4. Vestas Wind Turbine – V90 VCSS Data Sheets

4.1 VWVARS Data Sheet

Vestas Wind Systems A/S
Model Version 7.2

Nonstandard Model Data Sheet
VWVARS

VWVARS

VESTAS WIND TURBINE VARIABLES INTERFACE

This model is located at system bus # _____ (I_{BUS})
Machine ID # _____ (I_{MACH})
This model uses ICONs starting with # _____ (M)
and CONs # _____ (J)
and STATEs # _____ (K)
and VARs starting with # _____ (L)

ICON	#	Value	Description
M			No. of wind farm bus, I_{BUS}
M+1			Wind farm machine ID, I_{MACH}

VARs	#	Description
L		Available real power, P_{set}
L+1		Q or PF setpoint, Q_{set}
L+2		Real power after PQ chart, P_{trim}
L+3		React pwr after PQ chart, Q_{trim}
L+4		Real power after slope lim, P_{lim}
L+5		React pwr after slope lim, Q_{lim}
L+6		Real power request, P_{ref}
L+7		Reactive power request, Q_{ref}
L+8		Real power output, P_{actual}
L+9		Reactive power output, Q_{actual}
L+10		Real power measurement, P_{meas}
L+11		React pwr measurement, Q_{meas}
L+12		Torsion speed meas, δw_{meas}
L+13		Torsion speed, δw
L+14		Torsion damping power, P_{td}
L+15		AGO (LVRT) status, S_{AGO}
L+16		Active current for LVRT, I_P
L+17		Reactive current for LVRT, I_Q
L+18		DFIG mode of operat. (SDFIG)
L+19		Def. pitch strategy mode
L+20		Power from turbine, P_{WT}

All power quantities are in per unit on the machine base.

DYRE input line:

0 'USRMDL' 0 'VWVARS' 8 0 2 0 0 21 I_{BUS} ' I_{MACH} ' /

4.2 VWCORE Data Sheet

Vestas Wind Systems A/S
Model Version 7.2

Nonstandard Model Data Sheet
VWCORE

VWCORE

VESTAS WIND TURBINE GENERATOR (BEHAVIOURAL MODEL)

This model is located at system bus # _____ (I_{BUS})
Machine ID # _____ (I_{MACH})
This model uses ICONs starting with # _____ (M)
and CONs # _____ (J)
and STATEs # _____ (K)
and VARs starting with # _____ (L)

ICON	#	Value	Description
M			Flag for scaling of power at KPAUSE = 2, F_V 0 = not scaling, 1 = scaling
M+1			Flag for internal loop mode, F_I 0 = not in internal loop mode 1 = in internal loop

CON	#	Value	Description
J			Generator kVA rating, S
J+1			Gen voltage rating, V
J+2			Rated rotor current, I_R
J+3			Rated inverter current I_V
J+4			Gen winding ratio, R
J+5			Gen magnetisation, X_m
J+6			Gen leakage, X_{ls}
J+7			P proportional gain, K_{pp}
J+8			P integral gain, K_{ip}
J+9			P proportional gain, K_{pg}
J+10			P integral gain, K_{ig}
J+11			Torsion damp gain, K_{ud}
J+12			Torsion time const, T_{ud}
J+13			Short term curr lim, I_L
J+14			Torsion ramp-in rate, T_R
J+15			Stator resistance, Rs.
J+16			Rotor reactance, Xr
J+17			Transient reactance, Xsp
J+18			Transient open circuit time constant T0p.
J+19			Disp.
J+20			Rotor speed in transient DFIG model, wr
J+21			Maximum rotor voltage, vrmax
J+22			Time constant for stator voltage filter, Tfc
J+23			Model interface
J+24			Stator volt. filter time const (current injection)
J+25			Stator volt. threshold (current injection)
J+26			Current injection mode.

STATE	#	Description
K		Integ for active power
K+1		Integ for reactive power
K+2		Integ for torsion damp
K+3		Transient volt. real part
K+4		Transient volt. imag part
K+5		Stator volt. filtered real part
K+6		Stator volt. filtered imag part
K+7		Stator volt. filtered real part (current injection)

K+8		Stator volt. filtered imag part (current injection)
K+9		disp
K+10		disp
K+11		disp
K+12		disp

