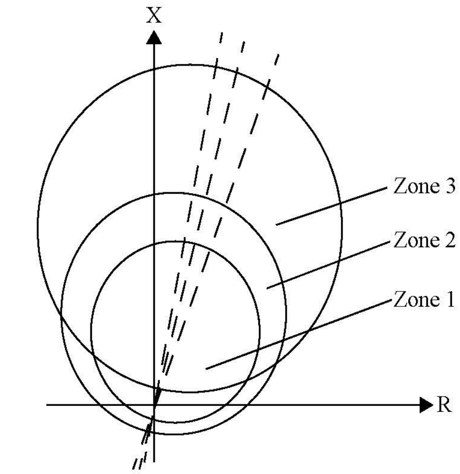
CONs	Value	Description
J+12		Angle of directional unit (only for impedance relay)
J+13		Threshold current (pu)
J+14		Self trip breaker time (cycles)
J+15		Self trip reclosure time (cycles)
J+16		Transfer trip breaker time (cycles)
J+17		Transfer trip reclosure time (cycles)
J+18		1st blinder type (±1 or ±2)
J+19		1st blinder intercept (pu)
J+20		1st blinder rotation (degrees)
J+21		2nd blinder type (±1 or ±2)
J+22		2nd blinder intercept (pu)
J+23		2nd blinder rotation (degrees)

VARs	Description
L	Apparent R
L+1	Apparent X
L+2	Current
L+3	VARs required for internal program logic
...	
L+9	

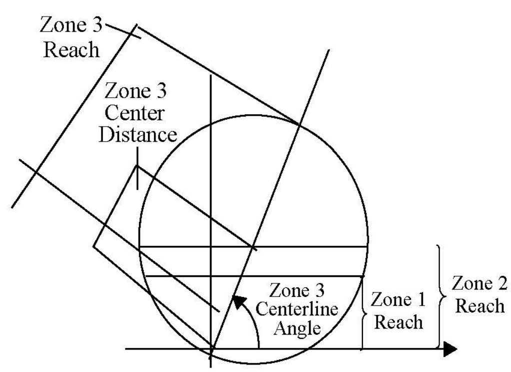
```
IBUS, 'DISTR1', JBUS, ID, RS, ICON(M) to ICON(M+10), CON(J) to CON(J+23)
 /
```



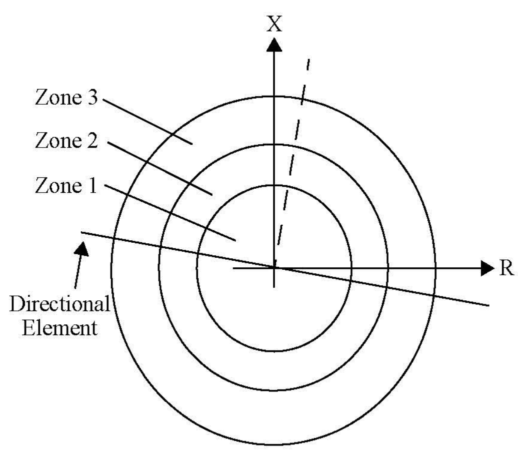
Zone Reach



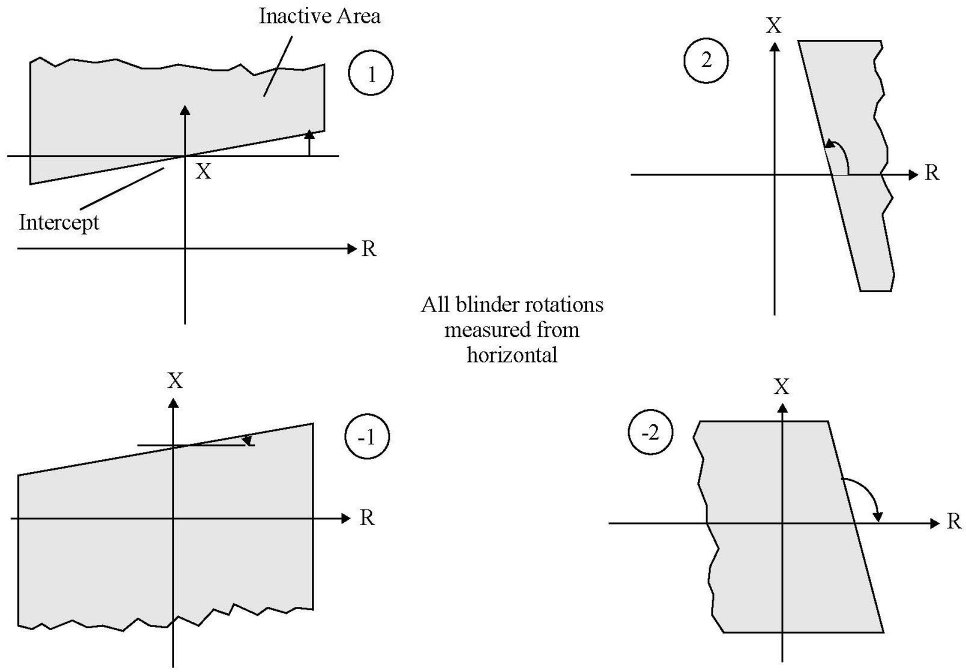
mho Distance



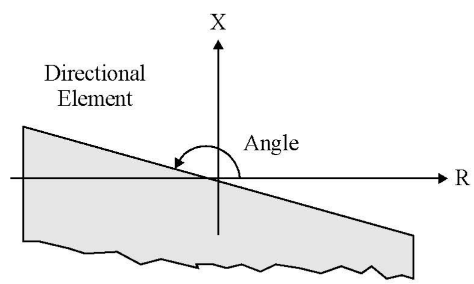
Reactance Distance



Impedance Distance



Blinder Types



mho, Impedance, or Reactance Distance Relay

11.3. DPDTR1

Rate of Change of Power Relay

ICONs	Value	Description
M		Operation mode: • 0 - Monitor • 1 - Monitor and operate
M+1		From bus number for transfer trip
M+2		To bus number
M+3		Circuit identifier
M+4	X	Delay flag
M+5	X	Time out flag for delay
M+6	X	Timer status

CONs	Value	Description
J		Breaker time (>0) (sec)
J+1		Delay time (sec)
J+2		Derivative threshold (>0) (MW/sec)
J+3		Power threshold (>0) (MW)
J+4		Filter constant in number of time steps

VARs	Description
L	Real power flow
L+1	Rate of change of power
L+2	Memory (for delay)
L+3	Mvar flow
L+4	MVA flow

```
IBUS, 'DPDTR1', JBUS, ID, RS, ICON(M) to ICON(M+3), CON(J) to CON(J+4)   /
```

11.4. RXR1

RXR Distance Relay

ICONs	Value	Description	
M		Operation mode: • 0 - Monitor • 1 - Monitor and operate	
M+1		From bus number	First transfer trip
M+2		To bus number	
M+3		Circuit ID	
M+4		From bus number	Second transfer
M+5		To bus number	
M+6		Circuit ID	
M+7		From bus number	Third transfer trip
M+8		To bus number	
M+9		Circuit ID	
M+10	X	Permissive flag for self trip [a]	
M+11	X	Permissive flag for transfer trip[b]	
M+12	X	ICONs required for internal program logic	
...	X		
M+24	X		

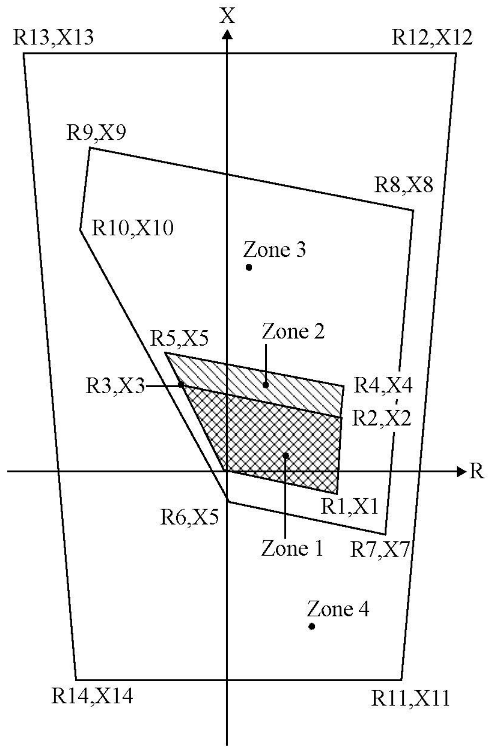
[a]Set to 1 and -1 by supervisory relay to block trip and force trip, respectively.
[b]Set to 1 by supervissory relay to block trip.

CONs	Value	Description	
J		R_1 (> 0)	
J+1		X_1	
J+2		R_2	
J+3		X_2 (> X1)	
J+4		R3 (< R2)	
J+5		X3 (> 0)	
J+6		R4	
J+7		X4 (> X1)	
J+8		R5 (< R4)	
J+9		X5 (> 0)	
J+10		R6	
J+11		X6	
J+12		R7 (> R6)	Polygon resistance and impedances to define four zones (as shown in the adjacent

CONs	Value	Description	
			figure) are in per unit on system base.
J+13		X7	
J+14		R8	
J+15		X8 (> X7)	
J+16		R9 (≥ R10, < R8)	
J+17		X9	
J+18		$R_1$0 (≤ R6)	
J+19		$X_1$0 (< X9, > X6)	
J+20		$R_1$1	
J+21		$X_1$1	
J+22		$R_1$2	
J+23		$X_1$2 (> X11)	
J+24		$R_1$3 (< R12)	
J+25		$X_1$3	
J+26		$R_1$4 (< R11)	
J+27		$X_1$4 (< X13)	
J+28		Zone 1 delay time (cycles)	
J+29		Zone 2 delay time (cycles)	
J+30		Zone 3 delay time (cycles)	
J+31		Zone 4 delay time (cycles)	
J+32		Threshold current (pu)	
J+33		Self trip breaker time (cycles)	
J+34		Self trip reclosure time (cycles)	
J+35		Transfer trip breaker time (cycles)	
J+36		Transfer trip reclosure time (cycles)	

VARs	Description
L	Apparent R
L+1	Apparent X
L+2	Current magnitude
L+3	VARs required for internal program logic
L+4	
L+5	
L+6	
L+7	

```
IBUS, 'RXR1', JBUS, ID, RS, ICON(M) to ICON(M+9), CON(J) to CON(J+36)   /
```




```
0, 'RXR', ICON(M) to ICON(M+14), CON(J) to CON(J+36)   /
```

11.5. SCGAP2

Series Capacitor Gap Relay

ICONs	Value	Description	
M		Number of reinsertion attempts	
M+1		From bus number	Series capacitor branch
M+2		To bus number	
M+3		Circuit ID	
M+4		From bus number	First transfer trip
M+5		To bus number	
M+6		Circuit ID	
M+7		From bus number	Second transfer trip
M+8		To bus number	
M+9		Circuit ID	
M+10		From bus number	Third transfer trip
M+11		To bus number	
M+12		Circuit ID	
M+13		Transfer trip option: • 0 - When gap flashes first time • 1 - When shorting switch closes	
M+14	X	ICONs required for internal program logic	
...	X		
M+22	X		

CONs	Value	Description
J		Gap firing current (pu)
J+1		Communication delay, Td (cycles)
J+2		Gap reinsertion current (pu)
J+3		Reinsertion time delay (cycles)
J+4		Shorting switch time (cycles)
J+5		Transfer trip breaker time (cycles)

VARs	Description
L	Current in monitored element
L+1	Original reactance
L+2	VARs required for internal logic
L+3	
L+4	
L+5	

```
IBUS, 'SCGAP2', JBUS, ID, RS, ICON(M) to ICON(M+13), CON(J) to CON(J+5)
  /
```

11.6. SLLP1

SLLP Tripping Relay

ICONs	Value	Description	
M		• 0 - Monitor • 1 - Monitor and operate	
M+1		From bus number	First transfer
M+2		To bus number	
M+3		Circuit ID	
M+4		From bus number	Second transfer trip
M+5		To bus number	
M+6		Circuit ID	
M+7		From bus number	Third transfer trip
M+8		To bus number	
M+9		Circuit ID	
M+10	X	Permissive flag for self trip[a]	
M+11	X	Permissive flag for transfer trip[b]	
M+12	X	ICONs required for internal program logic	
...	X		
M+20	X		

[a]Set to 1 and -1 by supervisory relay to block trip and force trip, respectively.
[b]Set to 1 by supervisory relay to block trip.

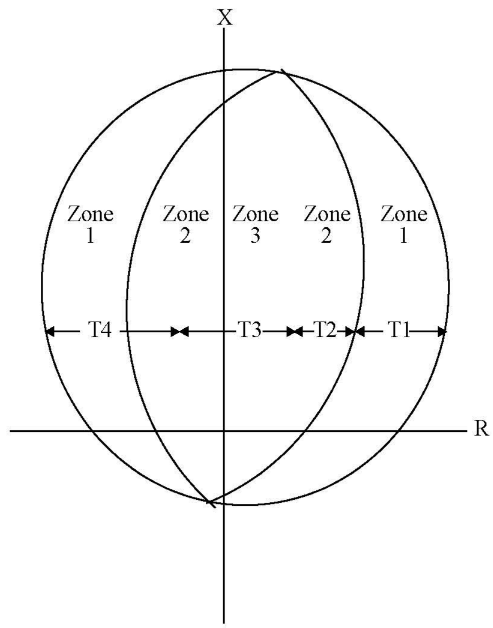
CONs	Value	Description
J		T_1 (cycles) (>0)
J+1		T_2 (cycles) (>0)
J+2		T_3 (cycles)[a]
J+3		T_4 (cycles)
J+4		R_1, resistance value of upper intersection (pu)
J+5		X_1, reactance value of upper intersection (pu)
J+6		R_2, resistance value of lower intersection (pu)
J+7		X_2, reactance value of lower intersection (pu)
J+8		P_1, perpendicular distance to inner center (pu)[b]
J+9		P_2, perpendicular distance to middle center (pu)
J+10		P_3, perpendicular distance to outer center (pu)
J+11		Threshold current (pu)
J+12		Self trip breaker time (cycles)
J+13		Transfer trip breaker time (cycles)

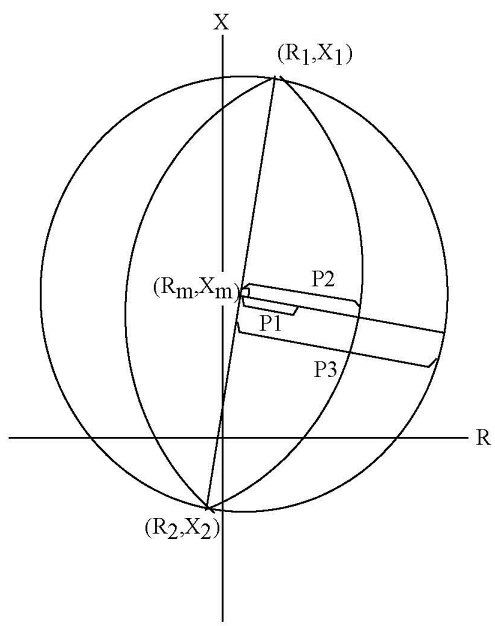
[a]Both T3 and T4 must be nonzero to cause tripping on the way out.
[b]P1 < P2 < P3 ≤ one-half distance between (R21, X1) and (Rm, Xm).

VARs	Description
L	Apparent R

VARs	Description
L+1	Apparent X
L+2	Current
L+3	VARs required for internal program logic
L+4	
L+5	

```
IBUS, 'SLLP1', JBUS, ID, RS, ICON(M) to ICON(M+9), CON(J) to CON(J+13)   /
```





(R_m,X_m) is Center of Segment Connecting (R1,X1) to (R2,X2)

11.7. SLNOS1

Straight Line Blinder Out-of-Step Relay

ICONs	Value	Description	
M		• 1 - Single blinder tripping • -1 - Single blinder blocking • +2 - Double blinder tripping • -2 - Double blinder tripping	
M+1		Operation mode: • 0 - Monitor • 1 - Monitor and operate	
M+2		From bus number	Second transfer
M+3		To bus number	
M+4		Circuit ID	
M+5		From bus number	Third transfer trip
M+6		To bus number	
M+7		Circuit ID	
M+8		From bus number	Third transfer trip
M+9		To bus number	
M+10		Circuit ID	
M+11		Supervisory ICON number (permissive ICON of another model)	
M+12	X	Permissive flag for self trip[a]	
M+13	X	Permissive flag for transfer trip[b]	
M+14	X	ICONs required for internal program logic	
...	X		
M+21	X		

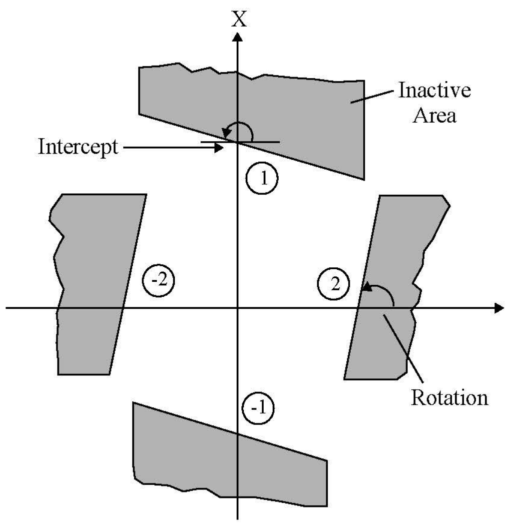
[a]Set to 1 and -1 by supervisory relay to block trip and force trip, respectively.
[b]Set to 1 by supervisory relay to block trip.

CONs	Value	Description
J		Interzone travel time (cycles)
J+1		Angle of first pair of impedance units (α)
J+2		Intercept of first line
J+3		Intercept of second line
J+4		Angle of second pair of impedance units (β)
J+5		Intercept of third line
J+6		Intercept of fourth line
J+7		Threshold current (pu)

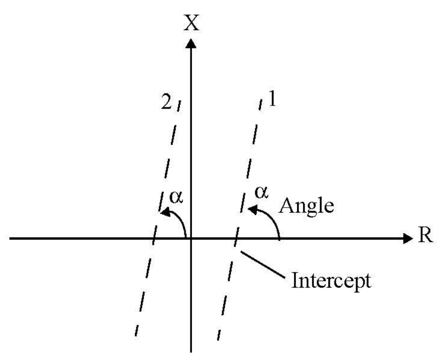
CONs	Value	Description
J+8		Self trip breaker time (cycles)
J+9		Transfer trip breaker and delay time (cycles)
J+10		First blinder type (+1 or +2)
J+11		First blinder intercept (pu)
J+12		First blinder rotation (degrees)
J+13		Second blinder type
J+14		Second blinder intercept (pu)
J+15		Second blinder rotation (degrees)

VARs	Description
L	Apparent R
L+1	Apparent X
L+2	Current
L+3	VARs required for internal program logic
L+4	
L+5	

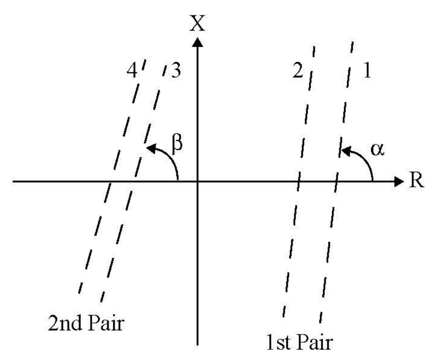
```
IBUS, 'SLNOS1', JBUS, ID, RS, ICON(M) to ICON(M+11), CON(J) to CON(J+15)
  /
```



Blinder Type Relay Characteristics



Single Blinder



Double Blinder

11.8. SLYPN1

GE Directional Comparison and Overcurrent Relay

ICONs	Value	Description
M		Operation mode: • 0 - Monitor • 1 - Monitor and operate
M+1		Overcurrent supervision bus IBUS: • +1 - Trip • 0 - None • -1 - Block
M+2		Overcurrent supervision bus JBUS: • +1 - Trip • 0 - None • -1 - Block
M+3		Out-of-step blocking: • 0 - No • 1 - Yes
M+4		ICONs required for internal program logic
...		
M+22		

CONs	Value	Description
J		Zone 1 operating time (cycles)
J+1		Zone 1 reach (diameter in pu)
J+2		Zone 1 centerline angle (degrees)
J+3		Zone 1 center distance (pu)
J+4		Zone 2 pickup time bus IBUS (cycles)
J+5		Zone 2 forward reach bus IBUS (pu)
J+6		Zone 2 reverse reach bus IBUS (pu) (>0)
J+7		Zone 2 centerline angle bus IBUS (degrees)
J+8		Zone 2 circle diameter bus IBUS (pu)
J+9		Zone 2 pickup time bus JBUS (cycles)
J+10		Zone 2 for reach bus JBUS (pu)
J+11		Zone 2 reverse reach bus JBUS (pu) (>0)
J+12		Zone 2 centerline angle bus JBUS (degrees)

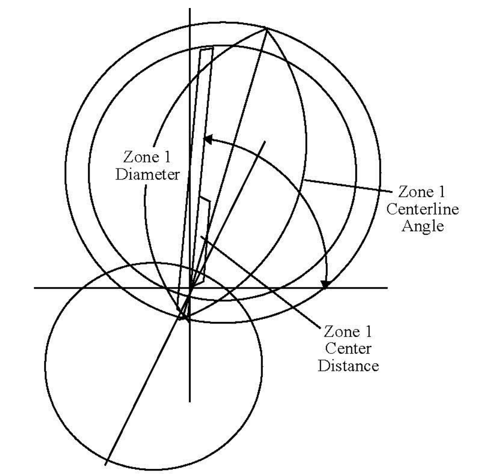
<table>
<tr><td>CONs</td><td>Value</td><td colspan="2">Description</td></tr>
<tr><td>J+13</td><td></td><td colspan="2">Zone 2 circle diameter bus JBUS (pu)</td></tr>
<tr><td>J+14</td><td></td><td colspan="2">Reverse reaching block bus IBUS (diameter in pu) (>0)</td></tr>
<tr><td>J+15</td><td></td><td colspan="2">Reverse reaching centerline angle bus IBUS (degrees) (>0)</td></tr>
<tr><td>J+16</td><td></td><td colspan="2">Reverse reaching center distance bus IBUS (pu)</td></tr>
<tr><td>J+17</td><td></td><td colspan="2">Reverse reaching block bus JBUS (diameter in pu) (>0)</td></tr>
<tr><td>J+18</td><td></td><td colspan="2">Reverse reaching centerline angle bus JBUS (degrees) (>0)</td></tr>
<tr><td>J+19</td><td></td><td colspan="2">Reverse reaching center distance bus JBUS (pu)</td></tr>
<tr><td>J+20</td><td></td><td colspan="2">Overcurrent supervisory level bus IBUS (pu)</td></tr>
<tr><td>J+21</td><td></td><td colspan="2">Overcurrent supervisory level bus JBUS (pu)</td></tr>
<tr><td>J+22</td><td></td><td colspan="2">Interzone travel time bus IBUS (cycles)</td></tr>
<tr><td>J+23</td><td></td><td colspan="2">Interzone travel time bus JBUS (cycles)</td></tr>
<tr><td>J+24</td><td></td><td>R</td><td rowspan="7">Equivalent values for single pole trip[b]</td></tr>
<tr><td>J+25</td><td></td><td>X[a]</td></tr>
<tr><td>J+26</td><td></td><td>B</td></tr>
<tr><td>J+27</td><td></td><td>GIBUS</td></tr>
<tr><td>J+28</td><td></td><td>BIBUS</td></tr>
<tr><td>J+29</td><td></td><td>GJBUS</td></tr>
<tr><td>J+30</td><td></td><td>BJBUS</td></tr>
<tr><td>J+31</td><td></td><td colspan="2">Breaker time (cycles)</td></tr>
<tr><td>J+32</td><td></td><td colspan="2">Reclosure time (cycles)</td></tr>
</table>

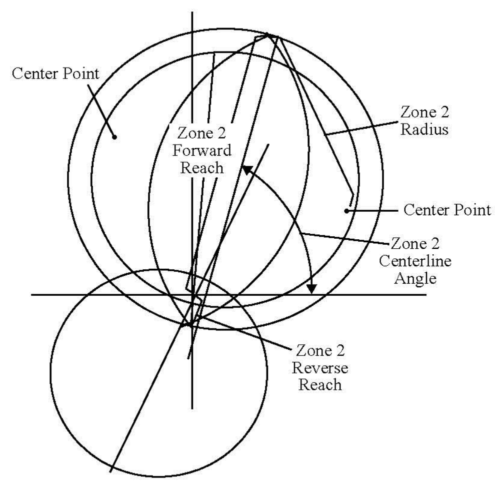
[a]if (X > 1000) all three phases are tripped.

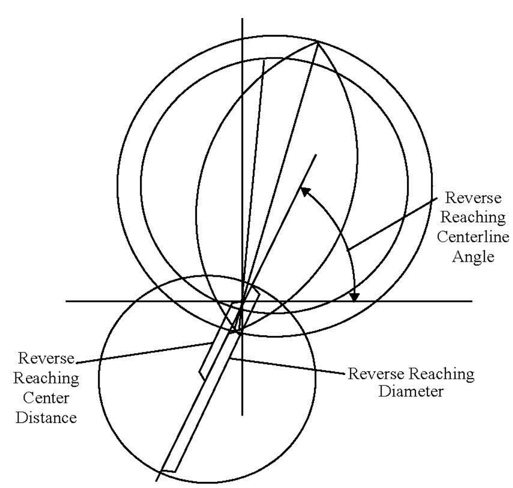
[b]These values may be obtained from activity SPCB

<table>
<tr><td>VARs</td><td>Description</td></tr>
<tr><td>L</td><td>Apparent R at bus IBUS</td></tr>
<tr><td>L+1</td><td>Apparent X at bus IBUS</td></tr>
<tr><td>L+2</td><td>Current at bus IBUS</td></tr>
<tr><td>L+3</td><td>Apparent R at bus JBUS</td></tr>
<tr><td>L+4</td><td>Apparent X at bus JBUS</td></tr>
<tr><td>L+5</td><td>Current at bus JBUS</td></tr>
<tr><td>L+6</td><td rowspan="3">VARS required for internal program logic</td></tr>
<tr><td>...</td></tr>
<tr><td>L+21</td></tr>
</table>

```
IBUS, 'SLYPN1', JBUS, ID, RS, ICON(M) to ICON(M+3), CON(J) to CON(J+32)
  /
```


Zone 1
Diameter
Zone 1
Centerline
Angle
Zone 1
Center
Distance


Center Point
Zone 2
Forward
Reach
Zone 2
Radius
Center Point
Zone 2
Centerline
Angle
Zone 2
Reverse
Reach


Reverse
Reaching
Centerline
Angle
Reverse
Reaching
Center
Distance
Reverse Reaching
Diameter

11.9. TIOCR1

Time Inverse Overcurrent Relay

ICONs	Value	Description	
M		Operation mode: 0 Monitor 1 Monitor and operate	
M+1		Bus number for load shedding	
M+2		Load ID for load shedding	
M+3		From bus number	First transfer trip
M+4		To bus number	
M+5		Circuit ID	
M+6		From bus number	Second transfer trip
M+7		To bus number	
M+8		Circuit ID	
M+9		From bus number	Third transfer trip
M+10		To bus number	
M+11		Circuit ID	
M+12	X	Relay status	
M+13	X	Breaker timer flag	
M+14	X	Breaker timeout flag	

CONs	Value	Description
J		Current threshold (pu on system base)
J+1		Zero current reset time (sec)
J+2		Lowest operating current (as a multiple of pickup)
J+3		Time to close relay (sec)
J+4		Second current point (as a multiple of pickup)
J+5		Time to close relay (sec)
J+6		Third current point (as a multiple of pickup)
J+7		Time to close relay (sec)
J+8		Fourth current point (as a multiple of pickup)
J+9		Time to close relay (sec)
J+10		Largest or saturation current (as a multiple of pickup)
J+11		Time to close relay (sec)
J+12		Breaker time (sec)
J+13		Fraction of load to be shed

VARs	Description
L	Current flow magnitude (pu)
L+1	Relay trip contact position

VARs	Description
L+2	Breaker timer memory

```
IBUS, 'TIOCR1', JBUS, ID, RS, ICON(M) to ICON(M+11), CON(J) to CON(J+13)
  /
```

Chapter 12
Auxiliary-Signal Models

This chapter contains a collection of data sheets for the auxiliary-signal models contained in the PSS®E dynamics model library.

Model	Description
CHAAUT	Chateauguay auxiliary signal model
CPAAUT	Frequency sensitive auxiliary signal model
DCCAUT	Comerford auxiliary signal model
DCVRFT	HVDC ac voltage controller model
FCTAXBU1	FACTS device Auxiliary Control Model
HVDCAT	General purpose auxiliary signal model
PAUX1T	Frequency sensitive auxiliary signal model
PAUX2T	Bus voltage angle sensitive auxiliary signal model
RBKELT	Runback model (can be used only with 2-terminal dc line models)
RUNBKT	Runback model (can be used only with two-terminal dc line models)
SQBAUT	dc line auxiliary signal model (can be used only with two-terminal dc line models)

12.1. CHAAUT

Chateauguay Auxiliary Signal Model

ICONs	Value	Description
M		IB, number of first bus where model is attached
M+1		JB, number of second bus where model is attached
M+2		ISW: >0 to subtract second signal from first <0 to subtract first signal from second

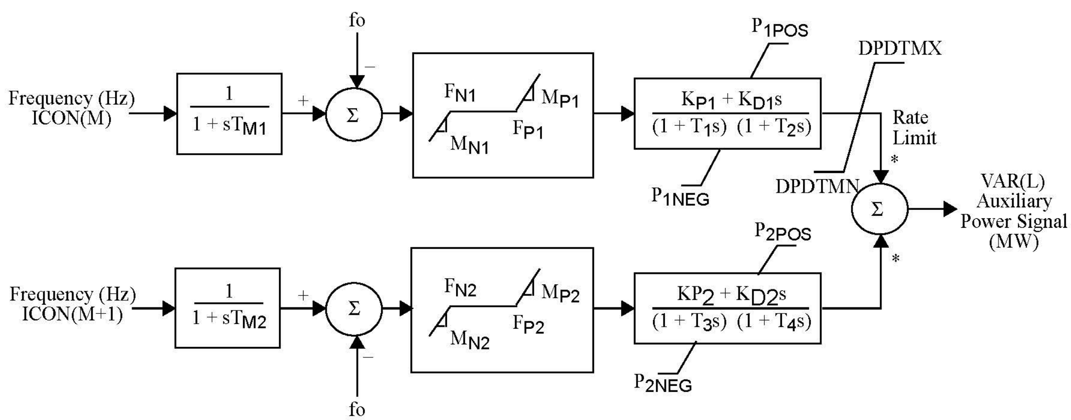
CONs	Value	Description
J		F_{P1}, positive frequency deviation dead band threshold (Hz)
J+1		F_{N1}, negative frequency deviation dead band threshold (Hz)
J+2		M_{P1}, positive slope (MW/Hz)
J+3		M_{N1}, negative slope (MW/Hz)
J+4		K_{P1}
J+5		K_{D1}
J+6		T_1, time constants (sec)
J+7		T_2, time constants (sec)
J+8		F_{P2}, positive frequency deviation dead band threshold (Hz)
J+9		F_{N2}, negative frequency deviation dead band threshold (Hz)
J+10		M_{P2}, positive slope (MW/Hz)
J+11		M_{N2}, negative slope (MW/Hz)
J+12		K_{P2}
J+13		K_{D2}
J+14		T_3, time constants (sec)
J+15		T_4, time constants (sec)
J+16		P_{MAX} (MW)
J+17		P_{MIN} (MW)
J+18		T_{M1}, transducer time constant (sec)
J+19		T_{M2}, transducer time constant (sec)
J+20		P_{1POS} (MW)
J+21		P_{1NEG} (MW)
J+22		P_{2POS} (MW)
J+23		P_{2NEG} (MW)

STATEs	Description
K	Integrator
K+1	Integrator
K+2	Integrator
K+3	Integrator

STATEs	Description
K+4	Transducer 1
K+5	Transducer 2

VAR	Description
L	Signal, MW

```
IDVX, 'CHAAUT', IDVT, ISG, ICON(M) to ICON(M+2), CON(J) to CON(J+23)   /
```



* + for ICON(M) input and – for ICON(M+1) input if ICON(M+2) ≥ 0
– for ICON(M) input and + for ICON(M+1) input if ICON(M+2) < 0

12.2. CPAAUT

Frequency Sensitive Auxiliary Signal Model

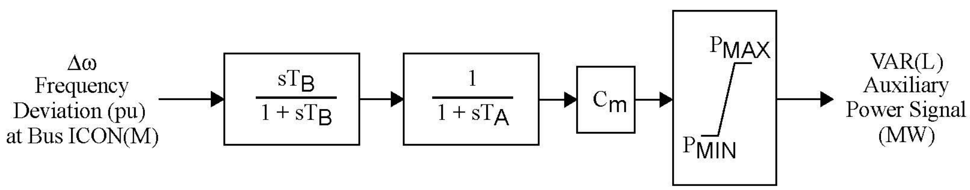
ICON	Value	Description
M		Bus number

CONs	Value	Description
J		C_m (MW per pu frequency)
J+1		T_B (>0) (sec)
J+2		T_A (>0) (sec)
J+3		P_{MAX} (MW)
J+4		P_{MIN} (MW)

STATEs	Description
K	Washout
K+1	Time constant

VAR	Description
L	Signal, MW

```
IDVX, 'CPAAUT', IDVT, ISG, ICON(M), CON(J) to CON(J+4)   /
```



12.3. DCCAUT

Comerford Auxiliary Signal Model

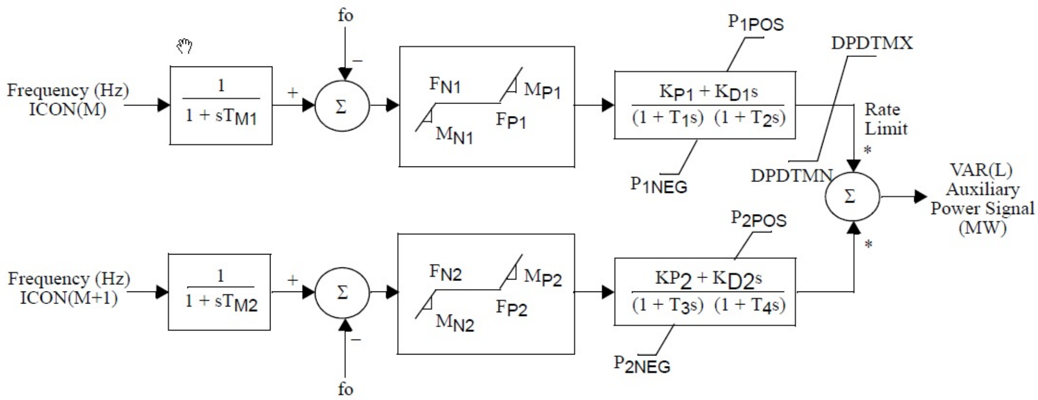
ICONs	Value	Description
M		IB, number of first bus where model is attached
M+1		JB, number of second bus where model is attached
M+2		ISW, ≥0 to subtract second signal from first, <0 to subtract first signal from second

CONs	Value	Description
J		F_{P1}, positive frequency deviation dead band threshold (Hz)
J+1		F_{N1}, negative frequency deviation dead band threshold (Hz)
J+2		M_{P1}, positive slope (MW/Hz)
J+3		M_{N1}, negative slope (MW/Hz)
J+4		K_{P1}
J+5		K_{D1}
J+6		T_1, time constants (sec)
J+7		T_2, time constants (sec)
J+8		F_{P2}, positive frequency deviation dead band threshold (Hz)
J+9		F_{N2}, negative frequency deviation dead band threshold (Hz)
J+10		M_{P2}, positive slope (MW/Hz)
J+11		M_{N2}, negative slope (MW/Hz)
J+12		K_{P2}
J+13		K_{D2}
J+14		T_3, time constants (sec)
J+15		T_4, time constants (sec)
J+16		DPDTMX, rate limit (MW/sec)
J+17		DPDTMN, rate limit (MW/sec)
J+18		T_{M1}, transducer time constant (sec)
J+19		T_{M2}, transducer time constant (sec)
J+20		P_{1POS}(MW)
J+21		P_{1NEG}(MW)
J+22		P_{2POS}(MW)
J+23		P_{2NEG}(MW)

STATEs	Description
K	Integrator
K+1	Integrator
K+2	Integrator
K+3	Integrator
K+4	Transducer 1
K+5	Transducer 2

VAR	Description
L	Signal, MW

```
IDVX, 'DCCAUT', IDVT, ISG, ICON(M) to ICON(M+2), CON(J) to CON(J+23)   /
```



* + for ICON(M) input and – for ICON(M+1) input if ICON(M+2) ≥ 0
– for ICON(M) input and + for ICON(M+1) input if ICON(M+2) < 0

12.4. DCVRFT

HVDC ac Voltage Controller

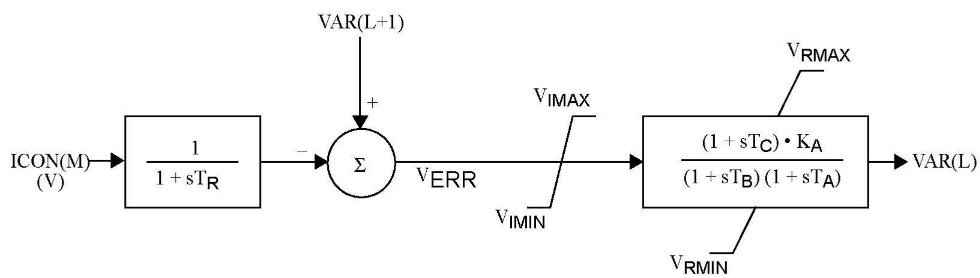
ICON	Value	Description
M		Bus number

CONs	Value	Description
J		T_R (sec)
J+1		V_{IMAX}
J+2		V_{IMIN}
J+3		T_C (sec)
J+4		T_B (sec)
J+5		K_A
J+6		T_A (sec)
J+7		V_{RMAX}
J+8		V_{RMIN}

STATEs	Description
K	$V_{measured}$
K+1	Lead lag
K+2	V_R

VARs	Description
L	HVDC DCV delta
L+1	Reference voltage

```
IDVX, 'DCVRFT', IDVT, ISG, ICON(M), CON(J) to CON(J+8)   /
```



12.5. FCTAXBU1

FACTS device Auxiliary Control Model

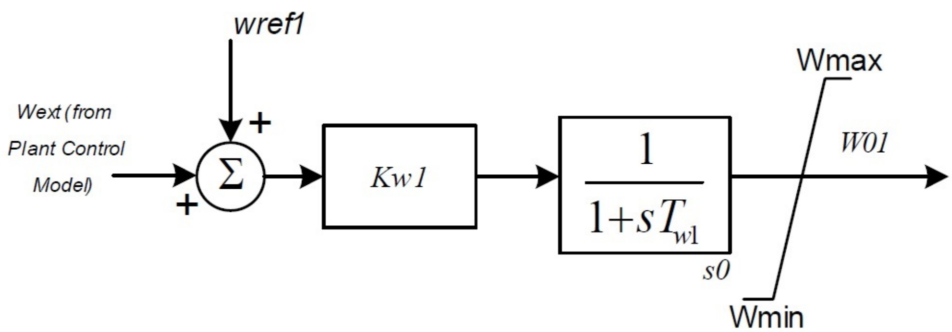
ICONs	Value	Description
M		Bus Number at which the plant controller model PLNTBU1 is attached

CONs	Value	Description
J		Tw1 (s), Measurement filter time constant
J+1		Kw1 (pu), Gain (cannot be equal to 0)
J+2		FCTBAS (>0), controlled FACTS unit size (MVA)
J+3		Wmax (pu), Maximum value of W01
J+4		Wmin (pu), Minimum value of W01

STATEs	Description
K	Measurement lag

VAR	Description
L	wref1, Reference (pu of FCTBAS)
L+1	W01, Model output (pu of FCTBAS)

```
'FACTS Name'  'USRAUX'   4   ISGX   'FCTAXBU1'   17   0   1   5   1
 2   ICON(M),  CON (J) to CON(J+4)   /
```



Notes:

1. This model receives input from the plant control model (PLNTBU1) which is connected at bus specified in ICON(M). If there is no plant control model attached at the bus spec- ified in ICON(M), then the input (Wext) to the FCTAXBU1model would be zero.
2. The FACTS device name (to be entered in single quotes) is the name of the FACTS device to which this model is attached.
3. FCTBAS is the MVA size of the FACTS device to which this auxiliary signal is attached. Model parameters have to be specified in pu of FCTBAS.
4. The number "4" in the dyr record indicates the PSS®E device type (FACTS device in this case) with which this auxiliary signal is associated with.

5. ISGX in the dyr record is the auxiliary signal index. This is any number 1 through the maximum number of auxiliary signals associated with the FACTS device (refer to the Table "Standard Maximum Program Capacities" in the PSS®E Program Operation Manual, in which this listed as to as "Auxiliary Signal injection point per FACTS device"). As of PSS®E version 33 and 34, this maximum is 1 (but could change in future PSS®E versions). Note that the ISGX value has to be coordinated with the auxiliary signal injection point in the FACTS device with which this auxiliary signal model is associated with. For example, if this auxiliary signal model is associated with PSS®E FACTS models CSTCNT or SVSMO3U2 or SVSMO3T2, then ISGX has to be 1.

12.6. HVDCAT

General Purpose Auxiliary Signal Model

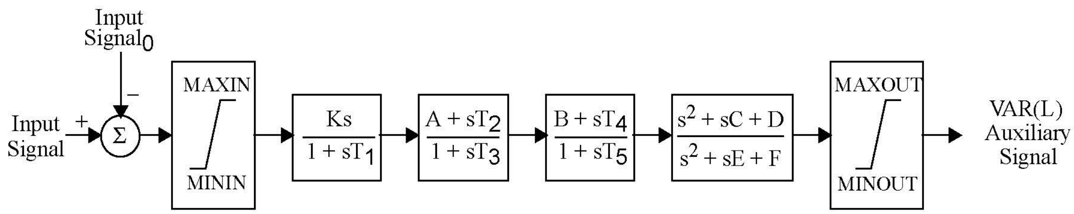
ICONs	Value	Description
M		Input code: 1 Current on branch (pu) 2 Power on branch (pu) 3 Frequency difference bus_i - bus_j (pu) 4 Voltage bus_i (pu) 5 Frequency bus_i (pu)
M+1		Bus_i number
M+2		Bus_j number or zero for input 4 and 5
M+3		Branch ID or zero for inputs 3, 4, and 5, or -1 for sum of parallel line flows

CONs	Value	Description
J		MININ
J+1		MAXIN
J+2		Ks
J+3		T_1 (> 0) (sec)
J+4		A (0 or 1)
J+5		T_2 (sec)
J+6		T_3 (sec)
J+7		B (0 or 1)
J+8		T_4 (sec)
J+9		T_5 (sec)
J+10		C
J+11		D
J+12		E
J+13		F
J+14		MINOUT
J+15		MAXOUT

STATEs	Description
K	Lag block
K+1	First lead-lag
K+2	Second lead-lag
K+3	2nd order block
K+4	2nd order block

VARs	Description
L	Signal
L+1	Internal
L+2	Storage

```
IDVX, 'HVDCAT', IDVT, ISG, ICON(M) to ICON(M+3), CON(J) to CON(J+15)   /
```



12.7. PAUX1T

Frequency Sensitive Auxiliary Signal Model

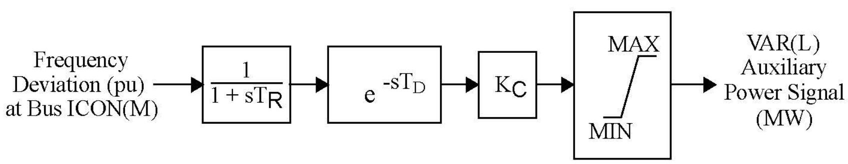
ICON	Value	Description
M		Bus number

CONs	Value	Description
J		T_r(>0) (sec)
J+1		T_D (sec) (<10 time steps)
J+2		K_C
J+3		MAX (MW)
J+4		MIN (MW)

STATE	Description
K	Sensor

VARs	Description
L	Signal, MW
L+1	Delay table
...	
L+10	

```
IDVX, 'PAUX1T', IDVT, ISG, ICON(M), CON(J) to CON(J+4)/
```



12.8. PAUX2T

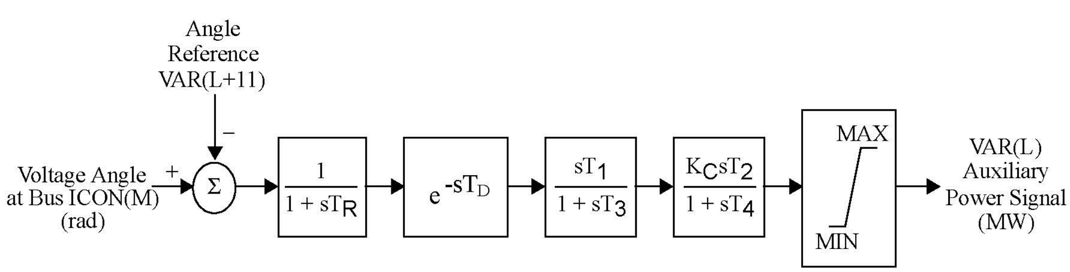
ICONs	Value	Description
M		Bus number

CONs	Value	Description
J		T_R (sec)
J+1		T_D (sec) (<9 time steps)
J+2		K_C
J+3		T_1 (>0) (sec)
J+4		T_2 (>0) (sec)
J+5		T_3 (>0) (sec)
J+6		T_4 (>0) (sec)
J+7		MAX (MW)
J+8		MIN (MW)

STATEs	Description
K	Sensor
K+1	Washout
K+2	Washout

VARs	Description
L	Signal, MW
L+1	Delay table
...	
L+9	
L+10	Memory
L+11	Reference

```
IDVX, 'PAUX2T', IDVT, ISG, ICON(M), CON(J) to CON(J+8)   /
```



12.9. RBKELT

Eel River Runback

(can be used with two-terminal dc line models only)

ICONs	Value	Description
M		Runback Flag: • 0 - Not active • 1 - Start runback
M+1		Internal ICON. Value need not be input by user.

CONs	Value	Description
J		FCOUT, final converter output (MW)
J+1		RBKTI, runback time (sec)
J+2		DELAY, time delay after ICON(M+1) set before runback starts

STATE	Description
K	Output signal (MW)

VARs	Description
L	Memory
L+1	Memory

```
IDVX, 'RBKELT', 1, ISG, ICON(M), CON(J) to CON(J+2)   /
```

12.10. RUNBKT

Two-Terminal dc Line Runback Model

ICON	Value	Description
M		• 1 - To runback • 0 - Otherwise

CONs	Value	Description
J		Slope, change in SETVAL per second [a]
J+1		Duration of runback (sec)
J+2		Final level of SETVAL

[a]When CON(J) ≠ 0, the magnitude of runback slope will be smaller of CON(J) or SETVAL – CON(J+2)/CON(J+1).

STATE	Description
K	Level of SETVAL

VARs	Description
L	Starting time for ramp
L+1	Final time for ramp

```
'2-Terminal DC Line Name', 'RUNBKT', 1, 1, ICON(M), CON(J) to CON(J
+2)..../
```

Note: This auxiliary signal modifies the SETVAL of 2-terminal DC lines.

12.11. SQBAUT

Frequency Sensitive dc Line Auxiliary Signal Model

(can be used with two-terminal dc lines only)

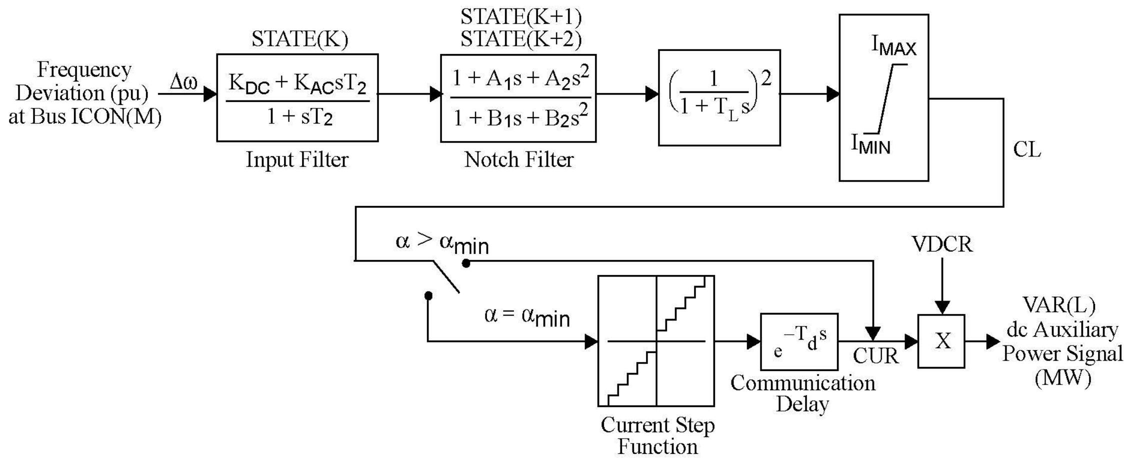
ICON	Value	Description
M		Bus number

CONs	Value	Description
J		K_{DC} (amps per pu frequency)
J+1		K_{AC} (amps per pu frequency)
J+2		T_2 (>0) (sec)
J+3		A_1
J+4		A2
J+5		B1
J+6		B2 (>0)
J+7		IMAX (amps)
J+8		I_{MIN} (amps)
J+9		Current step (amps)
J+10		T_d Communication delay (sec) <10 time steps
J+11		TL (sec)

STATEs	Description
K	Input filter
K+1	First notch filter STATE
K+2	Second notch filter STATE
K+3	First lag
K+4	Second lag

VARs	Description
L	Signal, MW
L+1	Delay table
...	
L+10	

```
IDVX, 'SQBUAT', 1, ISG, ICON(M), CON(J) to CON(J+11)   /
```


Frequency
Deviation (pu)
at Bus ICON(M)
Δω
STATE(K)
K DC + K AC sT 2
1 + sT 2
Input Filter
STATE(K+1)
STATE(K+2)
1 + A 1 s + A 2 s 2
1 + B 1 s + B 2 s 2
Notch Filter
1
1 + T L s
2
I MAX
I MIN
CL
α > α min
α = α min
Current Step
Function
e −T d s
Communication
Delay
CUR
VDCR
X
VAR(L)
dc Auxiliary
Power Signal
(MW)

Chapter 13

Two-Terminal dc Line Models

This chapter contains a collection of data sheets for the two-terminal dc line models contained in the PSS®E dynamics model library.

Model	Description
CDC1T	Two-terminal dc line model
CDC4T	Two-terminal dc line model
CDC6T	Two-terminal dc line model
CDC6TA	Two-terminal dc line model
CDC7T	dc line model
CDCABT	ABB dc line model for Kontek line
CEELRIT	
CEELT	New Eel River dc line and auxiliaries model. This model internally uses the following models: CHAAUT(auxiliary-signal model), CEEL2T (two-terminal dc line model), and RUNBKT (dc line runback model).
CEEL2T	New Eel River dc line model
CHIGATT	Highgate dc line model.
CHVDC2U1	WECC Generic 2-Terminal HVDC Model.
CMDWAST	Madawaska dc line model.
CMDWS2T	New Madawaska dc line model.
CMFORDT	Comerford dc line model.

13.1. CDC1T

Two-terminal DC Line Model

ICONs	Value	Description
M		Control mode:[a] • 0 - Blocked • 1 - Power • 2 - Current

[a]Not intended to be changed by user.

CONs	Value	Description
J		T_1, dc voltage transducer time constant
J+1		T_2, dc line or firing angle time constant
J+2		IMIN, minimum current demand (amps)
J+3		I_1, limit point 1, current (amps)
J+4		V_2, limit point 2, voltage (V)
J+5		I_2, limit point 2, current (amps)
J+6		V_3, limit point 3, voltage (V)
J+7		I_3, limit point 3, current (amps)
J+8		DELTI, current margin (pu)
J+9		V_{MIN}, shutdown voltage (pu)
J+10		V_{ON}, unblocking voltage (pu)
J+11		T_{MIN}, minimum blocking time (sec)
J+12		RAMP, recovery rate (pu/sec)

STATEs	Description
K	Measured inverter dc voltage
K+1	Measured line dc current

VARs	Description
L	Other signals (MW) [DC2SIG(1,I)]
L+1	VPCR, rectifier dc voltage
L+2	VDCI, inverter dc voltage
L+3	SETVAL, current (amps) or power (MW) demand
L+4	DC, dc current (amps)
L+5	ALPHA, alpha-rectifier (degrees)
L+6	GAMMA, gamma-inverter (degrees)
L+7	PACR, rectifier ac real power (pu)
L+8	QACR, rectifier ac reactive power (pu)
L+9	PACI, inverter ac real power (pu)
L+10	QACI, inverter ac reactive power (pu)

VARs	Description
L+11	KF, ramping factor
L+12	TON, unblocking time

Note: If GAMMIN = GAMMX in power flow, line is assumed to be in GAMMA control. This model uses auxiliary signal output stored in DC2SIG(1,I) (i.e., auxiliary signal index 1).

```
'DC Line Name', 'CDC1T', CON(J) to CON(J+12)   /
```

13.2. CDC4T

Two-terminal DC Line Model

ICONs	Value	Description
M		Bypass control flag:[a] • 0 - Not bypassed • 1 - Bypassed • 2 - Unbypass
M+1		Blocking control flag:[a] • 0 - Not bypassed • 1 - Bypassed • 2 - Unbypass
M+2		Switched mode control flag:[a] • 0 - Normal • 1 - Mode switched

[a]Not intended to be changed by the user.

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY[a], minimum gamma for dynamics (degrees)
J+2		TVDC, dc voltage transducer time constant (sec)
J+3		TIDC, dc current transducer time constant (sec)
J+4		VBLOCK, rectifier ac blocking voltage (pu)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLOCK, minimum blocking time (sec)
J+7		VBYPAS, inverter dc bypassing voltage (kV)
J+8		VUNBY, inverter ac unbypassing voltage (pu)
J+9		TBYPAS, minimum bypassing time (sec)
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (pu/sec)
J+14		C0, minimum current demand (amps)
J+15		V1, voltage limit point 1 (kV)
J+16		C1, Current limit point 1 (amps); >C0
J+17		V2, voltage limit point 2 (kV)
J+18		C2, current limit point 2 (amps)
J+19		V3, voltage limit point 3 (kV)

CONs	Value	Description
J+20		C3, current limit point 3 (amps)
J+21		TCMODE, minimum time stays in switched mode (sec)

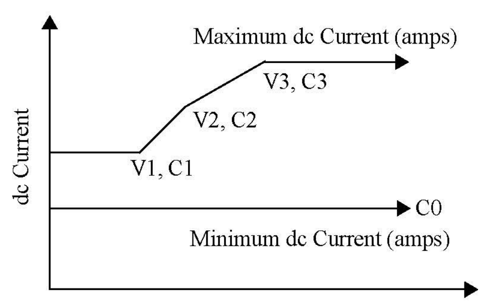
[a]Ignored if in gamma control (i.e., GAMMAX = GAMMIN in power flow).

STATEs	Description
K	Measured inverter dc voltage (V)
K+1	Measured inverter dc current (amps)

VARs	Description
L	Other signals, MW [DC2SIG(1,I)]
L+1	RESTR, time unblocks or) unbypasses (sec
L+2	VRF, voltage ramping factor
L+3	CRF, current ramping factor
L+4	VCOMP, compensating dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	TIME, reswitches mode

Note: This model uses auxiliary signal output stored in DC2SIG(1,I) (i.e., auxiliary signal index 1).

```
'DC Line Name', 'CDC4T', CON(J) to CON(J+21)   /
```



Voltage-Dependent Upper Current Limit

13.3. CDC6T

Two-terminal DC Line Model

ICONs	Value	Description
M		Bypass control flag:[a] • 0 - Not bypassed • 1 - Bypassed • 2 - Unbypass
M+1		Blocking control flag:[a] • 0 - Not blocked • 1 - Blocked • 2 - Unblocked
M+2		Switched mode control flag:[a] • 0 - Normal • 1 - Mode switched

[a]Not intended to be changed by the user.

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY[a], minimum gamma for dynamics (degrees)
J+2		TVDC, dc voltage transducer time constant (sec)
J+3		TIDC, dc current transducer time constant (sec)
J+4		VBLOCK, rectifier ac blocking voltage (pu)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLOCK, minimum blocking time (sec)
J+7		VBYPAS, inverter dc bypassing voltage (kV)
J+8		VUNBY, inverter ac unbypassing voltage (pu)
J+9		TBYPAS, minimum bypassing time (sec)
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (pu/sec)
J+14		C0, minimum current demand (amps)
J+15		V1, voltage limit point 1 (kV)
J+16		C1, current limit point 1 (amps); >C0
J+17		V2, voltage limit point 2 (kV)
J+18		C2, current limit point 2 (amps)
J+19		V3, voltage limit point 3 (kV)

CONs	Value	Description
J+20		C3, current limit point 3 (amps)
J+21		TCMODE, minimum time stays in switched mode (sec)
J+22		VDEBLK, rectifier ac voltage that causes a block if remains for time TDEBLK (pu)
J+23		TDEBLK, Time delay for block (sec)
J+24		TREBLK, time delay after rectifier ac voltage recovers above VUNBL before line unblocks (sec)
J+25		VINBLK, inverter ac voltage that causes block after communication delay TCOMB (pu)
J+26		TCOMB, communication delay to signal rectifier to block because of low inverter voltage (sec)
J+27		VACBYP, inverter ac voltage that causes bypass if remains for time TDEBYP (pu)
J+28		TDEBYP, time delay for bypass (sec)
J+29		TINBLK, time delay after inverter ac voltage recovers above VUNBY before line unblocks (this value should also include communication delay) (sec)
J+30		TINBYP, time delay after inverter ac voltage recovers above VUNBY before line unbypasses (sec)
J+31		TVRDC, rectifier dc voltage transducer time constant (sec)

[a]Ignored if in gamma control (i.e., GAMMAX = GAMMIN in power flow).

STATEs	Description
K	Measured inverter dc voltage (V)
K+1	Measured inverter dc current (amps)
K+2	Measured rectifier dc voltage (V)

VARs	Description
L	Other signals, MW [DC2SIG(1,I)]
L+1	RESTR, time unblocks or unbypasses (sec)
L+2	VRF, voltage ramping factor
L+3	CRF, current ramping factor
L+4	VCOMP, compensating dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	TIME, reswitches mode

VARs	Description
L+15	TIMER, rectifier blocking and unblocking timer
L+16	TIMEI, inverter blocking and unblocking timer
L+17	TIBYP, inverter bypass and unbypass timer

Note: This model uses auxiliary signal output stored in DC2SIG(1,I) (i.e., auxiliary signal index 1).

```
'DC Line Name', 'CDC6T', CON(J) to CON(J+31)   /
```

13.4. CDC6TA

Two-terminal DC Line Model

ICONs	Value	Description
M		Bypass control flag:[a] • 0 - Not bypassed • 1 - Bypassed • 2 - Unbypass
M+1		Blocking control flag:[a] • 0 - Not blocked • 1 - Blocked • 2 - Unblocked
M+2		Switched mode control flag:[a] • 0 - Normal • 1 - Mode switched

[a]Not intended to be changed by the user.

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY[a], minimum gamma for dynamics (degrees)
J+2		TVDC, dc voltage transducer time constant (sec)
J+3		TIDC, dc current transducer time constant (sec)
J+4		VBLOCK, rectifier ac blocking voltage (pu)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLOCK, minimum blocking time (sec)
J+7		VBYPAS, inverter dc bypassing voltage (kV)
J+8		VUNBY, inverter ac unbypassing voltage (pu)
J+9		TBYPAS, minimum bypassing time (sec)
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (pu/sec)
J+14		C0, minimum current demand (amps)
J+15		V1, voltage limit point 1 (kV)
J+16		C1, Current limit point 1 (amps); >C0
J+17		V2, Voltage limit point 2 (kV)
J+18		C2, current limit point 2 (amps)
J+19		V3, voltage limit point 3 (kV)

CONs	Value	Description
J+20		C3, current limit point 3 (amps)
J+21		TCMODE, minimum time stays in switched mode (sec)
J+22		VDEBLK, rectifier ac voltage that causes a block if remains for time TDEBLK (pu)
J+23		TDEBLK, time delay for block (sec)
J+24		TEEBLK, time delay after rectifier ac voltage recovers above VUNBL before line unblocks (sec)
J+25		VINBLK, inverter ac voltage that causes block after communication delay TCOMB (pu)
J+26		TCOMB, communication delay to signal rectifier to block because of low inverter voltage (sec)
J+27		VACBYP, inverter ac voltage that causes bypass if remains for time TDEBYP (pu)
J+28		TDEBYP, time delay for bypass (sec)
J+29		TINBLK, time delay after inverter ac voltage recovers above VUNBY before line unblocks (this value should also include communication delay) (sec)
J+30		TINBYP, time delay after inverter ac voltage recovers above VUNBY before line unbypasses (sec)
J+31		TVRDC, rectifier dc voltage transducer time constant (sec)

[a]Ignored if in gamma control (i.e., GAMMAX = GAMMIN in power flow).

STATEs	Description
K	Measured inverter dc voltage (V)
K+1	Measured inverter dc current (amps)
K+2	Measured rectifier dc voltage (V)

VARs	Description
L	Other signals, MW [DC2SIG(1,I)]
L+1	RESTR, time unblocks or unbypasses (sec)
L+2	VRF, voltage ramping factor
L+3	CRF, current ramping factor
L+4	VCOMP, compensating dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	TIME, reswitches mode

VARs	Description
L+15	TIMER, rectifier blocking and unblocking, timer
L+16	TIMEI, inverter blocking and unblocking, timer
L+17	TIBYP, inverter bypass and unbypass timer
L+18	Imeasured current in amps (I´r)
L+19	Idesired before VDCL in amps (IDESr)
L+20	VDCL output in amps I″MAXr)
L+21	GAMMOD[a], gamma modulation in degrees [DC2SIG (2, I)]
L+22	Low level modulation and current margin; makeup applied at rectifier in amps [DC2SIG (3, I)]
L+23	Low level modulation and current margin; makeup applied at inverter in amps [DC2SIG (4, I)]

[a]Only used if in constant gamma control (i.e., GAMMAX = GAMMIN in power flow).

Note: This model uses auxiliary signal outputs stored in DC2SIG(1,I) through DC2SIG(4,I) (i.e., auxiliary signal index 1 through 4).

```
'DC Line Name','CDC6TA', CON(J) to CON(J+31)   /
```

13.5. CDC7T

DC Line Model

ICONs	Value	Description
M		Blocking and Unblocking Simulation Flag: • 0 - None • 1 - Blocking • 2 - Unblocking
M+1		Overload simulation flag: • 0 - None • 1 - Overloaded
M+2		Control Configuration flag: • 1 : Rectifier in dc current control; inverter in gamma control • 2 : Rectifier in dc current control; inverter in dc voltage control • 3 : Rectifier in dc voltage control; inverter in dc current control
M+3		• 1 - Cable or cable + overhead • 2 - Overhead

CONs	Value	Notation	Description
J		Ts_VDC	dc voltage sensor time constant, sec.
J+1		Ts_idc	dc current sensor time constant, sec.
J+2		LRR	Rectifier smoothing reactor inductance, mH
J+3		RRR	Rectifier smoothing reactor resistance, ohm
J+4		LRI	Inverter smoothing reactor inductance, mH
J+5		RRI	Inverter smoothing reactor resistance, ohm
J+6		LOHR	Inductance of O/H dc line from rectifier side, mH
J+7		ROHR	Resistance of O/H dc line from rectifier side, ohm
J+8		LOHI	Inductance of O/H dc line from inverter side, mH
J+9		ROHI	Resistance of O/H dc line from inverter side, ohm
J+10		LDCC	Inductance of dc cable line, mH
J+11		RDCC	Damping resistance of dc cable line, ohm
J+12		CDCC	dc line capacitance, μF
J+13		LF1	dc fault shunt inductance, rectifier side, mH
J+14		RF1	dc fault shunt resistance, rectifier side, ohm

CONs	Value	Notation	Description
J+15		LF2	dc fault shunt inductance, mid-line, mH
J+16		RF2	dc fault shunt resistance, mid-line, ohm
J+17		LF3	dc fault shunt inductance, inverter side, mH
J+18		RF3	dc fault shunt resistance, inverter side, ohm
J+19		RCDCC	dc cable damping resistor
J+20		IDCRated	Rated dc current, A
J+21		VDCRated	Rated dc voltage, kV
J+22		VDCompR_Tdown	VDComp down time constant for VDCL, rectifier, sec
J+23		VDCompR_Tup	VDComp up time constant for VDCL, rectifier, sec
J+24		VDCompI_Tdown	VDComp down time constant for VDCL, inverter, sec
J+25		VDCompI_Tup	VDComp up time constant for VDCL, inverter, sec
J+26		IMargR	Current margin, rectifier, pu
J+27		IMargI	Current margin, inverter, pu
J+28		VMargR	Voltage margin, rectifier, pu
J+29		VMargI	Voltage margin, inverter, pu
J+30		GMargR	Gamma margin, rectifier, pu
J+31		GMargI	Gamma margin, inverter, pu
J+32		IDCERR_toV_GAIN_R	IDC error to V-control gain, rectifier
J+33		IDCERR_toV_GAIN_I	IDC error to V-control gain, inverter
J+34		IDCERR_toG_GAIN_I	IDC error to Gamma-control gain, inverter
J+35		VDComp_MEAS_GR	VDComp filter gain, rectifier, pu
J+36		VDComp_MEAS_GI	VDComp filter gain, inverter, pu
J+37		VDComp_MEAS_TR	VDComp filter time constant, rectifier, sec.
J+38		VDComp_MEAS_TR	VDComp filter time constant, inverter, sec.
J+39		DSEL_KBR	Selected controller output gain, rectifier
J+40		DSEL_KBI	Selected controller output gain, inverter
J+41		GPGR	PI-controller proportional gain, rectifier
J+42		TIGR	PI-controller integrator time constant, rectifier, sec.
J+43		GPGI	PI-controller proportional gain, inverter
J+44		TIGI	PI-controller integrator time constant, inverter, sec.
J+45		MAXALR	Max Alfa limit, rectifier
J+46		MINALR	Min Alfa limit, rectifier
J+47		MAXALI	Max Alfa limit, inverter
J+48		MINALI	Min Alfa limit, inverter
J+49		GAMA_ORDER1	Control configuration 1
J+50		GAMA_ORDER2	Control configuration 3

CONs	Value	Notation	Description
J+51		GAMDY	Min GAMA in dynamics
J+52		BLOCK_RATE	Rate of current order change when blocking, A/sec
J+53		UNBLOCK_RATE	Rate of current order change when unblocking, A/sec
J+54		TVDCP	VDC filter time constant for Pordr calculation, sec.
J+55 to J +64			5 pairs of rectifier VDCL coordinates (Vd1, Id1) ... (Vd5, Id5)[a]
J+65 to J +74			5 pairs of inverter VDCL coordinates (Vd1, Id1) ... (Vd5, Id5)[a]

[a] The VDCL characteristics can be specified using a minimum of 2 pairs and a maximum of 5 pairs of (Vd - Id) points. The rectifier data points are specified in CON (J+55) through CON(J+64), while the inverter data points are specified in CON(J+65) through CON(J+74). The first zero value for the (Vd - Id) pair signifies the end of VDCL data points.

STATEs	Description
K	Measured dc voltage, inverter, V
K+1	Measured dc current, inverter, A
K+2	Measured dc voltage, rectifier, V
K+3	Measured dc current, rectifier, A
K+4	IDCR, Rectifier dc current, A
K+5	IDCI, Inverter dc current, A
K+6	VCDC, DC line capacitor voltage, V
K+7	Rectifier VDComp filter, pu
K+8	Inverter VDComp filter, pu
K+9	Rectifier VDComp measured, pu
K+10	Inverter VDComp measured, pu
K+11	PI controller integrator, rectifier, rad
K+12	PI controller integrator, inverter, rad
K+13	IF1, fault current dc fault 1
K+14	IF2, fault current dc fault 2
K+15	IF3, fault current dc fault 3
K+16	VDC filter for power order calculation

VARs	Description
L	Other signals, MW [DC2SIG (1, I)][a]
L+1	PACR, pu active power at rectifier ac bus
L+2	QACR, pu reactive power at rectifier ac bus
L+3	PACI, pu active power at inverter ac bus
L+4	QACI, pu reactive power at inverter ac bus
L+5	VDCI, inverter dc voltage, V
L+6	VDCR, rectifier dc voltage, V
L+7	ALFA, degrees

VARs	Description
L+8	GAMA, degrees
L+9	Initial rectifier DC current order, A
L+10	Rectifier current order, limited by VDCL, pu
L+11	Inverter current order, limited by VDCL, pu
L+12	Current controller output, rectifier
L+13	Current controller output, inverter
L+14	Voltage controller output, rectifier
L+15	Voltage controller output, inverter
L+16	Gamma controller output, inverter
L+17	Selected controller output, rectifier
L+18	Selected controller output, inverter
L+19	Inverter Alpha, degrees
L+20	Initial VDComp (compensated dc voltage)
L+21	DC current order for block/unblock and overload, A
L+22	IDC1, sending end dc current, A
L+23	IDC2, receiving end dc current, A
L+24	PORD, power order, pu
L+25	Iorder, dc current order, pu

[a]CDC7T model can accept one auxiliary signal input (auxiliary signal index 1). The auxiliary signal has to be in units of MW. The auxiliary signal is summed with the power order, which is then used to derive the current order.

