Documentation

Description of the model of the

SMA Sunny Central solar inverters and

SMA Sunny Central Storage battery inverters

for EMT studies in PSCAD

Please consider the environment before you print this document.

Model Revision 10.00.13.06
Document Revision 10.11
Nov. 14, 2023

Note

The inverter model "SC xxxx" described in this document replaces all former revisions of PSCAD models of the solar inverter line Sunny Central and battery inverter line Sunny Central Storage.

Models of other inverter types are not affected and are not covered by SC xxxx.

The following PSCAD versions are currently supported:

- version 5.X (version 4.6 is still working but not recommended. Libraries are available on request)

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

- DIgSILENT PowerFactory (rms and EMT models)
- Siemens Power Technologies International PSS®E (rms models)
- General Electric International PSLF (rms models)
- Manitoba HVDC Research Centre PSCAD® (EMT model)
- PGSTech EMTP® (EMT model)
- ATP (EMT model)

Document history

Document version		Description
9.0	C.Hardt	New model release
9.2	C.Hardt	New model release
9.3	C.Hardt	New model release
9.6	C.Hardt	Model parameters
9.7	C.Hardt	New model release, model parameters
9.8	V.Sakschewski	DC coupling dynamic response improvements and model parameters
9.9	C.Hardt	New model release
10.0	V.Sakschewski	New firmware release
10.1	V.Sakschewski	DC Amp Control modus added → Electrolizer capability
10.2	V.Sakschewski	Further DC coupling dynamic response improvement
10.3	V.Sakschewski	new grid codes added
10.4	V.Sakschewski	Changes regarding 9.00.37.09
10.5	V.Sakschewski	Changes regarding 9.02.05.01
10.6	V.Sakschewski	Update Disclaimer
10.7	V.Sakschewski	Improvements for GF81 compiler
10.8	V.Sakschewski	First revision for Release 10 firmware
10.9	Ch. Hardt	DC limits added; PSCAD5 and DLL support
10.11	Ch. Hardt	MPPT parameters added

Model history

Model version	Description
9.00.00.00	Pre release R9 for GridForming studies - GridForming "Virtual impedance" mode updates - GridForming "Virtual inertia"
9.00.05.03	Country code fix (WGra, VArGra)
9.00.05.05	Internal interface work for logfile, config file (necessary due to support of EMTP)
9.00.13.04	R9 pre release version: Gridforming: parameter renamings, overcurrent functions, inertia, GridFollowing: optimized FRT entry and exit strategies
9.00.15.01	Snapshot fixed
9.00.22.02	Parameters for "VCtl_PkLimBlkPwm"
9.00.24.00	GriForm_Frt_VirtImpDlTm
9.00.26.00	Q(v) voltage initialization options
9.00.26.01	DC coupling dynamic response improvements
9.00.27.01	Fixes to precharge handling
9.00.27.02	Default parameter loading fix for "SCS 3950 UP" (Rating parameters were loaded for "SCS 3950 UP-XT-US")
9.00.28.00	Priorization in DC coupling
9.00.33.01	Further improvements regarding DC coupling
9.00.33.02	DC Amp Control modus added → Electrolizer capability
9.00.37.01	Further DC coupling dynamic response improvement
9.00.37.05	new grid codes added: US IEEE1547:2018 US IEEE1547:2018 SCS US IEEE1547:2018 + NERC US IEEE1547:2018 + NERC SCS ES TED749 GB G99 PT Portaria 73
9.00.37.09	Start ramp "WGraStr" is deactivated as default for simulation
9.02.05.01	Modifications for DC Link voltage instability
9.02.05.03	Compatibility with GF81
10.00.13.06	R10 prerelease

Model validity

This model is valid for inverters with firmware version from v10.00.13.

The inverter model "SC xxxx" described in this document is only intended for simulation of the SMA Sunny Central and Sunny Central Storage inverters listed below.

PV inverter	Storage inverter
SC 1850-EV-US	SCS 1900
SC 2000-EV-US	SCS 1900-US
SC 2000-US	SCS 2200
SC 2200	SCS 2200-US
SC 2200-US	SCS 2300 UP-XT
SC 2475	SCS 2300 UP-XT-US
SC 2500-EV	SCS 2400 UP-XT
SC 2500-EV-US	SCS 2400 UP-XT-US
SC 2660 UP	SCS 2475
SC 2660 UP-US	SCS 2475-US
SC 2750-EV	SCS 2500-EV
SC 2750-EV-US	SCS 2500-EV-US
SC 2800 UP	SCS 2530 UP-XT
SC 2800 UP-US	SCS 2530 UP-XT-US
SC 2930 UP	SCS 2630 UP-XT
SC 2930 UP-US	SCS 2630 UP-XT-US
SC 3000-EV	SCS 2750-EV
SC 3060 UP	SCS 2750-EV-US
SC 3060 UP-US	SCS 2900
SC 4000 UP	SCS 2900-US
SC 4000 UP-US	SCS 2900-US
SC 4200 UP	SCS 3000-EV
SC 4200 UP-US	SCS 3450 UP
SC 4400 UP	SCS 3450 UP-US
SC 4400 UP-US	SCS 3450 UP-XT
SC 4600 UP	SCS 3450 UP-XT-US
SC 4600 UP-US	SCS 3600 UP
	SCS 3600 UP-US
	SCS 3600 UP-XT
	SCS 3600 UP-XT-US
	SCS 3800 UP
	SCS 3800 UP-US
	SCS 3800 UP-XT
	SCS 3800 UP-XT-US
	SCS 3950 UP
	SCS 3950 UP-US
	SCS 3950 UP-XT
	SCS 3950 UP-XT-US

Contents

1 Installation requirements 8
2 Model validity 10
3 Model configuration 11
3.1 Model parameters 14
3.2 Runtime Parameter Update (RTUpd) 37
3.3 Transformer parameters 38
3.4 PPC parameters 38
3.5 Power Plant Manager / Hybrid Controller parameters 38
3.6 Runtime Messages 39
4 Special inverter functions for dynamic simulation 40
4.1 Active power control 40
4.1.1 Over Frequency-dependent active power *P*(*f*) – PV inverters 40
4.1.2 Under Frequency-dependent active power *P*(*f*) – PV inverters 40
4.2 Reactive power control 41
4.2.1 Reactive power provision by power factor set-point 41
4.2.2 Reactive power provision by Q set-point 42
4.2.3 Voltage-dependent reactive power Q(*U*) 42
4.3 Dynamic grid support 42
4.3.2 Dynamic grid support “limited/partial” 43
4.3.3 Dynamic grid support “Momentary Cessation” 43
4.4 Decoupling protection 43
4.4.1 Voltage decoupling protection 43
4.4.2 Frequency decoupling protection 44
4.4.3 PLL freeze logic 45
4.5 Power as a function of frequency, PV inverters – new functionality 45
4.5.1 Power as a function of frequency, battery inverters – new functionality 45
4.6 DC current and voltage limitation for SCS inverters 47
5 Model start-up 49

6 Debug Interface 51

7 Disclaimer 54

1 Installation requirements

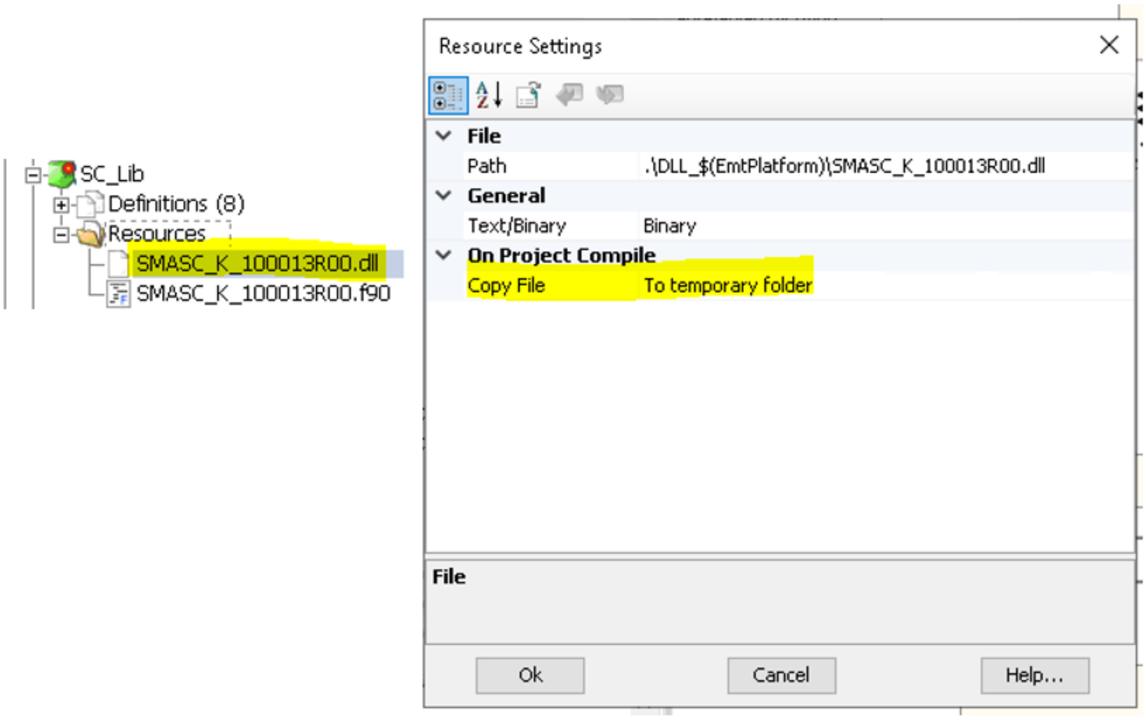
The model can run with GFortran or Intel Visual Fortran compiler. To the best of our knowledge, the Intel Fortran compiler has a speed advantage over the GFortran compiler coming with PSCAD5. We tested the model with Intel Visual Fortran 11 and higher.

The model has only been tested on Windows 10 64 bit machines.

The model package includes files listed in the table below.

SC_xxxx_VX_X_XX_PV_PPC.pscx	Demo case containing the inverters and a simple Power Plant Controller (PPC)
SMA_Workspace.pswx	PSCAD workspace file for the Demo case
SC_Lib.pslx	PSCAD library file containing the switched SC/SCS inverter model – inverter IGBT bridge modelled
SCAvg_Lib.pslx	PSCAD library file containing the averaged SC/SCS inverter model – inverter IGBT bridge averaged with voltage sources
DLL_x64/SMASC_K_[version].dll	Dynamic linked library for 64 bit
DLL_x86/SMASC_K_[version].dll	Dynamic linked library for 32 bit
DLL_x64/ SMASC_K_[version].f90	Fortran dll interface file
DLL_x86/ SMASC_K_[version].f90	Fortran dll interface file
Default.txt	Example configuration file
CfgFile[1..200].txt	Up to 200 different user configuration files can be used with the model – not provided in the package
SMA_Tools.pslx	PSCAD library containing helpful function blocks (e.g. for setting of the grid parameters)

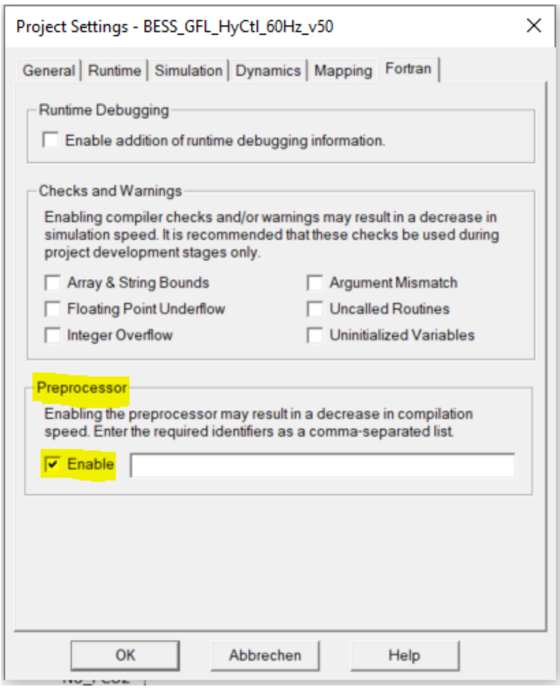
All these files must be placed in the working directory of PSCAD and the Dll files and f90 files have to be included under “Resources” on either the model case or in the library (recommended).



Since there is a common request in many markets to migrate to dynamic link libraries (.dll files) SMA switched to this integration method for PSCAD5. The DLL files can be included in PSCAD5 and be used with Intel Fortran as well as GFortran8.1.

Static libraries are still generated by SMA and are only available on request.

To be able to detect which compiler is used the following feature of PSCAD MUST be turned on:



Do not try to start the PSCAD project from a network drive. Please put it on your hard disk drive.

