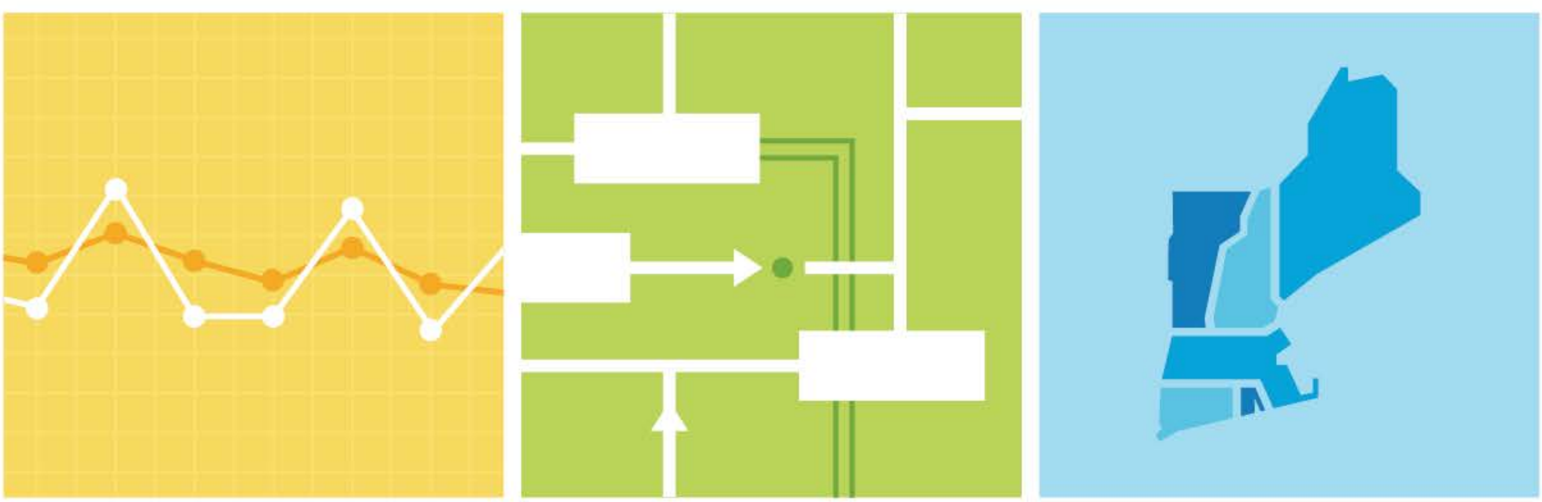
Generator Protection Modeling Practice & Guidelines

MARCH 12, 2019



Preface/Disclaimer

The descriptions included in this Generator Protection Modeling Practice & Guideline ("Guideline") are only examples that may help Lead Market Participants (Lead MPs) and Generator Owners in developing generator protection models. Lead MPs and Generators Owners must verify that the information included in this Guideline is appropriate for their specific models.

Table of Contents

Section 1 - Executive Summary

ISO New England (ISO) can use generator relay characteristics and models to more accurately determine appropriate generator dispatch based on system conditions to operate the system in a more reliable manner. The use of these relay characteristics will also allow ISO to reduce the likelihood of generators tripping due to voltage or frequency excursions.

This Guideline presents recommended best practices and examples for Lead Market Participants (Lead MPs) and Generator Owners (GOs) to develop and provide generator protection models for ISO stability studies. ISO uses the Siemens PTI PSS/E program for power systems analysis. Lead MPs must provide models in a format that is compatible with Siemens PTI Version currently in use by ISO New England. (ISO) Generators required to provide this data to ISO are described in ISO Operating Procedure OP-24 Relay Protection Outages, Settings and Coordination. As ISO updates PSS/e versions, Lead Market Participants for Generator Owners (Lead MPs for GOs) shall provide any necessary updates to models.

Entities may provide alternative models for equipment to those suggested in this Guideline, but any such alternative models must be compatible with Siemens PSS/E version 33 or higher. Entities shall provide models that are the best representation of their equipment as actually configured.

Entities may need additional resources to develop protection models. Several consulting companies that may have experience with model development are listed in this Guideline as suggestions to assist Lead MPs when the need may arise.

Under- and over- voltage and frequency relays may also be modeled for wind turbines, solar facilities, and other inverter-based technologies as described in this Guideline, whether these facilities are modeled with user-defined models or standard PSS/E library models.

Section 2 - Introduction

Generator relay settings are important for system studies as detailed in the NERC Considerations for Power Plant and Transmission System Protection Coordination Technical Reference Document[1].

Because ISO does not have access to all characteristics of individual generation facilities, it is necessary for the Lead MPs for those facilities to work with the owners and provide the information necessary to model the facilities. Improper modeling could lead to unnecessary issues for generators such as a reduction in generator dispatch or an inappropriate full load rejection if operated in conditions not envisioned when protection settings were developed. While simulation programs cannot account for all conditions, modelers with expertise in both PSS/E and protective relays should be retained to develop the models for generation protection equipment.

There are limits associated with size and interconnection voltage for generators that must provide protection models and OP-24 indicates which generators are required to provide information in association with this Guideline.

[1] NERC Considerations for Power Plant and Transmission System Protection Coordination Technical Reference Document Revision 2 System Protection and Control Subcommittee July 2015

Section 3 - Sources of Protection Settings Information

Modelers may find several sources of relay protection settings, including completed relay test sheets (uncompleted sheet form shown in Figure 1) that are typically maintained as records of relay testing. Generator manufacturers may also provide suggested settings for protective devices and relay manufacturers provide typical settings. Relay instruction books such as those available from ABB, General Electric, Schweitzer Engineering, Siemens and others describe the function and application of relays and provide typical settings. In any case, modelers must translate these sources of data into models that are useful with simulation programs.

Sample's Testing, LLC **Relay Test Form**

DESCRIPTION:

Manufacturer		Instruct. Book	
Pickup Range		CT Ratio	
Drawing No.		VT Ratio	
Relay Type		Device #	
Test Type/Set #		Test Set Calibration Date	
Other			

VISUAL AND MECHANICAL INSPECTION:

Crosscheck Nameplate with elementary drawings ☐			
Settings per Owner Provided Coordination Study ☐			
Cover Gasket ☐	Condensation/Rust ☐	Contact Condition ☐	Contact Condition ☐
Glass Intact ☐	Bearing Condition ☐	Glass Cleaned ☐	Power Supply ☐
Foreign Material ☐	Bearing Clearance ☐	Connections Tight ☐	Disc Clearance ☐
Other/Notes			

TEST VALUES AND RELAY SETTINGS:

Phase					
Test 1		Sec @		Per Unit	
Test 2		Sec @		Per Unit	
Specified		Time Dial		Volt Tap	
As Found		Time Dial		Volt Tap	
As Set		Time Dial		Volt Tap	

TEST OPERATIONS AS FOUND:

Time Element					Instantaneous			
			Pick Up		Time Value		Instantaneous Element	
	Set	Time Dial	1	2	1	2	1	2
Phase A								
Phase B								
Phase C								

TEST OPERATIONS AS LEFT:

Time Element					Instantaneous			
			Pick Up		Time Value		Instantaneous Element	
	Set	Time Dial	1	2	1	2	1	2
Phase A								
Phase B								
Phase C								

Figure 1 – Typical Relay Testing Form

Section 4- Obligation to Provide Generator Protection Models

Pursuant to the ISO Tariff and NERC TOP and IRO Standards, Lead MPs are required to provide specific information for relay models.