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'DC Line Name', CDC7T ', 0, 0, ICON(M+2), ICON(M+3), CON(J) to CON(J+74)
 /
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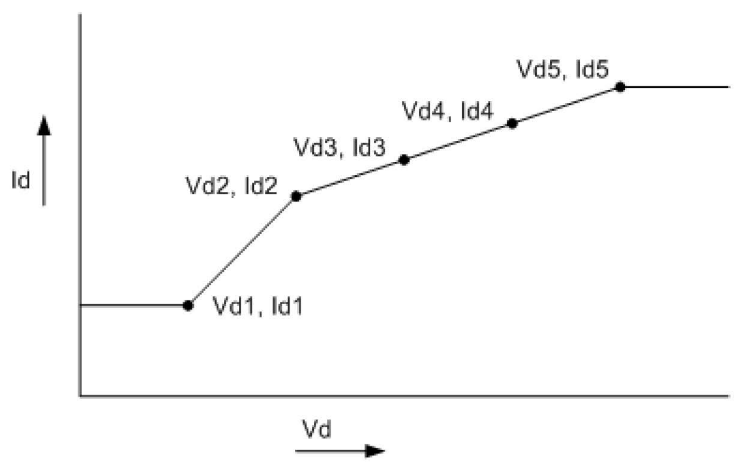

VDCL Characteristics

13.6. CDCABT

Kontek ABB DC Line Model

Refer to the PSS®E Program Application Guide for complete block diagrams of the controls and description of various functions.

ICONs	Value	Description
M		CURRENT DIRECTION, current from: • 1 - Rectifier • 0 - Inverter
M+1		Rectifier frequency control: • 1 - Enable • 0 - Disable
M+2		Inverter frequency control: • 1 - Enable • 0 - Disable
M+3		Rectifier power modulation: • 1 - Enable • 0 - Disable
M+4		Inverter power modulation:1 • 1 - Enable • 0 - Disable
M+5		Rectifier emergency power control: • 1 - Enable • 0 - Disable
M+6		Inverter emergency power control: • 1 - Enable • 0 - Disable
M+7		Inverter voltage control: • 1 - Enable • 0 - Disable
M+8		Rectifier phase shift correction: • 1 - Enable

ICONs	Value	Description
		• 0 - Disable
M+9		Inverter phase shift correction: • 1 - Enable • 0 - Disable

CONs	Value	Description
J		DELTMAX, user-specified time step (sec)
J+1		MANBYP_R, rectifier manually bypassed if 1
J+2		MANBYP_I, inverter manually bypassed if 1
J+3		T-BYPASS_MIN, minimum bypass time (sec)
J+4		GAMMACF, inverter gamma limit for commutation failure (deg)
J+5		VAC_NO_CF, inverter ac unbypass voltage (pu)
J+6		IdN, nominal dc current (amp)
J+7		CURMARG, current margin (amp)
J+8		TIDC_R, rectifier current measurement time constant (sec)
J+9		TVDC_R, rectifier current measurement time constant (sec)
J+10		RS_R, rectifier smoothing reactor resistance (Ω)
J+11		LS_R, rectifier smoothing reactor inductance (mH)
J+12		L_R, rectifier cable inductance (mH)
J+13		TIDC_I, inverter current measurement time constant (sec)
J+14		TVDC_I, inverter current measurement time constant (sec)
J+15		RS_I, inverter smoothing reactor resistance (Ω)
J+16		LS_I, inverter smoothing reactor (mH)
J+17		L_I, inverter cable inductance (mH)
J+18		CC, cable capacitance (μF)
J+19		RC, cable resistance (Ω)
J+20		IOMAX_MASTER, maximum current order for master controller (amp)
J+21		TMASTER_HIGH, master voltage time constant (sec)
J+22		TMASTER_LOW, master voltage time constant (sec)
J+23		UMASTERLIM, master voltage limit (V)
J+24		T_DOWN_R, rectifier VDCL time constant for decreasing voltage (sec)
J+25		T_UP_R, rectifier VDCL time constant for increasing voltage (sec)
J+26		Udbr_R, rectifier voltage knee for VDCL characteristic (kV)
J+27		IOMAXM_R, rectifier VDCL maximum lower current limit (amp)
J+28		IOMIN_R, rectifier VDCL minimum lower current limit (amp)
J+29		IMAX_R, rectifier VDCL maximum current limit (amp)
J+30		T_DOWN_I, inverter VDCL time constant for decreasing voltage (sec)
J+31		T_UP_I, inverter VDCL time constant for increasing voltage (sec)
J+32		Udbr_I, inverter voltage knee for VDCL characteristics (kV)
J+33		IOMAXIM_I, inverter VDCL maximum lower current limit (amp)

CONs	Value	Description
J+34		IOMIN_I, inverter VDCL minimum lower current limit (amp)
J+35		IMAX_I, inverter VDCL maximum current limit (amp)
J+36		T_IOF_R, rectifier CCA current order filter time constant (sec)
J+37		A_MAX_R, rectifier CCA limit (degrees)
J+38		A_MIN_R, rectifier CCA limit (degrees)
J+39		A_NOM_R, rectifier CCA nominal alpha used in linearization (degrees)
J+40		LINMAX_R, rectifier CCA limit of linearized alpha
J+41		LIN_MIN_R, rectifier CCA limit of linearized alpha
J+42		KP_R, rectifier CCA proportional gain (degrees/amps)
J+43		KI_TI_R, rectifier CCA integral constant (degrees/sec*amps)
J+44		APROP_MAX_R, rectifier CCA limit of proportional part (degrees)
J+45		APROP_MIN_R, rectifier CCA limit of proportional part (degrees)
J+46		AORDER_MIN_R, rectifier CCA limit of integral part (degrees)
J+47		T_IOF_I, inverter CCA current order filter time constant (sec)
J+48		A_MAX_I, inverter CCA limit (degrees)
J+49		A_MIN_I, inverter CCA limit (degrees)
J+50		A_NOM_I, inverter CCA nominal alpha used in linearization (degrees)
J+51		LIN_MAX_I, inverter CCA limit of linearized alpha
J+52		LIN_MIN_I, inverter CCA limit of linearized alpha
J+53		KP_I, inverter CCA proportional gain (degrees/amps)
J+54		KI_TI_I, inverter CCA integral constant (degrees/sec*amp)
J+55		APROP_MAX_I, inverter CCA limit of proportional part (degrees)
J+56		APROP_MIN_I, inverter CCA limit of proportional part (degrees)
J+57		AORDER_MIN_I, inverter CCA limit of integral part (degrees)
J+58		K1_R, rectifier alpha-max gain (A-1)
J+59		T1_R, rectifier alpha-max time constant (sec)
J+60		T2_R, rectifier alpha-max time constant (sec)
J+61		K1_MAX_R, rectifier alpha-max limit (A-1)
J+62		U_NORM_MAX_R, rectifier alpha-max voltage limit (pu)
J+63		U_NORM_MIN_R, rectifier alpha-max voltage limit (pu)
J+64		S1_MIN_R, rectifier alpha-max limits
J+65		MIN_AMAX_R, rectifier alpha-max limit (degrees)
J+66		GAMMAMIN_R, rectifier minimum nominal gamma (degrees)
J+67		K1_I, inverter alpha-max gain, (A-1)
J+68		T1_1, inverter alpha-max time constant (sec)
J+69		T2_I, inverter alpha-max time constant (sec)
J+70		K1_MAX_I, inverter alpha-max limit (A-1)
J+71		U_NORM_MAX_I, inverter alpha-max voltage limit (pu)
J+72		U_NORM_MIN_I, inverter alpha-max voltage limit (pu)
J+73		S1_MIN_I, inverter alpha-max limit

CONs	Value	Description
J+74		MIN_AMAX_I, inverter alpha-max limit (degrees)
J+75		GAMMAMIN_I, inverter minimum nominal gamma (degrees)
J+76		T_CFC_R, rectifier CFC time constant (sec)
J+77		ALFA_MAX_R, rectifier upper limit on alpha (degrees)
J+78		TALFA_MAX_I, inverter ac voltage measurement time constant (sec)
J+79		T_CFC_I, inverter CFC time constant (s-1)
J+80		ALFA_MIN_I, inverter CFC lower limit on alpha (degrees)
J+81		DELTGAM, inverter CFC gamma margin (degrees)
J+82		ALFA1 in CFC (degrees)
J+83		ALFA2 in CFC (degrees)
J+84		ALFA3 in CFC (degrees)
J+85		ALFA4 in CFC (degrees)
J+86		ALFA5 in CFC (degrees)
J+87		ALFA6 in CFC (degrees)
J+88		DALFA_MAX1 in CFC (degrees/sec)
J+89		DALFA_MAX2 in CFC (degrees/sec)
J+90		DALFA_MAX3 in CFC (degrees/sec)
J+91		DALFA_MAX4 in CFC (degrees/sec)
J+92		DALFA_MAX5 in CFC (degrees/sec)
J+93		DALFA_MIN1 in CFC (degrees/sec)
J+94		DALFA_MIN2 in CFC (degrees/sec)
J+95		DALFA_MIN3 in CFC (degrees/sec)
J+96		DALFA_MIN4 in CFC (degrees/sec)
J+97		T_PSC_R, rectifier phase shift correction time constant (sec)
J+98		T_PSC_I, inverter phase shift correction time constant (sec)
J+99		K_CC, inverter dynamic current compound gain (degrees)
J+100		T_CC1, inverter dynamic current compound time constant (sec)
J+101		T_CC2, inverter dynamic current compound time constant (sec)
J+102		DA_CC_LIMU, inverter dynamic current compound upper limit (degrees)
J+103		DA_CC_LIML, inverter dynamic current compound lower limit (degrees)
J+104		MAX_AORDER_MIN_R, transient controller rectifier maximum alpha (degrees)
J+105		TEN_TRCONR, transient controller rectifier time enable (sec)
J+106		TDIS_TRCONR, transient controller rectifier time disable (sec)
J+107		UAC_TRCONR, transient controller rectifier ac voltage limit (pu)
J+108		D_AORDER_MIN_R, transient controller rectifier alpha ramp down rate (degrees/sec)
J+109		TrCONI_DGAMA, transient controller inverter gamma increase (degrees)
J+110		TRCONI_TUP, transient controller inverter time constant (sec)

CONs	Value	Description
J+111		TRCONI_TDOWN, transient controller inverter time constant (sec)
J+112		TRCONI_ACVOLT_ACTIVE, transient controller inverter ac voltage limit (pu)
J+113		TRCONI_ACVOLT_DEACTIV, transient controller inverter ac voltage limit (pu)
J+114		GAMST_LIM, inverter gamma O start ac voltage limit (pu)
J+115		GANST_IORD, inverter gamma O start current order added to CCA (amp)
J+116		TIME_EN, inverter gamma O start time constant (sec)
J+117		TIME_DIS, inverter gamma O start time constant (sec)
J+118		VOLT_EN, inverter gamma O start dc voltage limit (V)
J+119		VOLT_DIS, inverter gamma O start dc voltage limit (V)
J+120		DB_R, rectifier frequency controller dead band (Hz)
J+121		K_FREQ_R, rectifier frequency controller gain (MW/Hz)
J+122		T_FREQ_R, rectifier frequency controller time constant (sec)
J+123		UL_FREQ_R, rectifier frequency controller upper limit (MW)
J+124		LL_FREQ_R, rectifier frequency controller lower limit (MW)
J+125		DB_I, inverter frequency controller dead band (Hz)
J+126		K_FREQ_I, inverter frequency controller gain (MW/Hz)
J+127		T_FREQ_I, inverter frequency controller time constant (sec)
J+128		UL_FREQ_I, inverter frequency controller upper limit (MW)
J+129		LL_FREQ_I, inverter frequency controller lower limit (MW)
J+130		T1DAMP_R, rectifier damping controller time constant (<> T2DAMP_R) (sec)
J+131		T2DAMP_R, rectifier damping controller time constant (sec)
J+132		KDAMP_R, rectifier damping controller gain (MW/Hz)
J+133		ULDAMP_R, rectifier damping controller upper limit (MW)
J+134		LldAMP_R, rectifier damping controller lower limit (MW)
J+135		T1DAMP_I, inverter damping controller time constant (<>T2DAMP_I) (sec)
J+136		T2_DAMP_I, inverter damping controller time constant (sec)
J+137		KDAMP_I, inverter damping controller gain (MW/Hz)
J+138		ULDAMP_I, inverter damping controller upper limit (MW)
J+139		LldAMP_I, inverter damping controller lower limit (MW)
J+140 to J +159		EPC_FLIMIT, EPC frequency limit (Hz)
J+160 to J +179		EPC_TIME EPC, time to apply active power (sec)
J+180 to J +199		EPC_DP EPC, active power step (MW)
J+200		KP_VC, inverter voltage controller gain (degrees (degrees/kV UdN)
J+201		TI_VC inverter voltage controller time constant (s*kV UdN/degrees)

CONs	Value	Description
J+202		DALFA_MAX_VC, inverter voltage control upper limit (degrees)
J+203		DALFA_MIN_VC, inverter voltage controller lower limit (degrees)

STATEs	Description
K	IDC_R, rectifier dc current (amps)
K+1	IM_R, rectifier dc current measurement (amps)
K+2	VM_R, rectifier dc voltage measurement (V)
K+3	IDC_I, inverter dc current (amps)
K+4	IM_I, inverter dc current measurement (amps)
K+5	VM_I, inverter dc voltage measurement (V)
K+6	VC, cable voltage (V)
K+7	UVDCOL_R, rectifier voltage measurement VDCL (V)
K+8	UVDCOL_I, inverter voltage measurement VDCL (V)
K+9	AINT_R, rectifier integral part of alpha-order CCA
K+10	AINT_I, inverter integral part of alpha-order CCA
K+11	Rectifier alpha integrator CFC (rad)
K+12	Inverter alpha integrator CFC (rad)
K+13	S1_R, rectifier state 1, alpha-max limitation
K+14	S1_I, inverter state 1, alpha-max limitation
K+15	S2_R, rectifier state 2, alpha-max limitation
K+16	S1_I, inverter state 2, alpha-max limitation
K+17	Inverter ac voltage measurement (pu)
K+18	Inverter transient controller state (rad)
K+19	FREQ_R, rectifier frequency control (MW)
K+20	FREQ_I, inverter frequency control (MW)
K+21	DAMP1_R, rectifier power modulation state 1
K+22	DAMP2_R, rectifier power modulation state 2
K+23	DAMP1_I, inverter power modulation state 1
K+24	DAMP2_I, inverter power modulation state 2
K+25	Master dc voltage rectifier (V)
K+26	Master dc voltage inverter (V)
K+27	Phase shift correction rectifier (rad)
K+28	Phase shift correction inverter (rad)
K+29	Dynamic current compound inverter state 1 (rad)
K+30	Dynamic current compound inverter state 2 (rad)
K+31	Current order filter rectifier alpha-max (amps)
K+32	Current order filter inverter alpha-max (amps)
K+33	Voltage control for long cables (rad)

VARs	Description
L	PRECT, rectifier dc active power (W)
L+1	QRECT, inverter dc reactive power (var)

VARs	Description
L+2	PINVRT, inverter dc active power (W)
L+3	QINVRT, inverter dc reactive power (var)
L+4	UDC_R, rectifier dc voltage (V)
L+5	UDC_I, inverter dc voltage (V)
L+6	MU_I, inverter overlap angle (rad)
L+7	GAMA_I, inverter gamma (rad)
L+8	IC, current in cable capacitance (amps)
L+9	PORDER, power order master controller (W)
L+10	IOO, current order master controller (amps)
L+11	TMASTER_R, master voltage time constant if rectifier is master (sec)
L+12	TMASTER_I, master voltage time constant if inverter is master (sec)
L+13	T_R, rectifier time constant VDCL
L+14	IOMAX_R, rectifier maximum current (amps)
L+15	IORDER_R, rectifier current order from VDCL (amps)
L+16	T_I, inverter time constant VDCL
L+17	IOMAX_I, inverter maximum current order VDCL (amps)
L+18	IORDER_I, inverter current order from VDCL (amps)
L+19	I_ERROR_R, rectifier current error CCA (amps)
L+20	APROP_R, rectifier proportional part of alpha CCA (rad)
L+21	ALPHA_ORDER_R, rectifier alpha order from CCA (rad)
L+22	I_ERROR_I, inverter current error CCA (amps)
L+23	APROP_I, inverter proportional part of alpha CCA (rad)
L+24	ALFA_ORDER_I, inverter alpha order from CCA (rad)
L+25	ALFA_MAX_ORDER_R, rectifier alpha maximum segment (rad)
L+26	ALFA_MAX_ORDER_I, inverter alpha maximum segment (rad)
L+27	GAMMIN_I, inverter minimum gamma in CFC (rad)
L+28	DELT_ALFA_MAX_R, rectifier upper limit of alpha error CFC (rad)
L+29	DELT_ALFA_MIN_R, rectifier lower limit of alpha error CFC (rad)
L+30	DELT_ALFA_MAX_I, inverter upper limit of alpha error CFC (rad)
L+31	DELT_ALFA_MIN_I, inverter lower limit of alpha error CFC (rad)
L+32	ALFA_MIN_R, rectifier lower limit of alpha order CFC (rad)
L+33	ALFA_MAX_I, inverter maximum limit of alpha order CFC (rad)
L+34	ALFA_R, alpha from rectifier CFC to the converter equations (rad)
L+35	ALFA_I, alpha from inverter CFC to the converter equations (rad)
L+36	DANG_R, rectifier phase shift correction contribution to alpha (rad)
L+37	DANG_I, inverter phase shift correction contribution to alpha (rad)
L+38	TrCONR_AORDER_MIN_R, rectifier transient controller added to the lower limit on alpha in CCA
L+39	TrCONI_T, inverter transient controller time constant (sec)
L+40	DELT_PO_FREQ_R, rectifier active power modulation from frequency controller (W)

VARs	Description
L+41	DELT_PO_FREQ_I, inverter active power modulation from frequency controller (W)
L+42	DELT_PO_DAMP_R, rectifier active power modulation from power modulation (W)
L+43	DELT_PO_DAMP_I, inverter active power modulation from power modulation (W)
L+44	EPC_POWER_R, rectifier EPC power (W)
L+45	EPC_POWER_I, inverter EPC power (W)
L+46	EPC_POWER, total EPC power (W)
L+47	DALFA_VC, inverter voltage control contribution to alpha (rad)
L+48 to L +158	Model internal memory

Note: This model does not use auxiliary signal model outputs.

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'DC Line Name', 'CDCABT', ICON(M) to ICON(M+9), CON(J) to CON(J+203)   /
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13.7. CEEL2T

Eel River DC Line Model

This model represents:

- Constant margin angle limits.
- Constant firing angle limits.
- Power controller time constant and limit on sensed DCV.
- Limit on sensed power order.
- Current order time constant.
- Voltage and current setpoint multiplier and ramp up.
- Inverter mode switch DV/DI characteristic.
- Maximum inverter firing angle limits.
- Current order auxiliary signal

ICONs	Value	Description
M		Inverter status:[a] • 0 - Normal • 1 - Blocked • 2 - Ramping
M+1		Rectifier status: • 0 - Normal • 1 - Blocked • 2 - Ramping
M+2		• 0 - Current limit uses inverter • >0 - Current limit uses VAR (ICON(M+2))
M+3		• 1 - VDCL on upper hysteresis path • 0 - VDCL on lower hysteresis path

[a]All the ICONs are set by the program.

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY[a], minimum gamma for dynamics (degrees)

CONs	Value	Description
J+2		DELAY for VDCL (sec)
J+3		TIDR, current order time constant (sec)
J+4		Sample rate for VDCL (sec)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLKBY, minimum blocking and bypass time (sec)
J+7		Inverter $\Delta V / \Delta I$ slope characteristic (V/amps)
J+8		VUNBY, inverter ac unbypassing voltage (pu)
J+9		ACCL, model acceleration factor
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (pu/sec)
J+14		C0, minimum current demand (amps)
J+15		CL (amps)
J+16		CH, current limit (amps); ≥ CL
J+17		VL1, voltage limit point 1 (pu)
J+18		VL2, voltage limit point 2 (pu)
J+19		VH1, voltage limit point 3 (pu)
J+20		VH2, voltage limit point 4 (pu)
J+21		ALFMXI, maximum inverter firing angle (degrees)
J+22		VDEBLK, rectifier ac voltage which causes a block if remains for time TDEBLK (pu)
J+23		TDEBLK, time delay for block (sec)
J+24		TREBLK, time delay after rectifier ac voltage recovers above VUNBL before line unblocks (sec)
J+25		VINBLK, inverter ac voltage which causes block after communication delay TCOMB (pu)
J+26		TCOMB, communication delay to signal rectifier to block because of low inverter voltage (sec)
J+27		VACBYP, inverter ac voltage which causes bypass if remains for time TDEBYP (pu)[b]
J+28		TDEBYP, time delay for bypass (sec)
J+29		TINBLK, time delay after inverter ac voltage recovers above VUNBY before line unblocks (this value should also include communication delay) (sec)
J+30		TINBYP, time delay after inverter ac voltage recovers above VUNBY before line unbypasses (sec)
J+31		TVP, power control VDC transducer time constant (sec)

[a]Ignored if in gamma control (i.e., GAMMAX = GAMMIN in power flow).

[b]The user can force a bypass by putting appropriate values in CON(J+27) and CON(J+28) of this model.

STATEs	Description
K	Power controller dc voltage (V), V_{DCP}

STATEs	Description
K+1	Current order (amps)

VARs	Description
L	Other signals, MW [DC2SIG(1,I)]
L+1	RESTR, time unblocks or unbypasses (sec)
L+2	VRF, voltage setpoint multiplier
L+3	CRF, current setpoint multiplier
L+4	VCOMP, compensated dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	Other VDC signals (kV) [DC2SIG(2,I)]
L+15	TIMER, rectifier blocking and unblocking, timer
L+16	TIMEI, inverter blocking and unblocking, timer
L+17	TIBYP, inverter bypass and unbypass timer
L+18	TDELAY, reference time for current limit delay
L+19	TSAMPL, reference time for current limit sampling
L+20	DCLVAC, current limit (amps)
L+21	VACIN, voltage which determines current limit

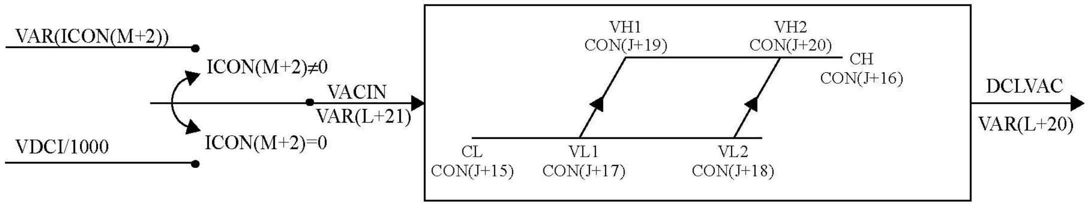
```
'DC Line Name', 'CEEL2T', CON(J) to CON(J+31)   /
```

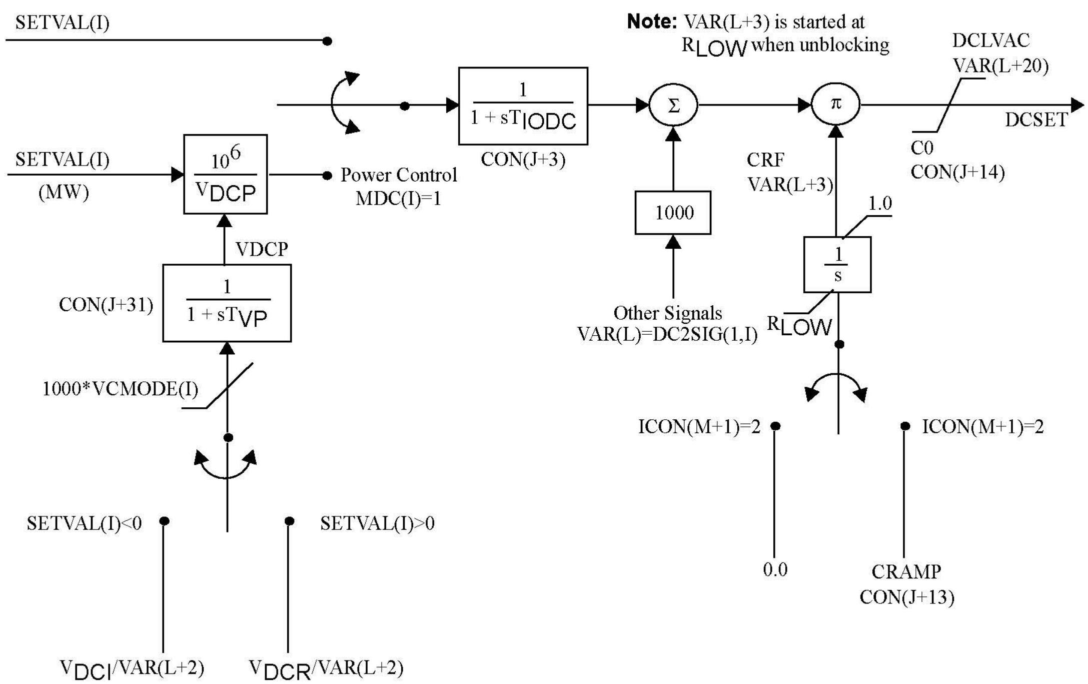
Notes:

1. When this model is called directly (i.e., not via model CEELT), the current limit uses inverter VDC (i.e., ICON(M+2) of this model is always 0 when called directly).

2. If the user wishes to block the converter, MDC(I) should be set tozero.

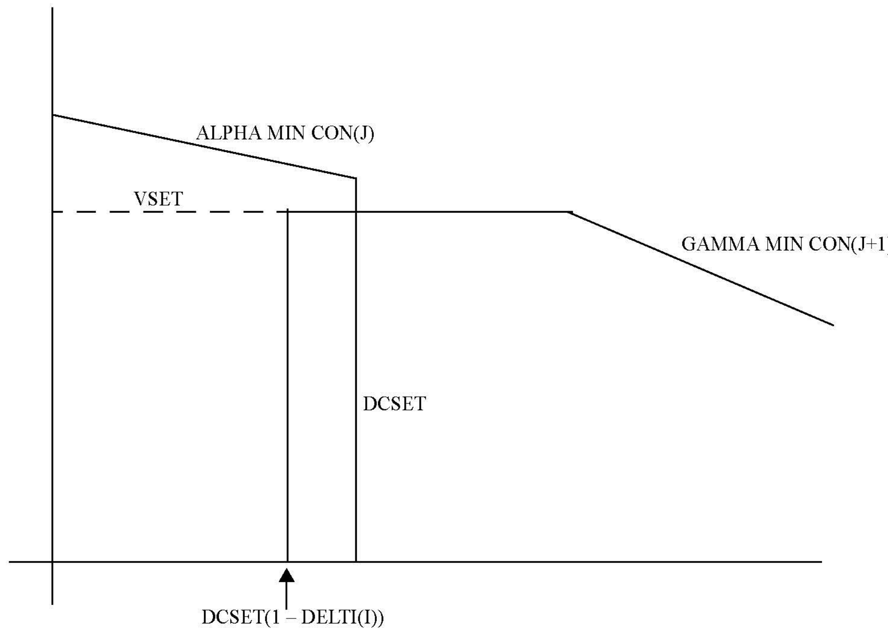
3. When called directly, this model uses auxiliary signal outputs stored in DC2SIG(1,I) (i.e., auxiliary signal index 1), and DC2SIG(2,I) (i.e., auxiliary signal index 2).



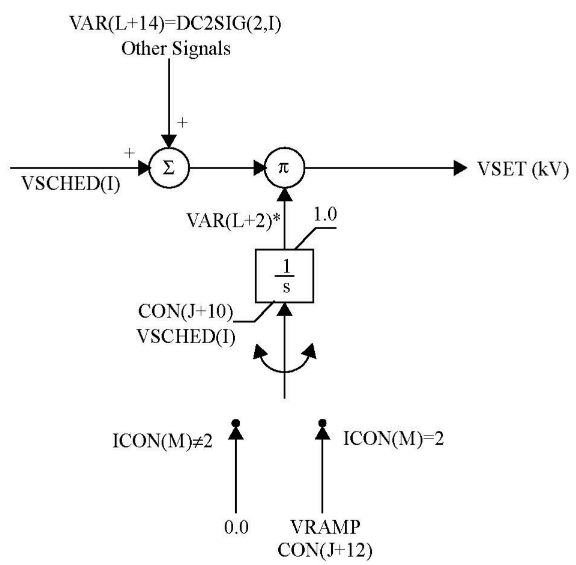


$$\text{If } (MDC(I) = 1),\ R_{LOW} = \frac{CON(J+11) * VSCHED}{1000 * |SETVAL\ (I)|}$$

$$\text{If } (MDC(I) = 2),\ R_{LOW} = \frac{CON(J+11)}{|SETVAL\ (I)|}$$



Inverter and Rectifier Coordination



*VAR(L+2) is also used by the power controller so that the current order is not increased when voltage is depressed. VAR(L+2) is started at the lower limit when unblocking or unbypassing.

dc Setpoint Control

13.8. CEELRIT

dc Line Model

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY[a], minimum gamma for dynamics (degrees)
J+2		VDCOLUP, VDCL time constant up (sec)
J+3		TIDR, current order time constant (sec)
J+4		VDCOLDN, VDCL time constants down (sec)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLKBY, minimum blocking and bypass time (sec)
J+7		Inverter Δ V/ Δ I slope characteristic (V/amps)
J+8		VUNBY, inverter ac unbypassing voltage (pu)
J+9		ACCL, model acceleration factor
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (pu/sec)
J+14		C0, minimum current demand (amps)
J+15		V1, voltage limit point 1
J+16		C1, current limit point 1 (amps); ≥C0
J+17		V2, voltage limit point 2
J+18		C2, current limit point 2 (amps)
J+19		V3, voltage limit point 3
J+20		C3, current limit point 3 (amps)
J+21		ALFMXI, maximum inverter firing angle (degrees)
J+22		VDEBLK, rectifier ac voltage which causes a block if remains for time TDEBLK (pu)
J+23		TDEBLK, time delay for block (sec)
J+24		TREBLK, time delay after rectifier ac voltage recovers above VUNBL before line unblocks (sec)
J+25		VINBLK, inverter ac voltage which causes block after communication delay TCOMB (pu)
J+26		TCOMB, communication delay to signal rectifier to block because of low inverter voltage (sec)
J+27		VACBYP, inverter ac voltage which causes bypass if remains for time TDEBYP (pu)
J+28		TDEBYP, time delay for bypass (sec)
J+29		TINBLK, time delay after inverter ac voltage recovers above VUNBY before line unblocks (this value should also include communication delay) (sec)
J+30		TINBYP, time delay after inverter ac voltage recovers above VUNBY before line unbypasses (sec)

CONs	Value	Description
J+31		TVP, power control VDC transducer time constant (sec)

[a]Ignored if in gamma control (i.e., GAMMAX = GAMMIN in power flow).

STATEs	Description
K	VDCOL, dc or ac voltage (kV or pu), VDCOL
K+1	Current order (amps)
K+2	Power controller dc voltage (V), VDCP

VARs	Description
L	Other signals, MW
L+1	RESTR, time unblocks or unbypasses (sec)
L+2	VRF, voltage setpoint multiplier
L+3	CRF, current setpoint multiplier
L+4	VCOMP, compensated dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	Other VDC signals (kV)
L+15	TIMER, rectifier blocking and unblocking, timer
L+16	TIMEI, inverter blocking and unblocking, timer
L+17	TIBYP, inverter bypass and unbypass timer

'DC Line Name', 'CEELRIT', CON(J) to CON(J+31) /

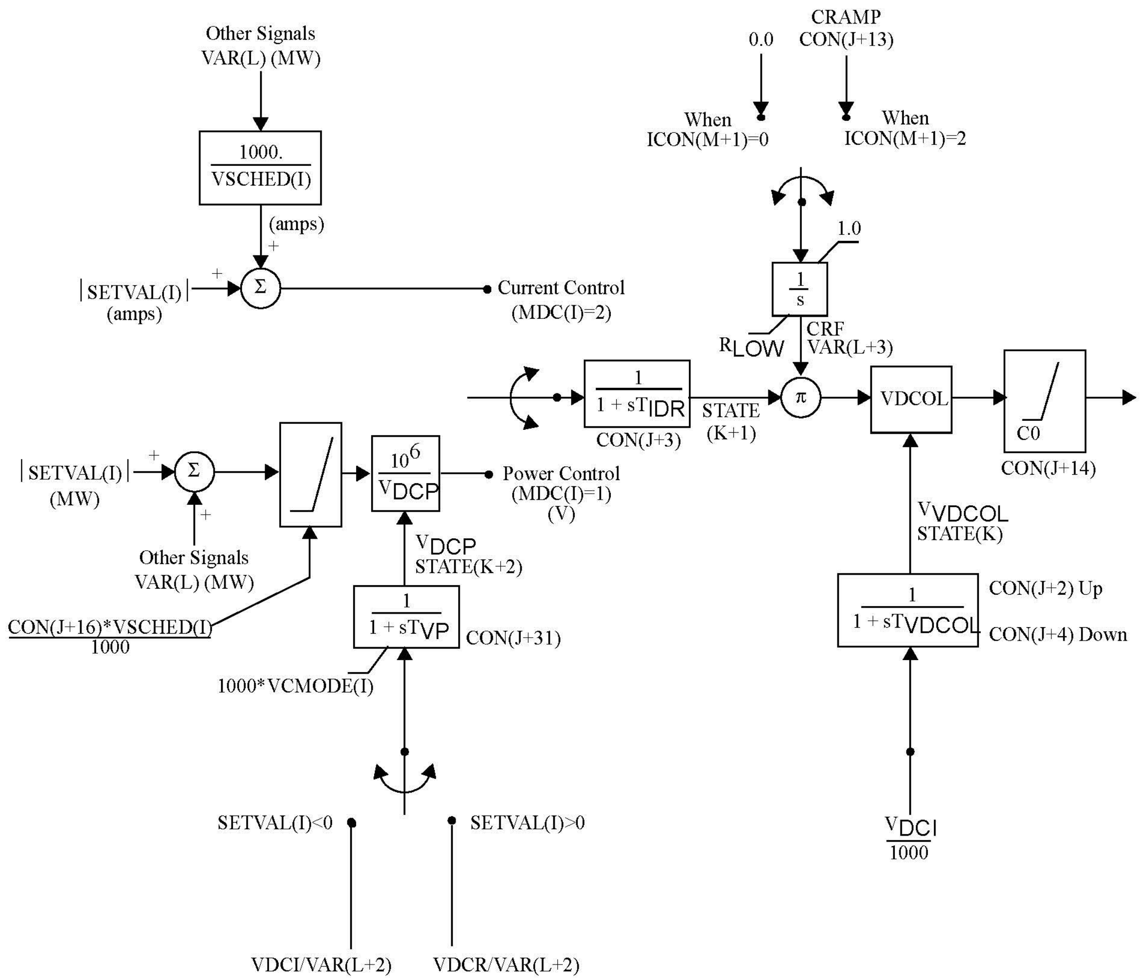
Note:

1. This model represents:

   - Constant margin angle limits.
   - Constant firing angle limits.
   - VDCL time constants for up and down.
   - Power controller time constant and limit on sensed DCV.
   - Limit on sensed power order.
   - Current order time constant.

- Voltage and current setpoint multiplier and ramp up.
- Inverter mode switch DV/DI characteristic.
- Maximum inverter firing angle limits

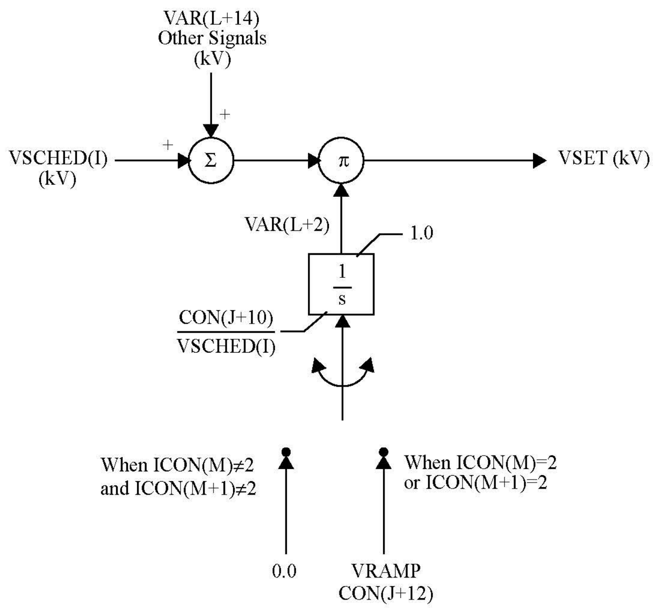
2. This model uses auxiliary signal index 1 for auxiliary signal in VAR(L), and auxiliary signal index 2 for the auxiliary signal in VAR(L), and auxiliary signal index 2 for the auxiliary signal in VAR(L+14).



$$\text{If (MDC(I) = 1), } R_{LOW} = \frac{\text{CON(J+11)*VSCHED(I)}}{1000 * |\text{SETVAL (I)}|}$$

$$\text{If (MDC(I) = 2), } R_{LOW} = \frac{\text{CON(J+11)}}{|\text{SETVAL (I)}|}$$

dc Setpoint Control



dc Setpoint Control (continued)

13.9. CEELT

Eel River dc Line and Auxiliaries Model

(combines CHAAUT, CEEL2T and RUNBK models)

```
'DC Line Name', 'CEELT', 3 CHAAUT ICONs, 24 CHAAUT CONs, 32 CEEL2T CONs,
 3RUNBK CONs   /
```

Notes:

1. This model uses the following ICON, CON, STATE, and VAR assignments:

   ```
   ICON:  M to M+7 (3 CHAAUT ICONs, 4 CEEL2T INTERNAL ICONs and 1 RUNBK ICON)
   
   CON:   J to J+58
   
   STATE: K to K+8 (6 CHAAUT STATEs, 2 CEEL2T STATEs, and 1 RUNBK STATE)
   
   VAR:   L to L+24 (1 CHAAUT VAR, 22 CEEL2T VARs and 2 RUNBK VARs)
   ```

2. This model sets ICON(M+5) (ICON belonging to model CEEL2T) to L+22 and places into VAR(L+22) the lower of the ac voltage at the inverter bus (or at the inverter firing angle measuring bus if one had been designated) or rectifier bus (or at the rectifier firing angle measuring bus if one had been designated).

3. The auxiliary-signal model output is in VAR(L).

4. Initially the model sets ICON(M+7) to 0. When the user wants to initiate runback of the dc line, ICON(M+7) has to be set to 1.

5. Since CEELT has an in-built auxiliary signal model, do not attach any other external auxiliary signal model.

13.10. CHIGATT

DC Line Model

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY, minimum gamma for dynamics (degrees)
J+2		VDCOLUP, voltage transducer time constant up (sec)
J+3		TIDC, dc current transducer time constant (sec)
J+4		VDCOLDN, voltage transducer time constant down (sec)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLKBY, minimum blocking and bypassing time (sec)
J+7		Inverter $\Delta V/\Delta I$ slope characteristic (V/amps)
J+8		VUNBY, inverter ac unbypassing voltage (pu)
J+9		ACCL, model acceleration factor
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (pu/sec)
J+14		C0, minimum current demand (amps)
J+15		V1, voltage limit point 1
J+16		C1, current limit (amps); ≥ C0
J+17		V2, voltage limit point 2
J+18		C2, current limit point 2 (amps)
J+19		V3, voltage limit point 3
J+20		C3, current limit point 3 (amps)
J+21		ALFMXI, maximum inverter firing angle (degrees)
J+22		VDEBLK, rectifier ac voltage that causes a block if remains for time TDEBLK (pu)
J+23		TDEBLK, time delay for block (sec)
J+24		TREBLK, time delay after rectifier ac voltage recovers above VUNBL before line unblocks (sec)
J+25		VINBLK, inverter ac voltage that causes block after communication delay TCOMB (pu)
J+26		TCOMB, communication delay to signal rectifier to block because of low inverter voltage (sec)
J+27		VACBYP, inverter ac voltage that causes bypass if remains for time TDEBYP (pu)
J+28		TDEBYP, time delay for bypass (sec)
J+29		TINBLK, time delay after inverter ac voltage recovers above VUNBY before line unblocks (this value should also include communication delay) (sec)
J+30		TINBYP, time delay after inverter ac voltage recovers above VUNBY before line unbypasses (sec)

CONs	Value	Description
J+31		TVP, power control VDC transducer time constant (sec)

STATEs	Description
K	VDCOL, dc or ac voltage (kV or pu), VVDCOL
K+1	Measured inverter dc current (amps)
K+2	Power controller dc voltage (V), VDCP

VARs	Description
L	Other signals, MW
L+1	RESTR, time unblocks or unbypasses (sec)
L+2	VRF, voltage setpoint multiplier
L+3	CRF, current setpoint multiplier
L+4	VCOMP, compensated dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	Other VDC signals (kV)
L+15	TIMER, rectifier blocking and unblocking timer
L+16	TIMEI, inverter blocking and unblocking timer
L+17	TIBYP, inverter bypass and unbypass timer

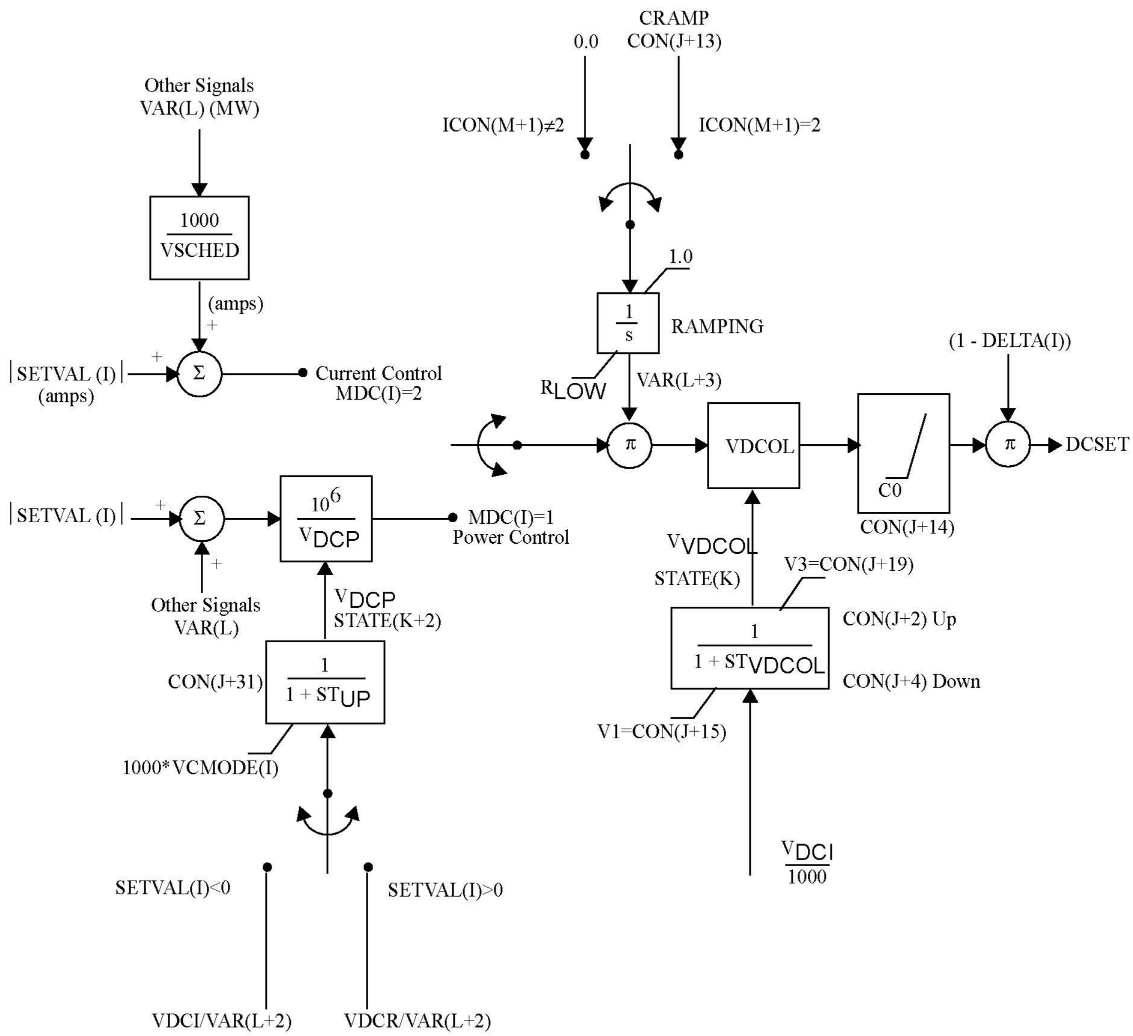
```
'DC Line Name', 'CHIGATT', CON(J) to CON(J+31)   /
```

Notes:

1. This model represents:

   - Constant margin angle limits.
   - Constant commutation limits.
   - VDCL time constants for up and down.
   - Power controller time constant and limit on sensed DCV.
   - Voltage and current setpoint multiplier and ramp up.
   - Inverter mode switch DV/DI characteristic.
   - Maximum inverter firing angle limits.

2. This model uses auxiliary signal index 1 for the auxiliary signal in VAR(L), and auxiliary signal index 2 for the auxiliary signal in VAR(L+14).



$$\text{If (MDC(I) = 1), } R_{LOW} = \frac{\text{CON(J+11)} * \text{VSCHED(I)}}{1000 * |\text{SETVAL (I)}|}$$

$$\text{If (MDC(I) = 2), } R_{LOW} = \frac{\text{CON(J+11)}}{|\text{SETVAL (I)}|}$$

dc Setpoint Control

13.11. CHVDC2U1

WECC Generic 2-Terminal HVDC Model

ICONs	Value	Description
M		Flag for AC VDCOL : • 0 - No AC VDCOL • 1 - AC VDCOL present both on rectifier and inverter side
M+1		Flag for RAML (Rectifier Alpha Minimum Limiter) logic : • 0 - No RAML logic • 1 - emulate RAML logic
M+2		Flag for including DC line dynamics : • 0 - dc line dynamics • 1 - Include dc line dynamics

CONs	Value	Description
J		KpR (pu), Current controller proportional gain (rectifier)
J+1		KiR (pu), Current controller integral gain (rectifier) (> 0)
J+2		AlphamaxR (degree), Maximum alpha (rectifier)
J+3		AlphaminR (degree), Minimum alpha (rectifier)
J+4		TalphR (s), Time constant for current control (rectifier) (> 0)
J+5		KpI (pu), Current controller proportional gain (inverter)
J+6		KiI (pu), Current controller integral gain (inverter) (> 0)
J+7		AlphaminI (degree), Minimum alpha (inverter)
J+8		TalphI (s) Time constant for current control (inverter) (> 0)
J+9		Kcos (pu), Proportional gain for alpha maximum calculation using Idcord (inverter)
J+10		Kref (pu), Gain for alpha maximum calculation using Idcord (inverter) (> 0)
J+11		Tref (s), Time constant for Kref (pu), Gain for alpha maximum calculation using Idcord (inverter)
J+12		Kmax (pu), Gain for alpha maximum calculation using Idcerr (inverter)
J+13		Tmax (s), Time constant for alpha maximum calculation using Ierr (inverter)
J+14		MaxcI (pu), Constant
J+15		MincI (pu), Constant
J+16		CosminI (pu), Constant
J+17		Tmeas (s), measurement delay
J+18		Maxrate (degree), Maximum rate of change of firing angle

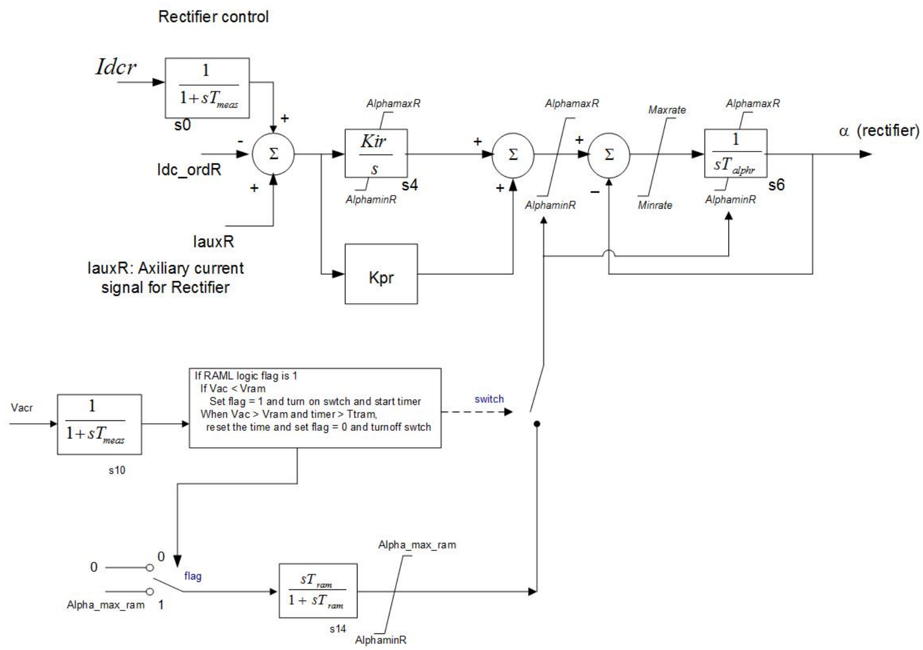
CONs	Value	Description
J+19		Minrate(degree), Minimum rate of change of firing angle
J+20		Idc1 (pu on Idcrated), VDCOL break point 1, (Idc1 > 0)
J+21		Idc2 (pu on Idcrated), VDCOL break point 2, (Idc2 > 0)
J+22		Vdc1 (pu on Vdcrated), VDCOL break point 1, (Vdc1 > 0)
J+23		Vdc2 (pu on Vdcrated), VDCOL break point 2, (Vdc2 > 0)
J+24		TupR (s), VDCOL up time constant (rectifier) (> 0)
J+25		TdnR (s), VDCOL down time constant (rectifier)
J+26		TupI (s), VDCOL up time constant (inverter) (> 0)
J+27		TdnI (s), VDCOL down time constant (inverter)
J+28		IdcRated (A), Rated dc current
J+29		VdcRated (kV), rated dc voltage
J+30		gama_cf (degree), Gamma angle threshold for inverter commutation failure
J+31		Vac_ucf (pu), AC voltage threshold for recovering from the commutation failure
J+32		Tcf (s), minimum duration of the commutation failure
J+33		max_err (pu), VDCOL AC voltage input error maximum limit
J+34		min_err (pu), VDCOL AC voltage input error minimum limit
J+35		Imax_lim (pu of rated dc current), AC VDCOL output current order maximum limit
J+36		Imin_lim (pu of rated dc current), AC VDCOL output current order minimum limit
J+37		Tvd (s), AC VDCOL integrator time constant (> 0)
J+38		Alpha_max_ram (degree), RAML maximum alpha
J+39		Tram (s), RAML washout time constant (> 0)
J+40		Vram (pu), RAML AC voltage set point
J+41		Ttram (s), RAML timer
J+42		Vacref (used in AC VDCOL)
J+43		Imarg (pu of rated dc current), dc current margin
J+44		Lline (mH), Total DC line inductance
J+45		Lsmr_rec (mH), inductance of rectifier side smoothing reactor
J+46		Lsmr_inv (mH), inductance of inverter side smoothing reactor
J+47		C (microF), DC line capacitance

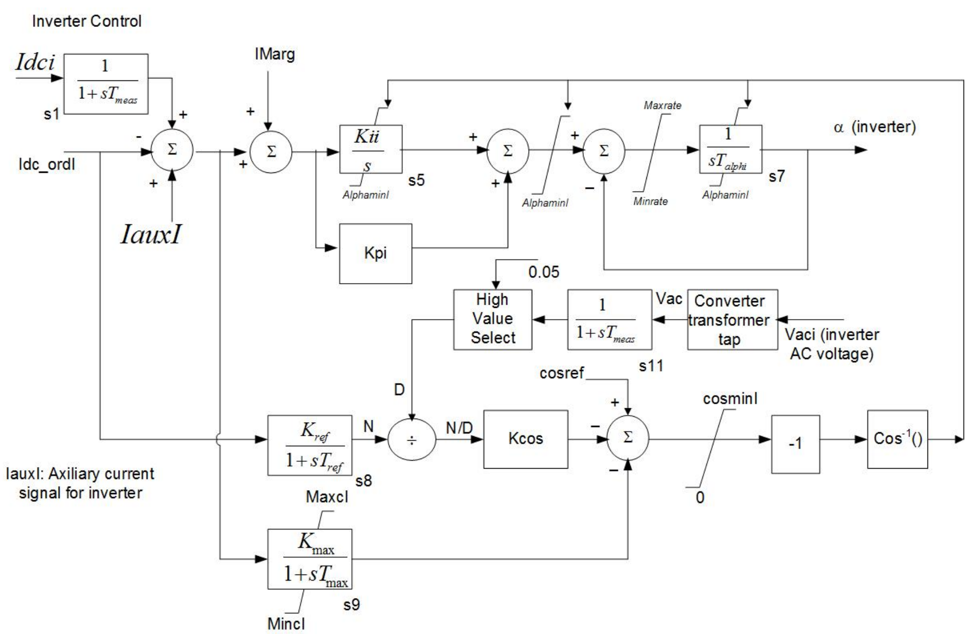
STATEs	Description
K	Measured dc current, rectifier
K+1	Measured dc current, inverter
K+2	VDCOL input (rectifier)
K+3	VDCOL input (inverter)
K+4	PI control (rectifier)
K+5	PI control (inverter)
K+6	Calculated Firing angle (rectifier)

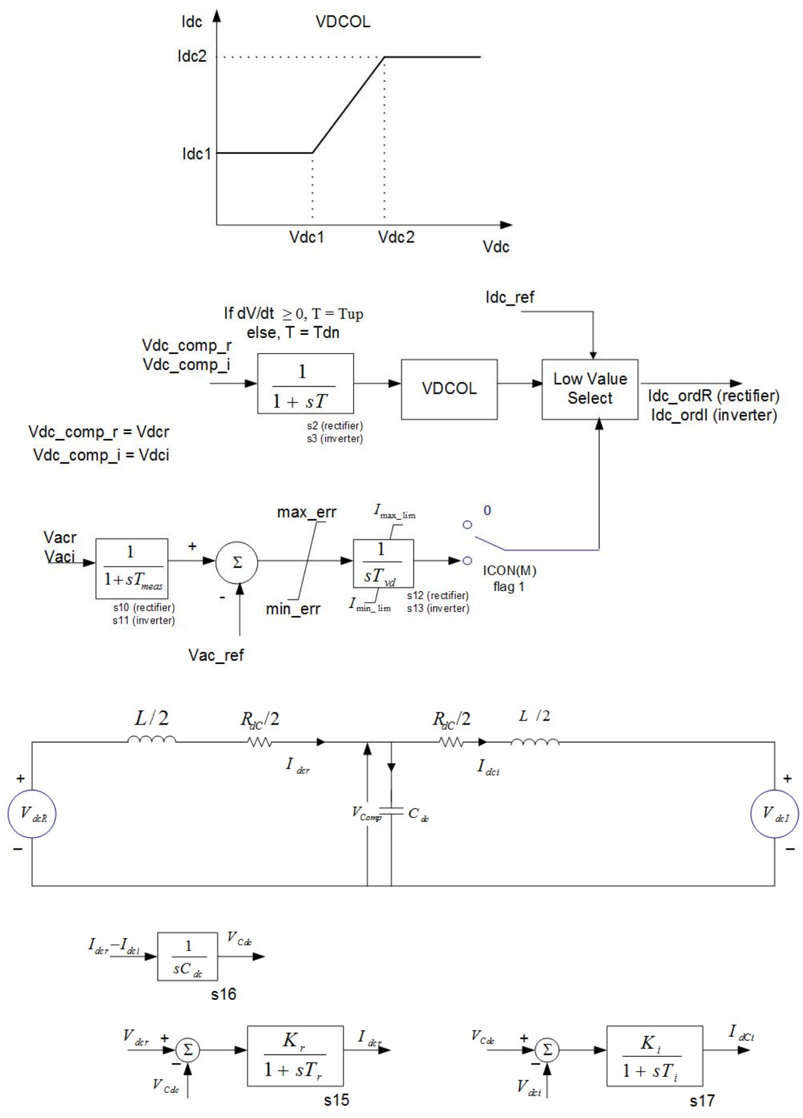
STATEs	Description
K+7	Calculated Firing angle (inverter)
K+8	Lag block for alpha maximum calculation using Idcord
K+9	Lag block for alpha maximum calculation using Idcerr
K+10	Measured ac voltage (rectifier)
K+11	Measured ac voltage (inverter)
K+12	Rectifier side AC VDCOL integrator
K+13	Inverter side AC VDCOL integrator
K+14	Rectifier Alpha Minimum Limiter (RAML) washout
K+15	DC line inductance
K+16	DC Line capacitance
K+17	DC Line inductance

VARs	Description
L	Rectifier Auxiliary signal (current signal in units of A)
L+1	Inverter Auxiliary signal (current signal in units of A)
L+2	Rectifier firing angle (degree)
L+3	Inverter firing angle (degree)
L+4	Inverter extinction angle (degree)
L+5	Rectifier dc current (A)
L+6	Rectifier dc voltage (kV)
L+7	Inverter dc current (A)
L+8	Inverter dc voltage (kV)
L+9	AC active power rectifier (MW)
L+10	AC reactive power rectifier (MVAR)
L+11	AC active power inverter (MW)
L+12	AC reactive power inverter (MVAR)
L+13	Idc_ordR (A), Rectifier dc current order (VDCOL Low Value Select output)
L+14	Idc_ordI (A), Inverter dc current order (VDCOL Low Value Select output)
L+15	Idc_ref (pu of IdcRated), reference dc current
L+16	cosref value (calculated at initialization)
L+17	AC VDCOL Vac_ref (pu)
L+18	RAML timer
L+19	Rectifier Alpha minimum as calculated by RAML logic (degree)
L+20	Calculated Inverter Alpha Maximum (degree)
L+21	Time at which commutation failure is initiated and time at which it comes off commutation failure
L+22	Commutation failure flag (> 0: no commutation failure, < 0: in commutation failure)
L+23	Value of Vram (see Notes)

```
'DC Line Name' 'USRDCL' 'CHVDC2U1' 18   1   3   48   18   24  ICON(M) to
 ICON(M+2) CON(J) to CON(J+47)   /
```


Rectifier control
Idcr
1
1+sTmeas
s0
Idc_ordR
IauxR
IauxR: Axiliary current
signal for Rectifier
Kir
s
s4
AlphamaxR
AlphaminR
Kpr
Maxrate
Minrate
1
sTalphr
s6
α (rectifier)
Vacr
1
1+sTmeas
s10
If RAML logic flag is 1
If Vac < Vram
Set flag = 1 and turn on swtch and start timer
When Vac > Vram and timer > Ttram,
reset the time and set flag = 0 and turnoff swtch
switch
0
flag
Alpha_max_ram
1
sTram
1 + sTram
s14
Alpha_max_ram
AlphaminR


Inverter Control
Idci
1
1+sTmeas
s1
Idc_ordI
IauxI
IMarg
Kii
s
s5
AlphaminI
Kpi
Maxrate
Minrate
1
sTalphi
s7
α (inverter)
0.05
High
Value
Select
1
1+sTmeas
s11
Vac
Converter
transformer
tap
Vaci (inverter
AC voltage)
cosref
D
Kref
1+sTref
s8
N
÷
N/D
Kcos
cosminI
0
-1
Cos-1()
IauxI: Axiliary current
signal for inverter
MaxcI
Kmax
1+sTmax
s9
MincI



$$K_r = \frac{R_{dc}}{2} \qquad T_r = \frac{L}{R_{dc}} \qquad K_i = \frac{R_{dc}}{2} \qquad T_i = \frac{L}{R_{dc}}$$

Notes:

1. In the DYR record the 2-terminal dc line name is the name of the dc line as specified in powerflow. The dc line name has to appear within single quotes.

2. This model uses Auxiliary signals with signal indices 1 (for rectifier) and 2 (for inverter). These signals are also placed in VAR(L) and VAR(L+1) of the model for plotting purposes. The auxiliary signal quantities

coming into this model are expected to be in units of Ampere (A). The model will convert it to the appropriate units as required by the model.

3. RAML stands for Rectifier Alpha minimum limiter. RAML, implemented for rectifier controls, acts to instantly raise the minimum rectifier firing angle (alpha minimum) to a set value (e.g., 25 degrees) immediately after a large ac voltage dip at the rectifier commutating bus (e.g., due to an AC fault on rectifier side), and then quickly ramps the alpha minimum back down to its normal minimum (e.g., 5 degrees). The intent is not to implement the exact representation of the RAML controls as implemented by some HVDC vendors, but rather to allow for the emulation of control action to mitigate overshoot in dc current following a rectifier side ac fault.

   At initialization the value of Vram (i.e., the RAML AC voltage set point) is stored in VAR(L+23). If during initialization Vacr (pu rectifier commutating bus voltage) is found to be less than Vram, the VAR(L+23) will be set equal to Vacr.

4. The DC VDCOL (voltage dependent current order limiter) is always in effect. The AC VDCOL (implemented per the reference given in an IEEE paper "Design and Implementation of AC VDCOL at Pacific Intertie" by R. Bunch and D. Kosterev, PWRD, Vol. 15, No. 1, January 2000) can be ON or OFF (depending on the flag value specified in ICON(M)).

   Upon initialization if Vacr (pu rectifier commutating bus voltage) and/or if Vaci (pu inverter commutating bus voltage) is less than Vac_ref, then Vac_ref will be set equal to the minimum of Vacr or Vaci and the new value will be stored in VAR(L+16) (i.e., the original Vac_ref data specified in CON(J+42) will not be modified but the revised Vac_ref value stored in VAR(L+16) will be used).

5. If the dc line dynamics is modeled (i.e., if ICON(M+2) is set equal to 1), then there are two possible scenarios:

   a. If the dc line capacitance C (specified in CON(J+47)) is greater than zero, and if the natural frequency (fn) of dc line (calculated as $\frac{1}{2\pi\sqrt{LC}}$, where L is the inductance as calculated above) is such that 3*fn*delt > 10, where delt is the simulation time step, then the dynamics associated with C is ignored.

   b. If C is specified to be equal to zero, the dynamics associated with the dc line capacitance is not modeled. The dynamics associated with the dc line resistance and inductance will still be modeled.

6. DC line is represented as a T-circuit comprising of R, L and C. The total effective inductance (L) is represented as:

   L = Lline + (Lsmr_rec + Lsmr_inv) + Nbr×1.75×(Lcom_rec + Lcom_inv)

   Nbr is the number of bridges

   Lcom_rec and Lcom_inv are the commutating transformer inductances (XCR and XCI values for rectifier and inverter as specified in powerflow and converted to inductance values) reactance

   The 1.75 factor is an approximation of the time-average value of commutating inductance due to overlap (see CIGRE-92 "DC Side Harmonics and Filtering in HVDC Transmission Systems" or M. P. Bahrman, K. J. Peterson and R. H. Lasseter, "DC system resonance analysis", IEEE Trans. PWRD, January 1987).

7. To disable simulation of commutation failure, set gama_cf ≤ 0.0 (i.e., CON(J+30) is set ≤ 0.0).

   The logic for emulating commutation failure is as follows:

```
Initialize comm_fail_flag = normal (i.e., flag is set to > 0.0)
if (inverter extinction angle (γ) < gama_cf)
    Initiate shorting of inverter (i.e., set Vdci = 0, but Idc is not 0)
    set commutation failure flag (i.e., set flag to < 0.0)
    set VAR(L+20)=TIME
end

if (commutation failure, i.e., if flag < 0.0)
    if ((Time - VAR(L+20) > Tcf) and (Vac_inverter ≥ Vac_ucf))
        release inverter short and let inverter recover
        reset commutation failure flag (i.e., set flag to > 0.0)
    end
end
```

8. There is no provision to simulate dc line faults using this model.

13.12. CMDWAST

DC Line Model

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY[a], minimum gamma for dynamics (degrees)
J+2		VDCOLUP, VDCOL time constant up (sec)
J+3		TIDC, dc current transducer time constant (sec)
J+4		VDCOLDN, VDCOL time constants down (sec)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLKBY, minimum blocking and bypass time (sec)
J+7		Inverter $\Delta V/\Delta I$ slope characteristic (V/amps)
J+8		VUNBY, inverter ac unbypassing voltage (pu)
J+9		ACCL, model acceleration factor
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (pu/sec)
J+14		C0, minimum current demand (amps)
J+15		V1, voltage limit point 1
J+16		C1, current limit point 1 (amps); ≥C0
J+17		V2, voltage limit point 2
J+18		C2, current limit point 2 (amps)
J+19		V3, voltage limit point 3
J+20		C3, current limit point 3 (amps)
J+21		ALFMXI, maximum inverter firing angle (degrees)
J+22		VDEBLK, rectifier ac voltage that causes a block if remains for time TDEBLK (pu)
J+23		TDEBLK, time delay for block (sec)
J+24		TREBLK, time delay after rectifier ac voltage recovers above VUNBL before line unblocks (sec)
J+25		VINBLK, inverter ac voltage that causes block after communication delay TCOMB (pu)
J+26		TCOMB, communication delay to signal rectifier to block because of low inverter voltage (sec)
J+27		VACBYP, inverter ac voltage that causes bypass if remains for time TDEBYP (pu)
J+28		TDEBYP, time delay for bypass (sec)
J+29		TINBLK, time delay after inverter ac voltage recovers above VUNBY before line unblocks (this value should also include communication delay) (sec)
J+30		VRAMPI, dc voltage threshold to ramp current up or down (kV)

CONs	Value	Description
J+31		TVP, power control VDC transducer time constant (sec)

[a]Ignored if in gamma control (i.e., GAMMAX = GAMMIN in power flow).

STATEs	Description
K	VDCOL, dc or ac voltage (kV or pu), VVDCOL
K+1	Measured inverter dc current (amps)
K+2	Power controller dc voltage (V), VDCP

VARs	Description
L	Other signals, KA
L+1	RESTR, time unblocks or unbypasses (sec)
L+2	VRF, voltage setpoint multiplier
L+3	CRF, current setpoint multiplier
L+4	VCOMP, compensated dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	Other VDC signals (kV)
L+15	TIMER, rectifier blocking and unblocking timer
L+16	TIMEI, inverter blocking and unblocking timer
L+17	TIBYP, inverter bypass and unbypass timer

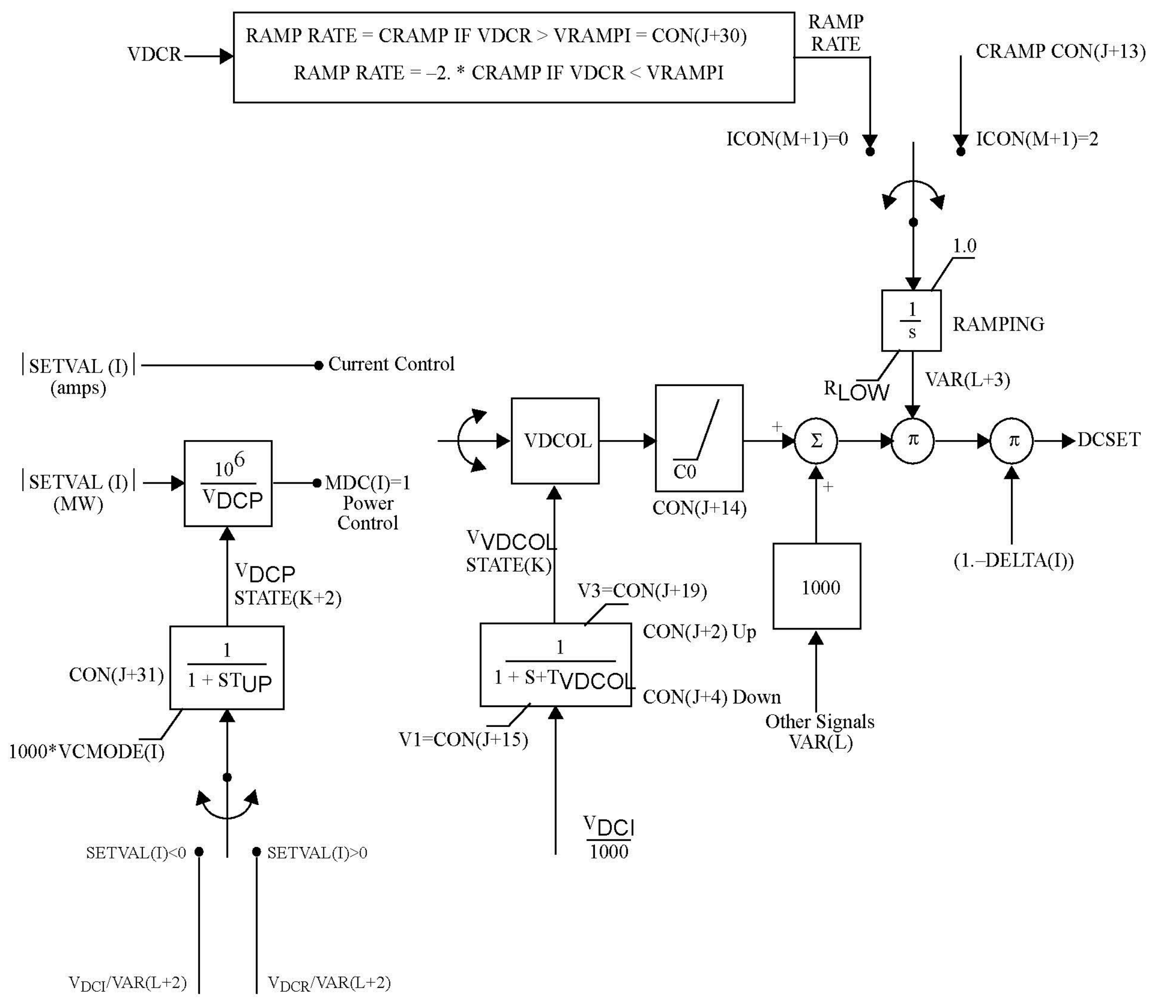
```
'DC Line Name', 'CMDWAST', CON(J) to CON(J+31)   /
```

Notes:

1. This model represents:
   - Constant margin angle limits.
   - Constant firing angle limits.
   - VDCL time constants for up and down.
   - Power controller time constant and limit on sensed DCV.
   - Voltage and current setpoint multiplier and ramp up.
   - Inverter mode switch $\Delta V/\Delta I$ characteristic.

