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 8

July 29, 2024

# Note

The following PSS®E versions are currently supported:

- version 33 compiled with Intel Visual Fortran Compiler Revision 11.1,
- versions 34.4 compiled with Intel Visual Fortran Compiler Revisions 15.0 (x86).
- versions 35.5 compiled with Intel Visual Fortran Compiler Revisions 19.1 (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<br>2. Shifting of Subroutines and Functions to CONTAINS<br>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<br>BugFix: ICON(M+2) with CHRCIN not working with v33 |
| 3.02 | Rahul Bhatia | 1.BugFix: Filt1.ABControlDFilTm & ABControlQFilTm not initialized correctly<br>2. Spike Mitigation Algorithm Implementation<br>3. Hardware current limitation of StkAmpLimon |
| 3.03 | Rahul Bhatia | 1.Introduced CON – Rtg.VarRtg to have adjustable reactive power rating<br>2.Introduced CON – Filt.AvalPwrFilTm as a filter for available power (active and reactive)<br>3. Communication of available active power to Hycon model. |
| 3.04 | Rahul Bhatia | 1.Update to Firmware release R10 |
| 3.05 | Rahul Bhatia | 1.Addition of HiVolOnLim and DynVolOnLimEna to VirtImp<br>2. Addition of CONs for VARtg, WRtg, AmpRtg<br>3. Addition of Setpoint filters and Rate limiter<br>4. Addition of SoC logic and DcAmpLimit controller<br>5. Bugfixes related to firmware release 10 |
| 3.06 | Rahul Bhatia | 1.Solving the base conversion issue |
| 3.07 | Rahul Bhatia | 1.Addition of new parameter Rtg1.DrtFac<br>2.BugFix: Initialization for voltage inertia |

| | | |
|---|---|---|
| | | 3.Changing of Resistance and Reactance values of generator |

# 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.

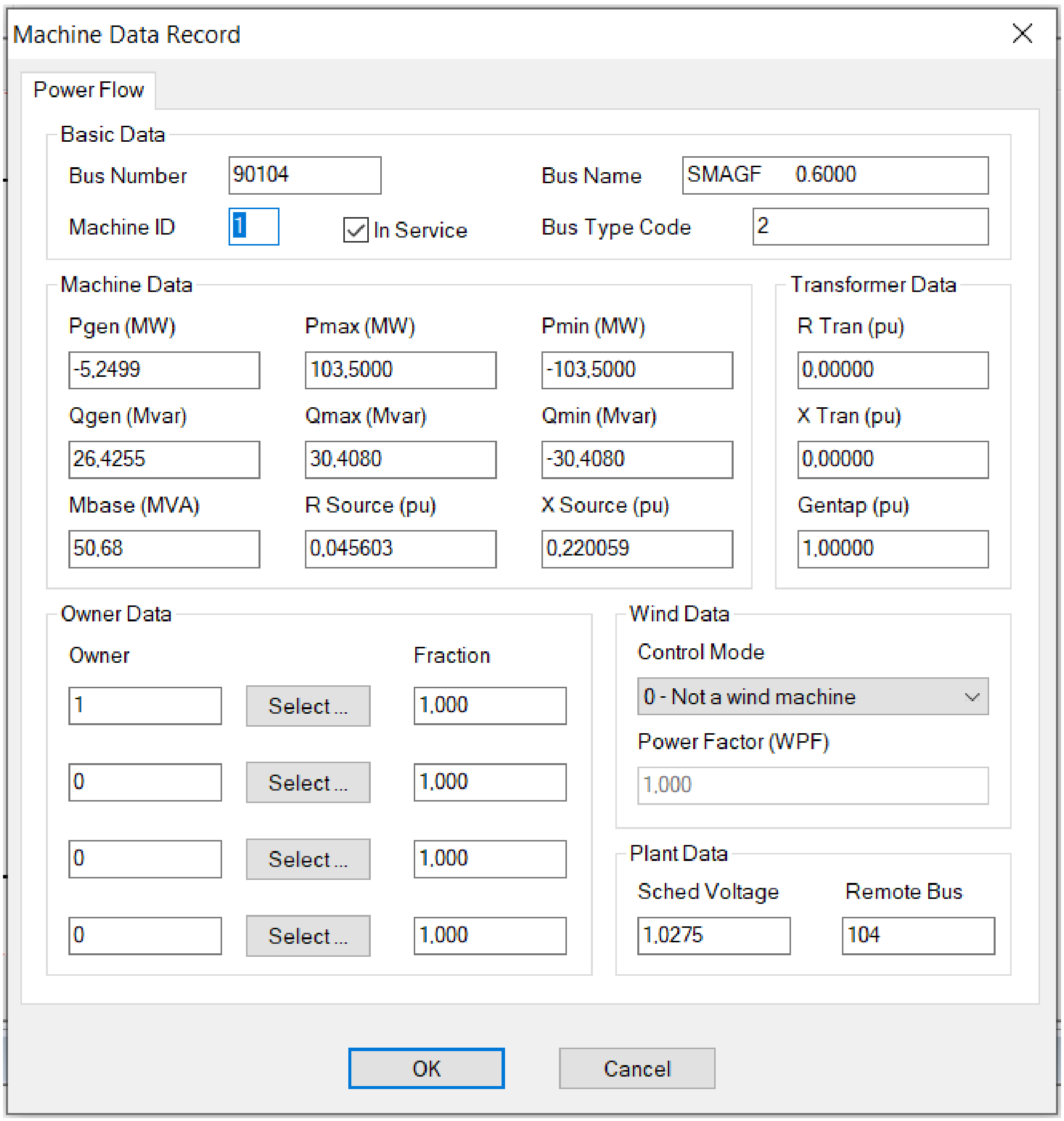


Figure 1: Typical data mask for machine entry in the PSS®E load flow program.

