FORMAT-CON-4

APPLICATON FORM FOR ADDITIONAL INFORMATION TO BE FURNISHED FOR SIGNING CONNECTION AGREEMENT TO INTER-STATE TRANSMISSION SYSTEM

General Information to the Applicants

1. Applicant given intimation for Connectivity to the grid by the CTU as per **FORMATCON-3** shall have to furnish additional details to CTU for signing of "Connection Agreement" as per the enclosed format..
2. The CTU will process the information provided in this format and will intimate the Connection details as per format given at **FORMAT-CON-5.** Pursuant to such Connection details, the applicant shall have to sign "Connection Agreement" with CTU prior to the physical inter-connection as per format given at **FORMAT-CON-6**. In case the connectivity is granted to the ISTS of an inter-State transmission licensee other than the CTU, a tripartite agreement shall be signed between the applicant, the Central Transmission Utility and such inter-State transmission licensee, in line with the provisions of the Regulations. After signing of the Agreement, Nodal Agency will provide a copy of the same to concerned SLDC/RLDC.

ADDITIONAL INFORMATION TO BE FURNISHED TO CTU FOR SIGNING OF "CONNECTION AGREEMENT" FOR CONNECTION TO INTER-STATE TRANSMISSION SYSTEM

A. DETAILS OF APPLICANT

1.	Name of the Applicant Company	:	
2.	Details of Grant of Connectivity (a) Connectivity Intimation No. (b) Date		
2.	Address for Correspondence	:	
3.	Contact Person 3.1 Prime Contact Person (a) Name (b) Designation (c) Phone No. (d) FAX (e) E-mail 9.4 Alternate Contact Person (a) Name (b) Designation (c) Phone No. (d) FAX (e) E-mail	:	
4.	Status of Applicant Company (Please tick the appropriate box)	:	☐ Generating Station including Captive generating plant ☐ Bulk Consumer
5.	Estimated time of completion of project (Please enclose PERT chart)		

B. MAPS AND DIAGRAMS

1. Provide necessary survey of India topo sheet clearly marking the location of the proposed site. **Schedule - I**
2. Provide site plan (both hard and soft copy in AutoCAD 2000 & above version) in appropriate scale. **Schedule – II.** The site plan should indicate following details
   a. The proposed location of the connection point
   b. Generators
   c. Transformer
   d. Site building

3. Provide an electrical Single Line Diagram (SLD) of the proposed facility detailing all significant items of plant. The plan is to be submitted in both hard copy and soft copy in AutoCAD 2000 & above version **Schedule - III**

C. DETAILS OF CONNECTION - GENERATION PLANT

1.	Type of Generation Plant (Hydro, Thermal, Gas etc	:	
2.	Rating of Generator Units	:	**Schedule – IV**
3.	Maximum Export Capacity Required	:	
4.	Maximum Import Capacity required This is the amount of import capacity that the site will require during startup (MVA)	:	
5.	Station house load during normal operating conditions (MW/MVAR)	:	
6.	Expected running regime e.g. base load, peaking etc	:	
7.	Generator Data for Fault (Short Circuit Studies)		**Schedule – V**

8.	Dynamic Simulation Data Generator Excitation Power System Stabilizer		 **Schedule – VI** **Schedule – VII** **Schedule – VIII**

D. DETAILS OF CONNECTION – BULK CONSUMER

1.	Type of Load (Industrial/Commercial) including type of industry, i.e. electric furnace, rolling mills, manufacturing, assembly line, etc.	:	
2.	Peak requirement of load in MVA, MW and MVAR	:	
3.	Peak import required in MVA, MW and MVAR	:	
4.	Month-wise Peak import required in MVA, MW and MVAR	:	
5.	Month-wise Energy requirement in MUs.	:	
6.	Data for Fault (Short Circuit Studies)		Single phase and three phase Fault level

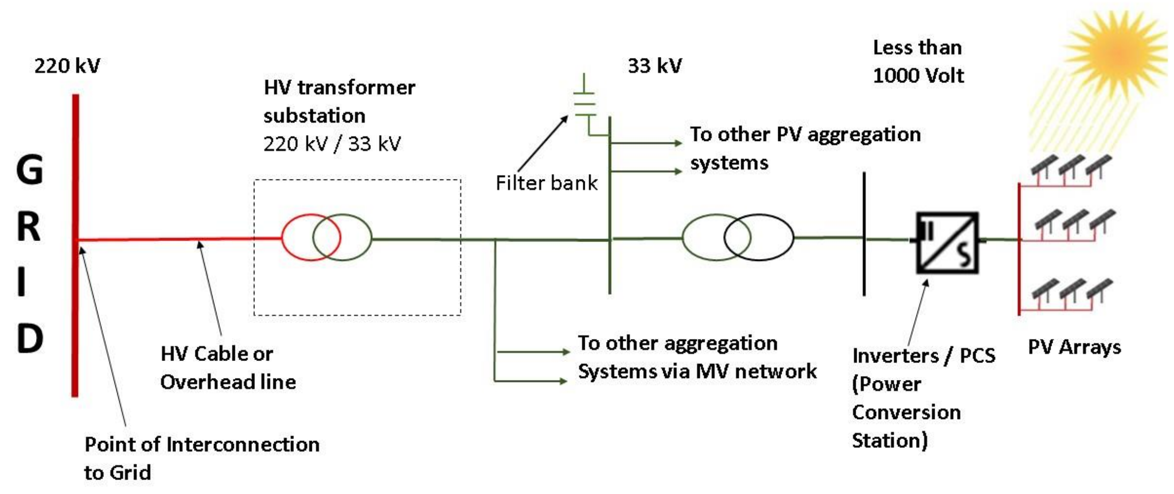
E. DETAILS OF CONNECTION – DATA AND VOICE COMMUNICATION

1.	Type Data Gateway (Remote Terminal Unit/ Substation Automation System Gateway)	:	(Whether RTU/ Substation Automation System Gateway ; and Number of data ports)
2.	Data Communication connectivity Standard followed (As per interface requirement and other guideline made available by the respective RLDC)	:	(Type of Communication Protocol, i.e. 101(serial port) or 104(Ethernet), etc.)

3.	Write here the communication media, interface and capacity being targeted for connection for Data and voice Communication	:	(Communication media: For example fibre optics, PLCC, etc. Interface : Example RS 232C, G.703) or as per mutual agreement Capacity : 1200 baud, 64 Kbps, 9.6 Kbps, etc as per mutual agreement)

F. DETAILS OF CONNECTION – SOLAR PV STATION

Models for Utility scale Solar generation farms:



In a typical utility scale solar farm / park, arrays of Solar PV panels connected to an inverter (Power Conditioning System / Power Conversion Station – PCS), which is stepped up to form part of the MV reticulation system (typically at 33 kV or less). A number of inverters are pooled and then stepped up to the voltage of 220 kV / 400 kV prior to connection to EHV grid. A Power Plant controllers (PPC) is usually installed at the point of interconnection to grid or the reticulation system. The PPC(s) control behavior of solar farms in accordance with mandates as per grid codes.

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

1. Generator or Converter

2. Electrical control including fault ride through
3. Power Plant Controller (PPC)
4. Energy storage (i.e. battery), if applicable

Depending on the nature of technology and usage of components at site, the requirements for steady state and dynamic modelling evolves.