VARs	#	Description
L		Dynamic limit for torsion damp
L+1		Saved time for torsion limit
L+2		Storage for raw real power
L+3		Storage for raw reactive power
L+4		Saved angle of stator voltage.
L+5		Disp.
L+6		Voltage in power flow, real part
L+7		Voltage in power flow, imag prt
L+8		Transient volt. steady state, real part
L+9		Transient volt. steady state, imag part
L+10		Saved value of rotor voltage, real part
L+11		Saved value of rotor voltage, imag part
L+12		Saved time
L+13		Memory for delay.
L+14		Memory for delay.
L+15		Memory for delay.
L+16		Memory for delay.
L+17		Memory for delay.
L+18		Memory for delay.
L+19		Memory for delay.
L+20		Memory for delay.
L+21		Memory for delay.
L+22		Memory for delay.
L+23		Memory pos. for delay. .
L+24		Required no. of pos. for delay.
L+25		Delta time for delay.
L+26		Next time step for update delay.
L+27		Delayed angle of voltage.
L+28		Save internal loop store(K) for VWCORE
L+29		Save internal loop store(K+1) for VWCORE
L+30		Save internal loop store(K+2) for VWCORE
L+31		Save internal loop store(K+3) for VWCORE
L+32		Save internal loop store(K+4) for VWCORE
L+33		Save internal loop store(K+5) for VWCORE
L+34		Save internal loop store(K+6) for VWCORE
L+35		Save internal loop store(K+7) for VWCORE
L+36		Save internal loop store(K+8) for VWCORE
L+37		Save internal loop store(K+9) for VWCORE
L+38		Save internal loop store(K+10) for VWCORE
L+39		Save internal loop store(K+11) for VWCORE
L+40		Save internal loop store(K+12) for VWCORE
L+41		Save internal loop store(K) for VWLVRT
L+42		Save internal loop store(K+1) for VWLVRT
L+43		Save internal loop store(K+2) for VWLVRT
L+44		Save internal loop store(K+3) for VWLVRT
L+45		Save internal loop store(K+4) for VWLVRT
L+46		Save internal loop store(K+5) for VWLVRT
L+47		Save internal loop store(K+6) for VWLVRT
L+48		Save internal loop store(K+7) for VWLVRT
L+49		Save internal loop store(K+8) for VWLVRT
L+50		Save internal loop store(K+9) for VWLVRT
L+51		Save internal loop store(K) for VWPWRC
L+52		Save internal loop store(K+1) for VWPWRC
L+53		Save internal loop store(K+2) for VWPWRC
L+54		Save internal loop store(K+3) for VWPWRC
L+55		Save internal loop store(K+4) for VWPWRC
L+56		Save internal loop store(K+5) for VWPWRC
L+57		Save internal loop store(K+6) for VWPWRC
L+58		Save internal loop store(K) for VWMECH
L+59		Save internal loop store(K+1) for VWMECH

L+60		Save internal loop store(K+2) for VWMECH
L+61		Save internal loop store(K+3) for VWMECH
L+62		Save internal loop store(K+4) for VWMECH
L+63		Save internal loop store(K+5) for VWMECH
L+64		Save internal loop store(K+6) for VWMECH
L+65		Save internal loop store(K+7) for VWMECH
L+66		Save internal loop store(K) for VWMEAS

L+67		Save internal loop store(K+1) for VWMEAS
L+68		Save internal loop store(K+2) for VWMEAS
L+69		Save internal loop store(K+3) for VWMEAS
L+70		Save internal loop store(K+4) for VWMEAS
L+71		Save internal loop store(K+5) for VWMEAS
L+72		Save internal loop store(K+6) for VWMEAS
L+73		Save internal loop store(K+7) for VWMEAS

DYRE input line:

I_{BUS} 'USRMDL ' I_{MACH} 'VWCORE ' 1 1 2 27 13 74 F_V F_I S V I_R I_V R X_m X_{ls} K_{pp} K_{ip} K_{pq} K_{iq} K_{ud} T_{ud} I_L T_R Rs Xr Xsp T0p Disp. wr vrmax Tfc CON (J+23) to CON (J+26) /

Note: The synchronous generator arrays (SPEED, PMECH, XADIFD and ECOMP) are used for identifying the CONEC models placement in the ICON, CON, STATE and VAR arrays.
Note: The synchronous generator arrays (EFD) is used for identifying models connected to the same bus.