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 'SMAGF307' 1 1 4 222 0 324 ICON(M) ICON(M+1)
ICON(M+2) ICON(M+3) CON(J) CON(J+1) ... CON(J+221)
```

## 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 | 0.0084 + j0.2523 | 0.0084 + j0.3027 |
| SCS2200 | 2,200 | 0,385 | 2200 | 0.00742 + j0.2238 | 0.00742 + j0.2686 |
| SCS2475 | 2,475 | 0,434 | 2475 | 0.0066 + j0.1981 | 0.0066 + j0.2378 |
| SCS2900 | 2,940 | 0,520 | 2940 | 0.0054 + j0.164 | 0.0054 + j0.1967 |
| SCS2300UPXT | 2,667 | 0,600 | 2667 | 0.0148 + j0.2118 | 0.0148 + j0.25415 |
| SCS2400UPXT | 2,800 | 0,630 | 2800 | 0.0141 + j0.2016 | 0.0141 + j0.22420 |
| SCS2530UPXT | 2,933 | 0,660 | 2933 | 0.0134 + j0.1924 | 0.0134 + j0.2310 |
| SCS2630UPXT | 3,067 | 0,690 | 3067 | 0.0128 + j0.1841 | 0.0128 + j0.2210 |
| SCS3450UP | 3,450 | 0,600 | 3450 | 0.0191 + j0.1926 | 0.0191 + j0.2312 |
| SCS3600UP | 3,620 | 0,630 | 3620 | 0.0182 + j0.1833 | 0.0182 + j0.2200 |
| SCS3800UP | 3,800 | 0,660 | 3800 | 0.0174 + j0.1753 | 0.0174 + j0.2104 |
| SCS3950UP | 3,960 | 0,690 | 3960 | 0.0166 + j0.1672 | 0.0166 + j0.2007 |
| SCS3450UPXT | 4,000 | 0,600 | 4000 | 0.0222 + j0.2234 | 0.0222 + j0.2680 |
| SCS3600UPXT | 4,200 | 0,630 | 4200 | 0.0211 + j0.2127 | 0.0211 + j0.2553 |
| SCS3800UPXT | 4,400 | 0,660 | 4400 | 0.0202 + j0.2030 | 0.0202 + j0.2437 |
| SCS3950UPXT | 4,600 | 0,690 | 4600 | 0.01934 + j0.1942 | 0.01934 + j0.2331 |

- 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 |
| M+3 | SCSOpCmd | 21521: Grid Forming P/f and Q/V droop | n/a | 21521 |

| | | | | |
|---|---|---|---|---|
| | | 22321: Grid Forming angle inertia and Q/V droop<br>22322: Grid Forming P/f droop and voltage Inertia<br>22323: Grid Forming angle inertia and voltage inertia<br>**(PSS/E Specific)** | | |

## 2.4.2 CONs

Table 3: List of CONs

| CON | Parameter | Description | Range min-max | Default |
|---|---|---|---|---|
| J+0 | Rtg.VARtg | Apparent power rating in kVA can be set using this parameter. If set to 0.0, then rated apparent power as per Inverter type (ICON(M+2)) will be used | n/a | 0.0 |
| J+1 | Rtg.WRtg | Active power rating in kW can be set using this parameter. If set to 0.0, then rated Active power as per Inverter type (ICON(M+2)) will be used | n/a | 0.0 |
| J+2 | 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+3 | Rtg.AmpRtg | Current rating in A can be set using this parameter. If set to 0.0, then rated current rating as per Inverter type (ICON(M+2)) will be used | n/a | 0.0 |
| J+4 | Rtg.VADrtPriMod | Prioritizing of control in case of derating<br>0: Q Priority, 1: P Priority | 0 or 1 | 0 |
| **J+5** | Rtg.DrtFac | Derating Factor to emulate the thermal derating of the device | 0 to 1.0 | 1.0 |
| J+6 | Spt.WGraMod | Active power gradient, activation | 0 or 1 | 0 |
| J+7 | Spt.VArGraMod | Reactive power gradient, activation | 0 or 1 | 0 |
| J+8 | Spt.WGra | Gradient for active power p.u./s | n/a | 100 |
| J+9 | Spt.VArGra | Gradient for reactive power p.u./s | n/a | 100 |
| J+10 | Spt.WFilMod | Filter for active power setpoint, activation | 0 or 1 | 0 |
| J+11 | Spt.VArFilMod | Filter for reactive power setpoint, activation | 0 or 1 | 0 |
| J+12 | Spt.WFilTm | WSpt, filter time constant in s | 3*timestep - n/a | 0.02 |

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|---|---|---|---|---|
| J+13 | Spt.VArFilTm | VArSpt, filter time constant in s | 3*timestep - n/a | 0.02 |
| J+14 | Filt.VolDQFilTm | DQ Voltage, filter time constant in s | 3*timestep - n/a | 0.46 |
| J+15 | Filt.VolPsFilTm | Voltage filter time constant for conversion VA to Amp in s | 3*timestep - n/a | 0.005 |
| J+16 | Filt.AmpDFilTm | D axis current, filter time constant in s | 3*timestep - n/a | 0.01 |
| J+17 | Filt.AmpQFilTm | Q axis current, filter time constant in s | 3*timestep - n/a | 0.01 |
| J+18 | Filt.ABControlDFilTm | Filter time constant for D-axis voltage for AB Control in s **(PSS/E Specific)** | 3*timestep - n/a | 0.01 |
| J+19 | Filt.ABControlQFilTm | Filter time constant for Q-axis voltage for AB Control in s **(PSS/E Specific)** | 3*timestep - n/a | 0.01 |
| J+20 | Filt.AvalPwrFilTm | Filter time constant for calculated available active and reactive power in s | 3*timestep - n/a | 0.1 |
| J+21 | Filt.VolSptGra | Rate limiter in p.u/s over voltage setpoint (VAR(L+3)) applied to the inverter | n/a | 5.0 |
| J+22 | AcCtl.WSptScal | AC current control, active power setpoint scaling factor | 1 - n/a | 1 |
| J+23 | AcCtl.VArSptScal | AC current control, reactive power setpoint scaling factor | 1 - n/a | 1 |
| J+24 | AcCtl.DrpHz | Active power frequency droop | n/a | -2.0 |
| J+25 | AcCtl.DrpVol | Reactive power voltage droop | n/a | 0.1 |
| J+26 | AcCtl.DrpTheta | Factor angle pre-control | n/a | -0.12 |
