INGECON® SUN Inverter PSS®E Dynamic Model Specification & Datasheet

INGECON® PSS®E Dynamic Model Specification. Ingeteam. V13

Ingeteam Power Technology S.A.

03/08//2015

Index

1. INTRODUCTION

This document describes the dynamic model of INGECON SUN® inverters developed for PSSE v.32 & v.33. The document is complemented by a user guide "Modeling and Simulation of Photovoltaic Plants with INGECON SUN® Inverters in PSS®E". The model can be used to study the behavior of a single INGECON SUN inverter, or a PV plant with several INGECON SUN inverters represented by a lumped model, under normal and perturbed grid operation.

The model is programmed in a single module as a generator model, named ING1AJ. The last two letters indicate the major and minor version. The model is structured in four main modules[1]:

- Measurement module
- PV panel module
- Electrical control module
- Power converter module

The general connectivity of the model is shown in Figure 1. Next sections describe the different modules in detail, specifying their inputs and outputs as well as the parameters used. The complete model datasheet can be consulted in Annex I.

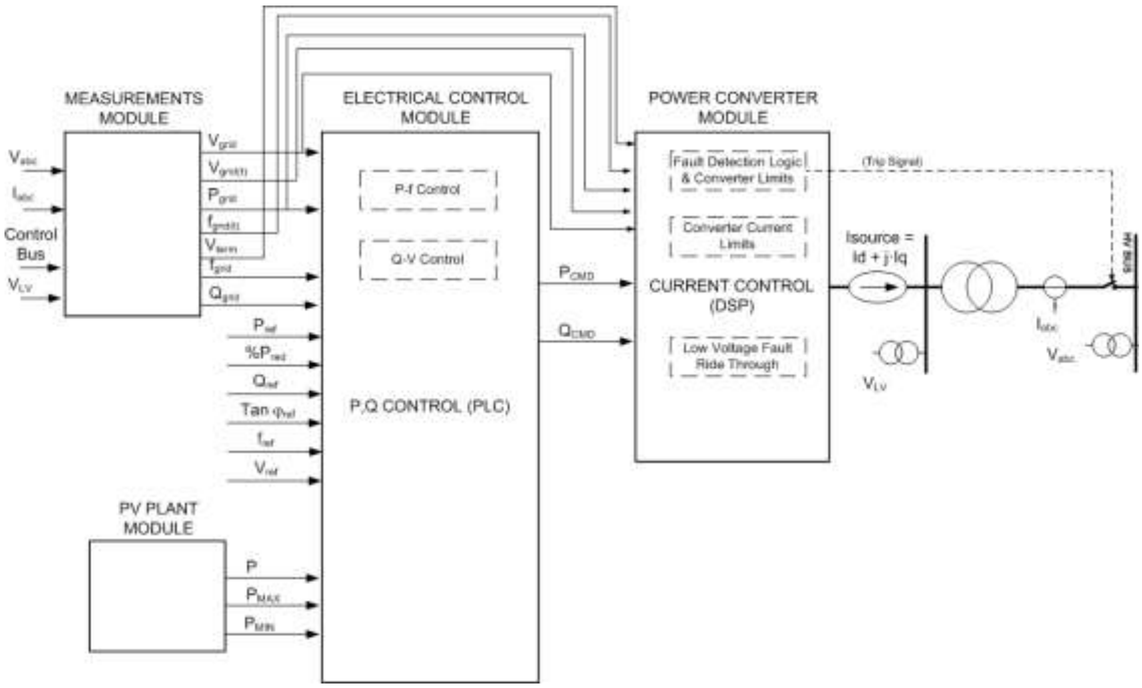

Figure 1. General model module connectivity diagram

The sign criteria followed for the power injected into the network is the generator criteria.

[1] This is the internal structure of the model. Externally, the user has to call only one model (ING1AJ) in the dynamic simulation process.

2. MEASUREMENTS MODULE

This module (Figure 2) provides the voltage at the inverter terminal and the voltage and frequency measured at the control bus. This bus is indicated by the user in ICON (M+4). Also, the module provides the active and reactive power supplied by the inverter. The module parameters are shown in Table 1.

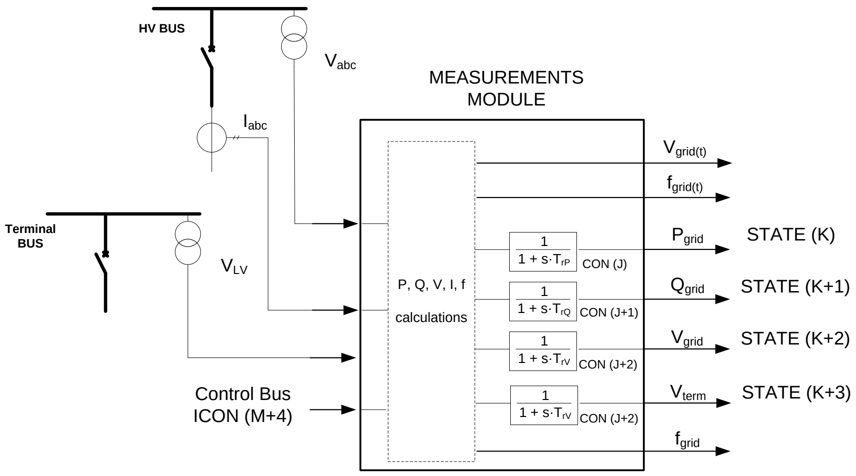

Figure 2. Block diagram of the measurement module

The module inputs are:

- Instantaneous control bus voltage (V_{abc})
- Instantaneous control bus current (I_{abc})
- Control Bus. ICON(M+4)
- Instantaneous terminal voltage (V_{LV})

The module outputs are:

- Measured active and reactive power injected to the grid (P_{grid}, Q_{grid}). STATE (K) and STATE (K+1)
- Measured control bus voltage (V_{grid}) and frequency[2] (f_{grid}). STATE (K+2)
- Measured terminal voltage (V_{term}). STATE (K+3)
- Instantaneous voltage and frequency at the control bus ($V_{grid(t)}$, $f_{grid(t)}$)

CON	Parameter
J	T_{rP}, Act. Power filter time constant (s)
J+1	T_{rQ}, Reac. Power filter time constant (s)
J+2	T_{rV}, Voltage filter time constant (s)

Table 1. Parameters of the measurement module

[2] The model does note use a delay transfer function for the frequency because PSS/E already uses an internal filter to calculate the frequency.

3. PV PANEL MODULE

This module models the aggregated output of the PV panels of the plant as a constant value, obtained from the initial power flow solution. The maximum (P_{MAX}) and minimum (P_{MIN}) panel aggregated output is entered by the user in CON (J+15) and CON (J+16), respectively.

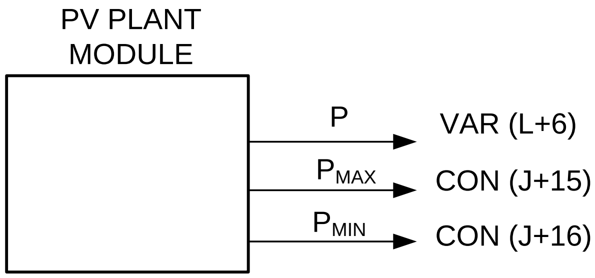

Figure 3. Block diagram of the PV plant module

The user can modify the output of the PV plant changing the value of VAR (L+6) to simulate a variation in the irradiance, the control action of a high level plant controller, or other events affecting the ouput of the PV panels.

