Documentation

Description of the model of the

SMA Hybrid Controller

for EMT studies in PSCAD

Please consider the environment before you print this document.

Model Revision 02.19.06.R.00
Document Revision 3.8
July 03, 2023

Note

The following PSCAD versions are currently supported:

- version 4.6 and higher

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 HVDC Research Centre PSCAD® (instantaneous value models)
- The Mathworks Matlab/Simulink® (rms and instantaneous value models, SMA internal only)
- ATP (EMT models)

Document history

Document version		Description
...	...	...
3.0	C.Hardt	Official R14 release version
3.1	C.Hardt	See model history
3.2	C.Hardt	Official R15 release version - See model history
3.3	V.Sakschewski	GEN_IOP Mode added - See model history
3.5	V.Sakschewski	Pre release R17 with power coordinator
3.6	V.Sakschewski	Pre release R18
3.7	V.Sakschewski	Official release R18
3.8	C.Hardt	Pre release R19

Model history

Model version		Description
02.08.00.R.03	HyCtl_PSCAD_Lib.pscx; HyCtl_if9.lib	First release
02.09.01.E.00	HyCtl_PSCAD_Lib.pscx; HyCtl_if9.lib	Parameter name correction
02.09.01.A.03		Parameter name correction
02.10.01.E.01		Corrections in Hybrid POI control
02.12.06.A.02		Version 12 - Corrections to voltage droop characteristics - Corrections to AutoPOI control (PV + Bat) application - Initialization PSCAD model
02.12.06.A.03		Adjustable sample time
02.12.06.A.04		Parameter file handling correction
02.12.06.A.05		Correction in the models FastStart mechanism; SpntRamp.PwrAtSpntFilterTm and SpntRamp.PwrRtSpntFilterTm could delay getting into steady state quickly
02.12.07.A.00		- Activation delay for P(f) to avoid nuisance activation due to transient measurement effect - Individual phase voltage measurements
02.12.08.A.01		- Control support for SC plus DPS Systems (DCDC converter for DC coupling)
02.12.09.A.00		- Apparent power limitation fix at entry to HVRT
02.13.00.A.00		Initialization issues with PSS/E fixed
02.13.01.A.01		Initialization issues with PSS/E fixed

02.13.03.A.00		Fixes P(f) during FRT
02.13.03.A.01		Access to the "Sales/market" setpoint. !! Attention !! Interface change
02.13.03.A.02		No functional change. Just recompilation.
02.14.01.A.00		Initialization issue in PV + BESS systems fixed
02.14.02.A.00		Correction in the reactive power limitation in Q(v) mode
02.14.02.A.02		Sample time correction PowerFactory interface
02.14.08.R.00		Alignment with official R14 release version
02.15.14.R.00		Added parameter FrqDroop.EnaActFrt to disable activation of FrqDroop during FRT
02.15.14.R.01	HyCtl_PSCAD_Lib.pscx	GenSets (GEN_IOP) capability is added Snapshot / Multi instance fix
02.16.16.R.02	HyCtl_PSCAD_Lib.pscx	R16 release: Functionality improvements
02.17.15.A.00	HyCtl_PSCAD_Lib.pscx	R17 pre-release: Power coordinator included
02.18.15.B.00	HyCtl_PSCAD_Lib.pscx	R18 pre-release
02.18.16.R.00	HyCtl_PSCAD_Lib.pscx	R18 release: - Separate voltage input for FRT triggering - Enables frequency response (FFR, EFR, PRL, DS3, FCAS) for PV systems
02.19.06.R.00		R19 pre-release: - Qlim(P) function

Model validity

The controller model "HyCtl_PSCAD_Lib" described in this document is only intended for simulation of the SMA Hybrid Controller.

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

Contents

1 Installation requirements

The model is able to run with GFortran or Intel Visual Fortran 32/64 bit compiler. To the best of our knowledge, the Intel Fortran compiler has significant speed advantage over the GFortran compiler coming with PSCAD. We tested the model with Intel Visual Fortran 11 and higher. The model is known to have issues with the snapshot function when using GFortran. These problems do occur outside of the SMA part of the model.

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

For compatibility a SMA PSCAD **Sunny Central inverter model > version 08.00.08.002** is required.

The model comes with the following files

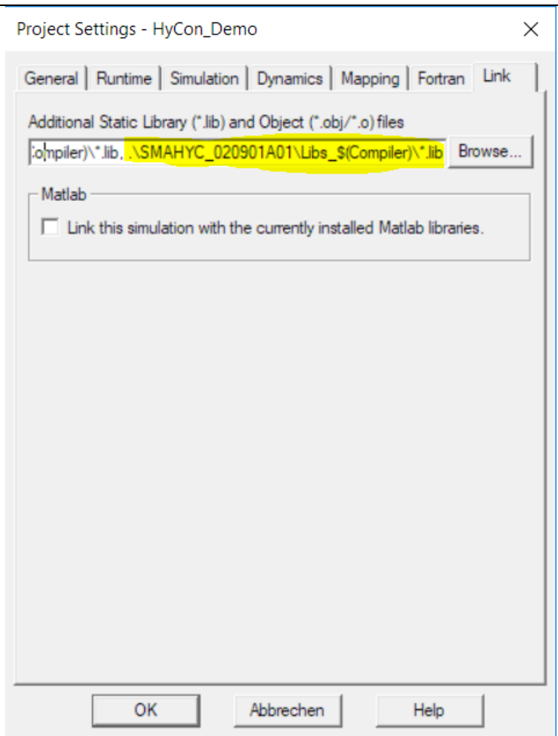
HyCtl_PSCAD_Lib.pslx	Library containing the PSCAD part of the Hybrid Controller
tbd	Demo case containing the Sunny Central inverters and an instance of the Hybrid controller
Libs_$(Compiler)/ SMAHYC_020XXXXXX _$(Compiler).lib	Hybrid Controller object code
Default_HyCtl.txt	Example of configuration file
HyCtl_Cfg [1..200].txt	Up to 200 different user configuration files

All these files and folders must be placed in the working directory of the PSCAD simulation case.