| J+27 | AcCtl.InertiaVolH | Inertia: Voltage magnitude inertia constant H_vol = 0.5 * (dQ/Snom) / (RoCoV/Vnom) | n/a | 1.5 |
| J+28 | AcCtl. InertiaThetaH | Inertia: Voltage angle inertia constant H_theta = 0.5 * (dP/Snom) / (RoCoF/Fnom) | n/a | 2.5 |
| J+29 | 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+30 | AcCtl.InertiaHzFbDmp | Inertia: Frequency feedback gain of voltage angle inertia control | n/a | 0.0 |
| J+31 | AcCtl.InertiaHzFbFilTm | Inertia: Frequency feedback time constant of voltage angle inertia control | n/a | 0.0 |
| J+32 | AcCtl.InertiaHzFbFil2Tm | Inertia: Frequency feedback time constant of voltage angle inertia control | n/a | 0.0 |
| J+33 | AcCtl.InertiaHzFwdDmp | Inertia: Feed-forward damping gain of voltage angle inertia control | n/a | 0.0 |

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|---|---|---|---|---|
| J+34 | AcCtl.InertiaVolFwdDmp | Inertia: Feed-forward damping gain of voltage magnitude inertia control | n/a | 0.0 |
| J+35 | AcCtl.InertiaVolFbDmp | Inertia: Voltage feedback gain of voltage magnitude inertia control | n/a | 0.0 |
| J+36 | AcCtl.InertiaVolFbDmp-FilTm | Inertia: Voltage feedback time constant of voltage magnitude inertia control | n/a | 0.0 |
| J+37 | AcCtl.InertiaVolFbDmp-Fil2Tm | Inertia: Voltage feedback time constant of voltage magnitude inertia control | n/a | 0.0 |
| J+38 | AcCtl.AmpDLimKp | AC current control, proportional amplification for active current limit | n/a | 0.6 |
| J+39 | AcCtl.AmpDLimKi | AC current control, integral amplification for active current limit | n/a | 22.5 |
| J+40 | AcCtl.InertiaAmpDLimKp | Inertia: AC current control, proportional amplification for active current limit | n/a | 0.6 |
| J+41 | AcCtl.InertiaAmpDLimKi | Inertia: AC current control, integral amplification for active current limit | n/a | 22.5 |
| J+42 | AcCtl.AmpPsDLim_Ki2Fac | AC current control, double integral amplification for active current limit | n/a | 0.00033333 |
| J+43 | AcCtl.AmpPsDLim_I2RocofLim | AC and DC limit control, minimum/maximum range control signal | n/a | 6.0 |
| J+44 | AcCtl.AmpPsDLim_I2CtlDownGain | AC current control, additional double integral amplification, if active current limit is not exceeded | n/a | 3.0 |
| J+45 | AcCtl.AmpQLimKp | AC current control, proportional amplification for reactive current limit | n/a | 2.4 |
| J+46 | AcCtl.AmpQLimKi | AC current control, integral amplification for reactive current limit | n/a | 90.0 |
| J+47 | AcCtl.InertiaAmpQLimKp | Inertia: AC current control, proportional amplification for reactive current limit | n/a | 2.4 |
| J+48 | AcCtl.InertiaAmpQLimKi | Inertia: AC current control, integral amplification for reactive current limit | n/a | 90.0 |
| J+49 | AcCtl.AmpPsQLim_Ki2Fac | AC current control, double integral amplification for reactive current limit | n/a | 0.00033333 |
| J+50 | AcCtl.AmpPsQLim_I2RocofLim | AC current control, minimum/maximum range control signal | n/a | 6.0 |
| J+51 | AcCtl.AmpPsQLim_I2CtlDownGain | AC current control, additional double integral amplification, if reactive current limit is not exceeded | n/a | 3.0 |
| J+52 | AcCtl.InertiaThetaW-CtlEna | Inertia: Enable active power inertia control | 0 to 1 | 0 |

| | | | | |
|---|---|---|---|---|
| J+53 | AcCtl.InertiaThetaWCtlV-olLim | Voltage limit for power regulation in phase inertia | n/a | 0.5 |
| J+54 | AcCtl.InertiaVolVArCtlEna | Inertia: Enable reactive power inertia control | 0 or 1 | 0 |
| J+55 | AcCtl.InertiaVolVArCtlVol-Lim | Voltage limit for power regulation in the voltage inertia | 0 to 1 | 0.5 |
| J+56 | AcCtl.Iner-tiaThetaFwdDmpFilTm | Inertia: Time constant for bandwidth limi-tation of angle feed-forward damping | 3*timestep - n/a or 0 | 0.0 |
| J+57 | AcCtl.Iner-tiaThetaFwdDmp | Inertia: Voltage angle feed-forward damping gain of voltage angle inertia control | n/a | -0.12 |
| J+58 | AcCtl.AmpPsDFbEna | Inertia: Activation of inner active current feedback of voltage angle inertia control | 0 or 1 | 1 |
| J+59 | AcCtl.AmpPsQFbEna | Inertia: Activation of inner reactive cur-rent feedback of voltage magnitude iner-tia control | 0 or 1 | 1 |
| J+60 | Ac-Ctl.AmpDLim_VolPsNomLim | AC current control, active current limi-ation, voltage limit for accurate active power limitation | 0 to 1 | 1 |
| J+61 | Ac-Ctl.AmpQLim_VolPsNomLim | AC current control, reactive current limi-ation, voltage limit for accurate reactive power limitation | 0 to 1 | 1 |
| J+62 | AcCtl.AmpDQLimEna | AC current control, limiting controller ac-tivation | 0 or 1 | 1 |
| J+63 | AcCtl.PriModPsRelEna | AC current control, Prioritization mode - positive sequence relative - for current limitation, activation | 0 or 1 | 0 |
| J+64 | AcCtl.VolABKi | AC voltage control integral gain | n/a | 120 |