The module outputs are:

- Active power supplied by the PV panels (P). VAR (L+6)
- Maximum available active power (P_{MAX}). CON (J+15)
- Minimum available active power (P_{MIN}). CON (j+16)

Note: The value of Pmax is entered in p.u. refered to the equivalent machine Mbase (the inverter MVA rating). For example, if the inverter has a rating of 10.5 MVA and the maximum output of the plant is 10 MW, the value of Pmax should be 10/10.5 = 0.9524 p.u.

4. ELECTRICAL CONTROL MODULE

The electrical control module calculates the active and reactive power commands when the plant operates in normal grid conditions. Figure 4 shows the complete structure of the module. The following subsections describe in detail the block diagrams of the different active and reactive control functions.

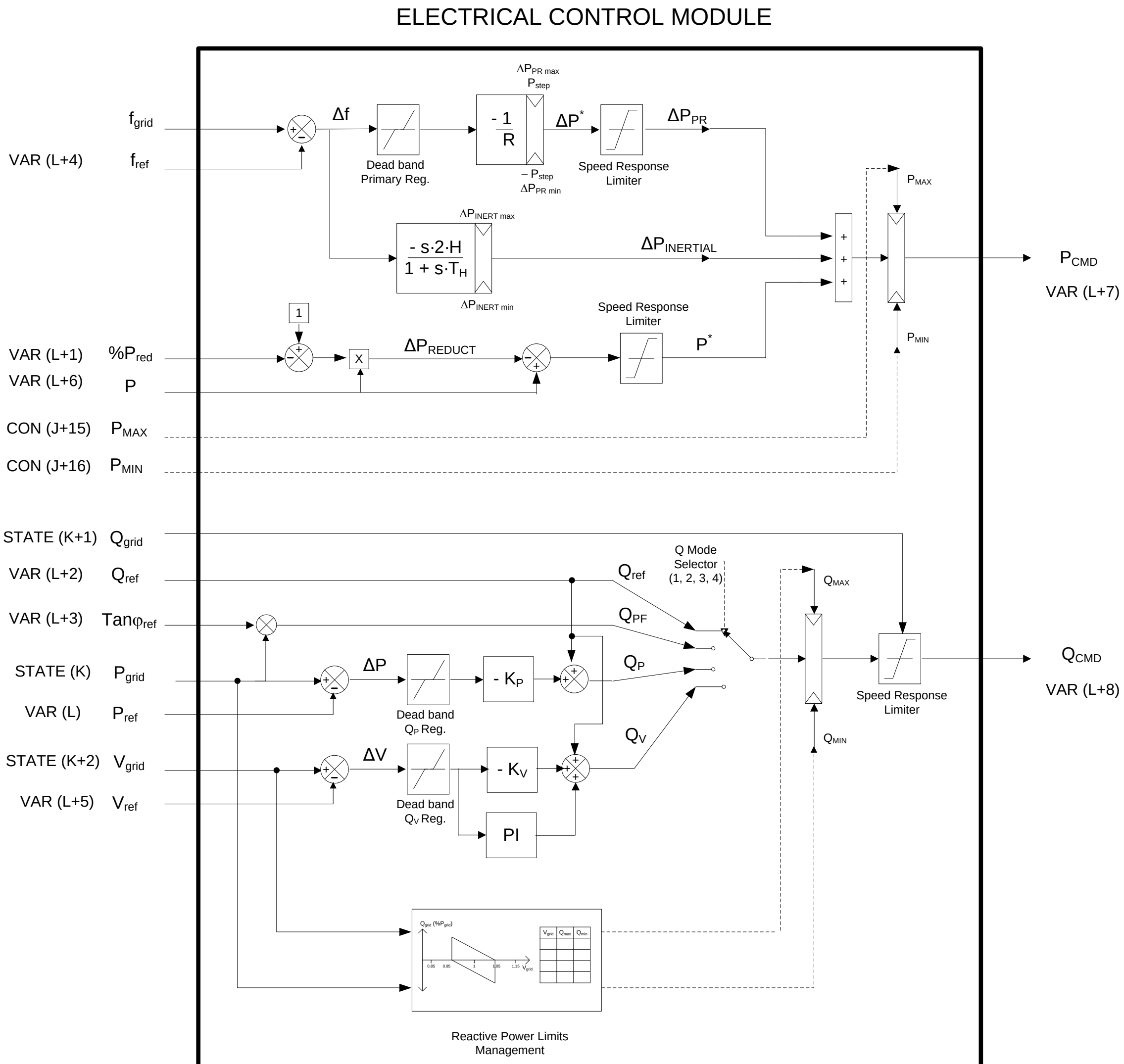

Figure 4. Block diagram of the electrical control module

The block inputs are:

- Active and reactive power measured (P_{grid}, Q_{grid}), control bus voltage (V_{grid}) and frequency measured (f_{grid}). STATE (K) to STATE (K+2).
- Active power reference value (P_{ref}), active power reduction order ($\%P_{red}$), reactive power reference value (Q_{ref}), power factor reference ($Tan\varphi_{ref}$) and voltage and frequency reference values (V_{ref}, f_{ref}). VAR (L) to VAR (L+5).
- Active power supplied by the panels (P) and maximum and minimum limit values (P_{MAX}, P_{MIN}). VAR (L+6), CON (J+15) and CON (J+16).

The block outputs are:

- Active power command (P_{CMD}). VAR (L+6)
- Reactive power command (Q_{CMD}). VAR (L+7)

4.1 Active power control

The active power control, shown in Figure 5, provides the active power setting P_{CMD} as the combination of the primary regulation response, the inertial response and the active power value supplied by the PV panels. This last value is affected by the active power reduction order and it is limited by a ramp.

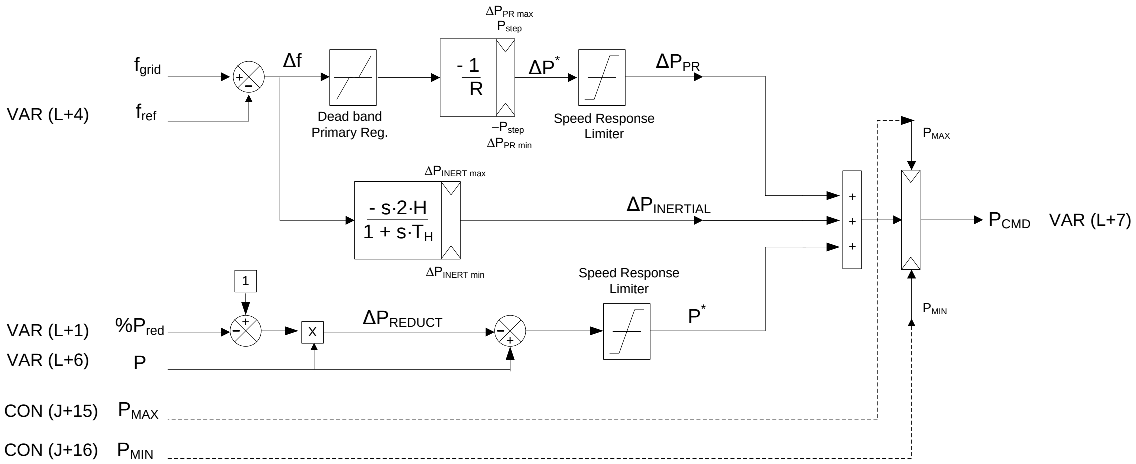

Figure 5. Block diagram of P-f control

4.1.1 Primary frequency control

The primary frequency control provides the plant response based on a droop characteristic with a dead band, as shown in Figures 6 and 7. The parameters of the block are detailed in Table 2.