4.1 Applicable sections of the ISO Tariff

The ISO Open Access Transmission Tariff (which is Section II of the ISO Tariff) requires Lead MPs to provide modeling data as requested by ISO. The applicable provision states as follows:

SECTION II

ISO NEW ENGLAND OPEN ACCESS TRANSMISSION TARIFF

II.22.2(c) Reporting Obligations: The Network Customer shall be responsible for all information required by the ERO, NPCC, the applicable PTO(s) or the ISO. The Network Customer shall respond promptly and completely to the ISO's and the applicable PTO(s)'reasonable requests for information, including but not limited to, data necessary for operations, maintenance, regulatory requirements and analysis.

4.2 NERC Standards

IRO-010-2 requires entities to provide relay model information . Excerpts from the specific requirements from the standards are included below:

IRO-010-2

R1. The Reliability Coordinator shall maintain a documented specification for the data necessary for it to perform its Operational Planning Analyses, Real-time monitoring, and Real-time Assessments. The data specification shall include but not be limited to: (Violation Risk Factor: Low) (Time Horizon: Operations Planning)

1.1. A list of data and information needed by the Reliability Coordinator to support its Operational Planning Analyses, Real-time monitoring, and Real-time Assessments including non-BES data and external network data, as deemed necessary by the Reliability Coordinator…

R3. Each Reliability Coordinator, Balancing Authority, Generator Owner, Generator Operator, Load-Serving Entity, Transmission Operator, Transmission Owner, and Distribution Provider receiving a data specification in Requirement R2 shall satisfy the obligations of the documented specifications using: (Violation Risk Factor: Medium) (Time Horizon: Operations Planning, Same-Day Operations, Real-time Operations)

3.1 A mutually agreeable format

3.2 A mutually agreeable process for resolving data conflicts

3.3 A mutually agreeable security protocol

Section 5 - Expertise and Consultants for Protection Modeling

Personnel with expertise in simulation models and familiarity with equipment should provide models. The following consultants may be able to assist in providing these models. ISO does not endorse consultants and entities should review references and capabilities of any consultants retained for protection model development.

General Electric Energy Systems
One River Road
Schenectady, NY 12345
http://www.geenergyconsulting.com/contact-us

Kestrel Power Engineering LLC.
9126 N 2150 E Rd.
Fairbury, Illinois, 61739
(815) 846-1278
https://kestrelpower.com/contact.php

Siemens PTI
400 State St
Schenectady, NY 12305
(518) 395-5000
http://w3.siemens.com/smartgrid/global/en/products-systems-solutions/software-solutions/planning-data-management-software/pti/pages/power-technologies-international-(pti).aspx

Section 6 – Submittal Format

6.1 Information Provided

Lead MP submittals should include supporting information such as the relay testing forms or other calculations used to develop the relay models. Submittals should also note when generators do not have certain relays. For instance, when generators are not fitted with over/under frequency relays please note that in the supporting documentation. Lead MPs must provide all relay characteristics in primary terms, not in the relay input secondary terms. Modelers shall use the following sheets or other PSS/E models to describe the relay functions and provide dyr files representing the generator protection functions.

6.2 Distance Relay (Device 21)

The suggested PSS/E model for a generator distance relay (Device 21) is the DISTR1 model. The Line Relay Model Data Sheet for the DISTR1 is provided below. Additional notes for the parameters used in the DISTR1 relay model are included in Table 1.

Table 1 – DISTR1 Generator Distance Model Considerations	
Zone 1 Operating Time	As shown on the Siemens model data sheet, this is the time needed for the relay to sense a faulted condition and initiate trip.
Zone 1 reach, angle and center distance	These characteristics specify the innermost mho circle size and position as illustrated by the Zone Reach diagram in the Siemens model data sheet
Zone 2 and Zone 3 pickup time	These settings include intentional delay time added for zone 2 and zone 3 along with the relay operating time
Angle of directional unit	As shown in the Impedance Distance illustration in Siemens model data sheet

11.2 DISTR1

mho, Impedance, or Reactance Distance Relay

Relay is located from bus	#_______	IBUS,
To bus	#_______	JBUS,
Circuit identifier	#_______	ID,
relay slot (1 or 2)	#_______	RS.
This model uses CONs starting with	#_______	J,
and VARs starting with	#_______	L,
and ICONs starting with	#_______	M.

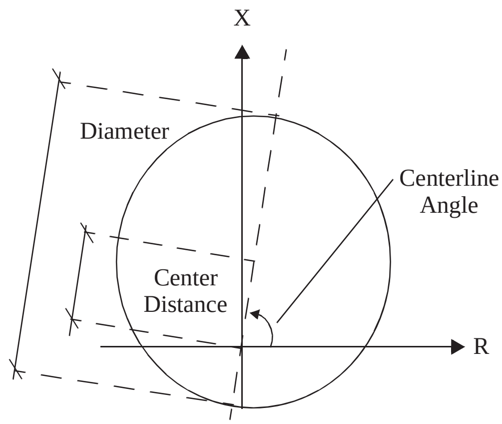
CONs	Value	Description
J		Zone 1 operating time (cycles)
J+1		Zone 1 reach (diameter or reactance) (pu)
J+2		Zone 1 centerline angle in degrees (0 for reactance relay)
J+3		Zone 1 center distance (0 for reactance relay)
J+4		Zone 2 pickup time (cycles)
J+5		Zone 2 reach (diameter or reactance) (pu)
J+6		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)
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	Value	Description
L		Apparent R
L+1		Apparent X
L+2		Current
L+3 . . . L+9		VARs required for internal program logic

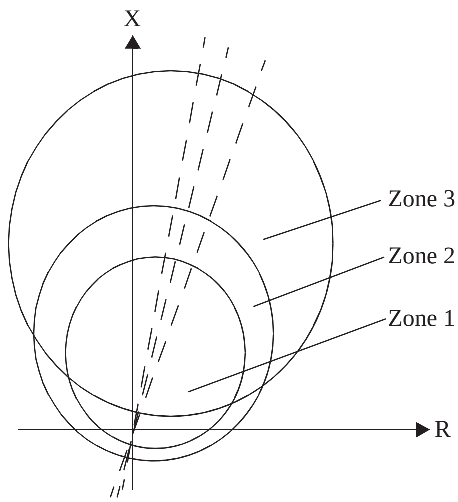
ICONs	Value	Description	
M		Type 1, mho distance Type 2, impedance distance Type 3, reactance distance	
M+1		0 Monitor 1 Monitor and operate	
M+2		From bus number	First transfer trip
M+3		To bus number	
M+4		Circuit ID	
M+5		From bus number	Second transfer trip
M+6		To bus number	
M+7		Circuit ID	
M+8		From bus number	Third transfer trip
M+9		To bus number	
M+10		Circuit ID	
M+11	X	Permissive flag for self trip[1]	
M+12	X	Permissive flag for transfer trip[2]	
M+13 . . . M+28	X	ICONs required for internal program logic	

1 Set to 1 and -1 by supervisory relay to block trip and force trip, respectively.
2 Set to 1 by supervisory relay to block trip.