- Maximum inverter firing angle limits.
- Current order auxiliary signal

2. This model uses auxiliary signal index 1 for auxiliary signal index 1 for auxiliary signal VAR(L) and auxiliary signal index 2 for the auxiliary signal VAR(L+14).



$$\text{If (MDC(I) = 1), } R_{LOW} = \frac{\text{CON(J+11) * VSCHED(I)}}{1000 * |\text{SETVAL (I)}|}$$

$$\text{If (MDC(I) = 2), } R_{LOW} = \frac{\text{CON(J+11)}}{|\text{SETVAL (I)}|}$$

dc Setpoint Control

13.13. CMDWS2T

Madawaska DC Line Model

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY[a], minimum gamma for dynamics (degrees)s minimum gamma for dynamics (degrees)
J+2		DELAY for VDCL (sec)
J+3		TIODC, TIDC, dc current order time constant (sec)
J+4		Sample rate for VDCL (sec)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLKBY, minimum blocking and bypass time (sec)
J+7		Inverter $\Delta V/\Delta I$ slope characteristic (V/amps)
J+8		VUNBY, inverter ac unbypassing and unblocking voltage (pu)
J+9		ACCL, model acceleration factor
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (amps/sec)
J+14		C0, minimum current demand (amps)
J+15		CL (amps)
J+16		CH, current limit (amps); ≥ C0
J+17		VL1, voltage limit point 1 (pu)
J+18		VL2, voltage limit point 2 (pu)
J+19		VH1, voltage limit point 3 (pu)
J+20		VH2, voltage limit point 4 (pu)
J+21		ALFMXI, maximum inverter firing angle (degrees)
J+22		VDEBLK, rectifier ac voltage that causes a block if remains for time TDEBLK (pu)
J+23		TDEBLK, time delay for block
J+24		TREBLK, time delay after rectifier ac voltage recovers above VUNBL before line unblocks
J+25		VINBLK, inverter ac voltage that causes block after communication delay TCOMB (pu)
J+26		TCOMB, communication delay to signal rectifier to block because of low inverter voltage (sec)
J+27		VACBYP, inverter ac voltage that causes bypass if remains for time TDEBYP (pu)
J+28		TDEBYP, time delay for bypass
J+29		TINBLK, time delay after inverter ac voltage recovers above VUNBY before line unblocks or unbypasses
J+30		VRAMPI, dc voltage threshold to ramp current up or down

CONs	Value	Description
J+31		TVP, power control VDC transducer time constant (sec)

[a]Ignored if in gamma control (i.e. GAMMX = GAMMN in power flow).

STATEs	Description
K	Power controller dc voltage (V),VDCP
K+1	Measured inverter dc current (amps)

VARs	Description
L	Other signals, KA
L+1	RESTR, time unblocks or unbypasses (sec)
L+2	VRF, voltage setpoint multiplier
L+3	DCLVDC, dc voltage dependent current limit
L+4	VCOMP, compensated dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)(V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	Other VDC signals (kV)
L+15	TIMER, rectifier blocking and unblocking timer
L+16	TIMEI, inverter blocking and unblocking timer
L+17	TIBYP, inverter bypass and unbypass timer
L+18	TDELAY, reference time for current limit delay
L+19	TSAMPL, reference time for current limit sampling
L+20	DCLVAC, ac voltage dependent current limit (amps)
L+21	VACIN, voltage that determines current limit
L+22	DCSET

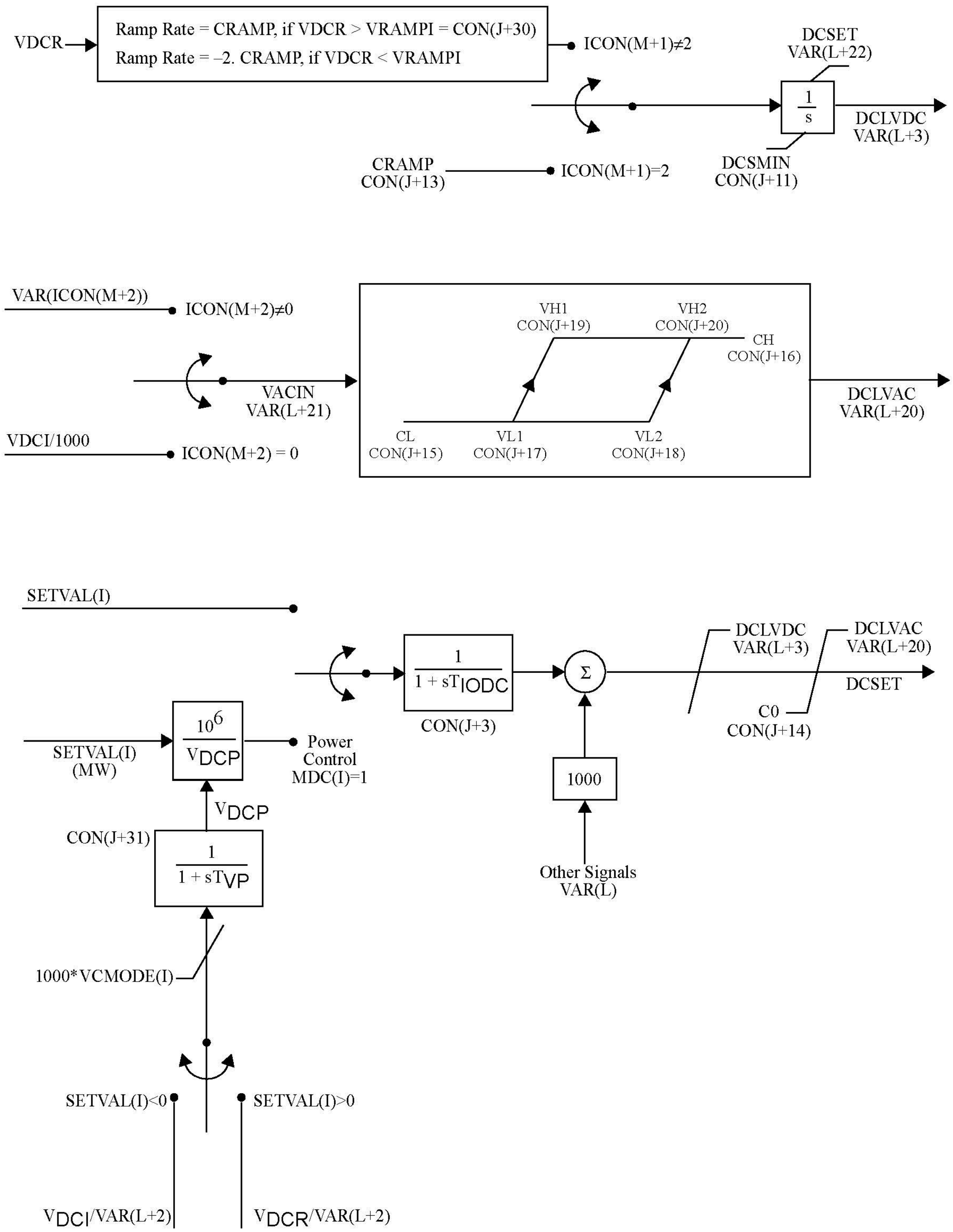
```
'DC Line Name', "CMDWS2T', CON(J) to CON(J+31)   /
```

Notes:

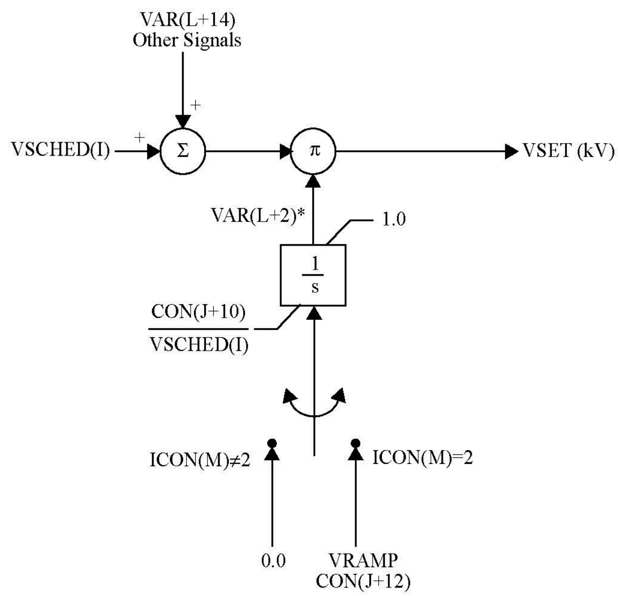
1. This model represents:
   - Constant margin angle limits.
   - Constant firing angle limits.
   - Power controller time constant and limit on sensed DCV.
   - Voltage setpoint ramp.

- Inverter mode switch $\Delta V/\Delta I$ characteristic.
- Maximum inverter firing angle limits.
- Current order auxiliary signal

2. Model uses two auxiliary signals. Auxiliary signal index 1 is the, "other signals' (KA)," i.e. VAR(L), while auxiliary signal index 2 is the, "VDC Signal (KV)," i.e. VAR(L+14).

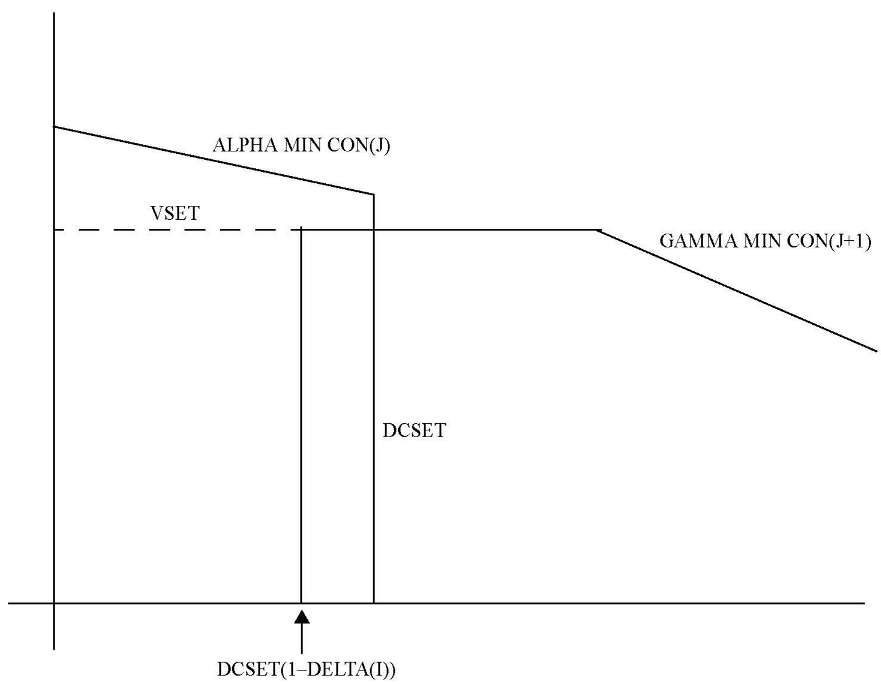


dc Current Setpoint Control



*This VAR is also used by the power controller so that the current order is not increased when voltage is depressed. VAR(L+2) is started at the lower limit when unblocking or unbypassing.

dc Voltage Setpoint Control (continued)



Inverter and Rectifier Coordination

13.14. CMFORDT

DC Line Model

CONs	Value	Description
J		ALFDY, minimum alpha for dynamics (degrees)
J+1		GAMDY, minimum gamma for dynamics (degrees)
J+2		VDCOLUP, VDCOL time constant up (sec)
J+3		TIDC, dc current transducer time constant (sec)
J+4		VDCDLDN, VDCOL time constants down (sec)
J+5		VUNBL, rectifier ac unblocking voltage (pu)
J+6		TBLKBY, minimum blocking and bypass time (sec)
J+7		Inverter $\Delta V/\Delta I$ slope characteristic (V/amps)
J+8		VUNBY, inverter ac unbypassing voltage (pu)
J+9		ACCL, model acceleration factor
J+10		RSVOLT, minimum dc voltage following block (kV)
J+11		RSCUR, minimum dc current following block (amps)
J+12		VRAMP, voltage recovery rate (pu/sec)
J+13		CRAMP, current recovery rate (pu/sec)
J+14		C0, minimum current demand (amps)
J+15		V1, voltage limit point 1
J+16		C1, current limit point 1 (amps); ≥C0
J+17		V2, voltage limit point 2
J+18		C2, current limit point 2 (amps)
J+19		V3, voltage limit point 3
J+20		C3, current limit point 3 (amps)
J+21		ALFMXI, maximum inverter firing angle (degrees)
J+22		VDCBLK, rectifier ac voltage that causes a block if remains for time TDEBLK (pu)
J+23		TDEBLK, time delay for block (sec)
J+24		TREBLK, time delay after rectifier ac voltage recovers above VUNBL before line unblocks (sec)
J+25		VINBLK, inverter ac voltage that causes block after communication delay TCOMB (pu)
J+26		TCOMB, communication delay to signal rectifier to block because of low inverter voltage (sec)
J+27		VACBYP, inverter ac voltage that causes bypass if remains for time TDEBYP (pu)
J+28		TDEBYP, time delay for bypass (sec)
J+29		TINBLK, time delay after inverter ac voltage recovers above VUNBY before line unblocks (this value should also include communication delay) (sec)
J+30		TINBYP, time delay after inverter ac voltage recovers above VUNBY before line unbypasses (sec)

CONs	Value	Description
J+31		TVP, power control VDC transducer time constant (sec)

STATEs	Description
K	VDCOL, dc or ac voltage (kV or pu), VVDCOL
K+1	Measured inverter dc current (amps)
K+2	Power controller dc voltage (V), VDCP

VARs	Description
L	Other signals, MW
L+1	RESTR, time unblocks or unbypasses (sec)
L+2	VRF, voltage setpoint multiplier
L+3	CRF, current setpoint multiplier
L+4	VCOMP, compensated dc voltage (V)
L+5	PACR, rectifier ac real power (pu)
L+6	QACR, rectifier ac reactive power (pu)
L+7	PACI, inverter ac real power (pu)
L+8	QACI, inverter ac reactive power (pu)
L+9	VDCI, inverter dc voltage (V)
L+10	VDCR, rectifier dc voltage (V)
L+11	DC, dc current (amps)
L+12	ALFA, alpha (degrees)
L+13	GAMA, gamma (degrees)
L+14	Other VDC signals (kV)
L+15	TIMER, rectifier blocking and unblocking timer
L+16	TIMEI, inverter blocking and unblocking timer
L+17	TIBYP, inverter bypass and unbypass timer

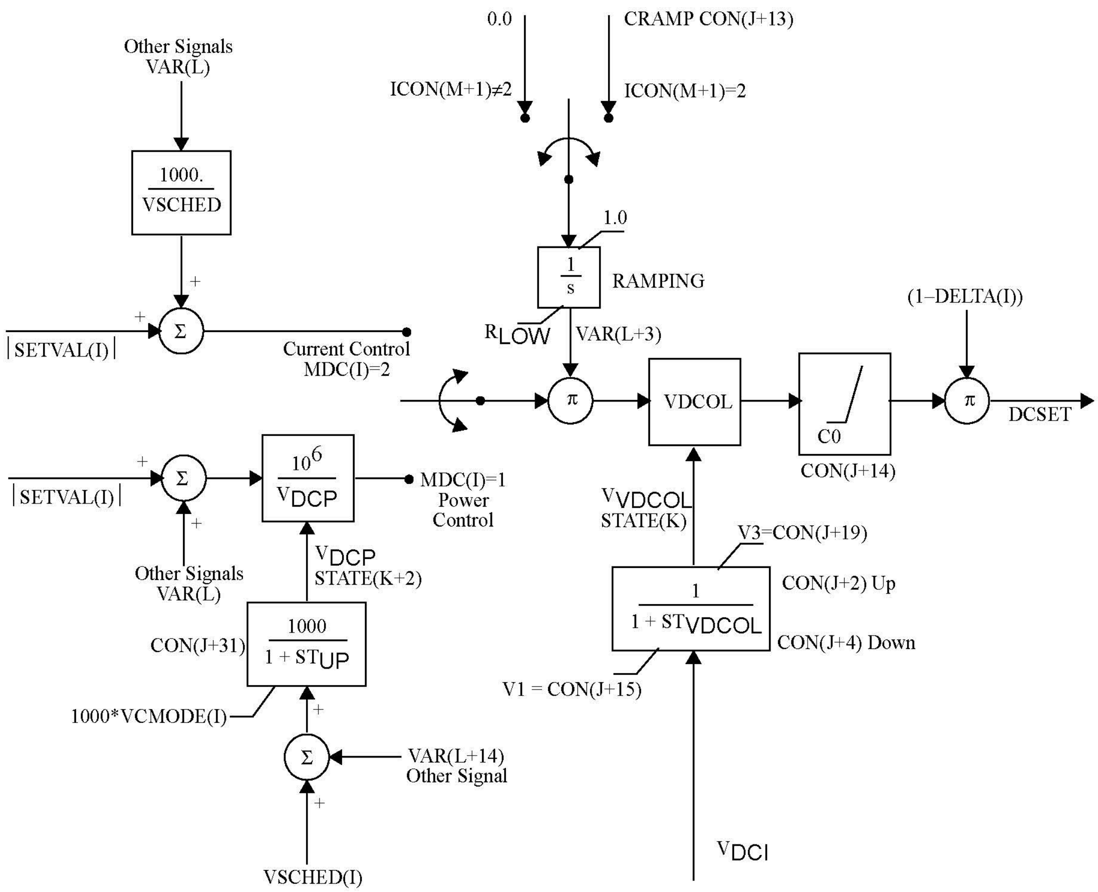
```
'DC Line Name', 'CMFORDT', CON(J) to CON(J+31)   /
```

Notes:

1. This model represents:

   - Constant margin angle limits.
   - Constant firing angle limits.
   - VDCL time constants for up and down.
   - Power controller time constant and limit on sensed DCV.
   - Voltage and current setpoint multiplier and ramp up.
   - Inverter mode switch DV/DI characteristic.
   - Maximum inverter firing angle limits.

2. Model uses two auxiliary signals. Auxiliary signal index 1 is the, "other signals (MW)', i.e. VAR(L), while auxiliary signal index 2 is the, "VDC Signal (KV)", i.e. VAR(L+14).



$$\text{If (MDC(I) = 1), } R_{LOW} = \frac{\text{CON(J+11) * VSCHED(I)}}{1000^{*}\,|\text{SETVAL (I)}|}$$

$$\text{If (MDC(I) = 2), } R_{LOW} = \frac{\text{CON(J+11)}}{|\text{SETVAL (I)}|}$$

dc Setpoint Control

Chapter 14
Multi-Terminal dc Line Models

This chapter contains a collection of data sheets for the multi-terminal dc line models contained in the PSS®E dynamics model library.

Model	Description
MTDC1T	Multiterminal (five converter) dc line model
MTDC2T	Multiterminal (five converter) dc line model
MTDC3T	Multiterminal (eight converter) dc line model

14.1. MTDC1T

Multiterminal (Five Converter) dc Line Model

ICONs	Value	Description
M		Entire line blocking flag:[a] • 0 - Not blocked • 1 - Blocked • 2 - Unblocking
M+1		Converter 1 flag:[a], [b] • 0 - Normal operation • 1 - Blocked • 2 - Unblocking
M+2		Converter 2 flag[a], [b]
M+3		Converter 3 flag[a], [b]
M+4		Converter 4 flag[a], [b]
M+5		Converter 5 flag[a], [b]
M+6		Mode switch flag:[c] • 0 - Normal • 1 - Mode switch

[a]Need not be input in DYRE data record. Can be changed by user for blocking/unblocking.
[b]Set to zero if this is voltage controlling converter (i.e., not used).
[c]Need not be input in DYRE data record. Flag set by model.

CONs	Value	Description
J		DY1, minimum angle converter 1 (degrees)
J+1		TVAC1, ac voltage transducer converter 1 (sec)
J+2		TVDC1, dc voltage transducer converter 1 (sec)
J+3		TIDC1, current transducer converter 1 (sec)
J+4		RSVLT1, minimum dc voltage following block, converter 1 (kV)[a]
J+5		RSCUR1, minimum dc current following block, converter 1 (amps)[b]
J+6		VRMP1, voltage recovery rate, converter 1 (pu/sec)[d]
J+7		CRMP1, current recovery rate, converter 1 (pu/sec)2
J+8		C0-1, minimum current demand converter 1 (ampsUsed as minimum current allowed even at voltage controlling bus.[c]
J+9		V1-1, voltage limit point 1, converter 1 (kV)[e]
J+10		C1-1, current limit point 1, converter 1 (amps)[e]
J+11		V2-1, voltage limit point 2, converter 1 (kV)[e]
J+12		C2-1, current limit point 2, converter 1 (amps)[e]
J+13		V3-1, voltage limit point 3, converter 1 (kV)[e]

CONs	Value	Description
J+14		C3-1, current limit point 3, converter 1 (amps)[e]
J+15		DY2, minimum angle converter 2 (degrees)
J+16		TVAC2, ac voltage transducer converter 2 (sec)
J+17		TVDC2, dc voltage transducer converter 2 (sec)
J+18		TIDC2, current transducer converter 2 (sec)
J+19		RSVLT2, minimum dc voltage following block, converter 2 (kV)[d]
J+20		RSCUR2, minimum dc current following block, converter 2 (amps)[e]
J+21		VRMP2, voltage recovery rate, converter 2 (pu/sec)[d]
J+22		CRMP2, current recovery rate, converter 2 (pu/sec)[e]
J+23		C0-2, minimum current demand converter 2 (amps)[c]
J+24		V1-2, voltage limit point 1, converter 2 (kV)[e]
J+25		C1-2, current limit point 1, converter 2 (amps)[e]
J+26		V2-2, voltage limit point 2, converter 2 (kV)[e]
J+27		C2-2, current limit point 2, converter 2 (amps)[e]
J+28		V3-2, voltage limit point 3, converter 2 (kV)[e]
J+29		C3-2, current limit point 3, converter 2 (amps)[e]
J+30		DY3, minimum angle converter 3 (degrees)
J+31		TVAC3, ac voltage transducer converter 3 (sec)
J+32		$TV_{DC}3$, dc voltage transducer converter 3 (sec)
J+33		TIDC3, current transducer converter 3 (sec)
J+34		RSVLT3, minimum dc voltage following block, converter 3 (kV)[d]
J+35		RSCUR3, minimum dc current following block, converter 3 (amps)[e]
J+36		VRMP3, voltage recovery rate, converter 3 (pu/sec)[d]
J+37		CRMP3, current recovery rate, converter 3 (pu/sec)[e]
J+38		C0-3, minimum current demand converter 3 (amps)[c]
J+39		V1-3, current limit point 1, converter 3 (kV)[e]
J+40		C1-3, current limit point 1, converter 3 (amps)[e]
J+41		V2-3, voltage limit point 2, converter 3 (kV)[e]
J+42		C2-3, current limit point 2, converter 3 (amps)[e]
J+43		V3-3, voltage limit point 3, converter 3 (kV)[e]
J+44		C3-3, current limit point 3, converter 3 (amps)[e]
J+45		DY4, minimum angle converter 4 (degrees)
J+46		TVAC4, ac voltage transducer converter 4 (sec)
J+47		$TV_{DC}4$, dc voltage transducer converter 4 (sec)
J+48		TIDC4, current transducer converter 4 (sec)
J+49		RSVLT4, minimum dc voltage following block, converter 4 (kV)[d]
J+50		RSCUR4, minimum dc current following block, converter 4 (amps)[e]
J+51		VRMP4, voltage recovery rate, converter 4 (pu/sec)[d]
J+52		CRMP4, current recovery rate, converter 4 (pu/sec)[e]
J+53		C0-4, minimum current demand converter 4 (amps)[c]
J+54		V1-4, voltage limit point 1, converter 4 (kV)[e]

CONs	Value	Description
J+55		C1-4, current limit point 1, converter 4 (amps)[e]
J+56		V2-4, voltage limit point 2, converter 4 (kV)[e]
J+57		C2-4, current limit point 2, converter 4 (amps)[e]
J+58		V3-4, voltage limit point 3, converter 4 (kV)[e]
J+59		C3-4, current limit point 3, converter 4 (amps)[e]
J+60		DY5, minimum angle converter 5 (degrees)
J+61		TVAC5, ac voltage transducer converter 5 (sec)
J+62		$TV_{DC}5$, dc voltage transducer converter 5 (sec)
J+63		TIDC5, current transducer converter 5 (sec)
J+64		RSVLT5, minimum dc voltage following block, converter 5 (kV)[d]
J+65		RSCUR5, minimum dc current following block, converter 5 (amps)[e]
J+66		VRMP5, Voltage recovery rate, converter 5 (pu/sec)[d]
J+67		CRMP5, current recovery rate, converter 5 (pu/sec)[e]
J+68		C0-5, minimum current demand converter 5 (amps)[f]
J+69		V1-5, voltage limit point 1, converter 5 (kV)[e]
J+70		C1-5, current limit point 1, converter 5 (amps)[e]
J+71		V2-5, voltage limit point 2, converter 5 (kV)[e]
J+72		C2-5, current limit point 2, converter 5 (amps)[e]
J+73		V3-5, voltage limit point 3, converter 5 (kV)[e]
J+74		C3-5, current limit point 3, converter 5 (amps)[e]
J+75		TCMODE (sec)

[a]Used only at voltage controlling converter.
[b]Used at all converters except voltage controlling converter.
[c]Used as minimum current allowed even at voltage controlling bus.
[d]Used only at voltage controlling converter.
[e]Used at all converters except voltage controlling converter.
[f]Used as minimum current allowed even at voltage controlling bus.

STATEs	Description
K	Measured ac voltage, converter 1
K+1	Measured dc voltage, converter 1
K+2	Measured dc current, converter 1
K+3	Measured ac voltage, converter 2
K+4	Measured dc voltage, converter 2
K+5	Measured dc current, converter 2
K+6	Measured ac voltage, converter 3
K+7	Measured dc voltage, converter 3
K+8	Measured dc current, converter 3
K+9	Measured ac voltage, converter 4
K+10	Measured dc voltage, converter 4
K+11	Measured dc current, converter 4
K+12	Measured ac voltage, converter 5

STATEs	Description
K+13	Measured dc voltage, converter 5
K+14	Measured dc current, converter 5

VARs	Description
L	VAC bus converter 1
L+1	P_{AC} bus converter 1
L+2	Q_{AC} bus converter 1
L+3	V_{DC} converter 1
L+4	IDC converter 1
L+5	Angle converter 1
L+6	VAC bus converter 2
L+7	P_{AC} bus converter 2
L+8	Q_{AC} bus converter 2
L+9	V_{DC} converter 2
L+10	IDC converter 2
L+11	Angle converter 2
L+12	VAC bus converter 3
L+13	P_{AC} bus converter 3
L+14	Q_{AC} bus converter 3
L+15	V_{DC} converter 3
L+16	IDC converter 3
L+17	Angle converter 3
L+18	VAC bus converter 4
L+19	P_{AC} bus converter 4
L+20	Q_{AC} bus converter 4
L+21	V_{DC} converter 4
L+22	IDC converter 4
L+23	Angle converter 4
L+24	VAC bus converter 5
L+25	P_{AC} bus converter 5
L+26	Q_{AC} bus converter 5
L+27	V_{DC} converter 5
L+28	IDC converter 5
L+29	Angle converter 5
L+30	Internal VARs required by model
L+31	
L+32	
L+33	
L+34	
L+35	

VARs	Description
LAUX	Auxiliary signal converter 1[a], [b] [DCMSIG(1,I)]
LAUX+1	Auxiliary signal converter 2[b] [DCMSIG(2,I)
LAUX+2	Auxiliary signal converter 3[b] [DCMSIG(3,I)]
LAUX+3	Auxiliary signal converter 4[b] [DCMSIG(4,I)]
LAUX+4	Auxiliary signal converter 5[b] [DCMSIG(5,I)]

[a]This model uses auxiliary signal outputs stored in DCMSIG(1,I) through DCMSIG(5,I) (i.e., auxiliary signal index 1 through 5).

[b]At voltage controlling inverter, only used if in gamma control (i.e., ANGMX = ANGMN in power flow).

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'DC Line Name', 'MTDC1T', CON(J) to CON(J+75)   /
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14.2. MTDC2T

MTDC2T

ICONs	Value	Description
M		Entire line blocking flag:[a] • 0 - Not blocked • 1 - Blocked • 2 - Ramp all current and voltage
M+1		Converter 1 flag:[a] • 0 - Normal operation • 1 - Blocked • 2 - Ramp current
M+2		Converter 2 flag[a]
M+3		Converter 3 flag[a]>
M+4		Converter 4 flag[a]
M+5		Converter 5 flag[a]
M+6		Voltage ramping flag:[b] • 0 - Normal operation • 1 - Ramp voltage

[a]Need not be input in DYRE data record. Can be changed by user for blocking/unblocking.
[b]Need not be input in DYRE data record. Flag set by model.

CONs	Value	Description
J		DY1, minimum angle converter 1 (degrees)
J+1		TVAC1, ac voltage transducer converter 1 (sec)
J+2		TVDC1, dc voltage transducer converter 1 (sec)
J+3		TIDC1, current transducer converter 1 (sec)
J+4		RSVLT1, minimum dc voltage following block, converter 1 (kV)[a]
J+5		RSCUR1, minimum dc current following block, converter 1 (amps)
J+6		VRMP1, voltage recovery rate, converter 1 (pu/sec)[a]
J+7		CRMP1, current recover rate, converter 1 (pu/sec)
J+8		C0-1, minimum current demand converter 1 (amps)
J+9		V1-1, minimum current demand converter 1
J+10		C1-1, minimum current demand converter 1 (amps)
J+11		V2-1, minimum current demand converter 1
J+12		C2-1, minimum current demand converter 1 (amps)
J+13		V3-1, minimum current demand converter 1
J+14		C3-1, minimum current demand converter 1 (amps)

CONs	Value	Description
J+15		DY2, minimum angle converter 2 (degrees)
J+16		TVAC2, ac voltage transducer converter 2 (sec)
J+17		TVDC2, dc voltage transducer converter 2 (sec)
J+18		TIDC2, current transducer converter 2 (sec)
J+19		RSVLT2, minimum dc voltage following block, converter 2 (kV)[a]
J+20		RSCUR2, minimum dc current following block, converter 2 (amps)
J+21		VRMP2, voltage recovery rate, converter 2 (pu/sec)1)[a]
J+22		CRMP2, current recover rate, converter 2 (pu/sec)
J+23		C0-2, minimum current demand converter 2 (amps)
J+24		V1-2, minimum current demand converter 2
J+25		C1-2, minimum current demand converter 2 (amps)
J+26		V2-2, minimum current demand converter 2
J+27		C2-2, minimum current demand converter 2 (amps)
J+28		V3-2, minimum current demand converter 2
J+29		C3-2, minimum current demand converter 2 (amps)
J+30		DY3, minimum angle converter 3 (degrees)
J+31		TVAC3, ac voltage transducer converter 3 (sec)
J+32		$TV_{DC}3$, dc voltage transducer converter 3 (sec)
J+33		TIDC3, current transducer converter 3 (sec)
J+34		RSVLT3, minimum dc voltage following block, converter 3 (kV))[a]
J+35		RSCUR3, minimum dc current following block, converter 3 (amps)
J+36		VRMP3, voltage recovery rate, converter 3 (pu/sec))[a]
J+37		CRMP3, current recover rate, converter 3 (pu/sec)
J+38		C0-3, minimum current demand converter 3 (amps)
J+39		V1-3, minimum current demand converter 3
J+40		C1-3, minimum current demand converter 3 (amps)
J+41		V2-3, minimum current demand converter 3
J+42		C2-3, minimum current demand converter 3 (amps)
J+43		V3-3, minimum current demand converter 3
J+44		C3-3, minimum current demand converter 3 (amps)
J+45		DY4, minimum angle converter 4 (degrees)
J+46		TVAC4, ac voltage transducer converter 4 (sec)
J+47		$TV_{DC}4$, dc voltage transducer converter 4 (sec)
J+48		TIDC4, current transducer converter 4 (sec)
J+49		RSVLT4, minimum dc voltage following block, converter 4 (kV))[a]
J+50		RSCUR4, minimum dc current following block, converter 4 (amps)
J+51		VRMP4, voltage recovery rate, converter 4 (pu/sec))[a]
J+52		CRMP4, current recovery rate, converter 4 (pu/sec)
J+53		C0-4, minimum current demand converter 4 (amps)
J+54		V1-4, minimum current demand converter 4
J+55		C1-4, minimum current demand converter 4 (amps)

CONs	Value	Description
J+56		V2-4, minimum current demand converter 4
J+57		C2-4, minimum current demand converter 4 (amps)
J+58		V3-4, minimum current demand converter 4
J+59		C3-4, minimum current demand converter 4 (amps)
J+60		DY5, minimum angle converter 5 (degrees)
J+61		TVAC5, ac voltage transducer converter 5 (seconds)
J+62		$TV_{DC}5$, dc voltage transducer converter 5 (seconds)
J+63		TIDC5, current transducer converter 5 (seconds)
J+64		RSVLT5, minimum dc voltage following block, converter 5 (kV))[a]
J+65		RSCUR5, minimum dc current following block, converter 5 (amps)
J+66		VRMP5, voltage recovery rate, converter 5 (pu/sec))[a]
J+67		CRMP5, current recovery rate, converter 5 (pu/sec)
J+68		C0-5, minimum current demand converter 5 (amps)
J+69		V1-5, minimum current demand converter 5
J+70		C1-5, minimum current demand converter 5 (amps)
J+71		V2-5, minimum current demand converter 5
J+72		C2-5, minimum current demand converter 5 (amps)
J+73		V3-5, minimum current demand converter 5
J+74		C3-5, minimum current demand converter 5 (amps)
J+75		TVF, power control V_{DC} transducer time constant (sec)
J+76		V_{DC}OLUP, voltage transducer time constants (sec)
J+77		V_{DC}OLON, voltage transducer time constants (sec)
J+78		Current margin (amps)
J+79		Converter 1 Δ V/ Δ I multiplier (pu)[b]
J+80		Converter 2 Δ V/ Δ I multiplier (pu))[b]
J+81		Converter 3 Δ V/ Δ I multiplier (pu)[b]
J+82		Converter 4 Δ V/ Δ I multiplier (pu)[b]
J+83		Converter 5 Δ V/ Δ I multiplier (pu)[b]

[a]Used only at voltage controlling converter.

[b]Used only at inverter.

STATEs	Description
K	Measured ac voltage, converter 1
K+1	Measured dc voltage, converter 1
K+2	Measured dc current, converter 1
K+3	Measured ac voltage, converter 2
K+4	Measured dc voltage, converter 2
K+5	Measured dc current, converter 2
K+6	Measured ac voltage, converter 3
K+7	Measured dc voltage, converter 3
K+8	Measured dc current, converter 3
K+9	Measured ac voltage, converter 4

STATEs	Description
K+10	Measured dc voltage, converter 4
K+11	Measured dc current, converter 4
K+12	Measured ac voltage, converter 5
K+13	Measured dc voltage, converter 5
K+14	Measured dc current, converter 5
K+15	Power controller voltage
K+16	V_{DC}L voltage

VARs	Description
L	VAC bus converter 1
L+1	P_{AC} bus converter 1
L+2	Q_{AC} bus converter 1
L+3	V_{DC} converter 1
L+4	IDC converter 1
L+5	Angle converter 1
L+6	VAC bus converter 2
L+7	P_{AC} bus converter 2
L+8	Q_{AC} bus converter 2
L+9	V_{DC} converter 2
L+10	IDC converter 2
L+11	Angle converter 2
L+12	VAC bus converter 3
L+13	P_{AC} bus converter 3
L+14	Q_{AC} bus converter 3
L+15	V_{DC} converter 3
L+16	IDC converter 3
L+17	Angle converter 3
L+18	VAC bus converter 4
L+19	P_{AC} bus converter 4
L+20	Q_{AC} bus converter 4
L+21	V_{DC} converter 4
L+22	IDC converter 4
L+23	Angle converter 4
L+24	VAC bus converter 5
L+25	P_{AC} bus converter 5
L+26	Q_{AC} bus converter 5
L+27	V_{DC} converter 5
L+28	IDC converter 5
L+29	Angle converter 5
L+30	CRF1 current setpoint multiplier
L+31	CRF2 current setpoint multiplier

VARs	Description
L+32	CRF3 current setpoint multiplier
L+33	CRF4 current setpoint multiplier
L+34	CRF5 current setpoint multiplier
L+35	VRF voltage setpoint multiplier
L+36	Internal memory
L+37	
L+38	
L+39	
L+40	
L+41	

VARs	Description
LAUX	Auxiliary signal converter 1[a], [b] [DCMSIG(1,I)]
LAUX+1	Auxiliary signal converter 2[b] [DCMSIG(2,I)]
LAUX+2	Auxiliary signal converter 3[b] [DCMSIG(3,I)]
LAUX+3	Auxiliary signal converter 4[b] [DCMSIG(4,I)]
LAUX+4	Auxiliary signal converter 5[b] [DCMSIG(5,I)]

[a]This model uses auxiliary signal outputs stored in DCMSIG(1,I) through DCMSIG(5,I) (i.e., auxiliary signal index 1 through 5).
[b]Used at all except voltage controlling converter.

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'DC Line Name', 'MTDC2T', CON(J) to CON(J+83)   /
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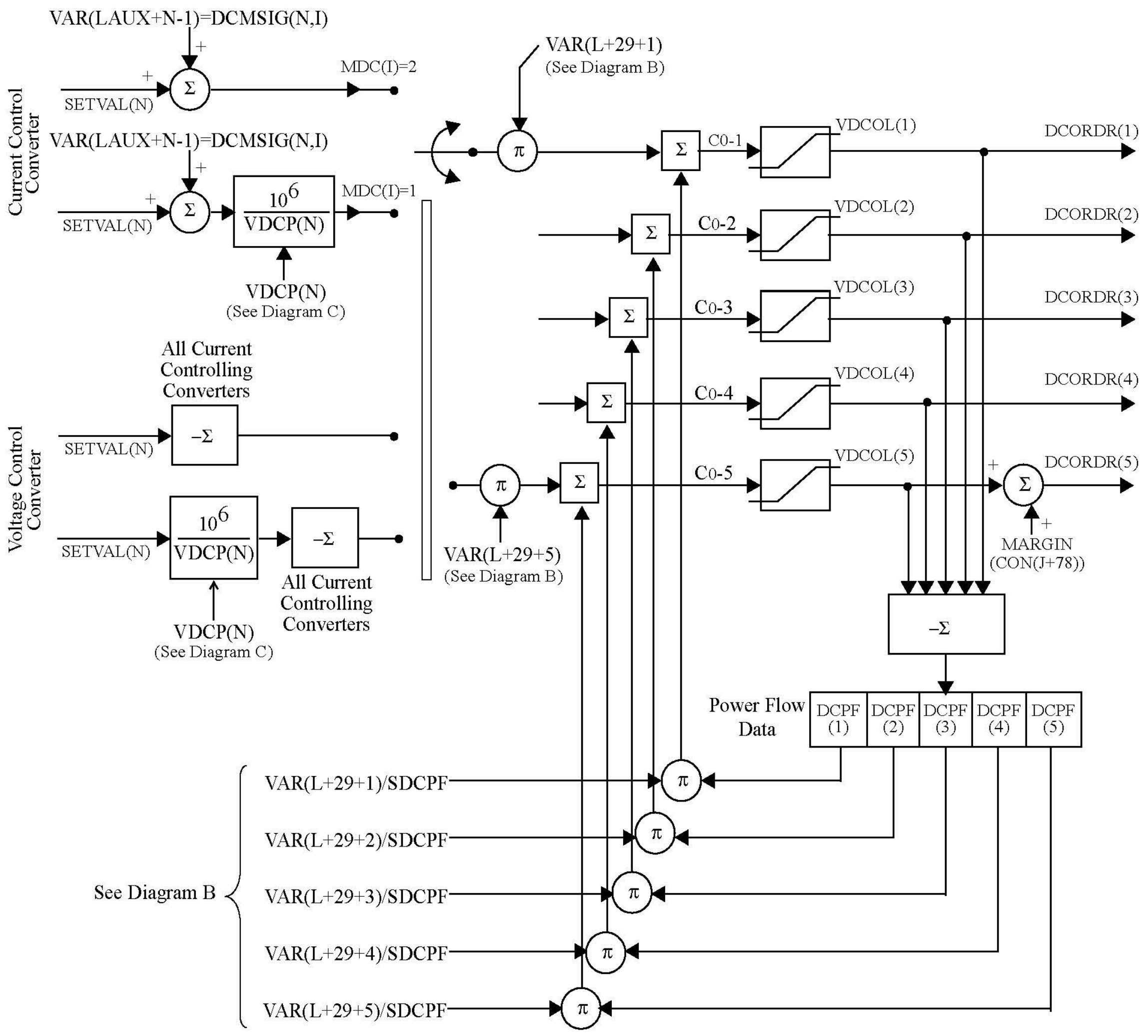


Diagram A
Block Diagram Assuming Converter #5 is a Voltage Controlling Converter

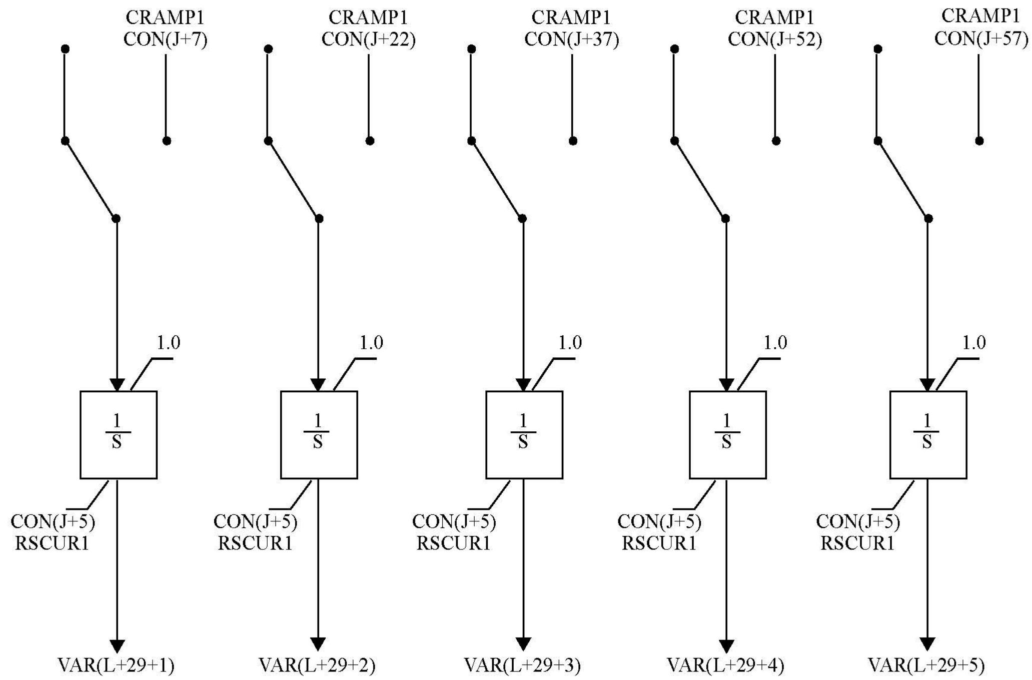


Diagram B
Current Ramping

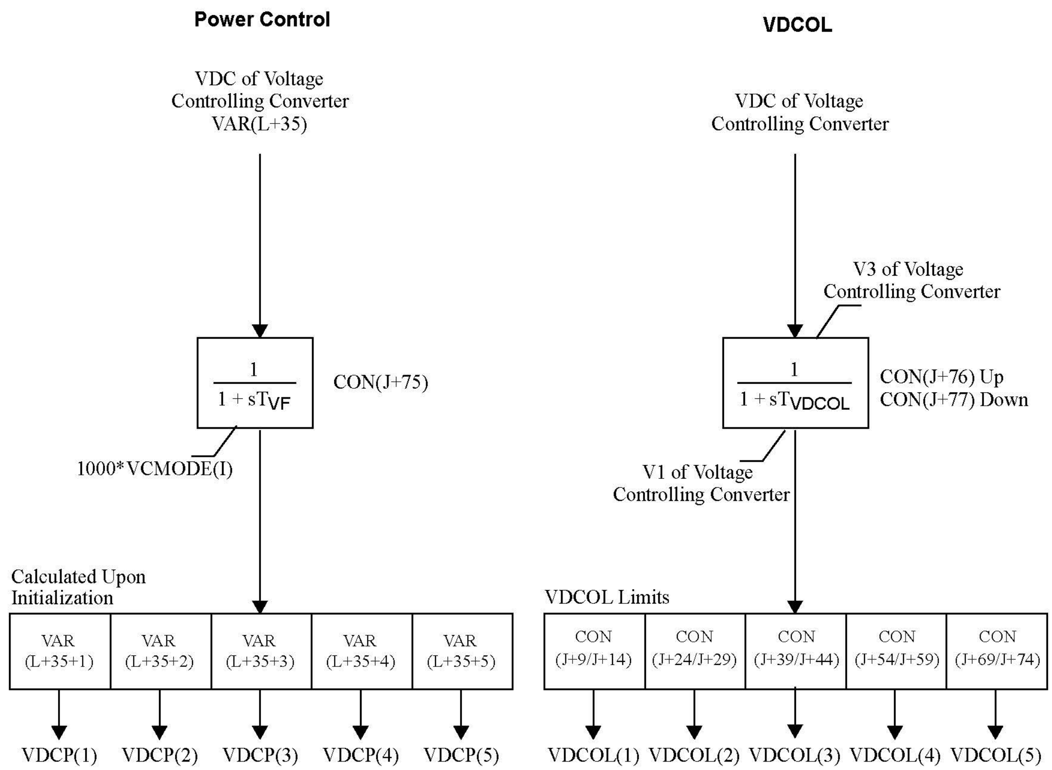


Diagram C

Converter Power Controller and Voltage-Dependent Current Limiter

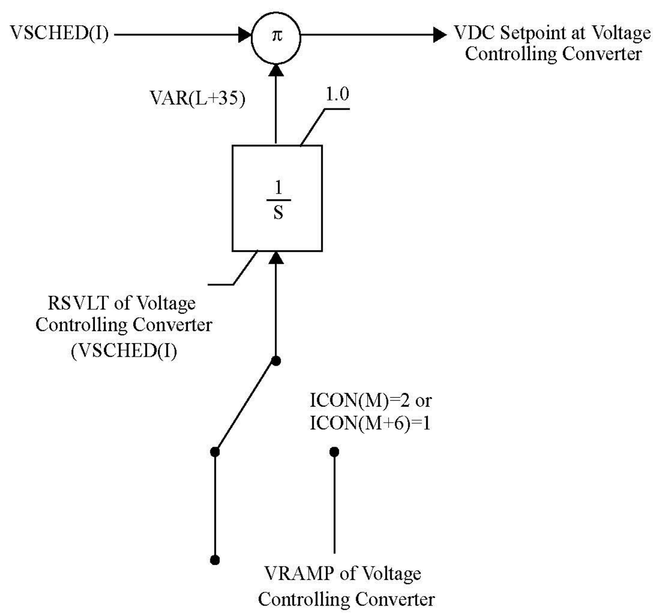


Diagram D
dc Voltage Setpoint Control

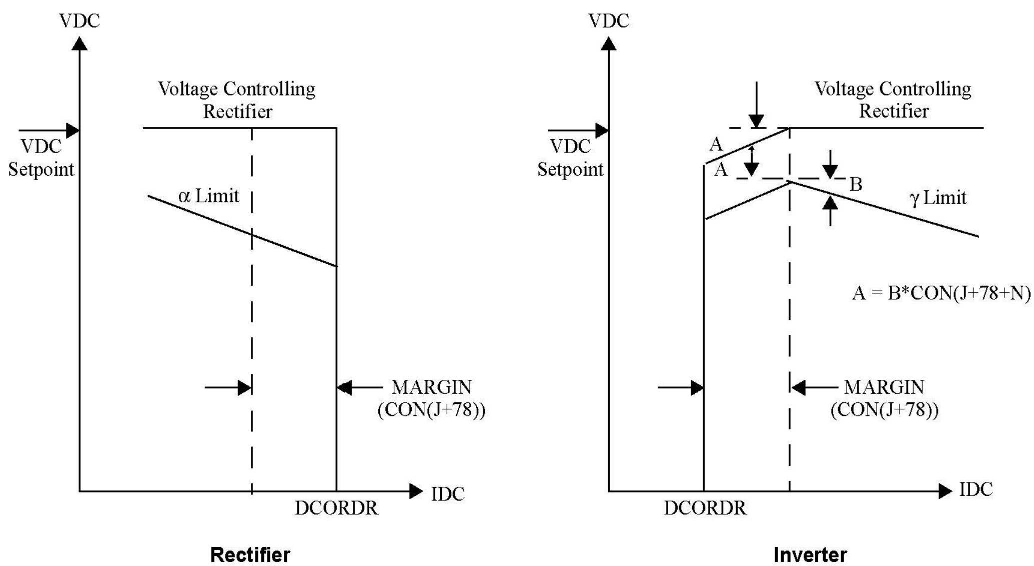


Diagram E
Converter Characteristics

14.3. MTDC3T

Multiterminal (Eight Converter) dc Line Model

ICONs	Value	Description
M		Entire line blocking flag:[a] • 0 - Not blocked • 1 - Blocked • 2 - Unblocking
M+1		Converter 1 flag:[a], [b] • 0 - Normal operation • 1 - Blocked • 2 - Unblocking
M+2		Converter 2 flag[a], [b]
M+3		Converter 3 flag[a], [b]
M+4		Converter 4 flag[a], [b]
M+5		Converter 5 flag[a], [b]
M+6		Converter 6 flag[a], [b]
M+7		Converter 7 flag[a], [b]
M+8		Converter 8 flag[a], [b]
M+9		Mode switch flag:[c] • 0 - Normal • 1 - Mode switch

[a]Set to zero if this is voltage controlling converter (i.e., not used).
[b]Need not be input in DYRE data record. Can be changed by user for blocking/unblocking.
[c]Need not be input in DYRE data record. Flag set by model.

CONs	Value	Description
J		DY1, minimum angle converter 1 (degrees)
J+1		TVAC1, ac voltage transducer converter 1 (sec)
J+2		TVDC1, dc voltage transducer converter 1 (sec)
J+3		TIDC1, current transducer converter 1 (sec)
J+4		RSVLT1, minimum dc voltage following block, converter 1(kV)[a]
J+5		RSCUR1, minimum dc current following block, converter 1 (amps)[b]
J+6		VRMP1, voltage recovery rate, converter 1 (pu/sec)[a]
J+7		CRMP1, current recovery rate, converter 1 (pu/sec)[b]
J+8		C0-1, minimum current demand converter 1 (amps)[c]
J+9		V1-1, voltage limit point, converter 1 (kV)[b]
J+10		C1-1, current limit point 1, converter 1 (amps)[b]

CONs	Value	Description
J+11		V2-1, voltage limit point 2, converter 1 (kV)[b]
J+12		C2-1, current limit point 2, converter 1 (amps)[b]
J+13		V3-1, voltage limit point 3, converter 1 (kV)[b]
J+14		C3-1, current limit point 3, converter 1 (amps)[b]
J+15		DY2, minimum angle converter 2 (degrees)
J+16		TVAC2, ac voltage transducer converter 2 (sec)
J+17		TVDC2, dc voltage transducer converter 2 (sec)
J+18		TIDC2, current transducer converter 2 (sec)
J+19		RSVLT2, minimum dc voltage following block, converter 2 (kV)[a]
J+20		RSCUR2, minimum dc current following block, converter 2 (amps)[b]
J+21		VRMP2, voltage recovery rate, converter 2 (pu/sec)[a]
J+22		CRMP2, current recovery rate, converter 2 (pu/sec)[b]
J+23		C0-2, minimum current demand converter 2 (amps)[c]
J+24		V1-2, voltage limit point 1, converter 2 (kV)[b]
J+25		C1-2, current limit point 1, converter 2 (amps)[b]
J+26		V2-2, voltage limit point 2, converter 2 (kV)[b]
J+27		C2-2, current limit point 2, converter 2 (amps)[b]
J+28		V3-2, voltage limit point 3, converter 2 (kV)[b]
J+29		C3-2, current limit point 3, converter 2 (amps)[b]
J+30		DY3, minimum angle converter 3 (degrees)
J+31		TVAC3, ac voltage transducer converter 3 (sec)
J+32		$TV_{DC}3$, dc voltage transducer converter 3 (sec)
J+33		TIDC3, current transducer converter 3 (sec)
J+34		RSVLT3, minimum dc voltage following block, converter 3 (kV)[a]
J+35		RSCUR3, minimum dc current following block, converter 3 (amps)[b]
J+36		VRMP3, voltage recovery rate, converter 3 (pu/sec)[a]
J+37		CRMP3, current recovery rate, converter 3 (pu/sec)[b]
J+38		C0-3, minimum current demand converter 3 (amps)[c]
J+39		V1-3, voltage limit point 1, converter 3 (kV)[b]
J+40		C1-3, current limit point 1, converter 3 (amps)[b]
J+41		V2-3, voltage limit point 2, converter 3 (kV)[b]
J+42		C2-3, current limit point 2, converter 3 (amps)[b]
J+43		V3-3, voltage limit point 3, converter 3 (kV)[b]
J+44		C3-3, current limit point 3, converter 3 (amps)[b]
J+45		DY4, minimum angle converter 4 (degrees)
J+46		TVAC4, ac voltage transducer converter 4 (sec)
J+47		$TV_{DC}4$, dc voltage transducer converter 4 (sec)
J+48		TIDC4, current transducer converter 4 (sec)
J+49		RSVLT4, minimum dc voltage following block, converter 4 (kV)[a]
J+50		RSCUR4, minimum dc current following block, converter 4 (amps)[b]
J+51		VRMP4, voltage recovery rate, converter 4 (pu/sec)[a]

CONs	Value	Description
J+52		CRMP4, current recovery rate, converter 4 (pu/sec)[b]
J+53		C0-4, minimum current demand converter 4 (amps)[c]
J+54		V1-4, voltage limit point 1, converter 4 (kV)[b]
J+55		C1-4, current limit point 1, converter 4 (amps)[b]
J+56		V2-4, voltage limit point 2, converter 4 (kV)[b]
J+57		C2-4, current limit point 2, converter 4 (amps)[b]
J+58		V3-4, voltage limit point 3, converter 4 (kV)[b]
J+59		C3-4, current limit point 3, converter 4 (amps)[b]
J+60		DY5, minimum angle converter 5 (degrees)
J+61		TVAC5, ac voltage transducer converter 5 (sec)
J+62		$TV_{DC}5$, dc voltage transducer converter 5 (sec)
J+63		TIDC5, current transducer converter 5 (sec)
J+64		RSVLT5, minimum dc voltage following block, converter 5 (kV)
J+65		RSCUR5, minimum dc current following block, converter 5 (amps)[b]
J+66		VRMP5, voltage recovery rate, converter 5 (pu/sec)[a]
J+67		CRMP5, current recovery rate, converter 5 (pu/sec)[b]
J+68		C0-5, minimum current demand converter 5 (amps)[c]
J+69		V1-5, voltage limit point 1, converter 5 (kV)[b]
J+70		C1-5, current limit point 1, converter 5 (amps)[b]
J+71		V2-5, voltage limit point 2, converter 5 (kV)[b]
J+72		C2-5, current limit point 2, converter 5 (amps)[b]
J+73		V3-5, voltage limit point 3, converter 5 (kV)[b]
J+74		C3-5, current limit point 3, converter 5 (amps)[b]
J+75		DY6, minimum angle converter 6 (degrees)
J+76		TVAC6, ac voltage transducer converter 6 (sec)
J+77		$TV_{DC}6$, dc voltage transducer converter 6 (sec)
J+78		TIDC6, current transducer converter 6 (sec)
J+79		RSVLT6, minimum dc voltage following block, converter 6 (kV)[a]
J+80		RSCUR6, minimum dc current following block, converter 6 (amps)[b]
J+81		VRMP6, voltage recovery rate, converter 6 (pu/sec)[a]
J+82		CRMP6, current recovery rate, converter 6 (pu/sec)[b]
J+83		C0-6, minimum current demand converter 6 (amps)[c]
J+84		V1-6, voltage limit point 1, converter 6 (kV)[b]
J+85		C1-6, current limit point 1, converter 6 (amps)[b]
J+86		V2-6, voltage limit point 2, converter 6 (kV)[b]
J+87		C2-6, current limit point 2, converter 6 (amps)[b]
J+88		V3-6, voltage limit point 3, converter 6 (kV)[b]
J+89		C3-6, current limit point 3, converter 6 (amps)[b]
J+90		DY7, minimum angle converter 7 (degrees)
J+91		TVAC7, ac voltage transducer converter 7 (sec)
J+92		$TV_{DC}7$, dc voltage transducer converter 7 (sec)

CONs	Value	Description
J+93		TIDC7, current transducer converter 7 (sec)
J+94		RSVLT7, minimum dc voltage following block, converter 7 (kV)[a]
J+95		RSCUR7, minimum dc current following block, converter 7 (amps)[b]
J+96		VRMP7, voltage recovery rate, converter 7 (pu/sec)[a]
J+97		CRMP7, current recovery rate, converter 7 (pu/sec)[b]
J+98		C0-7, minimum current demand converter 7 (amps)4
J+99		V1-7, voltage limit point 1, converter 7 (kV)[b]
J+100		C1-7, current limit point 1, converter 7 (amps)[b]
J+101		V2-7, voltage limit point 2, converter 7 (kV)[b]
J+102		C2-7, current limit point 2, converter 7 (amps)[b]
J+103		V3-7, voltage limit point 3, converter 7 (kV)[b]
J+104		C3-7, current limit point 3, converter 7 (amps)[b]
J+105		DY8, minimum angle converter 8 (degrees)
J+106		TVAC8, ac voltage transducer converter 8 (sec)
J+107		$TV_{DC}8$, dc voltage transducer converter 8 (sec)
J+108		TIDC8, current transducer converter 8 (sec)
J+109		RSVLT8, minimum dc voltage following block, converter 8 (kV)[a]
J+110		RSCUR8, minimum dc current following block, converter 8 (amps)[b]
J+111		VRMP8, voltage recovery rate, converter 8 (pu/sec)[a]
J+112		CRMP8, current recovery rate, converter 8 (pu/sec)[b]
J+113		C0-8, minimum current demand converter 8 (amps)4
J+114		V1-8, voltage limit point 1, converter 8 (kV)[b]
J+115		C1-8, current limit point 1, converter 8 (amps)[b]
J+116		V2-8, voltage limit point 2, converter 8 (kV)[b]
J+117		C2-8, current limit point 2, converter 8 (amps)[b]
J+118		V3-8, voltage limit point 3, converter 8 (kV)[b]
J+119		C3-8, current limit point 3, converter 8 (amps)[b]
J+120		TCMODE (sec)

[a]Used only at voltage controlling converter.

[b]Used at all except voltage controlling converter.

[c]Used as minimum current allowed even at voltage controlling bus.

STATEs	Description
K	Measured ac voltage, converter 1
K+1	Measured dc voltage, converter 1
K+2	Measured dc current, converter 1
K+3	Measured ac voltage, converter 2
K+4	Measured dc voltage, converter 2
K+5	Measured dc current, converter 2
K+6	Measured ac voltage, converter 3
K+7	Measured dc voltage, converter 3
K+8	Measured dc current, converter 3

STATEs	Description
K+9	Measured ac voltage, converter 4
K+10	Measured dc voltage, converter 4
K+11	Measured dc current, converter 4
K+12	Measured ac voltage, converter 5
K+13	Measured dc voltage, converter 5
K+14	Measured dc current, converter 5
K+15	Measured ac voltage, converter 6
K+16	Measured dc voltage, converter 6
K+17	Measured dc current, converter 6
K+18	Measured ac voltage, converter 7
K+19	Measured dc voltage, converter 7
K+20	Measured dc current, converter 7
K+21	Measured ac voltage, converter 8
K+22	Measured dc voltage, converter 8
K+23	Measured dc current, converter 8

VARs	Description
L	VAC bus converter 1
L+1	P_{AC} bus converter 1
L+2	Q_{AC} bus converter 1
L+3	V_{DC} converter 1
L+4	IDC converter 1
L+5	Angle converter 1
L+6	VAC bus converter 2
L+7	P_{AC} bus converter 2
L+8	Q_{AC} bus converter 2
L+9	V_{DC} converter 2
L+10	IDC converter 2
L+11	Angle converter 2
L+12	VAC bus converter 3
L+13	P_{AC} bus converter 3
L+14	Q_{AC} bus converter 3
L+15	V_{DC} converter 3
L+16	IDC converter 3
L+17	Angle converter 3
L+18	VAC bus converter 4
L+19	P_{AC} bus converter 4
L+20	Q_{AC} bus converter 4
L+21	V_{DC} converter 4
L+22	IDC converter 4
L+23	Angle converter 4

VARs	Description
L+24	VAC bus converter 5
L+25	P_{AC} bus converter 5
L+26	Q_{AC} bus converter 5
L+27	V_{DC} converter 5
L+28	IDC converter 5
L+29	Angle converter 5
L+30	VAC bus converter 6
L+31	P_{AC} bus converter 6
L+32	Q_{AC} bus converter 6
L+33	V_{DC} converter 6
L+34	IDC converter 6
L+35	Angle converter 6
L+36	VAC bus converter 7
L+37	P_{AC} bus converter 7
L+38	Q_{AC} bus converter 7
L+39	V_{DC} converter 7
L+40	IDC converter 7
L+41	Angle converter 7
L+42	VAC bus converter 8
L+43	P_{AC} bus converter 8
L+44	Q_{AC} bus converter 8
L+45	V_{DC} converter 8
L+46	IDC converter 8
L+47	Angle converter 8
L+48 ... L+56	VARs required for internal program logic

VARs	Description
LAUX	Auxiliary signal converter 1[a], [b] [DCMSIG(1,I)]
LAUX+1	Auxiliary signal converter 2[a] [DCMSIG(2,I)]
LAUX+2	Auxiliary signal converter 3[a] [DCMSIG(3,I)]
LAUX+3	Auxiliary signal converter 4[a] [DCMSIG(4,I)]
LAUX+4	Auxiliary signal converter 5[a] [DCMSIG(5,I)]
LAUX+5	Auxiliary signal converter 6[a] [DCMSIG(6,I)]
LAUX+6	Auxiliary signal converter 7[a] [DCMSIG(7,I)]
LAUX+7	Auxiliary signal converter 8[a] [DCMSIG(8,I)]

[a]This model uses auxiliary signal outputs stored in DCMSIG(1,I) through DCMSIG(8,I) (i.e., auxiliary signal index 1 through 8).

[b]At voltage controlling inverter, only used if in gamma control (i.e., ANGMX = ANGMN in power flow).

```
'DC Line Name', 'MTDC3T', CON(J) to CON(J+120)   /
```

Chapter 15
VSC dc Line Models

This chapter contains a collection of data sheets for the VSC dc line models contained in the PSS®E dynamics model library.

