Documentation

Description of model for

SMA Sunny Central Storage

inverter in grid forming mode for power flow and stability studies in PSS®E

Please consider the environment before you print this document

Document Revision 4
Sept 7, 2023

Note

The following PSS®E versions are currently supported:

- version 32 compiled with Intel Visual Fortran Compiler Revision 11.1,
- version 33 compiled with Intel Visual Fortran Compiler Revision 11.1,
- versions 34.2 and 34.4 compiled with Intel Visual Fortran Compiler Revisions 11.1 and 15.0 (x86).
- versions 35.5 compiled with Intel Visual Fortran Compiler Revisions 15.0 (x86).

Please contact SMA if models for other simulation platforms are required. Currently, SMA supports

- DIgSILENT PowerFactory (rms models)
- Siemens Power Technologies International PSS®E (rms models)
- General Electric International PSLF (rms models)
- Manitoba Hydro International Ltd. PSCAD® (instantaneous value models)
- ATP-EMTP (instantaneous value models)
- EMTP-RV (instantaneous value models)
- The Mathworks Matlab/Simulink® (rms and instantaneous value models, SMA internal only)

SMA model support

In case you require support from SMA Solar Technology AG regarding questions of model handling, model parameterization, or interpretation of simulation results, please send all relevant files to SMA including:

- The models you were using, or a reference to the model versions,
- the network in *.raw or *.sav format,
- the dyr file,
- simulation scripts in *.idv or *.py (Python) format that exactly replicate the relevant scenario,
- information on the PSS/E version.

Model history

Model version	Author	Description
1.04	Oliver Glitza	First release of SMA SC grid forming model; this version represents SMA SC SW Release 8
2.06	Oliver Glitza	First release of SMA SC grid forming model representing SMA SC SW Release 9
2.07	Oliver Glitza	Allows initialization with negative active power
2.08	Rahul Bhatia	1. BugFix: Writing of initial P & Q values to Hycon VARs 2. Shifting of Subroutines and Functions to CONTAINS 3. Using For loop for reading the plant controller VAR index
3.00	Rahul Bhatia	New release of SMA SC grid forming model; this version represents SMA SC SW Release 9. This is the second generation of the Grid forming model in PSS/E.
3.01	Rahul Bhatia	BugFix: Protection Settings not working BugFix: ICON(M+2) with CHRCIN not working with v33
3.02	Rahul Bhatia	1.BugFix: Filt1.ABControlDFilTm & ABControlQFilTm not initialized correctly 2. Spike Mitigation Algorithm Implementation 3. Hardware current limitation of StkAmpLimon
3.03	Rahul Bhatia	1.Introduced CON – Rtg.VarRtg to have adjustable reactive power rating 2.Introduced CON – Filt.AvalPwrFilTm as a filter for available power (active and reactive) 3. Communication of available active power to Hycon model.

Model validity

The inverter model "SMAGF" described in this document is mainly intended for simulation of the SMA Sunny Central inverters in grid forming mode.

Contents

1 Power flow model

An equivalence power plant utilizing SMA Sunny Central inverters may be modeled for power flow purposes as a generator connected to a P/V[1] bus (PSS®E type 2) with the appropriate nominal voltage. The

- aggregate MVA of the plant (`MBASE`),
- maximum active power (`PT`) and
- reactive power limits (`QT` and `QB`)

must be specified as integral multiple of the individual inverter unit ratings. However, the active power dispatch for the power flow simulation may be anywhere in the range of zero to (aggregate) `PT`.

[1] The symbol *U* or *u* is used for voltage throughout the document.

1.1 Generator data in PSS®E

Figure 1 shows a typical data mask for the machine entry in the PSS®E load flow program. It is important that the "R Source" and "X Source" values are parameterized as given by Table 1.

