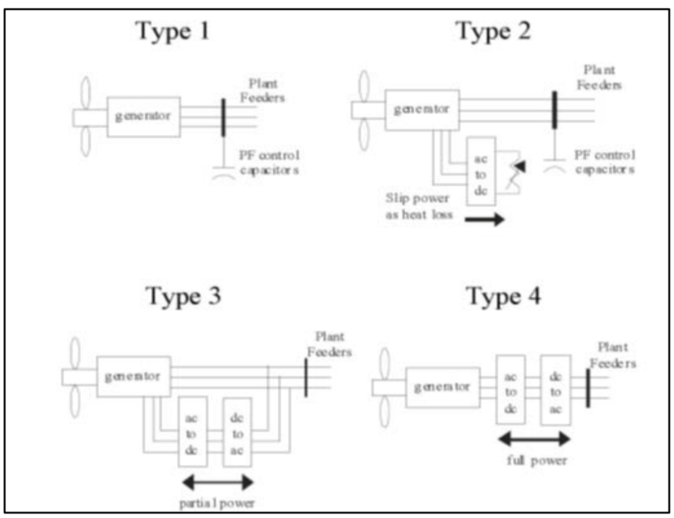
Annexure-I(C): Guidelines for Exchange of data for RMS modelling (Generic) of Wind Generating Stations

1. Wind generation technologies:

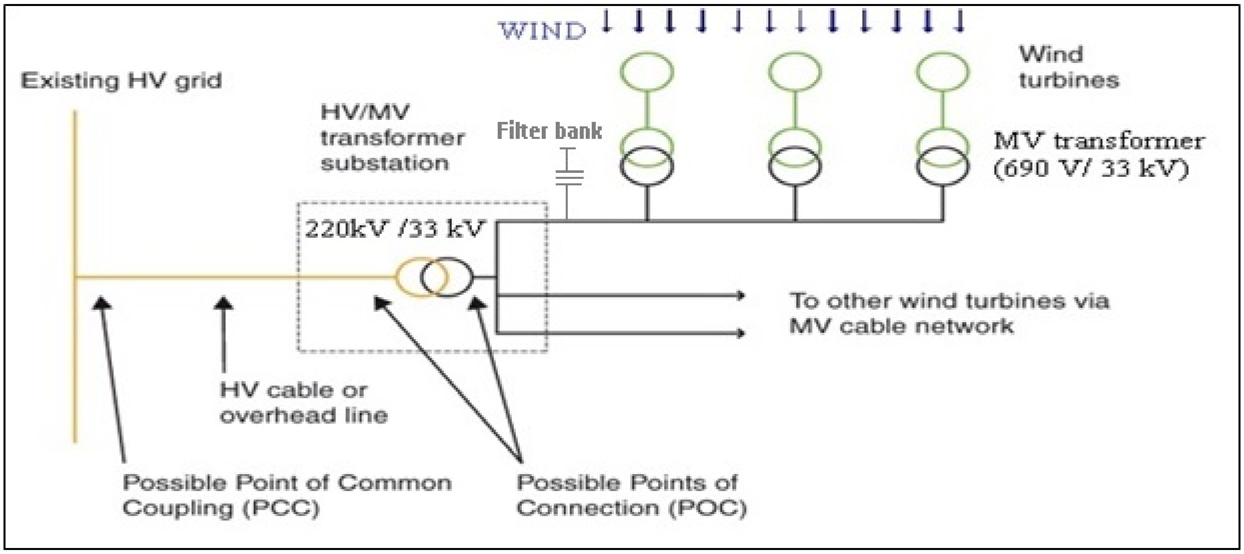
The majority of commercially available wind power plants use one of the wind turbine-generator (WTG) technologies listed below:

- Type-1 : Direct connected (Squirrel cage) induction generator (SCIG)
    - Fixed Speed stall control
    - Fixed Speed Active control
- Type-2 : Wound rotor induction generator (WRIG) with a variable resistor in the rotor circuit
- Type-3 : Doubly fed induction generator (DFIG) wind turbines ; Variable speed with rotor side converter
- Type-4 : Full converter wind turbine
    - Synchronous generator
    - Permanent Magnet Generator (PMG)



Wind energy plants are being increasingly coupled with complimentary Battery Energy Storage Systems (BESS) to reduce the variability of net power output from the renewable energy plant, provide higher output, or provide complimentary grid services such as frequency regulation. Modelling batteries / storage devices assume importance in such cases to capture the net impact of the plant on grid.