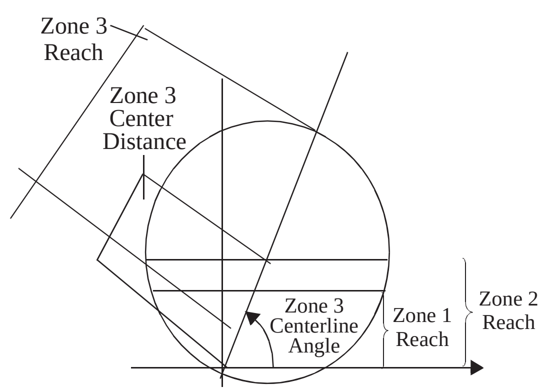
IBUS, 'DISTR1', JBUS, ID, RS, ICON(M) to ICON(M+10), CON(J) to CON(J+23) /



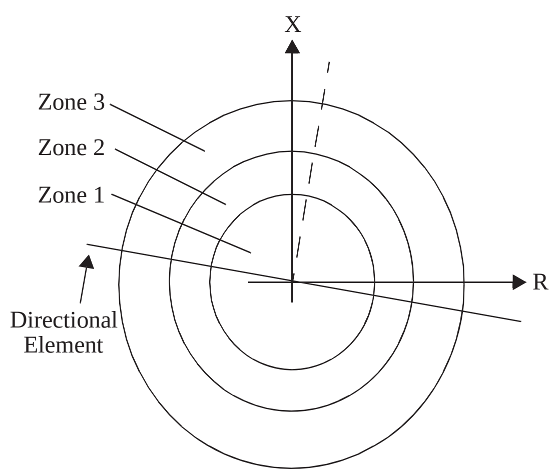
Zone Reach



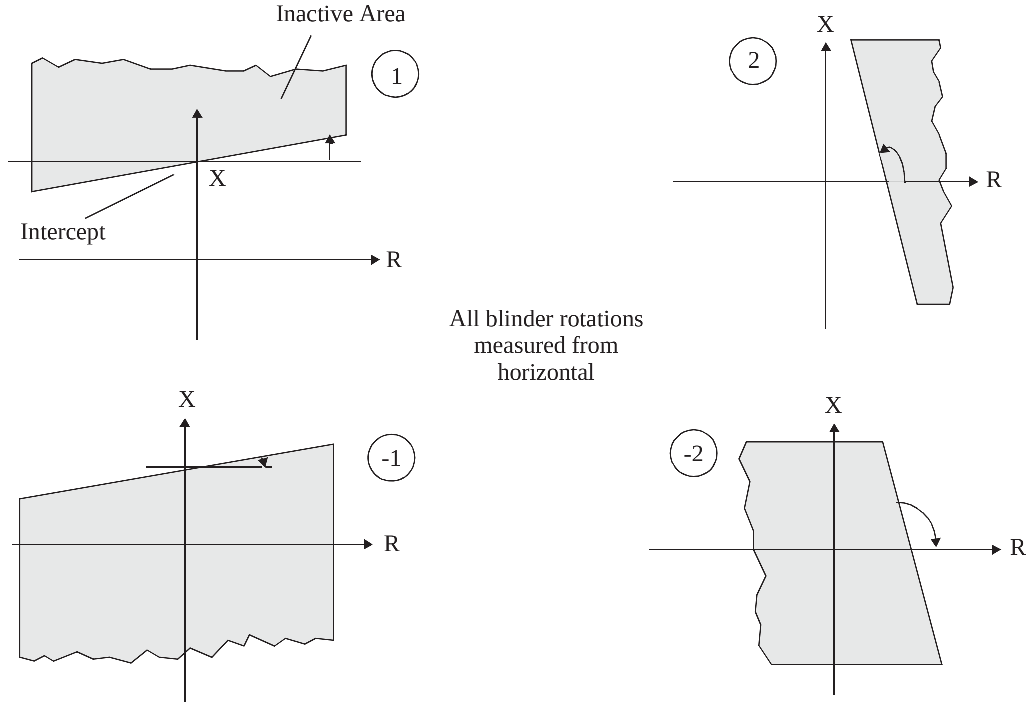
mho Distance



Reactance Distance



Impedance Distance



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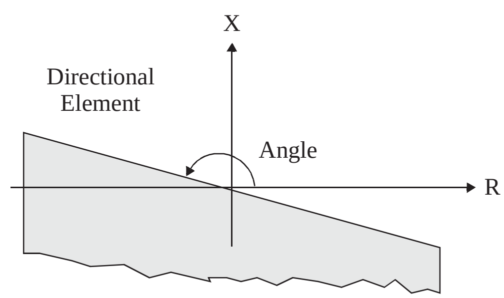


mho, Impedance, or Reactance Distance Relay

6.3 Volts/Hertz Relay (Device 24)

The Volts per Hertz relay may be represented by the Siemens PSS/E VPERHZU1. Notes on using Volts per Hertz relays (when applied) are included in Table 2.

Table 2 – Siemens VPERHZU1 Model Considerations
Note on Generator Volts/Hertz settings requirement: Volts per Hz protection – Unless already documented differently with ISO, Lead MPs for Generator Owners shall ensure that Volts per Hz (V/Hz) relay trip settings exceed 1.18 per unit for longer than two seconds cumulatively per event, and exceed 1.10 per unit for longer than 45 seconds cumulatively per event at each generator bus and generator step-up transformer high-side bus.

25.2 VPERHZU1

V/Hz Generator Relay Model

This model is located at bus	#_______	IBUS
Machine	#_______	ID
This model uses CONs starting with	#_______	J,
and STATEs starting with	#_______	K
and VARs starting with	#_______	L,
and ICONs starting with	#_______	M.

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)
J+9			TP5, relay pickup time (s)
J+10			TB, breaker time (s)
J+11			Tv, voltage measurement filter time constant (s)
J+12			Tf, 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

ICONs	#	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 to be available for user edits)	#	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)

Notes:

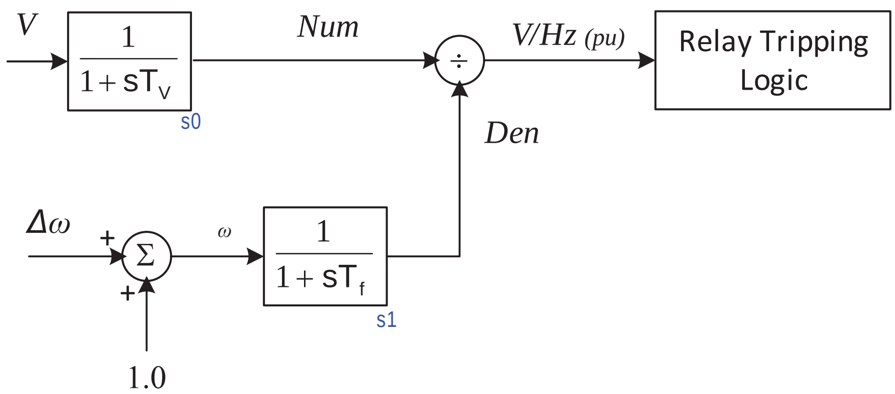
- This model uses 2 ICONs and 15 internal ICONs. ICONs (M+4) through (M+18) are control flags that are not to be changed by the user
- When ICON(M) is 1, setting ICON(M+1) equal to 1 will trip the generator, while setting ICON(M+1) equal to 2 will disconnect the generator bus (i.e., disconnects all equipment attached to the generator bus).
- ICONs marked "Internal ICONs" have to be entered as 0 (15 zeros) in the model dyr record.
- This model is treated as a "Machine Protection" model and can be accessed under the "Protection Models>Machine" tab in the dynamics data spreadsheet.