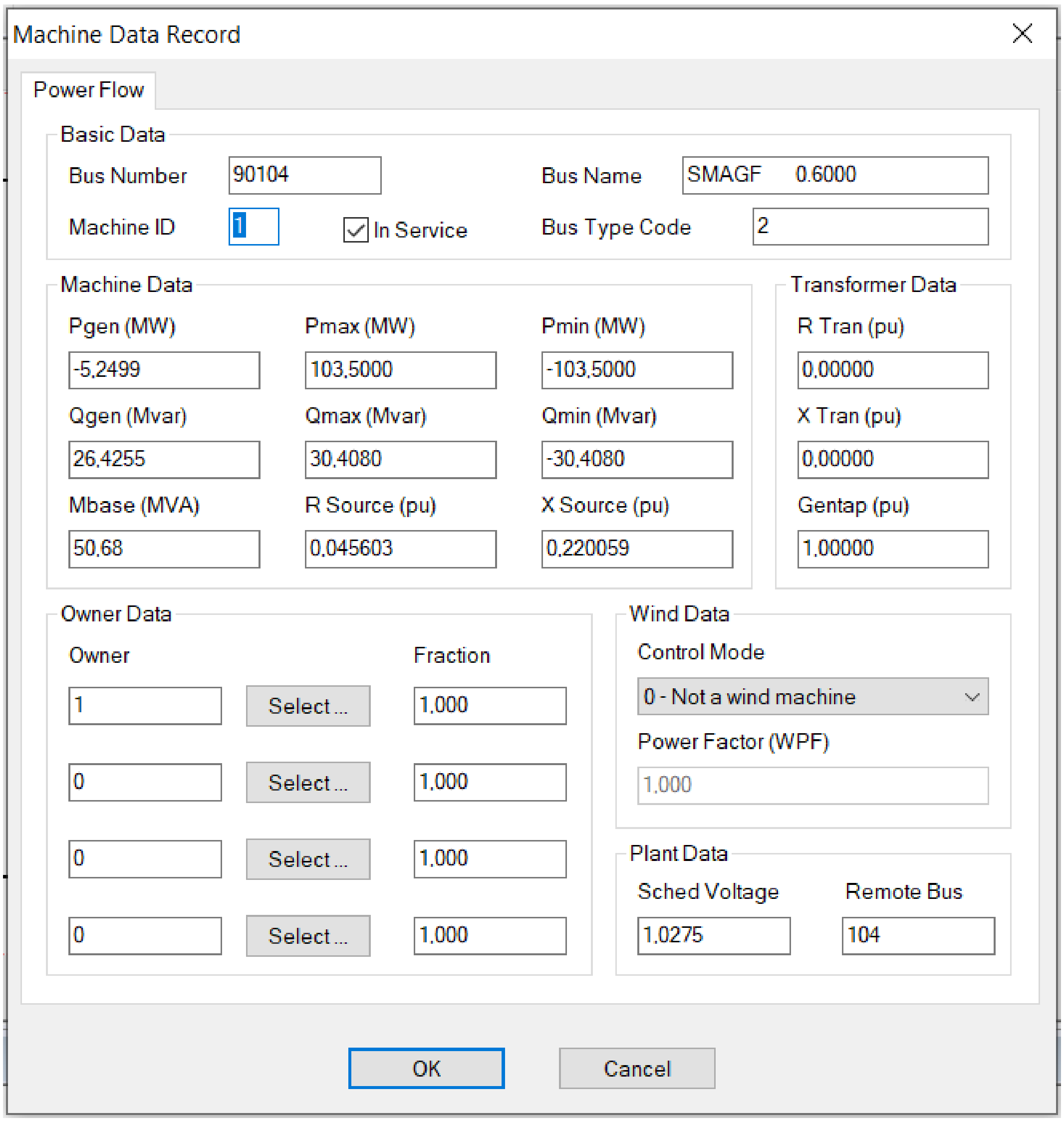

Figure 1: Typical data mask for machine entry in the PSS®E load flow program.

Furthermore, it is very important that the active power (Pgen), the reactive power (Qgen) and MBASE always satisfy the equation

$Pgen^2 + Qgen^2 <= MBASE^2$.

Otherwise, the model will not initialize correctly.

2 Dynamic model

The plant dynamic model has been implemented as a PSS®E user model called "SMAGFxxx", making use of PSS®E's "coordinated call model" technique.

2.1 Initialization

SMAGF initializes the active power dispatch from the steady-state solution and adjusts all internal variables and states accordingly.

Care must be taken that the reactive power limits of the inverter are not hit at initialization.

2.2 Machine array variables

Machine array variables are assigned as follows:

`ETERM(I)`	Measured Bus Voltage magnitude in p.u.
`PELEC(I)`	Measured Active power in p.u.
`QELEC(I)`	Measured Reactive power in p.u.
`VOTHSG(I)`	Measured Bus Frequency (Hz)
`ANGLE(I)`	Measured Bus angle
`ECOMP(I)`	Real component of current in p.u.
`VUEL(I)`	Imaginary component of current in p.u.
`EFD(I)`	Desired reactive power in p.u. (from plant control model)
`XADIFD(I)`	Desired active power in p.u. (from plant control model)

2.3 Dyr file entry

The model's dyr file entry is as follows:

```
BusNum 'USRMDL' 1 'SMAGF303' 1 1 3 174 0 221 ICON(M) ICON(M+1)
ICON(M+2) CON(J) CON(J+1) ... CON(J+173)
```

2.4 Model parameters

In this section there is given a standard parameterization only.

Table 1 provides a guidance on how ICON(M+2) should be set up based on the Inverter Type. It also provides the value of "R Source" and "X Source" values 1 p.u. for different inverter types as well as based on the Grid frequency

Table 1: Model Setup based on Inverter Type

Inverter Type	Rated apparent power (MVA)	Nominal Voltage Line-Line (kV)	ICON(M+2) InvType	Gen. Impedance R + jX p.u. (50Hz)	Gen.Impedance R + jX p.u. (60Hz)
SCS1900	1,900	0,337	1900	0.0502 + j0.2523	0.0502 + j0.3027
SCS2200	2,200	0,385	2200	0.0445 + j0.2238	0.0445 + j0.2686
SCS2475	2,475	0,434	2475	0.0394 + j0.1981	0.0394 + j0.2378
SCS2900	2,940	0,520	2940	0.0326 + j0.164	0.0326 + j0.1967
SCS2300UPXT	2,667	0,600	2667	0.0348 + j0.2185	0.0348 + j0.2622
SCS2400UPXT	2,800	0,630	2800	0.0331 + j0.2081	0.0331 + j0.2497
SCS2530UPXT	2,933	0,660	2933	0.0316 + j0.1986	0.0316 + j0.2383
SCS2630UPXT	3,067	0,690	3067	0.0302 + j0.19	0.0302 + j0.228
SCS3450UP	3,450	0,600	3450	0.0343 + j0.1854	0.0343 + j0.2225
SCS3600UP	3,620	0,630	3620	0.0326 + j0.1765	0.0326 + j0.2118
SCS3800UP	3,800	0,660	3800	0.0312 + j0.1688	0.0312 + j0.2026
SCS3950UP	3,960	0,690	3960	0.0297 + j0.1609	0.0297 + j0.1931
SCS3450UPXT	4,000	0,600	4000	0.0397 + j0.215	0.0397 + j0.258
SCS3600UPXT	4,200	0,630	4200	0.0378 + j0.2048	0.0378 + j0.2457
SCS3800UPXT	4,400	0,660	4400	0.0361 + j0.1954	0.0361 + j0.2345
SCS3950UPXT	4,600	0,690	4600	0.0345 + j0.1869	0.0345 + j0.2243

- Please set the ICON(M+2) and generator impedance in the load flow model based on the inverter used for the project