The Intel Fortran 15 version is a bit special: due to a change in the Microsoft Visual C compiler (MSVC) in version 2015+ there is an .if15 library version that is able to work with Microsoft Visual Studio 2015 and later. This file has the extension "_vs2015". Please use the "_vs2010" files for MSVC versions prior to 2015.

Please make sure that the *.lib file can be accessed properly and is selected according to the installed compiler. It is suggested to include below line adjusted to the corresponding version number to the "Link"->"Additional Static..." field. The "`$(Compiler)`" is a PSCAD internal variable that automatically uses the selected compiler extension.

```
.\ SMAHYC_021514R01\Libs_$(Compiler)\*.lib
```



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

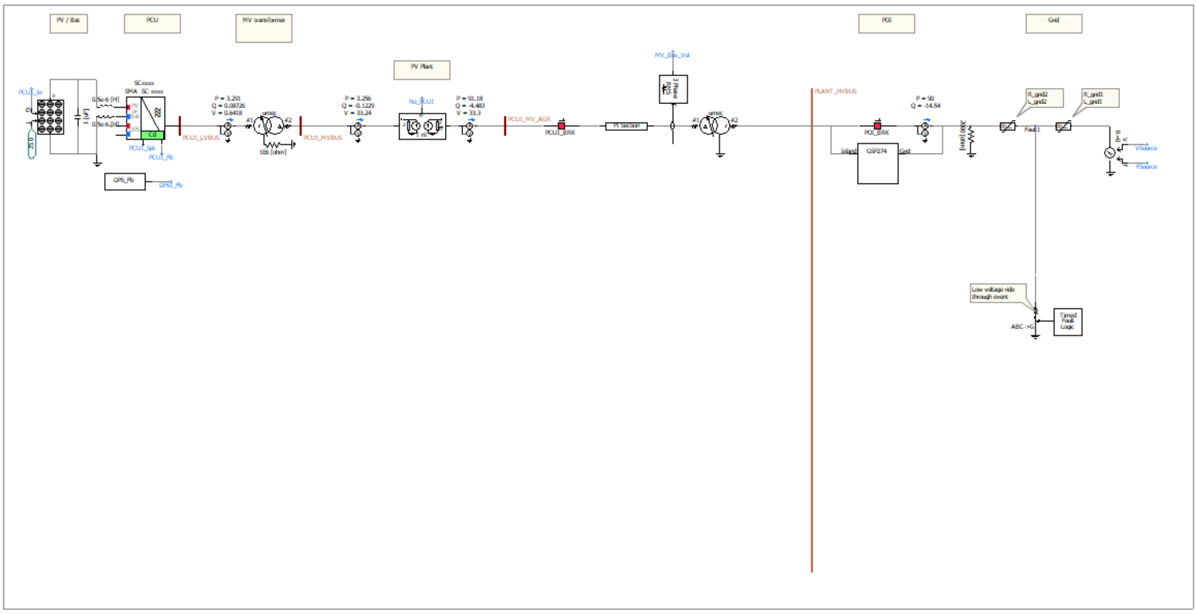
Load the "HyCtl_PSCAD_Lib.pslx" library into the study case.

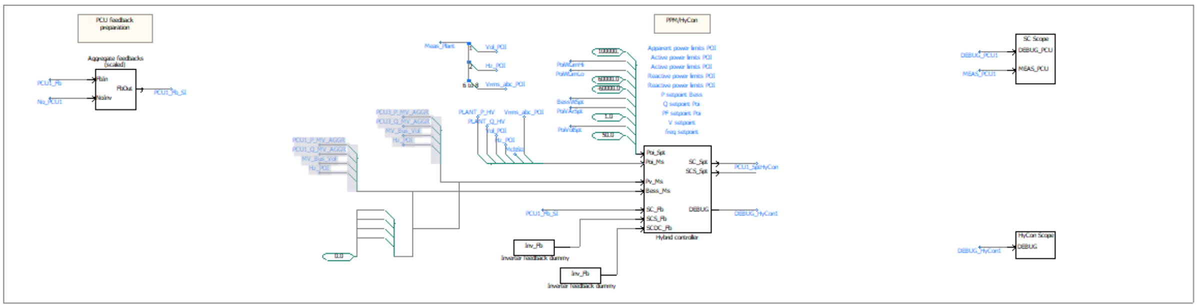
Due to a necessary change in the interface between the inverter model and the plant controller model not all versions of the inverter model are supported. Version 6+ models are generally compatible. Versions 5 with a 3 digit ending (e.g. 5.x.x.101) are also compatible. Please contact SMA for further assistance.

2 Configuring the model

The demo models come with three typical setups witch Hybrid Controller.

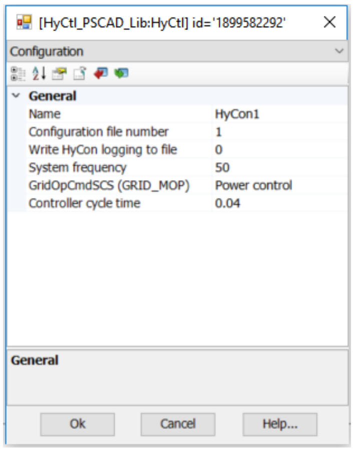
1. PV System with Hybrid Controller
2. Storage System (BESS) with Hybrid Controller
3. PV + DPS System (PV System with DCDC converter and battery)





Please check the documentation of the SMA inverter model for information on how to configure the inverters.

By “right clicking” on the Hybrid Controller symbol and selecting “Edit parameters…” it is possible to specify the following settings:



Parameter	Description	Default
	Mask parameters	
Name	Just an identifier for the controller block	e.g. HyCon
Configuration file number	Configuration file to be used for the simulation (see separate table below)	0
Write HyCon logging to file	Writes internal data output to a file instead of the PSCAD console	0
GridOpCmdSCS (Grid_MOP)	Grid operation command – power control or Grid Forming	
Controller cycle time	Cycle time of controller in seconds	0.04

2.1 Reading parameter from config files

The parameterization for the Hybrid Controller is done via separate configuration files. The following table gives an overview on the naming policies.