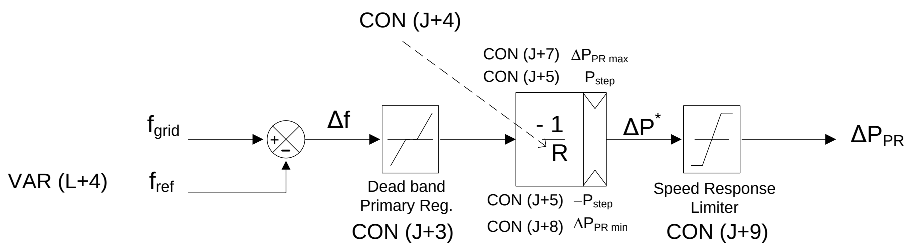

Figure 6. Block diagram of the primary frequency control

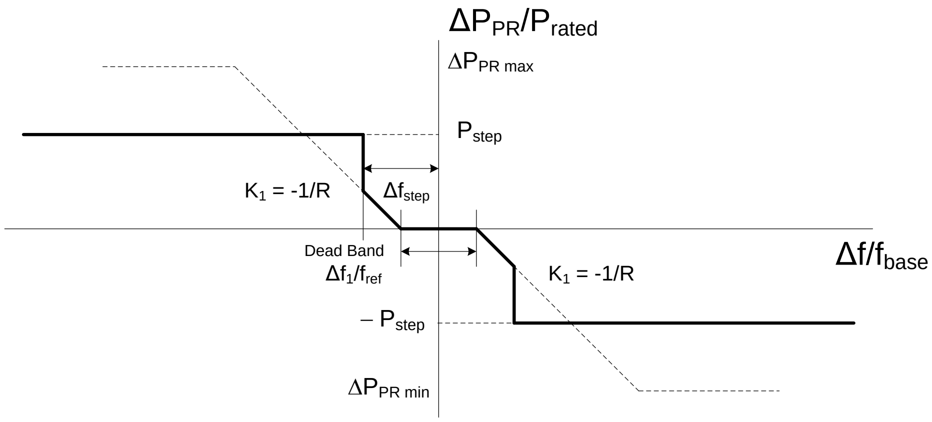

Figure 7. Droop characteristic of the primary frequency control

CON	Parameter
J+3	Δf1/fbase, Primary response dead band (pu)
J+4	R, Droop
J+5	P_{step}, P supplied during large frequency deviations (pu)
J+6	Δf_{step}, Transition from small to large frequency deviations (pu)
J+7	$\Delta P_{PR\ max}$, Maximum active power limit for primary response (pu)
J+8	$\Delta P_{PR\ min}$, Minimum active power limit for primary response (pu)
J+9	ΔP/Δt , Primary regulation response ramp (pu/s)

Table 2. Parameters of the primary frequency control

4.1.2 Virtual inertia

The emulation of the inertial response is represented in Figure 8, and the parameters of the function in Table 3.

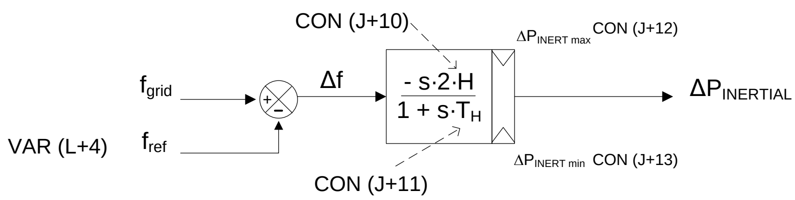

Figure 8. Block diagram for the emulation of the inertial response

A value of 0 in the inertia constant H cancels the inertial response.

CON	Parameter
J+10	H, Inertia constant (s)
J+11	T_H, Intertial response time constant (s)
J+12	$\Delta P_{INERT\ max}$, Maximum active power limit for inertial response (pu)
J+13	$\Delta P_{INERT\ min}$, Minimum active power limit for inertial response (pu)

Table 3. Paramters of the inertial response

4.1.3 Power reduction and ramp limit

The model allows decreasing the power output by means of the application of a power reduction order, as represented in Figure 9. The power reduction order is applied in p.u. For example, if the order is 0.2 pu, the power is reduced to 20% of the actual active power produced by the PV Panel (P). The step change produced by the power reduction order, and also the changes in the output of the PV Panel, are limited by a ramp that fixes a maximum rate of change of active power per time unit. This is the only configurable parameter of this block.

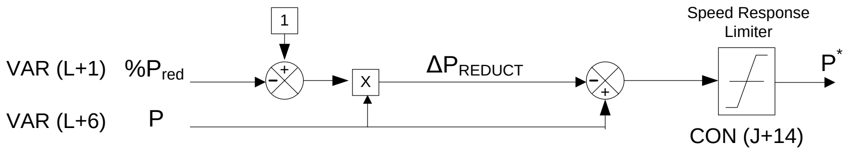

Figure 9. Block diagram for power reduction and ramp limit

CON	Parameter
J+14	ΔP/Δt , Active power ramp limit (pu/s)

Table 4. Parameters for power reduction and ramp limit

4.1.4 Limitation of the response of the active power control

The total active power setting is obtained as the sum of the power input plus the terms corresponding to primary, inertial and power reduction responses. This value is finally limited according to the PV panel power output limits, as shown in Figure 10.

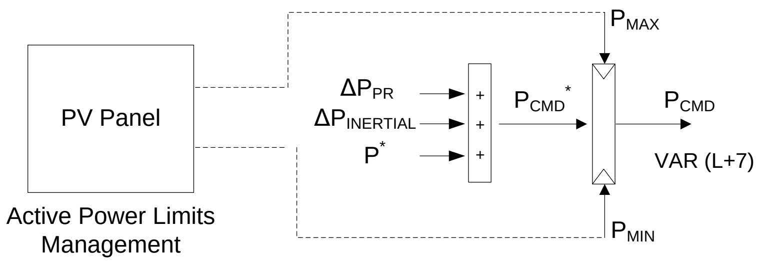

Figure 10. Block diagram of the limitation of the response of the active power control

4.2 Reactive power control

The reactive power control system provides the reactive power setting value Q_{CMD} (Figure 11). The value of reactive power supplied to the grid can be controlled by:

- Mode 1: fixed reactive power output (Q_{ref})
- Mode 2: fixed power factor (Q_{PF})
- Mode 3: power factor control by the power output (Q_P)
- Mode 4: voltage control (Q_V)

The control mode can be selected by specifying the appropriate value of the parameter Q Mode Selector in ICON (M+2).