2 Model validity

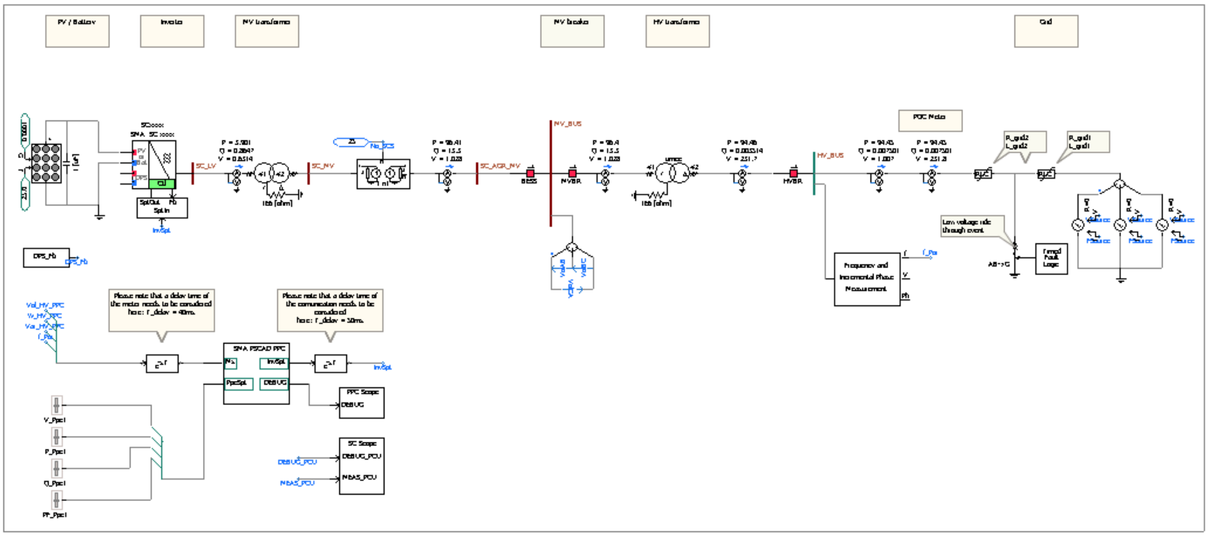
The model described in this document is intended for EMT type simulations of electrical energy systems deploying equipment from SMA Solar Technology AG.

In dynamic simulations the simulation step width must not be greater than 16.66667 µs. In general, 1.666667 or 16.66667 µs are good choices for the simulation step width and other values should not be chosen.

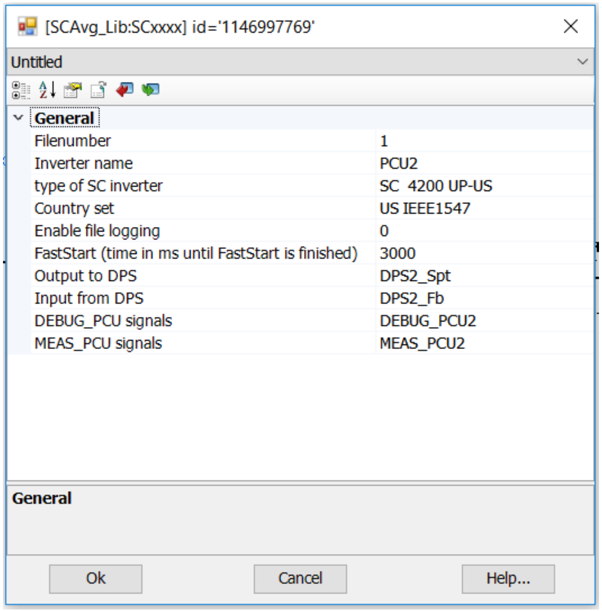
The model should only be used for simulation of phenomena occurring on the AC side of the inverter. It should not be used for simulations of the DC side, e.g. the connection of different photovoltaic modules to the equipment. It should also not be used for simulations of different weather conditions or irradiation effects or any other long-term phenomena.

3 Model configuration

The demo model "SC_xxxx_VX_X_XX_PV_PPC.pscx" contains one Sunny Central UP that consist of a SC solar inverter and LV transformer. This system is scaled with a scaling element to 25 times the power class of the selected inverter on the MV side. The Point of Connection (POC) on HV side is controlled with a Power Plant Manager / HybridController (PPM/HyCon).



To select the required inverter type, right click on the inverter symbol and select "Edit Parameters...". Changing from one inverter type to another requires adaptation of the DC voltage (PV array or battery) and the MV transformer (power rating, voltage level) according to the inverter's data sheet. Refer to inverter data sheet for more details.



User can also set the parameter (configuration) file for each inverter in the model.

Filenumber	Filename in the model directory
0	Default.txt
1	CfgFile1.txt*
2	CfgFile2.txt*
3	CfgFile3.txt*
…	…
200	CfgFile200.txt*

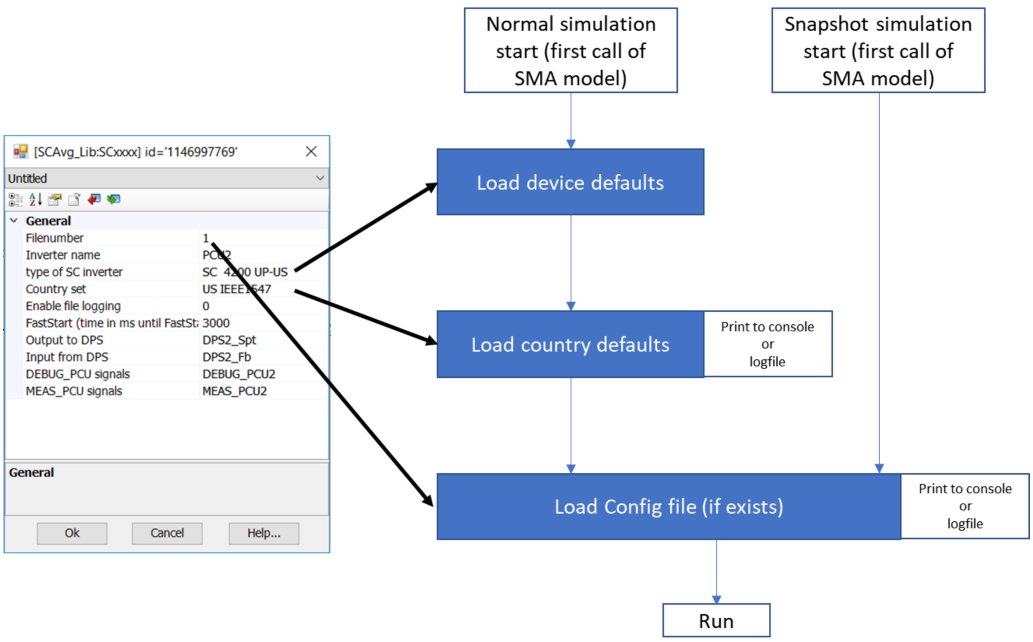
*The configuration files can be created by copying the "Default.txt" file and changing the content.

Please note the 'Default.txt' file contains example inverter settings not the actual default values in given firmware version.

If no configuration file is found the model runs with default inverter parameters in the given firmware version.

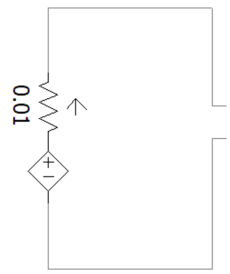
Beginning with version 8 of the model it is possible to load specific country parameter sets as in the real inverter (e.g. US IEEE1574 and more). The model prints these parameters and their default values either on the PSCAD runtime console or into a logging file in case "Enable file logging" is set to 1. The content of this file or parts of it can be transferred into the user specific config file and used as a starting point for changing project specific parameters.

The following figure gives an overview on the parameter loading sequence.



In case the simulation is started from a snapshot file (only possible with Intel Fortran compilers!!) the model reloads the project specific config file in the first timestep. Changes to the content or even changing the number of the file to load will affect the parameterization.

To simulate the storage SCS inverter the correct SCS inverter type must be selected via the “Edit Parameters....” menu and the DC source changed to represent the battery. Example of what the DC side may look like in this scenario is shown below.



For extracting the DEBUG_PCU and MEAS_PCU use the “SC DEBUG” scope block from the SC_Lib.pslx. Description of the available DEBUG signals is in Chapter 6.

“Input from DPS” and “Output to DPS” are needed for data exchange between the SMA DC/DC converter and the SMA Sunny Central PV inverter.

3.1 Model parameters

This section provides example parameters settings as provided in the example config file. Project specific parameter settings must be selected via studies.

Please note:

- Each inverter type has a set of default parameters for each firmware version. The parameters below and in example config file are just example settings and are NOT the default inverter/firmware parameters.
- Parameter values are not selected for any specific inverter type – settings should be crosschecked with inverter's datasheet to ensure the values are within the inverter's capability, e.g. the voltage/frequency protection times and levels.
- Most of the parameter names reflect the parameter names of the real inverter. In the real device the "_" is replaced by ".".
- Model specific parameters that are not present in real inverter are marked as such.
- **Most of the non-binary parameters can only have 2 decimal places unless otherwise stated – if more resolution is required please check with SMA.**

	Parameter	Description	Unit	Range	Example setting
		External set-points Setpoint interface: 1: WSpt (pu) 2: VArSpt (pu) 3: PFSpt 4: VolSpt (pu) 5: HzSpt (Hz) 6: SCSOpCmd 381:Stop 21415:Inverter Standby 21416:Power control 21417:DC voltage 21418:DC Amp control 21521:Gridforming P/f and Q/V droop 22321:GridForming angle inertia and Q/V Droop 22322:GridForming P/f droop and voltage Inertia 22323:GridForming angle inertia and voltage inertia 7: WSptMin (pu) 8: BatWSptMax (pu) 9: BatWSptMin (pu) 10: DCAmpSpt (A) 11: DCVolSpt (V) 12: RTUpd_UID 13: RTUpd_Value 14: ErrClr 15: Reserved 16: Reserved 17: Reserved			
1	WSpt	Active power set-point (from park controller or grid operator)	p.u. WRtg	-1 ... 1	1
2	VArSpt	Reactive power set-point (from park controller or grid operator)	p.u. VArRtg	-1 ... 1	0
3	PFSpt	Power factor set-point (from grid operator)	1	-1... 1	1

4	VolSpt	AC Voltage set-point (from grid operator)	p.u. VolRtg	0.0... 1.1	1
5	HzSpt	AC frequency set-point	Hz	45-65	50Hz/60Hz
6	SCSOpCmd (for SCS inverters)	Operation Command, used to define behavior of battery inverters Input needs to be activated via config file parameter "UseSCSOpCmd" 381: Stop 21415: Inverter Standby 21416: Power control 21417: DC voltage control 21418: DC Amp control 21521: GridForming Frequency Droop and Voltage Droop 22321: GridForming Angle Inertia and Voltage Droop 22322: GridForming Frequency Droop and Voltage Inertia 22323: GridForming Angle Inertia and Voltage Inertia			
7	WSptMin	Minimum active power setpoint for inverter when DC coupling is used	p.u. WRtg	-1 ... 1	
8	BatWSptMax	Maximum power set point for battery inverters when DC coupling is used	p.u. WRtg	-5 ... 5	Value can be lower/higher than +-1.0pu since DC coupled power can exceed WRtg
9	BatWSptMin	Minimum power set point for battery inverters when DC coupling is used	p.u. WRtg	-5 ... 5	Value can be lower/higher than +-1.0pu since DC coupled power can exceed WRtg
10	DCAmpSpt	DC current set point	A	-10000 10000	
11	VolSpt	DC voltage setoint	V		
12	RTUpd_UID	Runtime parameter update Unique Identifier of parameter (See chapter)			
13	RTUpd_Value	Runtime parameter update Value to set (See chapter 3.2)			

14	ErrClr	Clear inverter errors. Changing the counter to a different value acknowledges errors			
	Parameter	**Description**	**Unit**	**Range**	**Initial setting in example config file**
	General inverter parameters – if the Rtg parameters are commented out with the # the value corresponding to the inverter type selected via inverter mask in the model is used				
	VARtg	Nominal apparent power	kVA		Depends on inverter type
	WRtg	Nominal active power	kW		Depends on inverter type
	VArRtg	Nominal reactive power	kVAr		Depends on inverter type
	VolRtg	Nominal voltage	V		Depends on inverter type
	AmpRtg	Nominal current	A		Depends on inverter type
	HzRtg	Nominal grid frequency	Hz	45 ... 65	50
	VADrtPriMod	Priority of power injection VADRTPRIMOD_ VAR = reactive, VADRTPRIMOD_W = active			VADRTPRIMOD_ VAR
	GriMng_InvVArMod	Generation of reactive power set-point by inverter GRIMNG_INVVARMOD_OFF = reactive power set-point = 0, GRIMNG_INVVARMOD_VARCTLVOL = VArCtlVol /Q(U), inverter level voltage control			GRIMNG_INVVARMOD_OFF
	VArOpMod	Activation of external set-point for reactive power VAR_MOD_NONE = reactive power set-point = 0, VAR_MOD_CNST = external reactive power set-point, VAR_MOD_PF_CNST = external power factor set-point			VAR_MOD_CNST

	VArExlSpt_RefMod	Reactive power external setpoint, reference mode VAREXLSPTREFMOD_VARRTG = VArRtg as reference VAREXLSPTREFMOD_VARTG = VARtg as reference			VAREXLSPTREFMOD_VARRTG
	InvCtlMod	Inverter Control Mode for Firmware INVCTLMOD_GRIFEED_MPP = PV Inverter INVCTLMOD_BAT = Battery Inverter (SCS) INVCTLMOD_GRIFEED_DCLVOLCNST = constant DC link voltage			INVCTLMOD_GRIFEED_MPP
Dynamic grid support/Fault Ride Through (FRT) parameters (LVRT + HVRT)					
	Frt_Mod	SPT_FRT_DISABLE = no support, SPT_FRT_MOD_FULL = reactive current support (active current if possible), SPT_FRT_PARTIAL = gate blocking, SPT_FRT_MOD_AMPDCNST = active current constant, SPT_FRT_MOD_LOAMP = reduce current to 0 (momentary cessation) SPT_FRT_MOD_AMPDMAX = reactive current support (active current if possible) -> maximize active current even higher than prefault active current value			SPT_FRT_MOD_FULL
	Frt_LoGra1	Gradient starting from reference voltage 1 (LVRT). **2 decimal places only for all FRT gradients.**	p.u. AmpRtg/p.u. VolRtg	0 ... 2	0