| J+65 | AcCtl.VolABKp | AC voltage control Proportional gain **(PSS/E Specific)** | n/a | 0.01 |
| J+66 | AcCtl.AmpDQFilTm | AC current control, DQ current filter time constant | 3*timestep - n/a or 0 | 0.02 |
| J+67 | AcCtl.ParamFilTm | Inertia: Low pass filter time constant for smooth inertia parameter change | 3*timestep - n/a or 0 | 10.0 |
| J+68 | AcCtl.PreFreezeDlTm | PreFreeze delay time [ms] | 0 - 20 | 20.0 |
| J+69 | AcCtl.PreFreezeFilTm | PreFreeze filter time constant | 3*timestep - n/a or 0 | 0.02 |
| J+70 | AcCtl.InertiaHzDmp | Inertia: Voltage frequency damping gain of voltage angle inertia control | n/a | -1.0 |
| J+71 | AcCtl.InertiaVolDmp | Inertia: Voltage magnitude damping gain of voltage magnitude inertia control | n/a | 0.03 |

| | | | | |
|---|---|---|---|---|
| J+72 | AcCtl.PlantLevelInertia | Enable plant level inertia | 0 or 1 | 0 |
| J+73 | Frt.Frt_Mod | Grid forming FRT: Mode<br>1: GRIFORM_FRT_MOD_DISABLE<br>2: GRIFORM_FRT_MOD_FULL_VI<br>3:GRIFORM_FRT_MOD_FULL_VI_K_FAC_BASIC<br>4:GRIFORM_FRT_MOD_FULL_VI_K_FAC_ADVANCED | 1, 2, 3, 4 | 2 |
| J+74 | Frt.LoVolOnLim | Grid forming FRT: Lower voltage limit for entering FRT Mode **(PSS/E Specific)** | 0 to 1 | 0.8 |
| J+75 | Frt. HiVolOnLim | Grid forming FRT: Upper voltage limit for entering FRT Mode **(PSS/E Specific)** | 1 to n/a | 1.1 |
| J+76 | Frt.LoVolOffLim | Grid forming FRT: Lower voltage limit for return to normal mode | 0 to 1 | 0.9 |
| J+77 | Frt.HiVolOffLim | Grid forming FRT: Upper voltage limit for return to normal mode | 1 to 2 | 1.1 |
| J+78 | Frt.DynVolOnLimEna | Grid forming FRT: Activation of dynamic offset voltage limits for entering FRT mode **(PSS/E Specific)** | 0 or 1 | 0 |
| J+79 | Frt.DynVolOffLimEna | Grid forming FRT: Activation of dynamic offset voltage limits for return to normal mode | 0 or 1 | 0 |
| J+80 | Frt.VirtImpSwDetLim | Grid forming FRT: Current threshold for activation of virtual impedance | 1 to 2 | 1.4 |
| J+81 | Frt.VirtImpDlTm | Grid forming FRT: Delay time for activation of virtual impedance | n/a | 4 |
| J+82 | Frt.VirtImpLockTm | Grid forming FRT: Minimum duration time of virtual impedance | n/a | 100 |
| J+83 | Frt.VirtImpWaitTm | Grid forming FRT: Minimum duration time for reactivation of virtual impedance | n/a | 200 |
| J+84 | Frt.ResetTm | Time to jump back to initial state in FRT-Detection-Statemachine | n/a | 30 |
| J+85 | Frt.AmpCtlEna | Grid forming FRT: Activation of adaptive current control | 0 or 1 | 1.0 |
| J+86 | Frt.AMaxNomInit | Grid forming FRT: Init value of maximum short circuit current in the virtual impedance | n/a | 1.0 |
| J+87 | Frt.AMaxNom | Grid forming FRT: maximum short circuit current | n/a | 1.0 |
| J+88 | Frt.AmpCtlFilTm | Grid forming FRT: Adaptive current control, filter time constant | 3*timestep - n/a or 0 | 0.004 |

| | | | | |
|---|---|---|---|---|
| J+89 | Frt.CtlDevLimMax | Grid forming FRT: Adaptive apparent current control, maximum control deviation | n/a | 0.2 |
| J+90 | Frt.NegCtlDev_Gain | Amplification or reduction of the negative control deviation of the VI controller | n/a | 1 |
| J+91 | Frt.AmpCtlKp | Grid forming FRT: Adaptive current control, proportional gain | n/a | 0.0 |
| J+92 | Frt.AmpCtlKi | Grid forming FRT: Adaptive current control, integral gain | n/a | 10.0 |
| J+93 | Frt.VirtImpReact | Grid forming FRT: Virtual impedance, reactance | n/a | 0.167 |
| J+94 | Frt.VirtImpReactMin | Grid forming FRT: Virtual impedance, minimum reactance | n/a | 0.167 |
| J+95 | Frt.VirtImpReactFFWEna | Activation of the pre-control of the virtual reactance of the difference | 0 or 1 | 1 |
| J+96 | Frt.VirtImpReactFFWFac | Grid forming FRT: Virtual impedance, factor of feedforward of virtual reactance | n/a | 0.68 |
| J+97 | Frt.VirtImpRis | Grid forming FRT: Virtual impedance, resistance | n/a | 0 |
| J+98 | Frt.VirtImpRisInit | Grid forming FRT: Virtual impedance, resistance, init Value | n/a | 0.3 |
| J+99 | Frt.VirtImpRisFilTm | Grid forming FRT: Virtual impedance, time constant for decaying resistance | 3*timestep - n/a | 0.008 |
| J+100 | Frt.VolPsQFilTm | Grid forming FRT: VolPsQ control during virtual impedance, filter time constant of VolPsQ voltage | 3*timestep - n/a | 0.004 |
| J+101 | Frt.VolPsQCtlKp | Grid forming FRT: VolPsQ control during virtual impedance, proportional gain | n/a | -4.0 |
| J+102 | Frt.VolPsQCtlDZn | Grid forming FRT: VolPsQ Control during virtual impedance, limit of proportional zone gain | n/a | 0.25 |
| J+103 | Frt.VolPsQCtlDZnKp | Grid forming FRT: VolPsQ Control during virtual impedance, proportional zone gain | n/a | 0.0 |
| J+104 | Frt.VolPsQCtlHzOfsMax | Grid forming FRT: VolPsQ control during virtual impedance, maximum actuating variable in Hz | n/a | 1.0 |