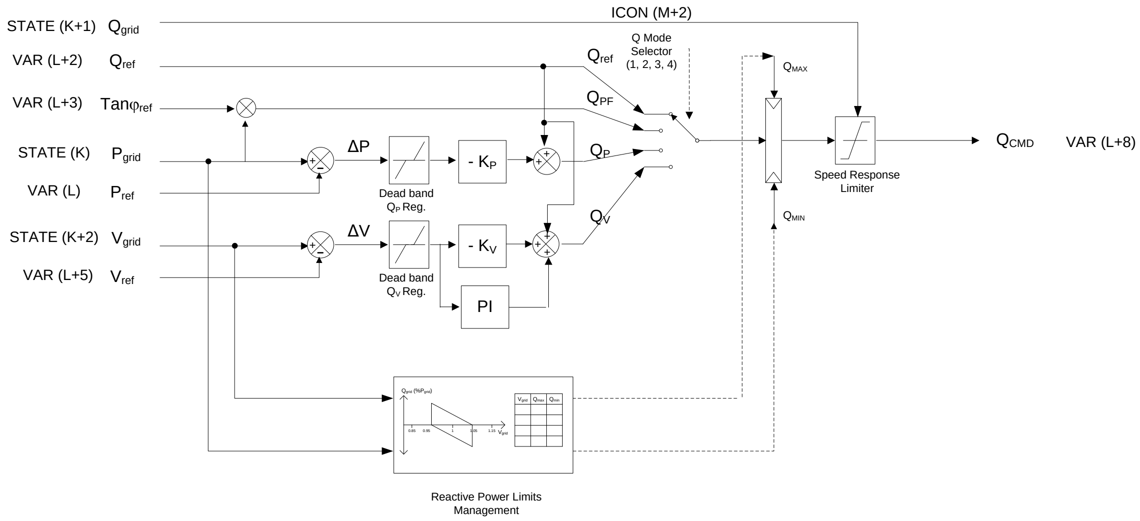

Figure 11. Block diagram of the reactive power control

4.2.1 Fixed reactive power

The reactive power command is constant and equal to the reactive power reference setting (Q_{ref}). This value can be adjusted by the user changing the value of VAR (L+2).

4.2.2 Fixed power factor

The reactive power command reference (Q_{PF}) is controlled according to the active power output of the inverter to keep the power factor in the inverter bus at its reference value (Figure 12). The reference is set by the user changing the value of VAR (L+3).

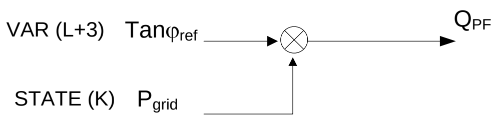

Figure 12. Block diagram of the reactive power control by a fixed power factor

4.2.3 Power factor control by the power output

In this case, the reactive power control determines the reactive power that should be generated according to the power output level (Q_P) (Figure 13).

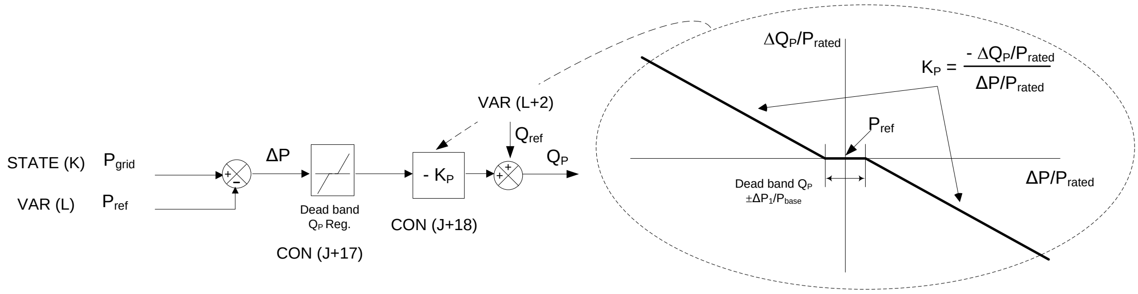

Figure 13. Block diagram of the control of reactive power by the power output

The parameters used by this function are shown in Table 5.

CON	Parameter
J+17	$\Delta P_1/P_{base}$, Power factor P control Dead band (pu)
J+18	K_P, Power factor P control gain

Table 5. Parameters used in the control of reactive power by the power output

4.2.4 Voltage control

Finally, the reactive power output can be controlled by determining the reactive power (Q_V) to be supplied according to the deviation of the voltage at the control bus from a reference value (Figure 14). The control strategy is based on proportional plus integral (PI) control actions with parallel reactive droop compensation.

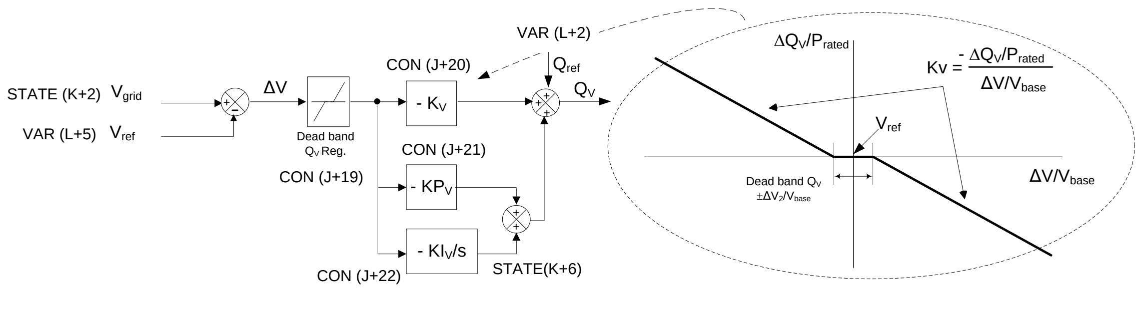

Figure 14. Block diagram of the control of reactive power by the voltage level

The parameters used are shown in Table 6.

CON	Parameter
J+19	$\Delta V_2/V_{base}$, voltage control Dead band (pu)
J+20	K_V, voltage control gain
J+21	KP_V, voltage control proportional constant
J+22	KI_V, voltage control integral constant

Table 6. Parameters used in the control of reactive power by the voltage level

4.2.5 Limitation of the response of the reactive power control

The output of the reactive power control during normal operation is limited according to the voltage and the active power level of the plant (Figure 15). The block calculates the maximum and minimum reactive power limits according to the values contained in a table, defined by the user, and limits the rate of change with a ramp.

The table is defined by 3 voltage points each with a value of Qmax and Qmin. The first point has to be the upper voltage level (point 1), the second one the nominal voltage level (point 2) and the third one the lower voltage level (point 3). Intermediate values are calculated using linear interpolation.