	Frt_LoGra2	Gradient starting from reference voltage 2 (LVRT)	p.u. AmpRtg/p.u. VolRtg	0 ... 2	2
	Frt_LoGra3	Gradient starting from reference voltage 3 (LVRT)	p.u. AmpRtg/p.u. VolRtg	0 ... 2	2
	Frt_HiGra1	Gradient starting from reference voltage 1 (HVRT)	p.u. AmpRtg/p.u. VolRtg	0 ... 2	0
	Frt_HiGra2	Gradient starting from reference voltage 2 (HVRT)	p.u. AmpRtg/p.u. VolRtg	0 ... 2	2
	Frt_HiGra3	Gradient starting from reference voltage 3 (HVRT)	p.u. AmpRtg/p.u. VolRtg	0 ... 2	2
	Frt_LoVolRef1	Reference voltage points for LVRT, have to be monotonically decreasing. **Only 2 decimal places for all reference voltages are possible.**	p.u. VolRtg	0 ... 1	1
	Frt_LoVolRef2	Reference voltage points for LVRT, have to be monotonically decreasing	p.u. VolRtg	0 ...1	0.9
	Frt_LoVolRef3	Reference voltage points for LVRT, have to be monotonically decreasing	p.u. VolRtg	0 ... 1	0
	Frt_HiVolRef1	Reference voltage points for HVRT, have to be monotonically increasing	p.u. VolRtg	1 ... 2	1
	Frt_HiVolRef2	Reference voltage points for HVRT, have to be monotonically increasing	p.u. VolRtg	1 ... 2	1.1
	Frt_HiVolRef3	Reference voltage points for HVRT, have to be monotonically increasing	p.u. VolRtg	1 ... 2	2
	Frt_LoDb	Dead band limits for LVRT - activation of FRT if voltage leaves LVRT – HVRT deadband. **2 decimal**	p.u. VolRtg	0 ... 1	0.9

		places for FRT deadband parameters.			
	Frt_HiDb	Dead band limits for HVRT – activation of FRT if voltage leaves LVRT – HVRT deadband	p.u. VolRtg	1 ... 1.5	1.1
	Frt_HystEna	Enable FRT deadband hysteresis SWITCH_STT_DISABLE = hysteresis disabled SWITCH_STT_ENABLE = hysteresis enabled			SWITCH_STT_DISABLE
	Frt_LoDbHyst	Band limit for LVRT, deactivation of FRT if voltage enters band	p.u. VolRtg		0.9
	Frt_HiDbHyst	Band limit for HVRT, deactivation of FRT if voltage enters band	p.u. VolRtg		1.1
	Frt_VolDFilTm	Time constant positive sequence voltage adaption	s	0 ... 600	1, reduced due to short term simulation
	Frt_VolFilMod	Reference voltage in case of FRT FRTVOLFILMOD_PT1 = voltage adaption via parameter Frt_VolDFilTm, FRTVOLFILMOD_VOLRTG= voltage rating			FRTVOLFILMOD_PT1
	Frt_WaitTmHi	Hvrt delay time	s	**0.2** ... 20	0.5
	Frt_WaitTmLo	Lvrt delay time	s	**0.2** ... 20	0.5
	Frt_WaitTm (only for backwards compatibility, pls. don´t use anymore)	Hvrt/Lvrt delay time – when this parameter in set both Frt_WaitTmHi and Frt_WaitTmLo are set to this value.	s	**0.2** ... 20	0.5
	Frt_AmpDGra	Active current gradient after voltage recovery	p.u./s	0.1...15	0.5 NER: >10
	Frt_AmpQGra	Maximum reactive current increase after FRT	p.u. AmpDQRtg/s	0.001 ... 1000	0.02

	Frt_AmpDLim	Maximum total active current during FRT	pu	0.1 ... 2.0	2.0 (values >1.0 turn limit function to off)
	Frt_AmpQLim	Maximum total reactive current during FRT	pu	0.1 ... 2.0	2.0 (values >1.0 turn limit function to off)
	Frt_AmpQFilTm	Filter time constant for reactive current, set to 1 for simulation of FRT	s	0...600	1
	Frt_VolDFilTm	Filter time constant for reference voltage averaging, set to 1 for simulation of FRT	s	0...600	1
	Frt_VolDFilBlkTm	FRT: maximum blocking time of the voltage adjustment filter during FRT	s	0...1000	40
ROCOF protection					
	HzCtl_DifMaxTm	Waiting time of the maximum permissible alteration rate	ms	0...1000000	1000
	HzCtl_DifMax	Maximum permissible alteration rate	Hz/s	0...50	50
Active power depending on frequency – SC PV inverters. Previous functionality. – if PPC is present this functionality is usually disabled in inverter					
	GriMng_HzFilTm	Time constant frequency filter WCtlHz, WCtlLoHz	s	0.1 ... 5	0.1
	WCtlHzMod	Activation of WCtlHz-function for overfrequency, SWITCH_STT_DISABLE = inactive, SWITCH_STT_ENABLE = active			SWITCH_STT_DISABLE
	WCtlHz_DrgIndMod	Activation drag indicator for when the frequency is decreasing from overfrequency event SWITCH_STT_DISABLE = inactive, SWITCH_STT_ENABLE = active			SWITCH_STT_DISABLE
	WCtlHz_RefMod	WCTLHZREFMOD_W = current active power,			WCTLHZREFMOD_W

		WCTLHZREFMOD_WNOM = nominal active power, WCTLHZREFMOD_VANOM = nominal apparent power			
	WCtlHz_Hz1	Start frequency first area of characteristic. **3 decimal places are possible for frequencies.in this function.**	Hz	0 ... 65	50.2
	WCtlHz_Hz2	Start frequency second area of characteristic	Hz	0 ... 65	65
	WCtlHz_Hz3	Start frequency third area of characteristic	Hz	0 ... 65	65
	WCtlHz_Hz4	Start frequency fourth area of characteristic	Hz	0 ... 65	65
	WCtlHz_HzGra1	Power gradient first frequency area	p.u. Wref*/Hz	0 ... 10	0.4
	WCtlHz_HzGra2	Power gradient second frequency area	p.u. Wref*/Hz	0 ... 10	0
	WCtlHz_HzGra3	Power gradient third frequency area	p.u. Wref*/Hz	0 ... 10	0
	WCtlHz_HzStopMin	Lower limit stop band	Hz	0 ... 65	0
	WCtlHz_HzStopMax	Upper limit stop band	Hz	0 ... 65	50.05
	WCtlHz_HzStopTm	Stop band - minimum dwell time of frequency (measurement value)	ms	0 ... 1000000	0
	WCtlHz_ WGraPosEna	Activation positive gradient for active power set-point 0 = inactive, 1 = active	1	0 / 1	0
	WCtlHz_ WGraNegEna	Activation negative gradient for active power set-point 0 = inactive, 1 = active	1	0 / 1	0
	WCtlHz_WGraPos	Positive gradient active power set-point	p.u. WRtg/s	0 ... 10	1

	WCtlHz_WGraNeg	Negative gradient active power set-point	p.u. WRtg/s	0 ... 10	1
	WCtlHz_HzQtlIntv	Quantization interval measurement value frequency	Hz	0 ... 0.1	0
	WCtlHz_CfgMod	WCTLHZCONFIGMOD_HZGRA = setting gradients, WCTLHZCONFIGMOD_W = setting power values			WCTLHZCONFIGMOD_HZGRA
	WCtlHz_W2	Active power at start of second area	p.u. WRef*	0 ... 1	0
	WCtlHz_W3	Active power at start of third area	p.u. WRef*	0 ... 1	0
	WCtlHz_W4	Active power at start of fourth area	p.u. WRef*	0 ... 1	0
	WCtlHz_EnaTm	Waiting time for activation (On delay)	ms	0 ... 1000000	0
	WCtlLoHzMod	Activation of WCtlLoHz-function for underfrequency, SWITCH_STT_DISABLE = inactive, SWITCH_STT_ENABLE = active			SWITCH_STT_DISABLE
	WCtlLoHz_DrgIndEna	Activation drag indicator for when the frequency is increasing SWITCH_STT_DISABLE = inactive, SWITCH_STT_ENABLE = active			SWITCH_STT_DISABLE
	WCtlLoHz_RefMod	WCTLHZREFMOD_W = current active power, WCTLHZREFMOD_WNOM = nominal active power, WCTLHZREFMOD_VANOM = nominal apparent power			WCTLHZREFMOD_W
	WCtlLoHz_Hz1	Start frequency first area of characteristic	Hz	0 ... 65	49.8
	WCtlLoHz_Hz2	Start frequency second area of characteristic	Hz	0 ... 65	45
	WCtlLoHz_Hz3	Start frequency third area of characteristic	Hz	0 ... 65	45

	WCtlLoHz_Hz4	Start frequency fourth area of characteristic	Hz	0 ... 65	45
	WCtlLoHz_HzGra1	Power gradient first frequency area	p.u. Wref*/Hz	0 ... 10	0.4
	WCtlLoHz_HzGra2	Power gradient second frequency area	p.u. Wref*/Hz	0 ... 10	0
	WCtlLoHz_HzGra3	Power gradient third frequency area	p.u. Wref*/Hz	0 ... 10	0
	WCtlLoHz_HzStopMin	Lower limit stop band	Hz	0 ... 65	49.95
	WCtlLoHz_HzStopMax	Upper limit stop band	Hz	0 ... 65	65
	WCtlLoHz_HzStopTm	Stop band - minimum dwell time of frequency (measurement value)	ms	0 ... 1000000	0
	WCtlLoHz_ WGraPosEna	Activation positive gradient for active power set-point 0 = inactive, 1 = active	1	0 / 1	1
	WCtlLoHz_ WGraNegEna	Activation negative gradient for active power set-point 0 = inactive, 1 = active	1	0 / 1	1
	WCtlLoHz_WGraPos	Positive gradient active power set-point	p.u. WRtg/s	0 ... 10	10
	WCtlLoHz_WGraNeg	Negative gradient active power set-point	p.u. WRtg/s	0 ... 10	10
	WCtlLoHz_HzQtlIntv	Quantization interval measurement value frequency	Hz	0 ... 0.1	0
	WCtlLoHz_CfgMod	WCTLHZCONFIGMOD_HZGRA = setting gradients, WCTLHZCONFIGMOD_W = setting power values			WCTLHZCONFIGMOD_ HZGRA
	WCtlLoHz_W2	Active power at start of second area	p.u. WRef*	0 ... 1	0
	WCtlLoHz_W3	Active power at start of third area	p.u. WRef*	0 ... 1	0

	WCtlLoHz_W4	Active power at start of fourth area	p.u. WRef*	0 ... 1	0
* WRef depends on WCtlHz_RefMod/ WCtlLoHz_RefMod and can be VARtg, WRtg or instantaneous measurement value of active power.					
Active power as a function of frequency – SC PV inverters. New functionality for AR-41XX and other standards – if PPC is present this functionality is usually disabled in inverter					
	WCtlHzLoHiMod	Activation of frequency-dependent active power control in case of over-/underfrequency SWITCH_STT_DISABLE = not activated SWITCH_STT_ENABLE = activated			SWITCH_STT_DISABLE
	WCtlHzLoHi_DrgIndOvEna	In case of overfrequency: activation of behavior when frequency is decreasing SWITCH_STT_DISABLE = not activated SWITCH_STT_ENABLE = activated			SWITCH_STT_DISABLE
	WCtlHzLoHi_DrgIndUnEna	In case of underfrequency: activation pf behavior when frequency is increasing SWITCH_STT_DISABLE = not activated SWITCH_STT_ENABLE = activated			SWITCH_STT_DISABLE
	WCtlHzLoHi_HzOv1	Overfrequency: cut off frequency of the 1st radio spectrum	Hz	0…70	50.02
	WCtlHzLoHi_HzOv2	Overfrequency: cut off frequency of the 2nd radio spectrum	Hz	0…70	65
	WCtlHzLoHi_HzOv3	Overfrequency: cut off frequency of the 3rd radio spectrum	Hz	0…70	65
	WCtlHzLoHi_HzOvGra1	Overfrequency: gradient of the 1st radio spectrum	%/Hz	-1000…0	-40
	WCtlHzLoHi_HzOvGra2	Overfrequency: gradient of the 2nd radio spectrum	%/Hz	-1000…0	0
	WCtlHzLoHi_HzOvGra3	Overfrequency: gradient of the 3rd radio spectrum	%/Hz	-1000…0	0
	WCtlHzLoHi_HzStopMax	Upper cutoff frequency of the return area	Hz	0…70	50.2
	WCtlHzLoHi_HzStopMin	Lower cut off frequency of the return area	Hz	0...70	49.8
	WCtlHzLoHi_HzStopTm	Minimum period that the power frequency must remain in the return area	s	0...1000	0
	WCtlHzLoHi_HzUn1	Underfrequency: cutoff frequency of the 1st radio spectrum	Hz	0…70	49.8
	WCtlHzLoHi_HzUn2	Underfrequency: cutoff frequency of the 2nd radio spectrum	Hz	0…70	45
	WCtlHzLoHi_HzUn3	Underfrequency: cutoff frequency of the 3rd radio spectrum	Hz	0…70	45