2.4.1 ICONs

Table 2: List of ICONs

ICON	Parameter	Description	Range	Default
M	PlntCtlType	1 = HyCon, 0 = no plant control **(PSS/E Specific)**	n/a	1
M+1	PlntCtlBus	Number of plant controller bus **(PSS/E Specific)**	n/a	n/a
M+2	InvType	InvType used. Refer Table 1 – Similar to Inverter Type selection in mask of inverter model block in PSCAD	n/a	4600

2.4.2 CONs

Table 3: List of CONs

CON	Parameter	Description	Range min-max	Default
J+0	Rtg.VarRtg	Reactive power rating in kVar can be set using this parameter. If set to 0.0, then rated reactive power as per Inverter type (ICON(M+2)) will be used	n/a	0.0
J+1	Rtg.VADrtPriMod	Prioritizing of control in case of derating 0: Q Priority, 1: P Priority	0 or 1	1
J+2	Filt.VolDQFilTm	DQ Voltage, filter time constant in s	3*timestep - n/a	0.46
J+3	Filt.AmpDQFilTm	DQ current, filter time constant in s	3*timestep - n/a	0.01
J+4	Filt.VolPsFilTm	Voltage filter time constant for conversion VA to Amp in s	3*timestep - n/a	0.005
J+5	Filt.ABControlDFilTm	Filter time constant for D-axis voltage for AB Control in s **(PSS/E Specific)**	3*timestep - n/a	0.01
J+6	Filt.ABControlQFilTm	Filter time constant for Q-axis voltage for AB Control in s **(PSS/E Specific)**	3*timestep - n/a	0.01
J+7	Filt.AvalPwrFilTm	Filter time constant for calculated available active and reactive power in s	3*timestep - n/a	0.1
J+8	AcCtl.WSptScal	AC current control, active power setpoint scaling factor	1 - n/a	1
J+9	AcCtl.VArSptScal	AC current control, reactive power setpoint scaling factor	1 - n/a	1
J+10	AcCtl.DrpHz	Active power frequency droop	n/a	-1
J+11	AcCtl.DrpVol	Reactive power voltage droop	n/a	0.03
J+12	AcCtl.DrpVolH	Inertia: Voltage magnitude inertia constant H_vol = 0.5 * (dQ/Snom) / (RoCoV/Vnom)	n/a	1.5
J+13	AcCtl.DrpVolDmp	Inertia: Reactive load imbalance feedfor-ward gain of voltage magnitude inertia control	n/a	0.0
J+14	AcCtl.DrpTheta	Factor angle pre-control	n/a	-0.12
J+15	AcCtl.DrpThetaH	Inertia: Voltage angle inertia constant H_theta = 0.5 * (dP/Snom) / (RoCoF/Fnom)	n/a	2.5
J+16	AcCtl.DrpThetaDmp	Inertia: Active load imbalance feedforward gain of voltage angle inertia control	n/a	0.0

J+17	AcCtl.DrpThetaFilTm	AC current control, Time constant of low pass filter for bandwidth limitation of phase feed forward damping	3*timestep - n/a or 0	0.0
J+18	AcCtl.DrpAmpD	Inertia: Frequency feedback gain of voltage angle inertia control	n/a	0.0
J+19	AcCtl.DrpAmpDFilTm	Inertia: Frequency feedback time constant of voltage angle inertia control	3*timestep - n/a or 0	0.0
J+20	AcCtl.DrpAmpDFil2Tm	Inertia: Frequency feedback time constant of voltage angle inertia control	3*timestep - n/a or 0	0.0
J+21	AcCtl.DrpAmpQ	Inertia: Voltage feedback gain of voltage magnitude inertia control	n/a	0.0
J+22	AcCtl.DrpAmpQFilTm	Inertia: Voltage feedback time constant of voltage magnitude inertia control	3*timestep - n/a or 0	0.0
J+23	AcCtl.DrpAmpQFil2Tm	Inertia: Voltage feedback time constant of voltage magnitude inertia control	3*timestep - n/a or 0	0.0
J+24	AcCtl.AmpDLimKp	AC current control, proportional amplification for active current limit	n/a	0.6
J+25	AcCtl.AmpDLimKi	AC current control, integral amplification for active current limit	n/a	22.5
J+26	AcCtl.AmpPsDLim_Ki2Fac	AC current control, double integral amplification for active current limit	n/a	0.00033333
J+27	AcCtl.AmpPsDLim_I2RocofLim	AC and DC limit control, minimum/maximum range control signal	n/a	6.0
J+28	AcCtl.AmpPsDLim_I2CtlDownGain	AC current control, additional double integral amplification, if active current limit is not exceeded	n/a	3.0
J+29	AcCtl.AmpQLimKp	AC current control, proportional amplification for reactive current limit	n/a	2.4
J+30	AcCtl.AmpQLimKi	AC current control, integral amplification for reactive current limit	n/a	90.0
J+31	AcCtl.AmpPsQLim_Ki2Fac	AC current control, double integral amplification for reactive current limit	n/a	0.00033333
J+32	AcCtl.AmpPsQLim_I2RocofLim	AC current control, minimum/maximum range control signal	n/a	6.0
J+33	AcCtl.AmpPsQLim_I2CtlDownGain	AC current control, additional double integral amplification, if reactive current limit is not exceeded	n/a	3.0
J+34	AcCtl.InertiaThetaMod	Inertia: Activation of voltage angle inertia	0 or 1	0
J+35	AcCtl.InertiaVolMod	Inertia: Activation of voltage magnitude inertia	0 or 1	0