Model	Description
HVDCPL1	Siemens HVDC plus model
VSCDCT	Two-terminal VSC dc line model

15.1. HVDCPL1

Siemens VSC DC line model for the HVDC Plus

ICONs	Value	Description
M		Type of Application: 1 = interconnected power systems (IPS application), 2 = Wind park (WP application)

CONs	Values	Description
J		Rated AC voltage on DC side of converter Xfmr [kV]
J+1		Rectifier transformer impedance [pu of SBASE]
J+2		Inverter transformer impedance [pu of SBASE]
J+3		DC line total inductance [H]
J+4		DC line total capacitance [F]
J+5		Gain GQr of the rectifier reactive power controller
J+6		Lead time constant TLeadQr of the rectifier reactive power controller [s]
J+7		Lag time constant TLagQr of the rectifier reactive power controller [s]
J+8		Gain GQi of the inverter reactive power controller
J+9		Lead time constant TLeadQi of the inverter reactive power controller [s]
J+10		Lag time constant TLagQi of the inverter reactive power controller [s]
J+11		Gain G1Ud of the DC voltage controller
J+12		Lead time constant TLead1Ud of the DC voltage controller [s]
J+13		Lag time constant TLag1Ud of the DC voltage controller [s]
J+14		Gain G2Ud of the DC voltage controller
J+15		Lead time constant TLead2Ud of the DC voltage controller [s]
J+16		Lag time constant TLag2Ud of the DC voltage controller [s]
J+17		Ramp rate of the inverter active power setting value [pu/s] (used for interconnected application)
J+18		Gain G_{1P} of the inverter active power controller (interconnected application)
J+19		Lead time constant TLead1P of the inverter active power controller [s] (interconnected application)
J+20		Lag time constant TLag1P of the inverter active power controller [s] (interconnected application)
J+21		Gain G_{2P} of the inverter active power controller (interconnected application)
J+22		Lead time constant TLead2P of the inverter active power controller [s] (interconnected application)
J+23		Lag time constant TLag2P of the inverter active power controller [s] (interconnected application)
J+24		TIntQr (s); Rectifier Q controller integrator time constant
J+25		LMXQr (pu); Rectifier Q controller integrator upper limit
J+26		LMNQr (pu); Rectifier Q controller integrator lower limit

CONs	Values	Description
J+27		TIntQi (s); Inverter Q controller integrator time constant
J+28		LMXQi (pu); Inverter Q controller integrator upper limit
J+29		LMNQi (pu); Inverter Q controller integrator lower limit
J+30		TIntUd (s); Inverter dc voltage controller integrator time constant
J+31		LMXIUd (pu); Inverter dc voltage controller integrator upper limit
J+32		LMNIUd(pu); Inverter dc voltage controller integrator lower limit
J+33		$T_I$ntP (s); Inverter P controller integrator integrator time constant
J+34		LMXP (pu); Inverter P controller integrator upper limit
J+35		LMNP (pu); Inverter P controller integrator lower limit
J+36		Tsync (s); Inverter POI Angle measurement delay
J+37		LMX1Ud (deg.); Rectifier dc voltage controller first lead-lag upper limit
J+38		LMN1Ud (deg.); Rectifier dc voltage controller first lead-lag lower limit
J+39		LMX2Ud (deg.); Rectifier dc voltage controller second lead-lag upper limit
J+40		LMN2Ud (deg.); Rectifier dc voltage controller second lead-lag lower limit
J+41		LMX1P (deg.); Inverter P controller first lead-lag upper limit
J+42		LMN1P (deg.); Inverter P controller first lead-lag lower limit
J+43		LMX2P (deg.); Inverter P controller second lead-lag upper limit
J+44		LMN2P (deg.); Inverter P controller second lead-lag lower limit
J+45		C_Module (F),Converter module capacitor
J+46		V_Module (kV), Converter module rated capacitor voltage
J+47		Protection threshold peak current of the IGBTs, kA
J+48		Model Acceleration factor(>0 and <=1)
J+49		Undervoltage characteristics, X1 (measured AC-voltage in pu)
J+50		Undervoltage characteristics, Y1 (AC-voltage reference in pu)
J+51		Undervoltage characteristics, X2
J+52		Undervoltage characteristics, Y2
J+53		Undervoltage characteristics, X3
J+54		Undervoltage characteristics, Y3
J+55		Undervoltage characteristics, X4
J+56		Undervoltage characteristics, Y4
J+57		Undervoltage characteristics, X5
J+58		Undervoltage characteristics, Y5
J+59		Undervoltage characteristics, X6
J+60		Undervoltage characteristics, Y6
J+61		Undervoltage characteristics, X7
J+62		Undervoltage characteristics, Y7
J+63		Undervoltage characteristics, X8

CONs	Values	Description
J+64		Undervoltage characteristics, Y8
J+65		Undervoltage characteristics, X9
J+66		Undervoltage characteristics, Y9
J+67		Undervoltage characteristics, X10
J+68		Undervoltage characteristics, Y10
J+69		Power-Voltage characteristics, X1 (measured AC-voltage in pu)
J+70		Power-Voltage characteristics, Y1 (maximum active power in pu of MVA rating of second converter)
J+71		Power-Voltage characteristics, X2
J+72		Power-Voltage characteristics, Y2
J+73		Power-Voltage characteristics, X3
J+74		Power-Voltage characteristics, Y3
J+75		Power-Voltage characteristics, X4
J+76		Power-Voltage characteristics, Y4
J+77		Power-Voltage characteristics, X5
J+78		Power-Voltage characteristics, Y5
J+79		Power-Voltage characteristics, X6
J+80		Power-Voltage characteristics, Y6
J+81		DC Chopper characteristics, X1 (Direct voltage in pu)
J+82		DC Chopper V-I characteristics, Y1 (chopper current in kA)
J+83		DC Chopper characteristics, X2
J+84		DC Chopper characteristics, Y2
J+85		DC Chopper characteristics, X3
J+86		DC Chopper characteristics, Y3
J+87		DC Chopper characteristics, X4
J+88		DC Chopper characteristics, Y4
J+89		DC Chopper characteristics, X5
J+90		DC Chopper characteristics, Y5
J+91		DC Chopper characteristics, X6
J+92		DC Chopper characteristics, Y6
J+93		DC Chopper characteristics, X7
J+94		DC Chopper characteristics, X7
J+95		DC Chopper characteristics, X8
J+96		DC Chopper characteristics, X8
J+97		DC Chopper characteristics, X9
J+98		DC Chopper characteristics, X9
J+99		DC Chopper characteristics, X10
J+100		DC Chopper characteristics, X10

STATEs	Description
K	Rectifier Q-control lead-lag
K+1	Rectifier Q-control integrator

STATEs	Description
K+2	Ud-control lead-lag 1
K+3	Ud-control lead-lag 2
K+4	Ud-control integrator
K+5	Inverter POI synchronisation angle [deg]
K+6	Inverter Q-control lead-lag
K+7	Inverter Q-control integrator
K+8	Rectifier capacitor voltage [V]
K+9	Rectifier DC line current [A]
K+10	Voltage of the DC line's equivalent capacitor [V]
K+11	Inverter DC line current [A]
K+12	Inverter capacitor voltage [V]
K+13	Inverter P-control lead-lag 1 (used only for an Interconnected application)
K+14	Inverter P-control lead-lag 2 (used only for an Interconnected application)
K+15	Inverter P-control integrator (used only for an Interconnected application)
K+16	Rectifier POI synchronisation angle [deg]
K+17	Inverter P-control rate limiter (used only for an Interconnected application)

VARs	Description
L	Rectifier Q-reference [pu of rectifier MVA rating]
L+1	Inverter Ud-reference [V] (only for a WP application)
L+2	Inverter Q-reference [pu of rectifier MVA rating]
L+3	Rectifier Q at the Point of Interconnection (POI) [pu of rectifier MVA rating]
L+4	Inverter voltage phase angle [rad]
L+5	Inverter Q at the POI [pu of rectifier MVA rating]
L+6	AC voltage reference [pu] (inverter Q-control)
L+7	Rectifier voltage magnitude [pu]
L+8	Inverter voltage magnitude [pu]
L+9	Rectifier voltage phase angle [rad]
L+10	Inverter direct current [A]
L+11	Rectifier direct current [A]
L+12	Chopper current [A]
L+13	Limit of the active power setting value [pu]
L+14	Rectifier active power at the POI [pu of rectifier MVA rating]
L+15	Setpoint of the rectifier voltage magnitude [pu]
L+16	Rectifier AC current [kA peak]
L+17	Inverter AC current [kA peak]
L+18	Setpoint of the inverter voltage magnitude [pu]
L+19	AC voltage reference [pu] rectifier Q-control)
L+20	Inverter active power at the POI [pu of inverter MVA rating]
L+21	Rectifier Vd-reference [V], used only for Interconnected application
L+22	Inverter real power-reference from the load flow [pu of inverter MVA rating]

VARs	Description
L+33	VARs required for internal program logic
...	
L+26	

Dynamic data record:

```
'VSC DC line name' HVDCPL1'

ICON(M), CON(J) to CON(J+100) /
```

Notes:

1. The model is suitable for time step increments in the range of 1ms - 10ms.

2. The converter transformer is a part of the model. It's reactance is used internally.

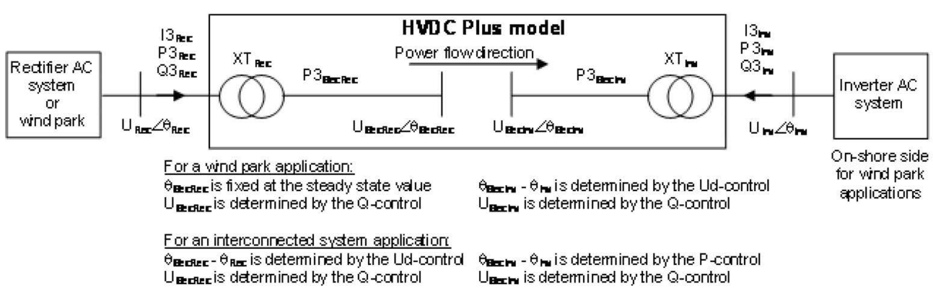
3. The model does not have provision for auxiliary signals (like damping controllers etc.).

4. Converter losses can be considered using the Aloss and Bloss coefficients, which are part of the VSC load flow data power record.

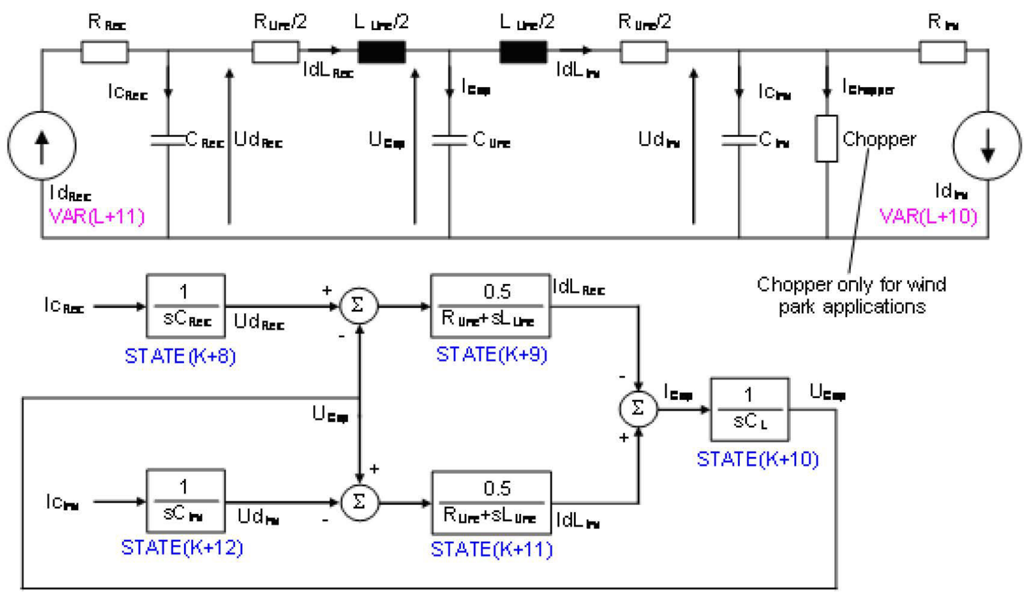
5. The respective VSC load flow model must not have a converter MVA rating (SMAX) of zero. If the user specifies a converter MVA rating of zero the model is ignored.

6. The DC chopper characteristics are required only for Wind park application. For interconnected applications, the 10 pairs of (X,Y) points representing the DC chopper characteristics can be set to zero.

15.1.1. Model Configuration

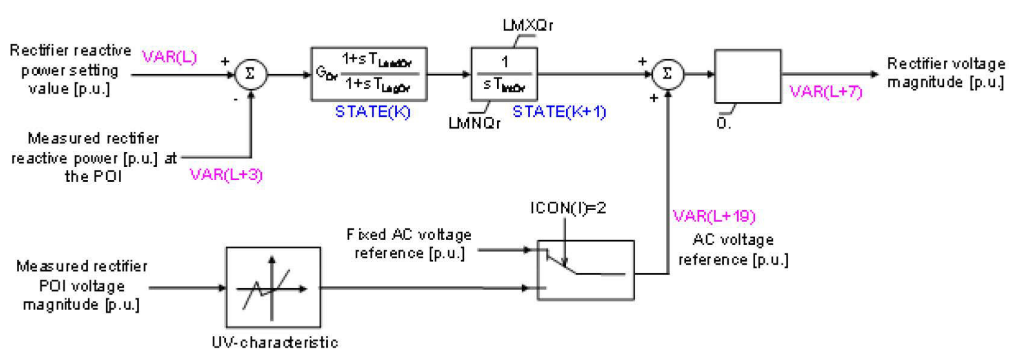


15.1.2. Model of the DC Circuit



15.1.3. HVDC Plus common control functions for all types of application

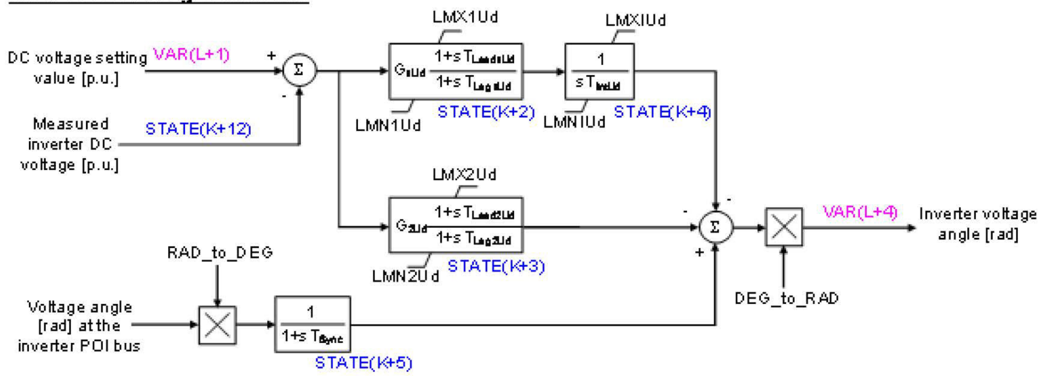
Rectifier reactive power controller



15.1.4. HVDC Plus control functions for a wind park application

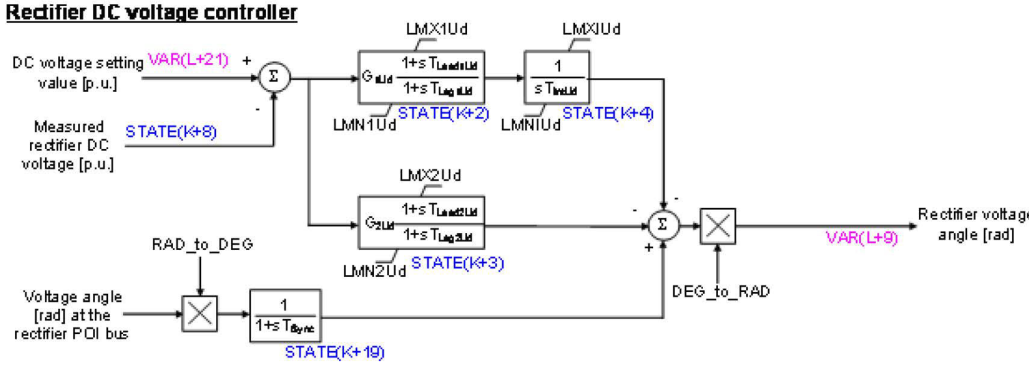
Fixed rectifier voltage angle

Inverter DC voltage controller

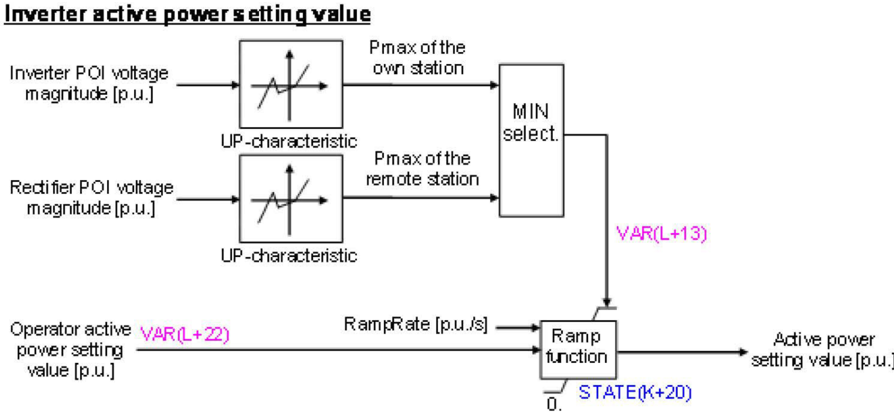


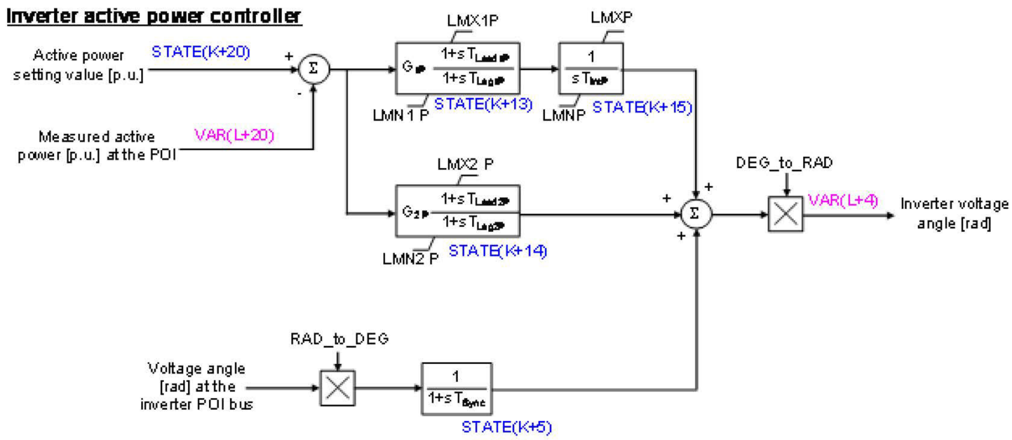
15.1.5. HVDC Plus control functions for an interconnected system application

Rectifier DC voltage controller



Inverter active power setting value




Inverter active power controller
Active power setting value [p.u.]
STATE(K+20)
Measured active power [p.u.] at the POI
VAR(L+20)
LMX1P
LMN1P
STATE(K+13)
LMXP
LMNP
STATE(K+15)
LMX2 P
LMN2 P
STATE(K+14)
DEG_to_RAD
VAR(L+4)
Inverter voltage angle [rad]
RAD_to_DEG
Voltage angle [rad] at the inverter POI bus
STATE(K+5)

15.2. VSCDCT

VSC DC Model with Two VSC Converters

ICONs	Value	Description
M	0	Block_Flag_1: 1 Blocked Converter (For VSC #1)
M+1	0	XFBus_Ctrl_Side_1, System bus number for voltage or reactive power control. When 0, controlled bus number is assigned from corresponding power flow input data (For VSC #1).
M+2	0	Block_Flag_2: 1 Blocked Converter (For VSC #2)
M+3	0	XFBus_Ctrl_Side_2, System bus number for voltage or reactive power control. When 0, controlled bus number is assigned from corresponding power flow input data (For VSC #2).

CONs	Values	Description
J		Tpo_1, Time constant of active power order controller, sec (For VSC #1).
J+1		AC_VC_Limits_1, Reactive power limit for ac voltage control, pu on converter MVA rating. When 0, it is not used and Qmax/Qmin pair is used instead (For VSC #1).
J+2		AC_Vctrl_kp_1, AC Voltage control proportional gain, converter MVA rating/BASEKV (For VSC #1).
J+3		T_ac_1 > 0.0, Time constant for AC voltage PI integral, sec (For VSC #1). When 0, VSC #1 is ignored.
J+4		$T_a$cm_1, Time constant of the ac voltage transducer, sec (For VSC #1).
J+5		I_{ACMAX}_1, Current Limit, pu on converter MVA rating (For VSC #1).
J+6		Droop_1, AC Voltage control droop, converter MVA rating/BASEKV (For VSC #1).
J+7		VCMX_1, Maximum VSC Bridge Internal Voltage (For VSC #1).
J+8		XREACT_1 > 0.0, Pu reactance of the ac series reactor on converter MVA rating (For VSC #1). When 0.0, default value 0.17 is used.
J+9		QMAX_1, Maximum system reactive limits in Mvars (For VSC #1). When AC-VC_Limits_1 >0, QMAX_1 is not used.
J+10		QMIN_1, Minimum system reactive limits in MVARs (For VSC #1). When AC-VC_Limits_1 >0, QMIN_1 is not used.
J+11		AC_VC_KT_1, Adjustment Parameter for the feedback from reactive power limiter to ac voltage controller (For VSC #1).
J+12		AC_VC_KTP_1, Adjustment Parameter for the feedback from current order limiter to ac voltage controller (For VSC #1).
J+13		Tpo_2, Time constant of active power order controller, sec (For VSC #2).
J+14		AC_VC_Limits_2, Reactive power limit for ac voltage control, pu on converter MVA rating. When 0, it is not used and Qmax/Qmin pair is used instead (For VSC #2).

CONs	Values	Description
J+15		AC_Vctrl_kp_2, AC Voltage control proportional gain, converter MVA rating/BASEKV (For VSC #2).
J+16		T_ac_2 > 0.0, Time constant for AC voltage PI integral, sec (For VSC #2). When 0, VSC #2 is ignored.
J+17		$T_a$cm_2, Time constant of the ac voltage transducer, sec (For VSC #2).
J+18		I_{ACMAX}_2, Current Limit, pu on converter MVA rating (For VSC #2).
J+19		Droop_2, AC Voltage control droop, converter MVA rating/BASEKV (For VSC #2).
J+20		VCMX_2, Maximum VSC Bridge Internal Voltage (For VSC #2).
J+21		XREACT_2 > 0.0, Pu reactance of the ac series reactor on converter MVA rating (For VSC #2). When 0.0, default value 0.17 is used.
J+22		QMAX_2, Maximum system reactive limits in MVARs (For VSC #2). When AC-VC_Limits_2 >0, QMAX_2 is not used.
J+23		QMIN_2, Minimum system reactive limits in MVARs (For VSC #2). When AC-VC_Limits_2 >0, QMIN_2 is not used.
J+24		AC_VC_KT_2, Adjustment Parameter for the feedback from reactive power limiter to ac voltage controller (For VSC #2).
J+25		AC_VC_KTP_2, Adjustment Parameter for the feedback from current order limiter to ac voltage controller (For VSC #2).
J+26		Tpo_DCL, Time constant of the power order controller, sec (For DC Line).
J+27		Tpo_lim, Time constant of the power order limit controller, sec (For DC Line).

STATEs	Description
K	P_ref_pu, Active power reference auxiliary input, pu on converter MVA rating (For VSC #1).
K+1	Uac_int, AC Voltage controller integral output, pu on converter MVA rating (For VSC #1.
K+2	Uac_p_filt, AC voltage measured, pu (For VSC #1).
K+3	P_ref_pu, Active power reference auxiliary input, pu on converter MVA rating (For VSC #2).
K+4	Uac_int, AC Voltage controller integral output, pu on converter MVA rating (For VSC #2).
K+5	Uac_p_filt, AC voltage measured, pu (For VSC #2).
K+6	P_ret_pu, Power Order, pu on SBASE (For DC Line).
K+7	Plimit, Power Order Limit, pu on SBASE (For DC Line).

VARs	Description
L	P_aux, Active power reference auxiliary order, MW (For VSC #1); uses auxiliary signal index #1
L+6	Q_ref, Reactive power order, pu on converter MVA rating (For VSC #1).
L+7	P_ref, Interface Active power, pu on SBASE (For VSC #1).

VARs	Description
L+10	PELE, Active power, pu on SBASE (For VSC #1).
L+11	QELE, Reactive power, pu on SBASE (For VSC #1).
L+12	P_aux, Active power reference auxiliary order, MW (For VSC #2); uses auxiliary signal index #2
L+18	Q_ref, Reactive power order, pu on converter MVA rating (For VSC #2).
L+19	P_ref, Interface Active power, pu on SBASE (For VSC #2).
L+22	PELE, Active power, pu on SBASE (For VSC #2).
L+23	QELE, Reactive power, pu on SBASE (For VSC #2).
L+24	P_ref_main, Active power main order, pu on SBASE (For DC Line).
L+32	Pzero_loss, DC system losses at zero current, MW (For DC Line).
L+33	Pdc_loss, DC losses, MW (For DC Line).
L+34 ... L+45	Isormod History, PSSE Variables for internal usage as well as: L+1 through L+5, L+8, L+9, L+13 through L+17, L+20, L+21, L+25 through L+31.

```
'VSC Name' , 'VSCDCT', ICON(M) to ICON(M+3), CON(J) to CON(J+27)   /
```

Notes:

The vendor, ABB, did not provide a block model diagram and thus we are unable to provide one.

Smax (Converter MVA rating) should be non-zero in power flow input data when VSCDCT model is used for stability simulations.

Chapter 16
FACTS Device Models

This chapter contains a collection of data sheets for the FACTS device (device modeled as FACTS in power flow) models contained in the PSS®E dynamics model library.

Model	Description
CSTCNT	Static Condenser (modeled as FACTS device in power flow).
SVSMO3T2	WECC Generic STATCOM based SVC model

16.1. CSTCNT

FACTS Device Static Condenser (STATCON)

ICON	Value	Description
M		IB, remotely regulated bus1 The remote bus has to be either a load bus or a generator bus. If this is not the case, internally the remote bus will be set same as local bus. If the user wants to input a remote bus that is the same as the local bus, IB can either be specified to be the local bus number, or can be set to 0.1

CONs	Value	Description
J		T_1 (>0)
J+1		T_2 (>0)
J+2		T_3 (>0)
J+3		T_4 (>0)
J+4		$K\left(\text{typical} = \frac{25}{dv/de_i}\right)$
J+5		Droop (typical = 0.03)
J+6		V_{MAX} (typical = 999)
J+7		V_{MIN} (typical = -999)
J+8		I_{CMAX} (typical = 1.25) Max capacitive current
J+9		I_{LMAX} (typical = 1.25) Max inductive current
J+10		V_{CUTOUT} (typical = 0.2)
J+11		E_{limit} (typical = 1.2)
J+12		X_t (>0) (transformer reactance, typical = 0.1)
J+13		Acc (acceleration factor, typical = 0.5)
J+14		STBASE (>0) STATCON base MVA

STATEs	Description
K	First regulator
K+1	Second regulator
K+2	Integrator

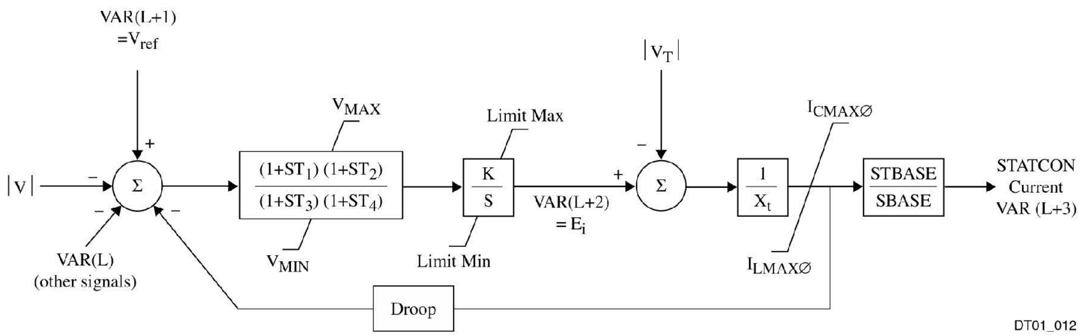
VARs	Description
L	Other signals [FCTSIG (1, NF)]1 This model uses auxiliary signal output stored in FCTSIG (1, NF), (i.e., auxiliary signal index 1).1
L+1	Vref
L+2	STATCON internal voltage (Ei)
L+3	STATCON current 2 Positive STATCON current [VAR(L+3)] corresponds to STATCON performance as capacitor.2 , 3, VAR(L+3) is on SBASE.3 4 Specify STATCON input parameters on STATCON base MVA.4

DYRE Data Record:

```
BUSID 'CSTCNT',IB,T1,T2,T3,T4,K,Droop,VMAX,VMIN,ICMAX,ILMAX,VCUTOUT,
Elimit,Xt,Acc,STBASE/
```

Where:

BUSID is the FACTS device name (in single quotes)



|V| : Voltage of the regulated bus, |VT| : Voltage at the STATCON bus.

Limit Max = |VT| + $XtI_{CMAXØ}$

Limit Min = |VT| - $XtI_{LMAXØ}$

Limit Max ≤ E_{limit}

where:

ICMAXØ = ICMAX when |VT| ≥ VCUTOUT

$$= \frac{I_{CMAX}*|V_T|}{V_{cutout}} \quad \text{otherwise}$$

ILMAXØ = ILMAX when |VT| ≥ V>CUTOUT

$$= \frac{I_{LMAX}*|V_T|}{V_{cutout}} \quad \text{otherwise}$$

16.2. SVSMO3T2

WECC Generic STATCOM based SVC model

ICON	Value	Description
M		Remote bus number for voltage regulation
M+1		Disable or enable coordinated MSS switching, 0 - no MSS switching, 1 - MSS switching based on STATCOM current
M+2		flag1, slow-reset off/on, flag1 (0/1)
M+3		flag2, non-linear droop off/on, flag2 (0/1)
M+4		1st MSS bus #
M+5		1st MSS Id (to be entered within single quotes)
M+6		2nd MSS bus #
M+7		2nd MSS Id (to be entered within single quotes)
M+8		3rd MSS bus #
M+9		3rd MSS Id (to be entered within single quotes)
M+10		4th MSS bus #
M+11		4th MSS Id (to be entered within single quotes)
M+12		5th MSS bus #
M+13		5th MSS Id (to be entered within single quotes)
M+14		6th MSS bus #
M+15		6th MSS Id (to be entered within single quotes)
M+16		7th MSS bus #
M+17		7th MSS Id (to be entered within single quotes)
M+18		8th MSS bus #
M+19		8th MSS Id (to be entered within single quotes)

CONs	Value	Description
J		Xc0, Linear droop
J+1		Tc1, Voltage measurement lead time constant
J+2		T_b1, Voltage measurement lag time constant
J+3		K_p, Proportional gain
J+4		K_I, Integral gain
J+5		Vemax, Voltage error max. (pu)
J+6		Vemin, Voltage error min. (pu)
J+7		T0, Firing sequence control delay (sec)
J+8		Imax1, Max. continuous current rating (pu on STATCOM BASE MVA (STBASE))
J+9		dbd, Deadband in voltage control (pu)
J+10		$K_d$bd, Ratio of outer to inner deadband
J+11		Tdbd, Deadband time (sec)
J+12		K_pr, Proportional gain for slow-reset control

CONs	Value	Description
J+13		K_Ir, Integral gain for slow-reset control
J+14		Idbd, Deadband range for slow-reset control (pu on STBASE)
J+15		Vr_{max}, Max. limit on slow-reset control output (pu)
J+16		Vr_{min}, Min. limit on slow-reset control output (pu)
J+17		Max. short-term current rating as a multiplier of max. continuous current rating pu
J+18		UV_1, Voltage at which STATCOM limit starts to be reduced linearly (pu)
J+19		UV_2, Voltage below which STATCOM is blocked (pu)
J+20		OV_1, Voltage above which STATCOM limit linearly drops (pu)
J+21		OV_2, Voltage above which STATCOM blocks (pu)
J+22		Vtrip, Voltage above which STATCOM trips after time dealy, Tdelay2 (pu)
J+23		Tdelay1, duration of short-term rating(sec)
J+24		Tdelay2, Trip time for V > Vtrip (sec)
J+25		Vrefmax, Max. voltage reference limit (pu)
J+26		Vrefmin, Min. voltage reference limit (pu)
J+27		Tc2, lead time constant (sec)
J+28		T_b2, lag time constant (sec)
J+29		I2t, short-term limit
J+30		Reset, Reset rate for I2t limit
J+31		hyst, Width of hysteresis loop for I2t limit
J+32		Xc1, Non-linear droop slope 1
J+33		Xc2, Non-linear droop slope 2
J+34		Xc3, Non-linear droop slope 3
J+35		V_1, Non-linear droop upper voltage (pu)
J+36		V_2, Non-linear droop lower voltage (pu)
J+37		Tmssbrk, time for MSS breaker to operate - typically ignore (sec)
J+38		Tout, Time MSC should be out before switching back in (sec)
J+39		TdelLC, time delay for switching in a MSS (sec)
J+40		Iupr, Upper threshold for switching MSSs (pu on STBASE)
J+41		Ilwr, Lower threshold for switching MSSs (pu on STBASE)
J+42		Sdelay, time for which STATCOM to remain blocked before being un-blocked (sec)
J+43		STBASE(>0), STATCOM base MVA

STATEs	Description
K+1	STATCOM main PI controller integrator
K+2	STATCOM output Lag
K+3	STATCOM slow-reset PI controller integrator
K+4	Short-term rating integrator
K+5	Lead-lag block

VARs	Description
L	STATCOM output, STATCOM terminal current (pu on STATCOM BASE MVA (ST-BASE))
L+1	STATCOM reactive power output (pu on STBASE)
L+2	STATCOM output in MVAr
L+3	Output of main PI controller
L+4	STATCOM lead-lag output before PI controller
L+5	STATCOM voltage error signal into lead-lag block
L+6	Reference voltage of STATCOM
L+7	Output of slow-secondary loop current PI regulator
L+8	Measurement lead-lag transducer output
L+9	Imax timer
L+10	Imax1*Ishrt
L+11	Timer for MSS starting >I demand
L+12	Timer for MSS starting <I demand
L+13 through L +20	Timer for MSS1 through MSS8
L+21	MSS timer monitors Tdelay+Tmssbrk
L+22	Deadband timer
L+23	I block timer
L+24	Time at which VBUS .GT. Vtrip
L+25	Scheduled voltage of STATCOM
L+26	Optional auxiliary signal (Vsig) input

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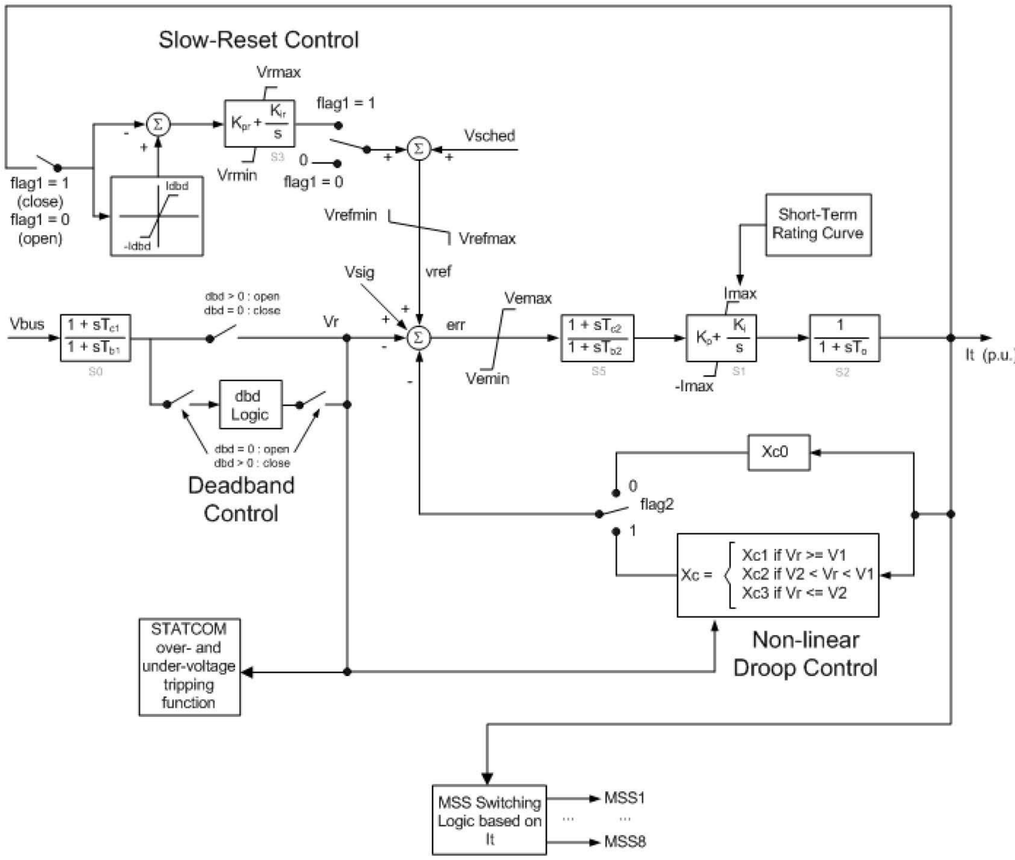
'FACTS Name' 'SVSMO3T2' , ICON(M) to ICON(M+19), CON(J) to CON(J+43)   /
```



Slow-Reset Control
Vrmax
flag1 = 1
Vsched
Vrmin
0
flag1 = 0
flag1 = 1
(close)
flag1 = 0
(open)
Idbd
-Idbd
Vrefmin
Vrefmax
Short-Term
Rating Curve
Vsig
vref
Imax
Vemax
Vbus
dbd > 0 : open
dbd = 0 : close
Vr
err
It (p.u.)
Vemin
-Imax
dbd
Logic
dbd = 0 : open
dbd > 0 : close
Deadband
Control
Xc0
0
flag2
1
Xc1 if Vr >= V1
Xc2 if V2 < Vr < V1
Xc3 if Vr <= V2
Non-linear
Droop Control
STATCOM
over- and
under-voltage
tripping
function
MSS Switching
Logic based on
It
MSS1
MSS8

Chapter 17

Generic Renewable Generator Models

This chapter contains a collection of data sheets for the generic renewable generator models contained in the PSS®E dynamics model library.

Model	Description
DERAU1	Distributed Energy Resource Generator/Converter Model
PVGU1	User written generator model to represent photo-voltaic (PV) systems
REGCA1	Renewable Energy Generator model
REGCAU2	Renewable Energy Generator/Converter model
REGCBU1	Renewable Energy Generator/Converter model
WT1G1	Direct connected (Type 1) generator
WT2G1	Induction generator with controlled external rotor resistor (Type 2)
WT3G1	Doubly-fed induction generator (Type 3)
WT3G2	Doubly-fed induction generator (Type 3), version 2
WT4G1	Wind generator model with power converter (Type 4)
WT4G2	Wind generator model with power converter (Type 4), version 2

17.1. DERAU1

Distributed Energy Resource Generator/Converter Model

ICON	Value	Description
M		PfFlag: • 1 : constant power factor • 0 : constant Q control
M+1		FreqFlag: • 1 : frequency control enabled • 0 : frequency control disabled
M+2		PQFlag: • 1 : priority for current limit • 0 : Q priority
M+3		GenFlag: • 1 : unit is a generator • 0 : unit is a storage device (Note 6)
M+4		VtripFlag (flag to enable/disable voltage trip logic): • 1 : enable • 0 : disable
M+5		FtripFlag (flag to enable/disable frequency trip logic): • 1 : enable • 0 : disable

CONs	Value	Description
J		T_{rv} (s), voltage measurement transducer time constant
J+1		Trf (s), frequency measurement transducer time constant
J+2		dbd1 (pu), lower voltage deadband (<= 0) (Note 2)
J+3		dbd2 (pu), upper voltage deadband (> 0) (Note 2)
J+4		Kqv (pu), proportional voltage control gain
J+5		Vref0 (pu), user specified voltage set-point (Note 2)
J+6		Tp (s), power measurement transducer time constant
J+7		Tiq (s), Q-control time constant
J+8		Ddn (pu), reciprocal of droop for over-frequency conditions (> 0)
J+9		Dup (pu), reciprocal of droop for under-frequency conditions (> 0)
J+10		fdbd1 (pu), deadband for frequency control, lower threshold (<= 0)

CONs	Value	Description
J+11		fdbd2 (pu), deadband for frequency control, upper threshold (>= 0)
J+12		femax (pu), frequency error upper limit
J+13		femin (pu), frequency error lower limit
J+14		PMAX (pu), Maximum power limit
J+15		PMIN (pu), Minimum power limit
J+16		dPmax (pu/s), Power reference maximum ramp rate (> 0)
J+17		dPmin (pu/s), Power reference minimum ramp rate (< 0)
J+18		Tpord (s), Power filter time constant
J+19		Kpg (pu), PI controller proportional gain
J+20		Kig (pu), PI controller integral gain
J+21		Imax (pu), Maximum converter current (see Note 3)
J+22		vl0 (pu), inverter voltage break-point for low voltage cut-out (Note 4)
J+23		vl1 (pu), inverter voltage break-point for low voltage cut-out (vl1 > vl0) (Note 4)
J+24		vh0 (pu), inverter voltage break-point for high voltage cut-out (Note 4)
J+25		vh1 (pu), inverter voltage break-point for high voltage cut-out (vh1 < vh0) (Note 4)
J+26		tv10 (s), low voltage cut-out timer corresponding to voltage vl0
J+27		tvl1 (s), low voltage cut-out timer corresponding to voltage vl1
J+28		tvh0 (s), high voltage cut-out timer corresponding to voltage vh0
J+29		tvh1 (s), high voltage cut-out timer corresponding to voltage vh1
J+30		Vrfrac, fraction of device that recovers after voltage comes back to within vl1 < V < vh1 (0 <= Vrfrac <= 1)
J+31		fl (Hz), inverter frequency break-point for low frequency cut-out (Note 5)
J+32		fh (Hz), inverter frequency break-point for high frequency cut-out (Note 5)
J+33		tfl (s), low frequency cut-out timer corresponding to frequency fl
J+34		tfh (s), high frequency cut-out timer corresponding to frequency fh
J+35		Tg (s), current control time constant (to represent behavior of inner control loops) (> 0)
J+36		rrpwr (pu/s), ramp rate for real power increase following a fault
J+37		Tv (s), time constant on the output of the multiplier
J+38		Vpr (pu), voltage below which frequency tripping is disabled
J+39		Iqhl (pu), Upper limit on reactive current injection Iqinj
J+40		Iqll (pu), Lower limit on reactive current injection Iqinj

STATEs	Description
K	voltage measurement lag
K+1	generator power measurement lag
K+2	first order lag for reactive current
K+3	lag block representing inner current loop for iq

STATEs	Description
K+4	lag block for output of multiplier block
K+5	frequency measurement lag
K+6	PI controller for real power path
K+7	first order lag for dpmax and dpmin
K+8	first order lag for Pord
K+9	lag block representing inner current loop for id

VARs	Description
L	bus voltage reference (Vref0)
L+1	power factor angle reference (pfaref), radians
L+2	reference frequency deviation
L+3	active power reference (Pref)
L+4	reactive power reference (Qref)
L+5	output of voltage deadband dbd1, dbd2
L+6	output of voltage deadband dbd1, dbd2
L+7	Ipcmd
L+8	Iqcmd
L+9	Vmin (vl0 <= Vmin <= vl1), minimum voltage at the terminals of the model after the tvl1 timer expires (for undervoltage tripping logic)
L+10	Vmax (vh1 <= Vmin <= vh0), maximum voltage at the terminals of the model after the tvh1 timer expires (for overvoltage tripping logic)
L+11	output of undervoltage voltage multiplier block (0 <= multiplier <= 1)
L+12	output of overvoltage voltage multiplier block (0 <= multiplier <= 1)
L+13	output of frequency multiplier block (is either 0 or 1)
L+14	time at which terminal voltage becomes less than vl0 followed by time at which vl0 timer expires
L+15	time at which terminal voltage becomes less than vl1 followed by time at which vl1 timer expires
L+16	time at which terminal voltage becomes greater than vh0 followed by time at which vh0 timer expires
L+17	time at which terminal voltage becomes greater than vh1 followed by time at which vh1 timer expires
L+18	time at which frequency becomes less than fl followed by time at which fl timer expires
L+19	time at which frequency becomes greater than fh followed by time at which fh timer expires
L+20	fraction of DER that tripped
L+21	bus voltage angle from previous time step
L+22	reactive current injection, Iqinj

```
IBUS   'USRMDL'   ID   'DERAU1'    101     1    6    41    10     23
 ICON(M) to ICON(M+5)     CON(J) to CON(J+40)    /
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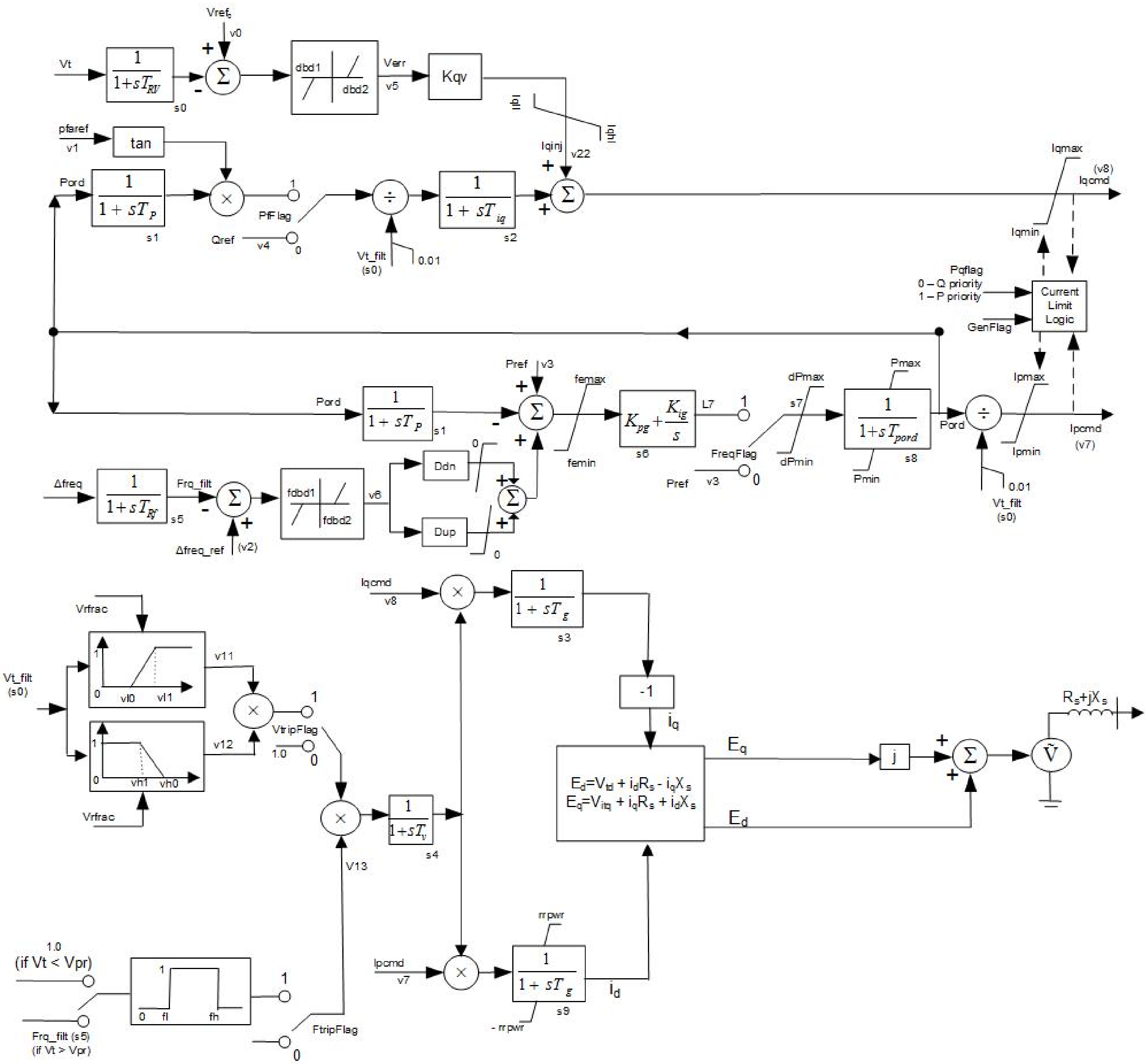


Notes:

1. Use of this model requires the machine to be designated as a renewable machine (in version 34 and above) and as a wind machine (in version 33).

2. Vref0 can be specified as an input parameter. If initial Vref0 is specified as being ≤ 0.0, model will set this to be equal to the initial terminal voltage Vt. If Vref0 is specified to be greater than zero, and if Kqv is greater than zero, then upon initialization model will check if dbd1 <= Vref0 – Vt <= dbd2. If

this condition is not met, the model will set the initial Vref0 to be equal to Vt to force the Vref0 – Vt to be within the deadbands dbd1 and dbd2. If dbd1=dbd2=0 (which should not be done since DG models are not intended to tightly control voltage) and Kqv is greater than zero, the model will set the initial Vref0 equal to Vt to force the error to zero.

3. Imax is used to calculate Ipmax and Iqmax

If Pqflag is 0 (Q-priority):

Iqmax = Imax

Iqmin = -Imax

Ipmax = sqrt((I_max)^2- (I_qcmd)^2)

Ipmin = -Ipmax

If Pqflag is 1 (P-priority):

Ipmax = Imax

Ipmin = -Imax

Iqmax = sqrt((I_max)^2-(I_pcmd)^2)

Iqmin = -Iqmax

4. vl0 can be equal to vl1 (both can be set equal to 0.0). Similarly vh0 can be equal to vh1 (greater than the initial machine terminal voltage).

At initialization, if vl0 or vl1 is found to be greater (or if vh0 or vh1 is less) than the initial vt (terminal voltage), the undervoltage (overvoltage) trip logic will be disabled. The parameters Vrfrac, vl0, vl1, vh0, vh1, tvl0, tvl1, tvh0, tvh1 collectively allow for emulation of partial tripping of aggregated distributed generation model. The linear drop-off between vl0 and vl1, and between vh0 and vh1 is intended to emulate the voltage gradient along the feeder

5. At initialization, if fl is found to be greater (or if fh is less) than the initial bus frequency, the frequency trip logic will be disabled.

6. 'genflag' (i.e., ICON(M+3)) value of 1 indicates the model is that of a renewable generator (i.e., can only generate real power), while a value of 0 indicates that the model is that of a storage device (i.e., it can be in the charging or discharging mode). If the model is that of a storage device, Ipmin is a negative number, else, Ipmin is zero.

7. The distributed generator (DG) model tripping and recovery logic for undervoltage is explained below. The tripping logic for overvoltage is similar to the undervoltage tripping logic.

The model is intended to be used as an aggregate model. The parameters Vrfrac, vl0, vl1, vh0, vh1, tvl0, tvl1, tvh0, and tvh1 allow for emulation of partial tripping of the aggregated distributed generator (which represents several DG on a feeder). The linear drop-off between vl0 and vl1 (for undervoltage) and vh0 and vh1 (for overvoltage conditions) is intended to emulate the gradient of the voltage along the feeder section. With reference to the linear trip curve shown below, the output of the trip block (which is the multiplier representing the remaining DG) could track the black or the red line.

When the voltage at the terminals goes below the Vlo setting, the multiplier is set to zero (i.e. all of the DER would have tripped).

If vt was less than vl0 for more than tvl0 seconds then the multiplier will always remain zero irrespective of whatever value vt subsequently is during simulation.

If vt is less than vl1 and if vt was less than vl1 for less than tvl1 seconds, the multiplier is calculated along the black line when the voltage recovers.

If vt is less than vl1 and if vt was less than vl1 for more than tvl1 seconds, the multiplier is calculated along the red line on recovery and the fraction that recovers is calculated using the Vrfrac data. This means that the Vrfrac data gets used only if the vl1 (or the vh1) timer times out.

If vt is greater than or equal to vl1 and if vt was less than vl1 for less than tvl1 seconds, then the multiplier is set equal to 1.0 (i.e., all of DG would be ON from the voltage point of view).

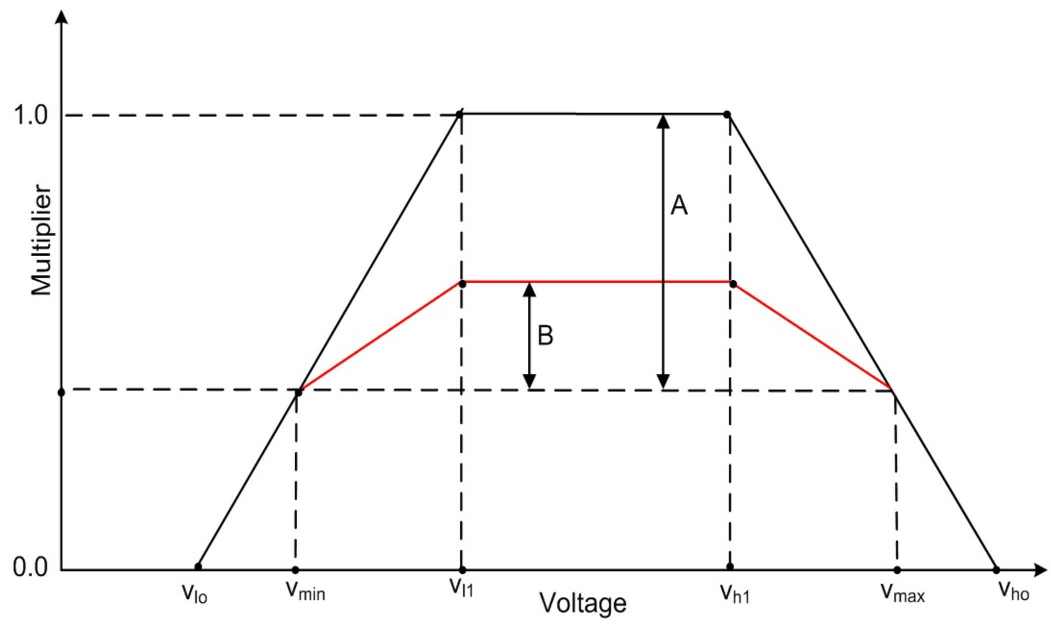
If vt is greater than or equal to vl1 and if vt was less than vl1 for more than tvl1 seconds, then the multiplier is set equal to B (=A*Vrfrac). The value of this multiplier is representative of the fraction of DG that will be ON following a prolonged undervoltage.

Similar logic holds for overvoltage tripping and recovery.

In the tripping logic figure shown below, Vmin is the lowest voltage (between vl0 and vl1, i.e., vl0 ≤ Vmin ≤ vl1) at the terminals of the DG during simulation after the timer tvl1 times out. With reference to the figure below,

B = A × Vrfrac

A can be shown to be equal to (vl1 - vmin)/(vl1 - vlo)

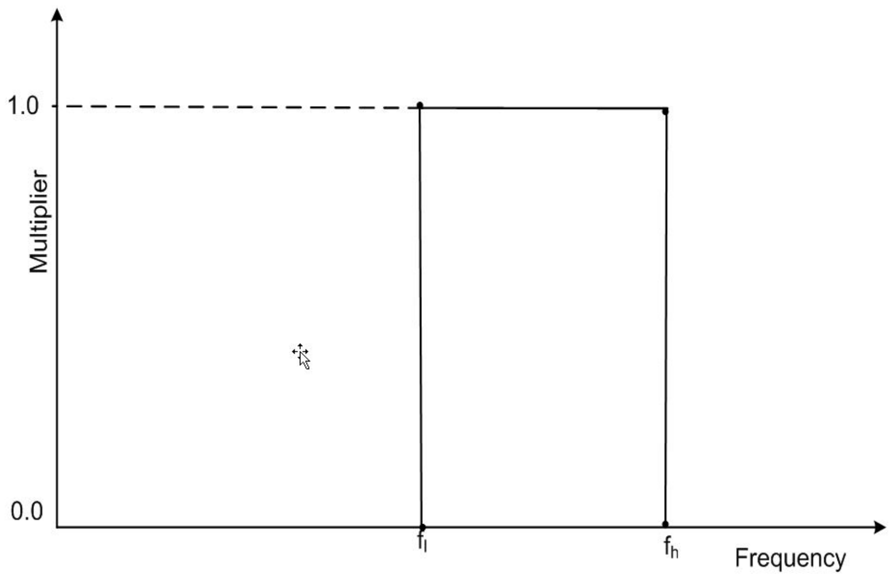


For the overvoltage tripping logic, the model uses Vmax, is the highest voltage (between vh0 and vh1, i.e., vh1≤ Vmax ≤ vh0) at the terminals of the DG during simulation after the timer tvh1 times out.

Following description about the purpose of the timers (tvl0, tvl1, tvh0, tvh1) has been taken from "Proposal for DER_A Model, WECC REMTF, dated October 11, 2016":

The purpose of the timers is to allow for the emulation of inverters disconnecting under low-voltage scenarios, for example, legacy technology may disconnect quickly for a small voltage dips (i.e. one may set vl1 = 0.9 and tvl1 = 0.1 s) while part of the aggregate model may be representing modern inverters that comply with newer standards where it will not disconnect unless the voltage drops significant for a longer duration (e.g. one may set vl0 = 0.5 and tvl0 = 1 s). Thus, this is to allow for testing various aspects of standards (such as IEEE Standard 1547 requirements, California Rule 21, etc.)

8. The tripping logic for frequency is as shown by the curve below.



If the frequency goes below fl for more than tfl seconds, then the multiplier for frequency trip logic is set to zero (i.e., the entire model will trip). Similarly, if the frequency goes above fh for more than tfh seconds, then the multiplier for frequency trip logic is set to zero (i.e., the entire model will trip). As long as the frequency (f) is such that fl ≤ f ≤ fh, the multiplier for frequency trip logic is 1.0.

The frequency trip logic is disabled if the voltage at the terminals of DG is less than the threshold Vpr specified in CON(J+38).

9. The machine in powerflow (to which this model is attached) should not have implicit transformer (i.e., RTRAN and XTRAN and in the powerflow record for this machine should be zero).

17.2. PVGU1

PV Converter

CONs	Value	Description
J		TIqCmd, Converter time constant for IQcmd, second
J+1		TIpCmd, Converter time constant for IPcmd, second
J+2		VLVPL1, Low voltage power logic (LVPL) voltage 1, pu
J+3		VLVPL2, LVPL voltage 2, pu
J+4		GLVPL gain
J+5		VHVRCR, High voltage reactive current (HVRC) logic voltage, pu
J+6		CURHVRCR, max. reactive current at VHVRCR, pu
J+7		Rip_LVPL, Rate of LVACR active current change
J+8		T_LVPL, voltage sensor for LVACR time constants

STATEs	Description
K	Converter lag for Ipcmd
K+1	Converter lag for Iqcmd
K+2	Voltage sensor for LVACR

VARs	Description
L through L+2	For internal use

```
IBUS 'USRMDL' ID 'PVGU1' 101 1 0 9 3 3 CON(J) to CON(J+8) /
```

17.3. REGCA1

Renewable Energy Generator/Converter Model

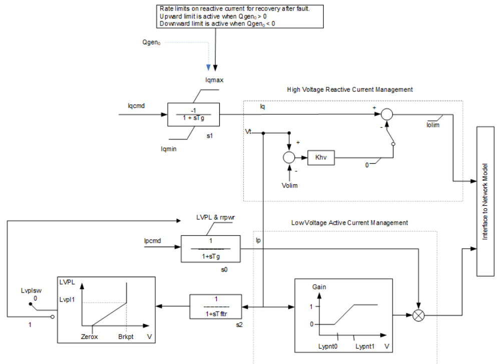
ICON	Value	Description
M		Lvplsw (Low Voltage Power Logic) switch (0: LVPL not present, 1:LVPL present)

CONs	Value	Description
J		T_g, Converter time constant (s)
J+1		Rrpwr, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)
J+2		Brkpt, LVPL characteristic voltage 2 (pu)
J+3		Zerox, LVPL characteristic voltage 1 (pu)
J+4		Lvpl1, LVPL gain (pu)
J+5		Volim, Voltage limit (pu) for high voltage reactive current management
J+6		Lvpnt1, High voltage point for low voltage active current management (pu)
J+7		Lvpnt0, Low voltage point for low voltage active current management (pu)
J+8		Iolim, Current limit (pu) for high voltage reactive current management (specified as a negative value)
J+9		Tfltr, Voltage filter time constant for low voltage active current management (s)
J+10		Khv, Overvoltage compensation gain used in the high voltage reactive current management
J+11		Iqrmax, Upper limit on rate of change for reactive current (pu)
J+12		Iqrmin, Lower limit on rate of change for reactive current (pu)
J+13		Accel, acceleration factor (0 < Accel <= 1)

STATEs	Description
K	Converter lag for Ipcmd
K+1	Converter lag for Iqcmd
K+2	Voltage filter for low voltage active current management

VARs	Description
L	Previous terminal voltage
L+1	Previous terminal voltage angle
L+2	Reactive current overvoltage correction
L+3	Initial machine reactive power from power flow

```
IBUS, 'REGCA1', ID, ICON(M), CON(J) to CON(J+13) /
```



Notes:

1. This model can be used with Type 3 and 4 wind machines. When used for modeling of Type 3 wind machine, the other models to be used along with this model are reeca1, repca1 (optional), wtdta1, wtpta1, wtara1, and wttqa1. When used for modeling of Type 4 machines, the other models to be used along with this model are reeca1, wtdta1, and repca1 (optional).

17.4. REGCAU2

Renewable Energy Generator/Converter Model

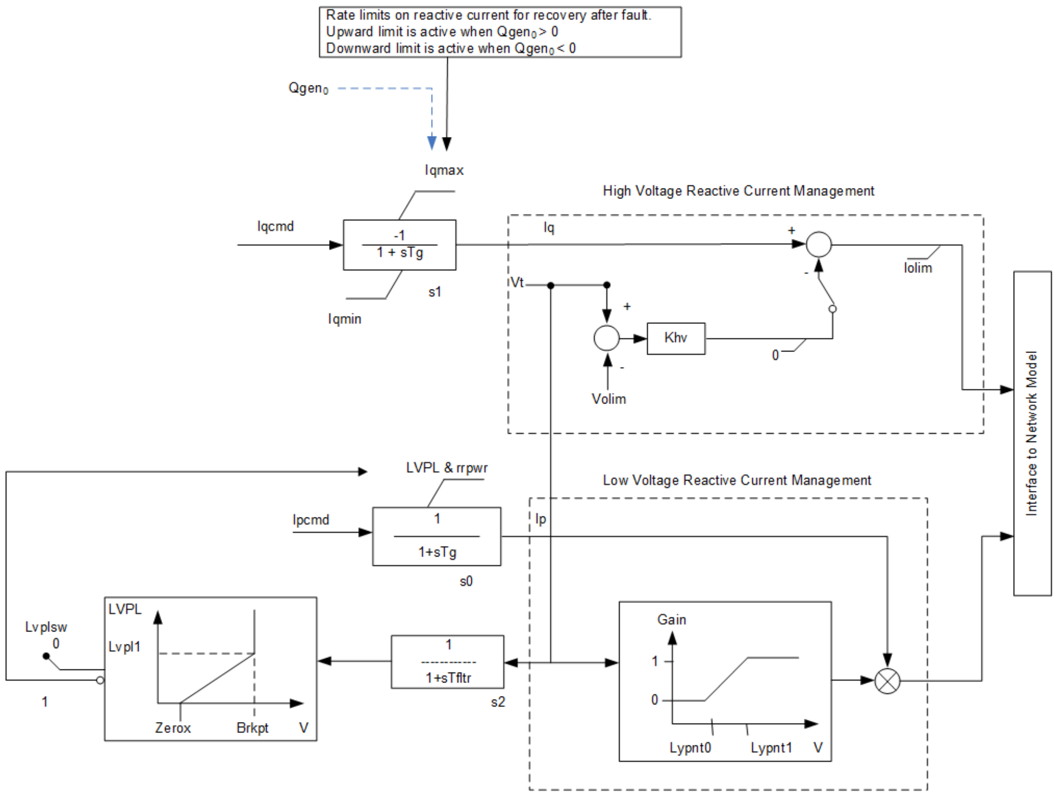
ICON	Value	Description
M		Lvplsw (Low Voltage Power Logic) switch (0: LVPL not present, 1:LVPL present)

CONs	Value	Description
J		T_g, Converter time constant (s)
J+1		Rrpwr, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)
J+2		Brkpt, LVPL characteristic voltage 2 (pu)
J+3		Zerox, LVPL characteristic voltage 1 (pu)
J+4		Lvpl1, LVPL gain (pu)
J+5		Volim, Voltage limit (pu) for high voltage reactive current management
J+6		Lvpnt1, High voltage point for low voltage active current management (pu)
J+7		Lvpnt0, Low voltage point for low voltage active current management (pu)
J+8		Iolim, Current limit (pu) for high voltage reactive current management (specified as a negative value)
J+9		Tfltr, Voltage filter time constant for low voltage active current management (s)
J+10		Khv, Overvoltage compensation gain used in the high voltage reactive current management
J+11		Iqrmax, Upper limit on rate of change for reactive current (pu)
J+12		Iqrmin, Lower limit on rate of change for reactive current (pu)
J+13		Accel, acceleration factor (0 < Accel <= 1)
J+14		Xe, generator effective reactance (pu of MBASE)

STATEs	Description
K	Converter lag for Iqcmd
K+1	Converter lag for Ipcmd
K+2	Voltage filter for low voltage active current management

VARs	Description
L	Previous terminal voltage
L+1	Previous terminal voltage angle
L+2	Reactive current overvoltage correction
L+3	Initial machine reactive power from power flow

```
IBUS, 'USRMDL', ID, 'REGCAU2', 101, 1, 1, 15, 3, 4, ICON(M), CON(J) to
 CON(J+14)  /
```



Notes:

1. This model can be used with Type 3 and 4 wind machines. When used for modeling of Type 3 wind machine, the other models to be used along with this model are reecau1, repcau1 (optional) wtdtau1, wtptau1, wtarau1, wttqau1. When used for modeling of Type 4 machines, the other models to be used along with the drive train control model are reecau1, wtdtau1, and repcau1 (optional).

17.5. REGCBU1

Renewable Energy Generator/Converter Model

ICON	Value	Description
M		RateFlag switch; 0: rate limit on active current, 1: rate limit on active power
M+1		PQ priority Flag; 0: Q priority, 1: P priority

CONs	Value	Description
J		Tg (s), Converter time constant (> 0)
J+1		Tfltr (s), Voltage filter time constant
J+2		Iqrmax (pu/s), Upper limit on rate of change for reactive current (> 0)
J+3		Iqrmin (pu/s), Lower limit on rate of change for reactive current (< 0)
J+4		rrpwr (pu/s), ramp rate for real power increase (or decrease for the case of battery in charging mode) following a fault (> 0)
J+5		Te (s), time constant to model inner control loops
J+6		Imax (pu), Maximum current rating of the converter (> 0)

STATEs	Description
K	Converter lag for Ipcmd
K+1	Converter lag for Iqcmd
K+2	Voltage measurement filter
K+3	lag block represeting inner control loop for Eq
K+4	lag block represeting inner control loop for Ed

VARs	Description
L	Ipcmd
L+1	Iqcmd
L+2	Initial machine reactive power from power flow
L+3	Total converter current
L+4	Caclulated limited on real part of converter current
L+5	Caclulated limited on reactive part of converter current
L+6	d-axis component of network current injection
L+7	q-axis component of network current injection

DYR Syntax:

```
IBUS   'USRMDL'    ID   'REGCBU1'   101   1   2   7   5   8   ICON(M) to
 ICON(M+1)   CON(J) to CON(J+6) /
```

Note(s):

1. Use of this model erquires the generator to be designated as a renewable machine in powerflow.

2. Model parameters are specified in per unit of machine MVA base.

3. The machine in powerflow (to which this model is attached) should not have implicit transformer (i.e., RTRAN and XTRAN in the powerflow record for this machine should be zero).

4. Re and Xe shown in the model block diagram are specified as RSORCE and XSORCE in the generator power record.

5. RateFlag (ICON(M)) can have a value of either 0 or 1. If RateFlag is 0, rate limit (rrpwr, i.e CON(J+4)) is applied on the rate of change (increase or decrease) of active current, and if RateFlag is 1, rrpwr is applied on the rate of increase (or decrease) of active power.

6. The ramp-rate of recovery after a fault on active-current (rrpwr) will also be imposed (in the opposite direction) when the model is being used to “emulate” charging of an energy storage device.

7. If the specified Tg value is less than 2×delt (delt being the simulation step), then Tg will be set equal to 2×DELT in the model. This is done to allow for the application of the rate limit rrpwr.

8. The lag block (Tfltr) allows for modeling of a small delay in the measurement of terminal voltage (Vt). Tfltr can be set to zero.

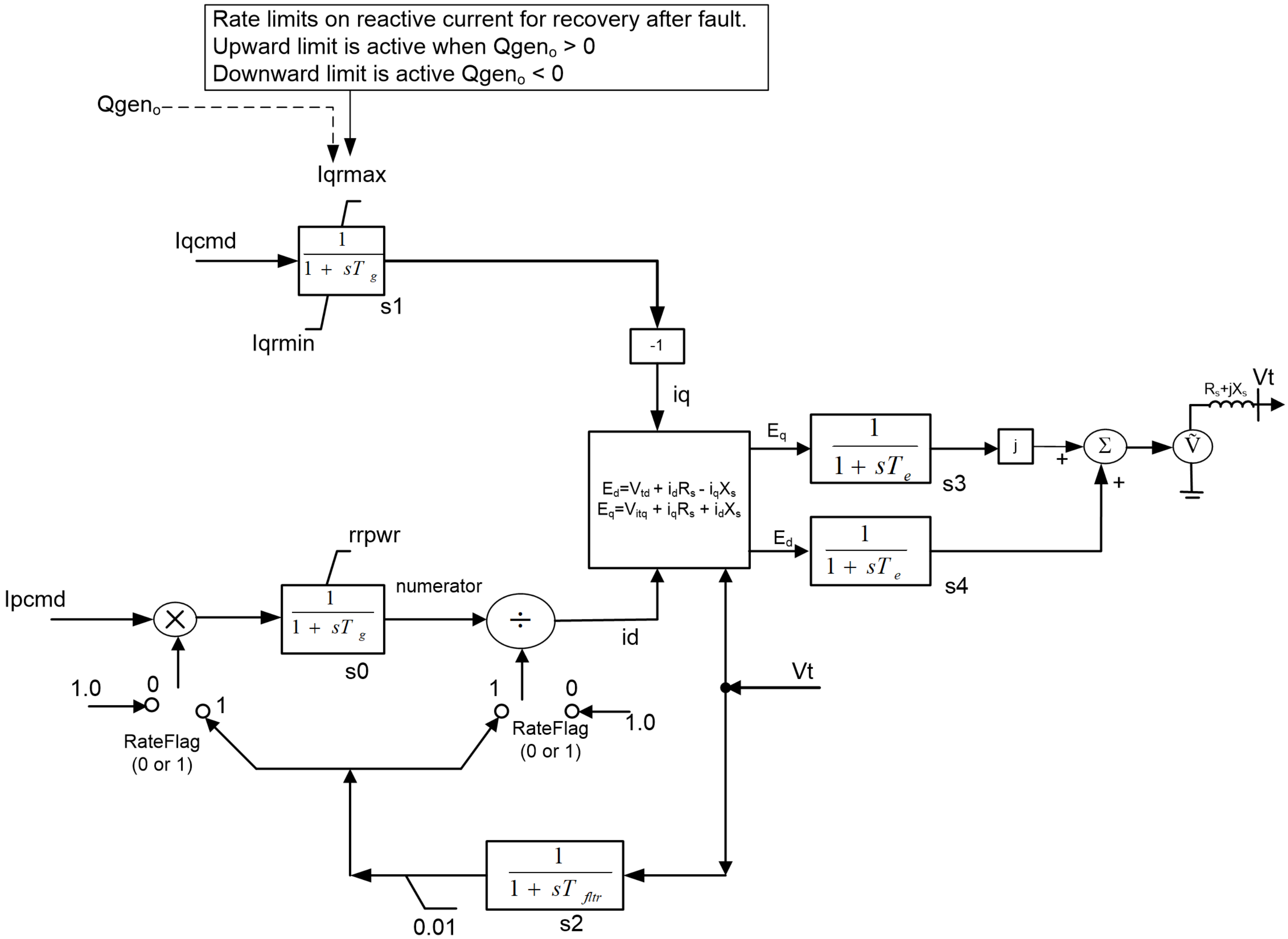
9. The hardcoded lower limit (0.01) at the output of the voltage measurement block is implemented to avoid division by zero. It is to be noted that the limit is on the output of the Tfltr block and not just the division arm. This is done to ensure that the same value of Vt is first multiplied by Ipcmd and then later Ipcmd is divided by the same number.

10. The current limit (Imax) and the PQ-priority flags are used to impose a limit on the total converter current. The PQ priority flag specified in this model should be consistent with the PQ priority flag in the corresponding electrical control model.

11. Iqrmax and Iqrmin are the rate limits of reactive current. The way the rate limits Iqrmax and Iqrmin are implemented is as described below.

    If the model initializes with an initial reactive power output that is greater than zero (i.e. reactive power being injected into the grid), then upon fault clearing the recovery of reactive current to its original value is limited at the rate of *Iqrmax*. In this case the rate limit Iqrmin (the rate limit imposed on the decrease of reactive current) is not effective, which means that the reactive current can be reduced as quickly as desired.

    If the model initializes with an initial reactive power output that is less than zero (i.e. reactive power being absorbed from the grid), then upon fault clearing the recovery of reactive current to its original value is limited at the rate of Iqrmin. In this case the rate limit *Iqrmax* (the rate limit imposed on the increase of reactive current) is not effective, which means that the reactive current can be increased as quickly as desired.