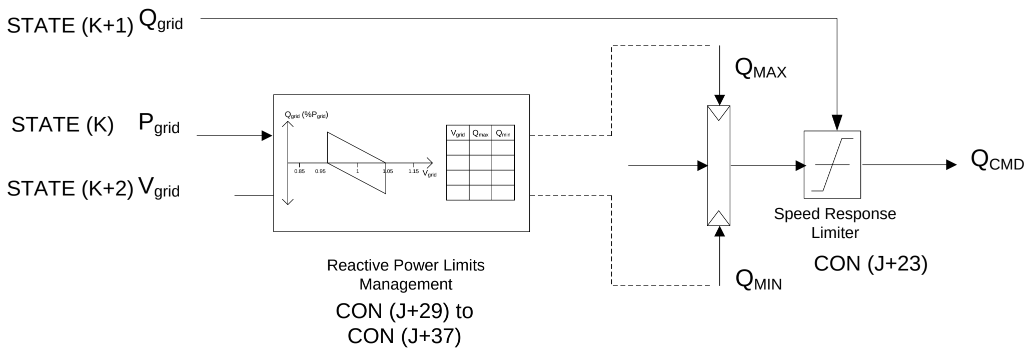

Figure 15. Block diagram of the reactive power limits management

The parameters used in this block are included in Table 7.

CON	Parameter
J+23	ΔQ/Δt, Reactive power ramp (pu/s)
J+29	Q limit curve point 1 V (pu)
J+30	Q limit curve point 1 Qmax (pu)
J+31	Q limit curve point 1 Qmin (pu)
J+32	Q limit curve point 2 V (pu)
J+33	Q limit curve point 2 Qmax (pu)
J+34	Q limit curve point 2 Qmin (pu)
J+35	Q limit curve point 3 V (pu)
J+36	Q limit curve point 3 Qmax (pu)
J+37	Q limit curve point 3 Qmin (pu)

Table 7. Parameters of the reactive power output limit funcition

5. POWER CONVERTER MODULE

The general block diagram of the Power Converter Module is shown in Figure 16. This module calculates the active and reactive current injected to the grid from the active and reactive power commands, or from the LVRT function in case of under voltage detection. Also, the module trips the plant in case of out of limits operation. The parameters of the converter model are included in Table 8.

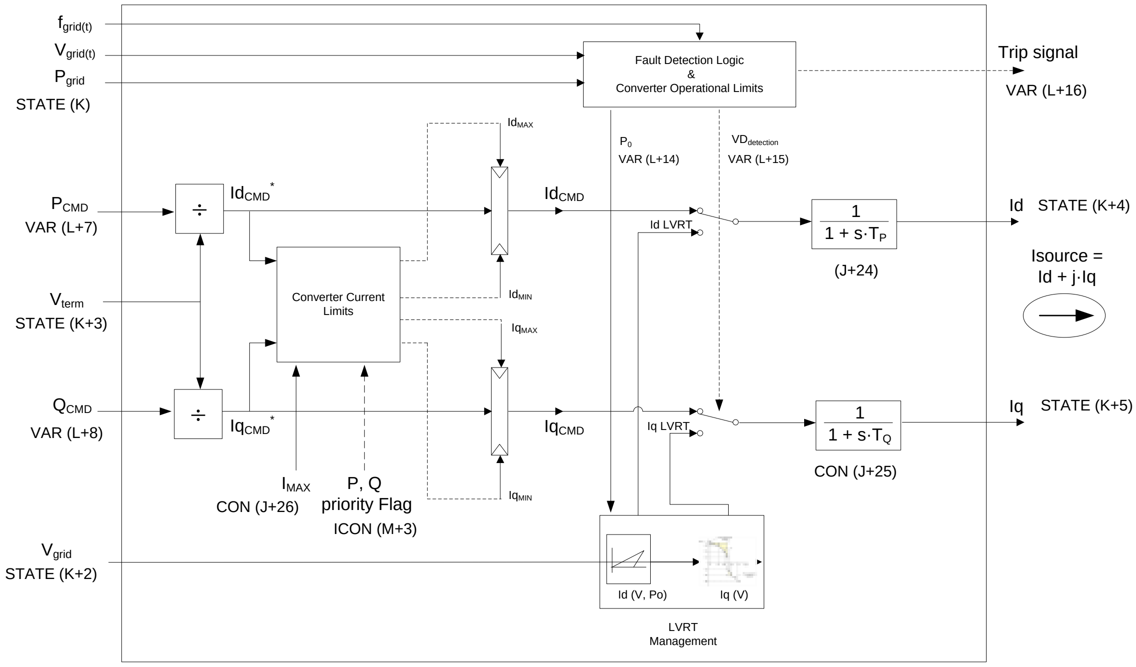

Figure 16. Block diagram of the power converter module

The block inputs are:

- Active and reactive power commands (P_{CMD}, Q_{CMD}). VAR (L+7) & VAR (L+8)
- Terminal voltage RMS value (V_{term}). STATE (K+3)
- Grid voltage RMS value (V_{grid}). STATE (K+2)
- Active power measurement (P_{grid}). STATE (K)
- Instantaneous grid voltage and frequency ($V_{grid(t)}$, $f_{grid(t)}$)

The block outputs are:

- Active current injection (Id). STATE (K+4)
- Reactive current injection (Iq). STATE (K+5)
- Trip signal. VAR (L+16)

CON	Parameters
J+24	T_P, Converter time constant for Id (s)
J+25	T_Q, Converter time constant for Iq (s)
J+26	I_{MAX} Converter maximum current rating (pu)

Table 8. Parameters of the power converter module

5.1 Fault detection logic and converter operational limits

This block monitors the frequency and the grid voltage. In case of over/under voltage, the block changes the operation of the converter to LVRT control, and in case of voltage and/or frequency out of limit operation, the block sends a trip signal and disconnects the plant from the grid. Figure 17 shows the block diagram and Table 9 the block parameters.