J+36	AcCtl.InertiaThetaW-CtlEna	Inertia: Enable active power inertia control	0 to 1	0
J+37	AcCtl.InertiaThetaWCt-lVolLim	Voltage limit for power regulation in phase inertia	n/a	0.5
J+38	AcCtl.InertiaVol-VArCtlEna	Inertia: Enable reactive power inertia con-trol	0 or 1	0
J+39	AcCtl.InertiaVolVArCtlV-olLim	Voltage limit for power regulation in the voltage inertia	0 to 1	0.5
J+40	AcCtl.AmpPsDFbEna	Inertia: Activation of inner active current feedback of voltage angle inertia control	0 or 1	1
J+41	AcCtl.AmpPsQFbEna	Inertia: Activation of inner reactive current feedback of voltage magnitude inertia con-trol	0 or 1	1
J+42	Ac-Ctl.AmpDLim_VolPsNomLim	AC current control, active current limiation, voltage limit for accurate active power limi-tation	0 to 1	1
J+43	Ac-Ctl.AmpQLim_VolPsNomLim	AC current control, reactive current limi-ation, voltage limit for accurate reactive power limitation	0 to 1	1
J+44	AcCtl.AmpDQLimEna	AC current control, limiting controller acti-vation	0 or 1	0
J+45	AcCtl.PriModPsRelEna	AC current control, Prioritization mode - positive sequence relative - for current limi-tation, activation	0 or 1	0
J+46	AcCtl.VolABKi	AC voltage control integral gain	n/a	120
J+47	AcCtl.VolABKp	AC voltage control Proportional gain **(PSS/E Specific)**	n/a	0.01
J+48	AcCtl.AmpDQFilTm	AC current control, DQ current filter time constant	3*timestep - n/a or 0	0.02
J+49	AcCtl.ParamFilTm	Inertia: Low pass filter time constant for smooth inertia parameter change	3*timestep - n/a or 0	10.0
J+50	Frt.Frt_Mod	Grid forming FRT: Mode	0, 1, 2	2
J+51	Frt.LoVolOnLim	Grid forming FRT: Lower voltage limit for entering FRT Mode **(PSS/E Specific)**	0 to 1	0.8
J+52	Frt.LoVolOffLim	Grid forming FRT: Lower voltage limit for return to normal mode	0 to 1	0.9
J+53	Frt.HiVolOffLim	Grid forming FRT: Upper voltage limit for return to normal mode	1 to 2	1.1
J+54	Frt.DynVolOffLimEna	Grid forming FRT: Activation of dynamic offset voltage limits for return to normal mode	0 or 1	0

J+55	Frt.VirtImpSwDetLim	Grid forming FRT: Current treshold for activation of virtual impdedance	1 to 2	1.4
J+56	Frt.VirtImpDlTm	Grid forming FRT: Delay time for activation of virtual impedance	n/a	4
J+57	Frt.VirtImpLockTm	Grid forming FRT: Minimum duration time of virtual impedance	n/a	100
J+58	Frt.VirtImpWaitTm	Grid forming FRT: Minimum duration time for reactivation of virtual impedance	n/a	200
J+59	Frt.ResetTm	Time to jump back to initial state in FRT-Detection-Statemachine	n/a	30
J+60	Frt.AmpCtlEna	Grid forming FRT: Activation of adaptive current control	0 or 1	1
J+61	Frt.AMaxNomInit	Grid forming FRT: Init value of maximum short circuit current in the virtual impedance	n/a	1.1
J+62	Frt.AMaxNom	Grid forming FRT: maximum short circuit current	n/a	1.1
J+63	Frt.AmpCtlFilTm	Grid forming FRT: Adaptive current control, filter time constant	3*timestep - n/a or 0	0.007
J+64	Frt.CtlDevLimMax	Grid forming FRT: Adaptive apparent current control, maximum control deviation	n/a	0.5
J+65	Frt.NegCtlDev_Gain	Amplification or reduction of the negative control deviation of the VI controller	n/a	1
J+66	Frt.AmpCtlKp	Grid forming FRT: Adaptive current control, proportional gain	n/a	0.0
J+67	Frt.AmpCtlKi	Grid forming FRT: Adaptive current control, integral gain	n/a	10.0
J+68	Frt.VirtImpReact	Grid forming FRT: Virtual impedance, reactance	n/a	0.0
J+69	Frt.VirtImpReactMin	Grid forming FRT: Virtual impedance, minimum reactance	n/a	0.0
J+70	Frt.VirtImpReactFFWEna	Activation of the pre-control of the virtual reactance of the difference	0 or 1	1
J+71	Frt.VirtImpReactFFWFac	Grid forming FRT: Virtual impedance, factor of feedforward of virtual reactance	n/a	0.68
J+72	Frt.VirtImpRis	Grid forming FRT: Virtual impedance, resistance	n/a	0
J+73	Frt.VirtImpRisInit	Grid forming FRT: Virtual impedance, resistance, init Value	n/a	0.3
J+74	Frt.AmpCtlPsQSpt	Maximum reactive current during virtual impedance	n/a	-1
J+75	Frt.AmpCtlRKp	Controller parameter Kp for virtual resistor	n/a	0