Rate limits on reactive current for recovery after fault.
Upward limit is active when Qgen$_o$ > 0
Downward limit is active Qgen$_o$ < 0
Qgen$_o$
Iqrmax
Iqcmd
$\frac{1}{1 + sT_g}$
s1
Iqrmin
-1
iq
$E_d = V_{td} + i_d R_s - i_q X_s$
$E_q = V_{itq} + i_q R_s + i_d X_s$
E_q
$\frac{1}{1 + sT_e}$
s3
j
+
Σ
+
Ṽ
$R_s + jX_s$
Vt
E_d
$\frac{1}{1 + sT_e}$
s4
rrpwr
Ipcmd
$\frac{1}{1 + sT_g}$
numerator
s0
÷
id
Vt
1.0
0
1
RateFlag
(0 or 1)
1
0
1.0
RateFlag
(0 or 1)
$\frac{1}{1 + sT_{fltr}}$
s2
0.01

17.6. WT1G1

Direct Connected (Type 1) Generator

CONs	Value	Description
J		T open circuit transient time constant, sec. (>0)
J+1		T″, open circuit subtransient time constant, sec. (≥ 0); if T″ = 0, single cage
J+2		X, synchronous reactance, pu
J+3		X´, transient reactance, pu
J+4		X″, subtransient reactance, pu (≥ 0); if X″ = 0, single cage
J+5		Xl, leakage reactance, pu
J+6		E1
J+7		S(E1)
J+8		E2
J+9		S(E2)

STATEs	Description
K	Eq´, transient flux q-component
K+1	Ed´, transient flux d-component
K+2	Eq″, subtransient flux q-component
K+3	Ed″, subtransient flux d-component
K+4	Internal

VARs	Description
L	Admittance of initial condition MVAr difference
L+1	Machine Q
L+2	Telec

```
IBUS, 'WT1G1', ID, CON(J) to CON(J+9) /
```

17.7. WT2G1

Induction Generator with Controlled External Rotor Resistor (Type 2)

CONs	Value	Description
J		XA, stator reactance, pu
J+1		XM, magnetizing reactance, pu
J+2		X1, rotor reactance, pu
J+3		R_ROT_MACH, rotor resistance, pu
J+4		R_ROT_MAX, a sum of R_ROT_MACH and total external resistance, pu
J+5		E1, first saturation coordinate
J+6		SE1, first saturation factor
J+7		E2, second saturation coordinate
J+8		SE2, second saturation factor
J+9		POWER_REF_1, first of 5 coordinate pairs of the power-slip curve
J+10		POWER_REF_2
J+11		POWER_REF_3
J+12		POWER_REF_4
J+13		POWER_REF_5
J+14		SLIP_1
J+15		SLIP_2
J+16		SLIP_3
J+17		SLIP_4
J+18		SLIP_5

STATEs	Description
K	Eq´, transient flux q-component
K+1	Ed´, transient flux d-component
K+2	Internal

VARs	Description
L	Admittance of the hidden shunt
L+1	Machine Q
L+2	Telec

```
IBUS, 'WT2G1', ID, CON(J) to CON(J+18) /
```

17.8. WT3G1

Doubly-Fed Induction Generator (Type 3)

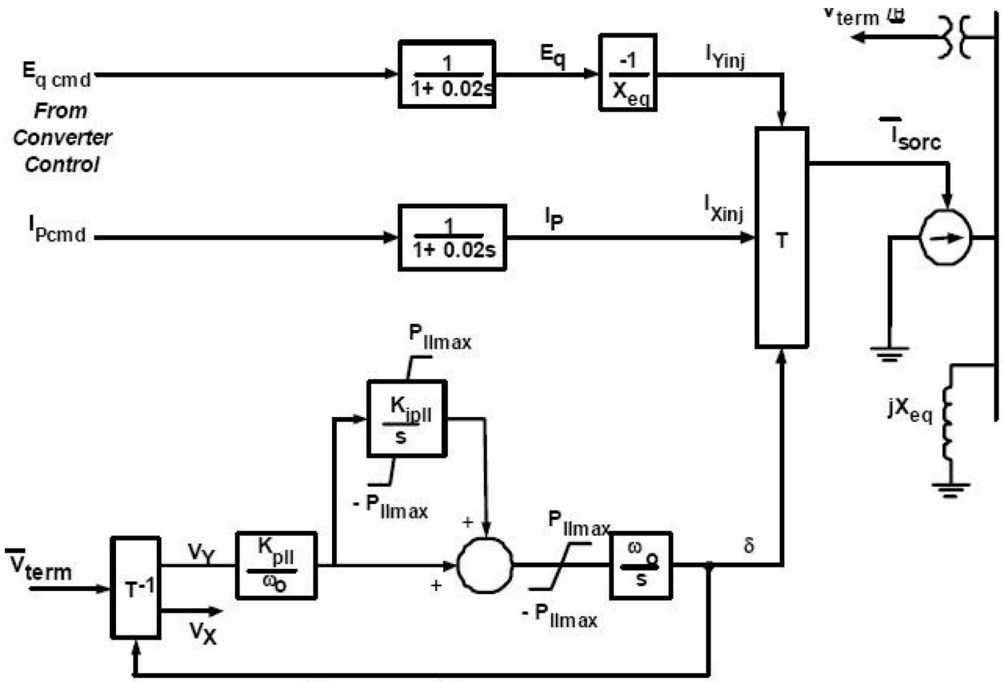
ICON		Description
M		Number of lumped wind turbines

CONs	Value	Description
J		Xeq, Equivalent reactance for current injection (pu)
J+1		Kpll, PLL first integrator gain
J+2		KIpll, PLL second integrator gain
J+3		Pllmax, PLL maximum limit
J+4		Prated, Turbine MW rating

STATEs	Description
K	Converter lag for Ipcmd
K+1	Converter lag for Eqcmd
K+2	PLL first integrator
K+3	PLL second integrator

VARs	Description
L	Vx, Real component of Vterm in generator ref. frame
L+1	VY, Imaginary component of Vterm in generator ref. frame
L+2	Ixinj, Active component of the injected current
L+3	Iyinj, Reactive component of the injected current

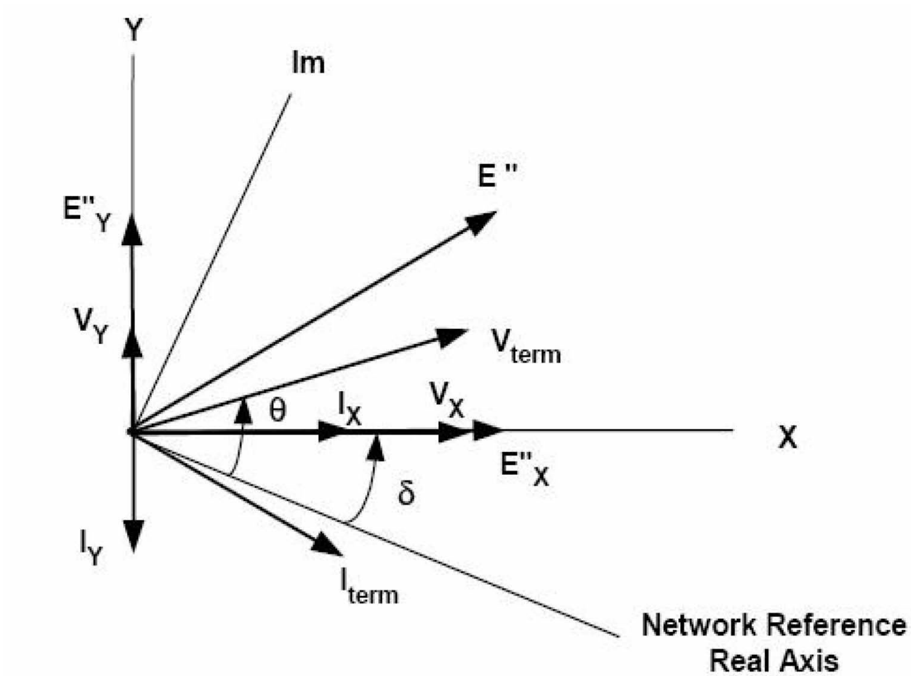
```
IBUS, 'WT3G1', ID, ICON(M), CON(J) to CON(J+4) /
```



Notes: 1. $\bar{V}_{term}$ and $\bar{I}_{sorc}$ are complex values on network reference frame.

2. In steady-state, $V_Y = 0$, $V_X = V_{term}$, and $\delta = \theta$.

3. X_{eq} = Imaginary (ZSORCE)



17.9. WT3G2

Doubly-Fed Induction Generator (Type 3)

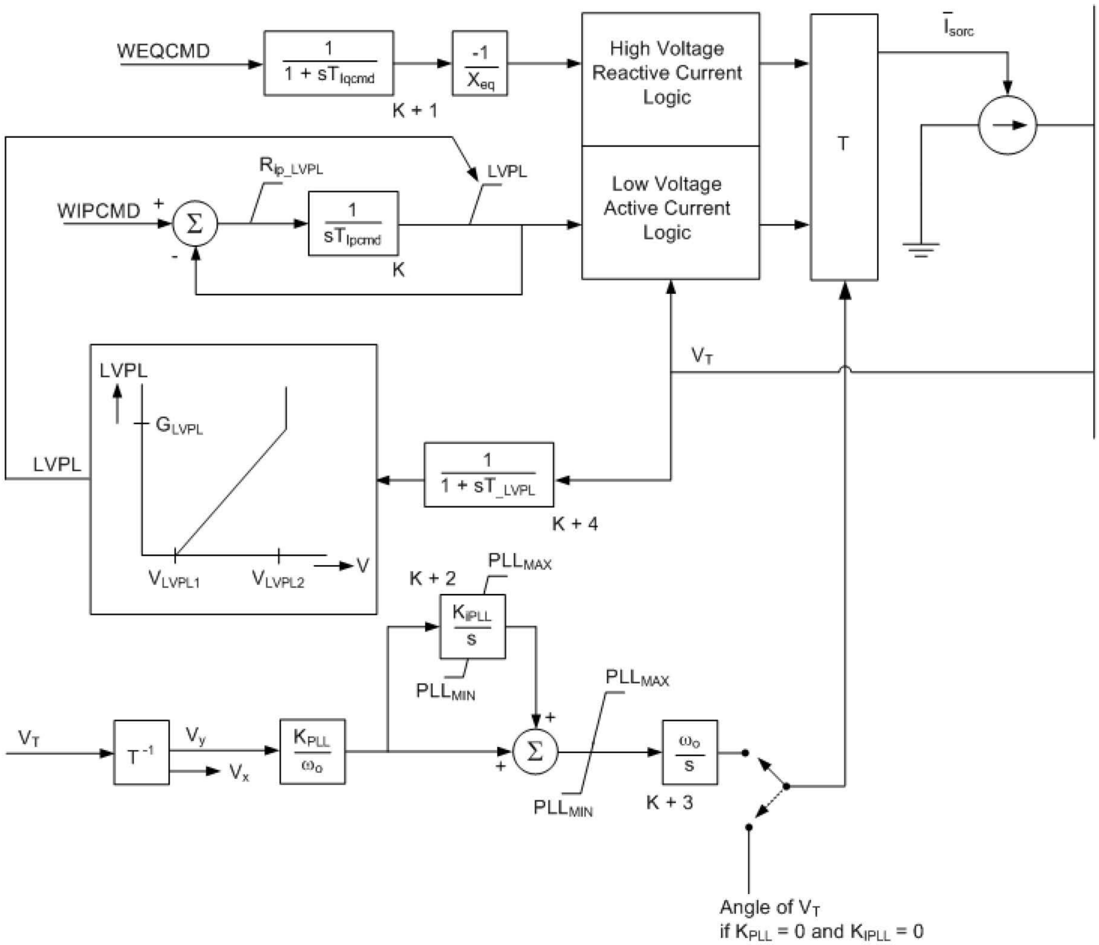
ICONs	Value	Description
M		Number of lumped wind turbines

CONs	Value	Description
J		TIQcmd, Converter time constant for IQcmd
J+1		Tipcmd, Converter time constant for IPcmd
J+2		KPLL, PLL gain
J+3		KIPLL, PLL integrator gain
J+4		PLLMAX, PLL max. limit
J+5		Prated
J+6		VLVPL1, LVPL voltage 1 Low voltage power logic
J+7		VLVPL2, LVPL voltage 2
J+8		GLVPL, LVPL gain
J+9		VHVRCR, High Voltage Reactive Current (HVRC) logic, pu voltage
J+10		CURHVRCR, HVRC logic, current (pu)
J+11		RIp_LVPL, Rate of active current change
J+12		T_LVPL, Voltage sensor for LVPL, second

STATEs	Description
K	Converter lag for Ipcmd
K+1	Converter lag for $I_Q$cmd
K+2	PLL first integrator
K+3	PLL second integrator
K+4	Voltage sensor for LVPL

VAR	Description
L	deltaQ, overvoltage correction factor

```
IBUS, 'WT3G2', ID, ICON(M), CON(J) TO COM(J+12) /
```



WEQCMD
1
1 + sT_Iqcmd
K + 1
-1
X_eq
High Voltage Reactive Current Logic
Low Voltage Active Current Logic
T
I_sorc
R_ip_LVPL
LVPL
WIPCMD
Σ
1
sT_Ipcmd
K
V_T
LVPL
G_LVPL
V_LVPL1
V_LVPL2
V
1
1 + sT_LVPL
K + 4
K + 2
PLL_MAX
K_IPLL
s
PLL_MIN
V_T
T^-1
V_y
V_x
K_PLL
ω_o
Σ
PLL_MAX
PLL_MIN
ω_o
s
K + 3
Angle of V_T
if K_PLL = 0 and K_IPLL = 0

17.10. WT4G1

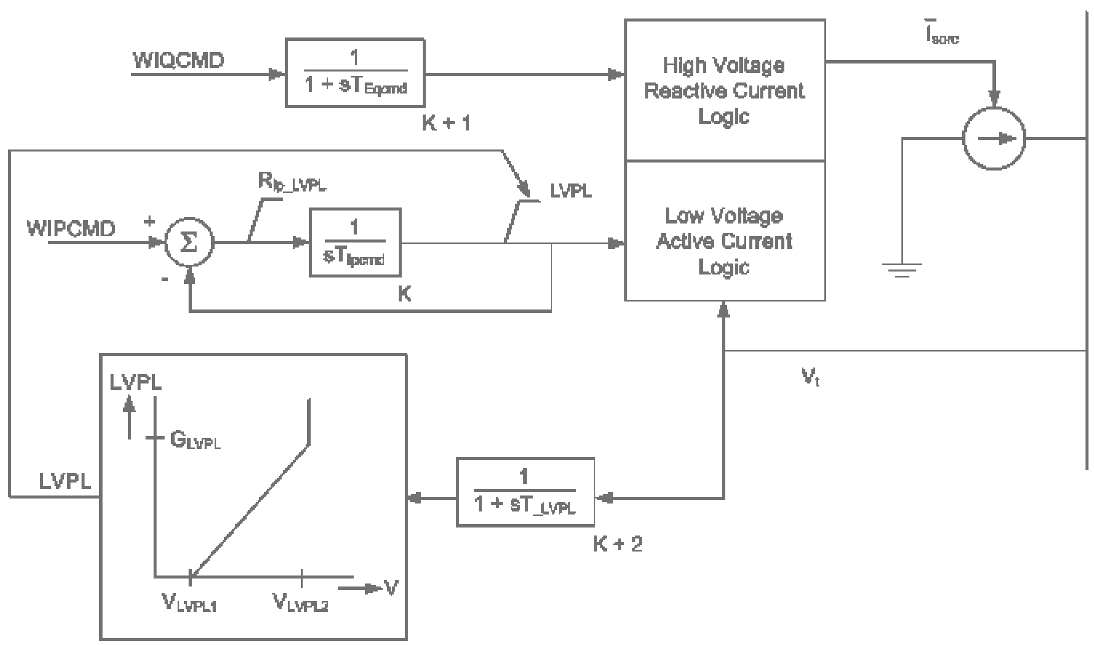
Wind Generator Model with Power Converter (Type 4)

CONs	Value	Description
J		TIQCmd, Converter time constant for IQcmd
J+1		TIPCmd, Converter time constant for IPcmd
J+2		VLVPL1, LVPL voltage 1 (Low voltage power logic)
J+3		VLVPL2, LVPL voltage 2
J+4		GLVPL, LVPL gain
J+5		VHVRCR, HVRCR voltage (High voltage reactive current limiter)
J+6		CURHVRCR, HVRCR current (Max. reactive current at VHVRCR)
J+7		RIp_LVPL, Rate of LVACR active current change
J+8		T_LVPL, Voltage sensor for LVACR time constant

STATEs	Description
K	Converter lag for Ipcmd
K+1	Converter lag for Eqcmd
K+2	Voltage sensor for LVACR

VARs	Description
L through L+4	For internal use
L+1	VAACC, previous Vterm angle
L+2	deltaQ, overvoltage correction factor

```
IBUS, 'WT4G1', ID, CON(J) to CON(J+8) /
```



17.11. WT4G2

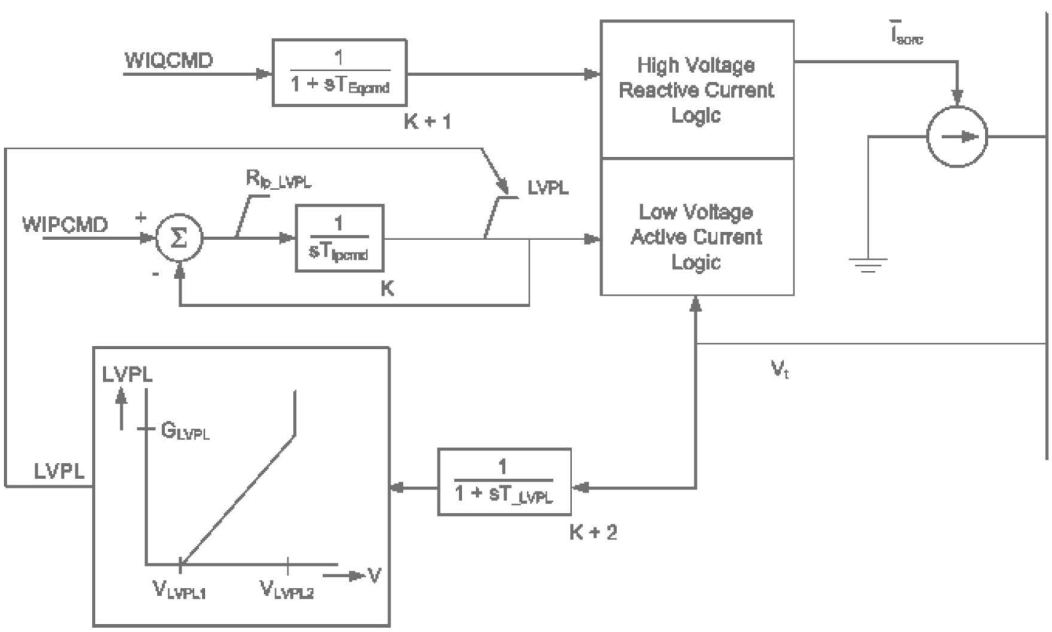
Wind Generator Model with Power Converter (Type 4)

CONs	Value	Description
J		T_{IQCmd}, Converter time constant for $I_Q$cmd
J+1		T_{IPCmd}, Converter time constant for IPcmd
J+2		VLVPL1, LVPL voltage 1 (Low voltage power logic)
J+3		VLVPL2, LVPL voltage 2
J+4		GLVPL, LVPL gain
J+5		VHVRCR, HVRCR voltage (High voltage reactive current limiter)
J+6		CURHVRCR, HVRCR current (Max. reactive current at VHVRCR)
J+7		RIp_LVPL, Rate of LVACR active current change
J+8		T_LVPL, Voltage sensor for LVACR time constant

STATEs	Description
K	Converter lag for Ipcmd
K+1	Converter lag for Eqcmd
K+2	Voltage sensor for LVACR

VARs	Description
L through L+4	For Internal Use

```
IBUS, 'WT4G2', ID CON(J) to CON(J+8) /
```



Chapter 18

Generic Renewable Electrical Control Models

This chapter contains a collection of data sheets for the generic wind electrical models contained in the PSS®E dynamics model library.

Model	Description
PVEU1	User written electrical control model for photo-voltaic(PV) systems
REECA1	Renewable Energy Electrical Model
REECB1	Renewable Energy Electrical Control model (for large scale PV)
REECCU1	Electrical Control Model for Utility Scale Battery Energy Storage
REECDU1	Generic Renewable Electrical Control Model
WT2E1	Rotor resistance control model for Type 2 wind generator
WT3E1	Electrical control for Type 3 wind generator
WT4E1	Electrical control models for Type 4 wind generator
WT4E2	Electrical control for Type 4 wind generator, version 2

18.1. PVEU1

Electrical Control Model for PV Converter

ICONs	Value	Description
M		Remote bus # for voltage control; 0 for local control
M+1		PFAFLG: • 1 if PF fast control enabled • 0 if PF fast control disabled
M+2		VARFLG: • 1 if Qord is provided by WindVar • 0 if Qord is not provided by WindVar, if VARFLG = PFAFLG = 0 then Qord is provided as as Qref = const
M+1		PQFLG: P/Q priority flag • 0 - Q priority • 1 - P priority

CONs	Value	Description
J		Tw, Filter time constant in voltage regulator (sec)
J+1		Kpv, Proportional gain in voltage regulator(pu)
J+2		Kiv, Integrator gain in voltage regulator (pu)
J+3		Kpp, Proportional gain in torque regulator (pu)
J+4		Kip, Integrator gain in torque regulator (pu
J+5		Kf, rate feedback gain (pu)
J+6		Tf, rate feedbacktime constant (sec.)
J+7		Qmx, Max limit in voltage regulator (pu)
J+8		Qmn, Min limit in voltage regulator (pu)
J+9		IPmax, Max active current limit (pu)
J+10		Trv, voltage sensor time constant (sec.)
J+11		dPMX, maximum power order rate (pu)
J+12		dPMN, minimum power order rate (pu)
J+13		Tpower, Power reference filter time constant, sec.
J+14		KQi, volt/Mvar gain
J+15		Vmincl, min. voltage limit
J+16		Vmaxcl, max. voltage limit
J+17		KVi, Int. volt/Term. voltage gain
J+18		Tv, Lag in WindVar controller (sec)
J+19		Tp, Pelec filter in fast PF controller (sec)
J+20		ImaxTD, Converter current limit (pu)
J+21		Iphl, Hard active current limit (pu)

CONs	Value	Description
J+22		Iqhl, Hard reactive current limit (pu)
J+23		PMX, Max power from PV plant, MW

STATEs	Description
K	Filter in Voltage regulator
K+1	Integrator in Voltage regulator
K+2	Integrator in active power regulator
K+3	Active power regulator feedback
K+4	Voltage sensor
K+5	Power reference filter
K+6	Mvar/Vref integrator
K+7	Verror/Internal machine voltage integrator
K+8	Lag of the WindVar controller
K+9	Input filter of PELEC for fast PF controller

VARs	Description
L	Remote bus referencevoltage
L+1	Q ref. if PFAFLG=0 & VARFLG=0
L+2	PF angle ref if PFAFLG=1
L+3	Power reference

Four possible configurations:

1. Current North American configuration with WindVAR:

   `VARFLG=1, PFAFLG=0, KQi small (e.g., KQi = 0.1)`

2. Current North American configuration without WindVAR:

   `VARFLG=0, PFAFLG=0, KQi very small (e.g., KQi = 0.001)`

3. European (PFA control) with WindVAR:

   `VARFLG=1, PFAFLG=0, KQi large (e.g., KQi = 0.5), KVi large`

4. European (PFA control) without WindVAR:

   `VARFLG=0, PFAFLG=1, Specify desired PFA, KQi`

   `large (e.g., KQi = 0.5), KVi large`

```
IBUS ' USRMDL' ID 'PVEU1' 102 0 4 24 10 4 ICON(M) to ICON(M+3) CON(J) to
 CON(J+23) /
```

18.2. REECA1

Generic Renewable Electrical Control Model

ICONs	Value	Description
M		Bus number for voltage control; local control if 0
M+1		PFFLAG: • 1 if power factor control • 0 if Q control (which can be controlled by an external signal)
M+2		VFLAG: • 1 if Q control • 0 if voltage control
M+3		QFLAG: • 1 if voltage or Q control • 0 if constant pf or Q control
M+4		PFLAG: • 1 if active current command has speed dependency • 0 for no dependency
M+5		PQFLAG, P/Q priority flag for current limit: • 0 for Q priority • 1 for P priority

CONs	Value	Description
J		Vdip (pu), low voltage threshold to activate reactive current injection logic
J+1		Vup (pu), Voltage above which reactive current injection logic is activated
J+2		Trv (s), Voltage filter time constant
J+3		dbd1 (pu), Voltage error dead band lower threshold (≤0)
J+4		dbd2 (pu), Voltage error dead band upper threshold (≥0)
J+5		Kqv (pu), Reactive current injection gain during over and undervoltage conditions
J+6		Iqh1 (pu), Upper limit on reactive current injection Iqinj
J+7		Iql1 (pu), Lower limit on reactive current injection Iqinj
J+8		Vref0 (pu), User defined reference (if 0, model initializes it to initial terminal voltage)
J+9		Iqfrz (pu), Value at which Iqinj is held for Thld seconds following a voltage dip if Thld > 0

CONs	Value	Description
J+10		Thld (s), Time for which Iqinj is held at Iqfrz after voltage dip returns to zero (see Note 1)
J+11		Thld2 (s) (≥0), Time for which the active current limit (IPMAX) is held at the faulted value after voltage dip returns to zero
J+12		Tp (s), Filter time constant for electrical power
J+13		QMax (pu), limit for reactive power regulator
J+14		QMin (pu) limit for reactive power regulator
J+15		VMAX (pu), Max. limit for voltage control
J+16		VMIN (pu), Min. limit for voltage control
J+17		Kqp (pu), Reactive power regulator proportional gain
J+18		Kqi (pu), Reactive power regulator integral gain
J+19		Kvp (pu), Voltage regulator proportional gain
J+20		Kvi (pu), Voltage regulator integral gain
J+21		Vbias (pu), User-defined bias (normally 0)
J+22		Tiq (s), Time constant on delay s4
J+23		dPmax (pu/s) (>0) Power reference max. ramp rate
J+24		dPmin (pu/s) (<0) Power reference min. ramp rate
J+25		PMAX (pu), Max. power limit
J+26		PMIN (pu), Min. power limit
J+27		Imax (pu), Maximum limit on total converter current
J+28		Tpord (s), Power filter time constant
J+29		Vq1 (pu), Reactive Power V-I pair, voltage
J+30		Iq1 (pu), Reactive Power V-I pair, current
J+31		Vq2 (pu) (Vq2>Vq1), Reactive Power V-I pair, voltage
J+32		Iq2 (pu) (Iq2>Iq1), Reactive Power V-I pair, current
J+33		Vq3 (pu) (Vq3>Vq2), Reactive Power V-I pair, voltage
J+34		Iq3 (pu) (Iq3>Iq2), Reactive Power V-I pair, current
J+35		Vq4 (pu) (Vq4>Vq3), Reactive Power V-I pair, voltage
J+36		Iq4 (pu) (Iq4>Iq3), Reactive Power V-I pair, current
J+37		Vp1 (pu), Real Power V-I pair, voltage
J+38		Ip1 (pu), Real Power V-I pair, current
J+39		Vp2 (pu) (Vp2>Vp1), Real Power V-I pair, voltage
J+40		Ip2 (pu) (Ip2>Ip1), Real Power V-I pair, current
J+41		Vp3 (pu) (Vp3>Vp2), Real Power V-I pair, voltage
J+42		Ip3 (pu) (Ip3>Ip2), Real Power V-I pair, current
J+43		Vp4 (pu) (Vp4>Vp3), Real Power V-I pair, voltage
J+44		Ip4 (pu) (Ip4>Ip3), Real Power V-I pair, current

STATEs	Description
K	Voltage Measurement filter
K+1	Real power filter
K+2	PI controller for reactive power

STATEs	Description
K+3	PI controller for voltage error
K+4	First Order lag for reactive current
K+5	First order lag for Pord

VAR	Description
L	Bus reference voltage (Vref0)
L+1	Storage of current state for state transition (possible values: 0, 1 or 2)
L+2	Power factor reference angle (pfaref), radians
L+3	user defined bias as calculated by the model
L+4	Timer for Thld counter
L+5	Previous value of power reference
L+6	Stored Ipmax value
L+7	Timer for Thld2 counter
L+8	Storage for voltage_dip (used only when Thld2 > 0)

IBUS, 'REECA1', ID, ICON(M) to ICON(M+5), CON(J) to CON(J+44) /

Notes:

1. This model can be used with Type 3 and 4 wind machines. When used for modeling of Type 3 wind machine, the other models to be used along with this model are regca1, repcta1 (optional), wtdta1, wtpta1, wtara1, wttqa1. When used for modeling of Type 4 machines, the other models to be used along with this control model are regca1, wtdta1, and repca1 (optional).

2. When used for modeling Type 3 machines set Pflag (i.e., ICON (M+4)) to 0. Speed dependency will be simulated by the Torque controller (WTTQA1).

3. Thld could be either zero, or less than zero or greater than zero.

   a) If Thld > 0, then once voltage_dip (voltage_dip is a flag which is set and reset in the model. Voltage_dip is 0 if the Vdip<VT<Vup, else it is 1) becomes 0, Iqinj is held at Iqfrz for Thld seconds.

   b) If Thld < 0, then once voltage_dip goes to 0, Iqinj remains state (equal to Iqv) for Thld seconds.

   c) If Thld = 0 , then Iqinj goes back to zero as soon as Voltage_dip becomes 0.

4. pfaref (the power factor angle reference) value is initialized by the model based on ini- tial real and reactive power outputs from the machine.

5. wg is the per unit generator speed and is set in the drive train model.

6. Qref is initialized by the model to a constant or can be connected to an external plant controller model).

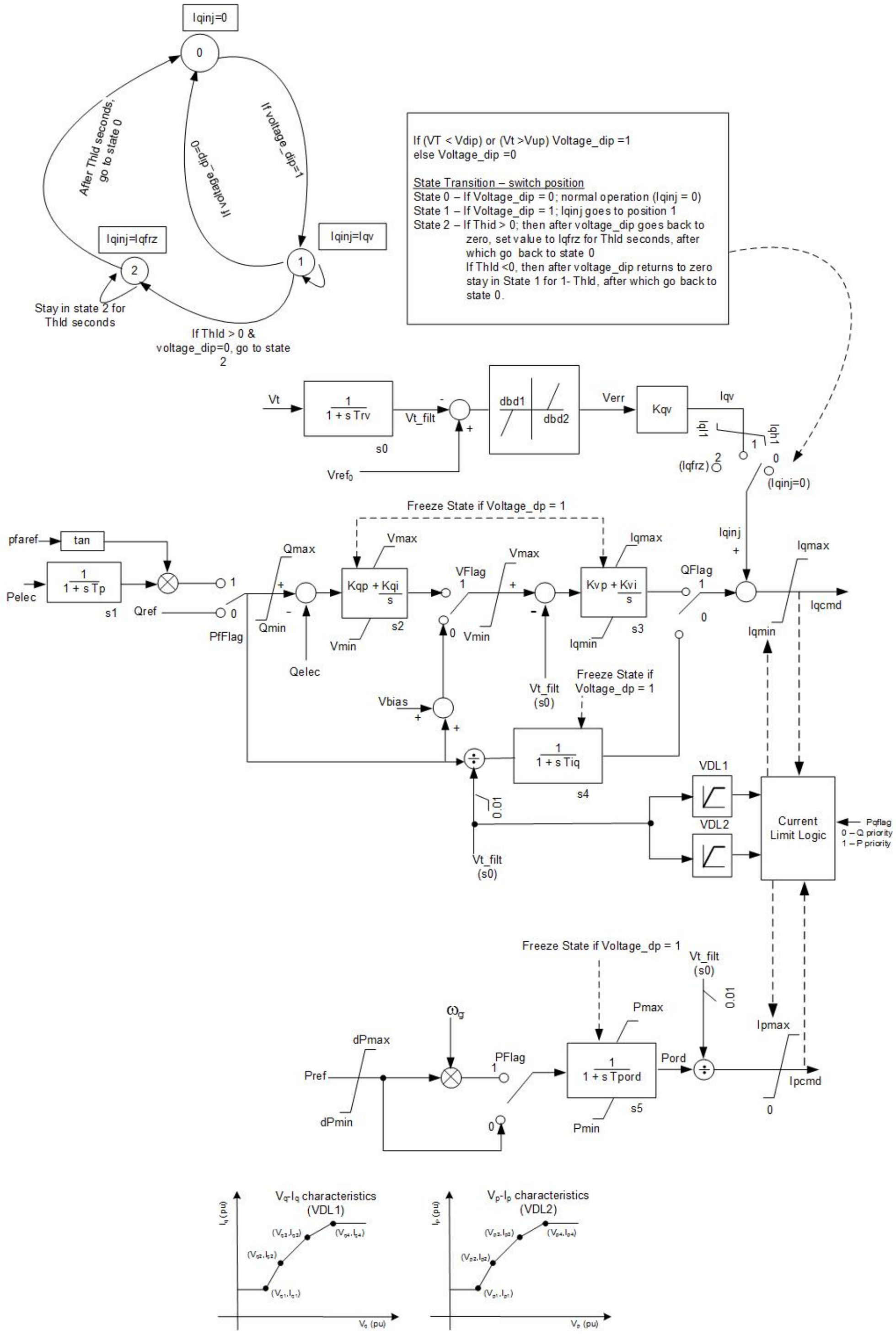
7. Pref is initialized by the model to a constant or can be connected to an external plant controller model).

8. Normally Vbias is zero. The user specified Vbias value (which is in CON(J+21)) is used only when the QFlag=1, VFlag=0 and PfFlag=0. For all other combinations of QFlag, VFlag and PfFlag values, the Vbias value is either not required or is calculated and stored in VAR(L+3).

9. ICON(M) contains the remote bus number. If this is 0 or if the remote bus number is not specified then the local bus is used for control.

10. The VDL1 characteristics are defined by 4 pairs of Vq-Iq points (pu voltage versus reac- tive current). Data for the first two pairs (Vq1, Iq1) and (Vq2, Iq2) is mandatory (i.e., these cannot be specified as zero). A maximum of 4 pairs of Vq-Iq points can be speci- fied. The first Vq entry that has a zero value, signals the end of Vq-Iq data. Unused Vq- Iq pairs should be entered as zero. The Vq-Iq values should be such that Vq1 < Vq2 < Vq3 < Vq4, and Iq1 ≤ Iq2 ≤ Iq3 ≤ Iq4.

11. The VDL2 characteristics are defined by 4 pairs of Vp-Ip points (pu voltage versus active current). Data for the first two pairs (Vp1, Ip1) and (Vp2, Ip2) is mandatory (i.e., these cannot be specified as zero). A maximum of 4 pairs of Vp-Ip points can be spec- ified. The first Vp entry that has a zero value, signals the end of Vp-Ip data. Unused Vp- Ip pairs should be entered as zero. The Vp-Ip values should be such that Vp1 < Vp2 < Vp3 < Vp4, and Ip1 ≤ Ip2 ≤ Ip3 ≤ Ip4.


Iqinj=0
If voltage_dip=1
If voltage_dip=0
After Thld seconds, go to state 0
Iqinj=Iqfrz
Iqinj=Iqv
Stay in state 2 for Thld seconds
If Thld > 0 & voltage_dip=0, go to state 2
If (VT < Vdip) or (Vt >Vup) Voltage_dip =1
else Voltage_dip =0
State Transition – switch position
State 0 – If Voltage_dip = 0; normal operation (Iqinj = 0)
State 1 – If Voltage_dip = 1; Iqinj goes to position 1
State 2 – If Thld > 0; then after voltage_dip goes back to zero, set value to Iqfrz for Thld seconds, after which go back to state 0
If Thld <0, then after voltage_dip returns to zero stay in State 1 for 1- Thld, after which go back to state 0.
Vt
1 / 1 + s Trv
s0
Vt_filt
Vref0
dbd1
dbd2
Verr
Kqv
Iqv
Iql1
Iqh1
(Iqfrz)
(Iqinj=0)
Iqinj
Freeze State if Voltage_dp = 1
pfaref
tan
Pelec
1 / 1 + s Tp
s1
Qref
PfFlag
Qmax
Qmin
Qelec
Kqp + Kqi/s
s2
Vmax
Vmin
VFlag
Vbias
Kvp + Kvi/s
s3
Iqmax
Iqmin
QFlag
Iqcmd
Freeze State if Voltage_dp = 1
1 / 1 + s Tiq
s4
0.01
Vt_filt (s0)
VDL1
VDL2
Current Limit Logic
Pqflag
0 – Q priority
1 – P priority
Freeze State if Voltage_dp = 1
Vt_filt (s0)
ωg
dPmax
dPmin
Pref
PFlag
1 / 1 + s Tpord
s5
Pmax
Pmin
Pord
Ipmax
Ipcmd
Vq-Iq characteristics (VDL1)
Vp-Ip characteristics (VDL2)
Iq (pu)
Ip (pu)
Vt (pu)
Vp (pu)

18.3. REECB1

Electrical Control Model for Large Scale PV

ICONs	Value	Description
M		Bus number for voltage control; local control if 0
M+1		PFFLAG (Power factor control flag): • 1 if power factor control • 0 if Q control (which can be controlled by an external signal)
M+2		VFLAG: • 1 if Q control • 0 if voltage control
M+3		QFLAG: • 1 if voltage or Q control • 0 if constant pf or Q control
M+4		PQFLAG, P/Q priority flag for current limit: • 0 for Q priority • 1 for P priority

CONs	Value	Description
J		Vdip (pu), low voltage threshold to activate reactive current injection logic
J+1		Vup (pu), Voltage above which reactive current injection logic is activated
J+2		Trv (s), Voltage filter time constant
J+3		dbd1 (pu), Voltage error dead band lower threshold (≤0)
J+4		dbd2 (pu), Voltage error dead band upper threshold (≥0)
J+5		Kqv (pu), Reactive current injection gain during over and undervoltage conditions
J+6		Iqh1 (pu), Upper limit on reactive current injection Iqinj
J+7		Iql1 (pu), Lower limit on reactive current injection Iqinj
J+8		Vref0 (pu), User defined reference (if 0, model initializes it to initial terminal voltage)
J+9		Tp (s), Filter time constant for electrical power
J+10		QMax (pu), limit for reactive power regulator
J+11		QMin (pu) limit for reactive power regulator
J+12		VMAX (pu), Max. limit for voltage control
J+13		VMIN (pu), Min. limit for voltage control

CONs	Value	Description
J+14		Kqp (pu), Reactive power regulator proportional gain
J+15		Kqi (pu), Reactive power regulator integral gain
J+16		Kvp (pu), Voltage regulator proportional gain
J+17		Kvi (pu), Voltage regulator integral gain
J+18		Tiq (s), Time constant on delay s4
J+19		dPmax (pu/s) (>0) Power reference max. ramp rate
J+20		dPmin (pu/s) (<0) Power reference min. ramp rate
J+21		PMAX (pu), Max. power limit
J+22		PMIN (pu), Min. power limit
J+23		Imax (pu), Maximum limit on total converter current
J+24		Tpord (s), Power filter time constant

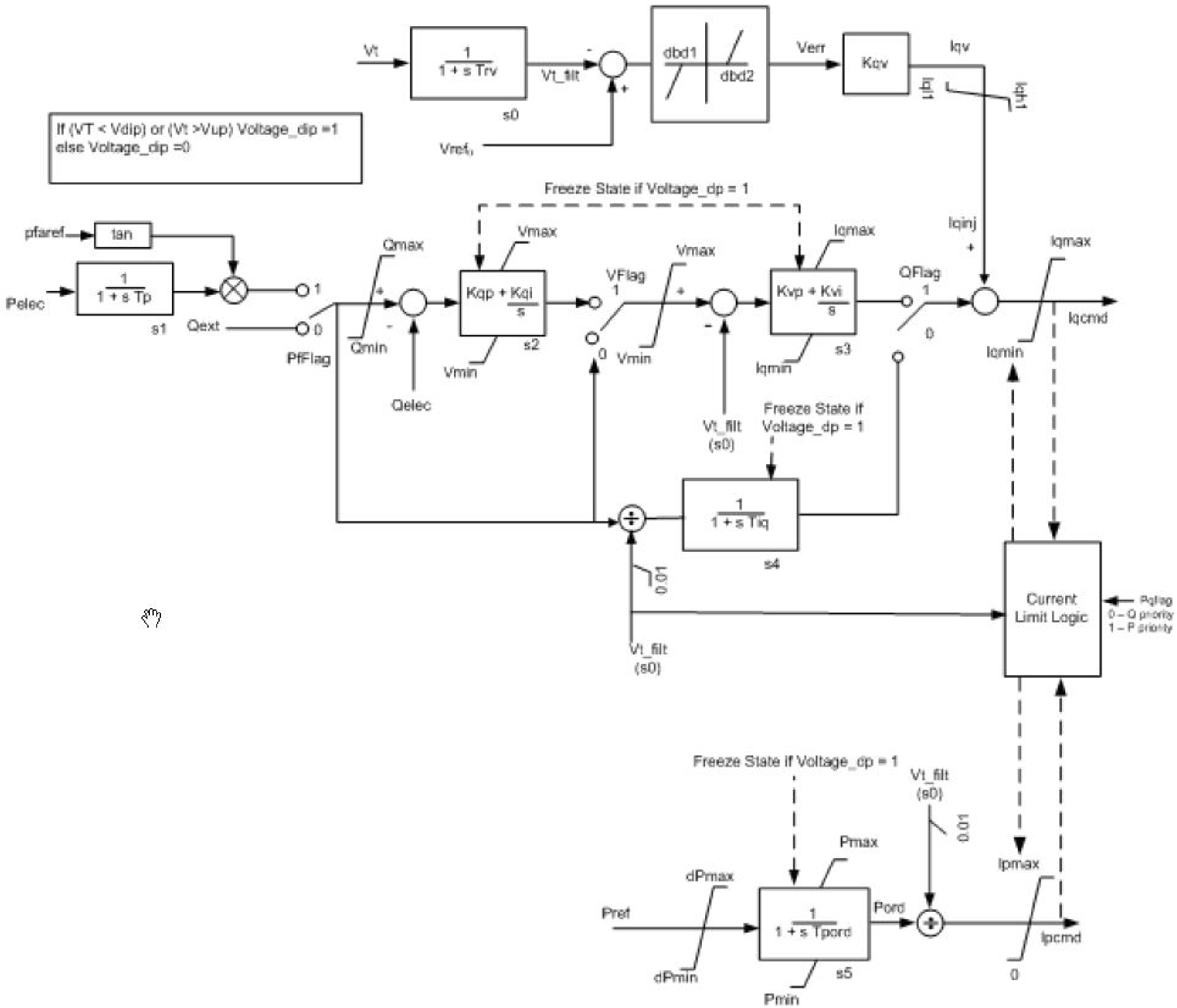
STATEs	Description
K	Voltage Measurement filter
K+1	Real power filter
K+2	PI controller for reactive power
K+3	PI controller for voltage error
K+4	First Order lag for reactive current
K+5	First order lag for Pord

VAR	Description
L	Bus reference voltage (Vref0)
L+1	Power factor reference angle (pfaref), radians
L+2	Real current command (Ipcmd)
L+3	Reactive current command (Iqcmd)

IBUS, 'REECB1', ID, ICON(M) to ICON(M+4), CON(J) to CON(J+24) /

Notes:

1. pfaref (the power factor angle reference) value is initialized by the model based on ini- tial real and reactive power outputs from the machine.
2. Qref is initialized by the model to a constant or can be connected to an external plant controller model).
3. Pref is initialized by the model to a constant or can be connected to an external plant controller model).
4. ICON(M) contains the remote bus number. If this is 0 or if the remote bus number is not specified then the local bus is used for control.
5. In using REECB1 to model large scale PV, the other models to be used along with this model are REGCA1 and REPCA1 (optional)


If (VT < Vdip) or (Vt >Vup) Voltage_dip =1
else Voltage_dip =0
Vt
1 / 1 + s Trv
s0
Vt_filt
Vref0
dbd1
dbd2
Verr
Kqv
Iqv
Iql1
Iqh1
Freeze State if Voltage_dp = 1
pfaref
tan
Pelec
1 / 1 + s Tp
s1
Qext
PfFlag
Qmax
Qmin
Qelec
Kqp + Kqi/s
s2
Vmax
Vmin
VFlag
Kvp + Kvi/s
s3
Iqmax
Iqmin
QFlag
Iqinj
Iqcmd
Icmin
Vt_filt
(s0)
Freeze State if
Voltage_dp = 1
1 / 1 + s Tiq
s4
0.01
Current
Limit Logic
Pqflag
0 – Q priority
1 – P priority
Freeze State if Voltage_dp = 1
Pmax
dPmax
Pref
dPmin
1 / 1 + s Tpord
s5
Pmin
Pord
Ipmax
Ipcmd
0

18.4. REECCU1

Electrical Control Model for Utility Scale Battery Energy Storage

ICONs	Value	Description
M		Bus number for voltage control; local control if 0
M+1		PFFLAG (Power factor control flag): • 1 if power factor control • 0 if Q control (which can be controlled by an external signal)
M+2		VFLAG: • 1 if Q control • 0 if voltage control
M+3		QFLAG: • 1 if voltage or Q control • 0 if constant pf or Q control
M+5		PQFLAG, P/Q priority flag for current limit: • 0 for Q priority • 1 for P priority

CONs	Value	Description
J		Vdip (pu), low voltage threshold to activate reactive current injection logic
J+1		Vup (pu), Voltage above which reactive current injection logic is activated
J+2		Trv (s), Voltage filter time constant
J+3		dbd1 (pu), Voltage error dead band lower threshold (≤0)
J+4		dbd2 (pu), Voltage error dead band upper threshold (≥0)
J+5		Kqv (pu), Reactive current injection gain during over and undervoltage conditions
J+6		Iqh1 (pu), Upper limit on reactive current injection Iqinj
J+7		Iql1 (pu), Lower limit on reactive current injection Iqinj
J+8		Vref0 (pu), User defined reference (if 0, model initializes it to initial terminal voltage)
J+9		Tp (s), Filter time constant for electrical power
J+10		QMax (pu), limit for reactive power regulator
J+11		QMin (pu) limit for reactive power regulator
J+12		VMAX (pu), Max. limit for voltage control
J+13		VMIN (pu), Min. limit for voltage control
J+14		Kqp (pu), Reactive power regulator proportional gain

CONs	Value	Description
J+15		Kqi (pu), Reactive power regulator integral gain
J+16		Kvp (pu), Voltage regulator proportional gain
J+17		Kvi (pu), Voltage regulator integral gain
J+18		Tiq (s), Time constant on delay s4
J+19		dPmax (pu/s) (>0) Power reference max. ramp rate
J+20		dPmin (pu/s) (<0) Power reference min. ramp rate
J+21		PMAX (pu), Max. power limit
J+22		PMIN (pu), Min. power limit
J+23		Imax (pu), Maximum limit on total converter current
J+24		Tpord (s), Power filter time constant
J+25		Vq1 (pu), Reactive Power V-I pair, voltage
J+26		Iq1 (pu), Reactive Power V-I pair, current
J+27		Vq2 (pu) (Vq2>Vq1), Reactive Power V-I pair, voltage
J+28		Iq2 (pu) (Iq2>Iq1), Reactive Power V-I pair, current
J+29		Vq3 (pu) (Vq3>Vq2), Reactive Power V-I pair, voltage
J+30		Iq3 (pu) (Iq3>Iq2), Reactive Power V-I pair, current
J+31		Vq4 (pu) (Vq4>Vq3), Reactive Power V-I pair, voltage
J+32		Iq4 (pu) (Iq4>Iq3), Reactive Power V-I pair, current
J+33		Vp1 (pu), Real Power V-I pair, voltage
J+34		Ip1 (pu), Real Power V-I pair, current
J+35		Vp2 (pu) (Vp2>Vp1), Real Power V-I pair, voltage
J+36		Ip2 (pu) (Ip2>Ip1), Real Power V-I pair, current
J+37		Vp3 (pu) (Vp3>Vp2), Real Power V-I pair, voltage
J+38		Ip3 (pu) (Ip3>Ip2), Real Power V-I pair, current
J+39		Vp4 (pu) (Vp4>Vp3), Real Power V-I pair, voltage
J+40		Ip4 (pu) (Ip4>Ip3), Real Power V-I pair, current
J+41		T, battery discharge time (s) (<0)
J+42		SOCini (pu), Initial state of charge
J+43		SOCmax (pu), Maximum allowable state of charge
J+44		SOCmin (pu), Minimum allowable state of charge

STATEs	Description
K	Voltage Measurement filter
K+1	Real power filter
K+2	PI controller for reactive power
K+3	PI controller for voltage error
K+4	First Order lag for reactive current
K+5	First order lag for Pord
K+6	Energy output from battery

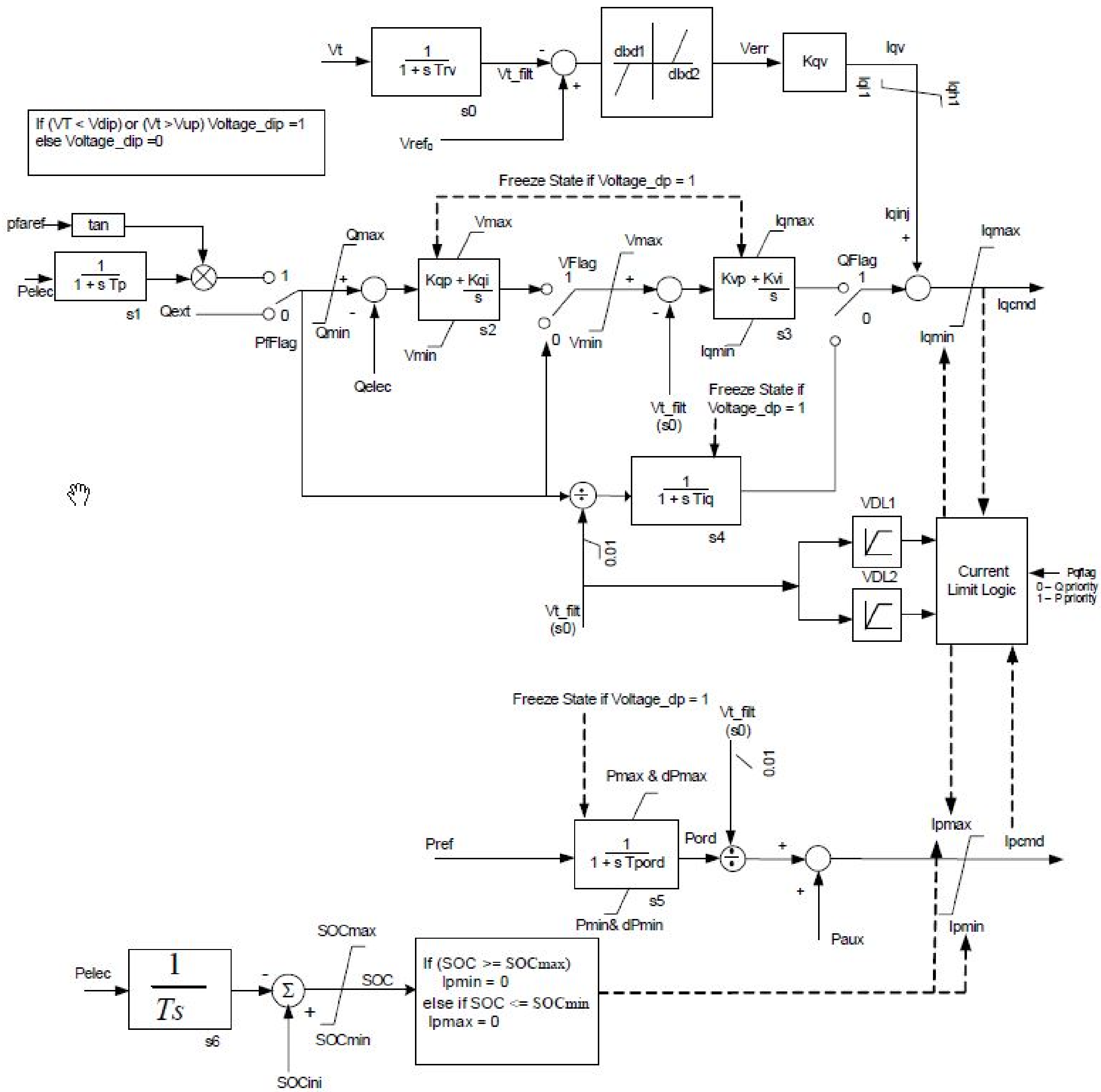
VAR	Description
L	Bus reference voltage (Vref0)

VAR	Description
L+1	Power factor reference angle (pfaref), radians
L+2	Real current command (Ipcmd)
L+3	Reactive current command (Iqcmd)
L+4	Battery Residual Energy
L+5	Auxiliary input signal, Paux

IBUS, 'USRMDL', ID, 'REECCU1', 102, 0, 5, 45, 7, 6, ICON(M) to ICON(M+4), CON(J) to CON(J+44) /

Notes:

1. pfaref (the power factor angle reference) value is initialized by the model based on ini- tial real and reactive power outputs from the machine.
2. Qref is initialized by the model to a constant or can be connected to an external plant controller model).
3. Pref is initialized by the model to a constant or can be connected to an external plant controller model).
4. ICON(M) contains the remote bus number. If this is 0 or if the remote bus number is not specified then the local bus is used for control.
5. SOCini represents the initial state of charge on the battery and is a user entered value. This is entered in pu; with 1 pu meaning that the batter is fully charged and 0 means the battery is completely discharged.
6. SOCmax is the maximum allowable state of charge. By definition the maximum value would be 1 pu; however it may be set to a smaller value (e.g., 0.8 pu) to represent spe- cific manu-facturer requirements that the battery will remain at or below a certain charging level (e.g., 80 %).
7. SOCmax is the minimum allowable state of charge. By definition the minimum value would be 0 pu; however it may be set to a larger value (e.g., 0.2 pu) to represent spe- cific manufac-turer requirements that the battery will remain at or above a certain charging level (e.g., 20 %).
8. Other models to be used with REECC1 are, REGCA1, and REPCA1
9. An auxiliary signal model can be attached to the signal represented as Paux. This can be used for interfacing with supplemental models like power oscillation damping control.


Vt
1 / 1 + s Trv
s0
Vt_filt
Vref0
dbd1
dbd2
Verr
Kqv
Iqv
Iql1
Iqh1
If (VT < Vdip) or (Vt > Vup) Voltage_dip =1
else Voltage_dip =0
Freeze State if Voltage_dp = 1
pfaref
tan
Pelec
1 / 1 + s Tp
s1
Qext
PfFlag
Qmax
Qmin
Qelec
Vmax
Vmin
Kqp + Kqi/s
s2
VFlag
Kvp + Kvi/s
s3
Iqmax
Iqmin
QFlag
Iqinj
Iqcmd
Vt_filt
(s0)
Freeze State if
Voltage_dp = 1
1 / 1 + s Tiq
s4
0.01
VDL1
VDL2
Current
Limit Logic
Pqflag
0 – Q priority
1 – P priority
Freeze State if Voltage_dp = 1
Pmax & dPmax
Pref
1 / 1 + s Tpord
s5
Pmin& dPmin
Pord
Paux
Ipmax
Ipmin
Ipcmd
Pelec
1 / Ts
s6
SOCmax
SOC
SOCmin
SOCini
If (SOC >= SOCmax)
Ipmin = 0
else if SOC <= SOCmin
Ipmax = 0

18.5. REECDU1

Generic Renewable Electrical Control Model

ICONs	Value	Description
M		PFFLAG: • 1 if power factor control • 0 if Q control (which can be controlled by an external signal)
M+1		VFLAG: • 1 if Q control • 0 if voltage control
M+2		QFLAG: • 1 if voltage or Q control • 0 if constant pf or Q control
M+3		PFLAG: • 1 if active current command has speed dependency • 0 for no dependency
M+4		PQFLAG, P/Q priority flag for current limit: • 0 for Q priority • 1 for P priority
M+5		VcmpFlag: • 1 for current compensation • 0 for reactive droop dompensation

CONs	Value	Description
J		Vdip (pu), low voltage threshold to activate reactive current injection logic
J+1		Vup (pu), Voltage above which reactive current injection logic is activated
J+2		Trv (s), Voltage filter time constant
J+3		dbd1 (pu), Voltage error dead band lower threshold (≤0)
J+4		dbd2 (pu), Voltage error dead band upper threshold (≥0)
J+5		Kqv (pu), Reactive current injection gain during over and undervoltage conditions
J+6		Iqh1 (pu), Upper limit on reactive current injection Iqinj
J+7		Iql1 (pu), Lower limit on reactive current injection Iqinj
J+8		Vref0 (pu), User defined reference (if 0, model initializes it to initial terminal voltage)

CONs	Value	Description
J+9		Iqfrz (pu), Value at which Iqcmdbl (value of Iqcmd before limit) is held (frozen) for Thld seconds after a voltage dip is over
J+10		Thld (s), Time for which Iqcmdbl is frozen after the voltage dip is over
J+11		Thld2 (s) (≥0), Time for which Ipcmdbl (value of Ipcmd before limit) is frozen after the voltage dip is over
J+12		Tp (s), Filter time constant for electrical power
J+13		QMax (pu), Maximum value of the signal Qext or Vext
J+14		QMin (pu) Minimum value of the signal Qext or Vext
J+15		VMAX (pu), Maximum limit for voltage control
J+16		VMIN (pu), Minimum limit for voltage control
J+17		Kqp (pu), Reactive power regulator proportional gain
J+18		Kqi (pu), Reactive power regulator integral gain
J+19		Kvp (pu), Voltage regulator proportional gain
J+20		Kvi (pu), Voltage regulator integral gain
J+21		Vbias (pu), User-defined bias (normally 0)
J+22		Tiq (s), Time constant on delay for block s4
J+23		dPmax (pu/s) (>0) Power reference maximum ramp rate
J+24		dPmin (pu/s) (<0) Power reference minimum ramp rate
J+25		PMAX (pu), Maximum power limit
J+26		PMIN (pu), Minimum power limit
J+27		Imax (pu), Maximum limit on total converter current
J+28		Tpord (s), Power filter time constant
J+29		Vq1 (pu), VDL table vq-iq pair (voltage)
J+30		Iq1 (pu), VDL table vq-iq pair (current)
J+31		Vq2 (pu), VDL table vq-iq pair (voltage)
J+32		Iq2 (pu), VDL table vq-iq pair (current)
J+33		Vq3 (pu), VDL table vq-iq pair (voltage)
J+34		Iq3 (pu), VDL table vq-iq pair (current)
J+35		Vq4 (pu), VDL table vq-iq pair (voltage)
J+36		Iq4 (pu), VDL table vq-iq pair (current)
J+37		Vq5 (pu), VDL table vq-iq pair (voltage)
J+38		Iq5 (pu), VDL table vq-iq pair (current)
J+39		Vq6 (pu), VDL table vq-iq pair (voltage)
J+40		Iq6 (pu), VDL table vq-iq pair (current)
J+41		Vq7 (pu), VDL table vq-iq pair (voltage)
J+42		Iq7 (pu), VDL table vq-iq pair (current)
J+43		Vq8 (pu), VDL table vq-iq pair (voltage)
J+44		Iq8 (pu), VDL table vq-iq pair (current)
J+45		Vq9 (pu), VDL table vq-iq pair (voltage)
J+46		Iq9 (pu), VDL table vq-iq pair (current)
J+47		Vq10 (pu), VDL table vq-iq pair (voltage)

CONs	Value	Description
J+48		Iq10 (pu), VDL table vq-iq pair (current)
J+49		Vp1 (pu), VDL table vp-ip pair (voltage)
J+50		Ip1 (pu), VDL table vp-ip pair (current)
J+51		Vp2 (pu), VDL table vp-ip pair (voltage)
J+52		Ip2 (pu), VDL table vp-ip pair (current)
J+53		Vp3 (pu), VDL table vp-ip pair (voltage)
J+54		Ip3 (pu), VDL table vp-ip pair (current)
J+55		Vp4 (pu), VDL table vp-ip pair (voltage)
J+56		Ip4 (pu), VDL table vp-ip pair (current)
J+57		Vp5 (pu), VDL table vp-ip pair (voltage)
J+58		Ip5 (pu), VDL table vp-ip pair (current)
J+59		Vp6 (pu), VDL table vp-ip pair (voltage)
J+60		Ip6 (pu), VDL table vp-ip pair (current)
J+61		Vp7 (pu), VDL table vp-ip pair (voltage)
J+62		Ip7 (pu), VDL table vp-ip pair (current)
J+63		Vp8 (pu), VDL table vp-ip pair (voltage)
J+64		Ip8 (pu), VDL table vp-ip pair (current)
J+65		Vp9 (pu), VDL table vp-ip pair (voltage)
J+66		Ip9 (pu), VDL table vp-ip pair (current)
J+67		Vp10 (pu), VDL table vp-ip pair (voltage)
J+68		Ip10 (pu), VDL table vp-ip pair (current)
J+69		rc (pu), Current compensation resistance
J+70		Xc (pu), Current compensation reactance
J+71		Tr1 (s), Time constant for reactive current compensation
J+72		Kc, Reactive current compensation gain
J+73		Ke, Scaling on Ipmin, (0 for generator, 0 < Ke ≤ 1 for storage)
J+74		Vblkl (pu), Voltage below which converter will block
J+75		Vblkh (pu), Voltage above which converter will block
J+76		Tblk (s), time for which converter will remain blocked after voltage is within the range Vblkl < Vt_filt < Vblkh

STATEs	Description
K	Voltage Measurement filter
K+1	Real power filter
K+2	PI controller for reactive power
K+3	PI controller for voltage error
K+4	First Order lag for reactive current
K+5	First order lag for Pord
K+6	First Order filter in droop compensation path

VARs	Description
L	Bus reference voltage (Vref0)

VARs	Description
L+1	Voltage deadband output
L+2	Power factor reference angle (pfaref), radians
L+3	Vbias as calculated by the model
L+4	Timer for Thld counter
L+5	Previous value of power reference
L+6	Input to create step change in Paux
L+7	Timer for Thld2 counter
L+8	Storage for voltage_dip flag
L+9	Ipmax
L+10	Ipmin
L+11	Iqmax
L+12	Iqmin
L+13	Ipcmd
L+14	Iqcmd
L+15	Input to create step change in Pref
L+16	Input to create step change in Qref
L+17	Timer for Tblk
L+18	Ipcmdbl (Ipcmd value before limit)
L+19	Iqcmdbl (Iqcmd value before limit)

DYR Syntax:

```
IBUS  'USRMDL'  ID  'REECDU1'  102  0  6  77  7  20  ICON(M) to
 ICON(M+5)  CON(J) to CON(J+76) /
```

Note(s):

Details of this model are given in 'Memo_RES_Modeling_Updates.pdf' which can be obtained from WECC website (www.wecc.org).

1. Model Parameters are specified in per unit of machine MVA base.

2. When the voltage Vtfilt is either less than Vdip or greater than Vup, the voltage_dip falg in the model is set to 1, else it is set to 0. In order to disable voltage dip check logic, set the CONs corresponding to Vdip and Vup to (say) -1.0 and 99.0 respectively. The *voltage_dip* flag is used in the model to freeze states and set the values of Iqcmd and Ipcmd.

3. The term VDL referenced in the CONs table above stands for Voltage-Dependent Limit. The VDL points represent the voltage-dependent limits on the inverter current. There are 10 pairs of VDLq points (shown as Vq-Iq pairs) to represent the reactive current limits followed by 10 pairs of VDLp points (shown as Vp-Ip pairs) to represent the active current limits.

   To ignore the VDLp set of points, set all the VDLp data points to zero. Similarly, to ignore the VDLq table, set all the VDLq data points to zero.

   The Vp data points (if specified) should be monotonically increasing (i.e., Vp1<Vp2<Vp3... <Vp10). The first Vp point can be zero. After this, the first Vp value of zero or if a Vp value is such that it is not

monotonically increasing signifies the end of Vp-Ip curve. Note that Ip values must be greater than or equal to zero.

The Vq data points (if specified) should be monotonically increasing (i.e., Vp1<Vp2<Vp3... <Vp10). The first Vq point can be zero. After this, the first Vq value of zero or if a Vq value is such that it is not monotonically increasing signifies the end of Vq-Iq curve. Note that Iq values can be negative signifying that both Iqmax and Iqmin are negative (which is used to force inductive current for very high voltage situations).

4. Imax is used to calculate Ipmax and Iqmax as described below:

```
If Pqflag is 0 (Q-priority):
    Iqmax = min (VDLq, Imax)
    If (Iqmax < 0)
        Iqmin = Iqmax
    else
        Iqmin = -Iqmax
    end
```

$$\text{Ipmax} = \min\left(VDLp, \sqrt{I_{\max}{}^2 - I_{qcmd}{}^2}\right)$$

```
    Ipmin = - Ke × Ipmax

If Pqflag is 1 (P-priority):
    Ipmax = min (VDLp, Imax)
    Ipmin = - Ke × Ipmax
```

$$\text{Iqmax} = \min\left(VDLq, \sqrt{I_{\max}{}^2 - I_{pcmd}{}^2}\right)$$

```
    If (Iqmax < 0)
        Iqmin = Iqmax
    else
        Iqmin = -Iqmax
    end
```

Note that if Iqmax is negative, then Iqmin must be equal but with opposite sign in order to force Iqcmd to this limit. This is used in some cases during extreme high voltage situations to make the inverter absorb reactive power.

5. The explanation for Ke is as follows:

- If Ke = 0, the model mimics a generator, i.e., Ipmin = 0. This means the unit cannot absorb active power.
- If 0 < Ke ≤ 1, the model mimics a storage device that is capable of also absorbing active current (charging mode). A value of Ke < 1 implies that the device has a lower capacity for absorbing real power as compared to its capacity for generating real power.
- Ke cannot be negative or greater than 1
- In case Iqmax is negative, then Iqmin must also be negative and the same value to force Iqcmd to this limit. Per the WECC REMTF memo (referenced above), this is used in some cases during extreme high voltages to make the inverter absorb reactive power.

6. Vref0 can be specified as an input parameter.

If initial Vref0 is specified as being ≤ 0.0, model will set this to be equal to the initial terminal voltage Vt.

If Vref0 is specified to be greater than zero, and if Kqv is greater than zero, then upon initialization model will check if dbd1 < Vref0 – Vt < dbd2. If this condition is not met, the model will set the initial Vref0 to be equal to Vt to force the Vref0 – Vt to be within the deadbands dbd1 and dbd2.

7. Local current-compensation is simulated using the block $\left[\left|\overrightarrow{Vt}-(rc+jxc)\times\overrightarrow{It}\right|\right]$. $\overrightarrow{Vt}$ and $\overrightarrow{It}$ are the complex generator terminal voltage and current to which this electrical control model is connected. rc and xc can both be set to zero to eliminate the modeling of current compensation. Note that rc and xc are specified in per unit of machine MVA base.

8. Local reactive-droop compensation simulated using the block Vt + Kc×Qelec. Vt is the magnitude of the machine terminal voltage and Qelec is the generator reactive power. Kc can be set to zero to eliminate the modeling of reactive-droop compensation.

9. The reactive-current injection arm (whose output is Iqinj) is always active if Kqv is greater than zero. To completely disable this arm, Kqv can be set to zero and Vdip and Vup can be set to (say) -99 and 99 to completely turn-off the voltage dip logic.

10. Thld is the time for which Iqcmdbl (value of Iqcmd before limit) is held at its current value (value just prior to the end of the *voltage_dip, i.e., before voltage_dip goes from 1 to 0*).

    If Thld < 0, then following a voltage dip, Iqcmdbl is held equal to Iqfrz for Thld seconds and is then released.

    Thld can be less than, equal to or greater than zero.

11. Thld2 is the time for which Ipcmdbl (value of Ipcmd before limit) is held at its current value (value just prior to the end of the *voltage_dip, i.e., before voltage_dip goes from 1 to 0*).

    Thld2 must be greater than or equal to zero.

12. Per details as specified in the WECC REMTF memo, the non-windup proportional-integrators corresponding to STATE(K+2) and STATE(K+3) (shown as s2 and s3 respectively in the block diagram) are linked as follows: if s3 hits its maximum limit and its derivative (ds3) is positive, then ds3 is set to 0, and furthermore if the derivative of s2 (i.e., ds2) is also positive, then ds2 is also set to 0 to prevent windup. However, if ds2 is negative, then ds2 is not set to 0. A similar rule is applied for s3 hitting its lower limit, but the check is whether ds3 and ds2 are negative.