	WCtlHzLoHi_HzUnGra1	Underfrequency: gradient of the 1st radio spectrum	%/Hz	-1000…0	-40
	WCtlHzLoHi_HzUnGra2	Underfrequency: gradient of the 2nd radio spectrum	%/Hz	-1000…0	0
	WCtlHzLoHi_HzUnGra3	Underfrequency: gradient of the 3rd radio spectrum	%/Hz	-1000…0	0
	WCtlHzLoHi_OvGraWRefMod	Overfrequency: Active power reference for the gradient, WCTLHZLOHI_WREFMOD_WNOM, WCTLHZLOHI_WREFMOD_WSNPTMAX			WCTLHZLOHI_WREFMOD_WNOM
	WCtlHzLoHi_UnGraWRefMod	Underfrequency: Active power reference for the gradient, WCTLHZLOHI_WREFMOD_WNOM, WCTLHZLOHI_WREFMOD_WSNPTMAX			WCTLHZLOHI_WREFMOD_WNOM
	WCtlHzLoHi_WGra	Gradient for the active power setpoint	%/minute	0…600000	9
	WCtlHzLoHi_WSptDl	Minimum duration outside of normal frequency range until start of WCtlHzLoHi	ms	0…500	0
	WCtlHzLoHi_WSptFilTm	Filter time constant (3*tau)	s	0.001…100	0.001
Active power as a function of frequency (WCtlHzBat) – SCS battery inverters					
	WCtlHzBatMod	P(f) function activation in battery inverter SWITCH_STT_ENABLE = activated SWITCH_STT_DISABLE = deactivated			SWITCH_STT_DISABLE
	WCtlHzBat_Hz1	Active power droop point 1 on Hz-axis	Hz	0…70	44.0
	WCtlHzBat_Hz2	Active power droop point 2 on Hz-axis	Hz	0…70	46.0
	WCtlHzBat_Hz3	Active power droop point 3 on Hz-axis	Hz	0…70	48.0
	WCtlHzBat_Hz4	Active power droop point 4 on Hz-axis	Hz	0…70	49.5
	WCtlHzBat_Hz5	Active power droop point 5 on Hz-axis	Hz	0…70	50.5

	WCtlHzBat_Hz6	Active power droop point 6 on Hz-axis	Hz	0…70	52.0
	WCtlHzBat_Hz7	Active power droop point 7 on Hz-axis	Hz	0…70	54.0
	WCtlHzBat_Hz8	Active power droop point 8 on Hz-axis	Hz	0…70	56.0
	WCtlHzBat_W1	Active power droop point 1 on W-axis	p.u. WRtg	-1…1	1.0
	WCtlHzBat_W2	Active power droop point 2 on W-axis	p.u. WRtg	-1…1	0.7
	WCtlHzBat_W3	Battery operation: Active power droop point 3 on W-axis	p.u. WRtg	-1…1	0.2
	WCtlHzBat_W4	Active power droop point 4 on W-axis	p.u. WRtg	-1…1	0.0
	WCtlHzBat_W5	Active power droop point 5 on W-axis	p.u. WRtg	-1…1	0.0
	WCtlHzBat_W6	Active power droop point 6 on W-axis	p.u. WRtg	-1…1	-0.2
	WCtlHzBat_W7	Active power droop point 7 on W-axis	p.u. WRtg	-1…1	-0.7
	WCtlHzBat_W8	Active power droop point 8 on W-axis	p.u. WRtg	-1…1	-1.0
Parameters power gradient for irradiation increase					
	AmpGra	Gradient for current increase during irradiance increase	p.u. AmpRtg/s	>0 ... 100	0.1
	AmpGraMod	Activation of gradient for irradiation increase SWITCH_STT_ENABLE = active SWITCH_STT_DISABLE = inactive			SWITCH_STT_DISABLE
Parameters for reactive power gradient					
	VArGraMod	Activation reactive power gradient SWITCH_STT_ENABLE = active SWITCH_STT_DISABLE = inactive			SWITCH_STT_ENABLE
	VArGra	Gradient reactive power set-point	p.u. VARtg/s	0 ... 2	0.2

Parameters for active power gradient					
	WGraStr	Gradient for start	p.u. VARtg/s		
	WGraMod	Activation active power gradient SWITCH_STT_ENABLE = active SWITCH_STT_DISABLE = inactive			SWITCH_STT_ENABLE
	WGra	Gradient active power set-point	p.u. VARtg/s	0 ... 10	1
	DcAmpSptGra	Gradient dc current set-point SCSOpCmd: 21418	A/s		500
Over/under frequency protection					
	HzCtl_OpMaxNom	Upper frequency limit for connection. Grid code dependent. This parameter in real inverter will be changed to a grid code dependent value during commissioning. PSCAD model does not have to be amended.	Hz	45 ... 65	50.5
	HzCtl_OpMinNom	Lower frequency limit for connection. Grid code dependent. This parameter in real inverter will be changed to a grid code dependent value during commissioning. PSCAD model does not have to be amended.	Hz	45 ... 65	49.3
	HzCtl_OpMaxNom-Recon	Upper frequency limit for connection after grid fault. Grid code dependent. This parameter in real inverter will be changed to a grid code dependent value during commissioning. PSCAD model does not have to be amended.	Hz	45 ... 65	50.5
	HzCtl_OpMinNomRecon	Lower frequency limit for connection after grid fault. Grid code dependent. This parameter in real inverter will be changed to a grid code dependent value during commissioning. PSCAD model does not have to be amended.	Hz	45 ... 65	49.3

	HzCtl_CorrTm	Correction of the internal delay of the measurement algorithms, all HzCtl_ protection times are corrected by the given time	ms		NER, AR-41XX: 0 IEEE1547: -55
	HzCtl_Hi1Lim	Upper frequency limit stage 1. **2 decimal places only for all limits.**	Hz	45 ... 65	51
	HzCtl_Hi1LimTm	Waiting time upper limit stage 1	ms	0 ... 1000000	1000
	HzCtl_Hi2Lim	Upper frequency limit stage 2	Hz	45 ... 65	55
	HzCtl_Hi2LimTm	Waiting time upper limit stage 2	ms	0 ... 1000000	10000
	HzCtl_Hi3Lim	Upper frequency limit stage 3	Hz	45 ... 65	55
	HzCtl_Hi3LimTm	Waiting time upper limit stage 3	ms	0 ... 1000000	10000
	HzCtl_Hi4Lim	Upper frequency limit stage 4	Hz	45 ... 65	55
	HzCtl_Hi4LimTm	Waiting time upper limit stage 4	ms	0 ... 1000000	10000
	HzCtl_Hi5Lim	Upper frequency limit stage 5	Hz	45 ... 65	55
	HzCtl_Hi5LimTm	Waiting time upper limit stage 5	ms	0 ... 1000000	10000
	HzCtl_Hi6Lim	Upper frequency limit stage 6	Hz	45 ... 65	55
	HzCtl_Hi6LimTm	Waiting time upper limit stage 6	ms	0 ... 1000000	10000
	HzCtl_Lo1Lim	Lower frequency limit stage 1	Hz	45 ... 65	49
	HzCtl_Lo1LimTm	Waiting time upper limit stage 1	ms	0 ... 1000000	1000
	HzCtl_Lo2Lim	Lower frequency limit stage 2	Hz	45 ... 65	45
	HzCtl_Lo2LimTm	Waiting time upper limit stage 2	ms	0 ... 1000000	10000
	HzCtl_Lo3Lim	Lower frequency limit stage 3	Hz	45 ... 65	45
	HzCtl_Lo3LimTm	Waiting time upper limit stage 3	ms	0 ... 1000000	10000
	HzCtl_Lo4Lim	Lower frequency limit stage 4	Hz	45 ... 65	45

	HzCtl_Lo4LimTm	Waiting time upper limit stage 4	ms	0 ... 1000000	10000
	HzCtl_Lo5Lim	Lower frequency limit stage 5	Hz	45 ... 65	45
	HzCtl_Lo5LimTm	Waiting time upper limit stage 5	ms	0 ... 1000000	10000
	HzCtl_Lo6Lim	Lower frequency limit stage 6	Hz	45 ... 65	45
	HzCtl_Lo6LimTm	Waiting time upper limit stage 6	ms	0 ... 1000000	10000
Over/under voltage protection					
	VCtl_OpMaxNom	Upper voltage limit for connection. Grid code dependent. This parameter in real inverter will be changed to a grid code dependent value during commissioning. PSCAD model does not have to be amended.	p.u. VolRtg	0 ... 2	1.10
	VCtl_OpMinNom	Lower voltage limit for connection. Grid code dependent. This parameter in real inverter will be changed to a grid code dependent value during commissioning. PSCAD model does not have to be amended.	p.u. VolRtg	0 ... 2	0.90
	VCtl_OpMaxNomRecon	Upper voltage limit for connection after grid fault. Grid code dependent. This parameter in real inverter will be changed to a grid code dependent value during commissioning. PSCAD model does not have to be amended.	p.u. VolRtg	0 ... 2	1.10
	VCtl_OpMinNomRecon	Lower voltage limit for connection after grid fault. Grid code dependent. This parameter in real inverter will be changed to a grid code dependent value during commissioning. PSCAD model does not have to be amended.	p.u. VolRtg	0 ... 2	0.90
	VCtl_CorrTm	Correction of the internal delay of the measurement algorithms, all	ms		NER, AR-41XX: 0

		VCtl_ protection times are corrected by the given time			IEEE1547: -33
	VCtl_Hi1Lim	Upper voltage limit stage 1. **2 decimal places only for all limits.**	p.u. VolRtg	0 ... 2	1.2
	VCtl_Hi1LimTm	Waiting time upper limit stage 1	ms	0 ... 1000000	10000
	VCtl_Hi2Lim	Upper voltage limit stage 2	p.u. VolRtg	0 ... 2	1.3
	VCtl_Hi2LimTm	Waiting time upper limit stage 2	ms	0 ... 1000000	16000
	VCtl_Hi3Lim	Upper voltage limit stage 3	p.u. VolRtg	0 ... 2	1.35
	VCtl_Hi3LimTm	Waiting time upper limit stage 3	ms	0 ... 1000000	10000
	VCtl_Hi4Lim	Upper voltage limit stage 4	p.u. VolRtg	0 ... 2	2
	VCtl_Hi4LimTm	Waiting time upper limit stage 4	ms	0 ... 1000000	10000
	VCtl_Hi5Lim	Upper voltage limit stage 5	p.u. VolRtg	0 ... 2	2
	VCtl_Hi5LimTm	Waiting time upper limit stage 5	ms	0 ... 1000000	10000
	VCtl_Lo1Lim	Lower voltage limit stage 1	p.u. VolRtg	0 ... 2	0.8
	VCtl_Lo1LimTm	Waiting time lower limit stage 1	ms	0 ... 1000000	10000
	VCtl_Lo2Lim	Lower voltage limit stage 2	p.u. VolRtg	0 ... 2	0.45
	VCtl_Lo2LimTm	Waiting time lower limit stage 2	ms	0 ... 1000000	16000
	VCtl_Lo3Lim	Lower voltage limit stage 3	p.u. VolRtg	0 ... 2	0
	VCtl_Lo3LimTm	Waiting time lower limit stage 3	ms	0 ... 1000000	10000
	VCtl_Lo4Lim	Lower voltage limit stage 4	p.u. VolRtg	0 ... 2	0
	VCtl_Lo4LimTm	Waiting time lower limit stage 4	ms	0 ... 1000000	10000
	VCtl_Lo5Lim	Lower voltage limit stage 5	p.u. VolRtg	0 ... 2	0
	VCtl_Lo5LimTm	Waiting time lower limit stage 5	ms	0 ... 1000000	10000

	VCtl_PkLim	Instantaneous voltage protection	p.u. VolRtg	0…1.5	1.5
	VCtl_PkLimTm	Instantaneous voltage protection time → 6=1ms	In 6kHz steps	0…1000	18
	VCtl_PkLimBlkPwm_Ena	Instantaneous voltage protection for blocking pulses, activation SWITCH_STT_ENABLE = active SWITCH_STT_DISABLE = inactive			SWITCH_STT_DISABLE
	VCtl_PkLimBlkPwm_BlkOffDlTm	Instantaneous voltage protection for blocking pulses, time delay for the reactivation of pulses → 6=1ms	In 6kHz steps		300
	VCtl_PkLimBlkPwm_PkLimAct	Instantaneous voltage protection for blocking pulses, limit for activa-tion	p.u. VolRtg		1.3
	VCtl_PkLimBlkPwm_PkLimActTm	Instantaneous voltage protection for blocking pulses, time delay for activation → 6=1ms	In 6kHz steps		6
	VCtl_PkLimBlkPwm_PkLimDeact	Instantaneous voltage protection for blocking pulses, limit for deacti-vation	p.u. VolRtg		0.5
	VCtl_PkLimBlkPwm_PkLimDeactTm	Instantaneous voltage protection for blocking pulses, time delay for deactivation → 6=1ms	In 6kHz steps		6
Reactive power control depending on voltage VArCtlVol					
	VArCtlVol_LoVolRef1HiVolRef1	Voltage reference value 1	p.u. VolRtg	0 … 2	1
	VArCtlVol_LoVAr1HiVAr1	AC voltage-dependent reactive power control: Reactive power at reference point 1	p.u. VolRtg	-1 … 1	0
	VArCtlVol_LoVolRef2	Voltage reference value 2 (below value 1). **3 decimal places possible for reference values.**	p.u. VolRtg	0 … 2	0.95
	VArCtlVol_LoVolRef3	Voltage reference value 3 (below value 1)	p.u. VolRtg	0 … 2	0
	VArCtlVol_HiVolRef2	Voltage reference value 2 (over value 1)	p.u. VolRtg	0 … 2	1.05