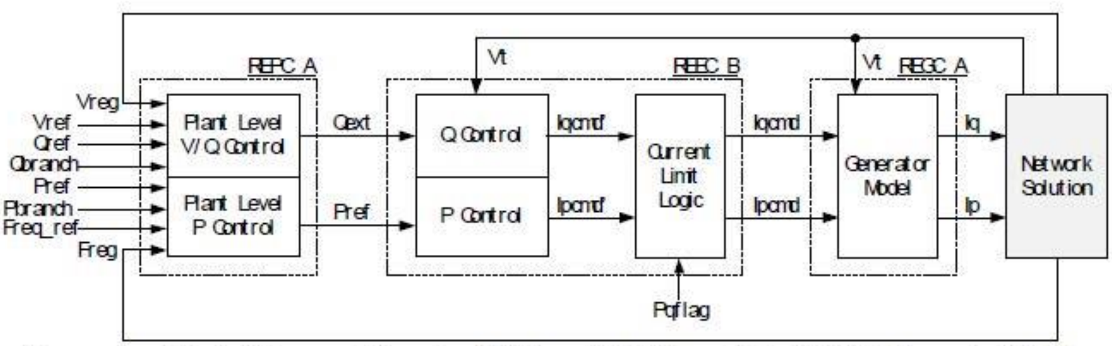


Figure 4 – Block Diagram Showing Different Modules of the WECC Generic Models

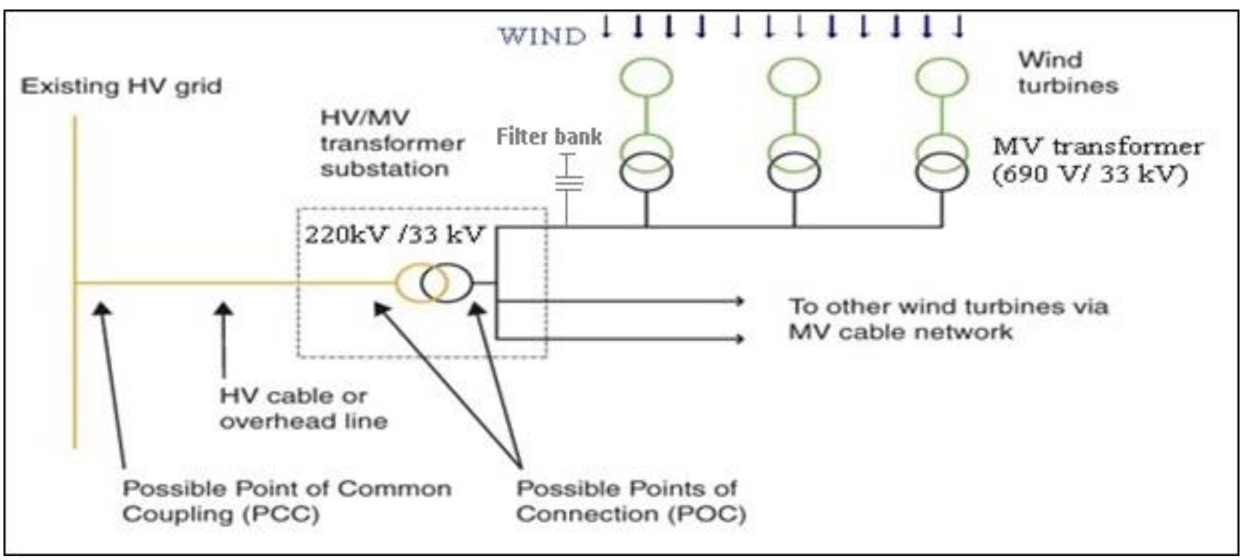
For CTU to have access to fit-for-purpose models of Solar farms/ parks connected to Indian grid, the following information shall be provided:

1. Electrical Single Line Diagram(SLD) of Solar farm /park depicting:
    - For individual Inverters / Power Condition system (PCS): Type, MW rating, MVAR capability, temperature dependent capability curves, short circuit contribution, Manufacturer, Model no., Harmonic profile of inverters
    - Configuration and Details of PV arrays behind each inverter / PCS
    - Reticulation system (MV system within the solar farm): Length of individual branch / twig, Type of conductor, Electrical parameters (R, X, B)
    - Details of MV (~660V/33kV) and HV (~33kV/220kV) step-up transformers: Rating, Impedance, Vector Group, Tap changers (Type, Tap Steps, Max Ratio and Min Ratio in p.u.)
    - Filters (active or passive) or capacitor banks
    - Aggregated steady state model validated for P injection and Q injection at the point of interconnection.
2. Generic models of Solar farms (**Refer Schedule - IX**)
    - Models should be suitable for an integration time step between 1ms and 20ms, and suitable for operation up-to 600s.
    - Including a Generic Power Plant Controller (PPC) model which represents the interaction of power plant with the grid. Settings of the Power Plant Controller may be tuned as per the existing setup on field.
    - Simulation results depicting validation of Generic models against User-Defined models (for P, Q, V, I) and against actual measurement (after commissioning) to be provided.

3. Encrypted user-defined model (UDM) in a format suitable for use in latest release of PSS/E (*.dll files) for electromechanical transient simulation for components of Solar farm: (in case of non-availability of validated generic model)
    - User guide for Encrypted models to be provided including instructions on how the model should be set-up
    - Corresponding transfer function block diagrams to be provided
    - Simulation results depicting validation of User-Defined models against actual measurement (P, Q, V, I) to be provided
    - The use of black-box type representation is not preferred.
    - Models should be suitable for an integration time step between 1ms and 10ms, and suitable for operation up-to and in excess of 100s.
4. Inverter datasheet
5. Voltage/reactive control strategy of farm, reactive capability curves at point of interconnection (temperature and voltage dependence)
6. Settings from an inverter / PCS (each model in the farm)
    - Mapping of settings from the inverter/PCS to the model (UDM and Generic)
7. Settings from the Power plant controller (PPC)
    - Mapping of settings from the inverter/PCS to the model (UDM and Generic)
8. Disturbance recordings – of Solar farm response to disturbance together with any associated information about the circumstances of the disturbance

G. <u>DETAILS OF CONNECTION – WIND GENERATING STATION</u>

Models for Wind generators:

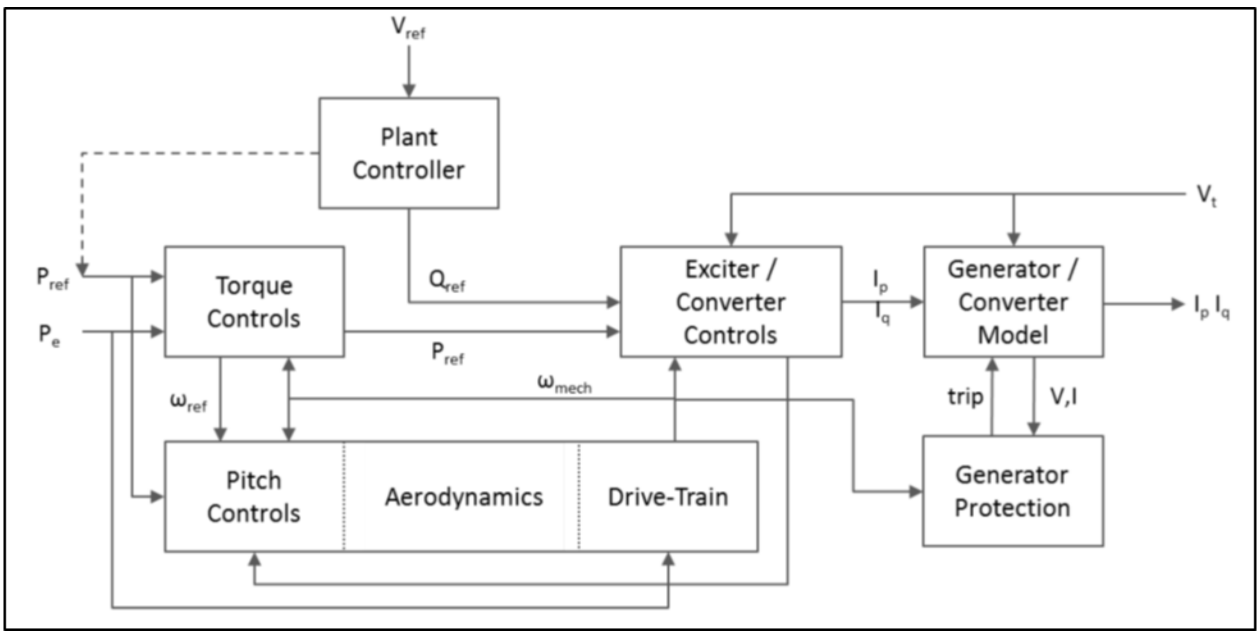


In a typical wind farm / park, individual WTGs (typically rated 3 MW or less) are connected in a system of twigs and feeders. Wind generation at around 660 V / 690 V is stepped up to a MV level of typically 33 kV in Indian system and finally pooled to grid at 220 kV / 400 kV through step-up transformers. 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 consist 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, the requirements for steady state and dynamic modelling evolves.



For CTU to have access to verified fit-for-purpose models of wind farms/ parks connected to Indian grid, the following information shall be provided:

1. Electrical Single Line Diagram (SLD) of Wind farm /park depicting:
    - For individual WTGs: Type, MW rating, MVAR capability, Manufacturer, Model no., capability curve

- Reticulation system (MV system within the wind farm): Length of individual branch / twig, Type of conductor, Electrical parameters (R, X, B)
- Filters (active or passive) or capacitor banks
- Details of MV (690V/33kV) and HV (33kV/220kV) step-up transformers: Rating, Impedance, Vector Group, Tap changers (Type, Tap Steps, Max Ratio and Min Ratio in p.u.)
- Aggregated steady state model validated for P injection and Q injection at the point of interconnection.

2. Generic models of WTGs / Wind farms (Refer **Schedule - X**)
    - Models should be suitable for an integration time step between 1ms and 20ms, and suitable for operation up-to 600s.
    - Including a Generic Power Plant Controller (PPC) model which represents the interaction of power plant with the grid. Settings of the Power Plant Controller may be tuned as per the existing setup on field.
    - Simulation results depicting validation of Generic models against User-Defined models (for P, Q, V, I) and against actual measurement (after commissioning) to be provided.
3. Encrypted user defined model (UDM) in a format suitable for latest release PSS/E (*.dll files) for electromechanical transient simulation for components of WTGs / Wind farm (in case non-availability of validated generic model)
    - User guide for Encrypted models to be provided including instructions on how the model should be set-up
    - Corresponding transfer function block diagrams to be provided
    - Simulation results depicting validation of User-Defined models against actual measurement (for P, Q, V, I) to be provided
    - The use of black-box type representation is not preferred.
    - Models should be suitable for an integration time step between 1ms and 10ms, and suitable for operation up-to and in excess of 100s.
4. Wind Turbine datasheet
5. Voltage/reactive control strategy of farm, reactive capability curves at the point of interconnection (Temperature and Voltage dependence)
6. Settings from a wind turbine (each model in the farm)
    - Mapping of settings from a wind turbine to the corresponding model (both UDM and generic)
7. Settings from the Power plant controller (PPC)
    - Mapping of settings from PPC to the corresponding model (UDM and Generic model)
8. Disturbance recordings – of wind farm response to grid disturbance together with any associated information about the circumstances of the disturbance

This is to certify that the above data submitted with the application are pertaining to connection sought for the ISTS. Further, any additional data sought for processing the application shall be furnished.

Authorized Signatory Of Applicant

Name :
Designation :
Seal :
Place :
Date :

Schedule – I : Survey of India topo sheet clearly marking the location of the proposed site

Schedule – II : Site plan in appropriate scale.

Schedule – III : Electrical Single Line Diagram (SLD) of the proposed facility detailing all significant items of plant.

Schedule – IV : Rating of Generating Units

(Add additional sheets if number of units are more)

		Unit – 1	Unit - 2	Unit – 3
1.	Unit Rating (MVA)			
2.	Normal Max. Continuous Generation Capacity at Normal operating temperature (MW)			
3	Normal Max. Continuous Export Capacity at Normal operating temperature (MW)			
4	Maximum (Peaking) generating Capacity at min ambient air temperature (MW)			
5	Maximum (Peaking) Export Capacity at min ambient air temperature (MW)			
6	Minimum Continuous Generating Capacity (MW)			
7	Minimum Export Generating Capacity (MW)			
8	Normal Maximum Lagging MVAR at rated MW output			
9.	Normal Maximum leading MVAR at rated MW output			

Please attach a capability Curve : ___________________________

Drawing no. of the Capability Diagram attachment

Schedule – V : Generator Data for Fault (Short Circuit Studies)

All data to be provided on pu machine MVA base

1.	Direct Axis Transient Reactance (Unsaturated)	Xd‘‘	
2.	Sub-transient Reactance (Unsaturated)	Xd’’	
3.	Synchronous Reactance	Xs	
4.	Zero Phase Sequence Reactance	Xo	
4.	Negative Phase Sequence Reactance	X2	

Schedule – VI : Dynamic Simulation Data

Generator Data

All data to be provided on pu machine MVA base

1.	Direct Axis Positive Phase Sequence Synchronous Reactance	Xd	
2.	Quadrature Axis Positive Phase Sequence Synchronous Reactance	Xq	
3.	Direct Axis Transient Reactance (unsaturated)	Xd‘‘	
4.	Quadrature Axis Transient Reactance (unsaturated)	Xq‘‘	
5.	Sub-Transient Reactance (unsaturated)	Xd‘‘‘‘	
5.	Armature Leakage Reactance	X*l*	
6.	Direct Axis Transient open circuit Time Constant (Secs)	Tdo‘‘	
7.	Direct Axis Subtransient open circuit Time Constant(Secs)	Tdo‘‘‘‘	
8.	Quadrature Axis Transient open circuit Time Constant(Secs)	Tqo‘‘	
9.	Quadrature Axis Subtransient open circuit Time Constant(Secs)	Tqo‘‘‘‘	
10.	Inertia of complete turbogenerator (MWs/MVA)	H	

11.	Please provide open circuit magnetization curve enter drawing number here or mention "assume" *if this not available then POWERGRID shall assume magnetic saturation characteristics as per the* ***Annexure-I***		

Excitation Data

Please submit Laplace domain control block diagram that represents the generator excitation system in accordance with the IEEE standard excitation model or as otherwise agreed with POWERGRID. This control block diagram should completely specify all the time constants and gains to fully explain the transfer function from the compensator or generator terminal voltage and field current to generator voltage. A list of acceptable IEEE standard excitation model available with PSS/E simulation package used by POWERGRID is shown in **Annexure-II**.