2. Models for Wind generators:

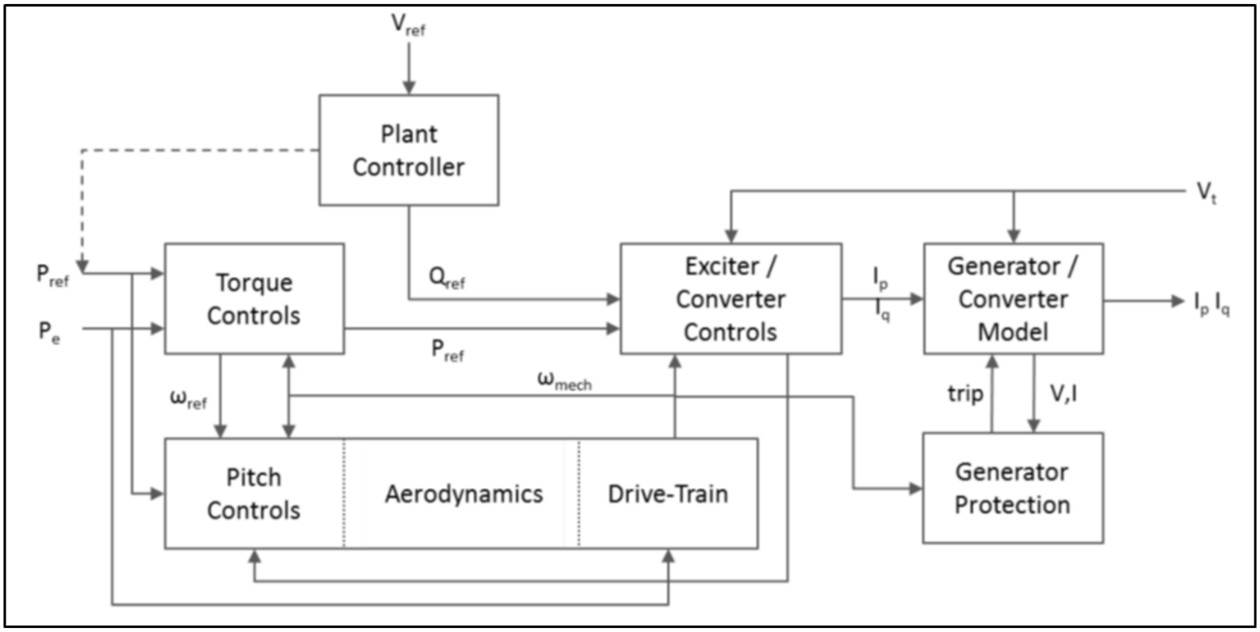


In a typical wind farm / park, individual WTGs (typically rated 3 MW or less) are connected in a system of twigs and feeders. Wind generation at around 660 V / 690 V is stepped up to a MV level of typically 33 kV in Indian system and finally pooled to grid at 220 kV / 400 kV through step-up transformers. A typical wind farm of 300 MW will be spread over an area of 600 acres, and power transmission within the farm is typically at 33 kV through overhead lines or underground cables. A Power Plant controllers (PPC) is usually installed at the point of interconnection to grid or at the reticulation system. The PPC(s) control behavior of wind farms in accordance with mandates as per grid codes.

The dynamic components of a wind farm consists of the following elements (illustrated in picture below):

1. Generator or Converter
2. Electrical control
3. Drive-Train model
4. Aerodynamics
5. Pitch controller
6. Torque controller
7. Power Plant Controller (PPC)
8. Energy storage (As applicable)

The components may or may not be present depending on the nature of technology used for wind power generation (i.e. type of turbine). Depending on the nature of technology, usage/configuration of components at site (‘As built’), the requirements for steady state and dynamic modelling evolves.