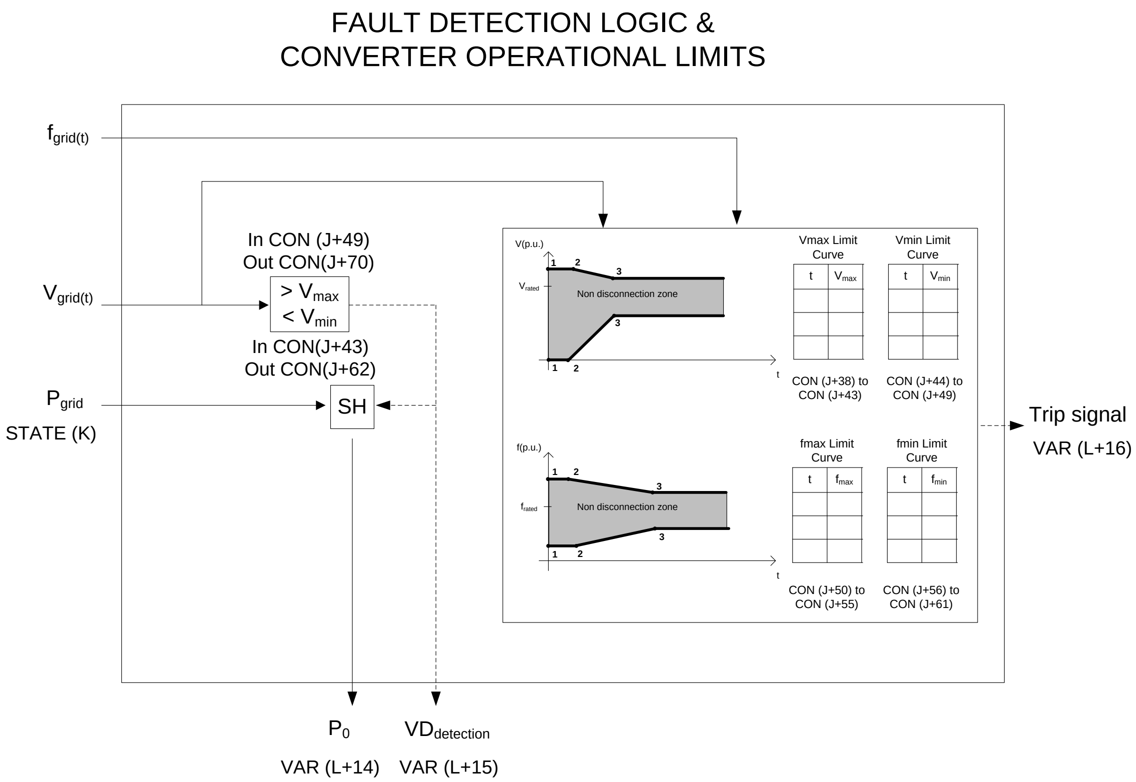

Figure 17. Fault detection logic & converter operational limits block diagram

The block inputs are:

- Grid voltage and frequency instantaneous value ($V_{grid(t)}$, $f_{grid(t)}$)
- Active power measured (P_{grid}). STATE (K)

The block outputs are:

- Initial active power at low voltage condition (P_0). VAR (L+14)
- Voltage disturbance detection signal ($VD_{detection}$). VAR(L+15)
- Trip signal (Trip signal). VAR (L+16)

CON	Parameters
J+27	t_in, HLVRT mode in ramp time (s)
J+28	t_out, HLVRT mode out ramp time (s)
J+38	V max limit curve Point 1 t (s)
J+39	V max limit curve Point 1 V (pu)
J+40	V max limit curve Point 2 t (s)
J+41	V max limit curve Point 2 V (pu)
J+42	V max limit curve Point 3 t (s)
J+43	V max limit curve Point 3 V (pu)
J+44	V min limit curve Point 1 t (s)
J+45	V min limit curve Point 1 V (pu)
J+46	V min limit curve Point 2 t (s)
J+47	V min limit curve Point 2 V (pu)
J+48	V min limit curve Point 3 t (s)
J+49	V min limit curve Point 3 V (pu)
J+50	f max limit curve Point 1 t (s)
J+51	f max limit curve Point 1 f (pu)
J+52	f max limit curve Point 2 t (s)
J+53	f max limit curve Point 2 f (pu)
J+54	f max limit curve Point 3 t (s)
J+55	f max limit curve Point 3 f (pu)
J+56	f min limit curve Point 1 t (s)
J+57	f min limit curve Point 1 f (pu)
J+58	f min limit curve Point 2 t (s)
J+59	f min limit curve Point 2 f (pu)
J+60	f min limit curve Point 3 t (s)
J+61	f min limit curve Point 3 f (pu)

Table 9. Parameters of the fault detection and converter operational limits block

The voltage limits are defined by two curves, one for the maximum limits and another one for the minimum limits. Each curve is defined by 3 time-voltage points ordered by increasing time and decreasing voltage, for the maximum limit curve, and increasing voltage for the minimum limit curve. The definition of the frequency limits is done in a similar way.

The block detects when the voltage and or the frequency is out of limits, activates a flag, registers the time associated with the event and calculates the corresponding maximum and minimum limit. The user can access all these variables in the following positions of the VAR array:

- VAR(L+17): Voltage Event Detection Flag: 1 overvoltage, -1 undervoltage, 0 otherwise
- VAR(L+18): Frequency Event Detection: 1 overfreq., -1 underfreq., 0 otherwise
- VAR(L+19): Maximum voltage limit
- VAR(L+20): Minimum voltage limit
- VAR(L+21): Maximum frequency limit
- VAR(L+22): Minimum frequency limit
- VAR(L+23): Time associated with a Vmax event

- VAR(L+24): Time associated with a Vmin event
- VAR(L+25): Time associated with a fmax event
- VAR(L+26): Time associated with a fmin event

The voltage disturbance detection signal ($VD_{detection}$) activates the internal Sample & Hold block and changes the state of the input selector of Figure 18 to change the behavior of the converter from PQ control to LVRT control. The inverter enters LVRT Mode with steady state maximum (CON(J+49)) and minimum (CON(J+43)) voltage limits and exits HLVRT Mode with V-Iq maximum (CON(J+70)) and minimum (CON(J+62)) voltage values. This hysteresis avoids the problem of hunting when the voltage is close to the steady state limits.

When the signal $VD_{detection}$ activates (+1 overvoltage; -1 undervoltage), the inverter changes from PQ control to LVRT control following a ramp with a time adjusted in CON(J+27). When the sigal deactivates (0), the inverter returns from LVRT control to PQ control operation following a ramp with a time adjusted in CON(J+28).

The model stores the time when the operation chages from PQ control to HLVRT control and v.v. in VAR(L+27) and VAR(L+28).

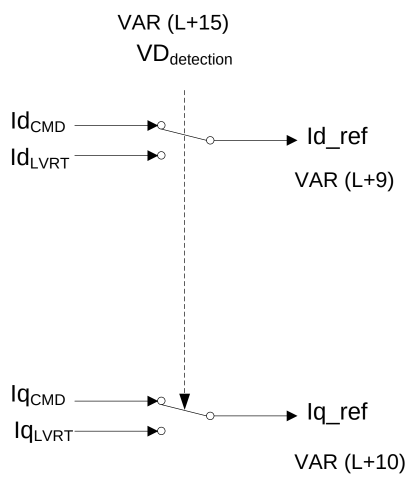

Figure 18. PQ control or LVRT control selector

5.2 Converter current limits

The current injected by the converter is limited according to the converter maximum current rating. First, the block shown in Figure 19 determines the active and reactive current limits, depending on the value of the P,Q priority flag. This flag is configured by the user in ICON (M+3).

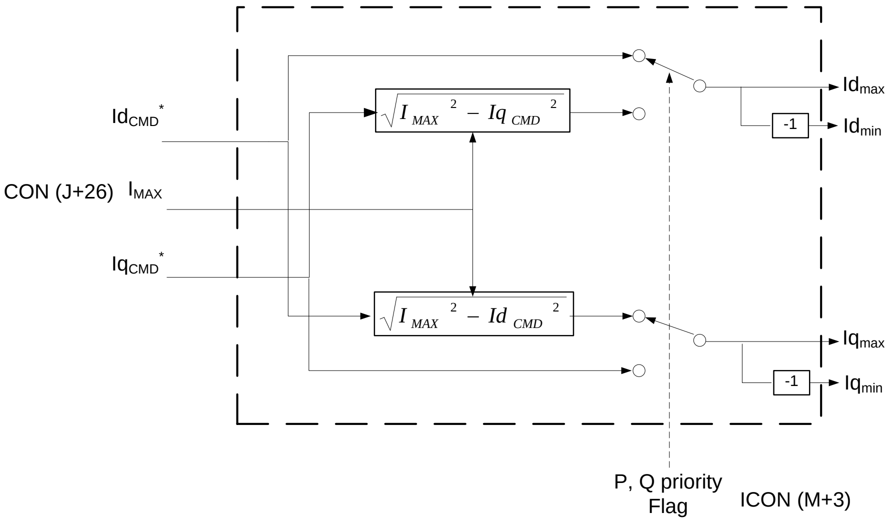

Figure 19. Current limits calculation block diagram

The block inputs are:

- Active and reactive unlimited current commands (Id_{CMD}^*, Iq_{CMD}^*)
- Maximum current rating (I_{grid}). CON (J+26)
- P, Q priority flag (P,Q priority Flag). ICON (M+3). If the flag is 0, the priority is for active current. If the flag is 1, the priority is for reactive current.