Number	Filename in the model directory
0	Default_HyCtl.txt
1	HyCtl_Cfg1.txt*
2	HyCtl_Cfg2.txt*
3	HyCtl_Cfg3.txt*
...	...
200	HyCtl_Cfg200.txt*

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

Multiply configurations files can be used to start the HyCon with different parameter setup. This feature can be used to accelerate the start up behavior of the simulated plant.

Example How to Use:

1. Define a file that contains the parameters for the project (these are the THE real RUG parameters for the project). This is the file entered on the mask of the HyCon block.
2. define a second file that contains the changes (e.g. ramps, controller) that would maybe speed up the start.

E.g.:

The HyCtl_Cfg60.txt are RUGs parameter and the HyCtl_Cfg199.txt contains changes that speed up the model start.

HyCtl_Cfg199.txt:

SpntRamp.PwrAtRateMax 60000 #maximum rate of active power setpoint for hole system in MW/min
SpntRamp.PwrRtRateMax 60000 #maximum rate of reactive power setpoint for hole system in MVar/min
SpntRamp.PwrAtSpntFilterTm 0.01 #Active power setpoint filter time, if greater than 0 ramps are disabled.
SpntRamp.PwrRtSpntFilterTm 0.01 #Reactive power setpoint filter time, if greater than 0 ramps are disabled.

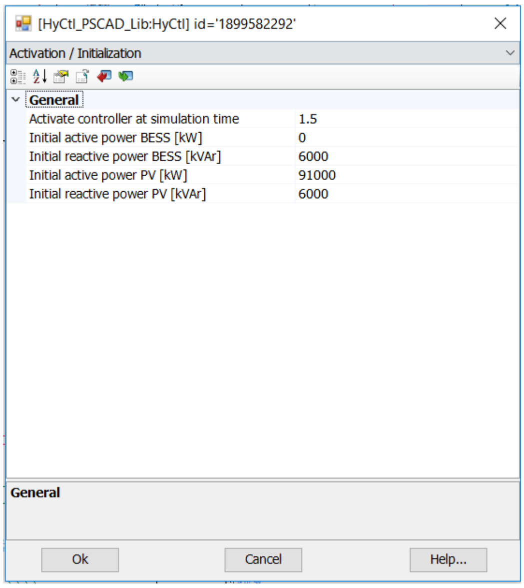
HyCtl_Cfg60.txt: add these parameters in the file

ReloadTime[0] 0.1
ReloadFile[0] 199
ReloadTime[1] 2.9
ReloadFile[1] 60

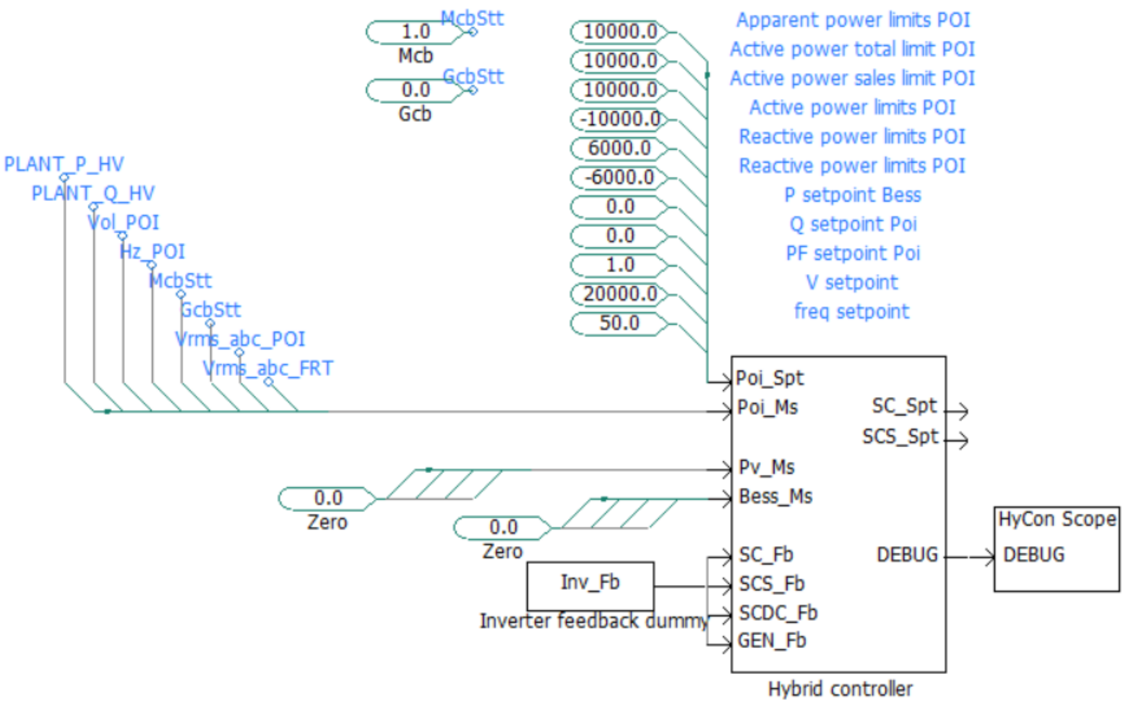
The model is configured at t = 0s with the RUG parameters. At t=0.1s the parameters from HyCtl_Cfg199.txt get loaded -> faster startup. At t = 2.9s the HyCtl_Cfg60.txt is reloaded to the RUG parameters.

2.2 Activation / Initialization of the controller

The model start into a steady state configuration can be influenced by assigning initial values that are being send to the inverters prior to the activation time of the controller. The controller tries then to take the present state of the system as a starting condition. Typically, it might give faster startup times if the inverters settle into a steady state that has been derived from a load flow calculation and the controller is activated afterwards.