| J+105 | Frt.VolPsQCtrlEna | Value of the VolPsQ P controller | 0 or 1 | 1.0 |
| J+106 | Frt.AMaxNomInitTm | Grid forming FRT: Initialization time of maximum short circuit current in the virtual impedance | n/a | 0.0 |

| | | | | |
|---|---|---|---|---|
| J+107 | Frt.ArmsMsMaxLim | Grid forming FRT: maximum limit for measured short circuit current in the virtual impedance | n/a | 1.3 |
| J+108 | Frt.AmpCtlOfsKiFac | Grid forming FRT: Adaptive current control, factor of current control offset | n/a | 4.0 |
| J+109 | Frt.AmpCtlOfsAMaxSpt | Grid forming FRT: Adaptive current control, maximum short circuit current of current control offset | n/a | 1.3 |
| J+110 | Frt.VirtImpReactFFWOfs | Grid forming FRT: Virtual impedance, offset of feedforward of virtual reactance | n/a | 0.03 |
| J+111 | Frt.KFacPs | Grid forming: K-Factor positive sequence | n/a | 6.0 |
| J+112 | Frt.FFWVolFilTm | Grid forming FRT: Virtual impedance, time constant of voltage adjustment of feedforward of virtual reactance | n/a | 0.001 |
| J+113 | Frt.AmpPsQPrioEna | Grid forming FRT: Virtual impedance, activation of the reactive current priority | 0 or 1 | 1.0 |
| J+114 | Frt.PsDCtlRng | Grid forming FRT: Virtual impedance, amplification factor for limitation of the active current with reactive current priority | n/a | 0.25 |
| J+115 | Frt.AmpPsDFFWMin | Grid forming FRT: Virtual impedance, minimum short circuit current of feedforward of virtual reactance | n/a | 0.18 |
| J+116 | Frt.FFWAmpLimOfs | Grid forming FRT: Virtual impedance, short circuit current offset of feedforward of virtual reactance | n/a | 0.03 |
| J+117 | Frt.EnaAmpPsDSptMan | Enable Manual setpoint for active current component | 0 or 1 | 0.0 |
| J+118 | Frt.AmpPsDSptMan | Manual setpoint for active current component | n/a | 0.0 |
| J+119 | Frt.AmpPsDFilTm | Grid forming FRT: Virtual impedance, time constant of the active current adjustmen | 3*timestep - n/a or 0 | 0.3 |
| J+120 | Frt.AmpPsDMin | Grid forming FRT: Virtual impedance, current d axis positive sequence, maximum charge limit | n/a | -1.0 |
| J+121 | Frt.AmpPsQFilTm | Grid forming FRT: Virtual impedance, time constant of the reactive current adjustment | 3*timestep - n/a or 0 | 0.3 |
| J+122 | OvAmp.AmpMaxNomSecFilTm | Overcurrent: Filter time constant of overcurrent factors | n/a | 0.02 |

| | | | | |
|---|---|---|---|---|
| J+123 | OvAmp.AmpMaxNomSec0Tm | Overcurrent: Duration in milliseconds for sector 0 | n/a | 76000 |
| J+124 | OvAmp.AmpMaxNomSec1Tm | Overcurrent: Duration in milliseconds for sector 1 | n/a | 100 |
| J+125 | OvAmp.AmpMaxNomSec2Tm | Overcurrent: Duration in milliseconds for sector 2 | n/a | 900 |
| J+126 | OvAmp.AmpMaxNomSec3Tm | Overcurrent: Duration in milliseconds for sector 3 | n/a | 4000 |
| J+127 | OvAmp.AmpMaxNomSec4Tm | Overcurrent: Duration in milliseconds for sector 4 | n/a | 9000 |
| J+128 | OvAmp.AmpMaxNomSec4TransTm | Overcurrent: Duration in milliseconds for sector 4 in transition mode | n/a | 13900 |
| J+129 | OvAmp.AmpMaxNomSec4ThmDrtTm | Intermediate time within the fourth and last sector in the virtual impedance in milliseconds | n/a | 2000 |
| J+130 | OvAmp.AmpMaxNomSec0 | Overcurrent: Nominal current factor for maximum apparent current in sector 0 | n/a | 1 |
| J+131 | OvAmp.AmpMaxNomSec1 | Overcurrent: Nominal current factor for maximum apparent current in sector 1 | n/a | 1.57 |
| J+132 | OvAmp.AmpMaxNomSec2 | Overcurrent: Nominal current factor for maximum apparent current in sector 2 | n/a | 1.25 |
| J+133 | OvAmp.AmpMaxNomSec3 | Overcurrent: Nominal current factor for maximum apparent current in sector 3 | n/a | 1.16 |
| J+134 | OvAmp.AmpMaxNomSec4 | Overcurrent: Nominal current factor for maximum apparent current in sector 4 | n/a | 0.95 |
| J+135 | OvAmp.AmpMaxNomSec3Obs | Overcurrent: Nominal current factor for current observation to move in sector 3 | n/a | 1.0 |
| J+136 | OvAmp.AmpMaxNomSec4Obs | Overcurrent: Nominal current factor for current observation to move in sector 4 | n/a | 1.0 |
| J+137 | OvAmp.AmpMaxNomSec4ObsHys | Overcurrent: Nominal current factor for current Hysteresis observation to move in sector 4 | n/a | 0.03 |
| J+138 | OvAmp.AmpPsDMaxNomSec0 | Overcurrent: Nominal current factor for maximum active current in sector 0 | n/a | 1 |
| J+139 | OvAmp.AmpPsDMaxNomSec1 | Overcurrent: Nominal current factor for maximum active current in sector 1 | n/a | 1.57 |
| J+140 | OvAmp.AmpPsDMaxNomSec2 | Overcurrent: Nominal current factor for maximum active current in sector 2 | n/a | 1.25 |
| J+141 | OvAmp.AmpPsDMaxNomSec3 | Overcurrent: Nominal current factor for maximum active current in sector 3 | n/a | 1.16 |