Please fill/tick the appropriate box below:

Please assume [model]

OR

If the excitation data is not available at this stage then POWERGRID shall assume exciter model given at **Annexure-III** which represents a typical excitation model.

Assume the model given at **Annexure-III** as our model [ ]

Schedule – VII: Two Winding Transformer Data

1.	Transformer positive sequence resistance (R1%)	
2.	Transformer positive sequence reactance (X1%)	
3.	Transformer zero sequence resistance (R0%)	
4.	Transformer zero sequence reactance (X0%)	
5.	Transformer Vector group	
5.	Nature of Tap Changer (on load/off load)	
6.	Number of steps and step size	

Schedule – VIII: Three Winding Transformer Data

1.	Transformer Vector group	
2.	Positive sequence resistance (R1HL1%) between HV/LV1	
3.	Positive sequence reactance (X1HL1%) between HV/LV1	
4.	zero sequence resistance (R0HL1%) between HV/LV1	
5.	zero sequence reactance (X0HL1%) between HV/LV1	
6.	Positive sequence resistance (R1HL2%) between HV/LV2	
7.	Positive sequence reactance (X1HL2%) between HV/LV2	
8.	Transformer zero sequence resistance (R0HL2%) between HV/LV2	
9.	zero sequence reactance (X0HL2%) between HV/LV2	
10.	Positive sequence resistance (R1L1L2%) between LV1/LV2	
11.	Positive sequence reactance (X1L1L2%) between LV1/LV2	
12.	zero sequence resistance (R0L1L2%) between LV1/LV2	
13.	zero sequence reactance (X0L1L2%) between LV1/LV2	
14.	Positive sequence resistance (R1HL1//L2%) between HV/(LV1+LV2)	
15.	Positive sequence reactance (X1HL1//L2%) between HV/(LV1+LV2)	
16.	zero sequence resistance (R0HL1//L2%) between HV/(LV1+LV2)	
17.	zero sequence reactance (X0HL1//L2%) between HV/(LV1+LV2	

Schedule – IX: Generic Models of Solar Farms

1.1 Generic models in PSS/E for modelling utility scale Solar PV installations:

Solar Technology	Generic model	Model Description
Utility Scale Solar PV	REGCA1	Renewable energy generator converter model
	REECA1	Renewable energy controls model
	REPCA1	Renewable energy plant controller
Utility Scale Battery Energy Storage System (BESS)	REECCU1	Electrical Control Model (To be used along with REGCA1 and REPCA1)

Refer Annexure – IV for Detailed block diagrams of the above models

Details of models in PSS/E for modelling Solar plants / farms / parks:

Category	Parameter Description	Data
Inverter Details	Manufacturer, model number and product details	
	Year of commissioning	
	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
Technology	• Grid following • Grid forming (viz. Assist in regulation of Voltage and Frequency) • Reactive power priority (Controls Pf or Voltage? Point of control?)	-
Single Line Diagram	Single line diagram of the solar farm showing number and location of inverters and PV arrays behind each inverter, 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 PV-array to Inverters, Inverters to MV reticulation system, MV reticulation system till Point of Interconnection (POI) at EHV level (220 kV/400 kV)	
Capability	DC/AC ratio	
	Number of inverters	
	Panel type	
	Number of modules per string	
	Tracking in 0/1/2 axes	
	Capability diagram at nominal (STC) and typical temperature	
Controls	Does the solar farm have a PPC? If yes, whether PPC controls all or part of the inverters in Solar 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	
	Is there a droop setting? • Voltage control • Frequency control	
	Is reactive power limited? Details thereof	
	Is active power limited below MPPT at high output? Details thereof	
	Temperature dependency details	
	Active power ramp rate limiters	
	Fault Ride Through (FRT) protocols and setpoints • LVRT • HVRT	
	Provide settings from controller	

Category	Parameter Description	Data
Reticulation System	Voltage of the reticulation system	
	Number of feeders	
	Cable schedules (lengths, cable size, conductor material, rating info)	
Inverter station transformer	Details of the turbine transformer, including vector group, impedance, and number of taps, tap position, tap ratio	
	Nameplate details	
Solar Farm step-up transformer	Details of the main solar 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 solar farm have a PPC? If yes, whether PPC controls all or part of the inverters in solar 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.	

1.2 Generic Models for Utility Scale Solar-PV generation:

Category	Parameter Description	Data
GENERATOR model		
Solar PV (REGCA1)	Tg, Converter time constant (s)	
	Rrpwr, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)	
	Brkpt, LVPL characteristic voltage 2 (pu)	
	Zerox, LVPL characteristic voltage 1 (pu)	
	Lvpl1, LVPL gain (pu)	
	Volim, Voltage limit (pu) for high voltage reactive current manage-	
	Lvpnt1, High voltage point for low voltage active current management (pu)	
	Lvpnt0, Low voltage point for low voltage active current management (pu)	
	Iolim, Current limit (pu) for high voltage reactive current management (specified as a negative value)	
	Tfltr, Voltage filter time constant for low voltage active current management (s)-	
	Khv, Overvoltage compensation gain used in the high voltage reactive 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		
Large Solar PV : (REECB1) [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)	
	Tp (s), Filter time constant for electrical power	

Category	**Parameter Description**	**Data**
Electrical Control model		
Large Solar PV : (REECB1) [Refer Block Diagrams]	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	

Category	Parameter Description	Data
Power Plant Controller (PPC) model		
Generic Power Plant Controller (PPC) model: (REPCA1)	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

Schedule – X: Generic Models of WTGs / Wind farms

1.1 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
		WTARA1	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	REGCA1	Renewable energy generator converter model
		REECA1	Renewable energy controls model
		WTDTA1	Drive train model
		REPCA1	Renewable energy plant controller
Storage	Utility Scale Battery Energy Storage System (BESS)	REECCU1	Electrical Control Model (To be used alongwith REGCA1 and REPCA1)

- Detailed block diagrams are enclosed at Annexure-V

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.	

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

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)	

1.3 Generic Models for Type-3 and Type-4 Wind turbine generators:

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		
WTDTA1	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)	