3. Generic models in PSS/E for different technologies of Wind Turbines

Wind Turbine type	Technology	Generic model	Model Description
Type-1	Direct connected (squirrel cage) induction generator (SCIG) a) Fixed Speed Stall Control b) Fixed Speed Active Control	WT1G1	Generator model (conventional induction generator)
		WT2T1	Drive train model (two-mass drive train model)
		wt1p_b	Pitch controller *(Use only for Type 1 with active stall*)
Type-2	Wound rotor induction generator (WRIG) with a variable resistor in the rotor circuit, and typically employs pitch control	WT2G1	Generator model (induction generator with external rotor resistance
		WT2E1	External resistance controller
		WT12T1	Drive train model
		wt1p_b (no equivalent in PSS/E)	Pitch controller
Type-3	Doubly fed induction generator (DFIG) wind turbines ; Variable speed with rotor side converter	REGCA1	Renewable energy generator converter model
		REECA1	Renewable energy controls model
		WTDTA1	Drive train model

Wind Turbine type	Technology	Generic model	Model Description
		WTARA	Wind turbine aerodynamic model
		WTPTA1	Simplified pitch controller model
		WTTQA1	Wind generator torque control
		REPCTA1	Renewable energy plant controller
Type-4	Full converter wind turbine Generator types: a) Synchronous b) Permanent Magnet type	REGC	Renewable energy generator converter model
		REEC	Renewable energy controls model
		WTDTA1	Drive train model
		REPCA	Renewable energy plant controller
Storage	Utility Scale Battery Energy Storage System (BESS)	REECCU	Electrical Control Model (To be used along with REGCA1 and REPCA1)

4. Details of models in PSS/E for modelling Wind plants / farms / parks:

Category	Parameter Description	Data
Generator Nameplate	Connection point voltage (kV)	
	Terminal voltage (kV)	
	Wind Farm - Rated active power (sent out) in MW	
	Turbine – Rated MVA	
	Turbine – Rated active power (PMAX) in MW	
	Number of wind turbines (Type wise)	
Reactive power capability	Capability chart at connection point [If not available, then for each individual wind turbine, and mode of operation of Power Plant Controller]	-
	QMAX	
	QMIN	
Single Line Diagram	Single line diagram of the wind farm/park showing number and location of turbines, cable run, transformers, feeders (including type of cables and electrical R,X,B parameters), and connection to transmission system Preferable : Electrical Single Line Diagram including details between individual WTGs and b/w WTGs and aggregation points	
Wind Turbine Details	Manufacturer and product details (include Year of Manufacture)	
	Year of commissioning	
	Fixed speed or variable speed	
	Type of turbine: stall control, pitch control, active stall control, limited variable speed, variable speed with partial or full-scale frequency converter	
	Hub height (in metre)	
	Rotor diameter (in metre)	
	Number of blades	
	Rotor speed (in rpm)	
	Gearbox ratio	
Generator	Type of generator: Type 1/ Type 2 / Type 3 / Type 4	
	Number of pole pairs	
	Stator resistance (in Ohms)	
	Rotor resistance (in Ohms)	
Speed control	Details of speed controller in wind turbine	
	Efficiency (Cp) curves	
	Cut-in wind speed	
	Wind speed at which full power is attained Cut-out wind speed	
	Pitch angle at low wind speed	

Category	Parameter Description	Data
Reticulation System	Voltage of the reticulation system	
	Number of feeders	
	Cable schedules (lengths, cable size, conductor material, rating info)	
Turbine Transformer	Details of the turbine transformer, including vector group, impedance, and number of taps, tap position, tap ratio	
	Nameplate details	
Wind-farm Step-up transformer	Details of the main wind farm step up transformer, including vector group, impedance, and tap position	
	Nameplate ; OLTC?	
	Controlled bus	
	Voltage setpoint	
	Dead band	
	Number of taps	
	Tap ratio range	
Connection Details	Voltage influence (maximum change etc)	
	Short circuit ratio (SCR)	
	· Min	
	· Max	
	Harmonic filters	
	STATCOM	
	Synchronous condensers	
	Battery Energy Storage System (if applicable)	
Power Plant Controller (PPC) Details	Does the wind farm have a PPC? If yes, whether PPC controls all or part of the WTGs in wind farm	
	What is the method of control – voltage regulation, power factor control, reactive power control?	
	Voltage control strategy (operating mode) - Controls MV Bus - Controls HV Bus - PF control - Q control - Voltage control	
	Is there a droop setting? - Voltage control - Frequency Control - Is there line drop compensation?	
	Is reactive power limited?	
	Temperature dependency	
	Active power ramp rate limiters	
	FRT protocols and setpoints - LVRT - HVRT	
	Provide settings from controller.	