4.2.1 Block diagram of Generator

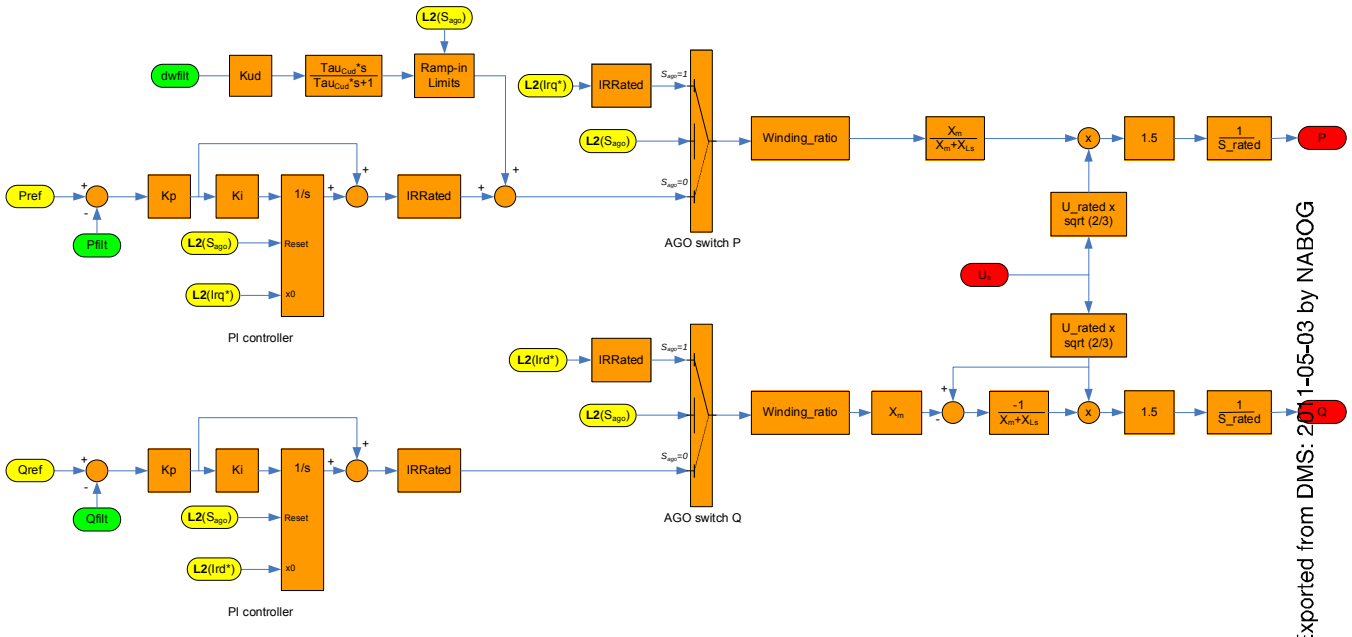

Figure 2: Full block diagram of the Generator controls sub-system

4.3 VWFPRT Data Sheet

Vestas Wind Systems A/S
Model Version 7.2

Nonstandard Model Data Sheet
VWFPRT

VWFPRT

FREQUENCY PROTECTION FOR VESTAS WIND TURBINE GENERATORS

This model is located at system bus # _____ (I_{BUS})
Machine ID # _____ (I_{MACH})
This model uses ICONs starting with # _____ (M)
and CONs # _____ (J)
and STATEs # _____ (K)
and VARs starting with # _____ (L)

ICON	#	Value	Description
M			No. of wind farm bus ,I_{BUS}
M+1			Wind farm machine ID ,I_{MACH}
M+2		0	Relay state (memory)

CONs	#	Value	Description
J			Underfrequency limit, F_{UF}
J+1			Underfrequency timeout, T_{UF}
J+2			Overfrequency limit , F_{OF}
J+3			Overfrequency timeout, T_{OF}

VARs	#	Description
L		Saved time value

All frequency quantities are in pu, time quantities in seconds.

DYRE input line:

0 'USRMDL' 0 'VWFPRT' 0 2 3 4 0 1 I_{BUS} 'I_{MACH}' 0 F_{UF} T_{UF} F_{OF} T_{OF} /

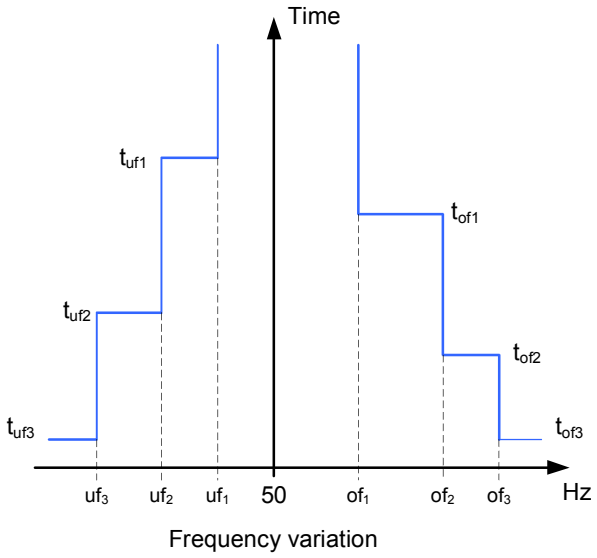

Figure 3: Frequency protection limits defined in the protection model

4.4 VWLVRT Data Sheet

Vestas Wind Systems A/S
Model Version 7.2

Nonstandard Model Data Sheet
VWLVRT

VWLVRT

VESTAS WIND TURBINE GENERATOR LOW VOLTAGE RIDE THROUGH

This model is located at system bus # _____ (I_{BUS})
Machine ID # _____ (I_{MACH})
This model uses ICONs starting with # _____ (M)
and CONs # _____ (J)
and STATEs # _____ (K)
and VARs starting with # _____ (L)

ICON	#	Value	Description
M			WTG bus number, I_{BUS}
M+1			WTG machine ID, I_{MACH}
M+2			AGO enabler (1=enable), E_{AGO}

CONs	#	Value	Description
J			AGO threshold, V_{AGO}
J+1			LVRT memory time, T_A
J+2			LVRT deactiv time, T_D
J+3			LVRT I_P pos slope, R_{IP+}, If equal zero then disabled
J+4			LVRT I_P neg slope, R_{IP-}, If equal zero then disabled
J+5			LVRT I_Q pos slope, R_{IQ+}, If equal zero then disabled
J+6			LVRT I_Q neg slope, R_{IQ-}, If equal zero then disabled
J+7			LVRT dip factor, RtU_{dip}
J+8			LVRT react ref, RtI_{reac}
J+9			Winding ratio est, R*
J+10			Magnetic reactance, X_m
J+11			Short term threshold, I_{R*}
J+12			Active current limit, L_{IP}
J+13			Gen voltage rating, V
J+14			Rated rotor current, I_R
J+15			Trigger level, U_{BCO}
J+16			Trigger time, t_{BCO}
J+17			Trigger level, U_{SRVO}
J+18			Trigger time, t_{SRVO}
J+19			Timeout, t_{SRVOTO}
J+20			Power ramp back time [pu/s] (Def. pitch strat.), P_{RAMP}
J+21			Long dip time [s]. (Def. pitch strategy.) , $t_{LongDip}$
J+22			Gen leakage, X_{ls}

STATE	#	Description
K		State for washout filter
K+1		State for low pass filter
K+2		Disp.
K+3		Disp.
K+4		Disp.
K+5		Disp.
K+6		Disp.
K+7		Disp.
K+8		Disp.
K+9		Disp.

VARs	#	Description
L		Saved time for slope limiters
L+1		Slope limit value for I_P
L+2		Slope limit value for I_Q
L+3		Slope limit value for S_{AGO}
L+4		Actual AGO threshold, V_{AGO2}
L+5		Timer 1 (SDFIG).
L+6		Timer 2 (SDFIG).
L+7		Timer 3 (SDFIG).
L+8		Timer (Def. pitch strategy)
L+9		State (Def. pitch strategy)
L+10		Slope limit value for PWT (Def. pitch strategy)
L+11		

L+12		
L+13		

L+14		

All power quantities are in per unit on the machine base. Slope limits are in p.u. per second.

DYRE input line:

0 ' USRMDL ' 0 'VWLVRT ' 8 0 3 23 10 15 I_{BUS} I_{MACH} E_{AGO} V_{AGO} T_A T_D R_{IP+} R_{IP-} R_{IQ+} R_{IQ-} RtU_{dip} RtI_{reac} R* X_m I_{R*} L_{IP} V I_R U_{BCO} t_{BCO} U_{SRVO} t_{SRVO} t_{SRVOTO} P_{RAMP} $t_{LongDip}$ X_{ls} /

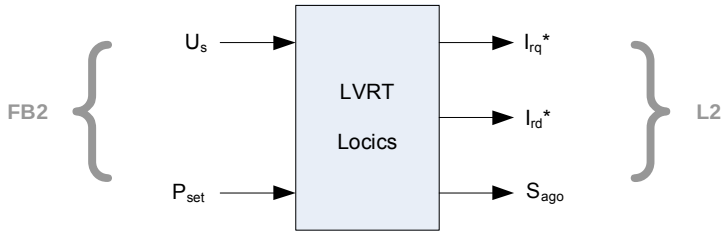

Figure 4: Top-level interface definition of the LVRT logics block

4.5 VWMEAS Data Sheet

Vestas Wind Systems A/S
Model Version 7.2

Nonstandard Model Data Sheet
VWMEAS

VWMEAS

VESTAS WIND TURBINE MEASUREMENTS MODEL

This model is located at system bus # _____ (I_{BUS})
Machine ID # _____ (I_{MACH})
This model uses ICONs starting with # _____ (M)
and CONs # _____ (J)
and STATEs # _____ (K)
and VARs starting with # _____ (L)