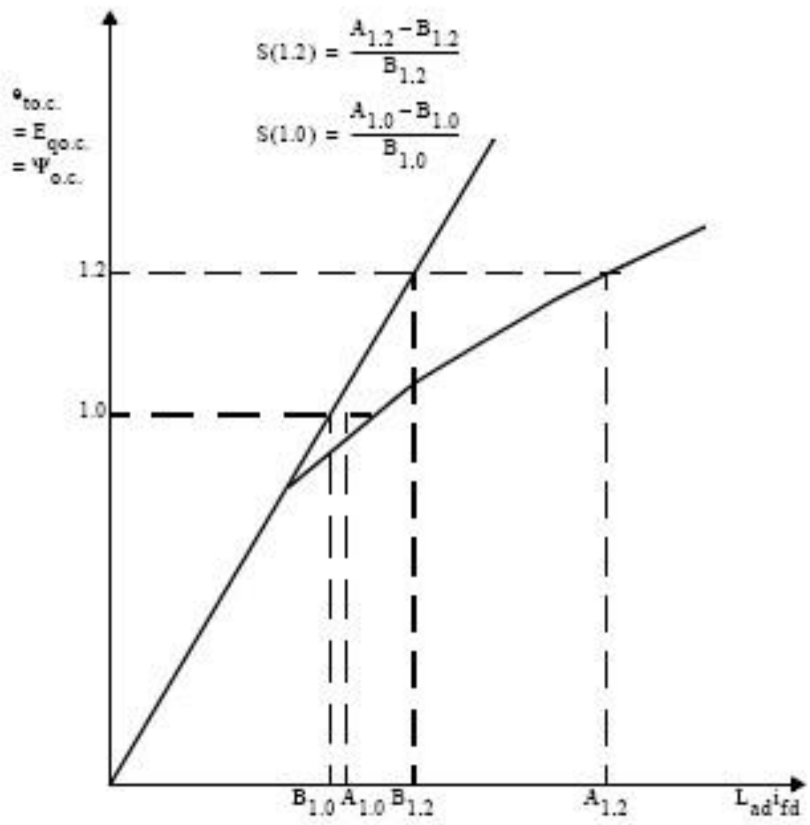
Category	**Parameter Description**	**Data**
Power Plant Controller (PPC) model		
Generic Power Plant Controller (PPC) model for Type-3 and Type-4 wind turbines : REPCTA1 for type 3, and REPCA1 for type 4 turbines	Tfltr, Voltage or reactive power measurement filter time constant (s)	
	Kp, Reactive power 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

Annexure-I

Open Circuit magnetization curve



Magnetic saturation data to be assumed

S(1.0) =

S(1.2) =

Annexure-II

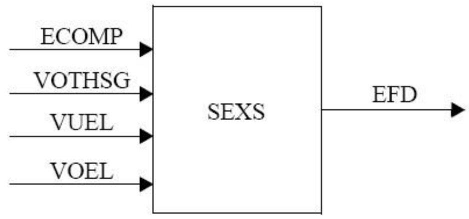
Acceptable IEEE standard excitation model available with PSS/E simulation package used by POWERGRID

Excitation System Models	
ESAC1A	1992 IEEE type AC1A excitation system model
ESAC2A	1992 IEEE type AC2A excitation system model
ESAC3A	1992 IEEE type AC3A excitation system model
ESAC4A	1992 IEEE type AC4A excitation system model
ESAC5A	1992 IEEE type AC5A excitation system model
ESAC6A	1992 IEEE type AC6A excitation system model
ESAC8B	Basler DECS model
ESDC1A	1992 IEEE type DC1A excitation system model
ESDC2A	1992 IEEE type DC2A excitation system model
ESST1A	1992 IEEE type ST1A excitation system model
ESST2A	1992 IEEE type ST2A excitation system model
ESST3A	1992 IEEE type ST3A excitation system model
EXAC1	1981 IEEE type AC1 excitation system model
EXAC1A	Modified type AC1 excitation system model
EXAC2	1981 IEEE type AC2 excitation system model
EXAC3	1981 IEEE type AC3 excitation system model
EXAC4	1981 IEEE type AC4 excitation system model
EXBAS	Basler static voltage regulator feeding dc or ac rotating exciter model
EXDC2	1981 IEEE type DC2 excitation system model
EXELI	Static PI transformer fed excitation system model
EXPIC1	Proportional/integral excitation system model
EXST1	1981 IEEE type ST1 excitation system model
EXST2	1981 IEEE type ST2 excitation system model
EXST2A	Modified 1981 IEEE type ST2 excitation system model
EXST3	1981 IEEE type ST3 excitation system model

IEEET1	1968 IEEE type 1 excitation system model
IEEET2	1968 IEEE type 2 excitation system model
IEEET3	1968 IEEE type 3 excitation system model
IEEET4	1968 IEEE type 4 excitation system model
IEEET5	Modified 1968 IEEE type 4 excitation system model
IEEEX1	1979 IEEE type 1 excitation system model and 1981 IEEE type DC1 model
IEEEX2	1979 IEEE type 2 excitation system model
IEEEX3	1979 IEEE type 3 excitation system model
IEEEX4	1979 IEEE type 4 excitation system, 1981 IEEE type DC3 and 1992 IEEE type DC3A models
IEET1A	Modified 1968 IEEE type 1 excitation system model
IEET1B	Modified 1968 IEEE type 1 excitation system model
IEET5A	Modified 1968 IEEE type 4 excitation system model
IEEX2A	1979 IEEE type 2A excitation system model
SCRX	Bus or solid fed SCR bridge excitation system model
SEXS	Simplified excitation system model

SEXS – Simplified Excitation System Model

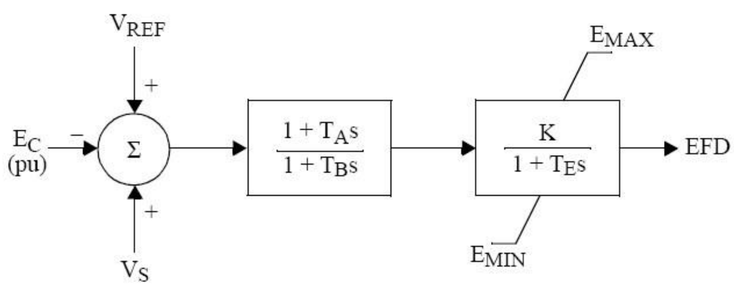
This model is located at system bus #_______ IBUS,
machine #_______ I.
This model uses CONs starting with #_______ J,
and STATEs starting with #_______ K.



CONs	#	Value	Description
J			T_A/T_B
J+1			T_B (>0) (sec)
J+2			K
J+3			T_E (sec)
J+4			E_{MIN} (pu on EFD base)
J+5			E_{MAX} (pu on EFD base)