J+76	Frt.AmpCtlRKi	Controller parameter Ki for virtual resistor	n/a	0
J+77	Frt.VirtImpRisFilTm	Grid forming FRT: Virtual impedance, time constant for decaying resistance	3*timestep - n/a	0.008
J+78	Frt.VolPsQFilTm	Grid forming FRT: VolPsQ control during virtual impedance, filter time constant of VolPsQ voltage	3*timestep - n/a	0.002
J+79	Frt.VolPsQCtlKp	Grid forming FRT: VolPsQ control during virtual impedance, proportional gain	n/a	-1.4
J+80	Frt.VolPsQCtlDZn	Grid forming FRT: VolPsQ Control during virtual impedance, limit of proportional zone gain	n/a	0.25
J+81	Frt.VolPsQCtlDZnKp	Grid forming FRT: VolPsQ Control during virtual impedance, proportional zone gain	n/a	0.0
J+82	Frt.VolPsQCtlHzOfsMax	Grid forming FRT: VolPsQ control during virtual impedance, maximum actuating variable in Hz	n/a	1.0
J+83	Frt.VolPsQCtrlEna	Value of the VolPsQ P controller	0 or1	0
J+84	Frt.DrpPreFreezeDetLim	Software threshold for the temporary freezing of the Droops	n/a	1.1
J+85	OvAmp.AmpMaxNomSecFilTm	Overcurrent: Filter time constant of overcurrent factors	n/a	0.02
J+86	OvAmp.AmpMaxNomSec0Tm	Overcurrent: Duration in milliseconds for sector 0	n/a	76000
J+87	OvAmp.AmpMaxNomSec1Tm	Overcurrent: Duration in milliseconds for sector 1	n/a	100
J+88	OvAmp.AmpMaxNomSec2Tm	Overcurrent: Duration in milliseconds for sector 2	n/a	900
J+89	OvAmp.AmpMaxNomSec3Tm	Overcurrent: Duration in milliseconds for sector 3	n/a	4000
J+90	OvAmp.AmpMaxNomSec4Tm	Overcurrent: Duration in milliseconds for sector 4	n/a	9000
J+91	OvAmp.AmpMaxNomSec4TransTm	Overcurrent: Duration in milliseconds for sector 4 in transition mode	n/a	13900
J+92	OvAmp.AmpMaxNomSec4ThmDrtTm	Intermediate time within the fourth and last sector in the virtual impedance in milliseconds	n/a	2000
J+93	OvAmp.AmpMaxNomSec0	Overcurrent: Nominal current factor for maximum apparent current in sector 0	n/a	1
J+94	OvAmp.AmpMaxNomSec1	Overcurrent: Nominal current factor for maximum apparent current in sector 1	n/a	1.57
J+95	OvAmp.AmpMaxNomSec2	Overcurrent: Nominal current factor for maximum apparent current in sector 2	n/a	1.25

J+96	OvAmp.AmpMaxNomSec3	Overcurrent: Nominal current factor for maximum apparent current in sector 3	n/a	1.16
J+97	OvAmp.AmpMaxNomSec4	Overcurrent: Nominal current factor for maximum apparent current in sector 4	n/a	0.95
J+98	OvAmp.AmpMaxNomSec3Obs	Overcurrent: Nominal current factor for current observation to move in sector 3	n/a	1.0
J+99	OvAmp.AmpMaxNomSec4Obs	Overcurrent: Nominal current factor for current observation to move in sector 4	n/a	1.0
J+100	OvAmp.AmpMaxNomSec4ObsHys	Overcurrent: Nominal current factor for current Hysteresis observation to move in sector 4	n/a	0.03
J+101	OvAmp.AmpPsDMaxNomSec0	Overcurrent: Nominal current factor for maximum active current in sector 0	n/a	1
J+102	OvAmp.AmpPsDMaxNomSec1	Overcurrent: Nominal current factor for maximum active current in sector 1	n/a	1.57
J+103	OvAmp.AmpPsDMaxNomSec2	Overcurrent: Nominal current factor for maximum active current in sector 2	n/a	1.25
J+104	OvAmp.AmpPsDMaxNomSec3	Overcurrent: Nominal current factor for maximum active current in sector 3	n/a	1.16
J+105	OvAmp.AmpPsQMaxNomSec0	Overcurrent: Nominal current factor for maximum reactive current in sector 0	n/a	1.0
J+106	OvAmp.AmpPsQMaxNomSec1	Overcurrent: Nominal current factor for maximum reactive current in sector 1	n/a	1.57
J+107	OvAmp.AmpPsQMaxNomSec2	Overcurrent: Nominal current factor for maximum reactive current in sector 2	n/a	1.25
J+108	OvAmp.AmpPsQMaxNomSec3	Overcurrent: Nominal current factor for maximum reactive current in sector 3	n/a	1.16
J+109	OvAmp.VirtImpEna	Overcurrent: Activation of overcurrent for virtual impedance	0 or 1	0
J+110	OvAmp.AcCtlEna	Overcurrent: Activation of overcurrent for grid forming	0 or 1	0
J+111	OvAmp.AmpMaxNomInit	Overcurrent: Init value of nominal current factor for maximum apparent current in the virtual impedance	n/a	1.57
J+112	OvAmp.TmpStkFilTm	Time constant of the low-pass filtering of the stack temperature	3*timestep - n/a or 0	0.5
J+113	OvAmp.TmpLimNormal	Overcurrent: Temperature limit for normal mode	n/a	142
J+114	OvAmp.TmpLimTrans	Overcurrent: Temperature limit for transition mode	n/a	147