2.3 Hybrid Controller Interface



Supported system combination

SC=Sunny Central PV

SCS = Sunny Central storage

SCDC = Sunny Central with DCDC converter

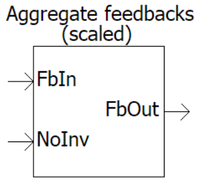
SC	SCS	SCDC	Restriction
X			
	X		
		X	
X	X		
X		X	

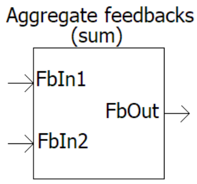
Bus-Name	Description	Unit
	INPUT-SET POINT	
Poi_Spt[1]	Apparent power limit at POI	kVA
Poi_Spt[2]	Upper active power limit at POI	kW
Poi_Spt[3]	Upper active power sales/market limit at POI	kW
Poi_Spt[4]	Lower active power limit at POI	kW
Poi_Spt[5]	Upper reactive power limit at POI	kVAr
Poi_Spt[6]	Lower reactive power limit at POI	kVAr
Poi_Spt[7]	Active power setpoint for battery energy storage system (BESS)	kW
Poi_Spt[8]	Reactive power setpoint at POI	kVAr
Poi_Spt[9]	Power factor set point	
Poi_Spt[10]	AC Voltage set-point	V
Poi_Spt[11]	AC frequency set-point for grid forming operation	Hz

Bus-Name	Description	Unit
	INPUT-MEASUREMENT	
Poi_Ms[1]	Active power measurement at POI	kW

Poi_Ms[2]	Reactive power measurement at POI	kVAr
Poi_Ms[3]	Voltage measurement at POI	kV
Poi_Ms[4]	Frequency measurement on grid side of mains circuit breaker	Hz
Poi_Ms[5]	Status of the mains circuit breaker	
Poi_Ms[6]	Voltage measurement at POI phase AB	kV
Poi_Ms[7]	Voltage measurement at POI phase BC	kV
Poi_Ms[8]	Voltage measurement at POI phase CA	kV
Poi_Ms[9]	Voltage measurement phase AB for FRT triggering	kV
Poi_Ms[10]	Voltage measurement phase BC for FRT triggering	kV
Poi_Ms[11]	Voltage measurement phase CA for FRT triggering	kV
PV_Ms[1]	Optional measurement: PV active power	kW
PV_Ms[2]	Optional measurement: PV reactive power	kVAr
PV_Ms[3]	Optional measurement: PV voltage	kV
PV_Ms[4]	Optional measurement: PV frequency	Hz
Bess_Ms[1]	Optional measurement: Bess active power	kW
Bess_Ms[2]	Optional measurement: Bess reactive power	kVAr
Bess_Ms[3]	Optional measurement: Bess voltage	kV
Bess_Ms[4]	Optional measurement: Bess frequency	Hz
SCS_Fb	Feedback signals from Sunny Central Storage inverters	
SC_Fb	Feedback signals from Sunny Central inverters	

The Hybrid Controller needs to know some feedback data received from the power conversion units. For an easier aggregation of the data you can use one of the following blocks provided with the controllers PSCAD library.





The upper block multiplies the PCU feedback signals and should be used in combination with scaling elements such as the ETRAN-Libraries scaling transformer or similar techniques.

The lower block simply adds the two inputs and can be used in case the user wants to model the PCUs individually.

Bus-Name	**Description**	**Unit**
	OUTPUT-INVERTER SET POINT	
SCS_Spt	Setpoints to Sunny Central Storage inverters	
SC_Spt	Setpoints to Sunny Central inverters and to Sunny Central Inverters with DPS System	

Bus-Name	**Description**	**Unit**
	INPUT-MEASUREMENT	
DEBUG [1]	maximum active external set point for system (PwrAtLimHi)	pu
DEBUG [2]	minimum active external set point for system (PwrAtLimLo)	pu
DEBUG [3]	maximum apparent power external set point for system (PwrApLim)	pu
DEBUG [4]	maximum active set point for system (after internal limitation (Ramp/filter/P(f)) (PvBatMax)	pu
DEBUG [5]	minimum active set point for system (after internal limitation (Ramp/filter/P(f)) (PvBatMin)	pu
DEBUG [6]	set point for PV active power controller (PvPwrAtLimTot)	pu
DEBUG [7]	set point for battery active power controller (BatPwrAtSpntTot)	pu
DEBUG [8]	Battery active power controller output (BatPwrAtSpnt_Cmd)	pu
DEBUG [9]	PV active power controller output (PvPwrAtLim_Cmd)	pu

DEBUG [10]	Activate P(f) (FrqDroopActive)	
DEBUG [11]	POIPwrAtCtrlMode (1: PV, 2:Bat) (AutoMode)	
DEBUG [12]	filtered, sensed frequency (FrqPoiFiltered)	pu
DEBUG [13]	reactive external Set point for System (PwrRtSpnt)	pu
DEBUG [14]	reactive Set point for System (after internal limitation (Ramp/filter/Q(V)) (PwrRtSpntTot)	pu
DEBUG [15]	reactive power controller output for Battery (after dispatch process) (BatPwrRtSpnt_Cmd)	pu
DEBUG [16]	reactive power controller output for PV (after dispatch process) (PvPwrRtSpnt_Cmd)	pu
DEBUG [17]	reactive power mode (PwrRtCtrlMode)	
DEBUG [18]	FRT Flag (FrtActive)	
DEBUG [19]	FRT low limit (VtgLoLim)	pu
DEBUG [20]	FRT high limit (VtgUpLim)	pu
DEBUG [21]	min. of all phase voltages for FRT Flag detection (Vtg_FRT)	pu
DEBUG [22]	max. of all phase voltages for FRT Flag detection (Vtg_FRT)	
DEBUG [23]	external voltage set point (unfiltered) (VtgSpnt)	pu
DEBUG [24]	Battery active power controller output (the signal is relevant for the frequency control in island systems) (BatGfPwrAtSpntOfs)	pu
DEBUG [25]	Battery reactive power controller output (the signal is relevant for the voltage control in island systems) (BatGfPwrRtSpntOfs)	pu
DEBUG [26]	Black start voltage set point (VtgNomSpnt)	pu
DEBUG [27]	sensed active poi power (PwrAtPoi)	pu
DEBUG [28]	sensed reactive poi power (PwrRtPoi)	pu

3 Configuring the Hybrid Controller

Model parameters

In this section there is given a standard parameterization only. Please note that there exist individual parameter sets depending on the application type and use case.