5. Generic Models for Type-1 and Type-2 Wind turbine generators:

Description of some generic models available in PSS/E Library is provided below:

Category	Parameter Description	Data
GENERATOR model		
Generator : Type-1 (WT1G1)	Synchronous reactance (ohms or pu) Xs	
	Transient reactance (ohms or pu) X’	
	Wound rotor induction generator (WRIG) with a variable resistor in the rotor circuit, and typically employs pitch control	
	Leakage reactance, X_L	
	Saturation curve (E1, S(E1), E2, S(E2)	
Generator : Type-2 (WT2G1)	XA, stator reactance (pu)	
	Doubly fed induction generator (DFIG) wind turbines ; Variable speed with rotor side converter	
	X1 rotor reactance (put)	
	R_Rot_Mach, rotor resistance (pu)	
	R_Rot_Max (sum of R_Rot_Mach + total external resistance) in pu	
	Saturation curve (E1, S(E1), E2, S(E2)	
	Power – slip curve (Top 5 points in the T-s curve)	
Electrical Control model		
Rotor Resistance Control : Type-2 (WT2E1)	TsP, rotor speed filter time constant, sec.	
	Tpe, power filter time constant, sec.	
	Ti, PI-controller integrator time constant, sec.	
	Kp, PI-controller proportional gain, pu	
	ROTRV_MAX, Output MAX limit	
	ROTRV_MIN, Output MIN limit	
Drive Train model		
Two-Mass Turbine Model for Type 1 and Type 2 Wind Generators : (WT12T1)	H, Total inertia constant, sec	
	DAMP, Machine damping factor, pu P/pu speed	
	Htfrac, Turbine inertia fraction (Hturb/H)1	
	Freq1, First shaft torsional resonant frequency, Hz	
	Dshaft, Shaft damping factor (pu)	

6. **Generic Models for Type-3 and Type-4 Wind turbine generators:**

Description of some generic models available in PSS/E Library is provided below:

Category	Parameter Description	Data
GENERATOR model		
Type-3 or Type-4 (REGCA1)	Tg, Converter time constant (s)	
	Rrpwr, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)	
	Wound rotor induction generator (WRIG) with a variable resistor in the rotor circuit, and typically employs pitch control	
	Zerox, LVPL characteristic voltage 1 (pu)	
	Lvpl1, LVPL gain (pu)	
	Volim, Voltage limit (pu) for high voltage reactive current manage-	
	Doubly fed induction generator (DFIG) wind turbines ; Variable speed with rotor side converter	
	Lvpnt1, High voltage point for low voltage active current manage-	
	ment (pu)	
	Lvpnt0, Low voltage point for low voltage active current manage-	
	ment (pu)	
	Iolim, Current limit (pu) for high voltage reactive current manage-	
	ment (specified as a negative value)	
	Tfltr, Voltage filter time constant for low voltage active current man-	
	agement (s)	
	Khv, Overvoltage compensation gain used in the high voltage reac-	
	tive current management	
	Iqrmax, Upper limit on rate of change for reactive current (pu)	
	Iqrmin, Lower limit on rate of change for reactive current (pu)	
	Accel, acceleration factor (0 < Accel <= 1)	
Electrical Control model		
Type-3 and Type-4 Wind turbines : (REECA1) [Refer Block Diagrams]	Vdip (pu), low voltage threshold to activate reactive current injection logic	
	Vup (pu), Voltage above which reactive current injection logic is activated	
	Trv (s), Voltage filter time constant	
	dbd1 (pu), Voltage error dead band lower threshold (≤0)	
	dbd2 (pu), Voltage error dead band upper threshold (≥0)	
	Kqv (pu), Reactive current injection gain during over and undervoltage conditions	
	Iqh1 (pu), Upper limit on reactive current injection Iqinj	
	Iql1 (pu), Lower limit on reactive current injection Iqinj	
	Vref0 (pu), User defined reference (if 0, model initializes it to initial terminal voltage)	
	Iqfrz (pu), Value at which Iqinj is held for Thld seconds following a voltage dip if Thld > 0	