| J+142 | OvAmp.AmpPsQMaxNomSec0 | Overcurrent: Nominal current factor for maximum reactive current in sector 0 | n/a | 1.0 |

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|---|---|---|---|---|
| J+143 | OvAmp.AmpPsQMaxNomSec1 | Overcurrent: Nominal current factor for maximum reactive current in sector 1 | n/a | 1.57 |
| J+144 | OvAmp.AmpPsQMaxNomSec2 | Overcurrent: Nominal current factor for maximum reactive current in sector 2 | n/a | 1.25 |
| J+145 | OvAmp.AmpPsQMaxNomSec3 | Overcurrent: Nominal current factor for maximum reactive current in sector 3 | n/a | 1.16 |
| J+146 | OvAmp.VirtImpEna | Overcurrent: Activation of overcurrent for virtual impedance | 0 or 1 | 0 |
| J+147 | OvAmp.AcCtlEna | Overcurrent: Activation of overcurrent for grid forming | 0 or 1 | 0 |
| J+148 | OvAmp.AmpMaxNomInit | Overcurrent: Init value of nominal current factor for maximum apparent current in the virtual impedance | n/a | 1.57 |
| J+149 | OvAmp.TmpStkFilTm | Time constant of the low-pass filtering of the stack temperature | 3*timestep - n/a or 0 | 0.5 |
| J+150 | OvAmp.TmpLimNormal | Overcurrent: Temperature limit for normal mode | n/a | 142 |
| J+151 | OvAmp.TmpLimTrans | Overcurrent: Temperature limit for transition mode | n/a | 147 |
| J+152 | OvAmp.NormalModHysTm | Overcurrent: Duration of hysteresis to move from normal mode to emergency mode | n/a | 1000 |
| J+153 | OvAmp.TransModHysTm | Time hysteresis in milliseconds for switching between emergency and transition mode | n/a | 150 |
| J+154 | OvAmp.ChangeModHysTm | Time hysteresis in milliseconds for switching between modes | n/a | 125 |
| J+155 | OvAmp.ArmsMsMaxLim | Overcurrent: Maximum limit for measured short circuit current in the virtual impedance | n/a | 1.62 |
| J+156 | OvAmp.StkAmpLimOn | Overcurrent: Hardware current limit at which the FPGA activates the FRT | n/a | 3000 |
| J+157 | OvAmp. AmpCtlOfsAMaxSpt | Overcurrent: Adaptive current control, maximum short circuit current of current control offset | n/a | 1.62 |
| J+158 | Ctl.HzOutLim | AC and DC limit control, minimum/maximum range control signal [Hz] | n/a | 5.0 |
| J+159 | Ctl.VolDQLim | Current setpoint calculation: voltage filter freeze limit, Grid forming modeGriF | | |
| J+160 | HW.OvAmpLimEna | Hardware current limit: Activation of overcurrent hardware current limits | 0 or 1 | 0 |

| | | | | |
|---|---|---|---|---|
| J+161 | HW.StkAmpLimOnFac | Calibration Factor for HW_StkAmpLimOn **(PSS/E Specific)** | n/a | 10 |
| J+162 | HzCtl.Hi1Lim | Monitoring the power frequency: upper switch-off limit 1 | n/a | 51 |
| J+163 | HzCtl.Hi1LimTm | Monitoring the power frequency: waiting time upper switch-off limit 1 | n/a | 1000 |
| J+164 | HzCtl.Hi2Lim | Monitoring the power frequency: upper switch-off limit 2 | n/a | 55 |
| J+165 | HzCtl.Hi2LimTm | Monitoring the power frequency: waiting time upper switch-off limit 2 | n/a | 10000 |
| J+166 | HzCtl.Hi3Lim | Monitoring the power frequency: upper switch-off limit 3 | n/a | 55 |
| J+167 | HzCtl.Hi3LimTm | Monitoring the power frequency: waiting time upper switch-off limit 3 | n/a | 10000 |
| J+168 | HzCtl.Hi4Lim | Monitoring the power frequency: upper switch-off limit 4 | n/a | 55 |
| J+169 | HzCtl.Hi4LimTm | Monitoring the power frequency: waiting time upper switch-off limit 4 | n/a | 10000 |
| J+170 | HzCtl.Hi5Lim | Monitoring the power frequency: upper switch-off limit 5 | n/a | 55 |
| J+171 | HzCtl.Hi5LimTm | Monitoring the power frequency: waiting time upper switch-off limit 5 | n/a | 10000 |
| J+172 | HzCtl.Hi6Lim | Monitoring the power frequency: upper switch-off limit 6 | n/a | 55 |
| J+173 | HzCtl.Hi6LimTm | Monitoring the power frequency: waiting time upper switch-off limit 6 | n/a | 10000 |
| J+174 | HzCtl.Lo1Lim | Monitoring the power frequency: lower switch-off limit 1 | n/a | 49 |
| J+175 | HzCtl.Lo1LimTm | Monitoring the power frequency: waiting time lower switch-off limit 1 | n/a | 1000 |
| J+176 | HzCtl.Lo2Lim | Monitoring the power frequency: lower switch-off limit 2 | n/a | 45 |
| J+177 | HzCtl.Lo2LimTm | Monitoring the power frequency: waiting time lower switch-off limit 2 | n/a | 10000 |
| J+178 | HzCtl.Lo3Lim | Monitoring the power frequency: lower switch-off limit 3 | n/a | 45 |
| J+179 | HzCtl.Lo3LimTm | Monitoring the power frequency: waiting time lower switch-off limit 3 | n/a | 10000 |
| J+180 | HzCtl.Lo4Lim | Monitoring the power frequency: lower switch-off limit 4 | n/a | 45 |
| J+181 | HzCtl.Lo4LimTm | Monitoring the power frequency: waiting time lower switch-off limit 4 | n/a | 10000 |

| | | | | |
|---|---|---|---|---|
| J+182 | HzCtl.Lo5Lim | Monitoring the power frequency: lower switch-off limit 5 | n/a | 45 |