3.1 Nominal Ratings

Name	Description	default	Range
GridService.PwrApNomPoi	Rated apparent power at the point of interconnection (POI)		0 – 1000000 [kVA]
GridService.PwrAtNomPoi	Rated active power at the point of interconnection (POI)		1 - 100000 [kW]
GridService.PwrRtNomPoi	Rated reactive power at the point of interconnection (POI)		0 – 1000000 [kVAr]
Meas.FacNom	Nominal frequency		50/60 Hz

Name	Description	default	Range
GridVtgCtrl.VtgNom	Rated voltage at the point of interconnection (POI)		1 – 220000 [V]

3.2 Setpoint gradients

Name	Description	default	Range
SpntRamp.PwrAtMode	Defines the operating state in which **PwrAtRateMax** is enabled 0: **PwrAtRateMax** is disabled. 1: **Genset Isolated Operation**: Gensets primarily supply the hybrid system 2: **Grid Mains Operation**: The utility grid primarily supplies the hybrid system	3	1 – 3

	3 **Genset Isolated Operation** and **Grid Mains Operation**: The utility grid and gensets primarily supply the hybrid system		
SpntRamp.PwrRtMode	Defines the operating state in which **PwrRtRateMax** is enabled 0 **PwrRtRateMax** is disabled. 1 **Genset Isolated Operation**: Gensets primarily supply the hybrid system 2 **Grid Mains Operation**: The utility grid primarily supplies the hybrid system 3 **Genset Isolated Operation** and **Grid Mains Operation**: The utility grid and gensets primarily supply the hybrid system	3	1 – 3
SpntRamp.PwrAtRateMax	Maximum rate of change of active power setpoint for entire hybrid system	100	1 – 100000 [MW/min]
SpntRamp.PwrRtRateMax	Maximum rate of change of reactive power setpoint for entire hybrid system	100	1 – 100000 [MW/min]
SpntRamp.PvPwrAtFall-RateMax	Maximum negative rate of the active power setpoint for PV inverters in percent per second (%/s) of related rated inverter power	20	0 – 1000 [%/s]
SpntRamp.PvPwrAtRiseRateMax	Maximum positive rate of the active power setpoint for PV inverters in percent per second (%/s) of related rated inverter power	5	0 – 1000 [%/s]
SpntRamp.BatPwrAtRiseRateMax	Maximum positive rate of change of active power setpoint for the storage system related to the cumulated rated power of the battery inverter	20	0 – 1000 [%/s]
SpntRamp.PwrRtFall-RateMax	Maximum negative rate of change of reactive power setpoint for the hybrid system related to the cumulated rated power of the PV and battery inverter	20	0 – 1000 [%/s]
SpntRamp.PwrRtRiseRateMax	Maximum positive rate of change of reactive power set-point for the hybrid system related to the cumulated rated power of the PV and battery inverter	20	0 – 1000 [%/s]
SpntRamp.PwrAtReset-ThrsldPc	Limiting value for the reset of the active power setpoint to the current active power value measured (related to the parameter **PwrAtNomPoi**)	5	0 – 100 [%]

3.3 General Grid Service settings

Name	Description	default	Range
GridService.FrqPoiFilterTm	Filter time constant for frequency. Every frequency change follows a defined time/frequency curve. The filter time con-stant defines the point in time at which 67% of the required frequency change must be reached	0	0 – 60 [s]
GridService.PwrAtPoiFilterTm	Filter time constant for measuring the current active power	0	0 – 600

			[s]
GridService.PwrRtPoiFilterTm	Filter time constant for measuring the current reactive power	0	0 – 600 [s]
GridService.PwrApPrioMode	Setpoint of reference value for limitation of apparent power 1 Active power 2 Reactive power	1	
GridService.CosPhiMinPoi	Minimum power factor at point of interconnection (POI) If **CosPhiMinPoi** is set to 0, the limitation is disabled.	0	0,1
GridService.PoiPwrAtCtrlMode	Defines which device class is specified to have priority controlling the active power at the POI 2 PV inverter setpoint 3 Battery inverter setpoint	2	2,3
GridService.EnaFrqRespForPv	Enables frequency response (FFR, EFR, PRL, DS3, FCAS) for PV systems. 0: ENA_NO 1: ENA_YES	0	0,1

3.4 Parameter for PI Controller

abc	Struct for controller settings BatPwrAtCtrl — **Battery Active Power Control** PvPwrAtCtrl — **PV Active Power Control** PwrRtCtrl — **Reactive Power Control**

Name	Description	default	Range
abc.Ena	Enable the PI controller	0	0,1
abc.SysStateMode	Defines the operating state of the Hybrid Controller in which the PI controller is active 1 Genset Isolated Operation: Gensets primarily supply the hybrid system 2 Battery Isolated Operation: Battery inverters primarily supply the hybrid system 3 Grid Mains Operation: The utility grid primarily supplies the hybrid system 4 Battery Isolated Operation and Grid Mains Operation: The utility grid and gensets primarily supply the hybrid system.	3	1,2,3,4
abc.CtrlKi	Integral gain for the control share of PI controller	1	-1000 –