	VArCtlVol_HiVolRef3	Voltage reference value 3 (over value 1)	p.u. VolRtg	0 ... 2	2
	VArCtlVol_LoGra1	Gradient 1, starting at reference value 1. **2 decimal places possible for gradients.**	p.u. VARtg/p.u. VolRtg	0 ... 100	5
	VArCtlVol_HiGra1	Gradient 1, starting at reference value 1	p.u. VARtg/p.u. VolRtg	0 ... 100	5
	VArCtlVol_LoGra2	Gradient 2	p.u. VARtg/p.u. VolRtg	0 ... 100	5
	VArCtlVol_HiGra2	Gradient 2	p.u. VARtg/p.u. VolRtg	0 ... 100	5
	VArCtlVol_LoGra3	Gradient 3	p.u. VARtg/p.u. VolRtg	0 ... 100	0
	VArCtlVol_HiGra3	Gradient 3	p.u. VARtg/p.u. VolRtg	0 ... 100	0
	VArCtlVol_VArSptFilTm	Filter time constant for reactive power	s	0 ... 1000	0.5
	VArCtlVol_VolNomSptMod	Selector for the voltage setpoint: VOLNOMSPTMOD_VOLNOMSPT = Setpoint VOLNOMSPTMOD_INVMS_VOLPSNOM = Filtered measurement value and initialize with "VArCtlVol_VolNomSptInit" VOLNOMSPTMOD_INVMS_VOLPSNOM_INITMEAS = Filtered measurement value and initialize with measured terminal voltage			VOLNOMSPTMOD_INVMS_VOLPSNOM
	VArCtlVol_VolNomSptInit	voltage setpoint at initialization	pu	0..2	1.0
	VArCtlVol_VolFilTm	Filter time constant voltage measurement	p.u. VolRtg	0 ... 1000	0.5
	VArCtlVol_VolPsNomHiLim	AC voltage-dependent reactive power control: upper limit for feedback voltage	p.u. VolRtg	1..2	1.1

	VArCtlVol_VolPsNomLoLim	AC voltage-dependent reactive power control: lower limit for feed-back voltage	p.u. VolRtg	0..1	0.9
Active Islanding Detection					
	Aid_Mod	Activation SWITCH_STT_ENABLE = active SWITCH_STT_DISABLE = inactive			SWITCH_STT_DISABLE
Phase Loss Detection (for YNd transformers only, N grounded)					
	Pld_Mod	Activation SWITCH_STT_ENABLE = active SWITCH_STT_DISABLE = inactive			SWITCH_STT_DISABLE
Grid Forming, Inertia and battery (Sunny Central Storage inverters) For more information on the **GridForming** and **Inertia** mode contact SMA to receive a personal copy of the technical information documents.					
	UseSCSOpCmd	Activate the external input SCSOpCmd for battery inverters in the PSCAD model		0/1	0
	GriForm_Mod	Activation of Grid-Forming-function (only if UseSCSOpCmd = 0) SWITCH_STT_DISABLE = inactive, SWITCH_STT_ENABLE = active			SWITCH_STT_DISABLE
	Bsc_InvStrMod	Start mode (precharge) of the inverter 0: Start from AC side 1: Start from DC side (e.g. Black-start)		0/1	0
	GriForm_AcCtl_DrpVol	Reactive Current – Voltage Droop	%V / AmpRtg (q-axis current)	0 ... 1	0.05
	GriForm_AcCtl_DrpHz	Active Current – Frequency Droop	Hz / AmpRtg (d-axis current)	-10...10	-1
	GriForm_AcCtl_InertiaHzDmp	Inertia: Voltage frequency damping gain of voltage angle inertia control	Hz/pu	-10...10	-1

	GriForm_AcCtl_InertiaH-zFwdDmp	Inertia: Voltage frequency feed-forward damping gain of voltage angle inertia control	None	0…1	0
	GriForm_AcCtl_InertiaH-zFbFilTm	Inertia: Frequency feedback time constant of voltage angle inertia control	s	0…1e5	0
	GriForm_AcCtl_InertiaThetaWCtlEna	Inertia: Enable active power inertia control SWITCH_STT_DISABLE = inactive, SWITCH_STT_ENABLE = active			SWITCH_STT_DISABLE
	GriForm_AcCtl_InertiaThetaH	Inertia: Voltage angle inertia constant H_theta = 0.5 * (dP/Snom) / (RoCoF/Fnom)	s	1e-3…1e5	2.5
	GriForm.AcCtl.InertiaThetaFwdDmp	Inertia: Voltage angle feed-forward damping gain of voltage angle inertia control	None	-5…5	-0.12
	GriForm_AcCtl_InertiaVolVArCtlEna	Inertia: Enable reactive power inertia control SWITCH_STT_DISABLE = inactive, SWITCH_STT_ENABLE = active			SWITCH_STT_DISABL
	GriForm_AcCtl_InertiaVolH	Inertia: Voltage magnitude inertia constant H_vol = 0.5 * (dQ/Snom) / (RoCoV/Vnom)	s	1e-3…1e5	1.5
	GriForm_AcCtl_InertiaVolFwdDmp	Inertia: Voltage magnitude feed-forward damping gain of voltage magnitude inertia control	None	0…1	0
	GriForm_AcCtl_InertiaVolFbDmpFilTm	Inertia: Voltage feedback time constant of voltage magnitude inertia control	s	0…1e5	0
0	GriForm_AcCtl_InertiaVolDmp	Inertia: Voltage magnitude damping gain of voltage magnitude inertia control	None	0…1	0.03
	GriForm_DcCtl_AmpKi	Limiting controller, DC Current, Integral amplification		0..1000	5
	GriForm_DcCtl_AmpKp	Limiting controller, DC Current, Proportional amplification		0..1000	0
	GriForm_DcCtl_VolKi	Limiting controller, DC Voltage,		0..1000	30

		Integral amplification			
	GriForm_DcCtl_VolKp	Limiting controller, DC Voltage, Proportional amplification		0..1000	0
	GriForm_AcCtl_AmpDQLimKi	Limiting controller, AC Current and AC Power, Integral amplification		0..100	4.5
	GriForm_AcCtl_AmpDQLimKp	Limiting controller, AC Current and AC Power, Proportional amplifica-tion		0..100	0.12
	GriForm_Frt_VirtImpLimTm	The maximum duration of the software protection phase (Virtual Impedance mode)	ms	0...1000000	5000
	GriForm.Frt.AMaxNom	Maximum short circuit current during software protection phase	pu	0..1.2	1.0 (Depends on application and inverter type)
PLL parameters None of these parameters can be changed without consultation and written permission from SMA. The below is provided for information only.					
	Pll_GriMon_HzGraLim	PLL grid monitoring, maximum rate of change of frequency	Hz/s		40
	Pll_Inv_HzGraLim	PLL inverter side, maximum rate of change of frequency	Hz/s		5
	Pll_Inv_DmpRto	PLL inverter side, controller attenu-ation time constant			1.5
	Pll_GriMon_DmpRto	PLL grid monitoring, controller at-tenuation			1.5
	Pll_Inv_HzFilOff2On_Vol	PLL inverter side, voltage threshold for the transition from Normal to Hz_Freeze_On (freeze limit)	p.u. VolRtg		0.6
	Pll_Inv_HzFilWt2On_Vol	PLL inverter side, voltage threshold for the transition from Wait to Hz_Freeze_On (freeze limit)	p.u. VolRtg		0.65
	Pll_Inv_HzFilOn2Wt_Vol	PLL inverter side, voltage threshold for the transition from Hz_Freeze_On to Wait (unfreeze limit)	p.u. VolRtg		0.75

	Pll_GriMon_HzFilOff2On_Vol	PLL grid monitoring, voltage threshold for the transition from Normal to Hz_Freeze_On (freeze limit)	p.u. VolRtg		0.3
	Pll_GriMon_HzFilWt2On_Vol	PLL grid monitoring, voltage threshold for the transition from Wait to Hz_Freeze_On (freeze limit)	p.u. VolRtg		0.6
	Pll_GriMon_HzFilOn2Wt_Vol	PLL grid monitoring, voltage threshold for the transition from Hz_Freeze_On to Wait (unfreeze limit)	p.u. VolRtg		0.7
	Pll_Inv_On2Srch_NomSum	PLL inverter side, moving average threshold of the voltage for the transition from On to Search		0...1000	120
	Pll_GriMon_On2Srch_NomSum	PLL grid monitoring, moving average threshold of the voltage for the transition from On to Search		0...1000	100
Battery limits for Sunny Central Storage .					
	BatCtl_DcVolDynMax	Upper dynamic battery voltage limit: inverter reduces power to maintain limit	V	0...2000	1450
	BatCtl_DcVolDynMin	Lower dynamic battery voltage limit: inverter reduces power to maintain limit	V	0...2000	650
	BatCtl_DcAmpDynMax	Dynamic battery current discharge limit: inverter reduces power to maintain limit	A	0..10000	10000
	BatCtl_DcAmpDynMin	Dynamic battery current charge limit: inverter reduces power to maintain limit	A	-10000..0	-10000
	BatCtl_DcVolOpMax	Upper operational battery voltage limit: inverter trips after time has expired	V	0..2000	1600
	BatCtl_DcVolOpMin	Lower operational battery voltage limit: inverter trips after time BatCtl_DcVolOpLimTm has expired	V	0..2000	500

	BatCtl_DcVolOpLimTm	Operational battery voltage limit time	ms	0..1E6	50
	BatCtl_DcAmpOpMax	Upper operational battery current discharge limit: inverter trips after BatCtl_DcAmpOpLimTm time has expired	A	0..10000	5000
	BatCtl_DcAmpOpMin	Lower operational battery current charge limit: inverter trips after time BatCtl_DcAmpOpLimTm has ex-pired	A	-10000..0	-5000
	BatCtl_DcAmpOpLimTm	Operational battery current limit time	ms	0..1E6	50

3.2 Runtime Parameter Update (RTUpd)

The model supports update of some control parameters during the runtime of a simulation. To do so a key/value pair has to be written to the RTUpd channels of the setpoint interface.

IMPORTANT: Only one parameter can be updated at each call of the SCK_Lib (typically 166.66667µs). So, it must be ensured that the RTUpd input signals are held constant for at least one call of the inverter controls. After the call the next parameter can be updated.

Currently the following parameters can be changed:

Channel name	RTUpd_UID
GriForm_AcCtl_InertiaThetaH	8909
GriForm_AcCtl_InertiaHzDmp	9194
GriForm_AcCtl_InertiaVolH	8917
GriForm_AcCtl_InertiaVolDmp	9200
GriForm_AcCtl_DrpHz	7576
GriForm_AcCtl_DrpVol	7577
BatCtl_DcVolDynMax	7272
BatCtl_DcVolDynMin	7273
BatCtl_DcAmpDynMax	7274

BatCtl_DcAmpDynMin	7275
BatCtl_DcVolOpMax	7305
BatCtl_DcVolOpMin	7306
BatCtl_DcVolOpLimTm	7706
BatCtl_DcAmpOpMax	7307
BatCtl_DcAmpOpMin	7308
BatCtl_DcAmpOpLimTm	7708

Example:

To change the dynamic voltage limit "BatCtl_DcVolDynMax"of a SCS battery inverter to e.g. 1300V set the RTUpd_UID to "7272" in combination with a RTUpd_Value of "1300" and hold it constant for at least one call of the inverter control library (200μs should be a safe time span). To change another parameter simply set a new RTUpd_Value and change the RTUpd_UID to that parameter. The RTUpd function only updates a parameter to RTUpd_Value on detection of a change of the RTUpd_UID. It does not copy the value permanently.

In the command window or log file the change is reported with the simulation time stamp and the new value:

```
2.000 RT-Update: BatCtl_DcVolDynMax: 1300.000
2.000 RT-Update: BatCtl_DcVolOpMax: 1450.000
2.001 RT-Update: BatCtl_DcAmpOpMax: 3000.000
```

3.3 Transformer parameters

Model users should amend the LV voltage of the inverter transformer to match the nominal inverter AC voltage level in V. Please refer to inverter's datasheet for information on the nominal AC voltage.

3.4 PPC parameters

For the Power Plant Controller (PPC) model parameters please refer to the PPC PSCAD model documentation.

3.5 Power Plant Manager / Hybrid Controller parameters

For the Power Plant Manager / Hybrid Controller (PPM/HYCON) model parameters please refer to the HYCON PSCAD model documentation.