J+115	OvAmp.NormalModHysTm	Overcurrent: Duration of hysteresis to move from normal mode to emergency mode	n/a	1000
J+116	OvAmp.TransModHysTm	Time hysteresis in milliseconds for switching between emergency and transition mode	n/a	150
J+117	OvAmp.ChangeModHysTm	Time hysteresis in milliseconds for switching between modes	n/a	125
J+118	OvAmp.StkAmpLimOn	Overcurrent: Hardware current limit at which the FPGA activates the FRT	n/a	3000
J+119	Ctl.HzOutLim	AC and DC limit control, minimum/maximum range control signal [Hz]	n/a	5.0
J+120	HW.OvAmpLimEna	Hardware current limit: Activation of overcurrent hardware current limits	0 or 1	0
J+121	HW.StkAmpLimOnFac	Calibration Factor for HW_StkAmpLimOn **(PSS/E Specific)**	n/a	10
J+122	HzCtl.Hi1Lim	Monitoring the power frequency: upper switch-off limit 1	n/a	51
J+123	HzCtl.Hi1LimTm	Monitoring the power frequency: waiting time upper switch-off limit 1	n/a	1000
J+124	HzCtl.Hi2Lim	Monitoring the power frequency: upper switch-off limit 2	n/a	55
J+125	HzCtl.Hi2LimTm	Monitoring the power frequency: waiting time upper switch-off limit 2	n/a	10000
J+126	HzCtl.Hi3Lim	Monitoring the power frequency: upper switch-off limit 3	n/a	55
J+127	HzCtl.Hi3LimTm	Monitoring the power frequency: waiting time upper switch-off limit 3	n/a	10000
J+128	HzCtl.Hi4Lim	Monitoring the power frequency: upper switch-off limit 4	n/a	55
J+129	HzCtl.Hi4LimTm	Monitoring the power frequency: waiting time upper switch-off limit 4	n/a	10000
J+130	HzCtl.Hi5Lim	Monitoring the power frequency: upper switch-off limit 5	n/a	55
J+131	HzCtl.Hi5LimTm	Monitoring the power frequency: waiting time upper switch-off limit 5	n/a	10000
J+132	HzCtl.Hi6Lim	Monitoring the power frequency: upper switch-off limit 6	n/a	55
J+133	HzCtl.Hi6LimTm	Monitoring the power frequency: waiting time upper switch-off limit 6	n/a	10000
J+134	HzCtl.Lo1Lim	Monitoring the power frequency: lower switch-off limit 1	n/a	49

J+135	HzCtl.Lo1LimTm	Monitoring the power frequency: waiting time lower switch-off limit 1	n/a	1000
J+136	HzCtl.Lo2Lim	Monitoring the power frequency: lower switch-off limit 2	n/a	45
J+137	HzCtl.Lo2LimTm	Monitoring the power frequency: waiting time lower switch-off limit 2	n/a	10000
J+138	HzCtl.Lo3Lim	Monitoring the power frequency: lower switch-off limit 3	n/a	45
J+139	HzCtl.Lo3LimTm	Monitoring the power frequency: waiting time lower switch-off limit 3	n/a	10000
J+140	HzCtl.Lo4Lim	Monitoring the power frequency: lower switch-off limit 4	n/a	45
J+141	HzCtl.Lo4LimTm	Monitoring the power frequency: waiting time lower switch-off limit 4	n/a	10000
J+142	HzCtl.Lo5Lim	Monitoring the power frequency: lower switch-off limit 5	n/a	45
J+143	HzCtl.Lo5LimTm	Monitoring the power frequency: waiting time lower switch-off limit 5	n/a	10000
J+144	HzCtl.Lo6Lim	Monitoring the power frequency: lower switch-off limit 6	n/a	45
J+145	HzCtl.Lo6LimTm	Monitoring the power frequency: waiting time lower switch-off limit 6	n/a	10000
J+146	VCtl.Hi1Lim	Monitoring the grid voltage: upper switch-off limit 1	n/a	1.15
J+147	VCtl.Hi1LimTm	Monitoring the grid voltage: waiting time upper switch-off limit 1	n/a	1000
J+148	VCtl.Hi2Lim	Monitoring the grid voltage: upper switch-off limit 2	n/a	1.3
J+149	VCtl.Hi2LimTm	Monitoring the grid voltage: waiting time upper switch-off limit 2	n/a	100
J+150	VCtl.Hi3Lim	Monitoring the grid voltage: upper switch-off limit 3	n/a	2.0
J+151	VCtl.Hi3LimTm	Monitoring the grid voltage: waiting time upper switch-off limit 3	n/a	10000
J+152	VCtl.Hi4Lim	Monitoring the grid voltage: upper switch-off limit 4	n/a	2.0
J+153	VCtl.Hi4LimTm	Monitoring the grid voltage: waiting time upper switch-off limit 4	n/a	10000
J+154	VCtl.Hi5Lim	Monitoring the grid voltage: upper switch-off limit 5	n/a	2.0
J+155	VCtl.Hi5LimTm	Monitoring the grid voltage: waiting time upper switch-off limit 5	n/a	10000

J+156	VCtl.Hi6Lim	Monitoring the grid voltage: upper switch-off limit 6	n/a	2.0
J+157	VCtl.Hi6LimTm	Monitoring the grid voltage: waiting time upper switch-off limit 6	n/a	10000
J+158	VCtl.Lo1Lim	Monitoring the grid voltage: lower switch-off limit 1	n/a	0.8
J+159	VCtl.Lo1LimTm	Monitoring the grid voltage: waiting time lower switch-off limit 1	n/a	1000
J+160	VCtl.Lo2Lim	Monitoring the grid voltage: lower switch-off limit 2	n/a	0.45
J+161	VCtl.Lo2LimTm	Monitoring the grid voltage: waiting time lower switch-off limit 2	n/a	300
J+162	VCtl.Lo3Lim	Monitoring the grid voltage: lower switch-off limit 3	n/a	0.0
J+163	VCtl.Lo3LimTm	Monitoring the grid voltage: waiting time lower switch-off limit 3	n/a	1000
J+164	VCtl.Lo4Lim	Monitoring the grid voltage: lower switch-off limit 4	n/a	0.0
J+165	VCtl.Lo4LimTm	Monitoring the grid voltage: waiting time lower switch-off limit 4	n/a	1000
J+166	VCtl.Lo5Lim	Monitoring the grid voltage: lower switch-off limit 5	n/a	0.0
J+167	VCtl.Lo5LimTm	Monitoring the grid voltage: waiting time lower switch-off limit 5	n/a	1000
J+168	VCtl.Lo6Lim	Monitoring the grid voltage: lower switch-off limit 6	n/a	0.0
J+169	VCtl.Lo6LimTm	Monitoring the grid voltage: waiting time lower switch-off limit 6	n/a	1000
J+170	Spk.dVol	1-time step change in voltage to activation entry and exit of spike mitigation logic **(PSS/E Specific)**	0.1 – 2.0	0.3
J+171	Spk.AmpHoldTm	Time in seconds during which the current is held to its [Pre-fault Value*Spk.AmpHold-Fac(X)] **(PSS/E Specific)**	0 – 0.1	0.005
J+172	Spk.AmpHoldFacD	Factor to scale the active part of Pre-fault value between 0.0 and [Pre-fault value] **(PSS/E Specific)**	0 to 1.0	0.0
J+173	Spk.AmpHoldFacQ	Factor to scale the reactive part of Pre-fault value between 0.0 and [Pre-fault value] **(PSS/E Specific)**	0 to 1.0	0.0