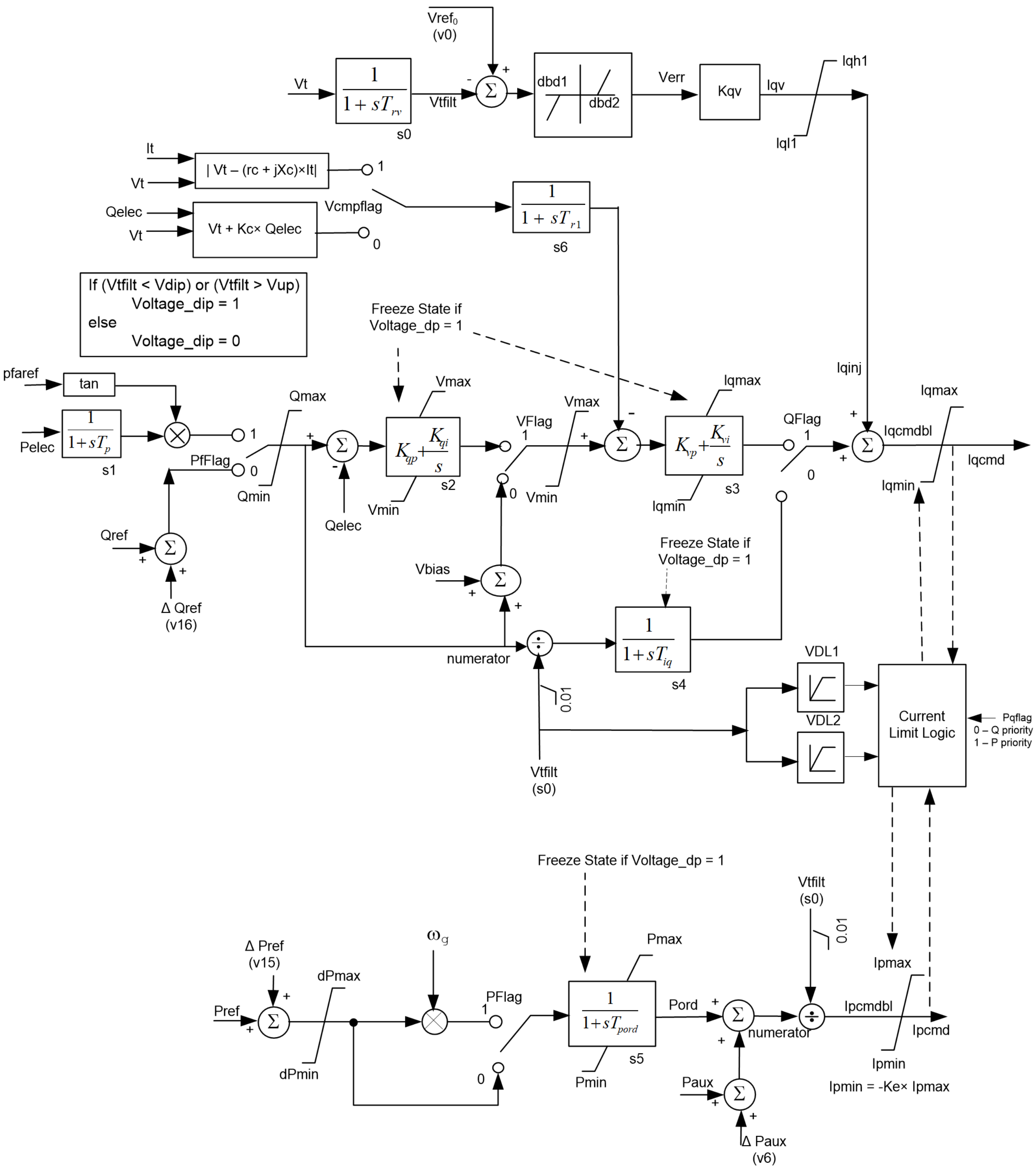
    For the freezing of the states s2, s3, s4 and s5, only the states are frozen, thus in the case of s2 and s3 the proportional gain, if non-zero, still acts during the voltage dip. Finally, for s5, if Tpord is zero then the time constant and freezing of the state are by-passed, however, the Pmax/Pmin limits are still applied.

13. VAR(L+15) and VAR(L+16) are been provided to allow users to perform step change in Pref & Qref commands. These are set to zero at model initialization.

14. Although it is possible to model the momentary cessation and the recovery delay by proper parametrization of the VDL data along with the Thld and Thld2 data, this may not be entirely desirable since the VDL table parameters are more typically used for modeling the voltage dependence of the inverter current limits.

    To model momentary cessation (inverter blocking), the parameters Vblkl, Vblkh and Tblk are used.

If the filtered voltage (Vtfilt) becomes less than Vblkl or becomes greater than Vblkh, then Iqmax, Iqmin, Ipmax, and Ipmin are all set to zero thus forcing the Iqcmd and Ipcmd to zero (to emulate inverter blocking). Once the inverter comes out of blocking mode (i.e., when voltage becomes such that Vblkl < Vtfilt < Vblkh), the current limits are released only after a delay of Tblk seconds (i.e., Ipmax, Iqmax, Ipmin and Iqmin are kept at zero for Tblk seconds before they are released).


Vref0
(v0)
Vt
1
1 + sTrv
s0
Vtfilt
dbd1
dbd2
Verr
Kqv
Iqv
Iqh1
Iql1
It
Vt
| Vt – (rc + jXc)×It|
1
Qelec
Vt
Vt + Kc× Qelec
Vcmpflag
0
1
1 + sTr1
s6
If (Vtfilt < Vdip) or (Vtfilt > Vup)
Voltage_dip = 1
else
Voltage_dip = 0
Freeze State if
Voltage_dp = 1
pfaref
tan
Pelec
1
1+sTp
s1
PfFlag
1
0
Qmax
Qmin
Qref
Δ Qref
(v16)
Qelec
Vmax
Vmin
Kqp + Kqi/s
s2
VFlag
1
0
Vmax
Vmin
Vbias
Iqmax
Iqmin
Kvp + Kvi/s
s3
QFlag
1
0
Iqinj
Iqmax
Iqcmdbl
Iqcmd
Iqmin
Freeze State if
Voltage_dp = 1
numerator
1
1+sTiq
s4
0.01
Vtfilt
(s0)
VDL1
VDL2
Current
Limit Logic
Pqflag
0 – Q priority
1 – P priority
Freeze State if Voltage_dp = 1
Vtfilt
(s0)
0.01
Δ Pref
(v15)
Pref
dPmax
dPmin
ωg
PFlag
1
0
Pmax
Pmin
1
1+sTpord
s5
Pord
numerator
Paux
Δ Paux
(v6)
Ipmax
Ipcmdbl
Ipcmd
Ipmin
Ipmin = -Ke× Ipmax

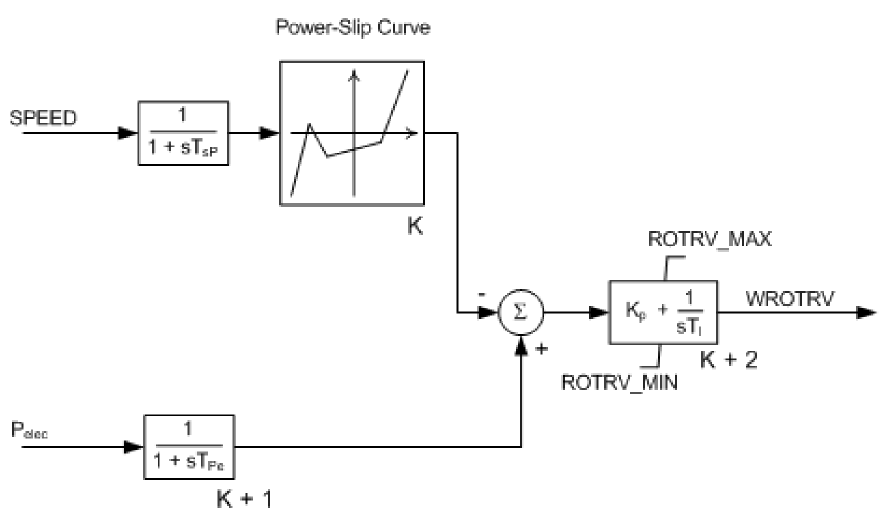
18.6. WT2E1

Rotor Resistance Control Model for the Type 2 Wind Generator

CONs	Value	Description
J		T_{sP}, rotor speed filter time constant, sec.
J+1		T_{pe}, power filter time constant, sec.
J+2		T_i, PI-controller integrator time constant, sec.
J+3		K_p, PI-controller proportional gain, pu
J+4		ROTRV_MAX, Output MAX limit
J+5		ROTRV_MIN, Output MIN limit

STATEs	Description
K	Rotor speed filter
K+1	Power filter
K+2	PI integrator

```
BUS, 'WT2E1', ID, CON(J) to CON(J+5) /
```



18.7. WT3E1

Electrical Control for Type 3 Wind Generator (for WT3G1 and WT3G2)

ICONs		Description
M		Remote bus # for voltage control; 0 for local voltage control
M+1		VARFLAG: • 0 - Constant Q control • 1 - Use Wind Plant reactive power control • -1 - Constant power factor control
M+2		VLTFLAG: • 0 : Bypass terminal voltage control • 1 : Eqcmd limits are calculated as VTerm and +XIQmin and VTerm and +XIQmax i.e limits are functions of terminal voltage • 2 : Eqcmd limits are equal to XIQmin and XIQmax
M+3		From bus of the interconnection transformer
M+4		To bus of the interconnection transformer
M+5		Interconnection transformer ID

CONs	Value	Description
J		T_{fv}, Filter time constant in voltage regulator (sec)
J+1		K_{pv}, Proportional gain in voltage regulator (pu)
J+2		K_{IV}, Integrator gain in voltage regulator (pu)
J+3		X_c, Line drop compensation reactance (pu)
J+4		T_{FP}, Filter time constant in torque regulator
J+5		K_{pp}, Proportional gain in torque regulator (pu)
J+6		K_{IP}, Integrator gain in torque regulator (pu)
J+7		P_{MX}, Max limit in torque regulator (pu)
J+8		P_{MN}, Min limit in torque regulator (pu)
J+9		Q_{MX}, Max limit in voltage regulator (pu)
J+10		Q_{MN}, Min limit in voltage regulator (pu)
J+11		IP_{MAX}, Max active current limit
J+12		T_{RV}, Voltage sensor time constant
J+13		RP_{MX}, Max power order derivative
J+14		RP_{MN}, Min power order derivative
J+15		$T_{\_Power}$, Power filter time constant
J+16		K_{qi}, MVAR/Voltage gain
J+17		V_{MINCL}, Min voltage limit
J+18		V_{MAXCL}, Max voltage limit

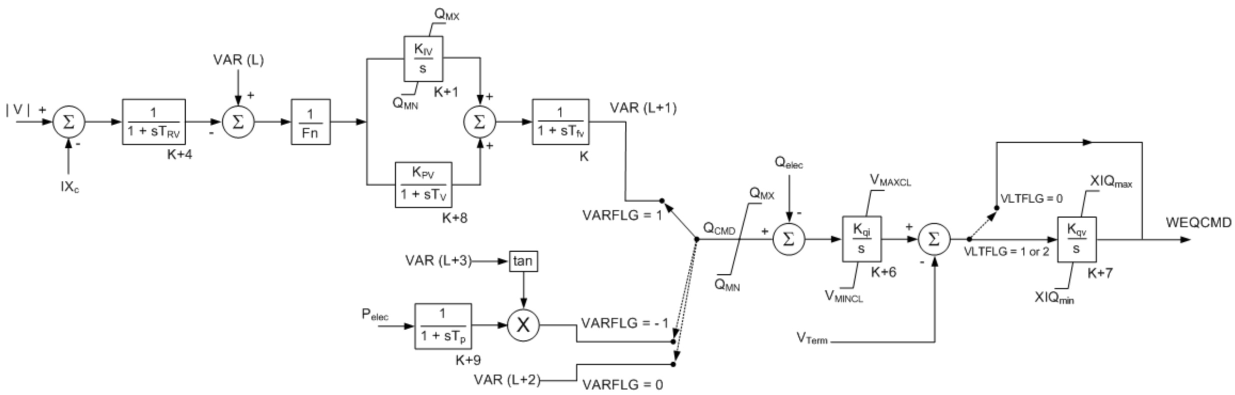
CONs	Value	Description
J+19		K_{qv}, Voltage/MVAR gain
J+20		XIQ_{min}
J+21		XIQmax
J+22		T_v, Lag time constant in WindVar controller
J+23		T_p, P_{elec} filter in fast PF controller
J+24		Fn, A portion of online wind turbines
J+25		ωP_{min}, Shaft speed at P_{min} (pu)
J+26		ωP_{20}, Shaft speed at 20% rated power (pu)
J+27		ωP_{40}, Shaft speed at 40% rated power (pu)
J+28		ωP_{60}, Shaft speed at 60% rated power (pu)
J+29		P_{min}, Minimum power for operating at ωP_{100} speed (pu)
J+30		ωP_{100}, Shaft speed at 100% rated power (pu)

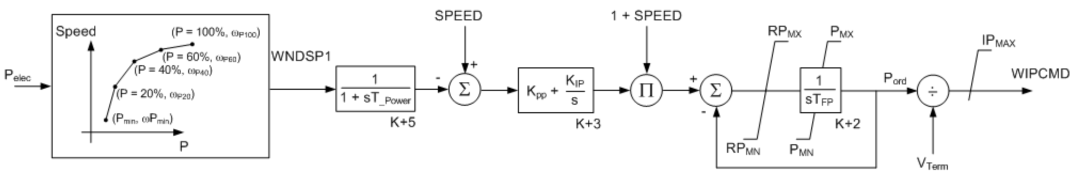
STATEs	Description
K	Filter in voltage regulator
K+1	Integrator in voltage regulator
K+2	Filter in torque regulator
K+3	Integrator in torque regulator
K+4	Voltage sensor
K+5	Power filter
K+6	MVAR/Vref integrator
K+7	Verror/internal machine voltage integrator
K+8	Lag of the WindVar controller
K+9	Input filter of Pelec for PF fast controller

VARs	Description
L	Remote bus ref voltage
L+1	MVAR order from MVAR emulator
L+2	Q reference if VARFLG=0
L+3	PF angle reference if VARFLG=-1 (radians)
L+4	Storage of MW for computation of compensated voltage
L+5	Storage of MVAR for computation of compensated voltage
L+6	Storage of MVA for computation of compensated voltage

WT3E1 model can be used with WT3G1 as well as WT3G2 models. When used with WT3G1 model, it is recommended that ICON(M+2) be set to 1; and when used with WT3G2 model, the ICON(M+2) be set to 2.

```
IBUS, 'WT3E1', ID, ICON(M) to ICON(M+5), CON(J) to CON(J+30)   /
```


Q_MX
K_IV / s
Q_MN
K+1
VAR (L)
| V |
1 / (1 + sT_RV)
K+4
IX_c
1 / Fn
K_PV / (1 + sT_V)
K+8
1 / (1 + sT_fv)
K
VAR (L+1)
VARFLG = 1
Q_elec
Q_CMD
Q_MX
Q_MN
V_MAXCL
K_qi / s
K+6
V_MINCL
VLTFLG = 0
VLTFLG = 1 or 2
XIQ_max
K_qv / s
K+7
XIQ_min
WEQCMD
V_Term
VAR (L+3)
tan
P_elec
1 / (1 + sT_p)
K+9
VARFLG = - 1
VAR (L+2)
VARFLG = 0


P_elec
Speed
(P = 100%, ωP100)
(P = 60%, ωP60)
(P = 40%, ωP40)
(P = 20%, ωP20)
(P_min, ωP_min)
P
WNDSP1
1 / (1 + sT_Power)
K+5
SPEED
K_pp + K_IP / s
K+3
1 + SPEED
RP_MX
RP_MN
P_MX
1 / sT_FP
P_MN
K+2
P_ord
IP_MAX
WIPCMD
V_Term

18.8. WT4E1

Electrical Control for Type 4 Wind Generator

ICONs		Description
M		Remote bus # for voltage control; 0 for local control
M+1		PFAFLG: • 1 if PF fast control enabled • 0 if PF fast control disabled
M+2		VARFLAG: • 1 if Qord is provided by WindVar • 0 if Qord is not provided by WindVar, if VARFLG = PFAFLG = 0 then Qord is provided as a Qref = const
M+3		PQFLAG, P/Q priority flag: • 0 for Q priority • 1 for P priority

CONs	Value	Description
J		T_{fv}, Filter time constant in Voltage regulator (sec)
J+1		K_{PV}, Proportional gain in Voltage regulator(pu)
J+2		K_{IV}, Integrator gain in Voltage regulator (pu)
J+3		Kpp, Proportional gain in Active Power regulator(pu)
J+4		K_{IP}, Integrator gain in Active Power regulator (pu)
J+5		K_f, Rate feedback gain (pu)
J+6		T_f, Rate feedback time constant (sec.)
J+7		Q_{MX}, Max limit in Voltage regulator (pu)
J+8		Q_{MN}, Min limit in Voltage regulator (pu)
J+9		IP_{max}, Max active current limit
J+10		T_{RV}, Voltage sensor time constant
J+11		dP_{MX}, Max limit in power PI controller (pu)
J+12		dP_{MN}, Min limit in power PI controller (pu)
J+13		$T_{\_Power}$, Power filter time constant
J+14		K_{QI}, MVAR/Voltage gain
J+15		V_{MINCL}, Min. voltage limit
J+16		V_{MAXCL}, Max. voltage limit
J+17		K_{VI}, Voltage/MVAR Gain
J+18		T_v, Lag time constant in WindVar controller
J+19		T_p, Pelec filter in fast PF controller
J+20		ImaxTD, Converter current limit

CONs	Value	Description
J+21		Iphl, Hard active current limit
J+22		Iqhl, Hard reactive current limit

STATEs	Description
K	Filter in voltage regulator
K+1	Integrator in voltage regulator
K+2	Integrator in active power regulator
K+3	Active power regulator feedback
K+4	Voltage sensor
K+5	Power filter
K+6	MVAR/Vref integrator
K+7	Verror/Internal machine voltage integrator
K+8	Lag of the WindVar controller
K+9	Input filter of Pelec for PF fast controller

VARs	Description
L	Remote bus reference voltage
L+1	Q reference if PFAFLG=0 & VARFLG=0
L+2	PFangle reference if PFAFLG=1
L+3	Power reference

```
IBUS, 'WT4E1', ID, ICON(M) to ICON(M+3), CON(J) to CON(J+22) /
```

Four possible configurations:

1. Current North American configuration with WindVAR:

```
varflg = 1; pfaflg = 0; Kqi small (0.1)
```

2. Current North American configuration without WindVAR:

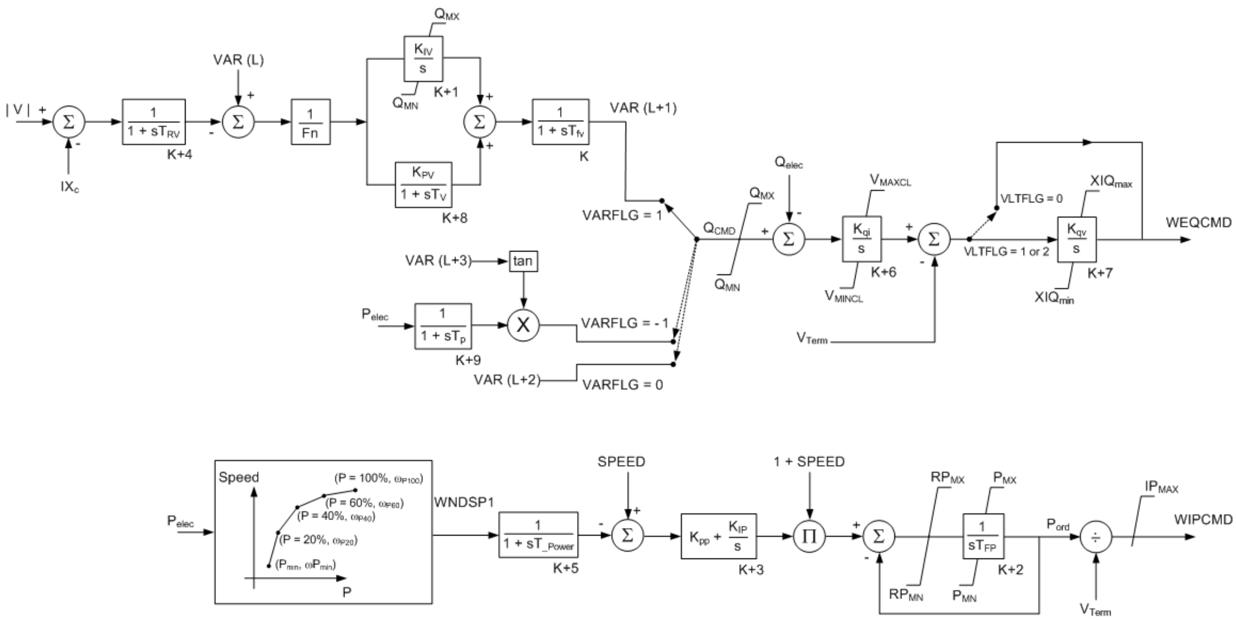
```
varflg = 0; pfaflg = 0; Kqi = very small (or 0.).
```

3. European (PFA control) with WindVAR:

```
varflg = 1; pfaflg = 0;Kqi large; Kvi larger
```

4. European (PFA control) without WindVAR:

```
varflg = 0; pfaflg =1; hold desired PFA Kqi large ; Kvi larger
```



Electrical Control for Type 4 Wind Generator

18.9. WT4E2

Electrical Control for Type 4 Wind Generator

ICONs		Description
M		Remote bus # for voltage control; 0 for local control
M+2		PFAFLG: • 1 if PF fast control enabled • 0 if PF fast control disabled
M+3		VARFLAG: • 1 if Qord is provided by WindVar • 0 if Qord is not provided by WindVar, if VARFLG = PFAFLG = 0 then Qord is provided as a Qref = const
M+5		PQFLAG, P/Q priority flag for current limit: • 0 for Q priority • 1 for P priority

CONs	Value	Description
J		T_{fv}, Filter time constant in Voltage regulator (sec)
J+1		K_{PV}, Proportional gain in Voltage regulator(pu)
J+2		K_{IV}, Integrator gain in Voltage regulator (pu)
J+3		Kpp, Proportional gain in Active Power regulator(pu)
J+4		K_{IP},Integrator gain in Active Power regulator (pu)
J+5		K_f, Rate feedback gain (pu)
J+6		T_f, Rate feedback time constant (sec.)
J+7		Q_{MX}, Max limit in Voltage regulator (pu)
J+8		Q_{MN}, Min limit in Voltage regulator (pu)
J+9		IP_{max}, Max active current limit
J+10		T_{RV}, Voltage sensor time constant
J+11		dP_{MX}, Max limit in power PI controller (pu)
J+12		dP_{MN}, Min limit in power PI controller (pu)
J+13		T_{Power}, Power filter time constant
J+14		K_{QI}, MVAR/Voltage gain
J+15		V_{MINCL}, Min. voltage limit
J+16		V_{MAXCL}, Max. voltage limit
J+17		K_{VI}, Voltage/MVAR Gain
J+18		T_v, Lag time constant in WindVar controller
J+19		T_p, Pelec filter in fast PF controller
J+20		ImaxTD, Converter current limit
J+21		Iphl, Hard active current limit

CONs	Value	Description
J+22		Iqhl, Hard reactive current limit
J+23		Tiqf, IQmax filter time constant, sec.
J+24		FRT_Thres, Voltage Threshold for FRT activation (pu)
J+25		FRT_Hys, FRT De-activation Hysteresis (pu)
J+26		FRT_Droop, FRT Droop
J+27		FRT_Iq_Gain, FRT Iq Gain
J+28		Max_FRT_Iq, Max FRT Iq
J+29		IQMax_Fact1, Factor 1 to adjust IQMX (pu)
J+30		IQMax_Fact2, Factor 2 to adjust IQMX (pu)
J+31		DC_Link_Droop, Voltage Drop in DC-Link cables (pu)
J+32		VinvMax0, Maximum inverter no-load voltage (pu)
J+33		NBR_X, Network bridge reactor reactance

STATEs	Description
K	Filter in voltage regulator
K+1	Integrator in voltage regulator
K+2	Integrator in active power regulator
K+3	Active power regulator feedback
K+4	Voltage sensor
K+5	Power filter
K+6	MVAR/Vref integrator
K+7	Verror/Internal machine voltage integrator
K+8	Lag of the WindVar controller
K+9	Input filter of Pelec for PF fast controller
K+10	IQmax filter

VARs	Description
L	Remote bus reference voltage
L+1	Q reference if PFAFLG=0 & VARFLG=0
L+2	PFangle reference if PFAFLG=1
L+3	Power reference

```
IBUS, '’WT4E2’, ID, ICON(M) to ICON(M+3), CON(J) to CON(J+33) /
```

Four possible configurations:

1. Current North American configuration with WindVAR:

   ```
   varflg = 1; pfaflg = 0; Kqi small (0.1)
   ```

2. Current North American configuration without WindVAR:

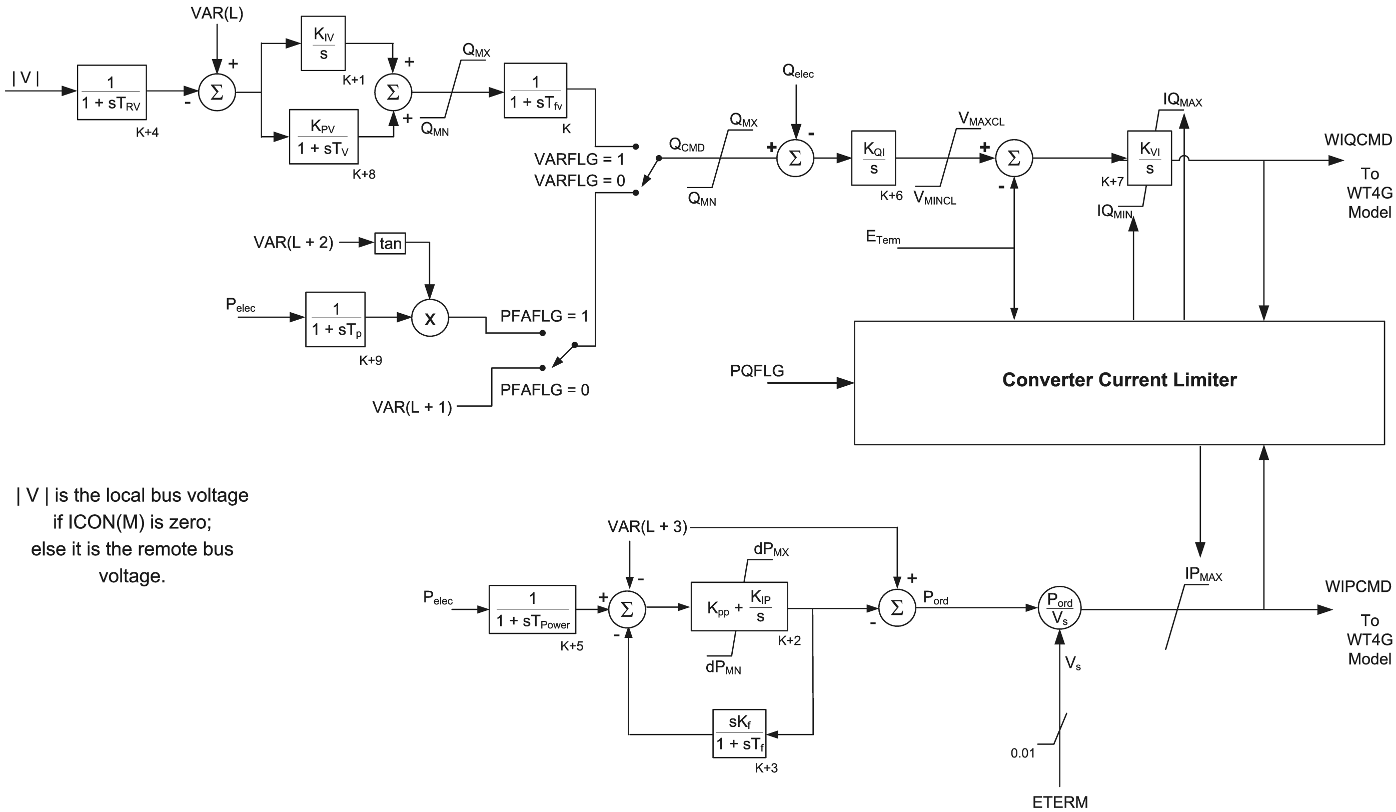
   ```
   varflg = 0; pfaflg = 0; Kqi = very small (or 0.).
   ```

3. European (PFA control) with WindVAR:

```
varflg = 1; pfaflg = 0;Kqi large; Kvi larger
```

4. European (PFA control) without WindVAR:

```
varflg = 0; pfaflg =1; hold desired PFA Kqi large ; Kvi larger
```



Chapter 19

Generic Renewable Drive Train Models

This chapter contains a collection of data sheets for the generic wind mechanical models contained in the PSS®E dynamics model library.

Model	Description
PANELU1	User written model to represent the linearized model of PV panel's output curve
WT12T1	Two mass turbine model for Type 1 and Type 2 wind generators
WT3T1	Mechanical system model for Type 3 wind generator
WTDTA1	Wind turbine Mechanical system model

19.1. PANELU1

PV I-P Characteristics

CONs	Value	Description
J		PDCMAX200, maximum power of panel at an irradiance of 200 W/m2, pu on PDCMAX1000 base
J+1		PDCMAX400, maximum power of panel at an irradiance of 400 W/m2, pu on PDCMAX1000 base
J+2		PDCMAX600, maximum power of panel at an irradiance of 600 W/m2, pu on PDCMAX1000 base
J+3		PDCMAX800, maximum power of panel at an irradiance of 800 W/m2, pu on PDCMAX1000 base
J+4		PDCMAX1000, maximum power of panel at an irradiance of 1000

VARs	Description
L	DC power from PV array

```
IBUS 'USRMDL' ID 'PANELU1' 103 0 0 5 0 1 CON(J) to CON(J+4) /
```

19.2. WT12T1

Two-Mass Turbine Model for Type 1 and Type 2 Wind Generators

CONs	Value	Description
J		H, Total inertia constant, sec
J+1		DAMP, Machine damping factor, pu P/pu speed
J+2		H_{tfrac}, Turbine inertia fraction (Hturb/H)1
J+3		Freq1, First shaft torsional resonant frequency, Hz
J+4		Dshaft, Shaft damping factor (pu)

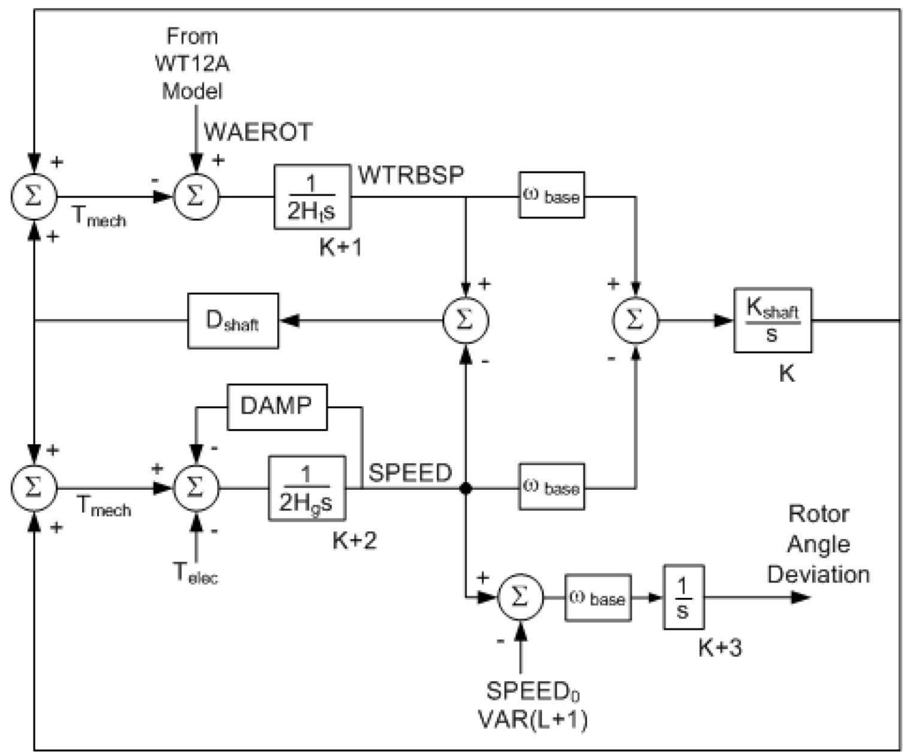
To simulate one-mass mechanical system, set $H_{tfrac} = 0$.

To simulate two-mass mechanical system, set H_{tfrac} as $0 < H_{tfrac} < 1$

STATEs	Description
K	Shaft twist angle, rad.
K+1	Turbine rotor speed deviation, pu
K+2	Generator speed deviation, pu
K+3	Generator rotor angle deviation, pu

VARs	Description
L	P_{aero} on the rotor blade, pu
L+1	Initial rotor slip
L+2	Initial internal angle

```
IBUS, 'WT12T1', ID, CON(J) to CON(J+4) /
```



$$H_t = H \times H_{tfrac}$$

$$H_g = H - H_t$$

$$K_{shaft} = \frac{2H_t \times H_g \times (2\pi \times Freq1)^2}{H \times \omega_0}$$

Two-Mass Shaft WT12T Model
for Type 1 & 2 Generic Wind Machines

19.3. WT3T1

Mechanical System Model for Type 3 Wind Generator (for WT3G1 and WT3G2)

In blkmdl, this model requires one reserved ICON.

CONs	Value	Description
J		VW, Initial wind, pu of rated wind speed
J+1		H, Total inertia constant, sec
J+2		DAMP, Machine damping factor, pu P/pu speed
J+3		K_{aero}, Aerodynamic gain factor
J+4		Theta2, BL_{ad}e pitch at twice rated wind speed, deg.
J+5		H_{tfrac}, Turbine inertia fraction (Hturb/H)
J+6		Freq1, First shaft torsional resonant frequency, Hz
J+7		D_{shaft}, Shaft damping factor (pu)

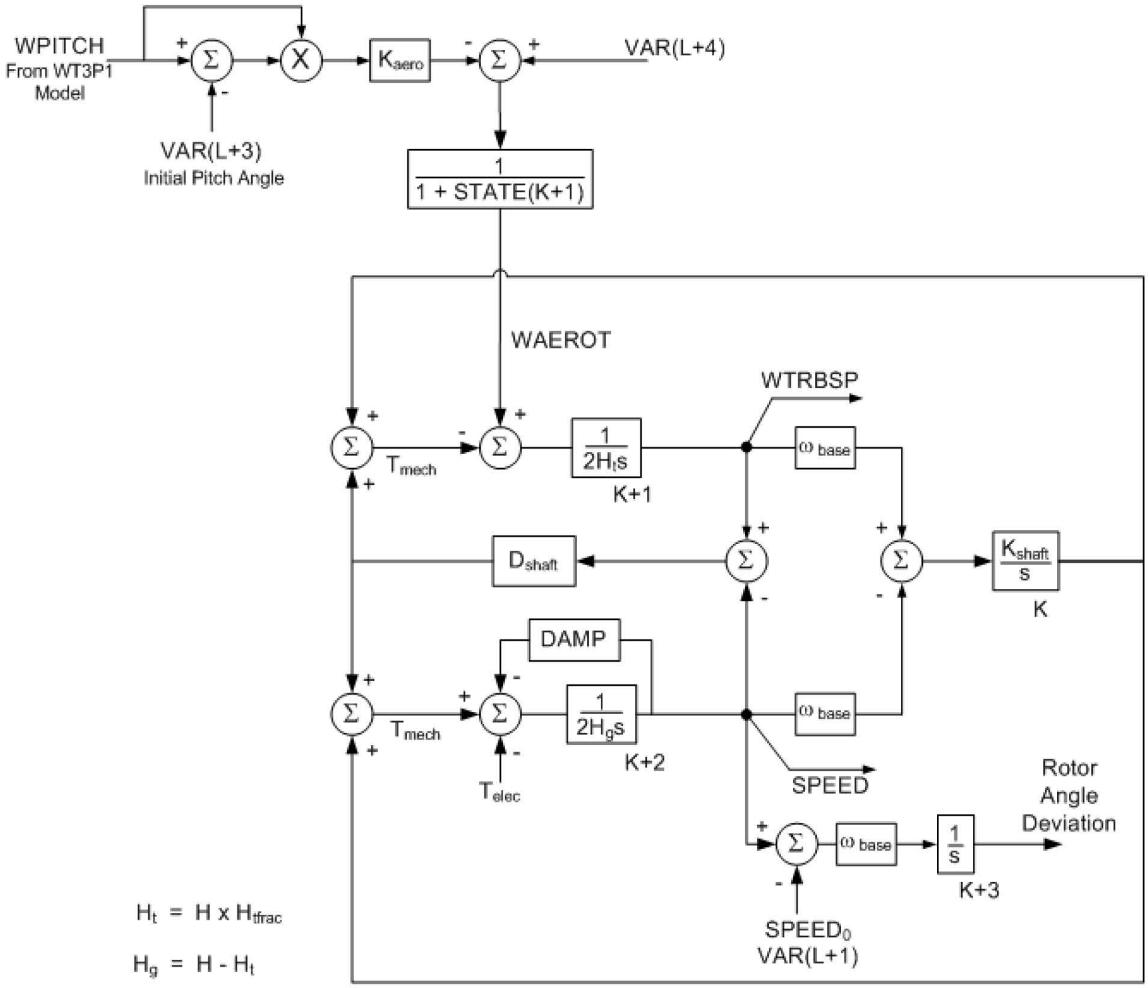
To simulate one-mass mechanical system, set $H_{tfrac} = 0$.

To simulate two-mass mechanical system, set H_{tfrac} as 0 < Htfrac < 1.

STATEs	Description
K	Shaft twist angle, rad.
K+1	Turbine rotor speed deviation, pu
K+2	Generator speed deviation, pu
K+3	Generator rotor angle deviation, pu

VARs	Description
L	P_{aero} on the rotor blade, pu
L+1	Initial rotor slip
L+2	Initial internal angle
L+3	Initial pitch angle
L+4	Paero initial

```
IBUS, 'WT3T1', ID, CON(J) to CON(J+7)   /
```



$H_t = H \times H_{tfrac}$

$H_g = H - H_t$

$$K_{shaft} = \frac{2H_t \times H_g \times (2\pi \times Freq1)^2}{H \times \omega_0}$$

19.4. WTDTA1

Generic Drive Train Model for Type 3 and Type 4 Wind Machines

CONs	Value	Description
J		H, Total inertia constant, sec
J+1		DAMP, Machine damping factor, pu P/pu speed
J+2		Htfrac, Turbine inertia fraction (Hturb/H)1
J+3		Freq1, First shaft torsional resonant frequency, Hz
J+4		Dshaft, Shaft damping factor (pu)

To simulate one-mass mechanical system, set H1tfrac = 0.

To simulate two-mass mechanical system, set Htfrac as 0 < Htfrac < 1

STATEs	Description
K	Shaft twist angle, rad.
K+1	Turbine rotor speed deviation, pu
K+2	Generator speed deviation, pu
K+3	Generator rotor angle deviation, pu

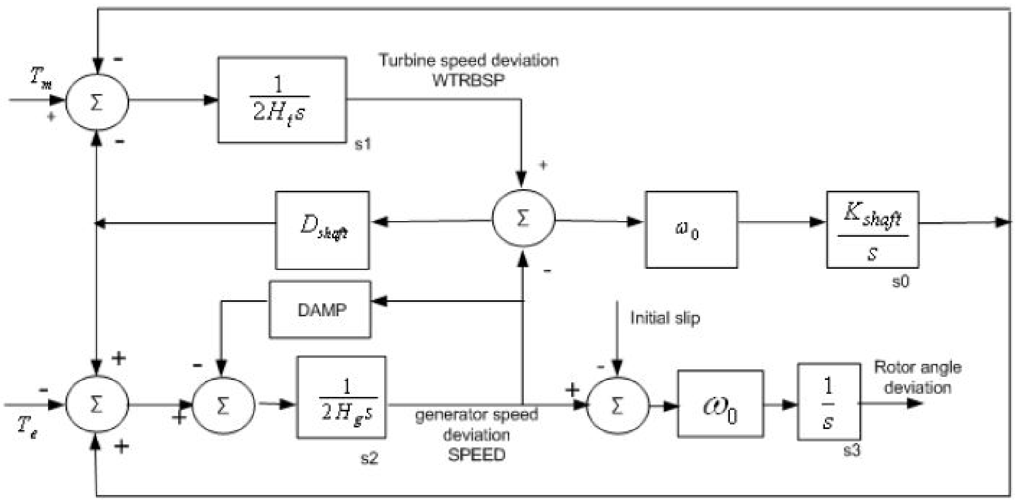
VARs	Description
L	Aerodynamic on the rotor blade, pu
L+1	Initial rotor slip
L+2	Initial internal angle

```
IBUS, 'WTDTA1', ID, CON(J) to CON(J+4)  /
```

Notes:

1. To simulate a one-mass mechanical system, set Htfrac=0. To simulate a two-mass me- chanical system, set Htfrac such that 0 < Htfrac < 1.

2. This model can be used with Type 3 and 4 wind machines. When used for modeling of Type 3 wind machine, the other models to be used along with the drive train control model are regca1, reeca1, repcta1 (optional), wtpta1, wtara1, wttqa1. When used for modeling of Type 4 machines, the other models to be used along with the drive train control model are regca1, reeca1, repca1 (optional).



$$H_t = H \times H_{tfrac}$$

$$H_g = H - H_t$$

$$K_{shaft} = \frac{2H_t \times H_g \times (2\pi \times Freq1)^2}{H \times \omega_0}$$

$\omega_0 = 2 \times \pi \times$system nominal frequency

Chapter 20

Generic Renewable Pitch Control Models

This chapter contains a collection of data sheets for the generic renewable pitch control models contained in the PSS®E dynamics model library.

Model	Description
IRRADU1	User written model to represent the linearized model of PV panel's solar irradiance profile.
WT3P1	Pitch control model for Type 3 wind generator
WTPTA1	Wind Turbine Pitch Control model

20.1. IRRADU1

PV Irradiance Profile

ICONs	Value	Description
M		In Service Flag: • 1: model is in service • 0: model is OFF

CONs	Value	Description
J		TIME1, Time of first data point, sec
J+1		IRRADIANCE1, Irradiance at first data point, W/m2
J+2		TIME2, Time of second data point, sec
J+3		IRRADIANCE2, Irradiance at second data point, W/m2
J+4		TIME3, Time of third data point, sec
J+5		IRRADIANCE3, Irradiance at third data point, W/m2
J+6		TIME4, Time of fourth data point, sec
J+7		IRRADIANCE4, Irradiance at forth data point, W/m2
J+8		TIME5, Time of fifth data point, sec
J+9		IRRADIANCE5, Irradiance at fifth data point, W/m2
J+10		TIME6, Time of sixth data point, sec
J+11		IRRADIANCE6, Irradiance at sixth data point, W/m2
J+12		TIME7, Time of seventh data point, sec
J+13		IRRADIANCE7, Irradiance at seventh data point, W/m2
J+14		TIME8, Time of eighth data point, sec
J+15		IRRADIANCE8, Irradiance at eighth at point, W/m2
J+16		TIME9, Time of ninth data point, sec
J+17		IRRADIANCE9, Irradiance at ninth data point, W/m2
J+18		TIME10, Time of tenth data point, sec
J+19		IRRADIANCE10, Irradiance at tenth data point, W/m2

VARs	Description
L	DC power from PV array

NOTE: A maximum of 10 pairs of time versus irradiance may be specified. The unused pairs should be entered as zero. TIME1 should be greater than 0 as the initial irradiance calculated from the load flow output.

```
IBUS 'USRMDL' ID 'IRRADU1' 104 0 1 20 0 1 ICON(M), CON(J) to CON(J+19) /
```

20.2. WT3P1

Pitch Control Model for Type 3 Wind Generator (for WT3G1 and WT3G2)

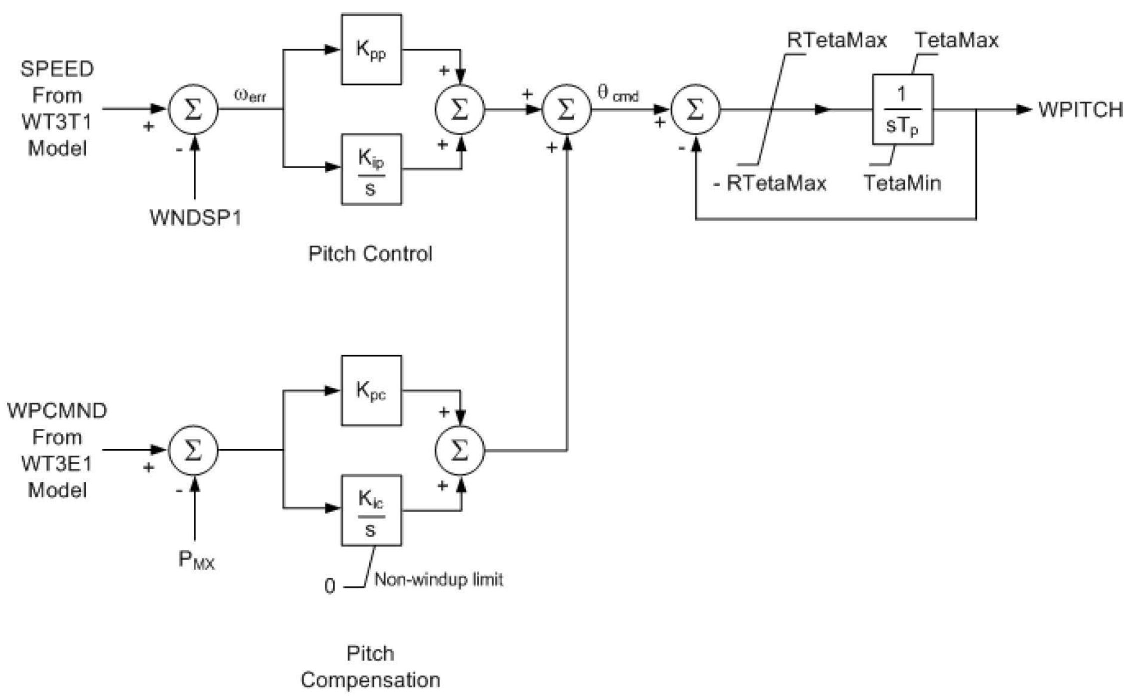
In blkmdl, this model requires one reserved ICON.

CONs	Value	Description
J		T_p, BLade response time constant
J+1		K_{pp}, Proportional gain of PI regulator (pu)
J+2		K_{Ip}, Integrator gain of PI regulator (pu)
J+3		K_{pc}, Proportional gain of the compensator (pu)
J+4		K_{Ic}, Integrator gain of the compensator (pu)
J+5		TetaMin, Lower pitch angle limit (degrees)
J+6		TetaMax, Upper pitch angle limit (degrees)
J+7		RTetaMax, Upper pitch angle rate limit (degrees/sec)
J+8		PMX, Power reference, pu on MBASE

Note: When a WT operates with a partial output, the DSTATE(K+2) may show INITIAL CONDITION SUSPECT. In this case no actions are needed.

STATEs	Description
K	Output lag
K+1	Pitch control
K+2	Pitch compensation

```
IBUS, 'WT3P1', ID, CON(J) to CON (J+8)   /
```



20.3. WTPTA1

Generic Pitch Control Model for Type 3 Wind Generator

CONs	Value	Description
J		Kiw, Pitch-control Integral Gain (pu)
J+1		Kpw, Pitch-control proportional gain (pu)
J+2		Kic, Pitch-compensation integral gain (pu)
J+3		Kpc, Pitch-compensation proportional gain (pu)
J+4		Kcc, Gain (pu)
J+5		Tp, Blade response time constant (s)
J+6		TetaMax, Maximum pitch angle (degrees)
J+7		TetaMin, Minimum pitch angle (degrees)
J+8		RTetaMax, Maximum pitch angle rate (degrees/s)
J+9		RTetaMin, Minimum pitch angle rate (degrees/s) (< 0)

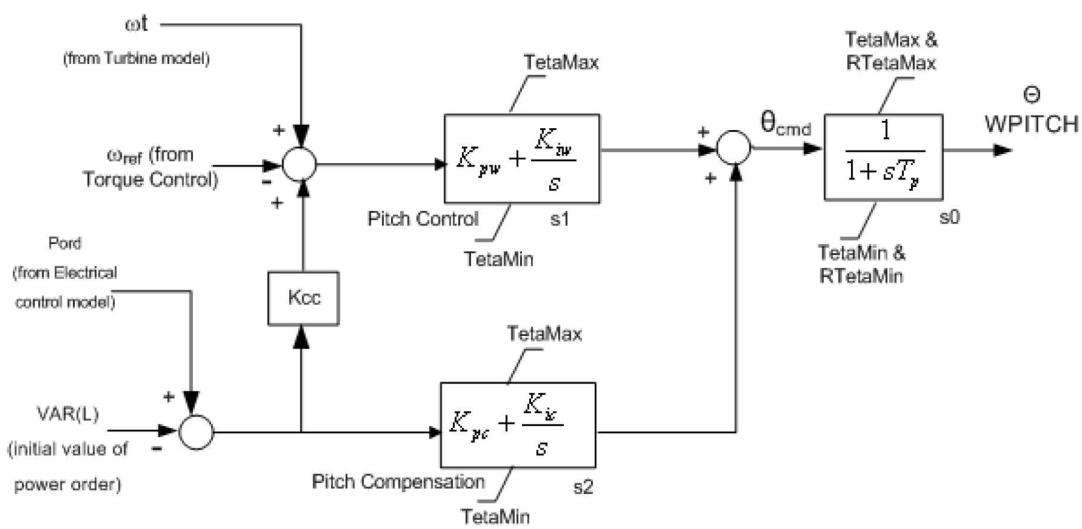
STATEs	Description
K	Output lag
K+1	Pitch control
K+2	Pitch compensation

VARs	Description
L	Pref from Plant control

```
IBUS, 'WTPTA1', ID, CON(J) to CON (J+9) /
```

Notes:

1. In modeling a Type 3 wind machine, the other models to be used along with this model are regca1, reeca1, repca1 (optional), wtdta1, wtara1, wttqa1.



Chapter 21
Generic Renewable Aerodynamic Models

This chapter contains a collection of data sheets for the generic renewable aerodynamic models contained in the PSS®E dynamics model library.

Model	Description
WT12A1	Pseudo-governor model for Type 1 and Type 2 wind generators
WT12A1U_B	Pseudo-governor model for Type 1 and Type 2 wind generators
WTARA1	Wind Turbine Aerodynamic model

21.1. WT12A1

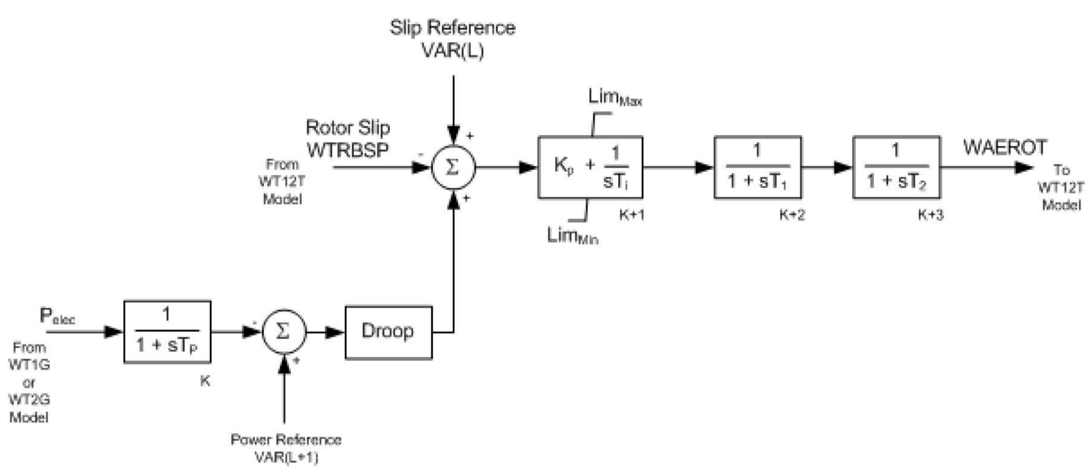
Pseudo-Governor Model for Type 1 and Type 2 Wind Generators

CONs	Value	Description
J		Droop
J+1		K_p, proportional gain, pu
J+2		T_i, integrator time constant, sec.
J+3		T_1, output filter 1 time constant, sec.
J+4		T_2, output filter 2 time constant, sec.
J+5		T_p, power filter time constant, sec.
J+6		Lim_{max}, maximum output limit
J+7		Lim_{min}, minimum output limit

STATEs	Description
K	Power filter
K+1	PI integrator
K+2	Output filter 1
K+3	Output filter 2

VARs	Description
L	Reference
L+1	Power reference

```
IBUS, 'WT12A1', ID, CON(J) to CON(J+7) /
```



21.2. WT12A1U_B

Pseudo-Governor Model for Type 1 and Type 2 Wind Generators

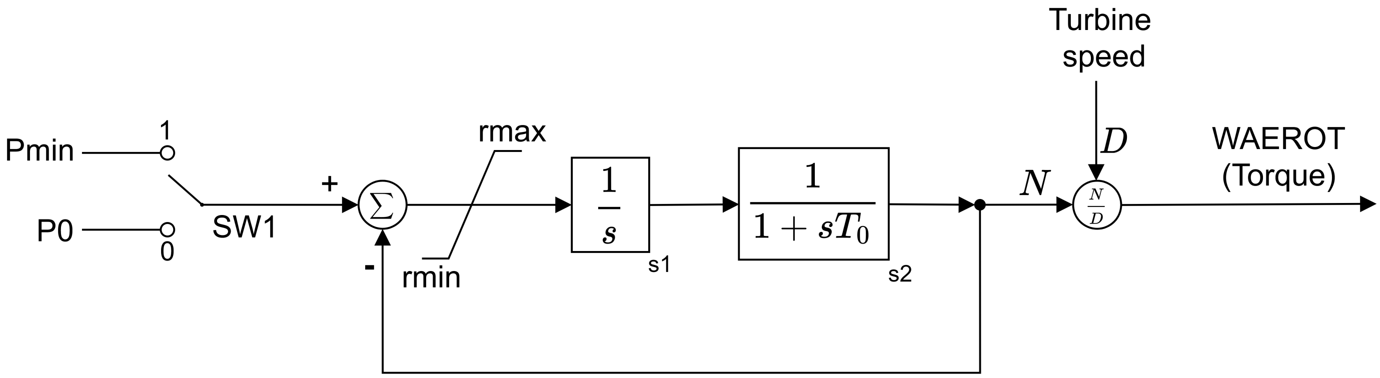
ICON	#	Value	Description
M			Reserved ICON (User should enter 0)

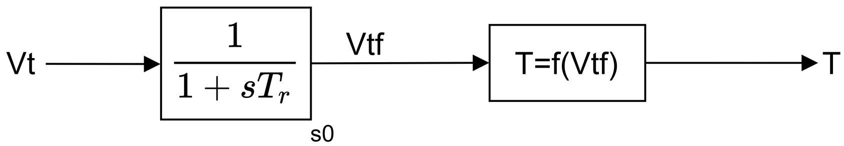
CONs	#	Value	Description
J			T_R, Voltage measurement time constant(s)
J+1			r_{max},Rate limit for increasing power(pu/s)(>0)
J+2			r_{min}, Rate limit for decreasinf power(pu/s)(>0)
J+3			T_0, Lag time constant
J+4			P_{min}(pu), Minimum Power setting (in PU of machine MVA base)
J+5			P_{set}(pu), (in PU of machine MVA base)
J+6			v_{t1},(pu voltage)
J+7			t_1, (sec)
J+8			v_{t2}
J+9			t_2
J+10			v_{t3}
J+11			t_3
J+12			v_{t4}
J+13			t_4

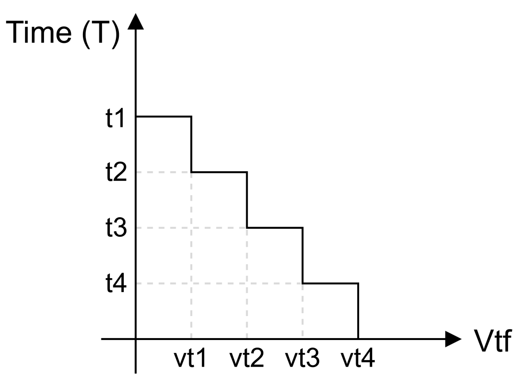
STATEs	#	Description
K		Integrator(s0)
K+1		Lag block for s1
K+2		Lag block for terminal voltage measurement

VARs	#	Description
L		Initial real power output of machine (pu of machine MVA base)
L+1		Used internal for time calculation

```
IBUS, 'USRMDL', ID ,'WT12A1U_B' 105 0 1 14 3 2 0 CON(J) to CON(J+13) /
```







Note(s):

(Model details as described below is taken from WECC document WECC Second Generation Wind Turbine Models dated January 23, 2014)

1. This model is the revised aerodynamic model for Type 1 and 2 machines that have active-stall scheme incorporated. This model will emulate the behavior of such machines where the mechanical power is ramped down and then back up following a disturbance (voltage-dip during a nearby transmissionfault). Per manufacturers, this is done to prevent the WTG from accelerating away and going unstable. If the Type 1 and 2 WTG are stall-regulated turbines (i.e., the blades are fixed to the rotor), this model or for that matter any pseudo-governor model (the old WT12A1 or this revised model) should not be applied.

For simulations where system frequency changes, subsequent changes in the slip-speed of the unit due to system frequency variations can results in a governor type action from the model. This is not a realistic response, since the legacy type 1 and 2 turbines do not generally provide primary frequency response.

For the legacy type 1 technologies many of the vendors would provide a functionality, for larger units (>1 MW) which had active-stall regulation, which would quickly ramp down mechanical power (by pitching the blades) when a nearby severe voltage dip (fault) was detected in order to assist with the low-voltage ride-through. This is not represented by this older model (WT12A1 model). Although, for a fault the older model can result in a momentary reduction in mechanical power, which is generally the correct behavior, but it is not a ramp down and back up, and so can be optimistic.

2. In this model, the integrator is used to ramp the turbine power power (and hence aerodynamic torque) down and back up. The rate limit rmin together with Pmin is used to effect the rate at which turbine power power is reduced and to what value during the disturbance. The rate limit rmax determines how quickly power is ramped back up after a given duration T. The time duration T, during which mechanical power is ramped down is based solely on the machine terminal voltage and determined from a four-piece curve shown above.

   The manner in which this is implemented is as follows. If the filtered voltage Vtf falls below vt4 and if P0 >= Pset, the switch position SW1 is changed by the model from 0 to 1. This change initiates the ramping down of the mechanical power at a rate of rmin to a minimum power (Pmin). This occurs for an amount of time as determined from the voltage (Vtf) versus time (T) look-up table. Once the given time (t1 or t2 or t3 or t4) corresponding to the voltage (vt1 or vt2 or vt3 or vt4) has elapsed, switch SW1 is toggled back to position 0 and the mechanical power ramps back up to the initial value P0 at a rate specified by rmax.

3. The values of vt1 through vt4 should be such that vt1 < vt2 < vt3 < vt4. If only vt4 data is specified, then set vt1 through vt3 as negative.

4. The values of t1 through t4 should be such that t4 < t3 < t2 < t1.

21.3. WTARA1

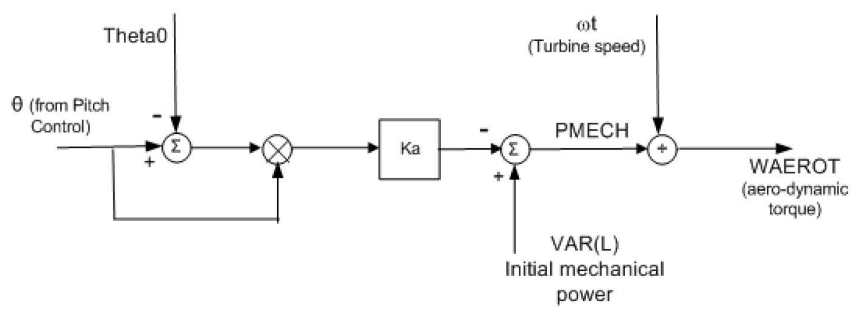
Generic Aerodynamic Model for Type 3 wind machine

CONs	Value	Description
J		Ka, Aerodynamic gain factor (pu/degrees)
J+1		Theta 0 Initial pitch angle (degrees)

VARs	Description
L	Initial mechanical power

Notes:

1. In modeling a Type 3 wind machine, the other models to be used along with this model are regca1, reeca1, repca1 (optional), wtdta1, wtpta1, wttqa1.



Chapter 22
Generic Renewable Torque Control Models

This chapter contains a collection of data sheets for the Wind Torque Controller models contained in the PSS®E dynamics model library. Generic Torque controller for Type 3 wind machines.

Model	Description
WTTQA1	Wind turbine Torque Control model

22.1. WTTQA1

Generic Torque controller for Type 3 wind machines

ICONs	Value	Description
M		Tflag, 0: for speed control, 1: for power control

CONs	Value	Description
J		Kpp, Proportional gain in torque regulator (pu)
J+1		KIP, Integrator gain in torque regulator (pu)
J+2		Tp, Electrical power filter time constant (s)
J+3		Twref, Speed-reference time constant (s)
J+4		Temax, Max limit in torque regulator (pu)
J+5		Temin, Min limit in torque regulator (pu)
J+6		p1, power (pu)
J+7		spd1, shaft speed for power p1 (pu)
J+8		p2, power (pu)
J+9		spd2, shaft speed for power p2 (pu)
J+10		p3, power (pu)
J+11		spd3, shaft speed for power p3 (pu)
J+12		p4, power (pu)
J+13		spd4, shaft speed for power p3 (pu)
J+14		TRATE, Total turbine rating (MW)

STATEs	Description
K	Electrical Power filter
K+1	Speed reference filter
K+2	PI controller

VARs	Description
L	Output of power-speed curve
L+1	Vdip value from electrical control model
L+2	Vup value from electrical control model

```
IBUS, 'WTTQA1', ID, ICON(M), CON(J) to CON(J+14) /
```

Notes:

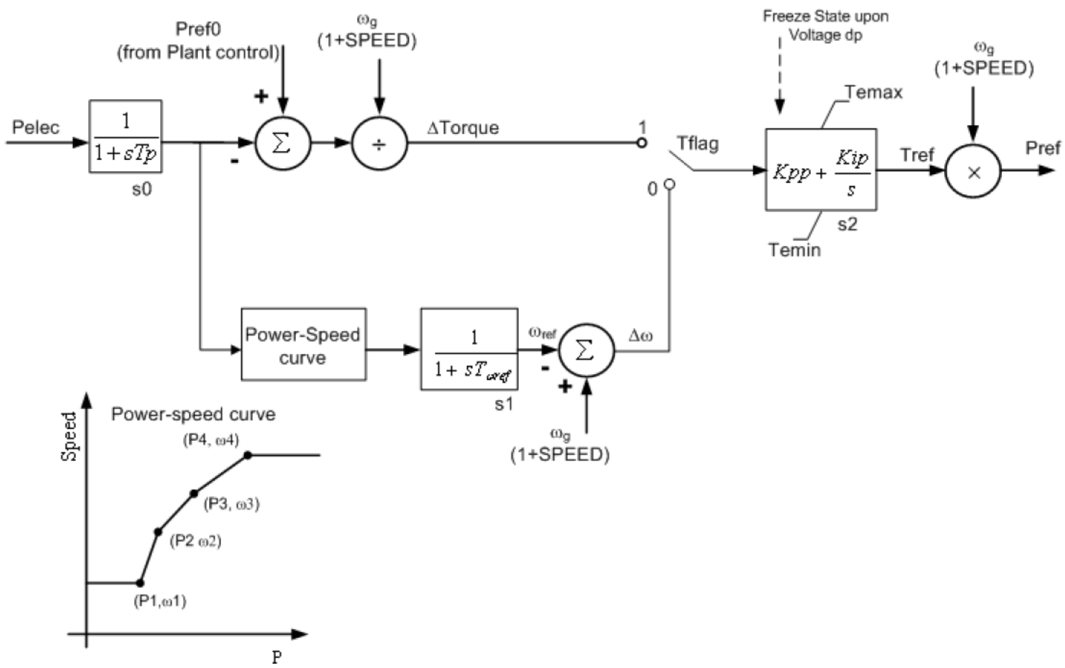
1. The power-speed curve points have to be specified as monotonically increasing pairs. If the power-speed curve points are all specified as zero, then the reference speed (Wref) is assumed to be 1.0 pu.

2. The speed points are per unit shaft speed values (these are not speed deviation values).

3. The turbine rating (TRATE) is the rating of each turbine times the total number of lumped machines being represented. The power points specified in CONs J+6, J+8, J+10 and J+12 are in per unit of TRATE. If TRATE is specified as zero, then the power points are assumed to be in per unit of machine MVA base (MBASE).

4. In modeling a Type 3 wind machine, the other models to be used along with torque control model are regca1, reeca1, repcta1 (optional), wtdta1, wtara1, wtpta1.

5. To simulate speed dependency, set Tflag (ICON (M)) to 0.



Chapter 23
Generic Renewable Plant Control Models

This chapter contains a collection of data sheets for the generic wind auxiliary control models contained in the PSS®E dynamics model library.