ICON	#	Value	Description
M			No. of wind farm bus, I_{BUS}
M+1			Wind farm machine ID, I_{MACH}

CON	#	Value	Description
J			Real pwr time const, T_P
J+1			React pwr time cnst, T_Q
J+2			Torsion time const, T_{Fud}

STATE	#	Description
K		Active power filter
K+1		Reactive power filter
K+2		Torsion sensing filter
K+3		Disp.
K+4		Disp.
K+5		Disp.
K+6		Disp.
K+7		Disp.

VARs	#	Description
L		Saved AGO state
L+1		Disp.
L+2		Disp.
L+3		Disp.
L+4		Disp.

DYRE input line:

0 'USRMDL' 0 'VWMEAS' 8 0 2 3 8 5 I_{BUS} ' I_{MACH} ' T_P T_Q T_{Fud} /

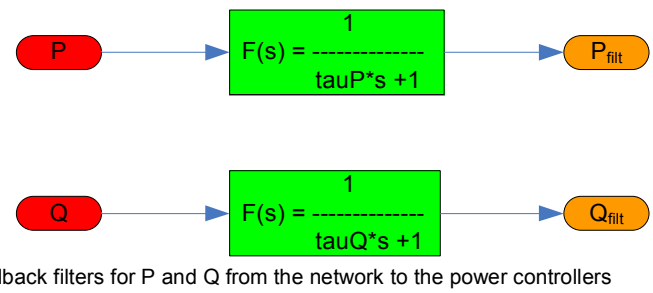

Figure 5: Feedback filters for P and Q from the network to the power controllers

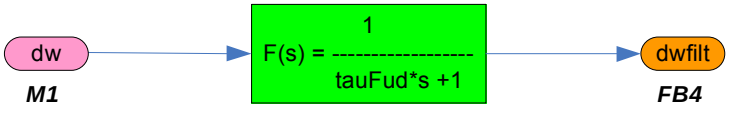

Figure 6: Feedback filter for the differential shaft speed

4.6 VWMECH Data Sheet

Vestas Wind Systems A/S
Model Version 7.2

Nonstandard Model Data Sheet
VWMECH

VWMECH

VESTAS DRIVE TRAIN MODEL

This model is located at system bus # _____ (I_{BUS})
Machine ID # _____ (I_{MACH})
This model uses ICONs starting with # _____ (M)
and CONs # _____ (J)
and STATEs # _____ (K)
and VARs starting with # _____ (L)

ICON	#	Value	Description
M			No. of wind farm bus, I_{BUS}
M+1			Wind farm machine ID, I_{MACH}

CON	#	Value	Description
J			Rated apparent kVA , S_B
J+1			Nom shaft speed (rad/s), W_G
J+2			Nominal torque (N m) , T_{nom}
J+3			Rotor inertia (kg m^2) ,J_{rot}
J+4			Generator inertia (kgm^2), J_{gen}
J+5			Shaft stiffness (N m/rad), K
J+6			Shaft damping(Nm/rads), D

STATE	#	Description
K		Integrator for rotor speed
K+1		Integrator for generator speed
K+2		Integrator for torsion accel
K+3		Disp.
K+4		Disp.
K+5		Disp.
K+6		Disp.
K+7		Disp.

DYRE input line:

0 'USRMDL' 0 'VWMECH' 8 0 2 7 8 0 I_{BUS} ' I_{MACH}' S_B W_G T_{nom} J_{rot} J_{gen} K D /