			1000
abc.CtrlKp	Integral gain for the proportional control share of PI controller	0	-1000 – 1000
abc.FeedForward-Offset	The configurable offset is added to the power setpoint.	0	0 – 100000
abc.PilotControl-Gain	Feed forward gain	1	0 – 2
abc.SpntDelaySamples	Delays the setpoint for PI controller by n samples (Can be used to give pilot control some time to take effect.)	3	0 – 100
abc.PiCtrlLimPc	Upper and lower limit of PI controller output. The value is assigned a positive sign for the upper limit and a negative sign for the lower limit	5	0 – 100
abc.MeasFilterTm	Filter time constant for measurement signal	0	0 – 600 [s]
abc.EnaStepReset	Enables the reset and holding of the integrator if rapid change or overshooting is detected 0 — Disables the function 1 — Enables the function	0	0,1
abc.StepReset-ThrsldPc	Threshold for detection of rapid change: • in terms of active power setpoints related to the parameter *GridService.PwrAtNomPoi* • in terms of reactive power setpoints related to the parameter *GridService.PwrRtNomPoi*	20	0 – 100 [%]
abc.OvershootResetPc	Offset for overshoot detection: • in terms of active power setpoints related to the parameter *GridService.PwrAtNomPoi* • in terms of reactive power setpoints related to the parameter *GridService.PwrRtNomPoi*	1	0 – 100 [%]

3.5 Reactive power functions

Name	Description	default	Range
PwrRt.PwrRtCtrlMode	Selects the reactive power control mode 303: External setpoint (PoiVArSpt) 1069: Q(v) voltage droop control *VtgPwrRtDroop* (VolSpt) 1074: Fixed CosPhi control (PoiPFSpt) 1076: CosPhi(P) control 1984: Voltage control (direct voltage control, no droop)	303	

Remark: Starting from release R12 the tag IDs for "Q(v) voltage droop" and "voltage control" have been swapped. Above table is valid from release R12.

3.5.1 Voltage-dependent reactive power control *VtgPwrRtDroop*

The function **Voltage Droop** controls the reactive power setpoints for all inverter with respect to a Q(V) characteristic. It is enabled by setting *PwrRt.PwrRtCtrlMode* to "1069".

Name	Description	Default	Range
VtgPwrRtDroop.SpntSrc	Defines how the setpoints are set from the Q(V) characteristic curve for the upper and lower limit of the primary reserve power 1: The setpoints result from the setting of the parameter *GridVtgCtrl.VtgNom* 2: The SCADA system specifies the setpoint (*VolSpt*) 3: The setpoints result from the measuring of the grid voltage and the set filter time for the voltage setpoint *VtgSpntFilterTm*	2	1,2,3
VtgPwrRtDroop.VtgFilterTm	Filter time for voltage measurement	0.5	0 – 100 [s]
VtgPwrRtDroop.VtgSpntFilterTm	Filter time for voltage setpoint (VolSpt)	0.5	0 – 600 [s]
VtgPwrRtDroop.VtgDbHi	Upper limit of deadband as a percentage of the rated grid voltage	0	0 – 100 [%]
VtgPwrRtDroop.VtgDbLo	Lower limit of deadband as a percentage of the rated grid voltage	0	-100 – 0 [%]

VtgPwrRtDroop.VtgBreakpoints[1-10]	Characteristic curve points for voltage 1 to 10 (in % of *GridVtgCtrl.VtgNom*)	0	-100 - 100 [%]
VtgPwrRtDroop.PwrRtDataPc[1-10]	Characteristic curve points for reactive power 1 to reactive power 10 (in % of *GridService.PwrRtNomPoi*)	0	-100 - 100 [%]

3.5.2 Power factor control *Fix CosPhi*

Power factor control to a given setpoint can be enabled by setting *PwrRt.PwrRtCtrlMode* to "1074".

Name	Description	De-fault	Range
FixCosPhi.PwrAtFilterTm	Filter time constant for active power	0	1 – 600 s

3.5.3 Active power-dependent reactive power limitation *PwrRtPwrAtLim*

The function **PwrRtPwrAtLim** (Qlim(P)) limits the maximum reactive power at the POI in dependency of the actual active power. The function can be used in combination with all reactive power modes.

Name	Description	Default	Range
PwrRtPwrAtLim.Ena	Enables function 0 – Disabled 1 – Enabled	0	0,1
PwrRtPwrAtLim.PwrAtFilterTm	Filter time for active power measurement	0.0	0 – 100 [s]
PwrRtPwrAtLim.PwrAtLimHiPc[1-10]	Active power breakpoints for the upper reactive power limits in % relative to PwrAtNomPoi		-200 – 200 [%]
PwrRtPwrAtLim.PwrRtLimHiPc[1-10]	Reactive power breakpoints for the upper reactive power limits in % relative to PwrRtNomPoi		-200 – 200 [%]
PwrRtPwrAtLim.PwrAtLimLoPc[1-10]	Active power breakpoints for the lower reactive power limits in % relative to PwrAtNomPoi		-200 – 200 [%]
PwrRtPwrAtLim.PwrRtLimLoPc[1-10]	Reactive power breakpoints for the lower reactive power limits in % relative to PwrRtNomPoi		-200 – 200 [%]

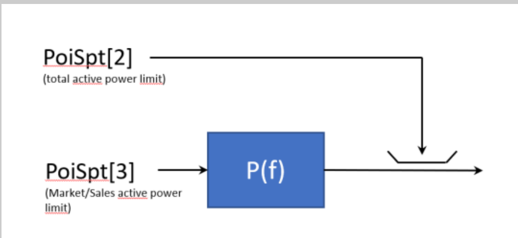
3.5.4 Distribution of reactive power setpoints

Name	Description	default	Range
Dispatch.PwrRtDispatchMode	Dispatch mode of reactive power between Batt and PV 0: Split reactive power between PV and Batt according to Dispatch.PvBatSpntSplitPc 1: Split reactive power according to all connected inverters	1	0,1
Dispatch.PvBatSpntSplitPc	Distribution of the reactive power setpoint among the PV and battery inverters **Examples: SpntSplitPc** = 100%: 100% allotted to the PV power plant and 0% to the storage system. **SpntSplitPc** = 0%: 0% allotted to the PV power plant and 100% to the storage system.	50	0-100 [%]