The block outputs are:

- Maximum and minimum active current limits (Id_{max}, Id_{min})
- Maximum and minimum reactive current limits (Iq_{max}, Iq_{min})

Once the limits are calculated, they are applied to two Max/Min limiters, one for the active current command and the other one for the reactive current command, as shown in Figure 20.

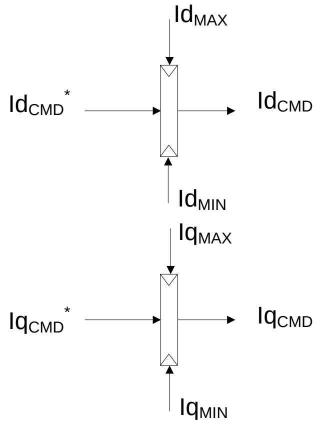

Figure 20. Active & reactive current commands limiters

5.3 High/Low Voltage Fault Ride Through

This block controls the behavior of the converter in case of a high or low voltage condition in the grid. The magnitude of the current injection depends on the grid voltage.

For the reactive component, the user has to define a 7 V-Iq point table. This table has to be ordered according to the numbering indicated in Figure 21. The block calculates the reactive current command using linear interpolation, depending on the value adjusted to parameter Iq_Mode in ICON(M+5):

- If Iq_Mode is set to 0: the current injection is calculated using linear interpolation with the values in p.u. interpreted as absolute values.
- If Iq_Mode is set to 1: the current injection is calculated using linear interpolation with the values in p.u. taken as the per unit change from the previous (before the voltage event) reactive current value. This way, the reactive current injection is the value calculated using linear interpolation plus the previous reactive current value, stored in variable VAR(L+30).

Finally, if the voltage recovery time is set to a value greater than 0, when the voltage returns to a value between setpoint Iq_LV_1V and Iq_HV_1V, the reactive current injection depends on the value adjusted to parameter Iq_Mode:

- If Iq_Mode is set to 0: the current injection is calculated using linear interpolation.
- If Iq_Mode is set to 1: the current injection is fixed to the prefault Iq value stored in VAR(L+30).

For the active component, the user has to define a 3 V-Id point table. This table has to be ordered by increasing values of voltage and increasing values of current, as indicated in Figure 21. The block calculates the active current command using linear interpolation.

To avoid injecting a current larger than the maximum limit of the converter (CON(J+26)), the final active current injection during HLVFRT operation is limited with reactive current injection priority.

The block inputs are:

- Grid voltage RMS value (V_{grid}). STATE (K+2)

The block outputs are:

- Active current command for low voltage condition (Id_{LVRT})
- Reactive current command for low voltage condition (Iq_{LVRT})

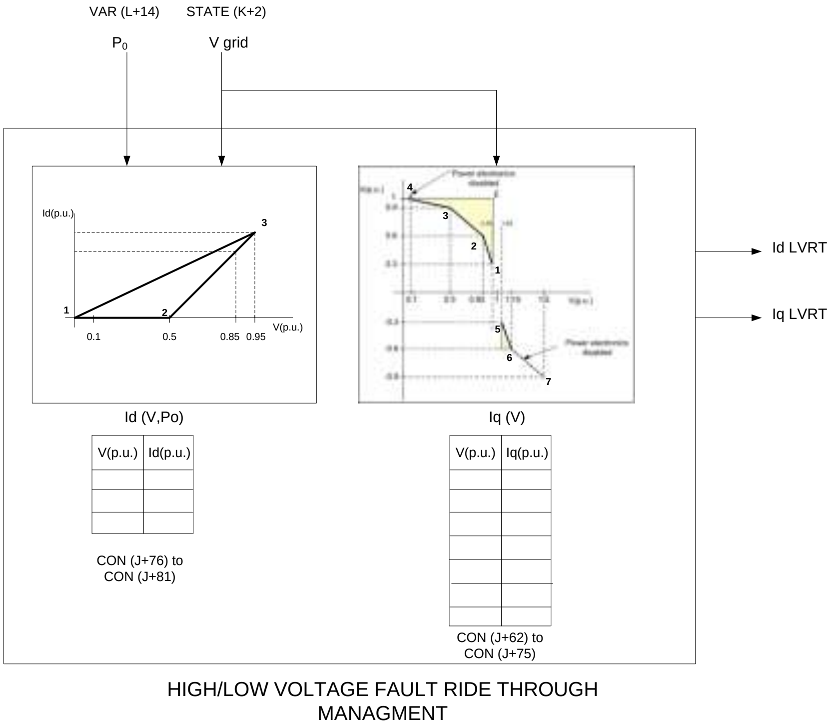

Figure 21. LVFRT management block diagram

CON	Parameters
J+62	Iq LVFRT Curve Point 1 V (pu)
J+63	Iq LVFRT Curve Point 1 Iq (pu)
J+64	Iq LVFRT Curve Point 2 V (pu)
J+65	Iq LVFRT Curve Point 2 Iq (pu)
J+66	Iq LVFRT Curve Point 3 V (pu)
J+67	Iq LVFRT Curve Point 3 Iq (pu)
J+68	Iq LVFRT Curve Point 4 V (pu)
J+69	Iq LVFRT Curve Point 4 Iq (pu)
J+70	Iq LVFRT Curve Point 5 V (pu)
J+71	Iq LVFRT Curve Point 5 Iq (pu)
J+72	Iq LVFRT Curve Point 6 V (pu)
J+73	Iq LVFRT Curve Point 6 Iq (pu)
J+74	Iq LVFRT Curve Point 7 V (pu)
J+75	Iq LVFRT Curve Point 7 Iq (pu)
J+76	Id LVFRT Curve Point 1 V (pu)
J+77	Id LVFRT Curve Point 1 Id (pu)
J+78	Id LVFRT Curve Point 2 V (pu)
J+79	Id LVFRT Curve Point 2 Id (pu)

J+80	Id LVFRT Curve Point 3 V (pu)
J+81	Id LVFRT Curve Point 3 Id (pu)

Table 10. Parameters of the LVFRT block

6. ANNEX I. ING1XY MODEL DATASHEET

ING1AJ

INGECON SUN PV Converter & Control

This model is located at system bus	#__________	IBUS
Machine	#__________	IM
This model uses:		
CONs stating with	#__________	J
STATEs stating with	#__________	K
VARs stating with	#__________	L
ICONs stating with	#__________	M