| J+183 | HzCtl.Lo5LimTm | Monitoring the power frequency: waiting time lower switch-off limit 5 | n/a | 10000 |
| J+184 | HzCtl.Lo6Lim | Monitoring the power frequency: lower switch-off limit 6 | n/a | 45 |
| J+185 | HzCtl.Lo6LimTm | Monitoring the power frequency: waiting time lower switch-off limit 6 | n/a | 10000 |
| J+186 | VCtl.Hi1Lim | Monitoring the grid voltage: upper switch-off limit 1 | n/a | 1.15 |
| J+187 | VCtl.Hi1LimTm | Monitoring the grid voltage: waiting time upper switch-off limit 1 | n/a | 1000 |
| J+188 | VCtl.Hi2Lim | Monitoring the grid voltage: upper switch-off limit 2 | n/a | 1.3 |
| J+189 | VCtl.Hi2LimTm | Monitoring the grid voltage: waiting time upper switch-off limit 2 | n/a | 100 |
| J+190 | VCtl.Hi3Lim | Monitoring the grid voltage: upper switch-off limit 3 | n/a | 2.0 |
| J+191 | VCtl.Hi3LimTm | Monitoring the grid voltage: waiting time upper switch-off limit 3 | n/a | 10000 |
| J+192 | VCtl.Hi4Lim | Monitoring the grid voltage: upper switch-off limit 4 | n/a | 2.0 |
| J+193 | VCtl.Hi4LimTm | Monitoring the grid voltage: waiting time upper switch-off limit 4 | n/a | 10000 |
| J+194 | VCtl.Hi5Lim | Monitoring the grid voltage: upper switch-off limit 5 | n/a | 2.0 |
| J+195 | VCtl.Hi5LimTm | Monitoring the grid voltage: waiting time upper switch-off limit 5 | n/a | 10000 |
| J+196 | VCtl.Hi6Lim | Monitoring the grid voltage: upper switch-off limit 6 | n/a | 2.0 |
| J+197 | VCtl.Hi6LimTm | Monitoring the grid voltage: waiting time upper switch-off limit 6 | n/a | 10000 |
| J+198 | VCtl.Lo1Lim | Monitoring the grid voltage: lower switch-off limit 1 | n/a | 0.8 |
| J+199 | VCtl.Lo1LimTm | Monitoring the grid voltage: waiting time lower switch-off limit 1 | n/a | 1000 |
| J+200 | VCtl.Lo2Lim | Monitoring the grid voltage: lower switch-off limit 2 | n/a | 0.45 |
| J+201 | VCtl.Lo2LimTm | Monitoring the grid voltage: waiting time lower switch-off limit 2 | n/a | 300 |
| J+202 | VCtl.Lo3Lim | Monitoring the grid voltage: lower switch-off limit 3 | n/a | 0.0 |

| | | | | |
|---|---|---|---|---|
| J+203 | VCtl.Lo3LimTm | Monitoring the grid voltage: waiting time lower switch-off limit 3 | n/a | 1000 |
| J+204 | VCtl.Lo4Lim | Monitoring the grid voltage: lower switch-off limit 4 | n/a | 0.0 |
| J+205 | VCtl.Lo4LimTm | Monitoring the grid voltage: waiting time lower switch-off limit 4 | n/a | 1000 |
| J+206 | VCtl.Lo5Lim | Monitoring the grid voltage: lower switch-off limit 5 | n/a | 0.0 |
| J+207 | VCtl.Lo5LimTm | Monitoring the grid voltage: waiting time lower switch-off limit 5 | n/a | 1000 |
| J+208 | VCtl.Lo6Lim | Monitoring the grid voltage: lower switch-off limit 6 | n/a | 0.0 |
| J+209 | VCtl.Lo6LimTm | Monitoring the grid voltage: waiting time lower switch-off limit 6 | n/a | 1000 |
| J+210 | 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+211 | Spk.AmpHoldTm | Time in seconds during which the current is held to its [Pre-fault Value*Spk.AmpHoldFac(X)] **(PSS/E Specific)** | 0 – 0.1 | 0.005 |
| J+212 | 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+213 | 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 |
| J+214 | SoC. DcVolIni | SoC Model: Initial value of the DC voltage for battery in kV **(PSS/E Specific)** | n/a | 1.1 |
| J+215 | SoC. DcVolMax | SoC Model: Maximum value of the DC voltage for battery in kV **(PSS/E Specific)** | n/a | 1.3 |
| J+216 | SoC. DcVolMin | SoC Model: Minimum value of the DC voltage for battery in kV **(PSS/E Specific)** | n/a | 0.8 |
| J+217 | SoC. DcAh | SoC Model: Capacity of the battery in Ah **(PSS/E Specific)** | n/a | 1e4 |
| J+218 | DcCtl.AmpKp | DC current control, proportional amplification, Grid forming mode | n/a | 0.0 |
| J+219 | DcCtl.AmpKi | DC current control, integral amplification, Grid forming mode | n/a | 5.0 |

| | | | | |
|---|---|---|---|---|
| J+220 | DcCtl.AmpKi2Fac | DC current control, double integral amplification for DC current limit, Grid forming mode | n/a | 0.00033 |
| J+221 | DcCtl.AmpI2CtlDownGain | DC current control, additional double integral amplification, if DC current limit is not exceeded, Grid forming mode | n/a | 3.0 |

### 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 | Iinv_d_filt |
| L+135 | Iinv_q_filt |
| L+136 | VI_X |
| L+137 | VI_R |
| L+138 | AmaxSpt_Filt2 |
| L+139 | AmaxSpt_timer |
| L+140 | FFW_VolDiff_Filt |
| L+141 | FFW_VI_X1_delay |
| L+142 | VolPsDSpt_Ofs |
| L+143 | VI_AmpPsDSpt |
| L+144 | AWFFWAmpPsD |
| L+145 | VolPsQSpt_Ofs |
| L+146 | Soc_sat |
| L+147 | DCVol |
| L+148 | CtlOut_P_Dc |
| L+149 | CtlOut_I_Dc |
| L+150 | Ki_max_hold |
| L+151 | Ki_min_hold |

| | |
|---|---|
| L+152 | PiCtrlWithLimit_Output |
| L+153 | PiCtrl_Integrator |
| L+154 | PiCtrl_Integrator2 |
| L+155 | PiCtrl_Integrator3 |
| L+156 | PiCtrlWithLimit_Output |