2.4.3 VARs

Table 4: List of VARs

VARs	Description
L+0	WSpt – Use this VAR to set active power setpoint when ICON(M) is set to 0
L+1	VarSpt – Use this VAR to set reactive power setpoint when ICON(M) is set to 0
L+2	FrqSpt - Use this VAR to set frequency setpoint
L+3	VolSpt - Use this VAR to set voltage setpoint
L+4	TmpStk – Use this VAR to set the temperature of stack – Default is 119 degrees
L+5	Xpu – X part of impedance for current injection – should be equal to X for gen. in LF
L+6	Rpu - R part of impedance for current injection – should be equal to R for gen. in LF
L+7	Unused
L+8	Unused
L+9	SetpointChangeFlag – Flag to detect setpoint change when ICON(M) is set to 0
L+10	Meas1.Vinv_d – d-axis inverter terminal voltage
L+11	Meas1.Vinv_q – q-axis inverter terminal voltage
L+12	Meas1.Iinv_d – d-axis inverter current
L+13	Meas1.Iinv_q – q – axis inverter current
L+14	Vth_r – real part of thevenin voltage applied in the current injection routine
L+15	Vth_i – imaginary part of thevenin voltage applied in the current injection routine
L+16	FRTDetect – Flag to Check whether FRT is enabled or not
L+17	VI_X – reactive part of Virtual impedance when in FRT
L+18	VI_R – real part of Virtual impedance when in FRT
L+19	Unused
L+20	AmpDQRtg
L+21	StkAmpLimOn
L+22	PreFaultCurrD
L+23	PreFaultCurrQ
L+24	SpikeFlagOn
L+25	SpikeFlagOff
L+26	SpikeTimer
L+27	Meas1.Pinv_hold
L+28	Meas1.Qinv_hold
L+29	Unused
L+30	VCtlHi1Lim_Out – Flag to check whether High Voltage Protection 1 is activated
L+31	VCtlHi1Lim_timer
L+32	VCtlHi2Lim_Out - Flag to check whether High Voltage Protection 2 is activated
L+33	VCtlHi2Lim_timer
L+34	VCtlHi3Lim_Out - Flag to check whether High Voltage Protection 3 is activated
L+35	VCtlHi3Lim_timer
L+36	VCtlHi4Lim_Out - Flag to check whether High Voltage Protection 4 is activated
L+37	VCtlHi4Lim_timer

L+38	VCtlHi5Lim_Out - Flag to check whether High Voltage Protection 5 is activated
L+39	VCtlHi5Lim_timer
L+40	VCtlHi6Lim_Out - Flag to check whether High Voltage Protection 6 is activated
L+41	VCtlHi6Lim_timer
L+42	VCtlLo1Lim_Out - Flag to check whether Low Voltage Protection 1 is activated
L+43	VCtlLo1Lim_timer
L+44	VCtlLo2Lim_Out - Flag to check whether Low Voltage Protection 2 is activated
L+45	VCtlLo2Lim_timer
L+46	VCtlLo3Lim_Out - Flag to check whether Low Voltage Protection 3 is activated
L+47	VCtlLo3Lim_timer
L+48	VCtlLo4Lim_Out - Flag to check whether Low Voltage Protection 4 is activated
L+49	VCtlLo4Lim_timer
L+50	VCtlLo5Lim_Out - Flag to check whether Low Voltage Protection 5 is activated
L+51	VCtlLo5Lim_timer
L+52	VCtlLo6Lim_Out - Flag to check whether Low Voltage Protection 6 is activated
L+53	VCtlLo6Lim_timer
L+54	HzCtlHi1Lim_Out - Flag to check whether High Frequency Protection 1 is activated
L+55	HzCtlHi1Lim_timer
L+56	HzCtlHi2Lim_Out - Flag to check whether High Frequency Protection 2 is activated
L+57	HzCtlHi2Lim_timer
L+58	HzCtlHi3Lim_Out - Flag to check whether High Frequency Protection 3 is activated
L+59	HzCtlHi3Lim_timer
L+60	HzCtlHi4Lim_Out - Flag to check whether High Frequency Protection 4 is activated
L+61	HzCtlHi4Lim_timer
L+62	HzCtlHi5Lim_Out - Flag to check whether High Frequency Protection 5 is activated
L+63	HzCtlHi5Lim_timer
L+64	HzCtlHi6Lim_Out - Flag to check whether High Frequency Protection 6 is activated
L+65	HzCtlHi6Lim_timer
L+66	HzCtlLo1Lim_Out - Flag to check whether Low Frequency Protection 1 is activated
L+67	HzCtlLo1Lim_timer
L+68	HzCtlLo2Lim_Out - Flag to check whether Low Frequency Protection 2 is activated
L+69	HzCtlLo2Lim_timer
L+70	HzCtlLo3Lim_Out - Flag to check whether Low Frequency Protection 3 is activated
L+71	HzCtlLo3Lim_time
L+72	HzCtlLo4Lim_Out - Flag to check whether Low Frequency Protection 4 is activated
L+73	HzCtlLo4Lim_timer
L+74	HzCtlLo5Lim_Out - Flag to check whether Low Frequency Protection 5 is activated
L+75	HzCtlLo5Lim_timer
L+76	HzCtlLo6Lim_Out - Flag to check whether Low Frequency Protection 6 is activated
L+77	HzCtlLo6Lim_timer
L+78	Control_Angle
L+79	Inverter_Voltage_Angle
L+80	CosPhi