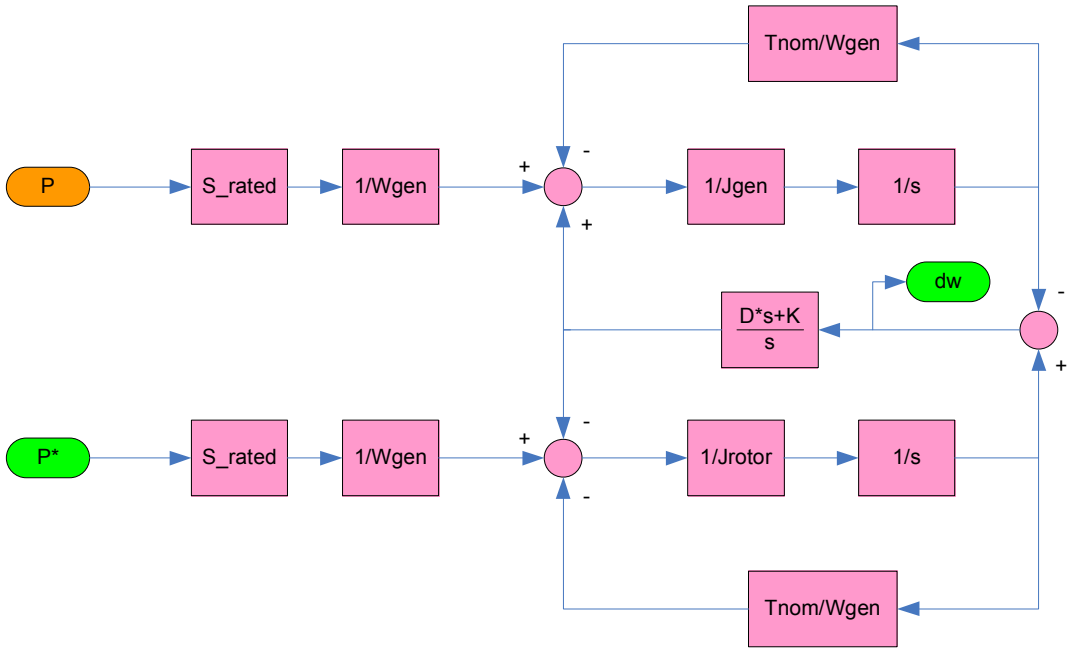

Figure 7: 2-mass model of the drive train in power reference

4.7 VWPWRC Data Sheet

Vestas Wind Systems A/S
Model Version 7.2

Nonstandard Model Data Sheet
VWPWRC

VWPWRC

VESTAS WIND TURBINE GENERATOR POWER CONTROL

This model is located at system bus # _____ (I_{BUS})
Machine ID # _____ (I_{MACH})
This model uses ICONs starting with # _____ (M)
and CONs # _____ (J)
and STATEs # _____ (K)
and VARs starting with # _____ (L)

ICONs	#	Value	Description
M			No. of wind farm bus, I_{BUS}
M+1			Wind farm machine ID, I_{MACH}
M+2			Control mode (0 = Q control, 1 = PF control), Mctrl

CONs	#	Value	Description
J			Real power export lim ,P_{lim}
J+1			Reactive pwr export lim, Q_{max}
J+2			Reactive pwr import lim, Q_{min}
J+3			Max active power when Q at export limit, $P_{qmax,max}$
J+4			Max active power when Q at import limit ,$P_{qmin,max}$
J+5			Min power factor for export at max real pwr , $PF_{qmax,min}$
J+6			Min power factor for import at max real pwr , $PF_{qmin,min}$
J+7			Min power factor for export at any pwr level, $PF_{min,e}$
J+8			Min power factor for import at any pwr level, $PF_{min,i}$
J+9			P pos slope limit, R_{P+}
J+10			P neg slope limit, R_{P-}
J+11			Q pos slope limit, R_{Q+}
J+12			Q neg slope limit, R_{Q-}
J+13			P ref time constant, T_P
J+14			Q ref time constant, T_Q
J+15		0	Not used
J+16		0	Not used
J+17		0	Not used
J+18		0	Not used
J+19		0	Not used
J+20		0	Not used

STATEs	#	Description
K		Active power reference filter
K+1		Reactive power reference filter
K+2		Disp.
K+3		Disp.
K+4		Disp.
K+5		Disp.
K+6		Disp.

VARs	#	Description
L		Saved time for slope limiters
L+1		Slope limit value for P_{ref}
L+2		Slope limit value for Q_{ref}
L+3		Disp.
L+4		Disp.

All power quantities are in per unit on the machine base. Slope limits are in p.u. per second.