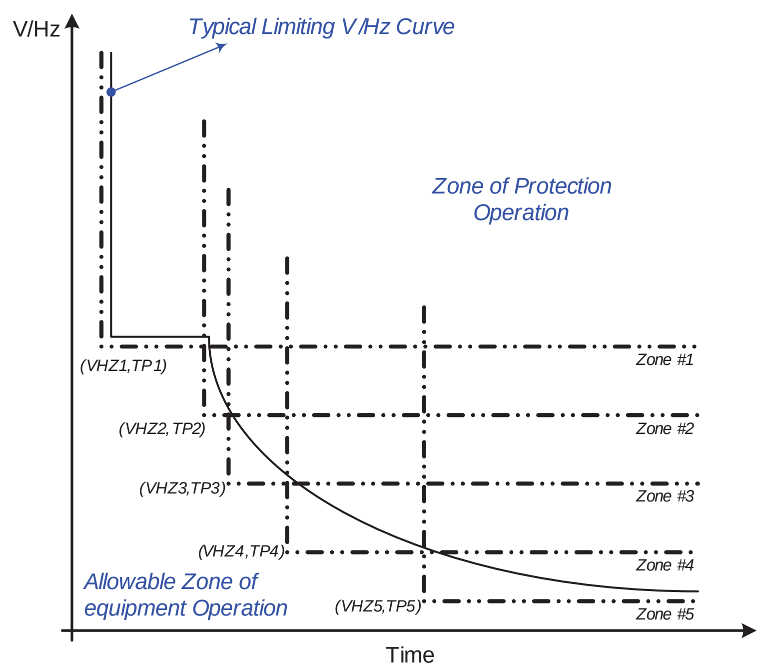
- Since bus frequency in PSS®E (which is calculated using bus voltage angle) is subject to instantaneous changes, this model uses speed deviation instead of bus frequency for the V/Hz calculation. In view of this, this model should be applied only to synchronous machines.
- ICON(M+2) specifies the number 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.
- 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+sTV
s0
Num
÷
V/Hz (pu)
Relay Tripping Logic
Den
Δω
+
Σ
+
ω
1
1+sTf
s1
1.0


V/Hz
Typical Limiting V/Hz Curve
Zone of Protection Operation
(VHZ1,TP1)
Zone #1
(VHZ2, TP2)
Zone #2
(VHZ3,TP3)
Zone #3
(VHZ4,TP4)
Zone #4
Allowable Zone of equipment Operation
(VHZ5,TP5)
Zone #5
Time

6.4 Under/Over Voltage Generator/Bus Relay (Device 27)

The IEEE C37.102 – IEEE Guide for AC Generator Protection does not recommend use of the 27 function for tripping, but only as an alarm that alerts operators to abnormal conditions that require operator intervention. When applied, the suggested model for over/under voltage relay considerations is VTGDCAT/VTGTPAT.

Table 3 includes notes on using the VTG models to simulate over/under voltage relays.

Table 3 - VTGDCAT/VTGTPAT Modeling Considerations
Modelers may use several VTGDCA or VTGGPAT relays to simulate relays that have several operating points e.g. trip-point 1@85% of rated voltage for 100 seconds, trip-point 2@75% of rated voltage for 10 seconds. NERC Standard PRC-024 provides requirements for voltage ride-through time duration.

31.1 VTGDCAT/VTGTPAT

Under/Over Voltage Generator Bus Disconnection Relay

Under/Over Voltage Generator Trip Relay

This model uses CONs starting with	#_______	J,
and VARs starting with	#_______	L,
and ICONs starting with	#_______	M.
and model instance	#_______	MINS (>0)

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)

VAR	#	Description
L		Timer memory

ICONs	#	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) (1)
M+4		Timeout flag (internal ICON) (1)
M+5		Timer status (internal ICON) (1)

(1) User input not required for internal ICONs.

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.

6.5 Reverse Power Relay (Device 32)

The reverse power relay is used to protect the generator from motoring that generally causes serious damage to large steam turbines and is undesired for gas turbine generators as well as inverter based technology.

A reverse power relay model is not available in PSS/E at this time. A user model may be used to represent the reverse power relay until a library model is available.

Table 4 – Reverse Power Relay Modeling Considerations
A user model is used until the reverse power relay library model is available.

6.6 Device 40 – Loss of Excitation Relay

Modelers may choose the Siemens PSS/E LOEXR1T model to represent a generator loss of excitation relay for conventional generators. Inverter based technology such as wind turbines or solar power facilities must use a different model or should ensure that it is considered in the user model for the turbine. Table 5 describes considerations for the LOEXR1T relay model.

Table 5 - LOEXR1T Relay Model Considerations
Usually generator loss of excitation relays have one or two protection zones where zone 1 provides fast tripping if the generator reaches its dynamic stability limit. Zone 2 tripping is initiated if the generator reaches its static stability limit. If zone 3 is not used then the reach can be set to zero to disable the trip circle.

25.1 LOEXR1T

Loss of Excitation Distance Relay

(for use with non-wind machines)

This model is located at bus	#_______	IBUS
Machine	#_______	ID
This model uses CONs starting with	#_______	J,
and VARs starting with	#_______	L,
and ICONs starting with	#_______	M.

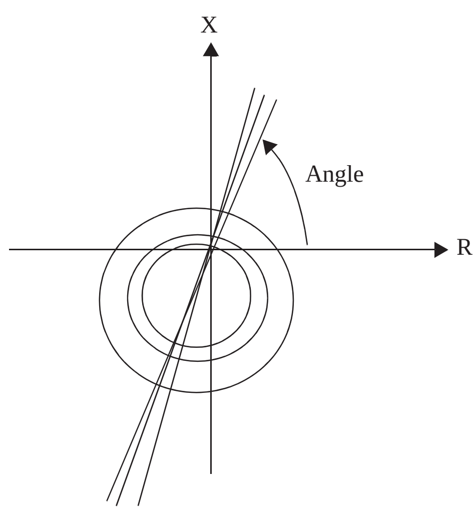
CONs	#	Description
J		T1, zone 1 operating time (cycles)
J+1		R1, zone 1 reach (diameter in pu)
J+2		A1, zone 1 centerline angle (degrees)
J+3		D1, zone 1 center distance (pu)
J+4		T2, zone 2 operating time (cycles)
J+5		R2, zone 2 reach (diameter in pu)
J+6		A2, zone 2 centerline angle (degrees)
J+7		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+3		
L+4		
L+5		

ICONs	#	Value	Description
M . . . M+7			ICONs required for internal logic (internal ICON)(1)

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) /

6.7 Overcurrent Protection (Device 51)

Device51T — Phase fault backup overcurrent, 51TG — Ground fault backup overcurrent, 51V —Voltage controlled or voltage restrained overcurrent may be modeled with the TIOCR1 model representing a time inverse overcurrent relay.

Table 6 – Overcurrent Modeling	

11.9 TIOCR1

Time Inverse Overcurrent Relay

Relay is located from bus	#_______	IBUS,
To bus	#_______	JBUS,
Circuit identifier	#_______	ID,
relay slot (1 or 2)	#_______	RS.
This model uses CONs starting with	#_______	J,
and VARs starting with	#_______	L,
and ICONs starting with	#_______	M.