L+81	SinPhi
L+82	Meas1.Vinv_d
L+83	Meas1.Vinv_q
L+84	Meas1.Vth_d
L+85	Meas1.Vth_q
L+86	Meas1.Iinv_d
L+87	Meas1.Iinv_q
L+88	AmaxSpt
L+89	Vmag_Filt
L+90	Vmag.Filt
L+91	Result_enaGoToSec2
L+92	ErrorCounter1
L+93	Result_enaGoToSec3
L+94	ErrorCounter2
L+95	Result_enaGoToSec4
L+96	ErrorCounter3
L+97	Result_enaGoToSec3FromSec0
L+98	ErrorCounter4
L+99	TempStk_Filt
L+100	CounterSec0
L+101	OvAmpStt
L+102	SubStt
L+103	noOvercurrentStt
L+104	HWTresholdHi
L+105	EnaThmDerating
L+106	AmaxNom
L+107	AmaxNomD
L+108	AmaxNomQ
L+109	AmaxNomInit
L+110	HysMode
L+111	HysMode_timer
L+112	TmpAcCtlOvAmpActive
L+113	Unused
L+114	disaOverCurrent_delay
L+115	AmaxNom_filt
L+116	AmaxNomD_filt
L+117	AmaxNomQ_filt
L+118	AMaxSpt
L+119	StkAmpLimOn
L+120	Vinv_d_filt
L+121	Vinv_q_filt
L+122	SW_FRT
L+123	SW_FRT_timer

L+124	VirtImpEna
L+125	FRT_States_timer
L+126	VirtImpEna_delay
L+127	Local_ResetTm_timer
L+128	AmaxSpt_Filt
L+129	AmpMax_Filt
L+130	Meas.Iinv_q_Filt
L+131	VI_X_PiCtrlWithLimit_Out
L+132	VI_X_PiCtrl_Integrator
L+133	VI_R_Filt
L+134	VI_R_PiCtrlWithLimit_Out
L+135	VI_R_PiCtrl_Integrator
L+136	VI_X
L+137	VI_R
L+138	Iinv_d_fil
L+139	Iinv_q_fil
L+140	Vmag_fil1
L+141	Vmag_fil2
L+142	CtlOut_P_D
L+143	CtlOut_I_D
L+144	Ki_max_hold
L+145	Ki_min_hold
L+146	PiCtrlWithLimit_Output
L+147	PiCtrl_Integrator
L+148	PiCtrl_Integrator2
L+149	PiCtrl_Integrator3
L+150	PiCtrlWithLimit_Output
L+151	PiCtrl_Integrator
L+152	PiCtrl_Integrator2
L+153	PiCtrl_Integrator3
L+154	CtlOut_D
L+155	CtlOut_P_Q
L+156	CtlOut_I_Q
L+157	Ki_max_hold
L+158	Ki_min_hold
L+159	PiCtrlWithLimit_Output
L+160	PiCtrl_Integrator
L+161	PiCtrl_Integrator2
L+162	PiCtrl_Integrator3
L+163	PiCtrlWithLimit_Output
L+164	PiCtrl_Integrator
L+165	PiCtrl_Integrator2
L+166	PiCtrl_Integrator3

L+167	CtlOut_Q
L+168	VirtImpEna_delay
L+169	WAval
L+170	VarAval
L+171	Ud_filt
L+172	Uq_filt
L+173	AmpPsDSpt
L+174	AmpPsQSpt
L+175	HzCtlOut
L+176	dTheta
L+177	dVol
L+178	Iinv_d_filt
L+179	Iinv_q_filt
L+180	Vmag.filt
L+181	DrpAmpDFilTm_filt
L+182	HPF_Filt_out_dHz
L+183	dHz_HPF_delay
L+184	DrpAmpDFilTm2_filt
L+185	HPF_Filt_out_dHz2
L+186	dHz2_HPF_delay
L+187	DrpAmpD_filt
L+188	InteriaPhsCtl_Kp_filt
L+189	InteriaPhsCtl_Ki_filt
L+190	AmpPsD_int
L+191	DrpAmpQFilTm_filt
L+192	HPF_Filt_out_dVol
L+193	dVol_HPF_delay
L+194	DrpAmpQFilTm2_filt
L+195	HPF_Filt_out_dVol2
L+196	dVol2_HPF_delay
L+197	DrpAmpQ_filt
L+198	InteriaVolCtl_Kp_filt
L+199	InteriaVolCtl_Ki_filt
L+200	AmpPsQ_int
L+201	dAmpD_filt
L+202	Hzin_hold
L+203	Thetain_hold
L+204	Volin_hold
L+205	Vinv_q_filt
L+206	VirtImpEna_delay
L+207	PreFreeze
L+208	PreFreeze_timer
L+209	Vinv_d

L+210	Vinv_q
L+211	Vinv_d_FRT
L+212	Vinv_q_FRT
L+213	Vinv_d_filt
L+214	Vinv_q_filt
L+215	Vinv_d_int
L+216	Vinv_q_int
L+217	Iinv_d_filt
L+218	Iinv_q_filt
L+219	Vth_r
L+220	Vth_i

3 Disclaimer

This document and the associated models have been prepared to facilitate the behavioral simulation of the response of SMA Sunny Central inverters to grid and parameter disturbances. The modeling data presented herein are intended to produce simulation results that closely approximate the response of the inverters to these disturbances, and do not necessarily represent the physical implementation of the inverter or plant control algorithms.