DYRE input line:

0 'USRMDL' 0 'VWPWRC' 8 0 3 21 7 5 I_{MACH} ' I_{BUS} ' M_{ctrl} P_{lim} Q_{max} Q_{min} $P_{qmax,max}$ $P_{qmin,max}$ $PF_{qmax,min}$ $PF_{qmin,min}$ $PF_{min,e}$ $PF_{min,i}$ R_{P+} R_{P-} R_{Q+} R_{Q-} T_P T_Q 0 0 0 0 0 0/

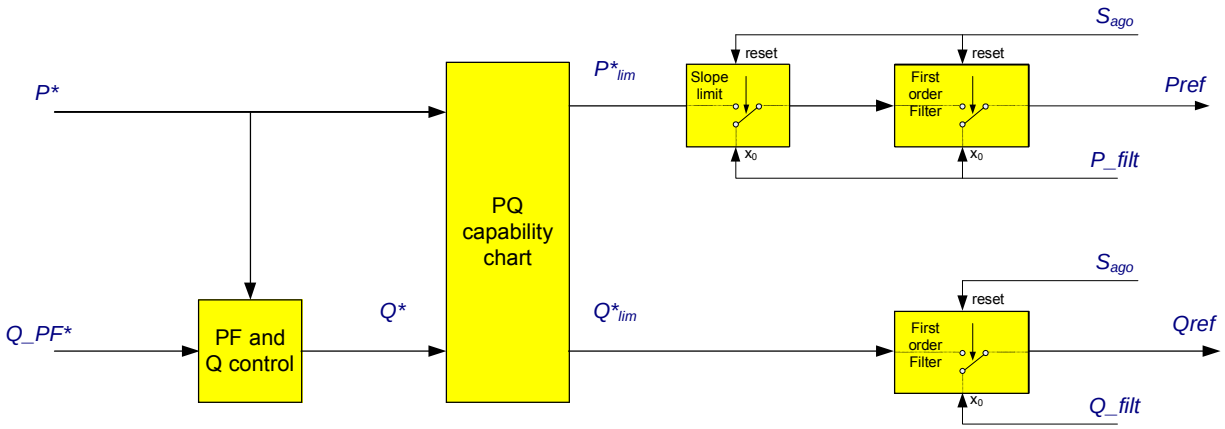

Figure 8: PQ-limits subsystem

4.8 VWVPRT Data Sheet

Vestas Wind Systems A/S
Model Version 7.2

Nonstandard Model Data Sheet
VWVPRT

VWVPRT

VOLTAGE PROTECTION FOR VESTAS WIND TURBINE GENERATORS

This model is located at system bus # _____ (I_{BUS})
Machine ID # _____ (I_{MACH})
This model uses ICONs starting with # _____ (M)
and CONs # _____ (J)
and STATEs # _____ (K)
and VARs starting with # _____ (L)

ICON	#	Value	Description
M			No. of wind farm bus ,I_{BUS}
M+1			Wind farm machine ID ,I_{MACH}
M+2			Protection enable flag ,S_{PROT}
M+3			LVRT protection flag ,S_{LVRT}
M+4		0	Lockout state (memory)
M+5		0	Relay state (memory)
M+6		0	Relay state (memory)

CONs	#	Value	Description
J			Extreme UV limit, V_{UE}
J+1			Extreme UV timeout , T_{UE}
J+2			Short-term UV limit , V_{US}
J+3			Short-term UV timeout , T_{US}
J+4			Continuous low V limit , V_{UC}
J+5			Mid-term UV timeout , T_{UM}
J+6			Continuous high V limit, V_{OC}
J+7			Mid-term OV timeout , T_{OM}
J+8			Short-term OV limit , V_{OS}
J+9			Short-term OV timeout, T_{OS}
J+10			Extreme OV limit, V_{OE}
J+11			Extreme OV timeout , T_{OE}
J+12			LVRT lowest voltage , V_{LVRT0}
J+13			Lowest voltage timeout, T_{LVRT0}
J+14			LVRT extreme UV limit, V_{LVRTE}
J+15			Extreme UV timeout , T_{LVRTE}
J+16			LVRT short-term UV ,V_{LVRTS}
J+17			Short-term UV timeout ,T_{LVRTS}
J+18			LVRT continuous low V, V_{LVRTC}
J+19			Mid-term UV timeout ,T_{LVRTM}

VARs	#	Description
L		Saved time for extreme UV
L+1		Saved time for short-term UV
L+2		Saved time for mid-term UV
L+3		Not used, but holds last UV recovery time
L+4		Saved time for mid-term OV
L+5		Saved time for short-term OV
L+6		Saved time for extreme OV
L+7		Saved time for LV extreme
L+8		Saved time for LV mid-t UV
L+9		Saved time for LV short-t UV
L+10		Not used, but holds last LVRT recovery time

All voltage quantities are in pu, time quantities in seconds. 'UV' = undervoltage, 'OV' = overvoltage.

If fewer than three distinct undervoltage and overvoltage levels are required, set two consecutive limit values equal, and ensure both have the same timeout figure.