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	Value	Description
L		Current flow magnitude (pu)
L+1		Relay trip contact position
L+2		Breaker timer memory

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	

IBUS, 'TIOCR1', JBUS, ID, RS, ICON(M) to ICON(M+11), CON(J) to CON(J+13) /

6.8 Device 59 — Overvoltage Relay Modeling

Over voltage relay modeling is performed with the same model as the one used for the undervoltage relay VTGDCA or VTGTPA as described in Section 6.4.

Table 7 – Overvoltage Relay Modeling Considerations
See Section 6.4 and model relay using VTGDCA or VTGTPA

6.9 Out of Step (Device 78)

Generator Out of Step protection may be modeled with the CIROS1 or the SLNOS1 relay models.

11.1 CIROS1

Double Circle or Lens Out-of-Step Tripping or Blocking Relay

Relay is located from bus	#_______	IBUS,
To bus	#_______	JBUS,
Circuit identifier	#_______	ID,
relay slot (1 or 2)	#_______	RS.
This model uses CONs starting with	#_______	J,
and VARs starting with	#_______	L,
and ICONs starting with	#_______	M.

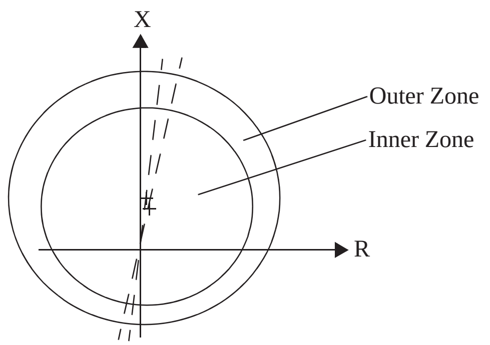
CONs	Value	Description
J		Interzone travel time (cycles)
J+1		Zone 1 (inner zone) diameter (pu)
J+2		Centerline angle (degrees)
J+3		Centerline distance (pu)
J+4		Zone 2 (outer zone) diameter
J+5		Centerline angle (degrees)
J+6		Centerline distance (pu)
J+7		Threshold current (pu)
J+8		Self trip breaker 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	Value	Description
L		Apparent R
L+1		Apparent X
L+2		Current
L+3		VARs required for internal program logic
L+4		
L+5		

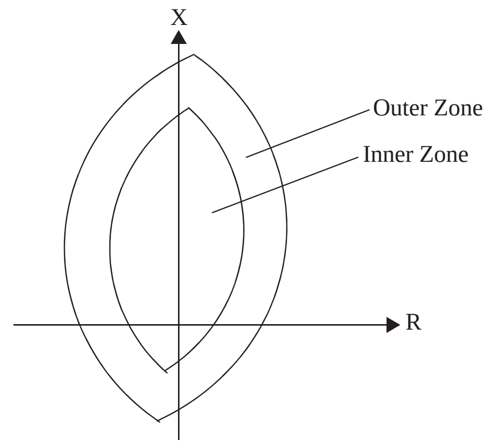
<table>
<tr><th>ICONs</th><th>Value</th><th colspan="2">Description</th></tr>
<tr><td>M</td><td></td><td colspan="2">Type +1 double circle tripping
Type -1 double circle blocking
Type +2 lens type tripping
Type -2 lens type blocking</td></tr>
<tr><td>M+1</td><td></td><td colspan="2">Operation mode:
0 Monitor
1 Monitor and operate</td></tr>
<tr><td>M+2</td><td></td><td>From bus number</td><td rowspan="3">First transfer trip</td></tr>
<tr><td>M+3</td><td></td><td>To bus number</td></tr>
<tr><td>M+4</td><td></td><td>Circuit ID</td></tr>
<tr><td>M+5</td><td></td><td>From bus number</td><td rowspan="3">Second transfer trip</td></tr>
<tr><td>M+6</td><td></td><td>To bus number</td></tr>
<tr><td>M+7</td><td></td><td>Circuit ID</td></tr>
<tr><td>M+8</td><td></td><td>From bus number</td><td rowspan="3">Third transfer trip</td></tr>
<tr><td>M+9</td><td></td><td>To bus number</td></tr>
<tr><td>M+10</td><td></td><td>Circuit ID</td></tr>
<tr><td>M+11</td><td></td><td colspan="2">Supervisory ICON (permissive flag ICON of another model)</td></tr>
<tr><td>M+12</td><td>X</td><td colspan="2">Permissive flag for self trip[1]</td></tr>
<tr><td>M+13</td><td>X</td><td colspan="2">Permissive flag for transfer trip[2]</td></tr>
<tr><td>M+14
.
.
.
M+20</td><td>X</td><td colspan="2">ICONs required for internal program logic</td></tr>
</table>

1 Set to 1 and -1 by supervisory relay to block trip and force trip, respectively.
2 Set to 1 by supervisory relay to block trip.

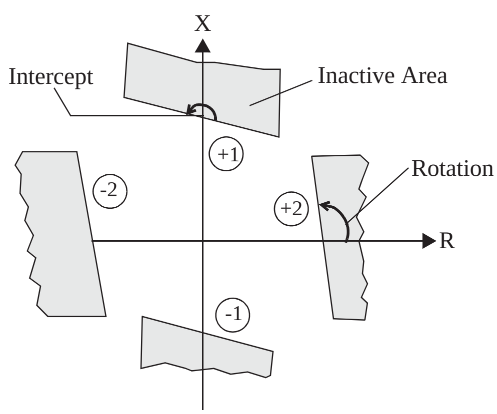
IBUS, ’CIROS1’, JBUS, ID, RS, ICON(M) to ICON(M+11), CON(J) to CON(J+15) /



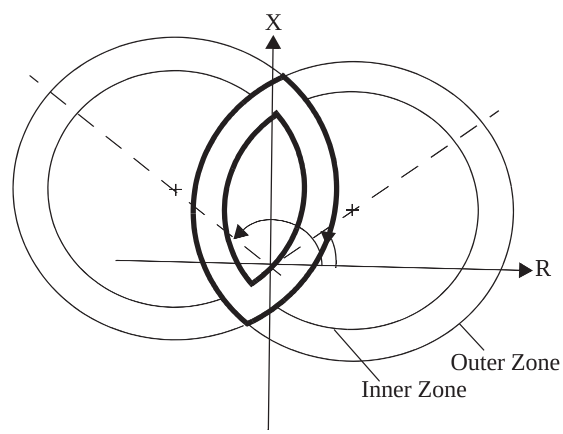
Double Circle



Lens Type



Blinder Types



Specification of Lens

Double Circle or Lens Out-of-Step Tripping or Blocking Relay

11.7 SLNOS1

Straight Line Blinder Out-of-Step Relay

Relay is located from bus	#_______	IBUS,
To bus	#_______	JBUS,
Circuit identifier	#_______	ID,
relay slot (1 or 2)	#_______	RS.
This model uses CONs starting with	#_______	J,
and VARs starting with	#_______	L,
and ICONs starting with	#_______	M.