Model	Description
REPCA1, REPCTA1	Plant Controller model
REAX4BU1, REAX3BU1	Renewable Energy Auxiliary Control model

23.1. REAX4BU1 & REAX3BU1

Renewable Energy Auxiliary Control Model

ICONs	Value	Description
M		Bus Number at which the Plant controller Model is attached

CONs	Value	Description
J		Tw1 (s), Measurement time constant
J+1		Kw1 (pu on MBASE), Gain for signal in reactive path (Note 3)
J+2		Kp1 (pu on MBASE), Gain for signal in real path (Note 3)
J+3		Wmax (pu), Maximum value of W01
J+4		Wmin (pu), Minimum value of W01
J+5		Pmax (pu), Maximum value of P01
J+6		Pmin (pu), Minimum value of P01

STATEs	Description
K	Measurement lag (reactive part)
K+1	Measurement lag (real part)

VARs	Description
L	wref1, Reference in reactive path (pu on MBASE)
L+1	W01, Model output in reactive part (pu on MBASE)
L+2	pref1, Reference in active path (pu on MBASE)
L+3	P01, Model output in active part (pu on MBASE)

DYR record when used with Type 4 machines:

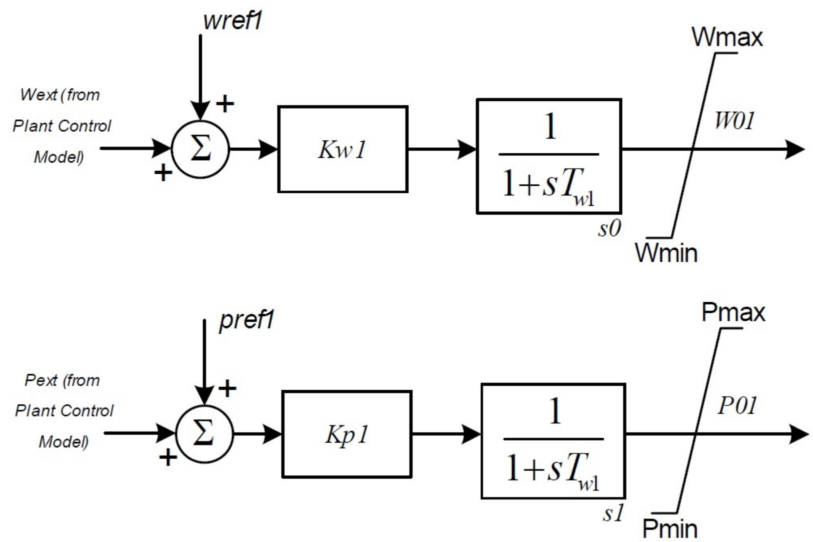
```
IBUS ’USRMDL'  ID  ‘REAX4BU1'  107  0 1 7 2 4 ICON(M), CON (J) to CON(J+6)
    /
```

DYR record when used with Type 3 machines:

```
IBUS   'USRMDL'   ID   ‘REAX3BU1'   107   0   1 7 2  4  ICON(M), CON (J)
 to CON(J+6)      /
```

Notes:

1. This model receives input from the plant control model (PLNTBU1) which is connected at bus specified in ICON(M). If there is no plant control model attached at the bus spec- ified in ICON(M), then the inputs (Wext and Pext) to the REAX4BU1and REAX3BU1 models would be zero.
2. Model parameters are specified in pu of the machine base (machine to which this model is attached).
3. Gains Kw1 and Kp1 should be non-zero.


wref1
Wmax
Wext (from
Plant Control
Model)
Kw1
1
1+sTw1
W01
s0
Wmin
pref1
Pmax
Pext (from
Plant Control
Model)
Kp1
1
1+sTw1
P01
s1
Pmin

23.2. REPCA1 & REPCTA1

Generic Renewable Plant Control Model

ICONs	Value	Description
M		Bus number for voltage control; local control if 0
M+1		Monitored branch FROM bus number for line drop compensation (if 0 generator power will be used)
M+2		Monitored branch TO bus number for line drop compensation (if 0 generator power will be used)
M+3		Branch circuit id for line drop compensation (enter in single quotes) (if 0 generator power will be used)
M+4		VC Flag (droop flag): • 0: with droop if power factor control • 1: with line drop compensation
M+5		RefFlag (flag for V or Q control): • 0: Q control • 1: voltage control
M+6		Fflag (flag to disable frequency control): • 1: enable control • 0: disable

CONs	Value	Description
J		Tfltr, Voltage or reactive power measurement filter time constant (s)
J+1		Kp, Reactive power PI control proportional gain (pu)
J+2		Ki, Reactive power PI control integral gain (pu)
J+3		Tft, Lead time constant (s)
J+4		Tfv, Lag time constant (s)
J+5		Vfrz, Voltage below which State s2 is frozen (pu)
J+6		Rc, Line drop compensation resistance (pu)
J+7		Xc, Line drop compensation reactance (pu)
J+8		Kc, Reactive current compensation gain (pu)
J+9		emax, upper limit on deadband output (pu)
J+10		emin, lower limit on deadband output (pu)
J+11		dbd1, lower threshold for reactive power control deadband (<=0)
J+12		dbd2, upper threshold for reactive power control deadband (>=0)
J+13		Qmax, Upper limit on output of V/Q control (pu)
J+14		Qmin, Lower limit on output of V/Q control (pu)
J+15		Kpg, Proportional gain for power control (pu)
J+16		Kig, Integral gain for power control (pu)

CONs	Value	Description
J+17		Tp, Real power measurement filter time constant (s)
J+18		fdbd1, Deadband for frequency control, lower threshold (specified as per unit frequency deviation) (<=0)
J+19		fdbd2, Deadband for frequency control, upper threshold (specified as per unit frequency deviation) (>=0)
J+20		femax, frequency error upper limit (pu)
J+21		femin, frequency error lower limit (pu)
J+22		Pmax, upper limit on power reference (pu)
J+23		Pmin, lower limit on power reference (pu)
J+24		Tg, Power Controller lag time constant (s)
J+25		Ddn, reciprocal of droop for over-frequency conditions (pu)
J+26		Dup, reciprocal of droop for under-frequency conditions (pu)

STATEs	Description
K	Voltage Measurement filter
K+1	Reactive power control filter
K+2	PI controller for reactive power
K+3	Lead-lag in reactive power path
K+4	Real power filter
K+5	PI controller for real power
K+6	Power controller first order lag

VARs	Description
L	Reference for voltage control (Vref)
L+1	Reactive power reference (Qref)
L+2	Frequency reference (Freq_ref)
L+3	Active Power reference (Plant_pref)
L+4	Line flow P MW
L+5	Line flow Q MVAr
L+6	Line flow MVA
L+7	Q/V Deadband output
L+8	Frequency deadband output

DYR record when used with Type 4 machines:

```
IBUS, 'REPCA1', ID, ICON(M) to ICON(M+6), CON(J) to CON(J+26) /
```

DYR record when used with Type 3 machines:

```
IBUS, 'REPCTA1', ID, ICON(M) to ICON(M+6), CON(J) to CON(J+26) /
```

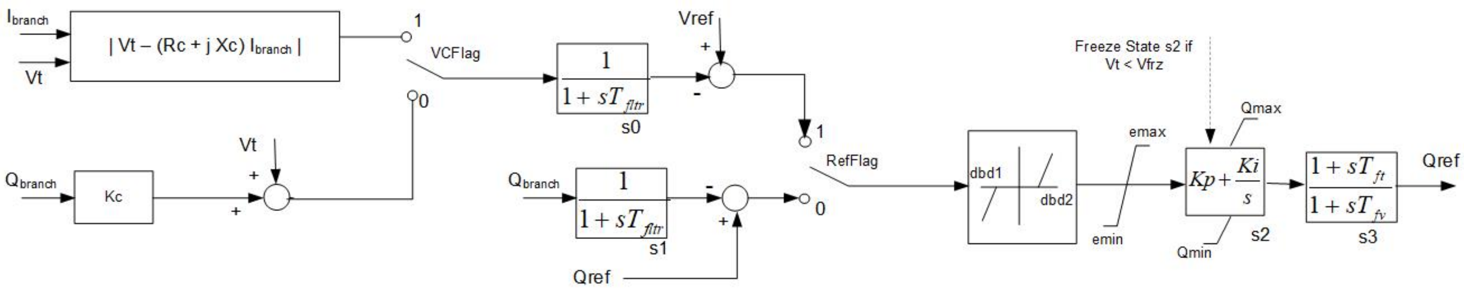
Notes:

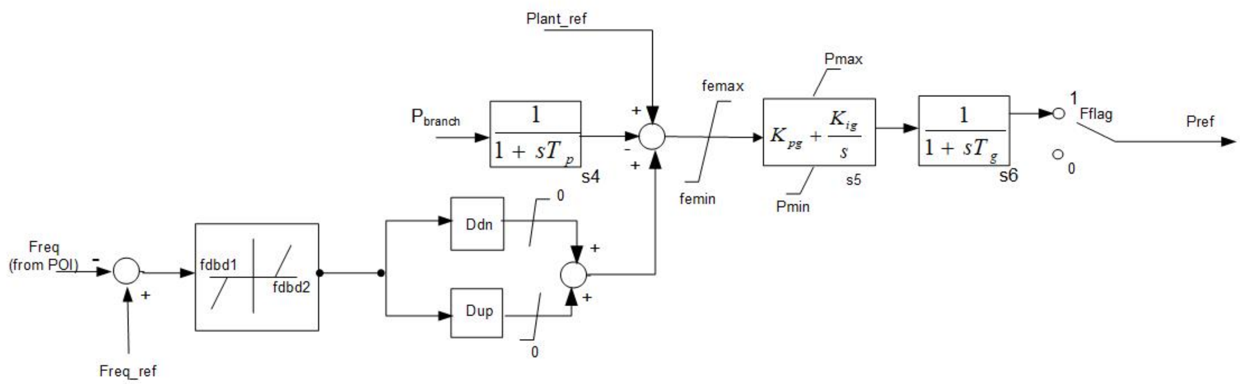
1. This model can be used with Type 3 and 4 wind machines. When used for modeling of Type 3 wind machine, the model name is REPCTA1, and the other models to be used along with this model are regca1,

reeca1, wtdta1, wtpta1, wtara1, wttqa1. When used for modeling of Type 4 machines, the model name is REPCA1, and the other models to be used along with this model are regca1, reeca1, wtdta1.

2. When used with Type 3 wind machine, the output (Pref) of the REPCTA1 model goes as an input Pref 0 into the Torque control model (wttqa1). When used with Type 4 wind ma-chine, the output (Pref) of the REPCA1 model goes as an input into the electrical control model (reeca1).

3. If ICON(M+1) is zero, then the generator active and reactive powers are used for line-drop compensation calculation.





Chapter 24
Switched Shunt Models

This chapter contains a collection of data sheets for the Switched Shunt models contained in the PSS®E dynamics model library.

Model	Description
ABBSVC1	ABB SVC Model
CHSVCT	SVC for switched shunt
CSSCST	SVC for switched shunt
SWSHNT	Switched shunt model
SVSMO1T2	WECC Generic Continuous Control SVC model
SVSMO2T2	WECC Generic Discrete Control SVC Model

24.1. ABBSVC1

ABB SVC Model

ICONs	Value	Description
M		IRGBUS, bus number of the regulated bus (this cannot be the bus at which the SVC is connected)
M+1		RPC, reactive power control flag • 0: None • 1: Supplementary Control • 2: External Caps • 3: Supplementary + External Caps
M+2		MSCBUS, external bus number where the MSCs are connected (this cannot be the bus at which the SVC is connected)
M+3		POD_ST, flag to indicate status of aux. signal • 0: None • 1: Supplementary Control • 2: External Caps • 3: Supplementary + External Caps
M+4		ENAB_IN, flag to indicate if sign of the aux. signal to be changed or not • 1: Change POD output sign when input signal becomes negative • 0: Do not change sign

CONs	Value	Description
J		SVC Base MVA (>0)
J+1		T_4, Integrator time constant (s) (>0)
J+2		T_S, Thyristor firing delay (s)
J+3		T_{TH}, Thyristor firing time constant (s)
J+4		XCC, Slope for capacitive range, on SVC base (pu voltage/pu current)
J+5		XCI, Slope for inductive range, on SVC base (pu voltage/pu current)
J+6		T_{LL1}, Voltage controller lead time constant (s)
J+7		T_{LL2}, Voltage controller lag time constant (s)
J+8		B1MAX, max. limit for voltage controller (pu on SVC base)
J+9		B1MIN, min. limit for voltage controller (pu on SVC base)
J+10		B2MAX, max. susceptance of SVC (pu on SVC base)
J+11		B2MIN, min. susceptance of SVC (pu on SVC base)
J+12		OVTHRSLD, overvoltage tripping threshold (pu)

CONs	Value	Description
J+13		OVDELAY, overvoltage tripping delay (s)
J+14		SVLOW, severe undervoltage strategy low voltage threshold (pu)
J+15		SVHIGH, severe undervoltage strategy high voltage threshold (pu)
J+16		SBFCLEAR, severe undervoltage strategy susceptance (pu on SVC base)
J+17		STBFCLEAR, timing of severe undervoltage strategy (s)
J+18		VLOW, undervoltage strategy low voltage threshold (pu)
J+19		VHIGH, undervoltage strategy high voltage threshold (pu)
J+20		USDELAY, undervoltage strategy delay (s)
J+21		BFCLEAR, undervoltage strategy susceptance (pu on SVC base)
J+22		TBFCLEAR, timing of undervoltage strategy (s)
J+23		V2MAX, max. SVC bus voltage limit (pu)
J+24		K_6, controller (V2) gain (pu)
J+25		T_6, controller (V2) time constant (s)
J+26		T_7, controller (V2) integrator time constant (s) (>0)
J+27		V2CLIM, controller (V2) minimum limit (pu on SVC base) (<0)
J+28		I1MAXC, maximum capacitive current limit (pu on SVC base) (>0)
J+29		K_8, controller (I1MAXC) gain (pu)
J+30		T_8, controller (I1MAXC) time constant (s)
J+31		T_9, controller (I1MAXC) integrator time constant (s) (>0)
J+32		IMAXCLIM, controller (I1MAXC) minimum limit (pu on SVC base) (<carat0)
J+33		IMINI, maximum inductive current limit (pu on SVC base) (<carat0)
J+34		K_{10}, controller (I1MINI) gain (pu)
J+35		T_{10}, controller (I1MINI) time constant (s)
J+36		T_{11}, controller (I1MINI)s integrator time constant (s) (>0)
J+37		IMINCLIM, controller (I1MINI) minimum limit (pu on SVC base) (>0)
J+38		ITCRMAX, maximum TCR current limit (pu on SVC base) (≥ 0)
J+39		K_1, controller (ITCR) gain (pu)
J+40		T_1, controller (ITCR) time constant (s)
J+41		T_2, controller (ITCR) integrator time constant (s) (>0)
J+42		TCRLIMTRG, TCR current limiter voltage trigger (pu)
J+43		TCRMIN, minimum TCR limit for ITCR control (pu on SVC base)
J+44		FSHUNT, fixed shunt compensation (pu on SVC base) (≥ 0) (this is always the filters, which are always capacitive; hence≥ zero)
J+45		BREGMAX, supplementary control capacitive threshold (pu on SVC base)
J+46		BREGMIN, supplementary control inductive threshold (pu on SVC base)
J+47		VREFMAX, maximum reference voltage for regulated bus voltage (pu)
J+48		VREFMIN, minimum reference voltage for regulated bus voltage (pu)

CONs	Value	Description
J+49		TBREG, integrator time constant for supplementary control(s) (>0)
J+50		DVBREGMAX, max. output of supplementary control (pu)
J+51		DVBREGMIN, min. output of supplementary control (pu)
J+52		BMAXDES, MSC slow switching capacitive threshold (pu on system base)
J+53		BMINDES, MSC slow switching inductive threshold (pu on system base)
J+54		TDELAY1, time delay for slow switching of MSCs (s)
J+55		BMAXDES2, MSC fast switching capacitive threshold (pu on system base)
J+56		BMINDES2, MSC fast switching inductive threshold (pu on system base)
J+57		TDELAY2, time delay for fast switching of MSCs, (s)
J+58		PODTW1, washout filter 1 time constant (s) (if zero, the washout is disabled)
J+59		PODTW2, washout filter 1 time constant (s) (>0) (if zero, the washout is disabled)
J+60		PODTM1, POD 1st lead-lag block lead time constant (s)
J+61		PODTM2, POD 1st lead-lag block lag time constant (s)
J+62		PODTM3, POD 2nd lead-lag block lead time constant (s)
J+63		PODTM4, POD 2nd lead-lag block lag time constant (s)
J+64		PODTM5, 3rd POD lead-lag block lead time constant (s)
J+65		PODTM6, 3rd POD lead-lag block lag time constant (s)
J+66		KPOD - POD gain (pu)
J+67		VPODMAX - POD max. output limit (pu)
J+68		VPODMIN - POD min. output limit (pu)
J+69		PODTW4 - washout filter 4 time constant (s)

STATEs	Description
K	Thyristor controller output (TTH) state
K+1	Lead-lag state
K+2	Voltage regulator integrator
K+3	Thyristor controller transport delay - State 1
K+4	Thyristor controller transport delay - State 2
K+5	ITCR controller time constant (T_1) state
K+6	ITCR controller integrator (T_2) state
K+7	V_2 controller time constant (T_6) state
K+8	V_2 controller integrator (T_7) state
K+9	I1MAX controller time constant (T_8) state
K+10	I1MAX controller time constant (T_9) state
K+11	I1MIN controller time constant (T_{10}) state
K+12	I1MIN controller integrator ($T_1$1) state

STATEs	Description
K+13	Integral part of supplementary controller, Max
K+14	Integral part of supplementary controller, Min
K+15	POD T_{w1} state
K+16	POD T_{w2} state
K+17	POD 1st lead-lag block state
K+18	POD 2nd lead-lag block state
K+19	POD 3rd lead-lag block state
K+20	POD T_{w4} state

VARs	Description
L	Auxiliary Signal
L+1	Switched Shunt Vref
L+2	B2 (pu SVC base), effective SVC admittance
L+3	B2 effective SVC admittance (pu system base, corrected for frequency)
L+4	B1 (pu system base), effective SVC admittance seen from HV side
L+5	Mvar1 - Mvar flow as measured from the "from" (HV) end of the transformer towards the "to" (LV) end
L+6	EFFB1MAX - Effective B1MAX
L+7	EFFB1MIN - Effective B1MIN
L+8	I1 - Current on high side of step-up transformer (pu on SVC base)
L+9	Itcr - Reactor current when all TSCs are off; in pu on SVC base - frequency corrected
L+10 ... L +21	Delay table
L+22	Auxiliary for Undervoltage Strategy
L+23	Auxiliary for Severe Undervoltage Strategy
L+24	Timer for Overvoltage Trip
L+25	Timer 1 for Slow Switching of MSCs (used with BMAXDES and BMINDES)
L+26	Timer 2 for Fast Switching of MSCs (used with BMAXDES2 and BMINDES2)
L+27	IN - POD Model VAR Input
L+28	$\Delta VREF$ - POD Model Output
L+29	POD Auxiliary Variable - Z-1
L+30	Transformer XT as retrieved from power flow (pu on SVC base)
L+31	• 0: POD not disabled • 1: POD diabled by over/under volatge strategies • -1: POD disabled by user

DYRE Record:

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IBUS 'ABBSVC1' ICON(M) through ICON(M+4), CON(J) to CON(J+69) /
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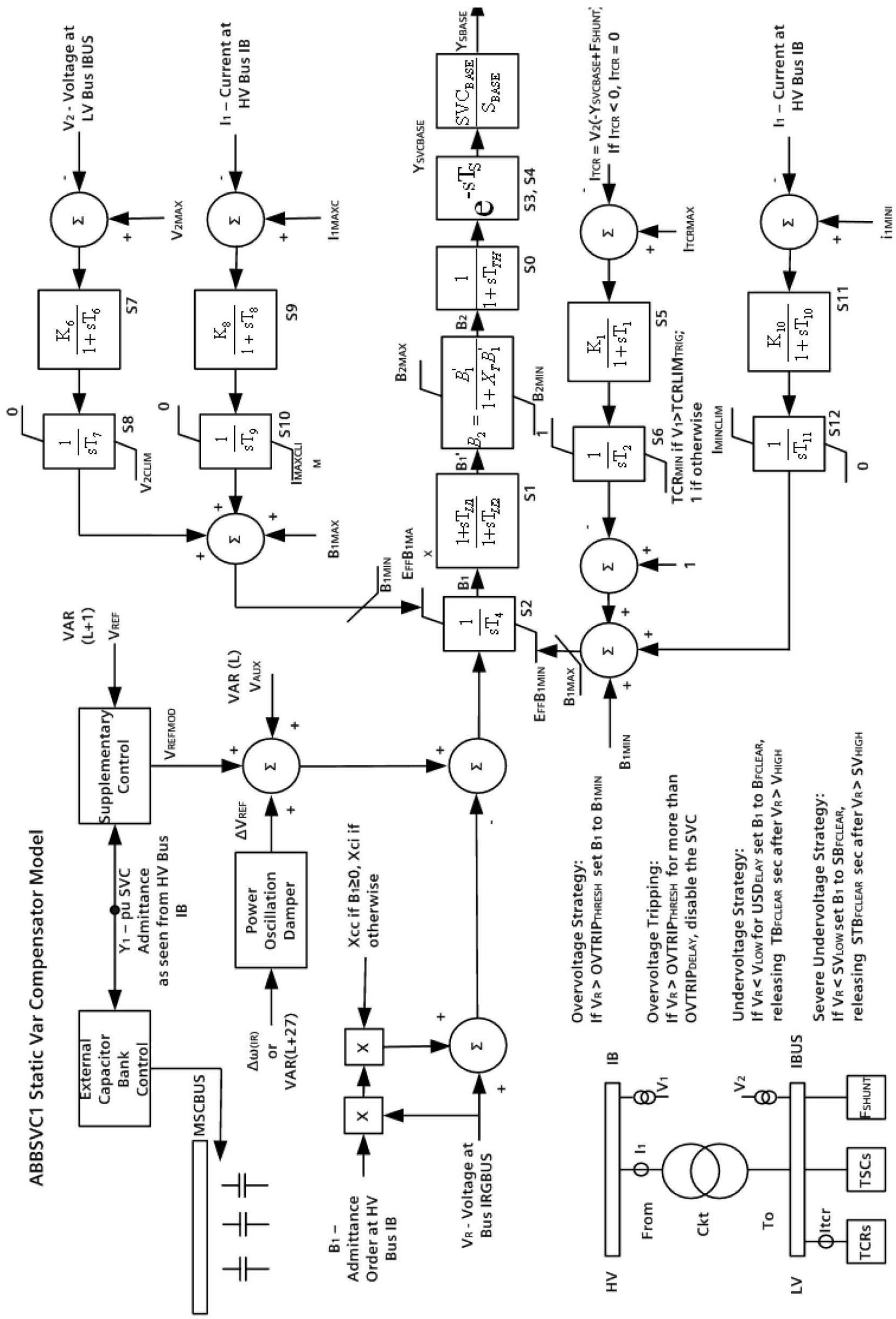
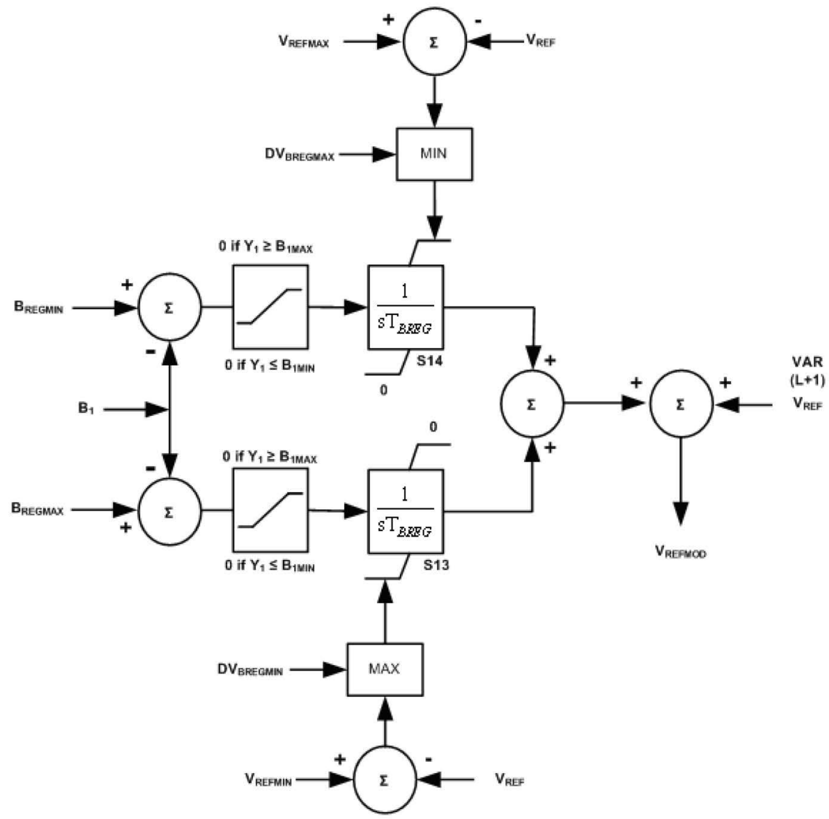
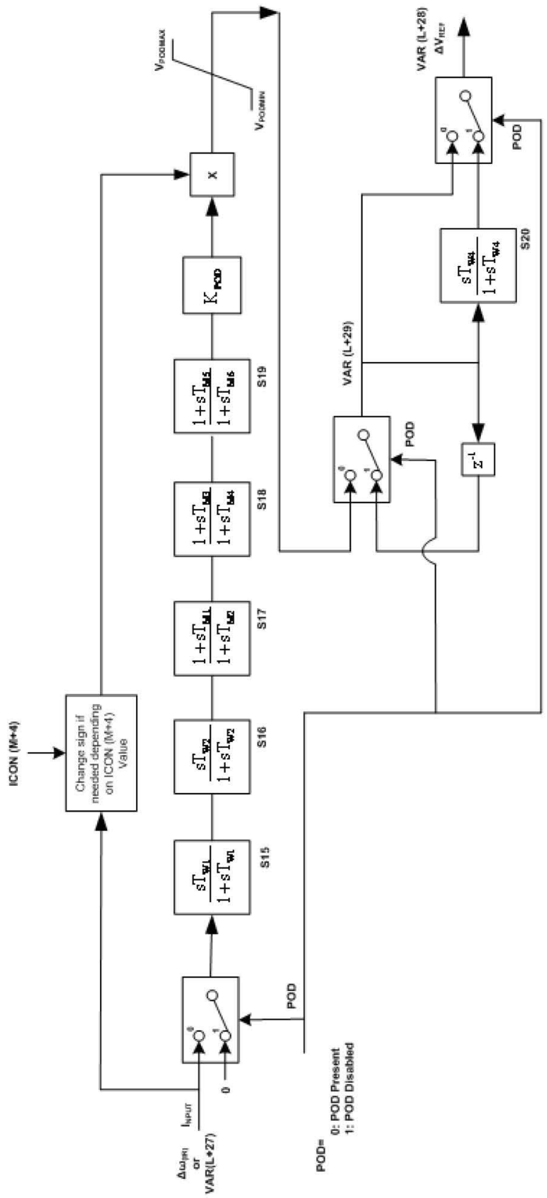

ABBSVC1 Static Var Compensator Model
External Capacitor Bank Control
MSCBUS
Y1 – pu SVC Admittance as seen from HV Bus IB
Supplementary Control
VAR (L+1) VREF
VREFMOD
Power Oscillation Damper
Δω(IR) or VAR(L+27)
ΔVREF
VAR (L) VAUX
Xcc if B1≥0, Xci if otherwise
B1 – Admittance Order at HV Bus IB
VR - Voltage at Bus IRGBUS
V2 - Voltage at LV Bus IBUS
V2MAX
S7
S8
V2CLIM
I1 – Current at HV Bus IB
I1MAXC
S9
S10
I1MAXCLIM
B1MAX
B1MIN
EFFB1MAX
EFFB1MIN
S2
S1
B2MAX
B2MIN
S0
S3, S4
YSVCBASE
YSBASE
ITCR = V2(-YSVCBASE+FSHUNT); If ITCR < 0, ITCR = 0
ITCRMAX
S5
S6
TCRMIN if V1>TCRLIMTRIG; 1 if otherwise
IMINCLIM
S11
S12
i1MINI
Overvoltage Strategy:
If VR > OVTRIPTHRESH set B1 to B1MIN
Overvoltage Tripping:
If VR > OVTRIPTHRESH for more than OVTRIPDELAY, disable the SVC
Undervoltage Strategy:
If VR < VLOW for USDELAY set B1 to BFCLEAR, releasing TBFCLEAR sec after VR > VHIGH
Severe Undervoltage Strategy:
If VR < SVLOW set B1 to SBFCLEAR, releasing STBFCLEAR sec after VR > SVHIGH
HV IB From Ckt To LV IBUS
V1 I1 V2 Itcr
TCRs TSCs FSHUNT



ABBSVC1 Model – Supplementary Control



ABBSVC1 Model – Power Oscillation Damper

24.2. CHSVCT

SVC for Switched Shunt

ICONs	Value	Description
M		IB, Remotely regulated bus
M+1		SWITCH, for SMF input
M+2		I, from bus for SMF signal
M+3		J, to bus for SMF signal
M+4		CKT, circuit ID for SMF signal

CONs	Value	Description
J		X_C
J+1		V_1
J+2		V_2
J+3		TD2
J+4		T_1
J+5		$T_2 > 0$
J+6		T_3
J+7		T_4
J+8		K
J+9		BFMAX
J+10		BFMIN
J+11		TD1
J+12		B_{MAX}
J+13		B_{MIN}
J+14		Km
J+15		T_W
J+16		TD3
J+17		T_{M1}
J+18		$T_{M2} > 0$
J+19		T_{M3}
J+20		T_{M4}
J+21		VS_{MAX}
J+22		VS_{MIN}

STATEs	Description
K	First VSF lag-lead
K+1	Second VSF lag-lead
K+2	Thyristor
K+3	First thyristor time delay
K+4	Second thyristor time delay
K+5	SMF control
K+6	First SMF time delay

STATEs	Description
K+7	Second SMF time delay
K+8	First SMF lead-lag
K+9	Second SMF lead-lag

VARs	Description
L	Other signals
L+1	V_{REF}
L+2	Y (system base)
L+3	Voltage clamp timer
L+4	I Line (system base)

SVCBASE = Σ Capacitors - Σ Reactors

If BF_{MAX} = 0.0, BFMAX = Σ Capacitors/SVCBASE

If BF_{MIN} = 0.0, BFMIN = Σ Reactors/SVCBASE

If B_{MAX} = 0.0, B_{MAX} = Σ Capacitors/SVCBASE

If B_{MIN} = 0.0, B_{MIN} = Σ Reactors/SVCBASE

If IB = 0, |VIB| = |VIBUS|

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IBUS, 'CHSVCT', ICON(M) to ICON(M+4), CON(J) to CON(J+22)   /
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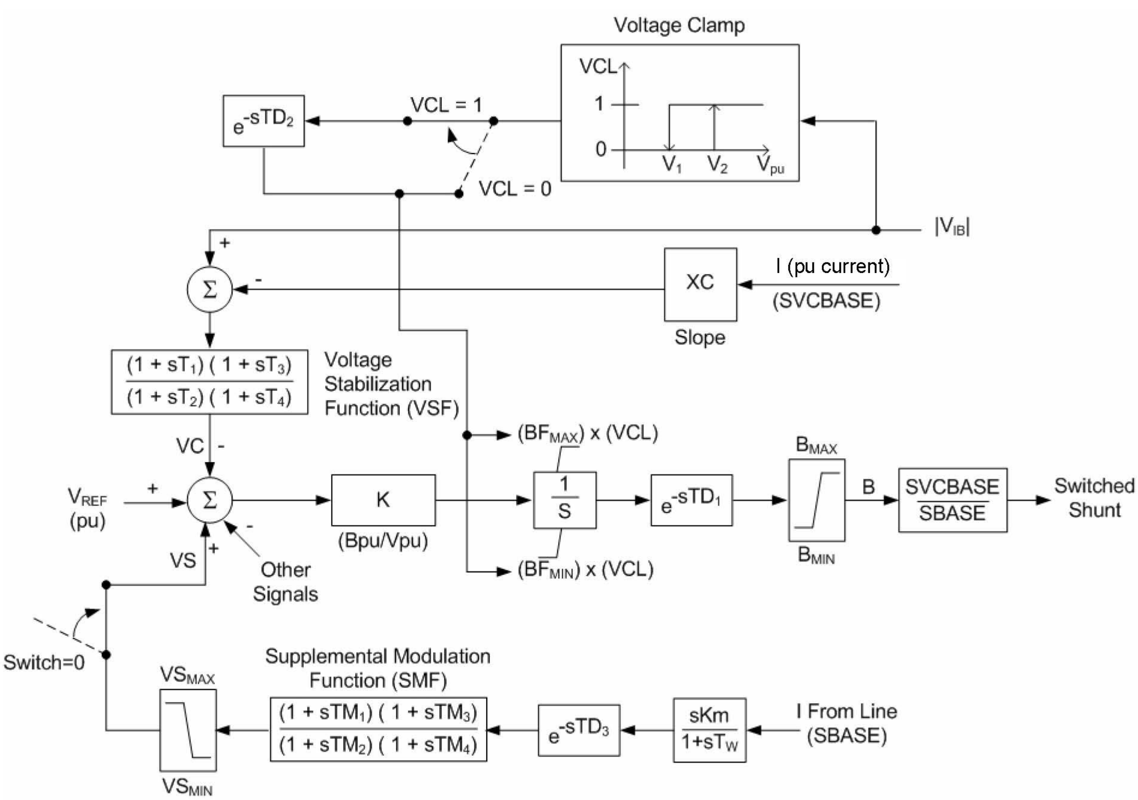


24.3. CSSCST

SVC for Switched Shunt

ICONs	Value	Description
M		IB, remotely regulated bus

CONs	Value	Description
J		K
J+1		T_1 (sec)
J+2		T_2 (sec)
J+3		T_3 (> 0) (sec)
J+4		T_4 (sec)
J+5		T_5 (sec)
J+6		V_{MAX}, Mvars
J+7		V_{MIN}, Mvars
J+8		V_{OV} (override voltage) (pu)

STATEs	Description
K	First regulator
K+1	Second regulator
K+2	Thyristor

VARs	Description
L	Other signals
L+1	V_{REF}
L+2	Y (system base)
L+3	B_{REF}

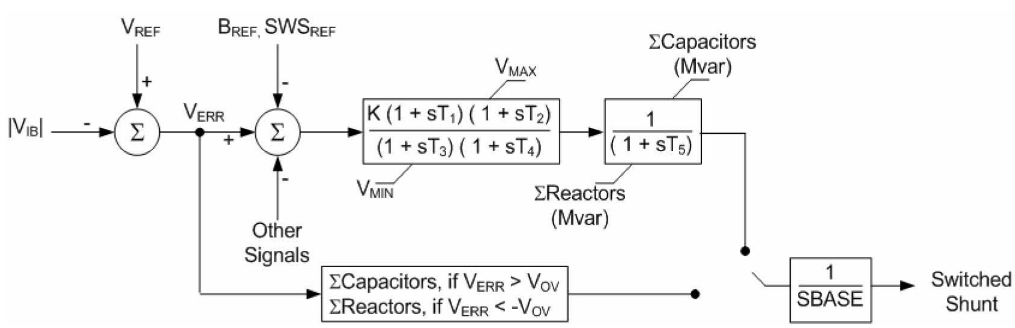
```
IBUS, 'CSSCST', ICON(M), CON(J) to CON(J+8)   /
```

If IB > 0, V_{REF} is initial voltage at bus IB

Otherwise, V_{REF} = (VSWHI + VSWLO) / 2

If V_{MAX} = 0.0, $V_{MAX} = \Sigma$ Capacitors

If V_{MIN} = 0.0, $V_{MIN} = \Sigma$ Reactors



24.4. SVSMO1T2

WECC Generic Continuous Control SVC model

ICONs	Value	Description
M		SVC remote bus # for voltage control (if 0 then SVC bus is used)
M+1		Flag for Mechanically Switched Shunt (MSS) switching: 0 - no MSS switching, 1 - MSS switching on Q [MVAr]
M+2		Flag for droop Control: 0 - linear droop; 1 - non-linear droop
M+3		1st MSS bus #
M+4		1st MSS Id (to be entered within single quotes)
M+5		2nd MSS bus #
M+6		2nd MSS Id (to be entered within single quotes)
M+7		3rd MSS bus #
M+8		3rd MSS Id (to be entered within single quotes)
M+9		4th MSS bus #
M+10		4th MSS Id (to be entered within single quotes)
M+11		5th MSS bus #
M+12		5th MSS Id (to be entered within single quotes)
M+13		6th MSS bus #
M+14		6th MSS Id (to be entered within single quotes)
M+15		7th MSS bus #
M+16		7th MSS Id (to be entered within single quotes)
M+17		8th MSS bus #
M+18		8th MSS Id (to be entered within single quotes)

CONs	Value	Description
J		UVSBmax, maximum capacitive limit during undervoltage (assumed filter size), pu on SBASE
J+1		UV1, undervoltage setting 1, pu
J+2		UV2, undervoltage setting 2, pu
J+3		UVT, undervoltage trip setting, pu
J+4		OV1, overvoltage setting 1, pu
J+5		OV2, overvoltage setting 2, pu
J+6		UVtm1, undervoltage trip time 1, sec.
J+7		UVtm2, undervoltage trip time 2, sec.
J+8		OVtm1, overvoltage trip time 1, sec.
J+9		OVtm2, overvoltage trip time 2, sec.
J+10		Xs1, slope/droop, pu on SBASE
J+11		Xs2, slope/droop, pu on SBASE
J+12		Xs3, slope/droop, pu on SBASE
J+13		Vup, upper voltage break-point for non-linear slope/droop, pu

J+14		VLOW, lower voltage break-point for non-linear slope/droop, pu
J+15		Tc1, voltage measurement lead time constant, sec.
J+16		Tb1, voltage measurment lag time constant, sec.
J+17		Tc2, lead time constant
J+18		Tb2, lag time constant
J+19		Kpv, proportional gain, pu
J+20		KIv, integral gain, pu/sec.
J+21		Vemax, voltage error max, pu
J+22		Vemin, voltage error min, pu
J+23		T2, thyristor firing sequence control time constant, T2>0, sec.
J+24		Bshrt, short-term maximum susceptance of SVC (short-term rating), pu on SBASE
J+25		Bmax, maximum susceptance of SVC (continuous rating), pu on SBASE
J+26		Bmin, minimum susceptance of SVC, pu on SBASE
J+27		Tshrt, duration of short-term rating, sec.
J+28		Kps, proportional gain of slow susceptance control, pu
J+29		KIs, integral gain of slow susceptance control, pu/sec.
J+30		Vrmax, maximum output of slow susceptance control, pu
J+31		Vrmin, minimum output of slow susceptance control, pu
J+32		Vdbd1, steady-state voltage deadband; SVC is inactive between Vref +Vdbd1 to Vref-Vdbd1, pu
J+33		Vdbd2, inner deadband, pu
J+34		Tdbd, Vdbd2 locked time, sec.
J+35		PLIdelay, delay in recovering if voltage remains below UV1 for longer than UVtm1, sec.
J+36		xeps, small delta added to the susceptance bandwidth of the slow-susceptance regulator in order to ensure its limits are not exactly identical to the MSS switching point, pu
J+37		Blcs, larger threshold for switching MSCs, MVAr
J+38		Bscs, smaller threshold for switching MSCs, MVAr
J+39		Blis, larger threshold for switching MSRs, MVAr
J+40		Bsis, smaller threshold for switching MSRs, MVAr
J+41		Tmssbrk, time for MSS breaker to operate, sec.
J+42		Tdelay1, time delay for larger threshold, sec.
J+43		Tdelay2, time delay for smaller threshold (should be larger than Tdelay1), sec.
J+44		Tout, time capacitor bank should be off before switching back on, sec.
J+45		Vrefmin, lower limit of $\Delta Vref$, pu
J+46		Vrefmax, upper limit of $\Delta Vref$, pu

STATEs	Description
K	Controlled voltage sensor

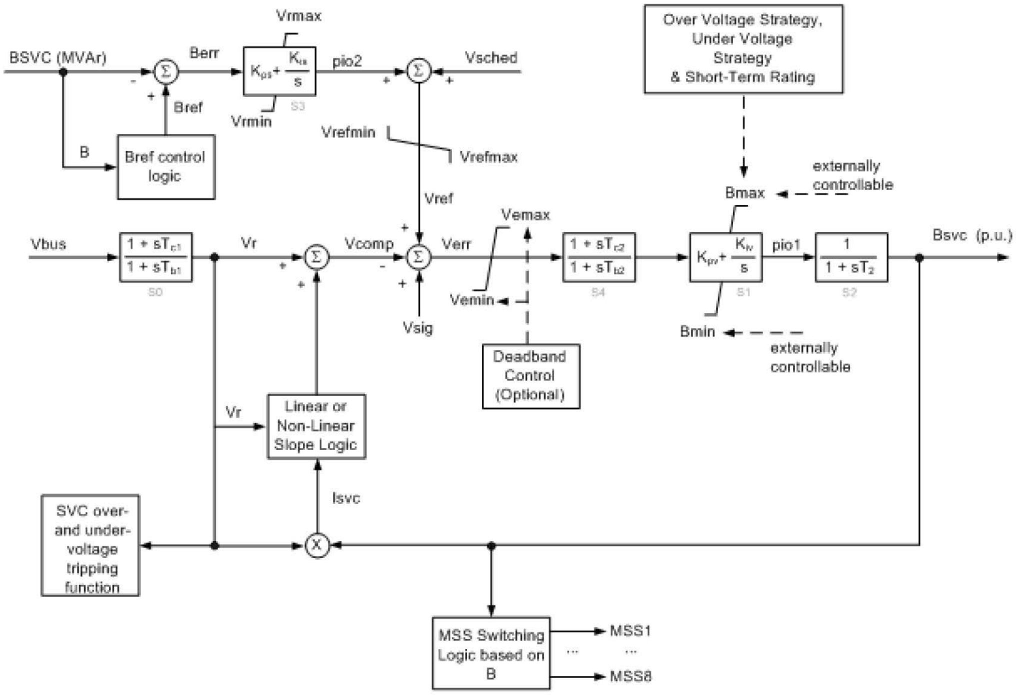
STATEs	Description
K+1	SVC main PI controller integrator
K+2	SVC output lag
K+3	SSC PI controller imtegrator
K+4	SVC lead/lag

VARs	Description
L	SVC output admittance, pu on SBASE
L+1	SVC PI controller output, pu on SBASE
L+2	SSC PI controller output, pu
L+3	Undervoltage timer, sec.
L+4	Rating dependent on voltage, pu on SBASE
L+5 ... L+18	Timers, delays set up by the model
L+19	Vmsrd, Vreg lead/lag output
L+20 ... L+22	Timers set up by the model
L+23	SVC V_{REF}, pu
L+24	SVC VSCHED, pu
L+25	optional POD input
L+26	SVC lead-lag output before PI controller
L+27	SVC voltage error
L+28	SVC output in MVAR

IBUS, 'SVSMO1T2', ICON(M) to ICON(M+18), CON(J) to CON(J+46) /

Notes:

1. SVSMO1T2 is a dynamic model of a continuously controlled Static Var Compensator (SVC) coupled with coordinated with mechanically switched shunts (MSS).
2. The SVC is to be modeled in PSSE power flow as a continuously controlled switched shunt. The SVC can coordinate with up to eight mechanically switched shunts (MSS). The MSS are modeled as fixed shunts in PSSE. The MSS can be capacitive or inductive.
3. The MSS can all be on the same bus (with different id), or they can be on eight different bus.
4. MSS id has to be entered within single quotes.
5. It is not necessary to input the MSS at all the eight buses. If MSS is not present, the MSS bus number and the MS bus id should be set to 0.


BSVC (MVAr)
Berr
Vrmax
pio2
Vsched
Bref
Vrmin
Vrefmin
Vrefmax
B
Bref control logic
Over Voltage Strategy, Under Voltage Strategy & Short-Term Rating
externally controllable
Bmax
Vref
Vemax
Vbus
Vr
Vcomp
Verr
pio1
Bsvc (p.u.)
Vemin
Vsig
Deadband Control (Optional)
Bmin
externally controllable
Linear or Non-Linear Slope Logic
Isvc
SVC over- and under-voltage tripping function
MSS Switching Logic based on B
MSS1
MSS8

24.5. SVSMO2T2

WECC Generic Discrete Control SVC Model

ICONs	Value	Description
M		SVC remote bus # for voltage control (if 0 then SVC bus is used)
M+1		Flag for Mechanically Switched Shunt (MSS) switching: 0 - no MSS switching, 1 - MSS switching on Q [MVAr]
M+2		Flag for droop Control: 0 - linear droop; 1 - non-linear droop
M+3		1st MSS bus #
M+4		1st MSS Id (to be entered within single quotes)
M+5		2nd MSS bus #
M+6		2nd MSS Id (to be entered within single quotes)
M+7		3rd MSS bus #
M+8		3rd MSS Id (to be entered within single quotes)
M+9		4th MSS bus #
M+10		4th MSS Id (to be entered within single quotes)
M+11		5th MSS bus #
M+12		5th MSS Id (to be entered within single quotes)
M+13		6th MSS bus #
M+14		6th MSS Id (to be entered within single quotes)
M+15		7th MSS bus #
M+16		7th MSS Id (to be entered within single quotes)
M+17		8th MSS bus #
M+18		8th MSS Id (to be entered within single quotes)

CONs	Value	Description
J		UVSBmax, maximum capacitive limit during undervoltage (assumed filter size), pu on SBASE
J+1		UV1, undervoltage setting 1,pu
J+2		UV2, undervoltage setting 2, pu
J+3		UVT, undervoltage trip setting, pu
J+4		OV1, overvoltage setting 1, pu
J+5		OV2, overvoltage setting 2, pu
J+6		UVtm1, undervoltage trip time 1, sec.
J+7		UVtm2, undervoltage trip time 2, sec.
J+8		OVtm1, overvoltage trip time 1, sec.
J+9		OVtm2, overvoltage trip time 2, sec.
J+10		Xs1, slope/droop, pu on SBASE
J+11		Xs2, slope/droop, pu on SBASE
J+12		Xs3, slope/droop, pu on SBASE
J+13		Vup, upper voltage break-point for non-linear slope/droop, pu
J+14		VLOW, lower voltage break-point for non-linear slope/droop, pu

CONs	Value	Description
J+15		Tc1, voltage measurement lead time constant, sec.
J+16		Tb1, voltage measurement lag time constant, sec.
J+17		Tc2, lead time constant
J+18		Tb2, lag time constant
J+19		Kpv, proportional gain, pu
J+20		KIv, integral gain, pu/sec
J+21		Vemax, voltage error max, pu
J+22		Vemin, voltage error min, pu
J+23		T2, thyristor firing sequence control time constant, T2>0, sec
J+24		Bshrt, short-term max. suceptance of SVC (short-term rating) , pu on SBASE
J+25		dbe, voltage error dadband (pu)
J+26		dbb, susceptance deadband (pu)
J+27		Tshrt, duration of short-term rating, sec.
J+28		Kps, proportional gain of slow susceptance control, pu
J+29		KIs, integral gain of slow susceptance control, pu/sec
J+30		Vrmax, maximum output of slow susceptance control, pu
J+31		Vrmin, minimum output of slow susceptance control, pu
J+32		Vdbd1, steady-state Voltage deadband; SVC is inactive between Vref +Vdbd1 to Vref-Vdbd1, pu
J+33		Vdbd2, inner deadband, pu
J+34		Tdbd, Vdbd2 locked time, sec
J+35		PLIdelay, delay in recovering if voltage remains below UV1 for longer than UVtm1, sec
J+36		xeps, small delta added to the susceptance bandwidth of the slow-susceptance regulator in order to ensure its limits are not exactly identical to the MSS switching point, pu
J+37		Blcs, larger threshold for switching MSCs, MVAr
J+38		Bscs, smaller threshold for switching MSCs, MVAr
J+39		Blis, larger threshold for switching MSRs, MVAr
J+40		Bsis, smaller threshold for switching MSRs, MVAr
J+41		Tmssbrk, time for MSS breaker to operate, sec
J+42		Tdelay1, time delay for larger threshold, sec
J+43		Tdelay2, time delay for smaller threshold (should be larger than Tdelay1), sec
J+44		Tout, time capacitor bank should be off before switching back on, sec
J+45		Vrefmin, lower limit of ΔVref, pu
J+46		Vrefmax, upper limit of ΔVref, pu

STATEs	Description
K	Controlled voltage sensor
K+1	SVC main PI controller integrator

STATEs	Description
K+2	SVC output lag
K+3	SSC PI controller integrator
K+4	SVC lead/lag

VARs	Description
L	SVC output admittance, pu on SBASE
L+1	SVC PI controller output, pu on SBASE
L+2	SSC PI controller output, pu
L+3	Undervoltage timer, sec
L+4	Rating dependent on voltage, pu on SBASE
L+5 ... L +18	Timers, delays set up by the model
L+19	Vmsrd, Vreg lead/lag output
L+20 ... L +22	Timers set up by the model
L+23	SVC V_{REF}, pu
L+24	SVC VSCHED, pu
L+25	optional POD input
L+26	SVC lead-lag output before PI controller
L+27	SVC voltage error
L+28	SVC output in MVAR
L+29	Total SVC capacitor admittance, pu on SBASE
L+30	Total SVC reactor admittance, pu on SBASE
L+31	Output of Look-up table
L+32 ... L +103	Internal VARs

IBUS, 'SVSMO2T2', ICON(M) to ICON(M+18), CON(J) to CON(J+46) /

Notes:

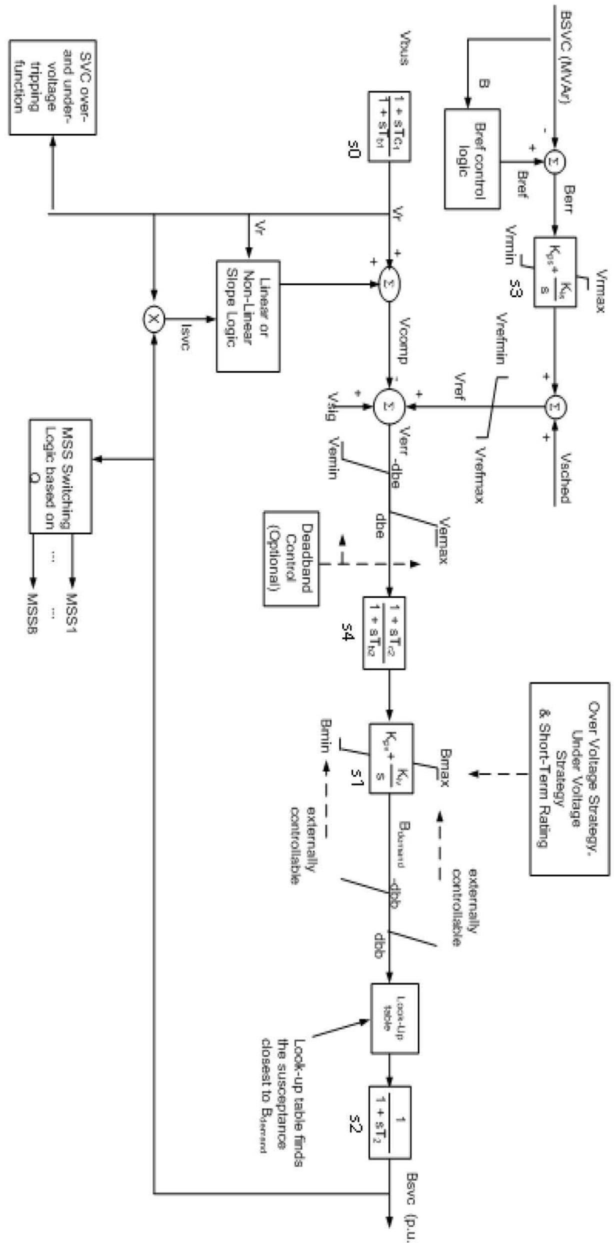
1. SVSMO2T2 is a dynamic model of a discretely controlled Static Var Compensator (SVC) coordinated with mechanically switched shunts (MSS).
2. The SVC is to be modeled in PSSE power flow as a discretely controlled switched shunt. The SVC can coordinate with up to eight mechanically switched shunts (MSS). The MSS are modeled as fixed shunts in PSSE. The MSS can be capacitive or inductive.
3. The MSS can all be on the same bus (with different id), or they can be on eight different buses.
4. The MSS id has to be entered within single quotes.
5. It is not necessary to input the MSS at all the eight buses. If there are eight or less MSS, the MSS bus number and the MS bus id should be set to 0 for the unused MSS entries.
6. The limits Bmax and Bmin shown on STATE(K+1) are the maximum capacitive rating in pu (Bmax), and the minimum inductive rating in pu (Bmin) of the SVC. These are computed by the model based on the possible combinations of available capacitor and the inductors in power flow.

7. The undervoltage setting values (UV1 and UV2) should be such that UV1 > UV2.

8. The overvoltage setting values (OV1 and OV2) should be such that OV1 < UV2.

9. Vdb1 and Vdb2 must have either positive values or zero (i.e. not negative).

10. The deadband control, slow-susceptance regulator, and non-linear slope are intended to keep the SVC output at a low steady state output. Only one of these controllers should be active. The dynamic model does not allow for the use of more than one of these controllers at the same time.



24.6. SVSMO2U2

ICONs	Value	Description
M		SVC remote bus # for voltage control (if 0 then SVC bus is used)
M+1		Flag for Mechanically Switched Shunt (MSS) switching: 0 - no MSS switching, 1 - MSS switching on Q [MVAr]
M+2		Flag for droop Control: 0 - linear droop; 1 - non-linear droop
M+3		1st MSS bus #
M+4		1st MSS Id (to be entered within single quotes)
M+5		2nd MSS bus #
M+6		2nd MSS Id (to be entered within single quotes)
M+7		3rd MSS bus #
M+8		3rd MSS Id (to be entered within single quotes)
M+9		4th MSS bus #
M+10		4th MSS Id (to be entered within single quotes)
M+11		5th MSS bus #
M+12		5th MSS Id (to be entered within single quotes)
M+13		6th MSS bus #
M+14		6th MSS Id (to be entered within single quotes)
M+15		7th MSS bus #
M+16		7th MSS Id (to be entered within single quotes)
M+17		8th MSS bus #
M+18		8th MSS Id (to be entered within single quotes)

CONs	Value	Description
J		UVSBmax, maximum capacitive limit during undervoltage (assumed filter size), pu on SBASE
J+1		UV_1, undervoltage setting 1, pu
J+2		UV_2, undervoltage setting 2, pu
J+3		UVT, undervoltage trip setting, pu
J+4		OV_1, overvoltage setting 1, pu
J+5		OV_2, overvoltage setting 2, pu
J+6		UVtm1, undervoltage trip time 1, sec.
J+7		$UVtm^2$, undervoltage trip time 2, sec.
J+8		OVtm1, overvoltage trip time 1, sec.
J+9		$OVtm^2$, overvoltage trip time 2, sec.
J+10		Xs1, slope/droop, pu on SBASE
J+11		Xs2, slope/droop, pu on SBASE
J+12		Xs3, slope/droop, pu on SBASE
J+13		Vup, upper voltage break-point for non-linear slope/droop, pu
J+14		V_{LOW}, lower voltage break-point for non-linear slope/droop, pu
J+15		Tc1, voltage measurement lead time constant, sec.
J+16		T_b1, voltage measurment lag time constant, sec.

CONs	Value	Description
J+17		Tc2, lead time constant
J+18		T_b2, lag time constant
J+19		K_pv, proportional gain, pu
J+20		K_Iv, integral gain, pu/sec.
J+21		Vemax, voltage error max, pu
J+22		Vemin, voltage error min, pu
J+23		T_2, thyristor firing sequence control time constant, T_2>0, sec.
J+24		Bshrt, short-term max. suceptance of SVC (short-term rating), pu on SBASE
J+25		dbe, voltage error dadband (pu)
J+26		dbb, susceptance deadband (pu)
J+27		Tshrt, duration of short-term rating, sec.
J+28		K_ps, proportional gain of slow susceptance control, pu
J+29		K_Is, integral gain of slow susceptance control, pu/sec.
J+30		Vr_{max}, maximum output of slow susceptance control, pu
J+31		Vr_{min}, minimum output of slow susceptance control, pu
J+32		Vdbd1, steady-state Voltage deadband; SVC is inactive between Vref +Vdbd1 to Vref-Vdbd1, pu
J+33		Vdbd2, inner deadband, pu
J+34		Tdbd, Vdbd2 locked time, sec.
J+35		PL_{ld}elay, delay in recovering if voltage remains below UV_1 for longer than UVtm1, sec.
J+36		xeps, small delta added to the susceptance bandwidth of the slow-susceptance regulator in order to ensure its limits are not exactly identical to the MSS switching point, pu
J+37		Blcs, larger threshold for switching MSCs, MVAr
J+38		Bscs, smaller threshold for switching MSCs, MVAr
J+39		Blis, larger threshold for switching MSRs, MVAr
J+40		Bsis, smaller threshold for switching MSRs, MVAr
J+41		Tmssbrk, time for MSS breaker to operate, sec.
J+42		Tdelay1, time delay for larger threshold, sec.
J+43		Tdelay2, time delay for smaller threshold (should be larger than Tdelay1), sec.
J+44		Tout, time capacitor bank should be off before switching back on, sec.
J+45		Vrefmin, lower limit of ΔVref, pu
J+46		Vrefmax, upper limit of ΔVref, pu

STATEs	Description
K	Controlled voltage sensor
K+1	SVC main PI controller integrator
K+2	SVC output lag
K+3	SSC PI controller integrator

STATEs	Description
K+4	SVC lead/lag

VARs	Description
L	SVC output admittance, pu on SBASE
L+1	SVC PI controller output, pu on SBASE
L+2	SSC PI controller output, pu
L+3	Undervoltage timer, sec.
L+4	Rating dependent on voltage, pu on SBASE
L+5 through L +18	Timers, delays set up by the model
L+19	Vmsrd, Vreg lead/lag output
L+20 through L +22	Timers set up by the model
L+23	SVC V_{REF}, pu
L+24	SVC VSCHED, pu
L+25	optional POD input
L+26	SVC lead-lag output before PI controller
L+27	SVC voltage error
L+28	SVC output in MVAR
L+29	Total SVC capacitor admittance, pu on SBASE
L+30	Total SVC reactor admittance, pu on SBASE
L+31	Output of Look-up table
L+32 ... L +103	Internal VARs

IBUS, 'USRSWS', 'SVSMO2U2', 24 1 22 47 5 104 ICON(M) to ICON(M+18), 0, 0, 0, CON(J) to CON(J+46) /

Notes:

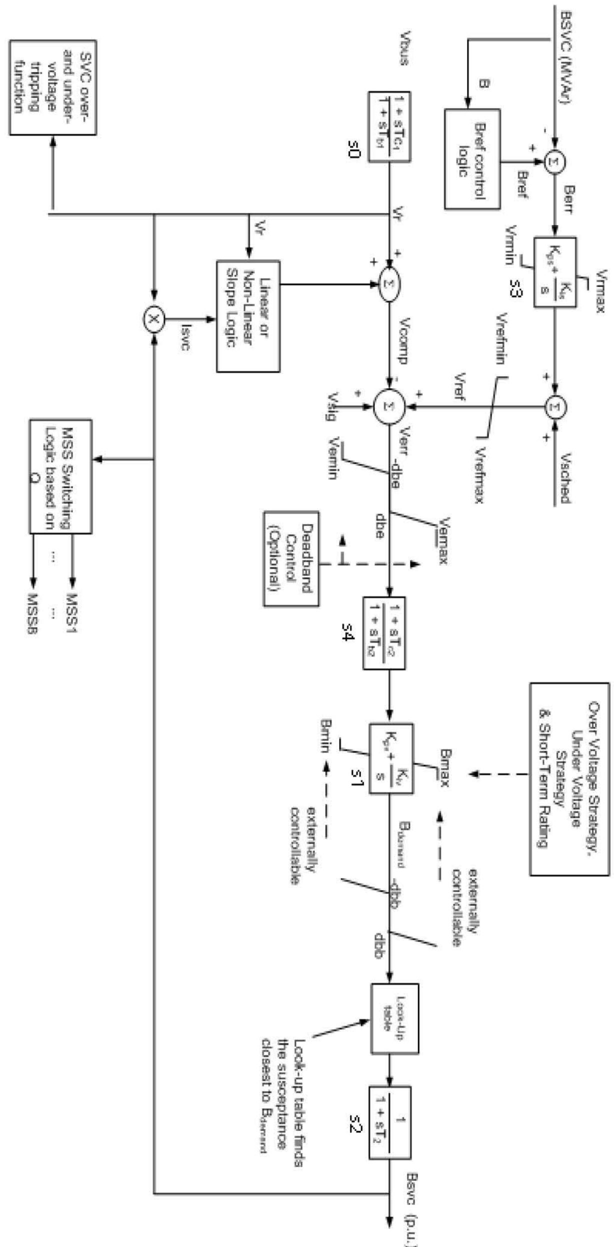
1. SVSMO2U2 is a dynamic model of a discretely controlled Static Var Compensator (SVC) coordinated with mechanically switched shunts (MSS).
2. The SVC is to be modeled in PSSE power flow as a discretely controlled switched shunt. The SVC can coordinate with up to eight mechanically switched shunts (MSS). The MSS are modeled as fixed shunts in PSSE. The MSS can be capacitive or inductive.
3. The MSS can all be on the same bus (with different id), or they can be on eight different buses.
4. The MSS id has to be entered within single quotes.
5. It is not necessary to input the MSS at all the eight buses. If there are eight or less MSS, the MSS bus number and the MS bus id should be set to 0 for the unused MSS entries.
6. The limits Bmax and Bmin shown on STATE(K+1) are the maximum capacitive rating in pu (Bmax), and the minimum inductive rating in pu (Bmin) of the SVC. These are computed by the model based on the possible combinations of available capacitor and the inductors in power flow.

7. The undervoltage setting values (UV_1 and UV_2) should be such that $UV_1 > UV_2$.

8. The overvoltage setting values (OV_1 and OV_2) should be such that $OV_1 < UV_2$.

9. Vdb1 and Vdb_2 must have either positive values or zero (i.e. not negative).

10. The deadband control, slow-susceptance regulator, and non-linear slope are intended to keep the SVC output at a low steady state output. Only one of these controllers should be active. The dynamic model does not allow for the use of more than one of these controllers at the same time.



24.7. SWSHNT

Switched Shunt Model

ICONs	Value	Description
M		IB, Remotely regulated bus
M+1		NS, Total number of switches allowed
M+2	X	Switch counter (Reserved ICON)
M+3	X	Delay flag (Reserved ICON)
M+4	X	Timeoutflag (Reserved ICON)
M+5	X	Timer status (Reserved ICON)

CONs	Value	Description
J		VIN1, zero or DELVUP or VHI (pu)
J+1		PT_1, pickup timer for high voltage (sec)
J+2		ST_1 (sec)[a] switch time to close if reactor; switch time to open if capacitor.
J+3		V_IN2, zero or DELVDO or VLO (pu)
J+4		PT_2, pickup timer for low voltage (sec)
J+5		ST_1 (sec) [a] switch time to close if reactor; switch time to open if capacitor

[a]Switch closing and opening can occur as a result of either high or low voltage. The switching action taken for high or low voltage is a function of the type of switched device (i.e., reactor or capacitor) and its status at the time the voltage limit is exceeded.

VARs	Description
L	Initial voltage
L+1	Timer
L+2	Maximum reactive
L+3	Maximum capacitive

```
IBUS, 'SWSHNT', ICON(M) to ICON(M+1), CON(J) to CON(J+5)   /
```

Chapter 25
Branch Device Models

This chapter contains a collection of data sheets for the Branch Device models contained in the PSS®E dynamics model library.

Model	Description
CRANIT	Series reactor model.

25.1. CRANIT

ICONs	Value	Description
M		CRANIT input code: • 1 - pu current on branch (branch between bus i and bus j) • 2 - pu current on branch (branch between bus i and bus j) • 3 - pu frequency difference between two buses (bus i and bus j) • 4 - pu bus voltage (bus i) • 5 - pu frequency deviation on bus (bus i) • 6 - machien speed deviation (machine at bus i)
M+1		External bus number of bus i.
M+2		External bus number of bus j (or zero for input 4 through 6).
M+3		Branch ID (for inputs 1 and 2), machine id (for input 6), or zero for inptus 3, 4, and 5. For input 2, an id of -1 indicates sum of parallel line flows.
M+4		Internal ICON[a]

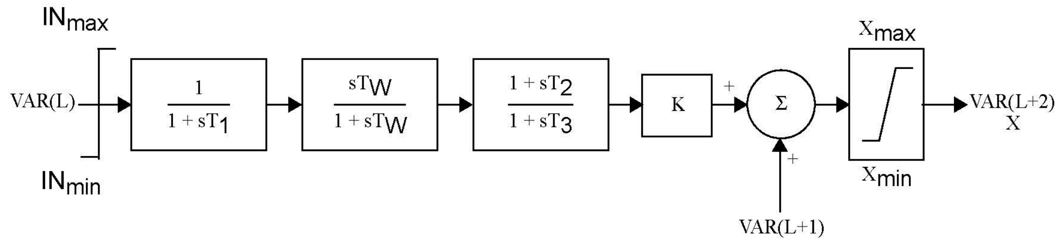
[a]No user input is requred for interal ICON.

CONs	Value	Description
J		T_1 (s)
J+1		T_2 (s)
J+2		T_3 (s) (> 0)
J+3		T_W (s) (> 0)
J+4		K
J+5		X_{max} (pu) max. limit on output
J+6		X_{min} (pu) min. limit on output
J+7		IN_{max} (pu) max. limit on input signal
J+8		IN_{min} (pu) min. limit on input signal

STATEs	Description
K	Transducer filter
K+1	Washout
K+2	Lead/lag

VARs	Description
L	Input signal
L+1	Initial output
L+2	Desired reactance

```
IBUS,'CRANIT',JBUS,ID, ICON(M) to ICON(M+3), CON(J) TO CON(J+8)   /
```


IN max
IN min
VAR(L)
1 / 1 + sT1
sTW / 1 + sTW
1 + sT2 / 1 + sT3
K
Σ
+
+
VAR(L+1)
X max
X min
VAR(L+2)
X

Chapter 26
Machine and Wind Machine Protection Models

This chapter contains a collection of data sheets for the Machine and Wind Protection models contained in the PSS®E dynamics model library.

Model	Description
LOEXR1T	Loss of excitation distance relay
MCREPWU1	Machine Reverse Power Relay Model
NRCGP3U	Generic Generator Protection Model
VPERHZU1	Volts per Hertz Model (to be applied only to synchronous machines)

26.1. LOEXR1T

Loss of Excitation Distance Relay (for use with non-wind machines)

ICONs	Value	Description
M	X	ICONs required for internal logic (internal ICON)(1)
...	X	
M+7	X	

CONs	Value	Description
J		T1, zone 1 operating time (cycles)
J+1		R1, zone 1 reach (diameter in pu)
J+2		A1, zone 1 centerline angle (degrees)
J+3		D1, zone 1 center distance (pu)
J+4		T2, zone 2 operating time (cycles)
J+5		R2, zone 2 reach (diameter in pu)
J+6		A2, zone 2 centerline angle (degrees)
J+7		D2, zone 2 center distance (pu)
J+8		T3, zone 3 operating time (cycles)
J+9		R3, zone 3 reach (diameter in pu)
J+10		A3, zone 3 centerline angle (degrees)
J+11		D3, zone 3 center distance (pu)
J+12		VPV, voltage pickup value (pu)
J+13		STB, self trip breaker time (cycles)

VARs	Description
L	Apparent R
L+1	Apparent X
L+2	VARS required for internal program logic
...	
L+5	

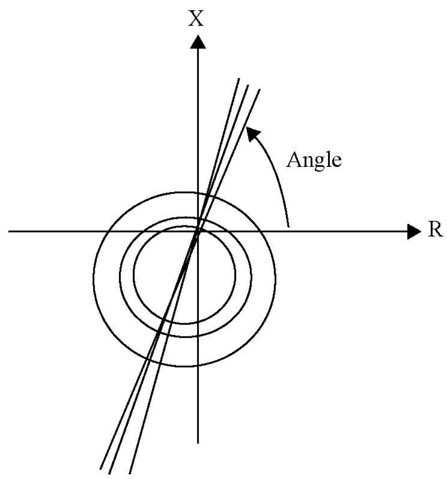
Notes:

1. Any zone reach can be set to zero to disable a circle.

2. The center distances are normally negative since R and X are assumed looking out from terminals.

3. The reaches and distances should be entered on MBASE.

4. The voltage pickup value should be set to a high value (10.0 pu) to disable it.




```
IBUS, 'LOEXR1T', ID, CON(J) to CON(J+13)   /
```

26.2. MCREPWU1

Machine Reverse Power Relay Model

ICONs	Value	Description
M		• 0 - monitor only • 1 - monitor & trip
M+1		Flag for Relay 1: • 0 - disable • 1 - enable
M+2		Flag for Relay 2: • 0 - disable • 1 - enable
M+3		Flag for Relay 3: • 0 - disable • 1 - enable

CONs	Value	Description
J		Pthr1, Pickup value for power (pu of machine MVA) (< 0 for reverse power check)
J+1		Tp1 (s), relay pick up time
J+2		Pthr2, Pickup value for power (pu of machine MVA) (< 0 for reverse power check)
J+3		Tp2 (s), relay pick up time
J+4		Pthr3, Pickup value for power (pu of machine MVA) (< 0 for reverse power check)
J+5		Tp3 (s), relay pick up time
J+6		Tb (s), breaker time
J+7		Tr (s), power transducer time constant

STATEs	Description
K	power measurement filter

VARs	Description
L	Relay 1 timer memory
L+1	Relay 2 timer memory
L+2	Relay 3 timer memory
L+3	Breaker timer

DYR Syntax:

```
IBUS    'USRMDL'   ID   'MCREPWU1'    405     2    4    8    1     4
 ICON(M:M+3)     CON(J) to CON(J+7)   /
```

Note(s):

1. The reverse power model will check if the machine reverse power is less than the specified value (as specified in CON's J, J+2 and J+4) for a duration as specified in CONs J+1, J+3 or J+5 seconds and will initiate a signal to trip the machine if ICON(M) is 1. If ICON(M) is 0, the relay is in monitoring mode and hence the machine will not be tripped. If ICON(M) is 1, once the trip command is sent to the breaker, the machine will be tripped after the breaker time (specified in CON(J+6)) elapses.

   For reverse power checks, the reverse power thresholds have to be specified as a negative value. Additionally, the threshold values are to be specified in per unit of the machine MVA base.

   Per relay manufacturers, in some steam generator applications it is desirable to trip the generator when the forward power is less than a small value. This is due to the fact that the trapped steam will cause the generator to supply a small amount of power even though the steam valves are closed. To simulate this behavior, the power threshold (CON(J)) can has o be specified as a positive value. The relay will trip when the measured forward power is less than this pickup value.

   The relay operation for the reverse power and for forward power mode are as shown in the Figure 1.

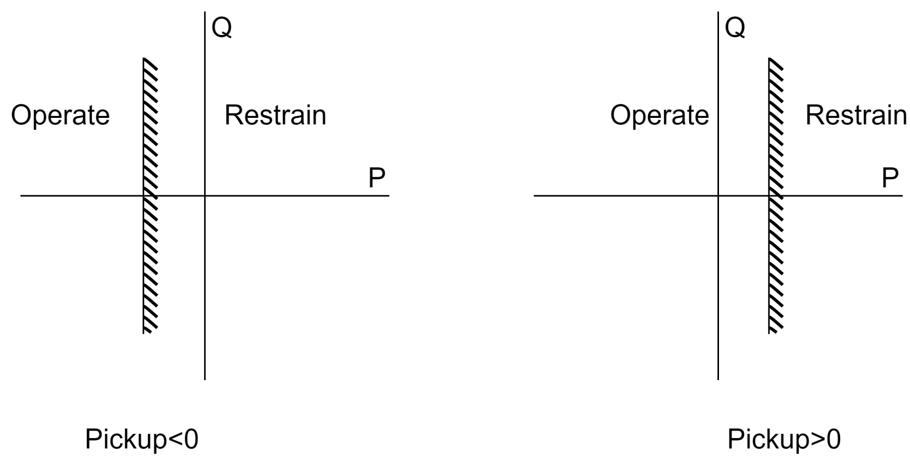


Figure 1: The relay operation for the reverse power and for forward power mode.

2. The reverse power relay is applicable only for synchronous machines. Additionally, the model will be applicable only if the machine is on-line (i.e., machine status is ON and if the bus to which the machine is connected is of type code 2 in dynamic simulation).

3. The model can be set (using the flag ICON(M)) to just monitor (i.e., with no tripping), or in monitor and trip mode. If the ICON(M) has a value other than 0 or 1, the model would be in 'monitor only' mode.