CONs	#	Value	Description
J			T_{rP}, Act. Power filter time constant (s)
J+1			T_{rQ}, Reac. Power filter time constant (s)
J+2			T_{rV}, Voltage filter time constant (s)
J+3			Δf1/fbase, Primary response dead band (pu)
J+4			R, Droop (pu)
J+5			P_{step}, P supplied during large frequency deviations (pu)
J+6			Δf_{step}, Transition from small to large frequency deviations (pu)
J+7			$\Delta P_{PR\ max}$, Maximum active power limit for primary response (pu)
J+8			$\Delta P_{PR\ min}$, Minimum active power limit for primary response (pu)
J+9			ΔP/Δt , Primary regulation response ramp (pu/s)
J+10			H, Inertia constant (s)
J+11			T_H, Intertial response time constant (s)
J+12			$\Delta P_{INERT\ max}$, Max active power limit for inertial response (pu)
J+13			$\Delta P_{INERT\ min}$, Min active power limit for inertial response (pu)
J+14			ΔP/Δt , Active power ramp limit (pu/s)
J+15			P_{MAX}, PV plant maximum output power (pu)
J+16			P_{Min}, PV plant minimum output power (pu)
J+17			$\Delta P_1/P_{base}$, Power factor P control Dead band (pu)
J+18			K_P, Power factor P control gain
J+19			$\Delta V_2/V_{base}$, voltage control Dead band (pu)
J+20			K_V, voltage control gain
J+21			KP_v, Voltage control proportional constant
J+22			KI_v, Voltage control integral constant
J+23			ΔQ/Δt, Reactive power ramp (pu/s)
J+24			T_P, Converter time constant for Id (s)
J+25			T_Q, Converter time constant for Iq (s)
J+26			I_{MAX} Converter maximum current rating (pu)
J+27			t_in, HLVRT mode in ramp time (s)
J+28			t_out, HLVRT mode out ramp time (s)

J+29			Q limit curve point 1 V (pu)
J+30			Q limit curve point 1 Qmax (pu)
J+31			Q limit curve point 1 Qmin (pu)
J+32			Q limit curve point 2 V (pu)
J+33			Q limit curve point 2 Qmax (pu)
J+34			Q limit curve point 2 Qmin (pu)
J+35			Q limit curve point 3 V (pu)
J+36			Q limit curve point 3 Qmax (pu)
J+37			Q limit curve point 3 Qmin (pu)
J+38			V max limit curve Point 1 t (s)
J+39			V max limit curve Point 1 V (pu)
J+40			V max limit curve Point 2 t (s)
J+41			V max limit curve Point 2 V (pu)
J+42			V max limit curve Point 3 t (s)
J+43			V max limit curve Point 3 V (pu)
J+44			V min limit curve Point 1 t (s)
J+45			V min limit curve Point 1 V (pu)
J+46			V min limit curve Point 2 t (s)
J+47			V min limit curve Point 2 V (pu)
J+48			V min limit curve Point 3 t (s)
J+49			V min limit curve Point 3 V (pu)
J+50			f max limit curve Point 1 t (s)
J+51			f max limit curve Point 1 f (pu)
J+52			f max limit curve Point 2 t (s)
J+53			f max limit curve Point 2 f (pu)
J+54			f max limit curve Point 3 t (s)
J+55			f max limit curve Point 3 f (pu)
J+56			f min limit curve Point 1 t (s)
J+57			f min limit curve Point 1 f (pu)
J+58			f min limit curve Point 2 t (s)
J+59			f min limit curve Point 2 f (pu)
J+60			f min limit curve Point 3 t (s)
J+61			f min limit curve Point 3 f (pu)
J+62			Iq LVFRT Curve Point 1 V (pu)
J+63			Iq LVFRT Curve Point 1 Iq (pu)
J+64			Iq LVFRT Curve Point 2 V (pu)
J+65			Iq LVFRT Curve Point 2 Iq (pu)
J+66			Iq LVFRT Curve Point 3 V (pu)
J+67			Iq LVFRT Curve Point 3 Iq (pu)
J+68			Iq LVFRT Curve Point 4 V (pu)
J+69			Iq LVFRT Curve Point 4 Iq (pu)
J+70			Iq LVFRT Curve Point 5 V (pu)
J+71			Iq LVFRT Curve Point 5 Iq (pu)

J+72			Iq LVFRT Curve Point 6 V (pu)
J+73			Iq LVFRT Curve Point 6 Iq (pu)
J+74			Iq LVFRT Curve Point 7 V (pu)
J+75			Iq LVFRT Curve Point 7 Iq (pu)
J+76			Id LVFRT Curve Point 1 V (pu)
J+77			Id LVFRT Curve Point 1 Id (pu)
J+78			Id LVFRT Curve Point 2 V (pu)
J+79			Id LVFRT Curve Point 2 Id (pu)
J+80			Id LVFRT Curve Point 3 V (pu)
J+81			Id LVFRT Curve Point 3 Id (pu)

STATEs	#	Value	Description
K			Measured active power (Pgrid)
K+1			Measured reactive power (Qgrid)
K+2			Measured voltage (Vgrid)
K+3			Terminal voltage filter (Vterm)
K+4			Id
K+5			Iq
K+6			Inertial response
K+7			V control PI regulator

VARs	#	Value	Description
L			Active power reference for voltage control (pu)
L+1			Active power reduction (pu)
L+2			Reactive power reference (pu)
L+3			Tan phi reference (pu)
L+4			Frequency reference (pu)
L+5			Voltage reference (pu)
L+6			PV panel output power (pu)
L+7			P command (pu MBASE)
L+8			Q command (pu MBASE)
L+9			Id_ref (pu MBASE)
L+10			Iq_ref (pu MBASE)
L+11			Memory primary regulation response ramp (pu)
L+12			Memory active power change ramp limit (pu)
L+13			Memory reactive power change ramp limit (pu)
L+14			Memory SH Fault Detection Logic
L+15			Voltage Disturbance Detection Flag
L+16			Trip Signal
L+17			Voltage Event Detection Flag
L+18			Frequency Event Detection Flag
L+19			Maximum voltage limit

L+20			Minimum voltage limit
L+21			Maximum frequency limit
L+22			Minimum frequency limit
L+23			Time associated with a Vmax event
L+24			Time associated with a Vmin event
L+25			Time associated with a fmax event
L+26			Time associated with a fmin event
L+27			HLVRT mode in time (s)
L+28			HLVRT mode out time (s)
L+29			Memory Id command
L+30			Memory Iq command
L+31			Voltage phase angle in PSS/E

ICONs	#	Value	Description
M			Transformer HV BUS
M+1			Transformer LV BUS
M+2			Q Mode Selector (1, 2, 3 or 4)
M+3			P,Q Priority Flag (0 –P priority, 1 – Q priority)
M+4			Control Bus
M+5			Iq LVRT Injection Mode (0–Absolute, 1 –Incremental)

Model call for version AA to AG:

IBUS 'USRMDL' ID 'ING1AJ' 1 1 6 82 8 32 ICONs from (M) to (M+5) CONs from (J) to (J+81)

Note 1:

No explicit representation of the inverter transformer is needed. The inverter can be connected directly to a HV bus. In this case, the model does not take into account the values of ICONs M and M+1, although the user must assign a value (i.e. 0) in the model call.

Also, the model works with 2 winding and 3 winding transformers.