3.6 Runtime Messages

During the start of the simulation the parameters are loaded from the config file and displayed in the PSCAD "Runtime Messages" window or a log file in the temporary simulation folder.

```
EMTDC(tm) Version 4.60 R#93051001
Time Summary: Start Date: 05-14-2018
Time Summary: Start Time: 14:51:37
At start of SMA_SCK_CInterface...
Number of bytes used for storing internal state data: 30584
This is : 7646 Integer state variables...
******************************
* S M A  Solar Technology AG *
*          ¸ 2018            *
*   Version: 05.01.08.00     *
*   External state buffer    *
******************************
Init done
Set Defaults done
Model: SCS 2200 1100V
Set Model done
The current working directory is C:\Users\fuetterer\Documents\GIT\EMT_Models\kodiak\kodiak\PSCAD\Ca
Opening CfgFile2.txt
Configuration File: SCxxxx
VARtg: 2200.00
WRtg: 2200.00
```

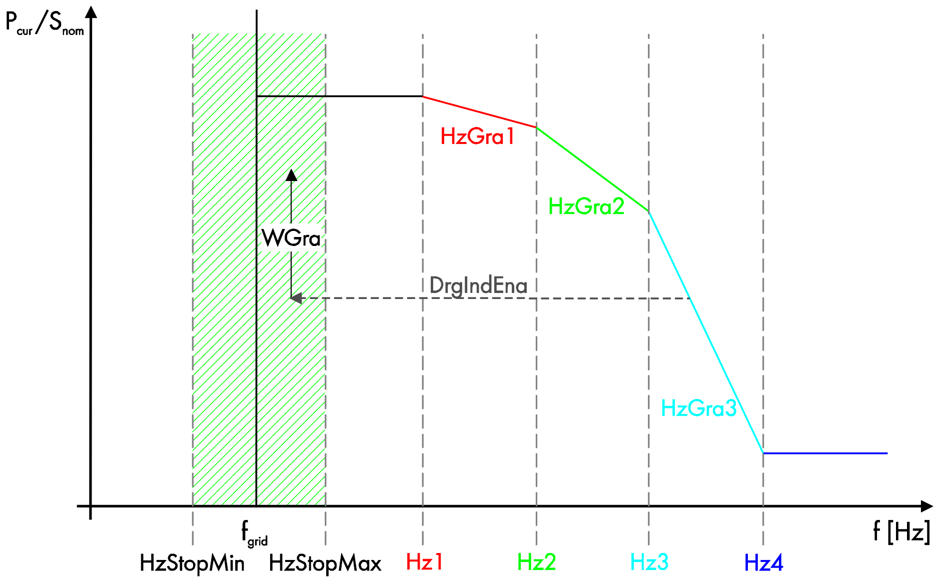
4 Special inverter functions for dynamic simulation

4.1 Active power control

4.1.1 Over Frequency-dependent active power *P*(*f*) – PV inverters

Activation: WCtlHzMod

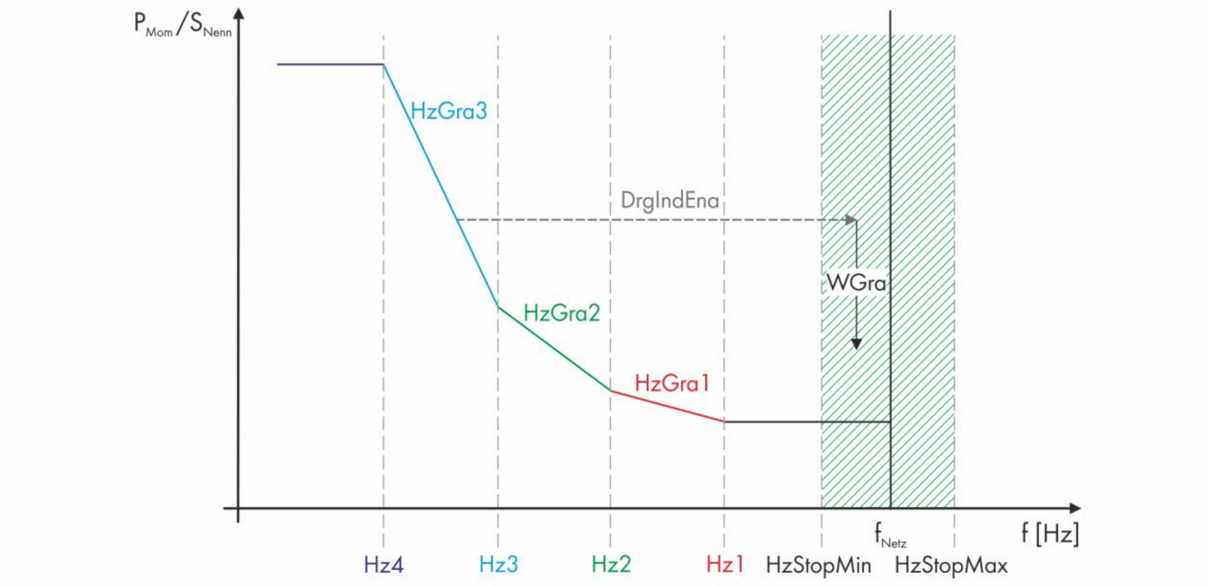
Description: This function provides frequency-dependent active power reduction in case of frequencies greater than the system frequency. The function can be parameterized in two ways: using gradients or using active power set-points. The type of parameterization can be chosen by changing parameter WCtlHz_CfgMod. Furthermore, it is possible to activate gradients for set-point changes resulting from the P(f) characteristic. This limits the speed of power changes.



4.1.2 Under Frequency-dependent active power *P*(*f*) – PV inverters

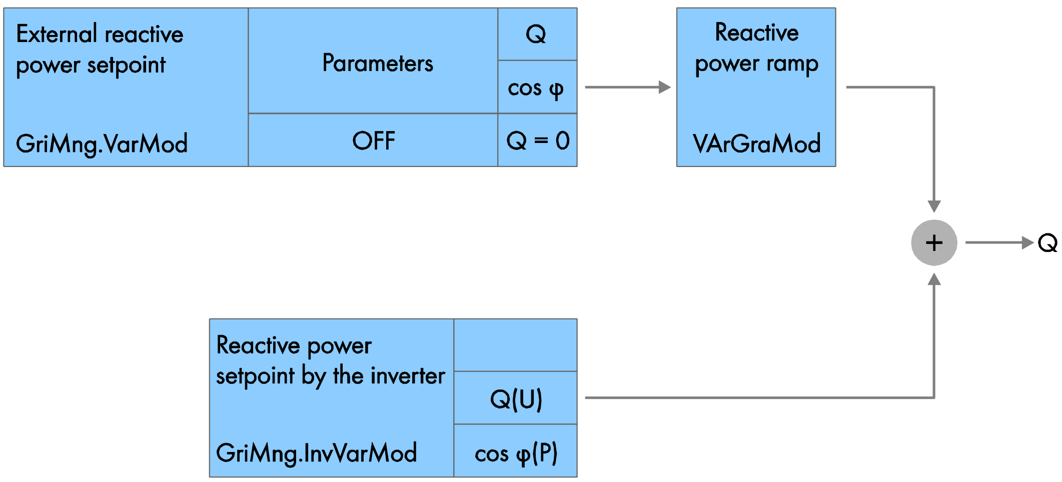
Activation: WCtlLoHzMod

Description: This function provides frequency-dependent active power increase in case of frequencies lower than the system frequency. This means it is allowed to overwrite external and internal curtailments except technical limits. The function can be parameterized in two ways: using gradients or using active power set-points. The type of parameterization can be chosen by changing parameter WCtlHz_CfgMod. Furthermore, it is possible to activate gradients for set-point changes resulting from the P(f) characteristic. This limits the speed of power changes.



4.2 Reactive power control

The reactive power set-point is generated as sum of an externally provided set-point (0, VArSpt or PFSpt) and an internally calculated set-point (0 or Q(U)) as shown here:



4.2.1 Reactive power provision by power factor set-point

Activation: VArOpMod = VAR_MOD_PF_CNST

Description: This function provides reactive power depending on a user-defined power factor. If GriMng_InvVArMod<> GRIMNG_INVVARMOD_OFF an additional reactive power set-point generated by the inverter may be added to the manually provided set-point.

4.2.2 Reactive power provision by Q set-point

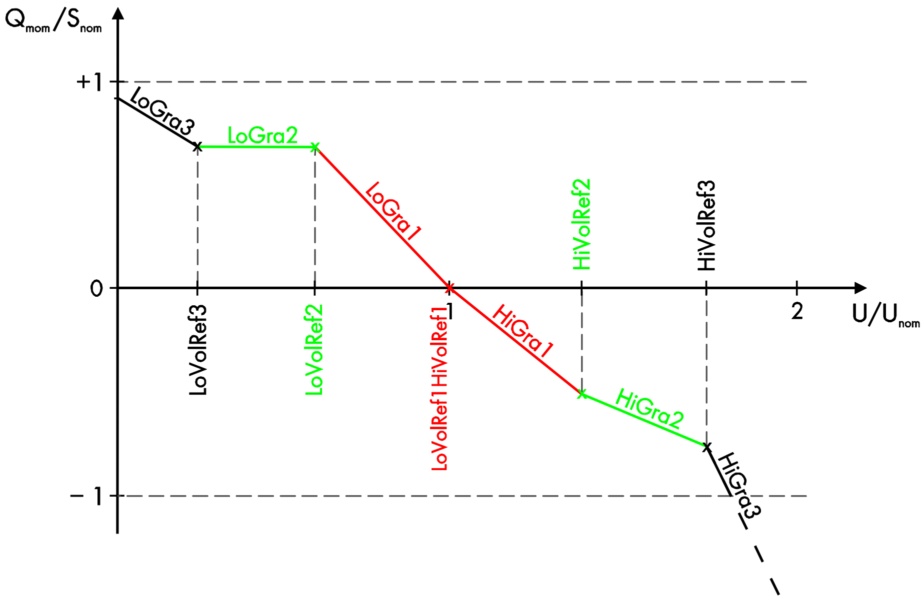
Activation: VArOpMod = VAR_MOD_CNST

Description: This function provides reactive power depending on a user-defined reactive power set-point. If GriMng_InvVArMod <> GRIMNG_INVVARMOD_OFF an additional reactive power set-point generated by the inverter may be add to the manually provided set-point.

4.2.3 Voltage-dependent reactive power Q(*U*)

Activation: GriMng_InvVArMod = GRIMNG_INVVARMOD_VARCTLVOL

Description: This function provides reactive power provision as a function of voltage *U*. The external set point VolNomSpt allows an AC voltage control which will shift the characteristic.

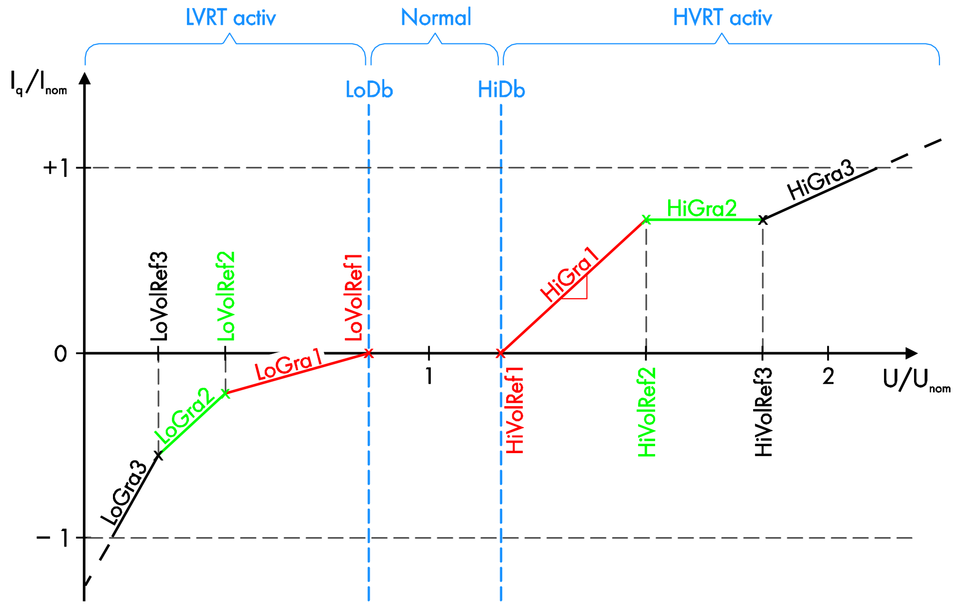


4.3 Dynamic grid support

4.3.1.1 Dynamic grid support "full"

Activation: Frt_Mod = SPT_FRT_MOD_FULL

Description: If the AC Voltage leaves a defined dead band (Frt_HiDb, Frt_LoDb), the inverter will support the grid with reactive current. Active current will be reduced if necessary.



4.3.2 Dynamic grid support "limited/partial"

Activation: Frt_Mod = SPT_FRT_MOD_PARTIAL

Description: The inverter is not tripped in case of voltage dips but disables feed-in of active and/or reactive power. After recurrence of the voltage the inverter resumes feed-in according to the parameterization before the voltage dip.