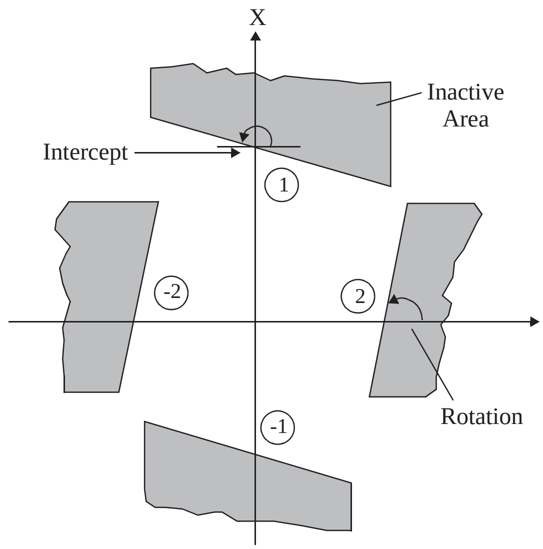
CONs	Value	Description
J		Interzone travel time (cycles)
J+1		Angle of first pair of impedance units (α)
J+2		Intercept of first line
J+3		Intercept of second line
J+4		Angle of second pair of impedance units (β)
J+5		Intercept of third line
J+6		Intercept of fourth line
J+7		Threshold current (pu)
J+8		Self trip breaker time (cycles)
J+9		Transfer trip breaker and delay time (cycles)
J+10		First blinder type ($\pm$1 or $\pm$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	Value	Description
L		Apparent R
L+1		Apparent X
L+2		Current
L+3		VARs required for internal program logic
L+4		
L+5		

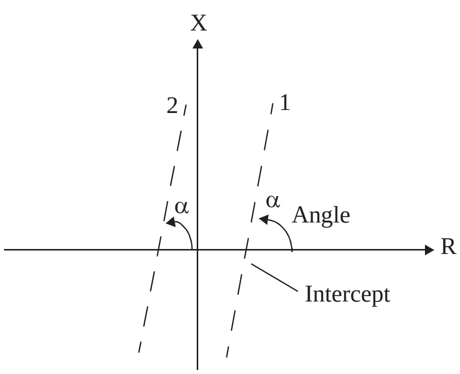
ICONs	Value	Description	
M		Type +1, single blinder tripping Type -1, single blinder blocking Type +2, double blinder tripping Type -2, double blinder blocking	
M+1		Operation mode: 0 Monitor 1 Monitor and operate	
M+2		From bus number	Second transfer trip
M+3		To bus number	
M+4		Circuit ID	
M+5		From 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[1]	
M+13	X	Permissive flag for transfer trip[2]	
M+14 . . . M+21	X	ICONs required for internal program logic	

1 Set to 1 and -1 by supervisory relay to block trip and force trip, respectively.
2 Set to 1 by supervisory relay to block trip.

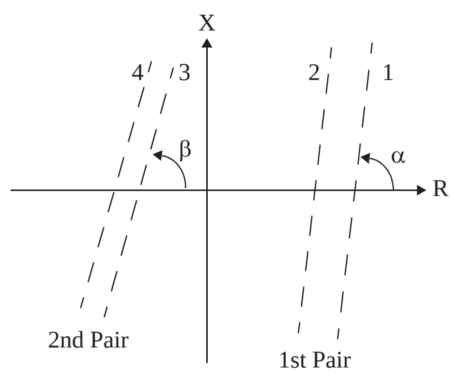
IBUS, ’SLNOS1’, JBUS, ID, RS, ICON(M) to ICON(M+11), CON(J) to CON(J+15) /



Blinder Type Relay Characteristics



Single Blinder



Double Blinder

6.10 Under/Over Frequency Relays (Device 81U/81O)

The Siemens FRQDCA/FRQTPA may be used to model Under/Over Frequency relays. The FRQDCA relay disconnects the generator bus and all other equipment attached to the bus while the FRQTPA model only disconnects the generator from the bus.

Table 9 – Over/Under Frequency Relay Model Considerations
More than one relay may be used to simulate multiple trip settings with differing frequency and time characteristics. For example, a relay with over frequency settings at 62 Hz for 1000 seconds and 64 Hz for 100 seconds can be modeled with two FRQDCA relays. Within the NPCC area, underfrequency relays must be set in accordance with the more stringent requirements of PRC-006-NPCC. For overfrequency relay settings, NERC Standard PRC-024 provides requirements.

31.2 FRQDCAT/FRQTPAT

Under/Over Frequency Generator Bus Disconnection Relay

Under/Over Frequency Generator Trip Relay

This model uses CONs starting with	#_______	J,
and VARs starting with	#_______	L
and ICONs starting with	#_______	M.
and model instance	#_______	MINS (>0)

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)

VAR	#	Description
L		Timer memory

ICONs	#	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) (1)
M+4		Timeout flag (internal ICON) (1)
M+5		Timer status (internal ICON) (1)

(1): 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.

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.

6.11 Excitation Limiter Modeling

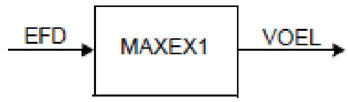
Excitation limiter models may not be compatible with each excitation system model. Modelers should work to ensure that the models provided are compatible. Future PSS/E releases will have more excitation limiter modeling capability. *

*- as an example, the ST6B gates in the underexcitation limiter voltage, however using a limiter model with this exciter model will provide erroneous results in PSS/E version 33.

5.1 MAXEX1

Maximum Excitation Limiter

This model is located at system bus #_______ IBUS,
Machine identifier #_______ ID,
This model uses CONs starting with #_______ J,
and VAR #_______ K,
and ICON #_______ M.

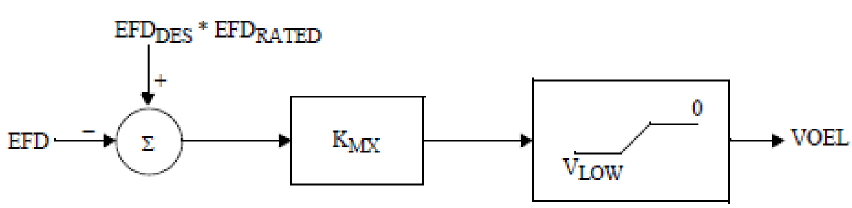


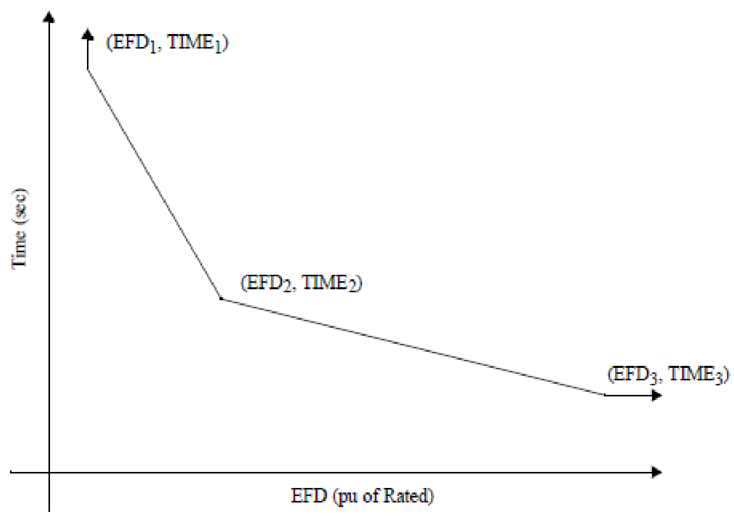
CONs	#	Value	Description
J			EFD_{RATED}
J+1			EFD_1 (pu of rated)
J+2			$TIME_1$
J+3			EFD_2 (pu of rated)
J+4			$TIME_2$
J+5			EFD_3 (pu of rated)
J+6			$TIME_3$
J+7			EFD_{DES} (pu of rated)
J+8			K_{MX}
J+9			V_{LOW}

VAR	#	Description
K		Contact position

ICON	#	Value	Description
M			Status

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

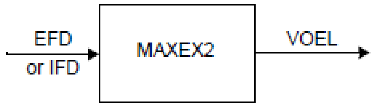



(EFD1, TIME1)
(EFD2, TIME2)
(EFD3, TIME3)
Time (sec)
EFD (pu of Rated)

5.2 MAXEX2

Maximum Excitation Limiter

This model is located at system bus #_______ IBUS,
Machine identifier #_______ ID,
This model uses CONs starting with #_______ J,
and VAR #_______ K,
and STATE #_______ L,
and ICON #_______ M.