Category	Parameter Description	Data
Electrical Control model		
Type-3 and Type-4 Wind turbines : (REECA1) [Refer Block Diagrams]	Thld (s), Time for which Iqinj is held at Iqfrz after voltage dip returns to zero (see Note 1)	
	Thld2 (s) (≥0), Time for which the active current limit (IPMAX) is held at the faulted value after voltage dip returns to zero	
	Tp (s), Filter time constant for electrical power	
	QMax (pu), limit for reactive power regulator	
	QMin (pu) limit for reactive power regulator	
	VMAX (pu), Max. limit for voltage control	
	VMIN (pu), Min. limit for voltage control	
	Kqp (pu), Reactive power regulator proportional gain	
	Kqi (pu), Reactive power regulator integral gain	
	Kvp (pu), Voltage regulator proportional gain	
	Kvi (pu), Voltage regulator integral gain	
	Vbias (pu), User-defined bias (normally 0)	
	Tiq (s), Time constant on delay s4	
	dPmax (pu/s) (>0) Power reference max. ramp rate	
	dPmin (pu/s) (<0) Power reference min. ramp rate	
	PMAX (pu), Max. power limit	
	PMIN (pu), Min. power limit	
	Imax (pu), Maximum limit on total converter current	
	Tpord (s), Power filter time constant	
	VQ-IQ characteristic (at least two pairs, up to 4 pairs of voltage and current in pu)	
	VP-IP characteristic (at least two pairs, up to 4 pairs, of voltage and current in pu)	[Refer Block Diagrams]
	Is turbine in PF control or Q control (including controlled by external signal)?	
	Is the turbine controlling voltage (directly, not than through PPC)?	
	If controlling voltage directly what bus does it control?	
	Is the turbine in P or Q priority mode?	
Drive Train model		
	H, Total inertia constant, sec	
	DAMP, Machine damping factor, pu P/pu speed	
	Htfrac, Turbine inertia fraction (Hturb/H)1	
	Freq1, First shaft torsional resonant frequency, Hz	
	Dshaft, Shaft damping factor (pu)	

Category	Parameter Description	Data
Pitch Control model [for Type-3 only]		
Generic Pitch Control model for Type-3 : (WTPA1)	Kiw, Pitch-control Integral Gain (pu)	
	Kpw, Pitch-control proportional gain (pu)	
	Kic, Pitch-compensation integral gain (pu)	
	Kpc, Pitch-compensation proportional gain (pu)	
	Kcc, Gain (pu)	
	Tp, Blade response time constant (s)	
	TetaMax, Maximum pitch angle (degrees)	
	TetaMin, Minimum pitch angle (degrees)	
	RTetaMax, Maximum pitch angle rate (degrees/s)	
	RTetaMin, Minimum pitch angle rate (degrees/s) (< 0)	
Aerodynamic model [For Type-3 only]		
(WTARA1)	Ka, Aerodynamic gain factor (pu/degrees)	
	Theta 0 Initial pitch angle (degrees)	
Torque Controller model [For Type-3 only]		
Generic Torque Controller for Type-3 wind machines : (WTTQA1)	Kpp, Proportional gain in torque regulator (pu)	
	KIP, Integrator gain in torque regulator (pu)	
	Tp, Electrical power filter time constant (s)	
	Twref, Speed-reference time constant (s)	
	Temax, Max limit in torque regulator (pu)	
	Temin, Min limit in torque regulator (pu)	
	p1, power (pu)	
	spd1, shaft speed for power p1 (pu)	
	p2, power (pu)	
	spd2, shaft speed for power p2 (pu)	
	p3, power (pu)	
	spd3, shaft speed for power p3 (pu)	
	p4, power (pu)	
	spd4, shaft speed for power p3 (pu)	
	TRATE, Total turbine rating (MW)	