4.3.3 Dynamic grid support "Momentary Cessation"

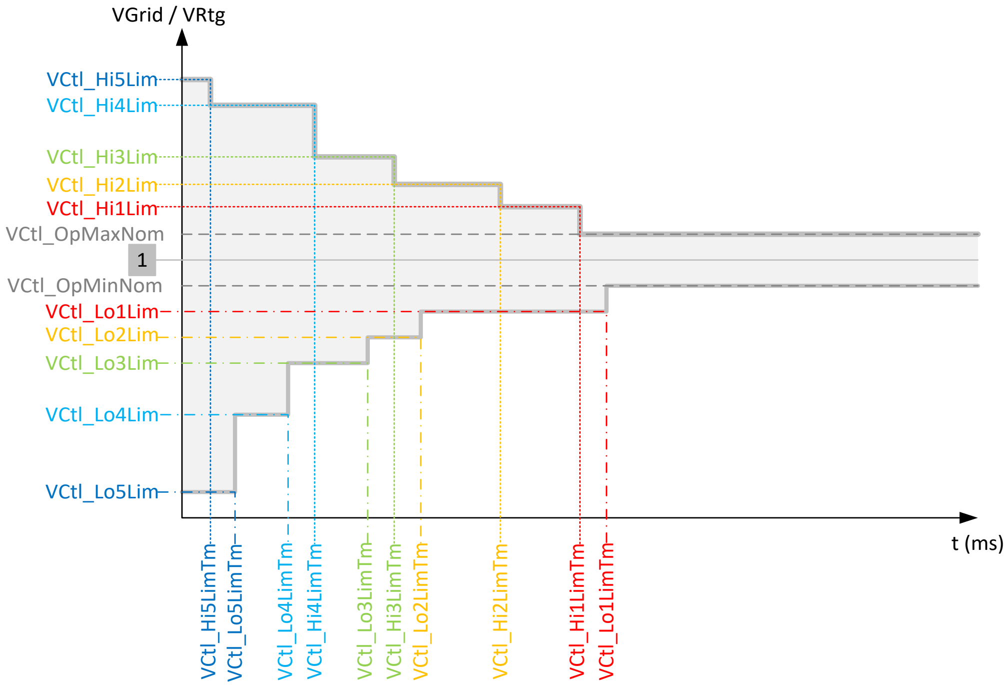
Activation: Frt_Mod = SPT_FRT_MOD_LOAMP

Description: The inverter is not tripped in case of voltage dips but tries to feed-in less current (< 0.1 p.u.)

4.4 Decoupling protection

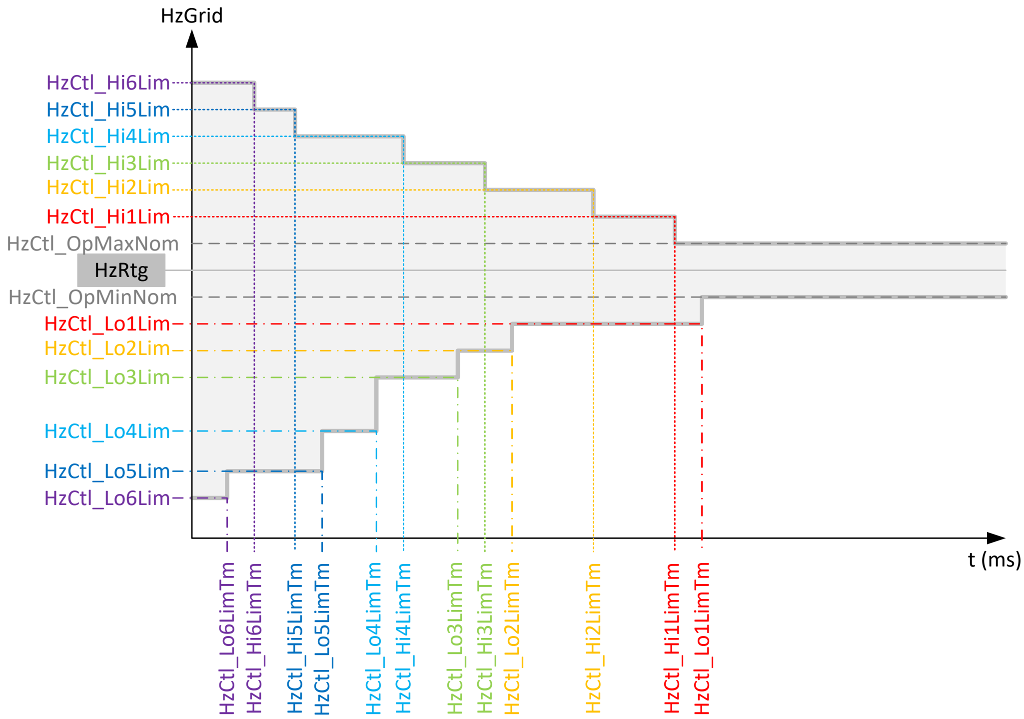
4.4.1 Voltage decoupling protection

Description: There are five overvoltage and five undervoltage trip points each with a distinct time delay.



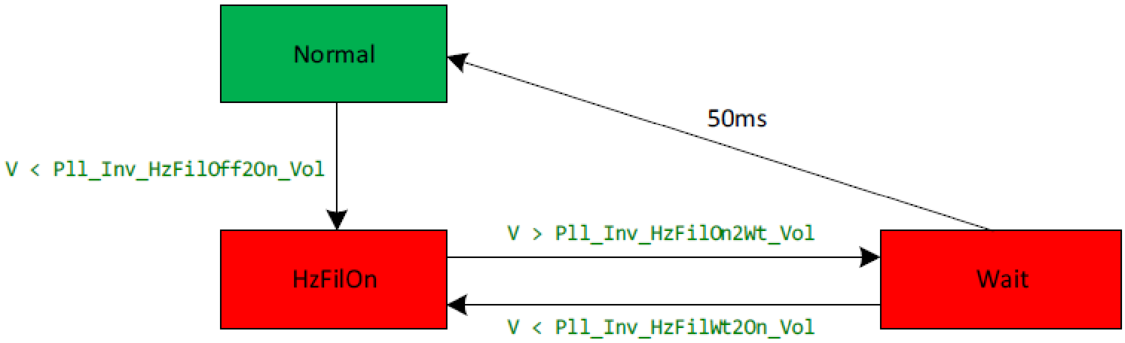
4.4.2 Frequency decoupling protection

Description: There are six over frequency and six underfrequency trip points each with a distinct time delay.



4.4.3 PLL freeze logic

No changes to these parameters are possible without permission from SMA.



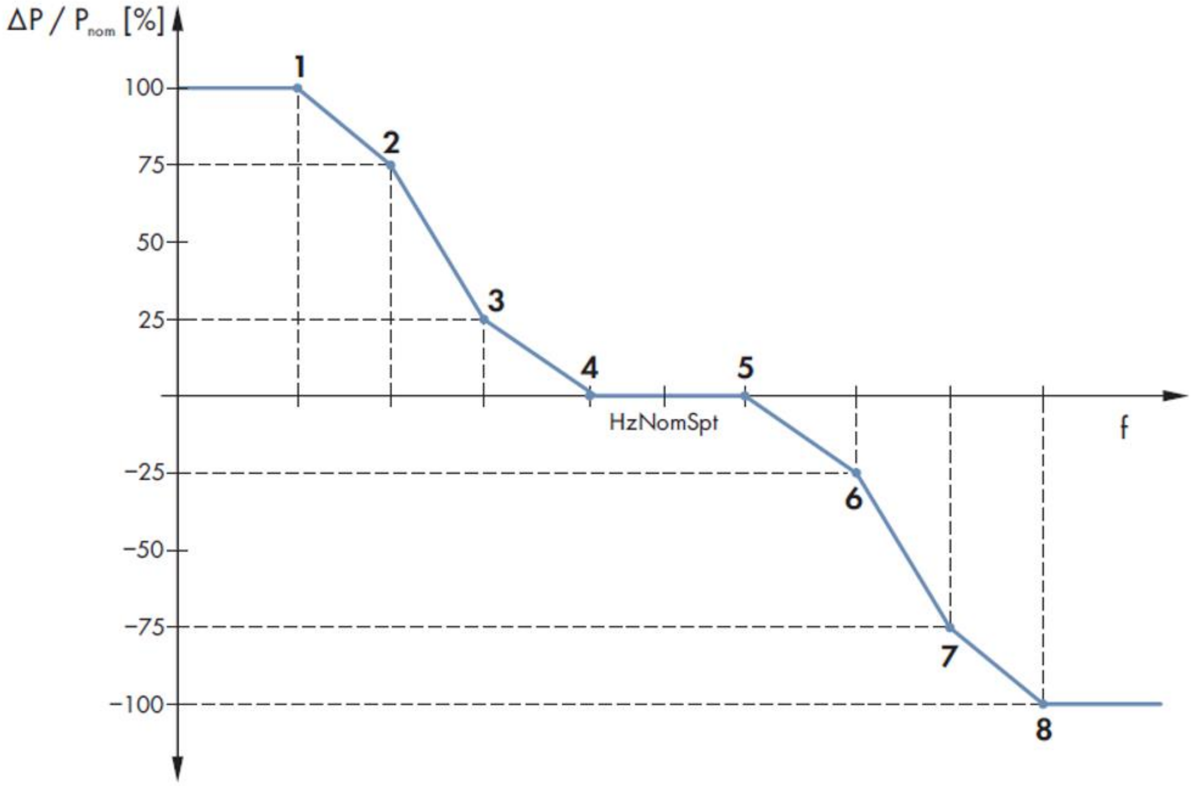
4.5 Power as a function of frequency, PV inverters – new functionality

This is a new functionality introduced for compliance with standard AR-41XX and other standards.

More details on the function will be included in the next document revision.

4.5.1 Power as a function of frequency, battery inverters – new functionality

This is a P(f) functionality for battery inverters.

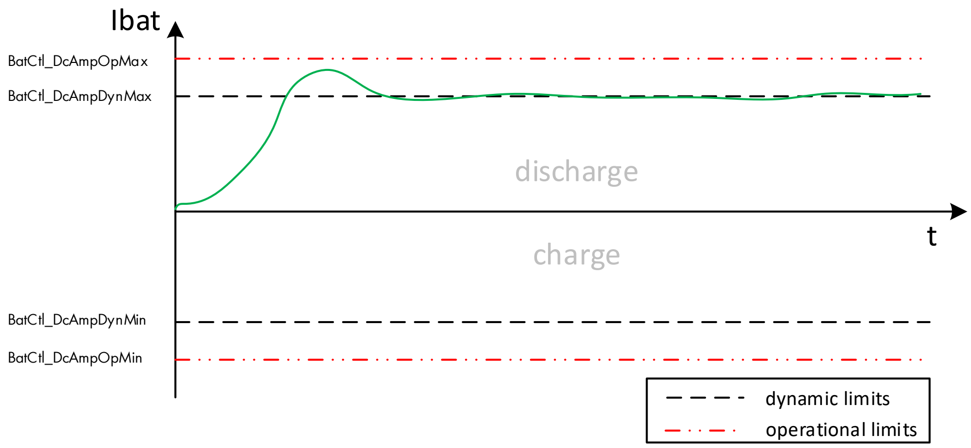


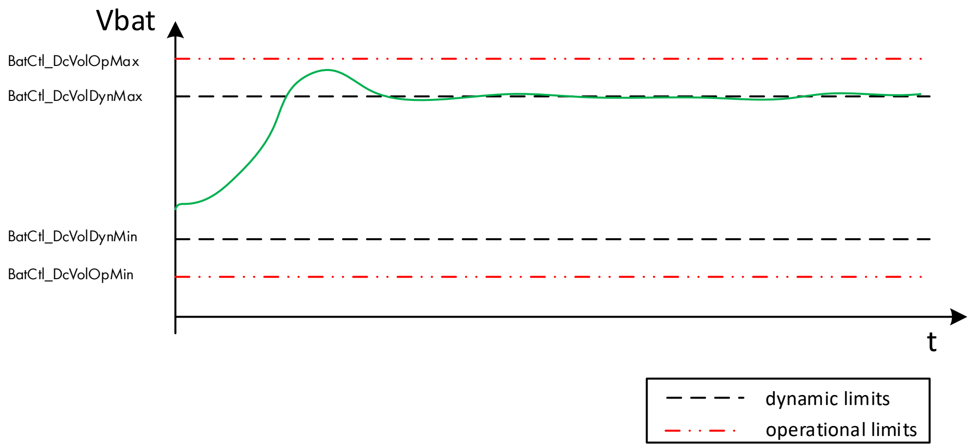
<table>
<tr><td></td><td>WCtlHzBatMod</td><td>Activation of WCtlHzBat-function
SWITCH_STT_DISABLE = inactive,
SWITCH_STT_ENABLE = active</td><td></td><td></td><td>SWITCH_STT_DISABLE</td></tr>
<tr><td></td><td>WCtlHzBat.Hzn</td><td>Grid frequency at support point n for the frequency-dependent active power control</td><td>Hz</td><td></td><td><table><tr><th>n</th><th>value</th></tr><tr><td>1</td><td>44</td></tr><tr><td>2</td><td>46</td></tr><tr><td>3</td><td>48</td></tr><tr><td>4</td><td>49.5</td></tr><tr><td>5</td><td>50.5</td></tr><tr><td>6</td><td>52</td></tr><tr><td>7</td><td>54</td></tr><tr><td>8</td><td>56</td></tr></table></td></tr>
<tr><td></td><td>WCtlHzBat.Wn</td><td>Additional active power setpoint at support point n</td><td>pu</td><td></td><td><table><tr><th>n</th><th>value</th></tr><tr><td>1</td><td>1.0</td></tr><tr><td>2</td><td>0.7</td></tr><tr><td>3</td><td>0.2</td></tr></table></td></tr>
</table>