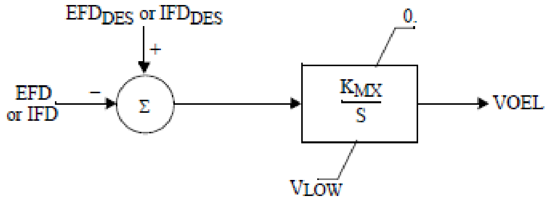
CONs	#	Value	Description
J			EFD_{RATED} or IFD_{RATED}
J+1			EFD_1 or IFD_1 (pu of rated)
J+2			$TIME_1$
J+3			EFD_2 or IFD_2 (pu of rated)
J+4			$TIME_2$
J+5			EFD_3 or IFD_3 (pu of rated)
J+6			$TIME_3$
J+7			EFD_{DES} or IFD_{DES} (pu of rated)
J+8			K_{MX}
J+9			V_{LOW} (< 0)

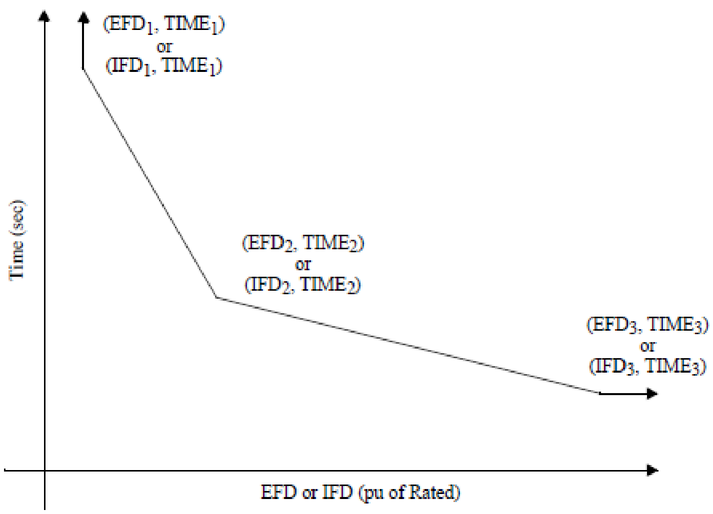
VAR	#	Description
K		Contact position

STATE	#	Description
L		Reset integrator

ICON	#	Value	Description
M			0 for EFD limiting, 1 for IFD limiting

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


EFDDES or IFDDES
+
EFD
or IFD
–
Σ
0.
KMX
S
VOEL
VLOW


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

4.4 UEL1

IEEE 421.5 2005 UEL1 Under-Excitation Limiter

This model is located at system bus	#_______	IBUS,
Machine identifier	#_______	ID,
This model uses CONs starting with	#_______	J,
and STATEs starting with	#_______	K,
and VARs starting with	#_______	L.

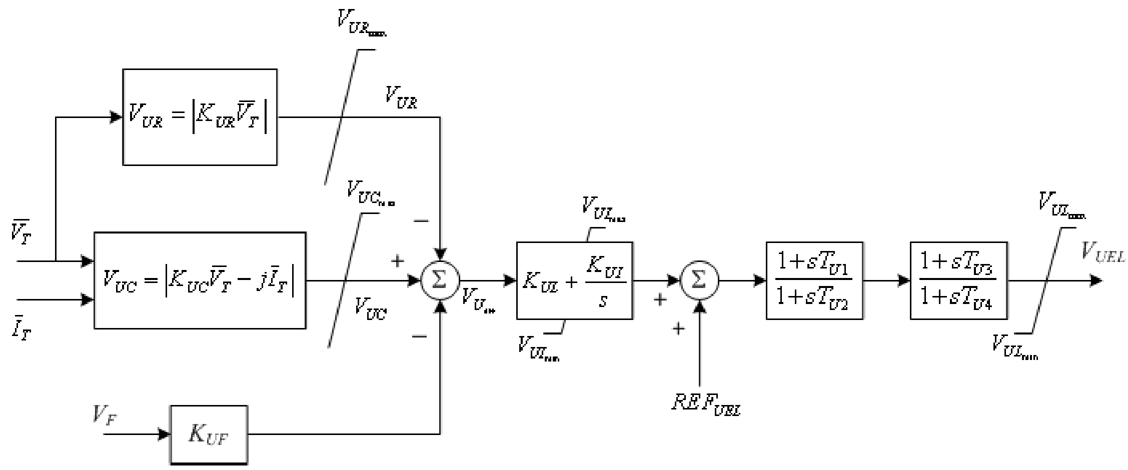
CONs	#	Value	Description
J			K_{UR}, UEL radius setting (pu)
J+1			K_{UC}, (pu) UEL center setting (pu)
J+2			K_{UF}, (pu) UEL excitation system stabilizer gain (pu)
J+3			V_{URMAX}, UEL maximum limit for radius phasor magnitude (pu)
J+4			V_{UCMAX}, UEL maximum limit for operating point phasor magnitude (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)[1]
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)[1]

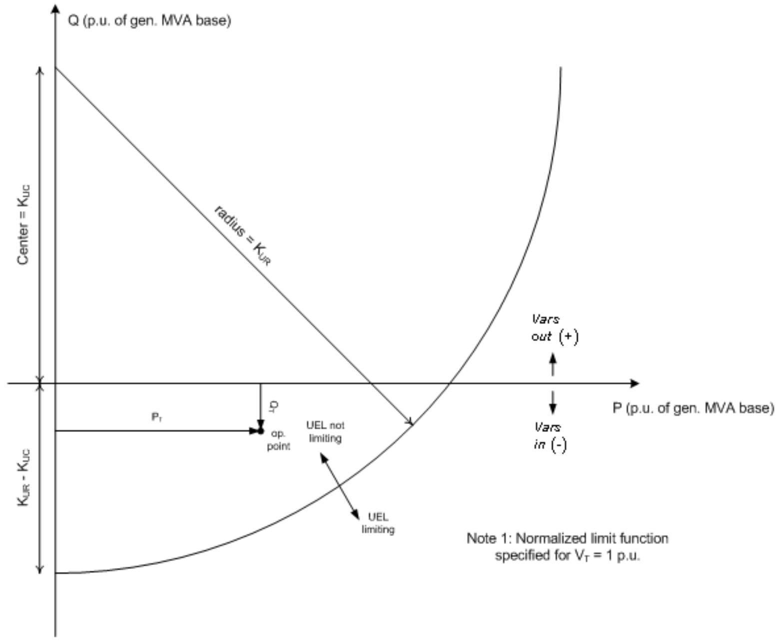
[1] V_{UIMIN} and V_{ULMIN} should be set to 0.0 for excitation systems where V_{UEL} is added to the summing junction of AVR reference, and should be set to a negative number of a relatively large magnitude if V_{UEL} enters the AVR through a HV (high value) gate.