DYRE input line:

0 'USRMDL' 0 'VWVPRT' 0 2 7 20 0 11 I_{BUS} 'I_{MACH}' S_{PROT} S_{LVRT} 0 0 0 V_{UE} T_{UE} V_{US} T_{US} V_{UC} T_{UM} V_{OC} T_{OM} V_{OS} T_{OS} V_{OE} T_{OE} V_{LVRT0} T_{LVRT0} V_{LVRTE} T_{LVRTE} V_{LVRTS} T_{LVRTS} V_{LVRTC} T_{LVRTM} /

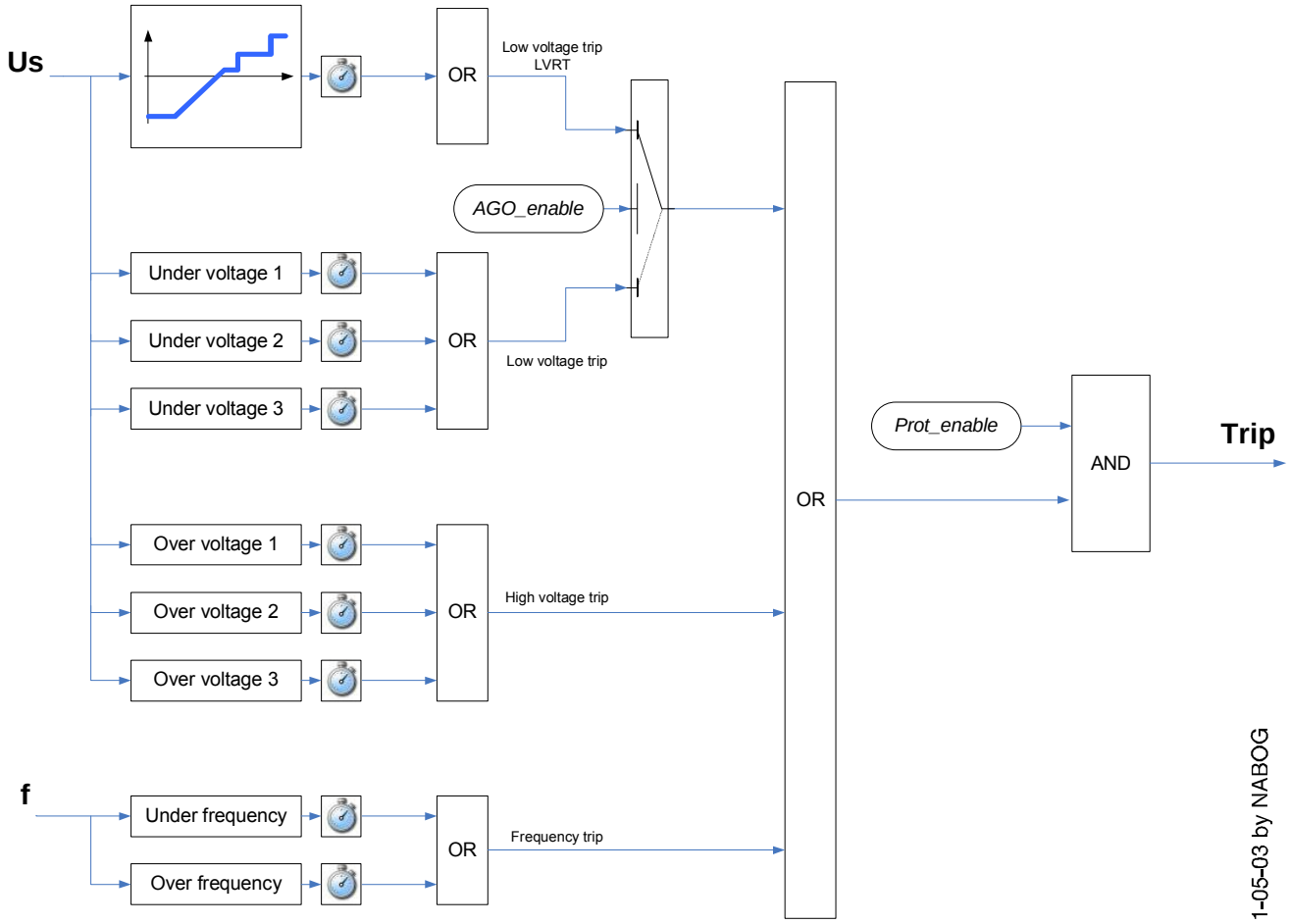

Figure 9: Protection layout of the WTG model