					4	0.0
					5	0.0
					6	-0.2
					7	-0.7
					8	-1.0

4.6 DC current and voltage limitation for SCS inverters

To dynamically keep the DC current and voltage within given ranges respective controllers have been implemented. The parameters are split according to the corresponding GridForming control modes. The battery limits can be set in the real inverter via the inverters Modbus interface (see chapter "Battery Communication" in the Technical Information document "Modbus Interface or Sunny Central Storage"). In the EMT model the limits can be configured via the config file as well as the "Runtime Parameter Update" feature (see chapter 3.2)





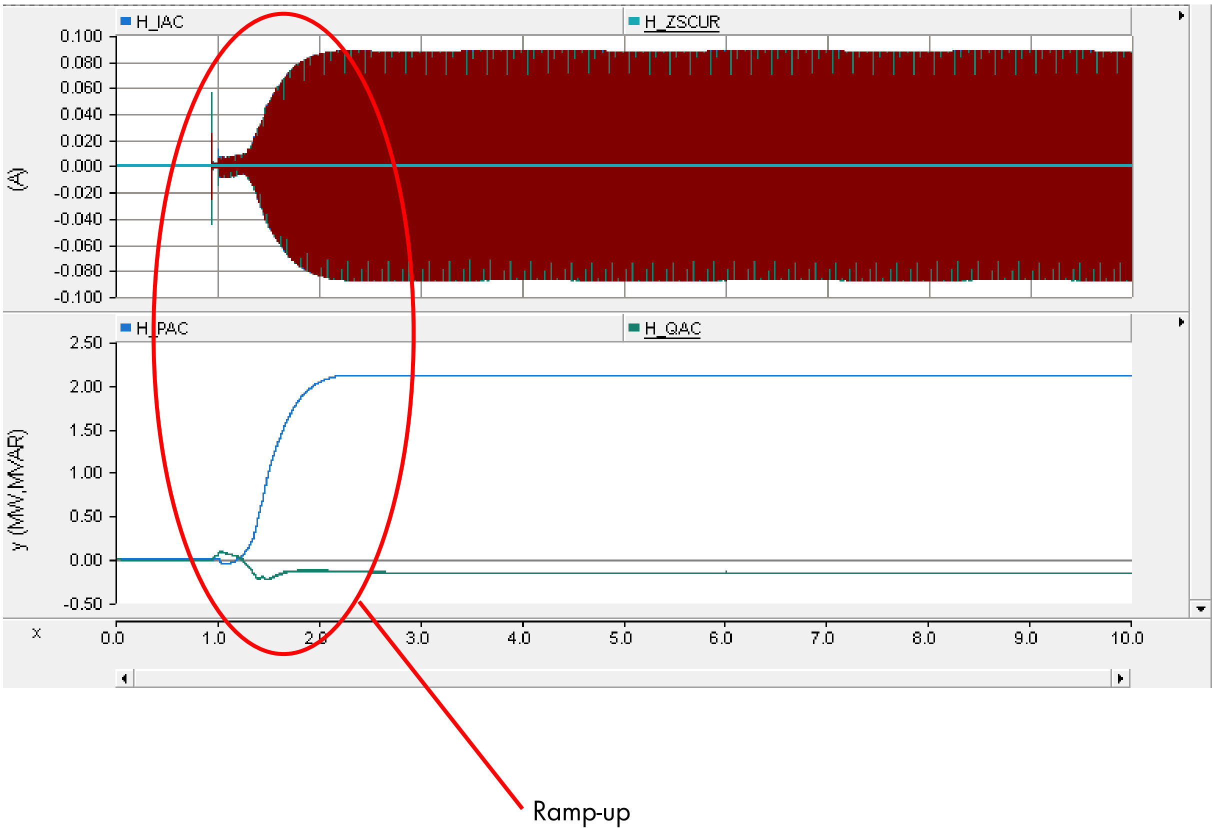
The following parameters can be used to fine-tune the PI control loops in case required.

	GridForming with droops	**GridForming with inertia**
DC current limitation		
proportional gain	GriForm_DcCtl_AmpKp (0)	GriForm_DcCtl_InertiaAmpKp (0)
integral gain	GriForm_DcCtl_AmpKi (5)	GriForm_DcCtl_InertiaAmpKi (20)
DC voltage limitation		
proportional gain	GriForm_DcCtl_VolKp (0)	GriForm_DcCtl_InertiaVolKp (0)
integral gain	GriForm_DcCtl_VolKi (30)	GriForm_DcCtl_InertiaVolKi (60)

5 Model start-up

The inverter model needs a certain amount of time for initialization and ramp-up. Please give the model time for this start-up procedure and wait until the steady-state has been reached before applying any changes to inverter setpoints or network conditions.

The PPC model also requires to reach a steady-state for the simulation to run correctly.



Fast start option:

In some simulation studies, it is required that the simulation model achieves a nearly steady state condition within 3 seconds.

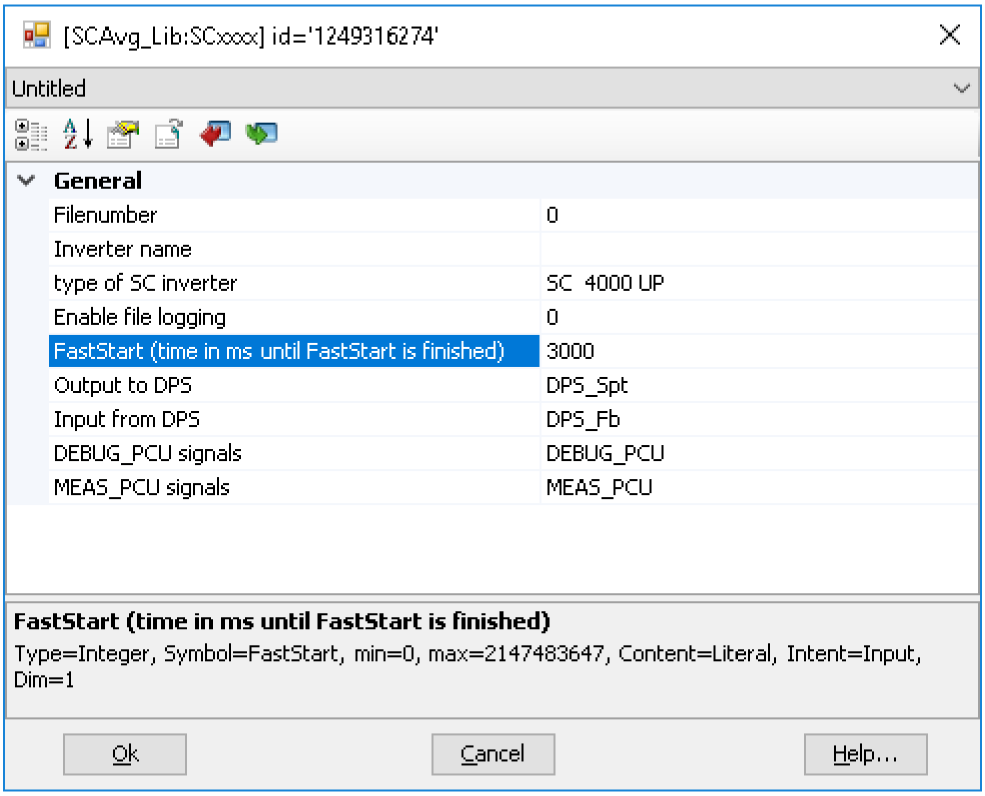
The steady state time depends among others on:

- Inverter ramp settings (ramp gradients)
- PPC – PI-controller settings
- PPC – ramp settings and control mode selected
- Network and grid specific parameters.

If the system conditions are changed by e.g. adding a transformer, line or a passive element, the system time response is changed as well.

The “**Fast start option**” in the inverter model allows the inverter to ignore the ramp parameter WGra and VArGra for the startup time specified allowing the model to initialize faster. After the startup procedure the WGra and VArGra parameters with the values from the parameter file will be considered.

To access the fast start up settings right click on inverter block and select “Edit Parameters...”.



6 Debug Interface

To analyze the behavior of the inverter the internal signals of the inverter can be plotted. The relevant signals can be extracted from the inverter mask.

The array DEBUG_PCU contains all relevant control signals e.g. dq components from current controller and from the PLL.

The array MEAS_PCU contains all physical measurement signals e.g. delta instantaneous voltage on the inverter terminal and stack currents from the inverter.

The following table gives an overview and explanation if all relevant signals.

DEBUG_PCU			
index	**name**	**description**	**unit**
1	Cpu2SubStt	operation mode state 97 = normal operation, 99 = FRT State	
2	ErrBits	error bits register	
3	AmpPsD	sensed current d component (positive sequence)	pu
4	AmpPsQ	sensed current q component (positive sequence) < 0: inverter is lagging. Voltage is increasing on inverter terminal > 0: inverter is leading. Voltage is decreasing on inverter terminal	pu
5	AmpPsDSpt	reference current d component (positive sequence)	pu
6	AmpPsQSpt	reference current q component (positive sequence)	pu
7	AmpNsD	sensed current d component (negative sequence)	pu
8	AmpNsQ	sensed current q component (negative sequence)	pu
9	AmpNsDSpt	reference current d component (negative sequence)	pu
10	AmpNsQSpt	reference current q component (negative sequence)	pu
11	MsPllCnv_Hz	Frequency from PLL	Hz
12	MsPllCnv_VolPsD	voltage d component from PLL (positive sequence)	pu
13	MsPllCnv_VolPsQ	voltage q component from PLL (positive sequence)	pu

14	MsPllCnv_VolNsD	voltage d component from PLL (negative sequence)	pu
15	MsPllCnv_VolNsQ	voltage d component from PLL (negative sequence)	pu
16	CtlSignals_VolPsD	reference voltage d component (positive sequence)	pu
17	CtlSignals_VolPsQ	reference voltage q component (positive sequence)	pu
18	MsMM_AccVolMonCheb	sense delta voltage	
19	MsPllMM_PllOpStt	PLL operation state	
20	IPC_CPU2_Error_GriErr1	Grid Error Flag 1	
21	IPC_CPU2_Error_GriErr2	Grid Error Flag 2	
22	IPC_CPU2_Fast_MppStt	MPP State	
23	IPC_CPU2_Fast_Mpp_PvVolSpt	MPP voltage set point	V
24	IPC_CPU2_Fast_DrtStt	Derating state	
25	SimDeltT	Delta simulation time	s
26	MsPllMM_VolPsD	voltage d component from MeasPLL (positive sequence)	Pu
27	MsPllMM_VolPsQ	voltage q component from MeasPLL (positive sequence)	pu
28	MsPllMM_VolPsDNotFil	voltage d component from MeasPLL (positive sequence) – not filtered	Pu
29	MsPllMM_VolPsQNotFil	voltage q component from MeasPLL (positive sequence) – not filtered	pu
30	MsPllMM_Hz	frequency from MeasPLL	Hz
31	Aid_HzHPFilOut	AID: Filtered signal after High Pass	
32	PLDOut	PLD output	
33	MsPllCnv_Vol_PsD	voltage d component from PLL (positive sequence)	
34	MsPllCnv_VolPsQNomSum10ms	nominal sum of the q component from PLL (positive sequence	

MEAS_PCU			
index	**name**	**description**	**unit**
1-3	ExtVtg	sensed delta voltage at inverter terminal	kV
4-6	CnvVtg	sensed delta voltage at capacitor of inverter filter	kV

7-9	StackCur	sensed stack currents	kA
10-12	CnvCurABC	sensed output current at inverter terminal	kA
13	CnvPAC	sensed active power at inverter terminal	MW
14	CnvQAC	sensed reactive power at inverter terminal	MVAr
15	PVVtg	sensed PV Generator voltage	kV
16	Ipv	sensed PV Current	kA
17	DCLinkVtg	sensed DC Link voltage	kV

7 Disclaimer

This document and the associated models have been prepared to facilitate the simulation of the response of SMA Sunny Central and Sunny Central Storage inverters to grid and parameter disturbances. The modeling data presented here is 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.

SMA Sunny Central (Storage) inverter EMT models usability for DC fault analysis

SMA Sunny Central (Storage) EMT models are designed to perform AC network stability analysis and accordingly all relevant details of the inverter hardware and software are rep-resented with the necessary level of detail.

Inverter DC quantities can impact AC operation and therefore must be considered. However, simplifications in that context are acceptable and even beneficial regarding model usability and simulation performance. One example would be aggregation of multiple PV strings to a single PV generator model. Consequently, further details like e. g. single PV string/battery fuses are not modelled, and accordingly detailed analysis of DC faults may lead to incorrect conclusions and should not be performed. If for any reason that would be a matter of interest, case specific consultation with SMA is recommended.

Applicability of parameters

The SMA PSCAD model is not able to check if values entered in the parameter configuration files are within the allowed range of the real inverter software and thus can be set during commissioning. Please refer to the SC/SCS Operating manual (Chapter "Instantaneous Values and Parameters") to check the range.