26.3. NRCGP3U

Generic Generator Protection Model

ICON	Value	Description
M		• 1 - alarm & trip • 0 - alarm only
M+1		• 1 - monitor specified generator • 2 - monitor all generators in area • 3 - monitor all generators in zone • 4 - monitor all generators in the entire case • 5 - monitor generators in owner
M+2		Flag for Relay 1 (V/Hz relay): • 1 - enable • 0 - disable
M+3		Flag for Relay 2 (under/over-voltage relay): • 1 - enable • 0 - disable
M+4		Flag for Relay 3 (reverse power relay): • 1 - enable • 0 - disable
M+5		Flag for Relay 4 (loss-of-field relay): • 1 - enable • 0 - disable
M+6		Flag for Relay 5 (stator over-current relay): • 1 - enable • 0 - disable
M+7		Flag for Relay 6 (over/under frequency relay): • 1 - enable • 0 - disable
M+8		Flag for Relay 7 (turbine power-load imbalance relay): • 1 - enable • 0 - disable

ICON	Value	Description
M+9		Flag for Relay 8 (over-excitation relay): • 1 - enable • 0 - disable

CON	Value	Description
J		Vhz (pu), V/Hz relay pickup setting
J+1		tvhz (s), V/Hz frequency relay time setting
J+2		vuv (pu), under-voltage relay pickup setting
J+3		tvuv (s), under-voltage relay time setting
J+4		vov (pu), over-voltage relay pickup setting
J+5		tvov (s), over-voltage relay time setting
J+6		pmtr (pu), reverse power relay pickup setting (< 0)
J+7		tpmtr (s), reverse power relay time setting
J+8		xz1 (pu), loss-of-field relay zone 1 pickup impedance (≥ 0)
J+9		xz2 (pu), loss-of-field relay zone 2 pickup impedance (≥ 0)
J+10		xoff (pu), loss-of-field relay impedance offset (≤ 0)
J+11		tz1 (s), loss-of-field relay zone 1 time setting
J+12		tz2 (s), loss-of-field relay zone 2 time setting
J+13		ioc (pu), stator over-current relay pickup setting (> 0)
J+14		koc (s), time factor for stator over-current relay
J+15		boc (s), timer coefficient for stator over-current relay
J+16		poc, inverse-time exponent for stator over-current relay (> 0)
J+17		troc (s), reset time for stator over-current relay (> 0)
J+18		fof (pu), over-frequency relay pickup setting (specified as per unit frequency)
J+19		tof (s), over-frequency relay time setting
J+20		fuf (pu), under-frequency relay pickup setting (specified as per unit frequency)
J+21		tuf (s), under-frequency relay time setting
J+22		delp (pu), delta power imbalance for power/load imbalance relay
J+23		tdelp (s), power/load imbalance time setting
J+24		ifoc (pu), over-excitation relay pickup setting
J+25		tfoc (s), over-excitation relay time setting

VAR	Description
L	Xz1 value used in simulation
L+1	Xz2 value used in simulation
L+2	Xoff value used in simulation

DYR Syntax:

```
IBUS  'USRMDL'  ID  'NRCGP3U'  405  2  10  26  0  3  ICON(M) to
 ICON(M+9),  CON(J) to CON(J+25)  /
```

Note(s):

Some of the explanations given below have been taken from NERC document 'Final_PCPMTF-Report.pdf' titled 'Generic Protection Model for Generator'.

GP3 is a generic generator protection model and includes the following functions:

- Over- and under-voltage protections
- Over- and under-frequency protections
- Reverse power protection
- Field-over-current protections
- Voltage Restrained Time Overcurrent relay
- Loss of field protection
- Turbine power/load unbalance protection
- V/Hz protection

1. The relay model will be applied to any machine only if all the following conditions are satisfied:
    - **Requirement A:** Machine is in-service and is a synchronous machine (i.e., the machine is not designated as being a renewable machine)
    - **Requirement B:** the dynamic model attached to that machine is one of the synchronous machine models provided as part of PSS®E library - GENROU, GENROE, GENSAL, GENSAE, GENTPJ1, GENDCO. It cannot be a GENCLS model.
    - **Requirement C:** the dynamic model has to be in-service (i.e., the model status should not be 'OFF')
2. If the machine (in the dyr record) to which the GP3 model is applied does not satisfy the requirements A, B and C above, the GP3 model will be disabled.
3. This model can be applied to just one generator (to the generator to which the model is applied in the dyr file), or all generators in the area to which the specified generator is attached, or all generators in the zone to which the specified generator is attached, or to every generators in the entire case. This is done by selecting an appropriate value for ICON(M+1). By default, the model will be applied to just the generator specified in the model dyr record.
4. ICON(M) can be set to either just alarm (which is the default action) or to alarm and trip the generator.
5. ICON(M+1) can be set to let GP3 model monitor the unit to which it is applied; or monitor all generators in an area/zone/owner/the entire system.
6. ICON(M+2) through ICON(M+9) can be used to select the desired GP3 relay functionality.
7. For the over and under-frequency relay model, per NERC GP3 model specification recommendation, the frequency used is the generator speed (ω) in per unit.

    If $\omega >$ fof for tof seconds, or if $\omega <$ fuf for tuf seconds, then alarm or alarm and trip the unit. If ω returns below (or above) the trip setpoint prior to the relay timing out, the relay is reset.

If the machine terminal voltage Vt < 0.7 pu, this relay function is disabled until Vt comes back up above 0.75 pu.

The values of fuf and fof specified in the dyr record should be the per unit frequency (and not per unit frequency deviation).

8. Voltage restrained time-overcurrent protection logic:

The trip times (taken from NERC document, are from IEEE C37.112) are as outlined below.

$$Ttrip = \left(\frac{koc}{\left(\frac{|It|}{ipickup}\right)^{poc} - 1} + boc \right)$$

$$Treset = \frac{troc}{\left(\frac{|It|}{ipickup}\right)^{2} - 1}$$

|It| is the magnitude of the stator current in pu, Ttrip is the trip time in seconds, and Trest is the reset time in seconds.

$$T(It) = \begin{cases} T_{trip}, & |It| > ipickup \\ T_{reset}, & |It| < ipickup \\ -troc, & |It| = ipickup \end{cases}$$

The pickup current “ipickup” is determined as shown in the Figure 1.

The relay trip and reset logic is implemented as described below.

At initialization a counter (count) is initialized to zero.

During simulation, |It| could be greater than ipickup, less than ipickup, or equal to ipickup. In every case the variable ‘count’ is calculated as follows.

$$count = count + \frac{\Delta t}{T(It)}$$

Where Δt is the simulation time step. if |It| > ipickup, variable T(It) is equal Ttrip. In this case, when count becomes greater than or equal to 1, the relay either just alarms, or alarms and trips.

In calculating Ttrip, if koc (i.e., CON(J+14)) and boc (i.e., CON(J+15)) both are zero, T(It) will become zero and as a results the ‘count’ calculation will result in division by zero. To avoid this, if both koc and boc are zero, koc and boc will be set equal to 0.05 and 0.1 respectively.

If |It| < ipickup, variable T(It) is equal Ttrip. Note that in this case, Ttrip will be negative. When |It| = ipickup, T(It) is equal to -troc. In both these cases, when count becomes less than or equal to 0, the relay resets.

In calculating Treset, if troc (i.e., CON(J+17)) is zero, T(It) will become zero and as a results the ‘count’ calculation will result in division by zero. To avoid this, troc will be set equal to 5.0.

9. Loss-of-field protection logic:

The loss-of-field relay is the offset mho relay with two zones. This is shown in Figure 2. The relay is modeled as follows.

At every time step, the generator apparent impedance (in pu on generator MVA base) is calculated as Zgen = Vt/It (complex values) = Rgen +jXgen

If Zgen enters zone 1 (i.e., $Rgen^2 + (Xgen - Xoff + Xz1/2)^2 < (Xz1/2)^2$) for tz1 seconds, then alarm (or alarm and trip) the unit. If Zgen exits zone 1 before the relay times out, the timer is reset.

If Zgen enters zone 2 (i.e., $Rgen^2 + (Xgen - Xoff + Xz2/2)^2 < (Xz2/2)^2$) for tz2 seconds, then alarm (or alarm and trip) the unit. If Zgen exits zone 2 before the relay times out, the timer is reset.

If the model is applied to a single generator, the values of Xz1, Xz2 and Xoff are taken from the dyr file (i.e., CONs J+8 through J+10).

If either Xz1 or Xz2 is entered as zero, or if the model is applied to generators on a area/zone/owner/all basis, then the model will use the default values of Xz1 = 1 pu, Xz2 = Xd, and Xoff = - X'd/2 (Xd and X'd read from the generator model to which the GP3 model is attached in the dyr file).

10. Power/Load imbalance relay logic:

    In this generic model, the electrical load is taken to be the generator power (Pelec) and the power developed by the turbine is the turbine-governor model output (Pmech). The protection logic is that if (Pmech – Pelec) > delp for tdelp seconds, then relay alarms (or alarms and trip) the unit. If the (Pmech – Pelec) goes back below delp before the relay times out, then relay timer is reset.

11. Over-excitation relay logic:

    The over-excitation logic alarms (or alarms and trips) the machine if the field current (Ifd) is greater than ifoc for tfoc seconds. If the field current returns below the trip point before the relay times out, then the over-excitation relay is reset.

12. Other than 'Loss-of-field' and 'voltage restrained time over-current' protection models (which are modeled as described above), all other GP3 protection functions are modeled using simple definite-time trip logic.

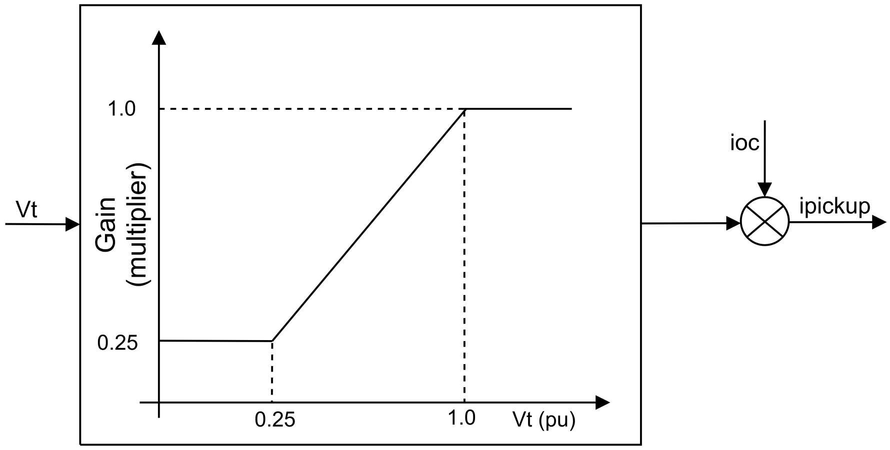


Figure 1: Voltage-restraint function in the inverse-time over-current relay

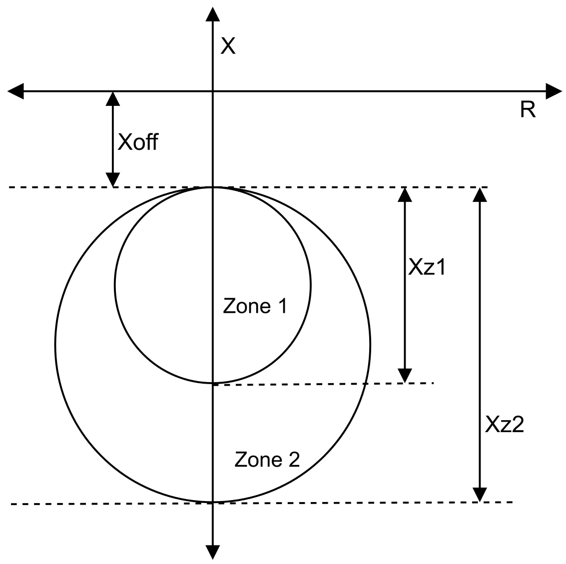


Figure 2: R-X diagram of the offset-mho type loss-of-load relay

26.4. VPERHZU1

V/Hz Generator Relay Model

ICONs	Value	Description
M		• 0 - Monitor mode • 1 - Tripping mode
M+1	Used only if ICON(M) is 1:	• 1 - Trip generator • 2 - Disconnect the generator bus
M+2		Number of zones (any value 1 through 5) used to model the V/Hz

ICONs (Not available for user edits)	Value	Description
M+3		Delay flag - (timer 1)
M+4		Time-out flag - (timer 1)
M+5		Timer status - (timer 1)
M+6		Delay flag - (timer 2)
M+7		Time-out flag - (timer 2)
M+8		Timer status - (timer 2)
M+9		Delay flag - (timer 3)
M+10		Time-out flag - (timer 3)
M+11		Timer status - (timer 3)
M+12		Delay flag - (timer 4)
M+13		Time-out flag - (timer 4)
M+14		Timer status - (timer 4)
M+15		Delay flag - (timer 5)
M+16		Time-out flag - (timer 5)
M+17		Timer status - (timer 5)

CONs	Value	Description
J		VHz1, upper voltage threshold (pu)
J+1		TP1, relay pickup time (s) (*)
J+2		VHz2, upper voltage threshold (pu)
J+3		TP2, relay pickup time (s)
J+4		VHz3, upper voltage threshold (pu)
J+5		TP3, relay pickup time (s)
J+6		VHz4, upper voltage threshold (pu)
J+7		TP4, relay pickup time (s)
J+8		VHz5, upper voltage threshold (pu)

CONs	Value	Description
J+9		TP5, relay pickup time (s)
J+10		T_B, breaker time (s)
J+11		T_V, voltage measurement filter time constant (s)
J+12		T_f, frequency measurement filter time constant (s)

STATEs	Description
K	Measured voltage
K+1	Measured speed deviation

VARs	Description
L	Sensed V/Hz (pu)
L+1	Timer 1 memory
L+2	Timer 2 memory
L+3	Timer 3 memory
L+4	Timer 4 memory
L+5	Timer 5 memory

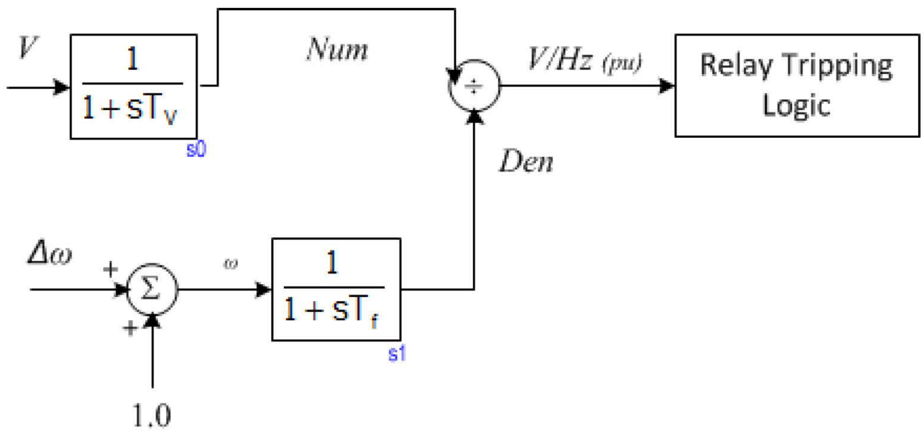
Notes:

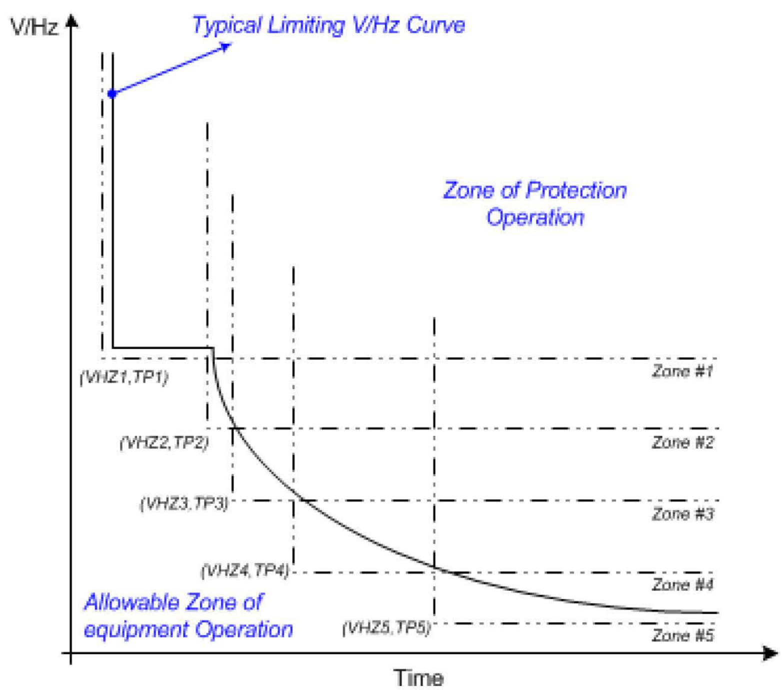
1. This model uses 2 ICONs and 15 internal ICONs. ICONs (M+4) through (M+18) are control flags that are not to be changed by the user
2. When ICON(M) is 1, setting ICON(M+1) equal to 1 will trip the generator, while setting ICON(M+1) equal to 2 will disconnect the generator bus (i.e., disconnects all equipment attached to the generator bus).
3. ICONs marked "Internal ICONs" have to be entered as 0 (15 zeros) in the model dyr record.
4. This model is treated as a "Machine Protection" model and can be accessed under the "Protection Models>Machine" tab in the dynamics data spreadsheet.
5. Since bus frequency in PSS®E (which is calculated using bus voltage angle) is subject to instantaneous changes, this model uses speed deviation instead of bus frequency for the V/Hz calculation. In view of this, this model should be applied only to synchronous machines.
6. ICON(M+2) specifies the number of zones used to model the relay. If this ICON has a value of 1, then only one zone z1 is used; and hence CON(J+2) through CON(J+0) can all be set to zero. If ICON(M+2) is set to 2 (indicating 2 zones: z1 and z2), then only one zones z1 and z2 are used; and hence CON(J +4) through CON(J+9) can all be set to zero.
7. If all 5 zones are used, then the data input for VHz1, VHz2, and Tp1, Tp2 etc. have to be such that VHz1>VHz2>VHz3>VHz4>VHz5, and Tp1<Tp2<Tp3<Tp4<Tp5.

DYRE data report format:

```
IBUS 'USRMDL' ID 'VPERHZU1' 405 2 18 13 2 6 ICON(M) to ICON(M+2),

ICON(M+3) to ICON(M+17) to be entered as 0, CON(J) to CON(J+12) /
```


V
1
1 + sT_V
s0
Num
V/Hz (pu)
Relay Tripping Logic
Den
Δω
+
+
ω
1
1 + sT_f
s1
1.0


V/Hz
Typical Limiting V/Hz Curve
Zone of Protection Operation
(VHZ1,TP1)
(VHZ2,TP2)
(VHZ3,TP3)
(VHZ4,TP4)
(VHZ5,TP5)
Zone #1
Zone #2
Zone #3
Zone #4
Zone #5
Allowable Zone of equipment Operation
Time

Chapter 27

Two-winding Transformer Device Models

This chapter contains a collection of data sheets for the Two-winding Device Transformer models contained in the PSS®E dynamics model library.

Model	Description
OLTC1T	TWo-winding transformer online tap changer model.
OLPS1T	Two-winding transformer phase shift regulator model.
VFT1	Variable frequency transformer model.

27.1. OLPS1T

Two-Winding Transformer Phase Shifter Model

ICONs	Value	Description
M		Delay flag (Internal ICON)[a]
M+1		Timeoutflag (Internal ICON)[a]
M+2		Timer status flag (Internal ICON)[a]

[a]No user input is required for internal ICON.

CONs	Value	Description
J		T_D, time delay (sec)
J+1		T_C, time constant of shift mechanism (sec)
J+2		T_{SD}, time before subsequent signal sent (sec)

VARs	Description
L	Time delay
L+1	Phase shifter timer
L+2	Subsequent timer
L+3	MW flow

```
IBUS,'OLPS1T',JBUS,ID,CON(J) to CON(J+2) /
```

27.2. OLTC1T

Two-winding Transformer Online Tap Changer Model

ICONs	Value	Description
M		Delay flag (Internal ICON)[a]
M+1		Timeoutflag (Internal ICON) [a]
M+2		Timer status flag (Internal ICON) [a]

[a]No user input is required for internal ICON.

CONs	Value	Description
J		T_D, time delay (sec)
J+1		T_C, time constant of tap changer (sec)
J+2		T_{SD}, time before subsequent tap signal sent (sec)

VARs	Description
L	Time delay
L+1	Tap changer timer
L+2	Subsequent timer

```
IBUS,'OLTC1T',JBUS,ID,CON(J) TO CON(J+3)
```

27.3. VFT1

GE Variable Frequency Transformer

Internal ICONs*	Value	Description
M		Bus sequence number of IBUS
M+1		Bus sequence number of JBUS
M+2		Circuit ID
M+3		Direction of rotation

CONs	Value	Description
J		H, Inertia (sec)
J+1		X_{th1}, Thevenin Impedance Side 1 (pu)
J+2		X_{th2}, Thevenin Impedance Side 2 (pu)
J+3		T_{fx}, Frequency Transducer Time Constant(pu)
J+4		K_{PP}, Proportional Gain, Power Control
J+5		K_{PI}, Integral Gain, Power Control
J+6		Fp_{lim}, Limit Freq. Control (pu)
J+7		Fp_{limi}, Limit Freq. Control integrator (pu)
J+8		T_{fSRx}, Frequency branch Time Constant (s)
J+9		Fsr_{Lim}, Frequency Control, max & min Limits (pu)
J+10		$Frate_{Lim}$, (±)Frequency Control, max & min rate Limits (pu/s)
J+11		Kp_{stab}, Proportional Gain, Speed Stabilizing
J+12		Wp_{stab}, LP Filter Freq, Speed Stabilizing (rad/s)
J+13		$F_{p}\_stab_{Lim}$, Max & Min Limits, Speed Stabilizing (pu/s)
J+14		Td FP_{stab}, Time Constant, Stabilizing branch from Freq Ctrl (s)
J+15		K_{WP}, Proportional Gain, Speed Controller
J+16		K_{WI}, Integral Gain, Speed Controller
J+17		T_{drv}, Motor Drive Time Constant (s)
J+18		$TRQ_{\_rate}$, Torque Rate Limits (pu)
J+19		$TRQ_{\_vdtl\_max}$, Torque Voltage Dependance Max Limit (pu)
J+20		$TRQ_{\_vdtl\_min}$, Torque Voltage Dependance Min Limit (pu)
J+21		Tv_{dtl} Time Constant, Torque Voltage Dependance (pu)
J+22		SPD_rtr_base, Base Speed, Rotor (rpm)
J+23		SPD_mtr_base, Base Speed, Motor (rpm)
J+24		$IMTR_{max}$, Drive motor Tapered Current limit, Max Current (pu)
J+25		$IMTR_{Taper}$ Drive motor Tapered Current limit, Current Gain (pu)
J+26		Spd_{Taper} Drive motor Tapered Current limit, Speed Gain (pu)
J+27		Trq_{Acel_Lim}, Acceleration Limit, Torque (pu)
J+28		V_{PX}, Shut Down Voltage, Voltage Dependant Power Limit (pu)
J+29		V_{P1}, Unrestricted Voltage, Voltage Dependant Power Limit (pu)

CONs	Value	Description
J+30		Tup, Time Constant on up ramp, Voltage Dependant Power Limit (s)
J+31		Tdown, Time Constant on down ramp, Voltage Dependant Power Limit (s)
J+32		Plim0, Max Power Limit, Voltage Dependant Power Limit (pu)
J+33		R1, dFth Ramp Rate Side 1, VFT Governor (pu)
J+34		R2, dFth Ramp Rate Side 2, VFT Governor (pu)
J+35		FDB1, dFth deadband Side 1, VFT Governor (pu)
J+36		FDB2, dFth deadband Side 1, VFT Governor (pu)
J+37		TGOV, Time Constant, VFT Governor (s)
J+38		Dpg_mx1, Upper Frequency Input Limit, VFT Governor (pu)
J+39		Dpg_mx2, Lower Frequency Input Limit, VFT Governor (pu)
J+40		Deph_F, Admittance Matrix Re-factorizing Angle (degree)
J+41		T_{Pfbk}, Power Feedback Time Constant (s)

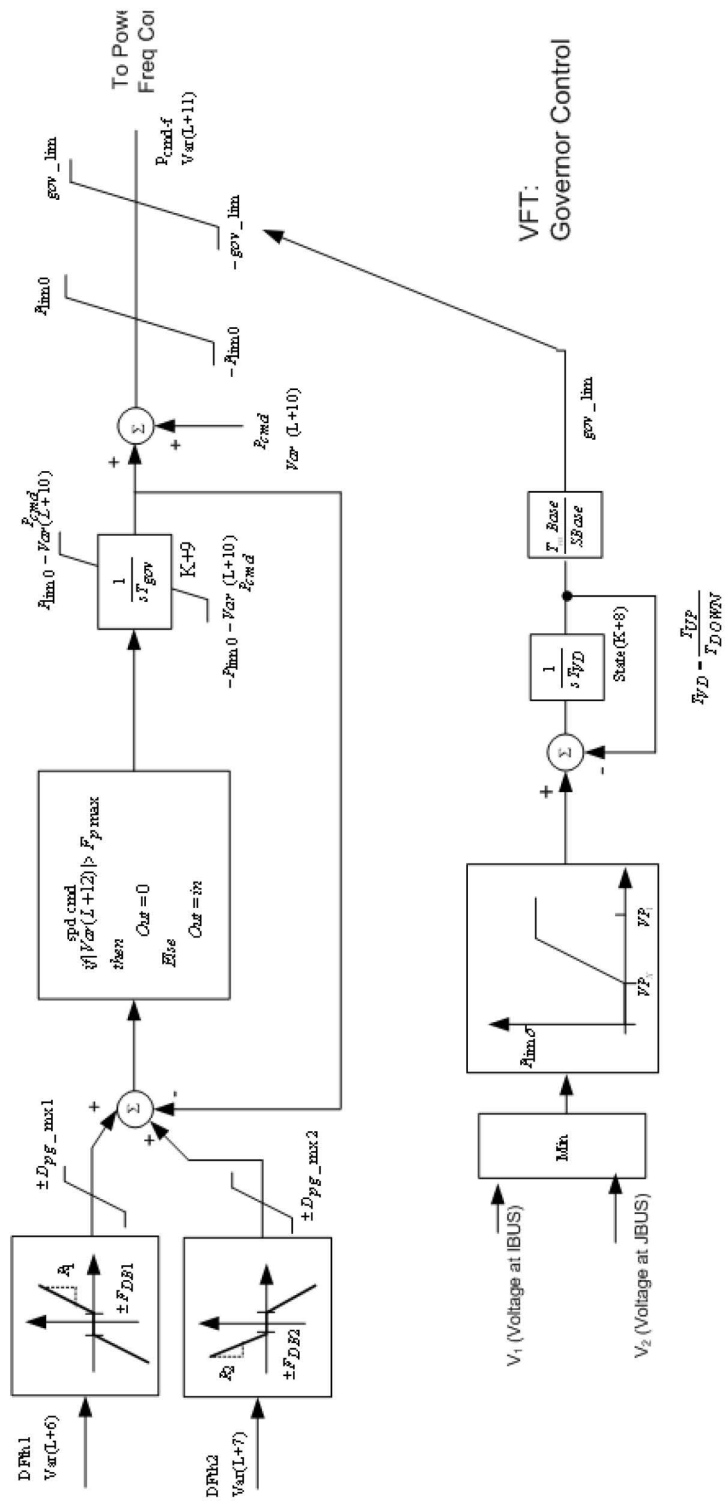
STATEs	Description
K	Rotor Angle (rad)
K+1	Rotor Speed (rad/s)
K+2	Speed PI Controller
K+3	Power PI Controller
K+4	Frequency PI Controller
K+5	Frequency Stabilizing Path
K+6	Speed Stabilizing Path
K+7	VDTL Filter
K+8	VDPL Filter
K+9	Governor Output
K+10	Thevenin Freq Transducer 1
K+11	Thevenin Freq Transducer 2
K+12	Rotor Drive Torque (pu)
K+13	Power Feedback (MW)

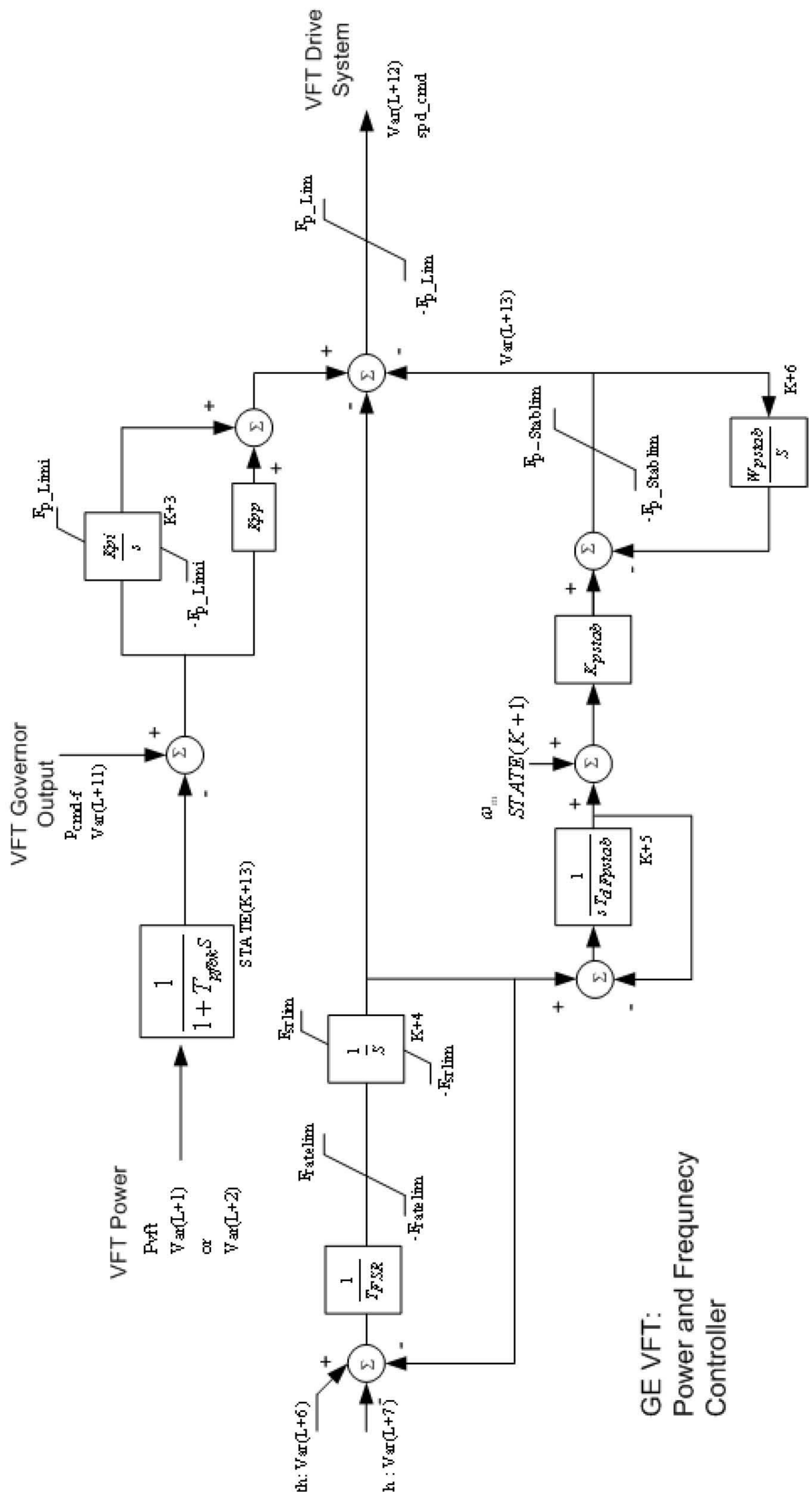
VARs	Description
L	VFT Angle (deg)
L+1	P side 1 (MW)
L+2	P side 2 (MW)
L+3	Te, Electric Torque (pu)
L+4	Q side 1 (Mvar)
L+5	Q side 2 (Mvar)
L+6	dFth1, Thevenin Frequency 1 (pu)
L+7	dFth2, Thevenin Frequency 2 (pu)
L+8	Vth1, Thevenin Voltage 1 (pu)
L+9	Vth2, Thevenin Voltage 2 (pu)

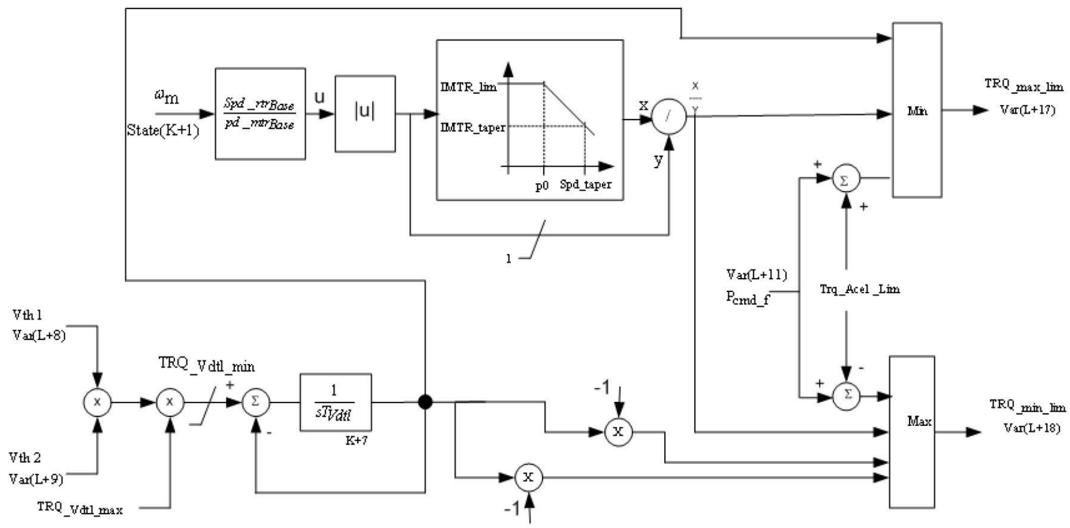
VARs	Description
L+10	Pcmd, Power Command Setpt (MW)
L+11	Pcmd_f, Final Power Cmd (pu)
L+12	Spd_cmd, Speed Command (pu)
L+13	Fpstab, Stabilizing Feedback (pu)
L+14	LFpu_low (pu)
L+15	LFpu_high (pu)
L+16	Drive Torque Limit (pu)
L+17	Final Torque Limit, High (pu)
L+18	Final Torque Limit, Low (pu)

*Internal Icons need not be input by users.

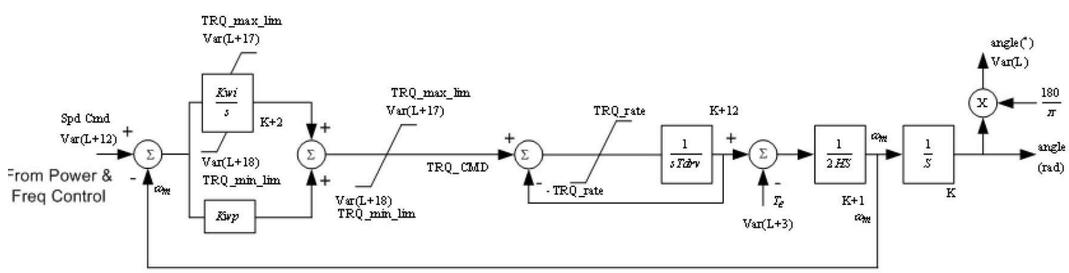
```
IBUS, 'VFT1', JBUS, ID, CON(J) to CON (J+41)/
```


VFT:
Governor Control
gov_lim
Min
V1 (Voltage at IBUS)
V2 (Voltage at JBUS)
DFth1
Var(L+6)
DFth2
Var(L+7)
spd cmd
Out = 0
Out = in
Pcmd-f
Var(L+11)
State(K+8)


VFT Drive System
Var(L+12)
spd_cmd
VFT Governor Output
Var(L+11)
Var(L+13)
VFT Power
Pvft
Var(L+1)
or
Var(L+2)
STATE(K+13)
K+3
K+4
K+5
K+6
th: Var(L+6)
h : Var(L+7)
GE VFT:
Power and Frequency
Controller



VFT Torque Limiter



VFT: Drive System

Notes:

The real power flowing across the VFT is stored in VAR(L+1) and VAR(L+2) for the from and to side flows respectively, with the convention of positive flow from the bus into the VFT. Similarly the reactive power is stored in VAR(L+4) and VAR(L+5). Note that the default channels for branch flow for the VFT should NOT be used as they do not generally take into account the movement in VFT. That is, if plotting the VTF flow is desired, the VFT model VARS should be used.

At initialization, the initial active power flow is stored in Pcmd. To simulate a change in the active power flow setpoint, change Pcmd, VAR(L+10), to the new setpoint. Note that the relative direction of the power flow must be taken into account.

When the VFT rotates by an angle greater than the admittance re-factorizing angle, CON(J+40), the power flow admittance matrix will be re-factorized. This re-factorization speeds up the network solution and prevents a potential divergent solution when the VFT alters the power flow significantly from the initial conditions. As a starting point, Siemens PTI recommends a value of 20 degrees for this re-factorization angle, but this angle may need to be adjusted based on the characteristics of the power system modeled.

Chapter 28

Three-winding Transformer Device Models

This chapter contains a collection of data sheets for the Three-winding Device Transformer models contained in the PSS®E dynamics model library.

Model	Description
OLTC3T	Online tap changer model for three-winding transformers.
OLPS3T	Online phase shift regulator model for three-winding transformers.

28.1. OLPS3T

Online Phase Shift Regulator Model for Three-Winding Transformers

ICONs	Value	Description
M		Delay flag (Internal ICON)[a]
M+1		Timeoutflag (Internal ICON)[a]
M+2		Timer status flag (Internal ICON)[a]
M+3		(Internal ICON)[a]

[a]No user input is required for intenral ICON.

CONs	Value	Description
J		T_D, time delay (sec)
J+1		T_C, time constant of shift mechanism (sec)
J+2		T_{SD}, time before subsequent signal sent (sec)

VARs	Description
L	Time delay
L+1	Phase shift timer
L+2	Subsequent timer
L+3	MW flow

```
IBUS,'OLPS3T',JBUS,KBUS,ID,CON(J) to CON(J+2) /
```

28.2. OLTC3T

Online Tap Changer Model for Three-Winding Transformers

ICONs	Value	Description
M		Delay flag (Internal ICON)[a]
M+1		Timeoutflag (Internal ICON)[a]
M+2		Timer status flag (Internal ICON)[a]
M+3		(Internal ICON)[a]

[a]No user input is required for internal ICON.

CONs	Value	Description
J		T_D, time delay (sec)
J+1		T_C, time constant of tap changer (sec)
J+2		T_{SD}, time before subsequent tap signal sent (sec)

VARs	Description
L	Time delay
L+1	Tap changer timer
L+2	Subsequent timer

```
IBUS,'OLTC3T',JBUS,KBUS,ID,CON(J) to CON(J+2) /
```

Chapter 29

Two-terminal dc Other Models

This chapter contains a collection of data sheets for the Two-terminal dc Other models contained in the PSS®E dynamics model library.

Model	Description
DCTC1T	Two-terminal dc line tap changer model.

29.1. DCTC1T

Two Terminal Online dc Tap Changer Model

ICONs	Value	Description
M		Delay flag rectifier (Internal ICON)[a]
M+1		timeout flag rectifier (Internal ICON)[a]
M+2		Timer status flag rectifier (Internal ICON)[a]
M+3		Delay flag inverter (Internal ICON)[a]
M+4		timeout flag inverter (Internal ICON)[a]
M+5		Timer status flag inverter (Internal ICON)[a]

[a]No user input is required for internal ICON.

CONs	Value	Description
J		T_{DR}, time delay for rectifier (sec)
J+1		T_{CR}, time constant of rectifier tap changer (sec)
J+2		T_{SDR}, time before subsequent rectifier tap signal sent (sec)
J+3		T_{DI}, time delay for inverter (sec)
J+4		T_{CI}, time constant of inverter tap changer (sec)
J+5		T_{SDI}, time before subsequent inverter tap signal sent (sec)

VARs	Description
L	Time delay (rectifier)
L+1	Tap changer timer (rectifier)
L+2	Subsequent timer (rectifier)
L+3	Time delay (inverter)
L+4	Tap changer timer (inverter)
L+5	Subsequent timer (inverter)

```
'DC NAME', 'DCTC1T', CON(J) to CON(J+5)   /
```

Chapter 30
Bus Other Models

This chapter contains a collection of data sheets for the Bus Other models contained in the PSS®E dynamics model library.

Model	Description
PLNTBU1	Generic Plant Control model
GetBusPhsVLTU	Model to Get Bus Individual Phase Voltage Magnitude and Angle
GetBusSeqVLTU	Model to Get Bus Sequence Voltage Magnitude and Angle

30.1. PLNTBU1

Generic Plant Control Model

ICONs	Value	Description
M		Bus number for voltage control (Note 4)
M+1		FROM bus number of the monitored branch for line drop compensation
M+2		TO bus number of the monitored branch for line drop compensation
M+3		Circuit id of the monitored branch for line drop compensation (enter in single quotes)
M+4		VCFlag (droop flag): 0 - with droop 1 - with line drop compensation
M+5		RefFlag (flag for V or Q control): 0 - Q control 1 - Voltage control 2 - Power factor control
M+6		Fflag (flag to disable frequency control): 1 - Enable control 0 - Disable control

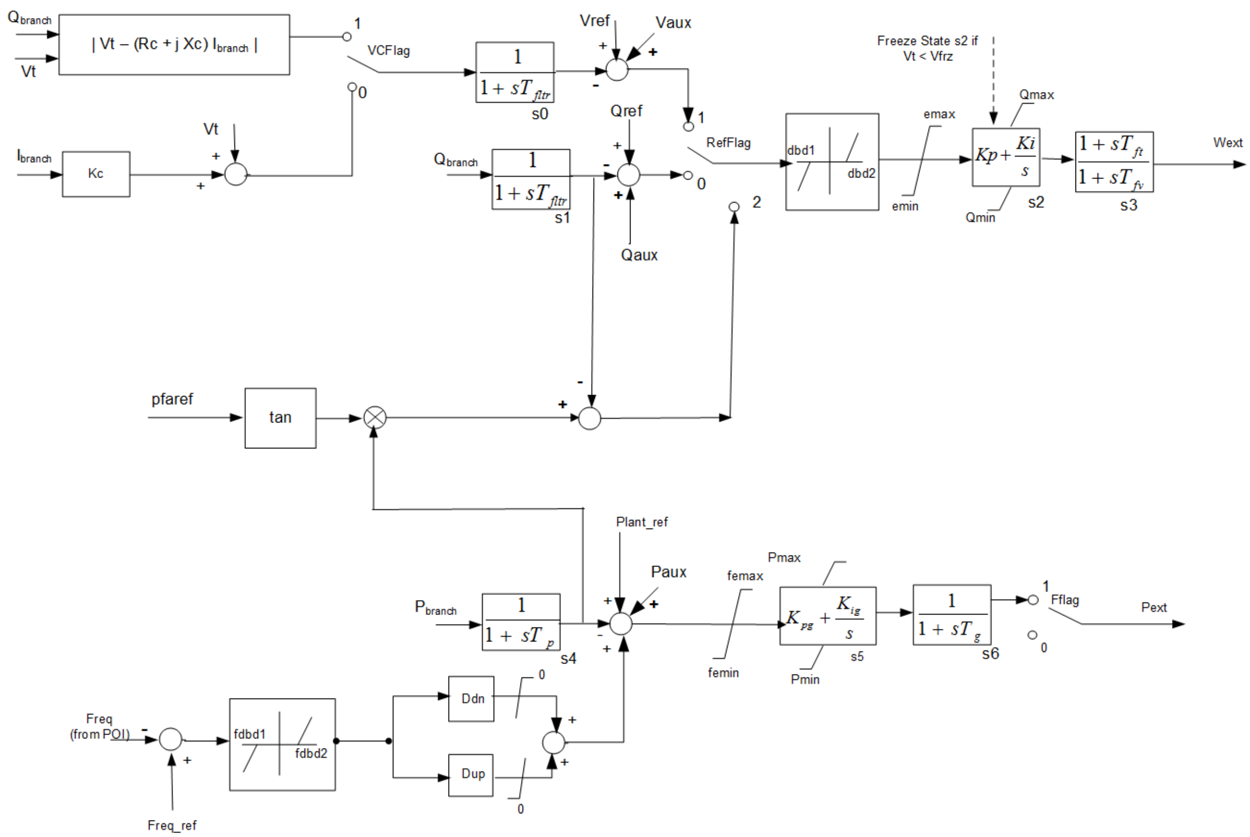
CONs	Value	Description
J		T_{fltr}, Voltage or reactive power measurement filter time constant (s)
J+1		K_p, Reactive power PI control proportional gain (pu)
J+2		K_I, Reactive power PI control integral gain (pu)
J+3		T_{FT}, Lead time constant (s)
J+4		T_{FV}, Lag time constant (s)
J+5		V_{FRZ}, Voltage below which State s2 is frozen (pu)
J+6		R_C, Line drop compensation resistance (pu of SBASE)
J+7		X_C, Line drop compensation reactance (pu of SBASE)
J+8		K_C, Reactive current compensation gain (pu)
J+9		E_{MAX}, Upper limit on deadband output (pu)
J+10		E_{MIN}, Lower limit on deadband output (pu)
J+11		D_{BD1}, Lower threshold for reactive power control deadband (<=0)
J+12		D_{BD2}, Upper threshold for reactive power control deadband (>=0)
J+13		Q_{MAX}, Upper limit on output of V/Q control (pu)
J+14		Q_{MIN}, Lower limit on output of V/Q control (pu)
J+15		K_{PG}, Proportional gain for power control (pu)

CONs	Value	Description
J+16		K_{IG}, Integral gain for power control (pu)
J+17		T_P, Real power measurement filter time constant (s)
J+18		F_{DBD1}, Deadband for frequency control, lower threshold (<=0)
J+19		F_{DBD2}, Deadband for frequency control, upper threshold (>=0)
J+20		FE_{MAX}, Frequency error upper limit (pu)
J+21		FE_{MIN}, Frequency error lower limit (pu)
J+22		P_{MAX}, Upper limit on power reference (pu)
J+23		P_{MIN}, Lower limit on power reference (pu)
J+24		T_G, Power Controller lag time constant (s)
J+25		D_{DN}, Reciprocal of droop for over-frequency conditions (pu)
J+26		D_{UP}, Reciprocal of droop for under-frequency conditions (pu)
J+27		MVA_P, Plant Controller MVA base - (Note 1)

STATEs	Description
K	Voltage Measurement filter
K+1	Reactive power control filter
K+2	PI controller for reactive power
K+3	Lead-lag in reactive power path
K+4	Real power filter
K+5	PI controller for real power
K+6	Power controller first order lag

VARs	Description
L	Reference for voltage control (V_{REF})
L+1	Reactive power reference (Q_{REF})
L+2	Frequency reference (Freq_ref)
L+3	Active Power reference (Plant_pref)
L+4	Line flow P MW
L+5	Line flow Q MVAr
L+6	Line flow MVA
L+7	Q/V Deadband output
L+8	Frequency deadband output
L+9	Power Factor angle Reference (radians) (P_{FAREF})
L+10	Auxiliary signal for voltage controller (pu) (V_{AUX}) - (Note 2)
L+11	Auxiliary signal for Q controller (pu) (Q_{AUX}) - (Note 2)
L+12	Auxiliary signal for P controller (pu) (P_{AUX}) - (Note 2)
L+13	Plant controller output - reactive part (W_{EXT}) - (Note 2)
L+14	Plant controller output - real part (P_{EXT}) - (Note 2)

```
IBUS, 'USRBUS', 'PLNTBU1', 504, 0, 7, 28, 7, 15, ICON(M) to ICON(M+6),
 CON(J) to CON(J+27) /
```



Notes:

1. If CON(J+27) is zero, model parameters are assumed to be in per unit of System Base.

2. W_{EXT}, P_{EXT}, Q_{AUX}, P_{AUX}, are in per unit of system base (SBASE).

3. The bus number which is monitored by the plant controller. This is typically the point of interconnection bus (IBUS to which the model is attached, and specified in the dyr record of this model). If ICON(M) is specified as 0, then IBUS specified in the dyr record will be used for monitoring.

4. Unless otherwise stated, parameters are in per unit of plant controller MVA base (specified in CON(J +27)).

5. This model has to be used with other models like REAX4BU1 (auxiliary signal model for Type 4 wind machines), REAX3BU1 (auxiliary signal model for Type 3 wind machines), SVCAXBU1 (auxiliary signal model for SVC), FCTAXBU1 (auxiliary signal model for FACTS device), or SYNAXBU1 (auxiliary signal model for synchronous condenser). The inputs to models REAX4BU1, REAX3BU1, SVCAXBU1 and SYNAXBU1 are the output from the PLNTBU1 model.

30.2. GetBusPhsVLTU

Model to Get Bus Individual Phase Voltage Magnitude and Angle

ICON	Value	Description
M		Flag- 1: get A-Phase voltage and angle, else 0
M+1		Flag- 1: get B-Phase voltage and angle, else 0
M+2		Flag- 1: get C-Phase voltage and angle, else 0

VAR	Description
L	A-phase Voltage magnitude (pu)
L+1	A-Phase Voltage angle (degrees)
L+2	B-phase Voltage magnitude (pu)
L+3	B-Phase Voltage angle (degrees)
L+4	C-phase Voltage magnitude (pu)
L+5	C-Phase Voltage angle (degrees)

DYR Syntax:

```
IBUS   'USRBUS'   'GetBusPhsVLTU'    504     2       3      0         0
   6        ICON(M) to ICON(M+2)   /
```

Note(s):

1. This model will get the A-phase, B-phase, and C-phase magnitude and angle of the phase voltage of the bus to which the model is attached. The calculated voltage magnitude and angle values are stored in VARs L through L+5.

2. The voltage values are in per unit, the angle values are in degrees.

3. For any phase (A, B or C), if the voltage and angle values for that phase are not required, set the corresponding ICON value to 0.

4. If the bus is out-of-service, the VARs containing the voltage and angle values will all be zero.

30.3. GetBusSeqVLTU

Model to Get Bus Sequence Voltage Magnitude and Angle

ICON	Value	Description
M		Flag- 1: get positive-sequence voltage magnitude and angle, else 0
M+1		Flag- 1: get negative-sequence voltage magnitude and angle, else 0
M+2		Flag- 1: get zero-sequence voltage magnitude and angle, else 0

VAR	Description
L	positive-sequence voltage magnitude (pu)
L+1	positive-sequence voltage angle (degrees)
L+2	negative-sequence voltage magnitude (pu)
L+3	negative-sequence voltage angle (degrees)
L+4	zero-sequence voltage magnitude (pu)
L+5	zero-sequence voltage angle (degrees)

DYR Syntax:

```
IBUS   'USRBUS'   'GetBusSeqVLTU'    504    2      3     0       0
   6       ICON(M) to ICON(M+2)   /
```

Note(s):

1. This model will get the positive, negative and zero sequence voltage magnitude and angle of the bus to which the model is attached. The calculated voltage magnitude and angle values are stored in VARs L through L+5.

2. The voltage values are in per unit, the angle values are in degrees.

3. If any of the sequence voltage magnitude and angle values are not required, set the corresponding ICON value to 0. For example, if the zero-sequence voltage and angle values are not needed, set ICON(M+2) to 0.

4. If the bus is out-of-service, the VARs containing the voltage and angle values will all be zero.

Chapter 31

Switched Shunt Other Models

This chapter contains a collection of data sheets for the Switched Shunt Other models contained in the PSS®E dynamics model library.

Model	Description
SWSAXBU1	Switched Shunt Auxiliary Control model

31.1. SWSAXBU1

Switched Shunt Auxiliary Control Model

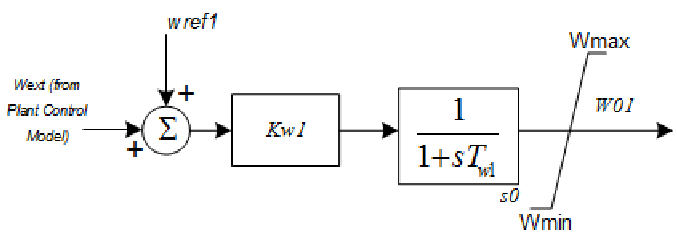
ICONs	Value	Description
M		Bus Number at which the Plant controller Model is attached

CONs	Value	Description
J		T_{W1} Measurement time constant (s)
J+1		K_{W1} Gain for signal in reactive path (cannot be equal to 0) (pu)
J+2		W_{MAX}, Maximum value of W_{01} (pu)
J+3		W_{MIN}, Minimum value of W_{01} (pu)

STATEs	Description
K	Measurement lag

VARs	Description
L	W_{REF1}, (pu on Machine MVA base)
L+1	W_{01}, (pu of system base), Model output (reactive part)

```
IBUS 'USRSWS' 'SWSAXBU1' 510 0 1 4 1 2 ICON(M), CON (J) to CON(J+3) /
```



Notes:

1. This model receives input from the plant control model which is connected at bus specified in ICON(M). If there is no plant control model attached at the bus specified in ICON(M), then the input (Wext) to the SWSAXBU1 model would be zero.

2. The IBUS in the dyr record is the bus at which the switched shunt (representing the SVC in PSS®E power flow) is connected.

3. Model parameters are in per unit of the system base.

Chapter 32
Miscellaneous Other Models

This chapter contains a collection of data sheets for the Miscellaneous Other models contained in the PSS®E dynamics model library.

Model	Description
VTGDCAT, VTGTPAT	Under/over voltage generator bus disconnection relay. Under/over voltage generator trip relay.
FRQDCAT, FRQTPAT	Under/over frequency generator bus disconnection relay. Under/over frequency generator trip relay.
SAT2T	Transformer saturation model.
SWCAPT	Switched capacitor bank model.

32.1. FRQDCAT, FRQTPAT

Under/Over Frequency Generator Bus Disconnection Relay

Under/Over Frequency Generator Trip Relay

FRQDCA

ICONs	Value	Description
M		Bus number where frequency is monitored
M+1		Bus number of generator bus where relay is located
M+2		Generator ID
M+3		Delay flag (internal ICON) [a]
M+4		Timeoutflag (internal ICON)[a]
M+5		Timer status (internal ICON)[a]

[a]User input not required for internal ICON. ICONS (M+3) through (M+5) are control flags and are not to be changed by the user.

CONs	Value	Description
J		FL, Lower frequency threshold (Hz)
J+1		FU, Upper frequency threshold (Hz)
J+2		TP, Relay pickup time (sec)
J+3		TB, Breaker time (sec)

VARs	Description
L	Timer memory

```
MINS,'FRQDCAT', ICON(M) to ICON(M+2), CON(J) TO CON(J+3) /
```

or

```
MINS,'FRQTPAT',ICON(M) to ICON(M+2), CON(J) TO CON(J+3) /
```

Note: Model FRQDCAT disconnects generator bus (i.e., disconnects all equipment attached to the generator bus).

Model FRQTPAT disconnects generators only.

32.2. SAT2T

Transformer Saturation Model

ICONs	Value	Description
M		Bus number

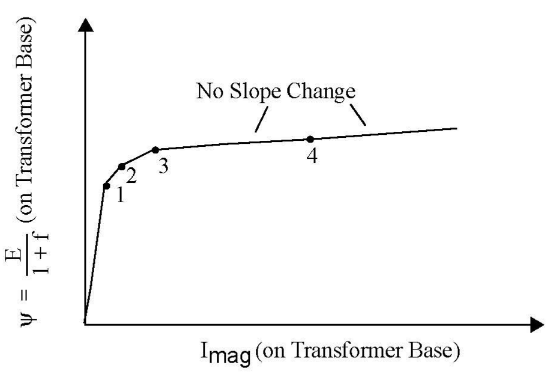
CONs	Value	Description
J		ψ1
J+1		I_1
J+2		ψ2
J+3		I_2
J+4		ψ3
J+5		I3
J+6		ψ4
J+7		I_4
J+8		Acceleration factor
J+9		Transformer MVA base

VARs	Description
L	Memory

```
MINS,'SAT2T', ICON(M), CON(J) TO CON(J+9) /
```

Note:

1. The ψ−I (flux linkage-Current) values have to increase monotonically.
2. The SAT curve is speified as a set of 4 pairs of ψ−I points. It is not necessary to specify all the 4 pairs of (ψ−I) data points. CON(J) (i.e., ψ1) and CON(J+1) (i.e., I1) have to be greater than zero. After that the first ψ that is specified as zero signifies the end of the SAT curve points.
3. The SAT curve is specified in per unit on TRMVA. If TRMVA is zero, the data points are assumed to be on SBASE.



32.3. SWCAPT

Switched Capacitor Bank Model

ICONs	Value	Description
M		Bus number

CONs	Value	Description
J		Capacitor Mvar
J+1		VSP, voltage setpoint (pu)
J+2		T_D, delay (sec)

VARs	Description
L	Memory

```
MINS,'SWCAPT', ICON(M),CON(J) TO CON(J+2) /
```

32.4. VTGDCAT, VTGTPAT

Under/Over Voltage Generator Bus Disconnection Relay

Under/Over Voltage Generator Trip Relay

ICONs	Value	Description
M		Bus number where voltage is monitored
M+1		Bus number of generator bus where relay is located
M+2		Generator ID
M+3		Delay flag (internal ICON)[a]
M+4		Timeoutflag (internal ICON)[a]
M+5		Timer status (internal ICON)[a]

[a]User input not required for internal ICONs.

CONs	Value	Description
J		VL, Lower voltage threshold (pu)
J+1		VU, Upper voltage threshold (pu)
J+2		TP, Relay pickup time (sec)
J+3		TB, Breaker time (sec)

VARs	Description
L	Timer memory

Note: ICONs (M+3) through (M+5) are control flags that are not to be changed by the user.

```
MINS, ’VTGDCAT’, ICON(M) TO ICON(M+2), CON(J) to CON(J+3) /
```

or

```
MINS,’VTGTPAT’,ICON(M) to ICON(M+2), CON(J) TO CON(J+3) /
```

Note: Model VTGDCAT disconnects generator bus (i.e., disconnects all equipment attached to the generator bus).

Model VTGTPAT disconnects generators only.

Chapter 33
Machine Other Models

This chapter contains a collection of data sheets for the Machine Other models contained in the PSS®E dynamics model library.

Model	Description
TSTGOV1	Frequency playback model
GetGenSeqCURU	Model to Get Generator Sequence Current Magnitude and Angle

33.1. TSTGOV1

ICONs	Value	Description
M		0 : for grid code test (trapezoidal frequency shape 1: to read frequency and power data points from a file
M+1		Load id (enter in single quotes)

CONs	Value	Description
J		TSTART1 (seconds)
J+1		TEND1 (seconds)
J+2		FREQUENCY1 (Hz)
J+3		TSTART2 (seconds)
J+4		TEND2 (SECONDS)
J+5		FREQUENCY2 (Hz)

VARs	Description
L	Measured frequency from file
L+1	Measured Pelec of generator from file

```
IBUS 'USRMDL' ID 'TSTGOV1' 505 0 2 6 0 2 ICON(M) to ICON(M+1), CON (J) to
 (J+5) /
```

Notes:

1. Although the model is in a user-written model format, use of this model will not require compile or link.

2. In order to use this model, a single-machine with a load connected to it has to be created. For details, please see Program Application Guide, Volume II, chapter on "Other PSS/E Models"

3. If ICON(M) is 1 (i.e, read measured frequency and power data from a file), then CON(J) through CON(J+5) can be specified as zero. The file containing the measurement has to be supplied in a file whose name is 'FTIME1.DAT'. The file must be present in the folder from where PSS®E is started. The format of this data file must be one data record per line, with each data record containing the measured data in this order:

   Time, Frequency, Power
   The data is read free format. The units of time should be seconds; the units of frequency should be Hz, and the units of power are MW. There is no restriction in the number of data points supplied in the data file 'FTIME1.DAT'.

33.2. GetGenSeqCURU

Model to Get Generator Sequence Current Magnitude and Angle

ICON	Value	Description
M		Flag- 1: get positive-sequence current magnitude and angle, else 0
M+1		Flag- 1: get negative-sequence current magnitude and angle, else 0
M+2		Flag- 1: get zero-sequence current magnitude and angle, else 0

VAR	Description
L	positive-sequence current magnitude (pu)
L+1	positive-sequence current angle (degrees)
L+2	negative-sequence current magnitude (pu)
L+3	negative-sequence current angle (degrees)
L+4	zero-sequence current magnitude (pu)
L+5	zero-sequence current angle (degrees)

DYR Syntax:

```
IBUS   'USRMDL'   ID   'GetGenSeqCURU'   505    2      3      0
  0       6       ICON(M) to ICON(M+2)   /
```

Note(s):

1. This model will get the positive, negative and zero sequence current magnitude and angle of the machine to which the model is attached. The calculated current magnitude and angle values are stored in VARs L through L+5.

2. The current values are in per unit of the machine MVA, the angle values are in degrees.

3. If any of the sequence current magnitude and angle values are not required, set the corresponding ICON value to 0. For example, if the zero-sequence current and angle values are not needed, set ICON(M+2) to 0.

4. If the bus is out-of-service, or if the generator is out-of-service, the VARs containing the current and angle values will all be zero.

Chapter 34
Branch Other Models

This chapter contains a collection of data sheets for the Branch Other models contained in the PSS®E dynamics model library.

Model	Description
GetBrnSeqCURU	Model to Get Branch Sequence Current Magnitude and Angle

34.1. GetBrnSeqCURU

Model to Get Branch Sequence Current Magnitude and Angle

ICON	Value	Description
M		Flag- 1: get positive-sequence current magnitude and angle, else 0
M+1		Flag- 1: get negative-sequence current magnitude and angle, else 0
M+2		Flag- 1: get zero-sequence current magnitude and angle, else 0

VAR	Description
L	positive-sequence current magnitude (pu)
L+1	positive-sequence current angle (degrees)
L+2	negative-sequence current magnitude (pu)
L+3	negative-sequence current angle (degrees)
L+4	zero-sequence current magnitude (pu)
L+5	zero-sequence current angle (degrees)

DYR Syntax:

```
IBUS   'USRBRN'   JBUS    ID    'GetBrnSeqCURU'    501     2       3
 0         0       6       ICON(M) to ICON(M+2)   /
```

Note(s):

1. This model will get the positive, negative and zero sequence current magnitude and angle of the branch to which the model is attached. The calculated current magnitude and angle values are stored in VARs L through L+5.

2. The current values are in per unit of system MVA base, the angle values are in degrees.

3. If any of the sequence current magnitude and angle values are not required, set the corresponding ICON value to 0. For example, if the zero-sequence current and angle values are not needed, set ICON(M+2) to 0.

4. The model can be attached to any branch (including zero-impedance lines). The model cannot be attached to 2-winding or 3-winding transformers.

5. If the branch (to which the model is attached) is out-of-service, the VARs containing the current and angle values will all be zero.

Chapter 35
Model Functions

This chapter contains a collection of data sheets for the models functions for Models contained in the PSS®E dynamics model library.

Model	Description
BSDSCN	Function for bus disconnection.
FLOW	Function to obtain branch flow.
FLOW1	Function to obtain branch flow.
FLOW2	Function to obtain branch flow for a winding of a three-winding transformer.
FLOW3	Function to obtain branch flow for a winding of a three-winding transformer.
GENTMC	Function to calculate Generator terminal current.
GENTMZ	Function to calculate Generator apparent impedance.
GENTRP	Function to trip a generator.
LINESW	Function to switch a branch.
LINRCL	Line reclose function.
LINTRP	Function to trip a line.
PTOTOW, PTOTZN, PTOTAR, PTOTAL	Calculation of Power totals by subsystem. Subsystem type is indicated by characters of five and six of the model name as follows: OW for Owner, ZN for Zone, AR for Area, and AL for all buses.
RELAY2	Apparent impedance monitoring.
RELAY3	Apparent impedance monitoring for a winding of three-winding transformer.
VOLMAG	Bus voltage monitoring.

35.1. BSDSCN

Function to disconnect a bus

Function call: CALL BSDSCN(M)

ICONs	Value	Description
M		Bus number

BSDSCN takes no action when called at a t^+ (i.e., if KPAUSE is two).

35.2. FLOW

Function to calculate Branch Flow

Function call: CALL FLOW (I,N,M,L)

Flow is calculated out of the bus number contained in ICON(I).

N, M, and/or L may be zero to bypass storing of the respective quantity.

ICONs	Value	Description
I		From bus number
I+1		To bus number
I+2		Circuit identifier1[a]
I+3		Switch: 0 to ignore line shunt component 1 to include it

[a]Enter circuit identifier of -1 to sum flows of all parallel circuits between the two buses.

VARs	Description
N	MW
M	Mvar
L	MVA

35.3. FLOW1

Branch Flow Model

Function to calculate branch flow

Function call: CALL FLOW1 (I,N,M,L)

Flow is calculated out the bus number contain in ICON(I).

N, M, and/or L may be zero to bypass storing of the respective quantity.

ICONs	Value	Description
I		From bus number
I+1		To bus number
I+2		Circuit identifier[a]

[a]Enter circuit identifier of -1 to sum flows of all parallel circuits between the two buses.

VARs	Description
N	MW
M	Mvar
L	MVA

Note: Flows include the line shunt component at the from bus end.

This function can also be be selected in activity CHAN or CHSB.

35.4. FLOW2

Function to calculate Branch Flow

Function call: CALL FLOW2 (I,N,M,L)

Flow is calculated out of the bus number contained in ICON(I).

N, M, and/or L may be zero to bypass storing of the respective quantity.

ICONs	Value	Description
I		From bus number
I+1		To bus number
I+2		Circuit identifier[a]

[a]Enter circuit identifier of -1 to sum flows of all parallel circuits between the two buses.

VARs	Description
N	MW
M	Mvar
L	MVA

Note: Flows do not include the line shunt components.

35.5. FLOW3

Function to calculate Three-Winding Transformer Flow Model

Function call: CALL FLOW3 (I,N,M,L)

Flow is calculated out the bus number contain in ICON(I).

N, M, and/or L may be zero to bypass storing of the respective quantity.

ICONs	Value	Description
I		From bus number
I+1		To bus number
I+2		Third bus number
I+3		Circuit identifier

VARs	Description
N	MW
M	Mvar
L	MVA

Note: Flows include the magnetizing admittance component at the from bus end if it is the bus to which winding one is connected.

This function can also be selected in activity CHAN or CHSB.

35.6. GENTMC

Function to calculate Generator Terminal Current Model

Function call: CALL GENTMC(L,M)

ICONs	Value	Description
M		Bus number
M+1		Machine identifier

VARs	Description
L	Current magnitude on MBASE
L+1	Current angle (radians)

This funtion can also be selected in activity CHAN or CHSB.

35.7. GENTMZ

Function to call

Generator Apparent Impedance Model

Function call: GENTMZ (L,I)

ICONs	Value	Description
M		Bus number
M+1		Machine identifier

VARs	Description
L	Apparent resistance on MBASE
L+1	Apparent reactance on MBASE

The apparent impedance is expressed from the terminals looking out into the system.

This function can also be selected in activity CHAN or CHSB.

35.8. GENTRP

Function to trip a Generator

Function call: CALL GENTRP (IBUS, 'I')

GENTRP takes no action when called at a t+ (i.e., if KPAUSE is two).

35.9. LINESW

Function for Branch Switching

Function call: CALL LINESW (I,IS)

The line is tripped if IS is zero; otherwise, the line status is set to in-service.

ICONs	Value	Description
M		From bus number
M+1		To bus number
M+2		Circuit identifier

LINESW takes no action when called at a t+ (i.e., if KPAUSE is two).

35.10. LINRCL

Function for Branch Reclosing

Function call: CALL LINRCL (M)

ICONs	Value	Description
M		From bus number
M+1		To bus number
M+2		Circuit identifier

LINRCL takes no action when called at a t^+ (i.e., if KPAUSE is two).

35.11. LINTRP

Function for Branch Tripping

Function call: CALL LINTRP (M)

ICONs	Value	Description
M		From bus number
M+1		To bus number
M+2		Circuit identifier

LINTRP takes no action when called at a t^+ (i.e., if KPAUSE is two).

35.12. PTOTOW, PTOTZN, PTOTAR, PTOTAL

Function to Calculate

Power Totals by Subsystem

Function call: CALL PTOTxx (I,L)

ICONs	Value	Description
M		Subsystem number or zero for PTOTAL

VARs	Description
L	Mechanical power, PM
L+1	Electrical power, PE
L+2	Accelerating power, PM-PE
L+3	Load power, PL
L+4	PE-PL

This function can also be selected in activity CHSB.SU or by employing the subsystem power totals selection of the selet channels by subsystem dialog.

Model suffix xx	ICON(I) Description
OW	Owner number
ZN	Zone number
AR	Area number
AL	0

35.13. RELAY2

Relay Checking Model

M and/or N may be zero to bypass storing of the respective component of the apparent impedance

ICONs	Value	Description
I		From bus number
I+1		To bus number
I+2		Circuit identifier

VARs	Description
N	Apparent resistance
M	Apparent reactance

This function can also be selected in activity CHAN or CHSB.

35.14. RELAY3

Three-Winding Transformer Relay Checking function

Function call: CALL RELAY3 (I,N,M)

M and/or N may be zero to bypass storing of the respective component of the apparent impedance.

ICONs	Value	Description
I		From bus number
I+1		To bus number
I+2		Third bus number
I+3		Circuit identifier

VARs	Description
N	Apparent resistance
M	Apparent reactance

This function can also be selected in activity CHAN or CHSB.

35.15. VOLMAG

Voltage Monitoring Function

Function Call: CALL VOLMAG (M,J,K)

ICONs	Value	Description
M		Bus number

VARs [a]	Description
J	Voltage magnitude
K	Phase angle

[a]J or K may be zero to bypass storing of that quantity.

This function can also be selected in activity CHAN or CHSB.