Category	Parameter Description	Data
Power Plant Controller (PPC) model		
Generic Power Plant Controller (PPC) model for Type-3 and Type-4 wind turbines : REPCTA1 for type 3, and REPCA1 for type 4 turbines	Tfltr, Voltage or reactive power measurement filter time constant (s)	
	Kp, Reactive power PI control proportional gain (pu)	
	Ki, Reactive power PI control integral gain (pu)	
	Tft, Lead time constant (s)	
	Tfv, Lag time constant (s)	
	Vfrz, Voltage below which State s2 is frozen (pu)	
	Rc, Line drop compensation resistance (pu)	
	Xc, Line drop compensation reactance (pu)	
	Kc, Reactive current compensation gain (pu)	
	emax, upper limit on deadband output (pu)	
	emin, lower limit on deadband output (pu)	
	dbd1, lower threshold for reactive power control deadband (<=0)	
	dbd2, upper threshold for reactive power control deadband (>=0)	
	Qmax, Upper limit on output of V/Q control (pu)	
	Qmin, Lower limit on output of V/Q control (pu)	
	Kpg, Proportional gain for power control (pu)	
	Kig, Proportional gain for power control (pu)	
	Tp, Real power measurement filter time constant (s)	
	fdbd1, Deadband for frequency control, lower threshold (<=0)	
	Fdbd2, Deadband for frequency control, upper threshold (>=0)	
	femax, frequency error upper limit (pu)	
	femin, frequency error lower limit (pu)	
	Pmax, upper limit on power reference (pu)	
	Pmin, lower limit on power reference (pu)	
	Tg, Power Controller lag time constant (s)	
	Ddn, droop for over-frequency conditions (pu)	
	Dup, droop for under-frequency conditions (pu)	

Category	Parameter Description	Data
Electrical Control model : BESS		
Generic Electrical Control model for Utility Scale BESS: (REECCU1)	Vdip (pu), low voltage threshold to activate reactive current injection logic	
	Vup (pu), Voltage above which reactive current injection logic is activated	
	Trv (s), Voltage filter time constant	
	dbd1 (pu), Voltage error dead band lower threshold (≤0)	
	dbd2 (pu), Voltage error dead band upper threshold (≥0)	
	Kqv (pu), Reactive current injection gain during over and undervoltage conditions	
	Iqh1 (pu), Upper limit on reactive current injection Iqinj	
	Iql1 (pu), Lower limit on reactive current injection Iqinj	
	Vref0 (pu), User defined reference (if 0, model initializes it to initial terminal voltage)	
	Tp (s), Filter time constant for electrical power	
	QMax (pu), limit for reactive power regulator	
	QMin (pu) limit for reactive power regulator	
	VMAX (pu), Max. limit for voltage control	
	VMIN (pu), Min. limit for voltage control	
	Kqp (pu), Reactive power regulator proportional gain	
	Kqi (pu), Reactive power regulator integral gain	
	Kvp (pu), Voltage regulator proportional gain	
	Kvi (pu), Voltage regulator integral gain	
	Tiq (s), Time constant on delay s4	
	dPmax (pu/s) (>0) Power reference max. ramp rate	
	dPmin (pu/s) (<0) Power reference min. ramp rate	
	PMAX (pu), Max. power limit	
	PMIN (pu), Min. power limit	
	Imax (pu), Maximum limit on total converter current	
	Tpord (s), Power filter time constant	
	Vq and Iq curve (Reactive Power V-I pair in p.u.) : 4 points	
	Vp and Ip curve (Active Power V-I pair in p.u.) : 4 points	
	T, battery discharge time (s) (<0)	
	SOCini (pu), Initial state of charge	
	SOCmax (pu), Maximum allowable state of charge	
	SOCmin (pu), Minimum allowable state of charge	

Note: SOCini represents the initial state of charge on the battery and is a user entered value. This is entered in pu; with 1 pu meaning that the batter is fully charged and 0 means the battery is completely discharged