3.6 Active power functions

3.6.1 P(f) characteristic Curve

Name	Description	default	Range
FrqDroop.Ena	Enable the **Power Frequency Response** function	0	0,1
FrqDroop.ActDelay	Activation delay for P(f)-characteristic	0.1	0 – 10 [s]
FrqDroop.EnaActFrt	Enables activation during FRT	1	0 - 1
FrqDroop.DroopMode	Defines the characteristic of the droop Curve 1 – The active power values of the configurable P(f) characteristic curve relate to the rated system power. The characteristic curve sends the active power setpoint directly depending on the current frequency 2 – The active power values of the configurable P(f) characteristic curve relate to the active power before overfrequency occurs. The active power values of the P(f) characteristic curve are multiplied by the active power before overfrequency occurs 3 – The active power values of the configurable P(f) characteristic curve relate to the rated system power. The P(f) characteristic curve is shifted on the P axis in order to start with the active power before overfrequency occurs	3	1,2,3
FrqDroop.FrqOffsets	Characteristic curve points for frequency 1 to 10		-5 – 5

<table>
<tr><td>[1-10]</td><td></td><td></td><td>[Hz]</td></tr>
<tr><td>FrqDroop.PwrAtDataPc [1-10]</td><td>Characteristic curve points for inverter 1 to 10 (related to the rated system power)</td><td></td><td>0 – 200 [%]</td></tr>
<tr><td>FrqDroop.ResetMode</td><td>Defines when the reset mode is enabled<table><tr><td>1</td><td>Not enabled</td></tr><tr><td>2</td><td>Enabled during over frequency</td></tr><tr><td>3</td><td>Enabled during under frequency</td></tr><tr><td>4</td><td>Enabled during over- and under frequency.</td></tr></table></td><td>1</td><td>1,2,3,4</td></tr>
<tr><td>FrqDroop.ResetFrqOffset1</td><td>Defines the reset frequency during overfrequency</td><td>-0.2</td><td>-5 – 5 [Hz]</td></tr>
<tr><td>FrqDroop.ResetFrqOffset2</td><td>Defines the reset frequency during underfrequency</td><td>0.2</td><td>-5 – 5 [Hz]</td></tr>
<tr><td>FrqDroop.ResetTm</td><td>Switch-off delay for reset frequency ResetTm determines the time for which the currently measured frequency must be greater or less than the reset frequency</td><td>0 – 3600 s</td><td>0 [s]</td></tr>
<tr><td>FrqDroop.UseBatPwr</td><td>Enables the consumption and supply of active power by the battery inverters to comply with the P(f) characteristic curve<table><tr><td>1</td><td>Disables power output</td></tr><tr><td>2</td><td>Enables power output</td></tr></table></td><td>1</td><td>1,2</td></tr>
<tr><td>FrqDroop.UnderFrqMode</td><td>Mode for active power increase of battery inverters during underfrequency)<table><tr><td>1</td><td>The active power is not limited</td></tr><tr><td>2</td><td>The active power is limited by the parameter MaxRelPwrIncrease
or
by the “upper active power limit” at POI Poi_Spt[2]:

</td></tr></table></td><td>1</td><td>1,2</td></tr>
<tr><td>FrqDroop.MaxRelPwrIncrease</td><td>Maximum relative power increase related to the difference between PwrAt- NomPoi and the active power that has been measured before underfrequency occurs</td><td>33.33</td><td>0 – 100 [%]</td></tr>
<tr><td>FrqDroop.OverFrqMode</td><td>Mode to reduce power output of the battery inverters during overfrequency<table><tr><td>1</td><td>The power output is not limited.</td></tr><tr><td>2</td><td>The power output is limited by the parameters Min-PwrSpnt and</td></tr></table></td><td>1</td><td>1,2</td></tr>
<tr><td>FrqDroop.MinPwrSpnt</td><td>Minimum setpoint of electrical power that must be reached by the P(f) characteristic curve (related to PwrAtNom-Poi)</td><td>5</td><td>0 – 100</td></tr>
</table>

			[%]
FrqDroop.MaxPwrDecrease	Maximum reduction of electrical power during overfrequency (related to **PwrAtNomPoi**)	10	0 – 100 [%]

3.6.2 Energy Shifting Function

Name	Description	default	Range
EgyShift.Ena	Enables this function	1	0,1
EgyShift.UseFullPvPwr	Enables the battery charging with the entire PV power	0	0,1
EgyShift.EnaDisWithPv	Enables the discharge of the battery when PV power is available. Only if the PV power is greater than zero will the battery be discharged.	0	0,1
EgyShift.EnaPrioRrc		0	
EgyShift.ChrFromPvSpntLimPc	Charging the battery from PV is limited by this value based on the maximum charge power of the battery system The battery is charged when there is surplus PV energy. The charging setpoint of the storage system is limited to this value.	50	0 – 100 [%]
EgyShift.DisBatSpntLimPc	Amount of power provided by the battery based on the maximum discharge power of the battery system The buffered energy is released by the storage system if too little PV power is available. The setpoint for discharging the battery is limited to this value.	10	0 – 100 [%]
EgyShift.MinDisTm	Minimum time for the battery to provide power The energy required must be stored in the battery.	1800	60 – 200000 [s]
EgyShift.TolerancePc	Tolerance for reducing the MPP power When determining the maximum charging power, the Hybrid Controller takes the reduced MPP power into account	5	0 – 100 [%]
EgyShift.RampRate	Rate of change of the setpoint for the intermediate storage	2	1-100 [%/s]

3.7 FRT detection

Name	Description	default	Range
FrtDetection.Ena	Enables the **FRT Detection** function	0	0,1

FrtDetection.FilterTm	Filter-time constant for upper and lower limiting value of grid voltage	20	0 – 100 [s]
FrtDetection.VtgUpLimPC	Upper voltage threshold for FRT detection related to the value of **ThrsldMode**	110	100 – 500 [%]
FrtDetection.VtgLoLimPC	Upper voltage threshold for FRT detection related to the value of **ThrsldMode**	90	0 – 100 [%]
FrtDetection.StopDelay	Delay time for leaving the dynamic gird support	1	0 – 3600 [s]
FrtDetection.ThrsldMode	Selects the source for calculation of the upper and lower voltage threshold 1 | The calculation of voltage thresholds is based on the measured voltage and the filter-time setting 2 | The setpoints result from the setting of the parameter **VtgNom**	2	1,2
FrtDetection.VtgNom	Nominal voltage for FRT detection in V	400	400 – 1e6
FrtDetection.RefMode	Defines the reference point for FRT detection 1: FRTDETECT_REF_MODE_DEDICATED 0: FRTDETECT_REF_MODE	0	1,2