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 = K_{UC}
radius = K_{UR}
Vars out (+)
Vars in (-)
P (p.u. of gen. MVA base)
P_T
Q_T
op. point
UEL not limiting
UEL limiting
K_{UR} - K_{UC}
Note 1: Normalized limit function specified for V_T = 1 p.u.

4.5 UEL2

IEEE 421.5 2005 UEL2 Minimum Excitation Limiter

This model is located at system bus #_______ IBUS,
Machine identifier #_______ ID.
This model uses CONs starting with #_______ J,
and STATEs starting with #_______ K,
and VARs starting with #_______ L,
and ICONs starting with #_______ M.

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)[1]
J+15			Q_0 (pu on gen. MVA base)[1]
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			Q3 (pu on gen. MVA base)
J+22			P_4 (pu on gen. MVA base)

CONs	#	Value	Description
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)
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[2]
J+37			V_{ULMIN} (pu) UEL output minimum limit[1]

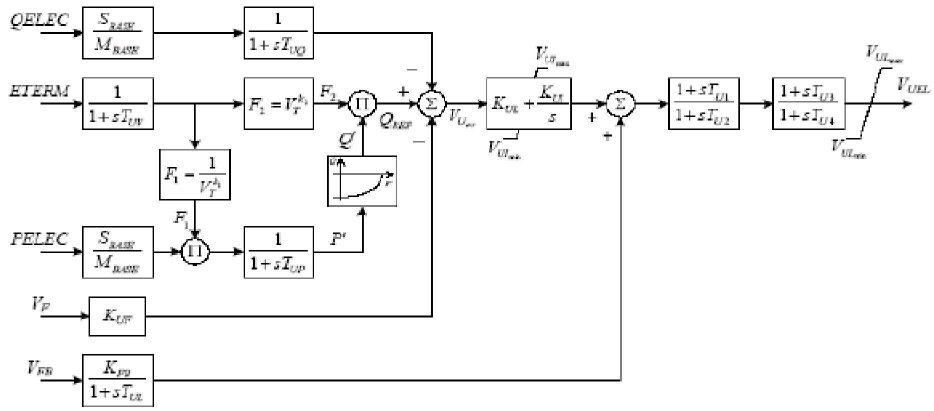
1 A maximum if 10 pairs may be specified. The unused pairs should be entered as zero.
2 V_{UIMIN} and V_{ULMIN} should be set to 0.0 for excitation systems where V_{UEL} is added to the reference.

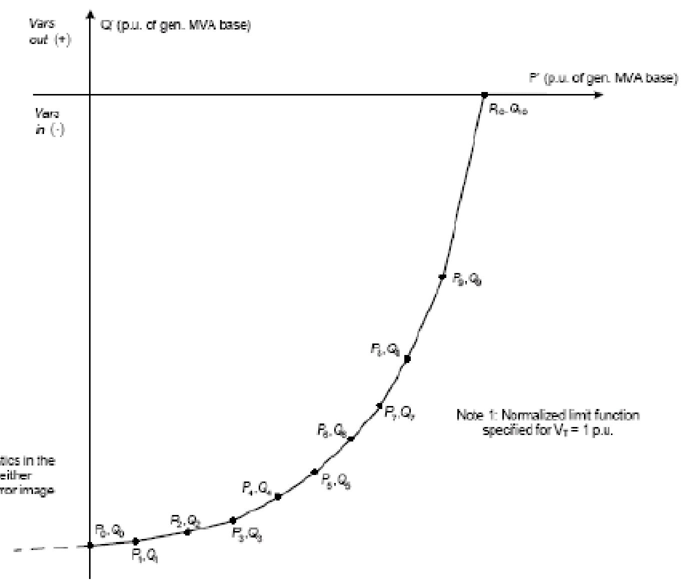
STATEs	#	Description
K		Voltage filter output
K+1		Real power filter output
K+2		Reactive power filter output
K+3		Integrator
K+4		Reference feedback block
K+5		First lead-lag
K+6		Second lead-lag

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

ICON	#	Value	Description
M			k_1, exponent in function F_1
M+1			k_2, exponent in function F_2
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

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

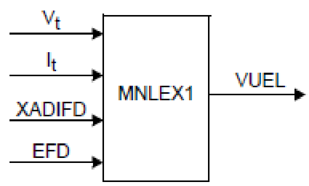

QELEC
ETERM
PELEC
V_F
V_{FB}
$\frac{S_{BASE}}{M_{BASE}}$
$\frac{1}{1+sT_{UQ}}$
$\frac{1}{1+sT_{UV}}$
$F_2 = V_T^{k_2}$
$F_1 = \frac{1}{V_T^{k_1}}$
$\frac{1}{1+sT_{UP}}$
K_{UF}
$\frac{K_{FB}}{1+sT_{UL}}$
Q_{REF}
$K_{UL} + \frac{K_{UI}}{s}$
$\frac{1+sT_{U1}}{1+sT_{U2}}$
$\frac{1+sT_{U3}}{1+sT_{U4}}$
V_{UEL}


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

4.1 MNLEX1

Minimum Excitation Limiter

This model is located at system bus #_______ IBUS,
Machine identifier #_______ ID,
This model uses CONs starting with #_______ J,
and STATEs starting with #_______ K,
and VAR #_______ L.

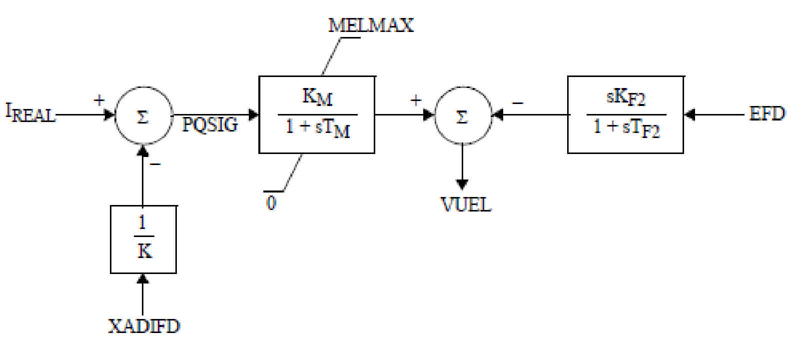


CONs	#	Value	Description
J			K_{F2}
J+1			$T_{F2} > 0$ (sec)
J+2			K_M, MEL gain
J+3			T_M, MEL time constant (sec)
J+4			MELMAX
J+5			K, MEL slope (>0)

STATEs	#	Description
K		MEL feedback integrator
K+1		MEL

VAR	#	Description
L		PQSIG

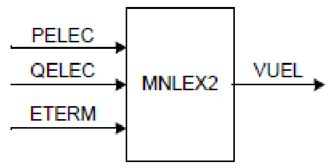
IBUS, 'MNLEX1', ID, CON(J) to CON(J+5) /



4.2 MNLEX2

Minimum Excitation Limiter

This model is located at system bus #_______ IBUS,
Machine identifier #_______ ID,
This model uses CONs starting with #_______ J,
and STATEs starting with #_______ K,
and VAR #_______ L.



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

VAR	#	Description
L		PQSIG

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