| L+157 | PiCtrl_Integrator |
| L+158 | PiCtrl_Integrator2 |
| L+159 | PiCtrl_Integrator3 |
| L+160 | CtlOut_Dc |
| L+161 | AmpDOfs_DcLim_Stt |
| L+162 | Iinv_d_fil |
| L+163 | Iinv_q_fil |
| L+164 | Vmag_fil1 |
| L+165 | Vmag_fil2 |
| L+166 | CtlOut_P_D |
| L+167 | CtlOut_I_D |
| L+168 | Ki_max_hold |
| L+169 | Ki_min_hold |
| L+170 | PiCtrlWithLimit_Output |
| L+171 | PiCtrl_Integrator |
| L+172 | PiCtrl_Integrator2 |
| L+173 | PiCtrl_Integrator3 |
| L+174 | PiCtrlWithLimit_Output |
| L+175 | PiCtrl_Integrator |
| L+176 | PiCtrl_Integrator2 |
| L+177 | PiCtrl_Integrator3 |
| L+178 | CtlOut_D |
| L+179 | CtlOut_P_Q |
| L+180 | CtlOut_I_Q |
| L+181 | Ki_max_hold |
| L+182 | Ki_min_hold |
| L+183 | PiCtrlWithLimit_Output |
| L+184 | PiCtrl_Integrator |
| L+185 | PiCtrl_Integrator2 |
| L+186 | PiCtrl_Integrator3 |
| L+187 | PiCtrlWithLimit_Output |
| L+188 | PiCtrl_Integrator |
| L+189 | PiCtrl_Integrator2 |
| L+190 | PiCtrl_Integrator3 |
| L+191 | CtlOut_Q |
| L+192 | VirtImpEna_delay |

| | |
|---|---|
| L+193 | WAval |
| L+194 | VarAval |
| L+195 | IC1_Delay |
| L+196 | IC2_Delay |
| L+197 | IC1_Delay |
| L+198 | IC2_Delay |
| L+199 | AmpDOfs_DrtStt |
| L+200 | AmpQOfs_DrtStt |
| L+201 | WSptOut |
| L+202 | VarSptOut |
| L+203 | WSptFilt |
| L+204 | VarSptFilt |
| L+205 | Ud_filt |
| L+206 | Uq_filt |
| L+207 | AmpPsDSpt |
| L+208 | AmpPsQSpt |
| L+209 | dHz |
| L+210 | dTheta |
| L+211 | dVol |
| L+212 | Iinv_d_filt |
| L+213 | Iinv_q_filt |
| L+214 | Vmag.filt |
| L+215 | DrpAmpDFilTm_filt |
| L+216 | HPF_Filt_out_dHz |
| L+217 | dHz_HPF_delay |
| L+218 | DrpAmpDFilTm2_filt |
| L+219 | HPF_Filt_out_dHz2 |
| L+220 | dHz2_HPF_delay |
| L+221 | DrpAmpD_filt |
| L+222 | InteriaPhsCtl_Kp_filt |
| L+223 | InteriaPhsCtl_Ki_filt |
| L+224 | AmpPsD_int |
| L+225 | DrpAmpQFilTm_filt |
| L+226 | HPF_Filt_out_dVol |
| L+227 | dVol_HPF_delay |
| L+228 | DrpAmpQFilTm2_filt |
| L+229 | HPF_Filt_out_dVol2 |
| L+230 | dVol2_HPF_delay |
| L+231 | DrpAmpQ_filt |
| L+232 | InteriaVolCtl_Kp_filt |
| L+233 | InteriaVolCtl_Ki_filt |

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|---|---|
| L+234 | AmpPsQ_int |
| L+235 | dAmpD_filt |
| L+236 | DrpHz_Filt |
| L+237 | DrpTheta_Filt |
| L+238 | DrpVol_Filt |
| L+239 | Vinv_q_filt |
| L+240 | VirtImpEna_delay |
| L+241 | dHz_out |
| L+242 | dHz_filt |
| L+243 | dHz_Filt_delay1 |
| L+244 | dHz_Filt_delay2 |
| L+245 | dHz_Filt_delay3 |
| L+246 | dHz_Filt_delay4 |
| L+247 | dHz_Filt_delay5 |
| L+248 | dHz_Filt_delay6 |
| L+249 | dHz_Filt_delay7 |
| L+250 | dHz_Filt_delay8 |
| L+251 | dHz_Filt_delay9 |
| L+252 | dHz_Filt_delay10 |
| L+253 | dHz_Filt_delay11 |
| L+254 | dHz_Filt_delay12 |
| L+255 | dHz_Filt_delay13 |
| L+256 | dHz_Filt_delay14 |
| L+257 | dHz_Filt_delay15 |
| L+258 | dHz_Filt_delay16 |
| L+259 | dHz_Filt_delay17 |
| L+260 | dHz_Filt_delay18 |
| L+261 | dHz_Filt_delay19 |
| L+262 | dHz_Filt_delay20 |
| L+263 | dHz_Filt_delay21 |
| L+264 | dTheta_out |
| L+265 | dTheta_filt |
| L+266 | dTheta_Filt_delay1 |
| L+267 | dTheta_Filt_delay2 |
| L+268 | dTheta_Filt_delay3 |
| L+269 | dTheta_Filt_delay4 |
| L+270 | dTheta_Filt_delay5 |
| L+271 | dTheta_Filt_delay6 |
| L+272 | dTheta_Filt_delay7 |
| L+273 | dTheta_Filt_delay8 |
| L+274 | dTheta_Filt_delay9 |

| | |
|---|---|
| L+275 | dTheta_Filt_delay10 |
| L+276 | dTheta_Filt_delay11 |
| L+277 | dTheta_Filt_delay12 |
| L+278 | dTheta_Filt_delay13 |
| L+279 | dTheta_Filt_delay14 |
| L+280 | dTheta_Filt_delay15 |
| L+281 | dTheta_Filt_delay16 |
| L+282 | dTheta_Filt_delay17 |
| L+283 | dTheta_Filt_delay18 |
| L+284 | dTheta_Filt_delay19 |
| L+285 | dTheta_Filt_delay20 |
| L+286 | dTheta_Filt_delay21 |
| L+287 | dVol |
| L+288 | dVol_filt |
| L+289 | dVol_Filt_delay1 |
| L+290 | dVol_Filt_delay2 |
| L+291 | dVol_Filt_delay3 |
| L+292 | dVol_Filt_delay4 |
| L+293 | dVol_Filt_delay5 |
| L+294 | dVol_Filt_delay6 |
| L+295 | dVol_Filt_delay7 |
| L+296 | dVol_Filt_delay8 |
| L+297 | dVol_Filt_delay9 |
| L+298 | dVol_Filt_delay10 |
| L+299 | dVol_Filt_delay11 |
| L+300 | dVol_Filt_delay12 |
| L+301 | dVol_Filt_delay13 |
| L+302 | dVol_Filt_delay14 |
| L+303 | dVol_Filt_delay15 |
| L+304 | dVol_Filt_delay16 |
| L+305 | dVol_Filt_delay17 |
| L+306 | dVol_Filt_delay18 |
| L+307 | dVol_Filt_delay19 |
| L+308 | dVol_Filt_delay20 |
| L+309 | dVol_Filt_delay21 |
| L+310 | VolPsDSpt |
| L+311 | VolPsDSpt_rate |
| L+312 | Vinv_d |
| L+313 | Vinv_q |
| L+314 | Vinv_d_FRT |
| L+315 | Vinv_q_FRT |

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|---|---|
| L+316 | Vinv_d_filt |
| L+317 | Vinv_q_filt |
| L+318 | Vinv_d_int |
| L+319 | Vinv_q_int |
| L+320 | Iinv_d_filt |
| L+321 | Iinv_q_filt |
| L+322 | ur |
| L+323 | ui |

# 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.