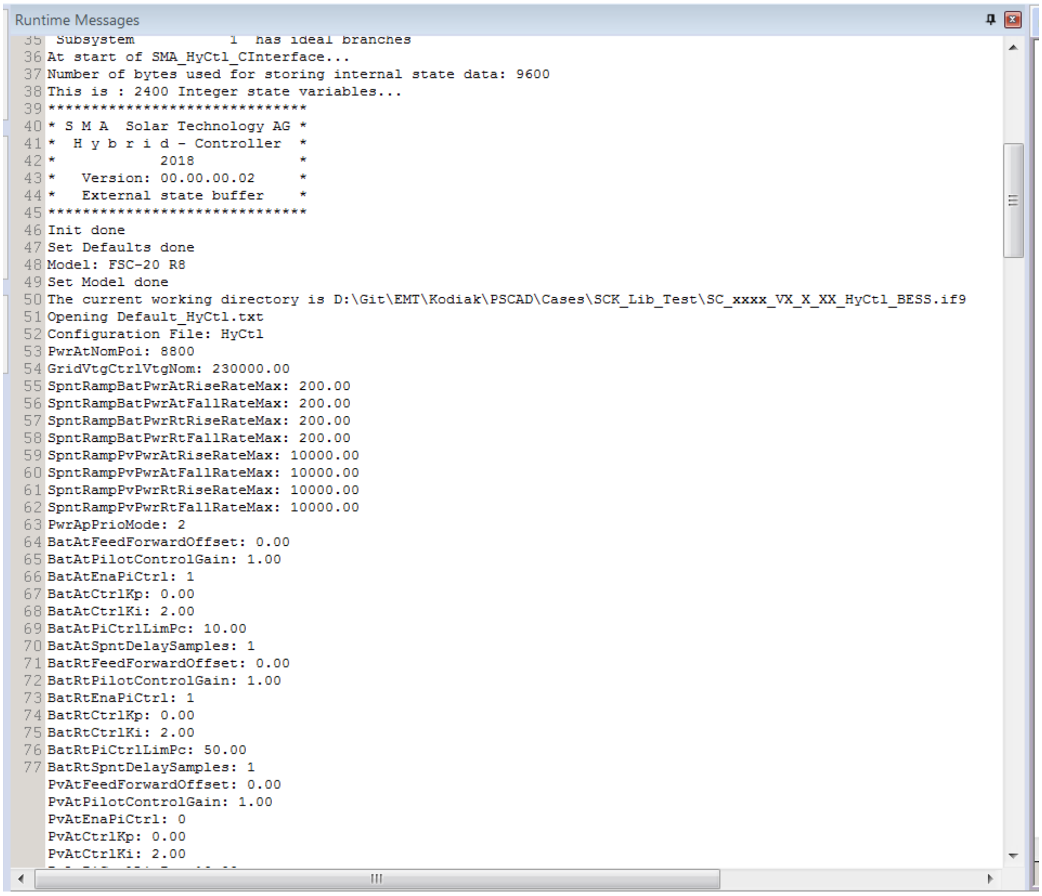
4 General information

Characteristic curves/look-up tables

There are no monotony checks included in the model! The user must take care that all parameters which are used within look-up tables fulfill the respective monotony requirements.

5 Runtime Messages

During the start of the simulation the parameter file used and the parameters loaded are displayed in the PSCAD "Runtime Messages" window.



```
Runtime Messages
 Subsystem           1  has ideal branches
At start of SMA_HyCtl_CInterface...
Number of bytes used for storing internal state data: 9600
This is : 2400 Integer state variables...
******************************
* S M A  Solar Technology AG *
*  H y b r i d - Controller  *
*            2018            *
*   Version: 00.00.00.02     *
*   External state buffer    *
******************************
Init done
Set Defaults done
Model: FSC-20 R8
Set Model done
The current working directory is D:\Git\EMT\Kodiak\PSCAD\Cases\SCK_Lib_Test\SC_xxxx_VX_X_XX_HyCtl_BESS.if9
Opening Default_HyCtl.txt
Configuration File: HyCtl
PwrAtNomPoi: 8800
GridVtgCtrlVtgNom: 230000.00
SpntRampBatPwrAtRiseRateMax: 200.00
SpntRampBatPwrAtFallRateMax: 200.00
SpntRampBatPwrRtRiseRateMax: 200.00
SpntRampBatPwrRtFallRateMax: 200.00
SpntRampPvPwrAtRiseRateMax: 10000.00
SpntRampPvPwrAtFallRateMax: 10000.00
SpntRampPvPwrRtRiseRateMax: 10000.00
SpntRampPvPwrRtFallRateMax: 10000.00
PwrApPrioMode: 2
BatAtFeedForwardOffset: 0.00
BatAtPilotControlGain: 1.00
BatAtEnaPiCtrl: 1
BatAtCtrlKp: 0.00
BatAtCtrlKi: 2.00
BatAtPiCtrlLimPc: 10.00
BatAtSpntDelaySamples: 1
BatRtFeedForwardOffset: 0.00
BatRtPilotControlGain: 1.00
BatRtEnaPiCtrl: 1
BatRtCtrlKp: 0.00
BatRtCtrlKi: 2.00
BatRtPiCtrlLimPc: 50.00
BatRtSpntDelaySamples: 1
PvAtFeedForwardOffset: 0.00
PvAtPilotControlGain: 1.00
PvAtEnaPiCtrl: 0
PvAtCtrlKp: 0.00
PvAtCtrlKi: 2.00
```

6 Disclaimer

This document and the associated models have been prepared to facilitate the 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.