STATEs	#	Description
K		First integrator
K+1		Second integrator

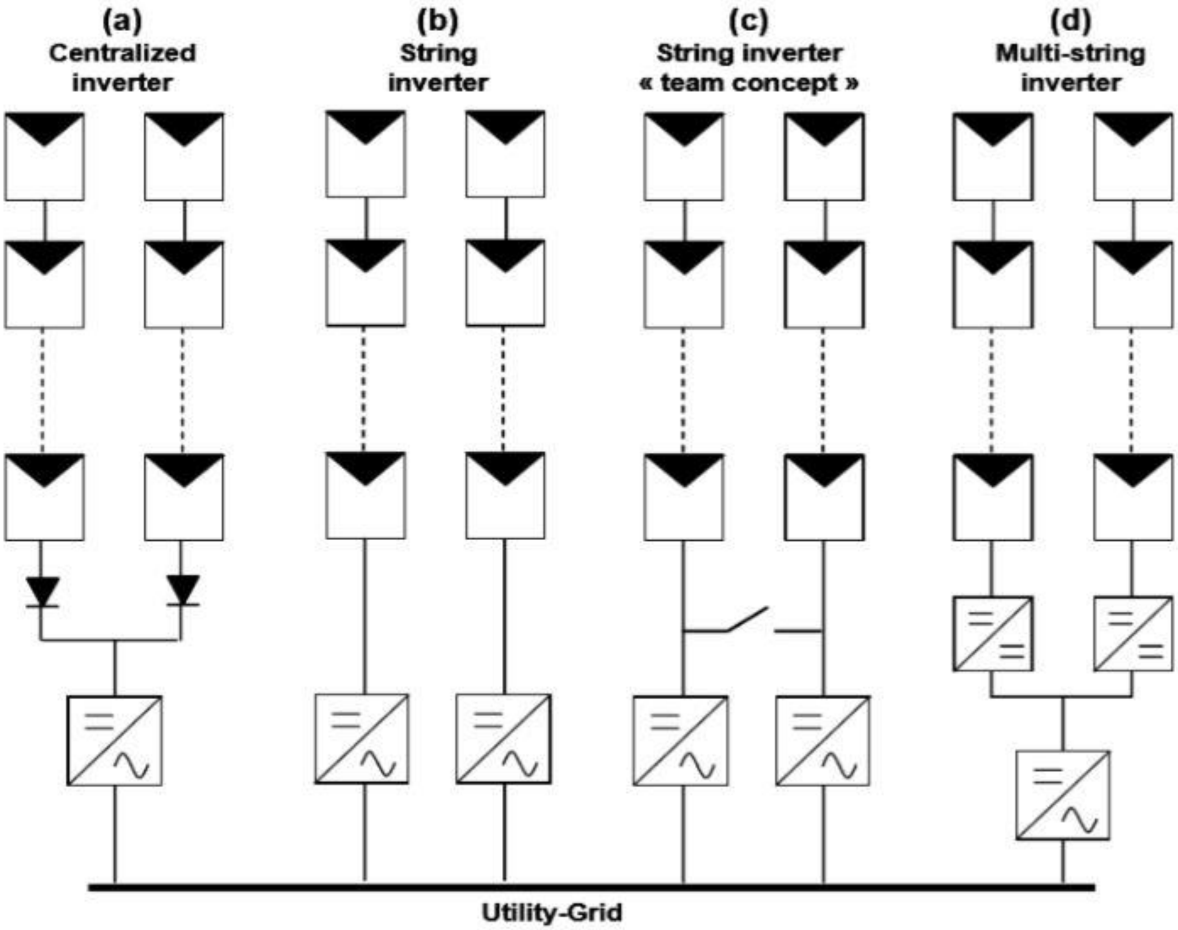
IBUS, 'SEXS', I, T_A/T_B, T_B, K, T_E, E_{MIN}, E_{MAX}/



V_S = VOTHSG + VUEL + VOEL

Inverter Configurations:

Inverters within a Solar farm can be present in different configurations, as indicated below:

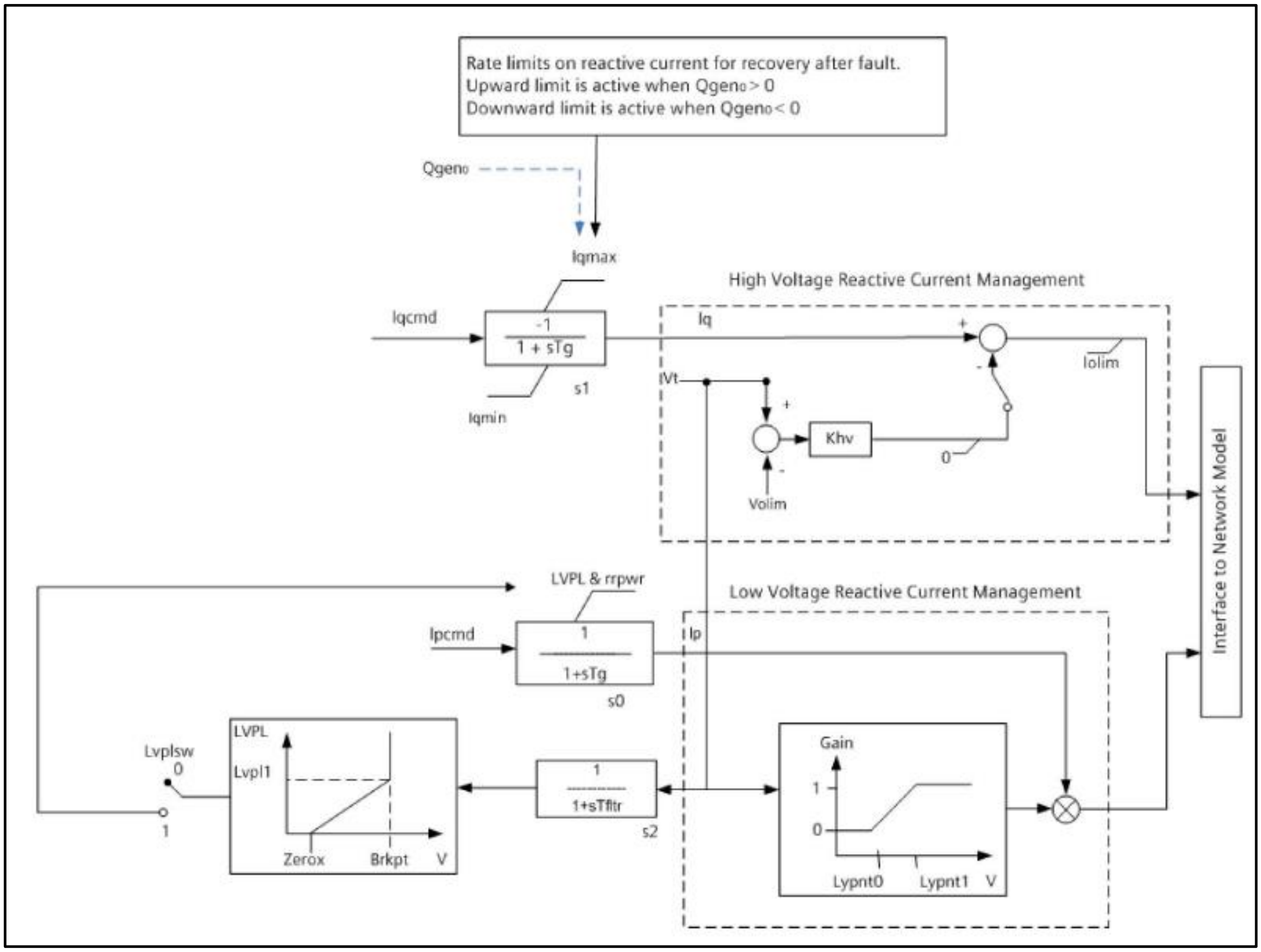


The data furnished must take into account the individual inverter configurations accordingly.

Block Diagrams:

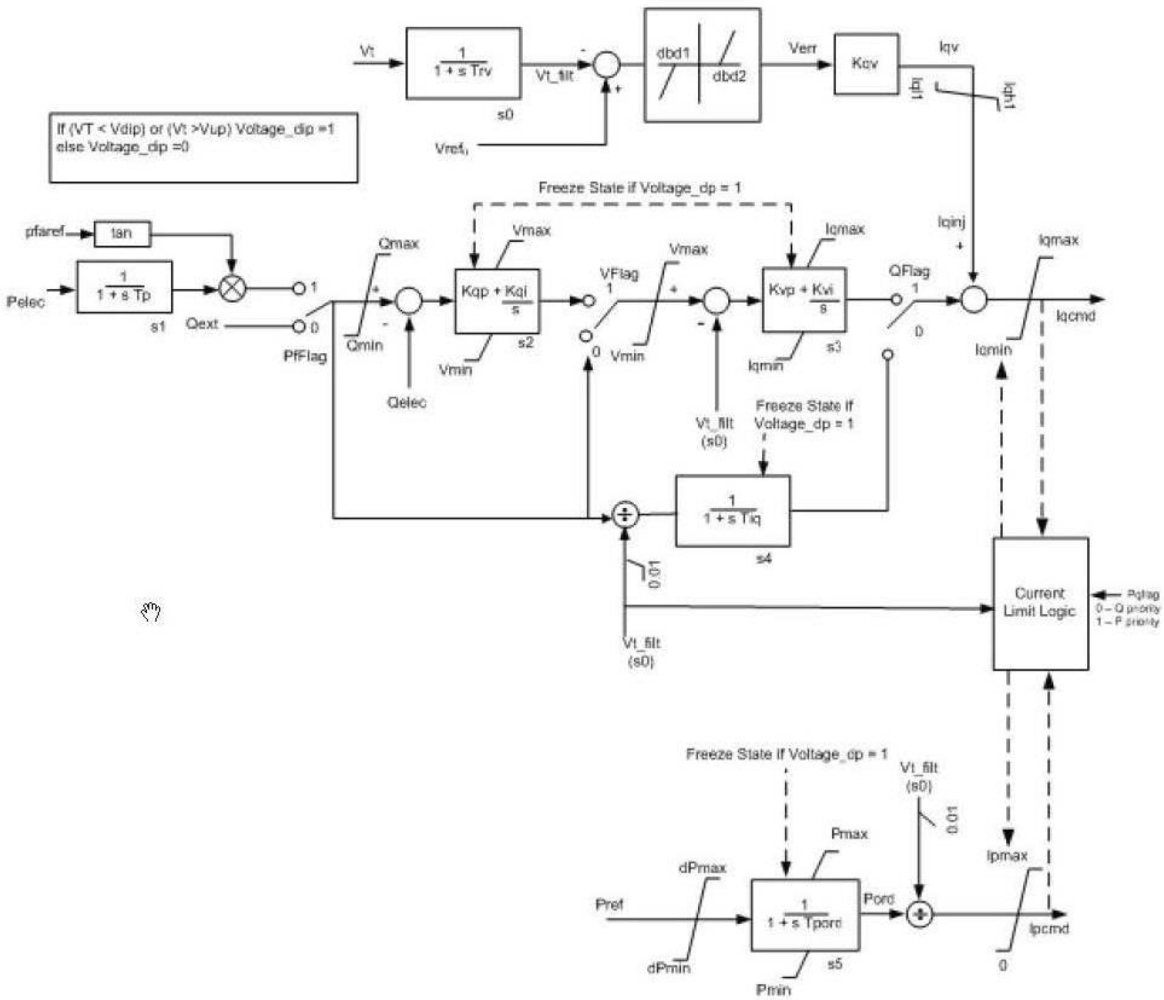
A. Generators:

- **REGCA1:** Generic Model for Utility Scale Solar PV



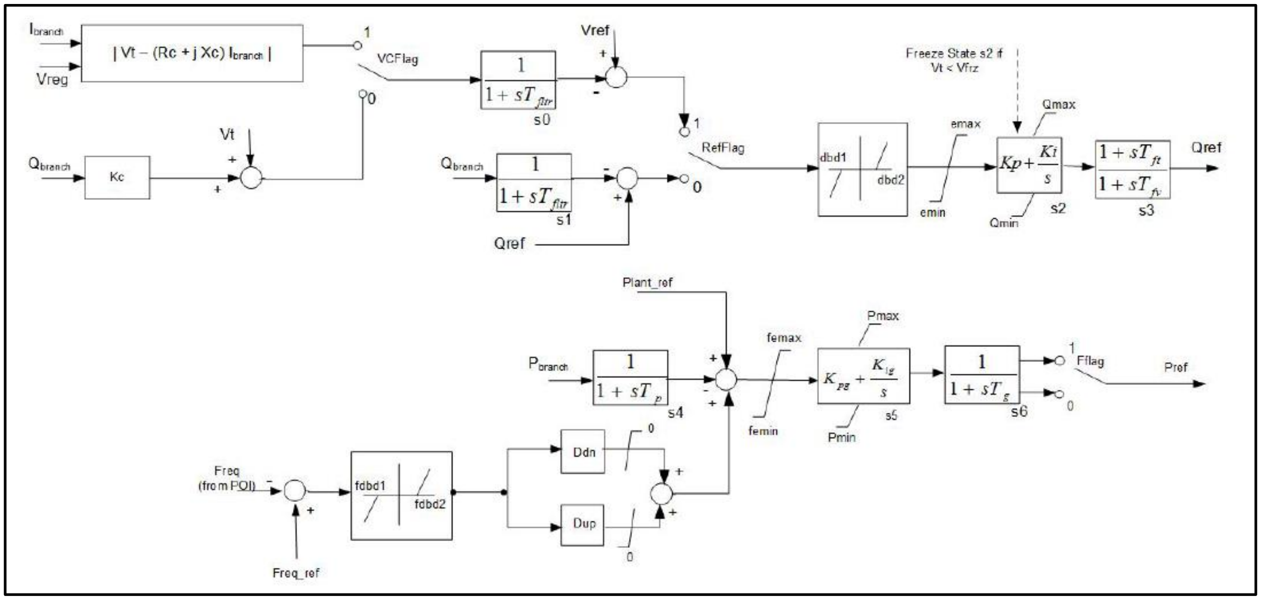
B. Electrical Control:

- **REECB1:** Generic Model for Utility Scale Solar PV

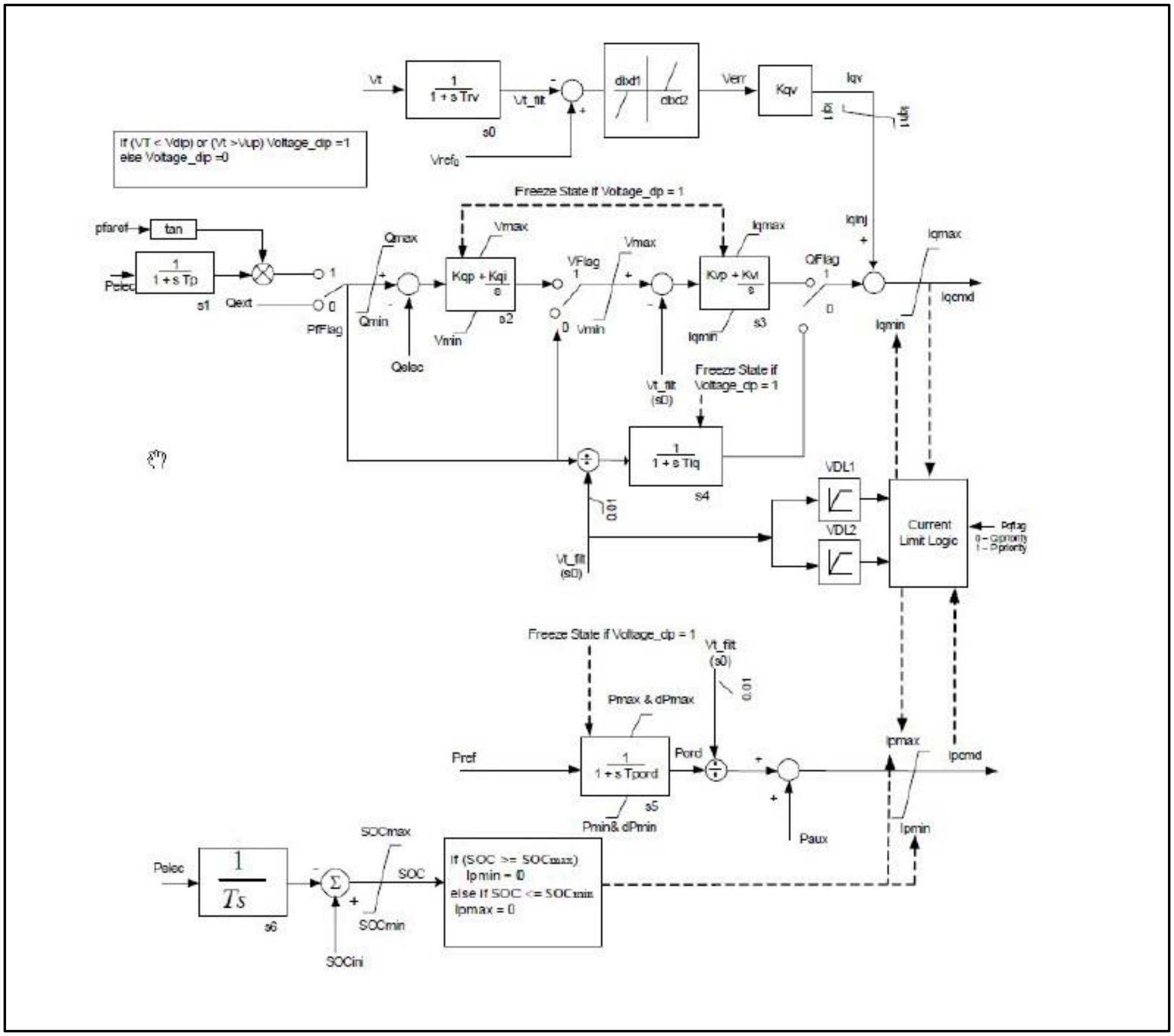


C. Power Plant Controller (PPC) Model:

- **REPCA1** for Utility scale Solar PV:



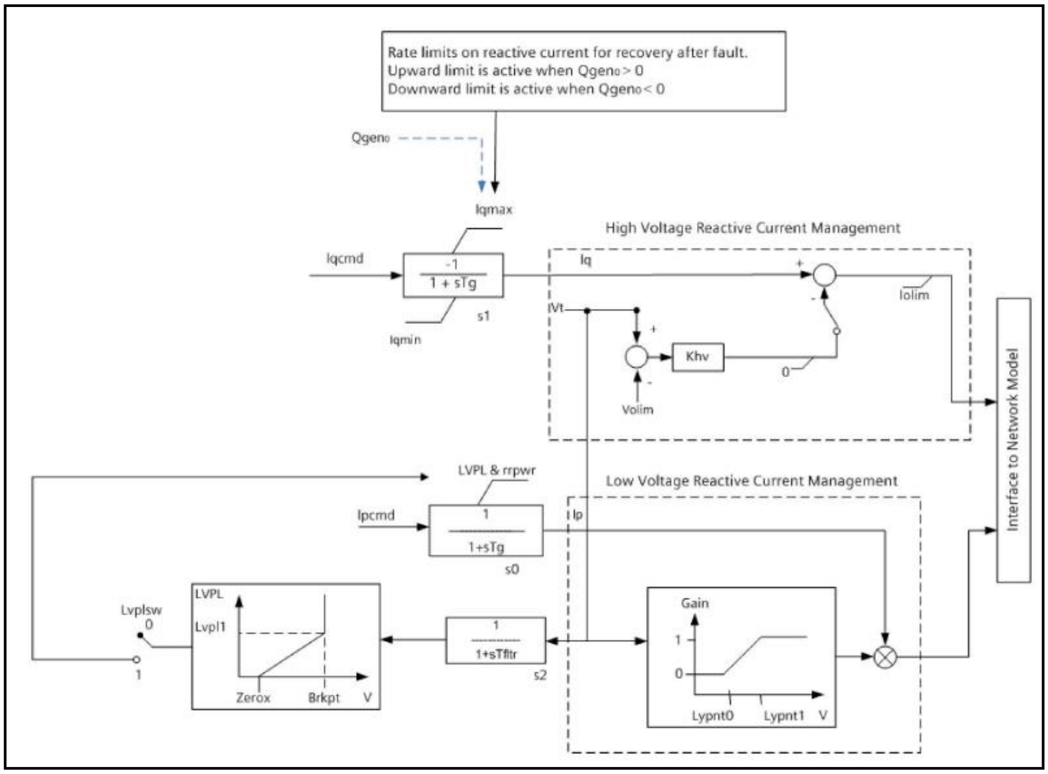
D. Electrical Control Model for Utility Scale Battery Energy Storage System (BESS):



Block Diagrams

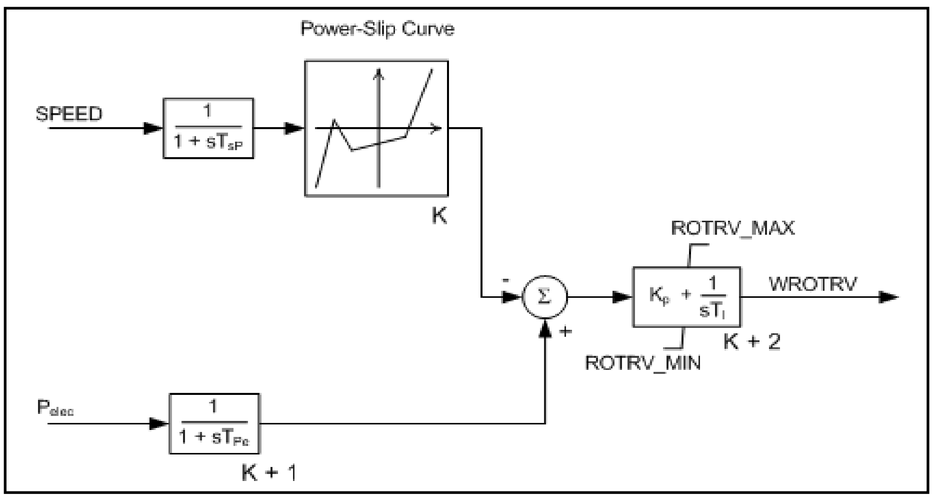
A. Generators:

- REGCA1: Generic Model for Type-3 and Type-4 wind turbines



B. Electrical Control:

- Type-2 (WT2E1) : Rotor Resistance Control



- Type-3 or Type-4 (REECA1) :

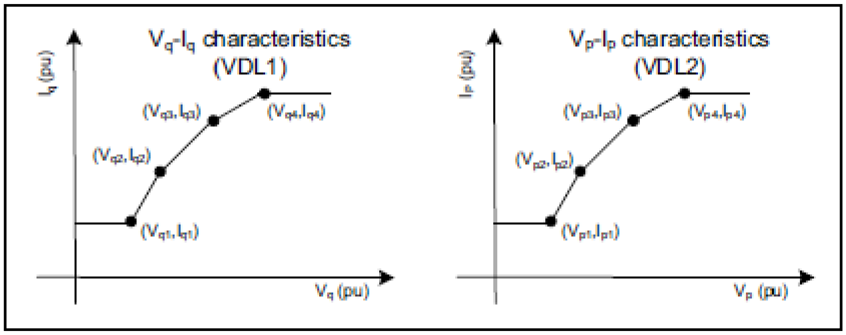
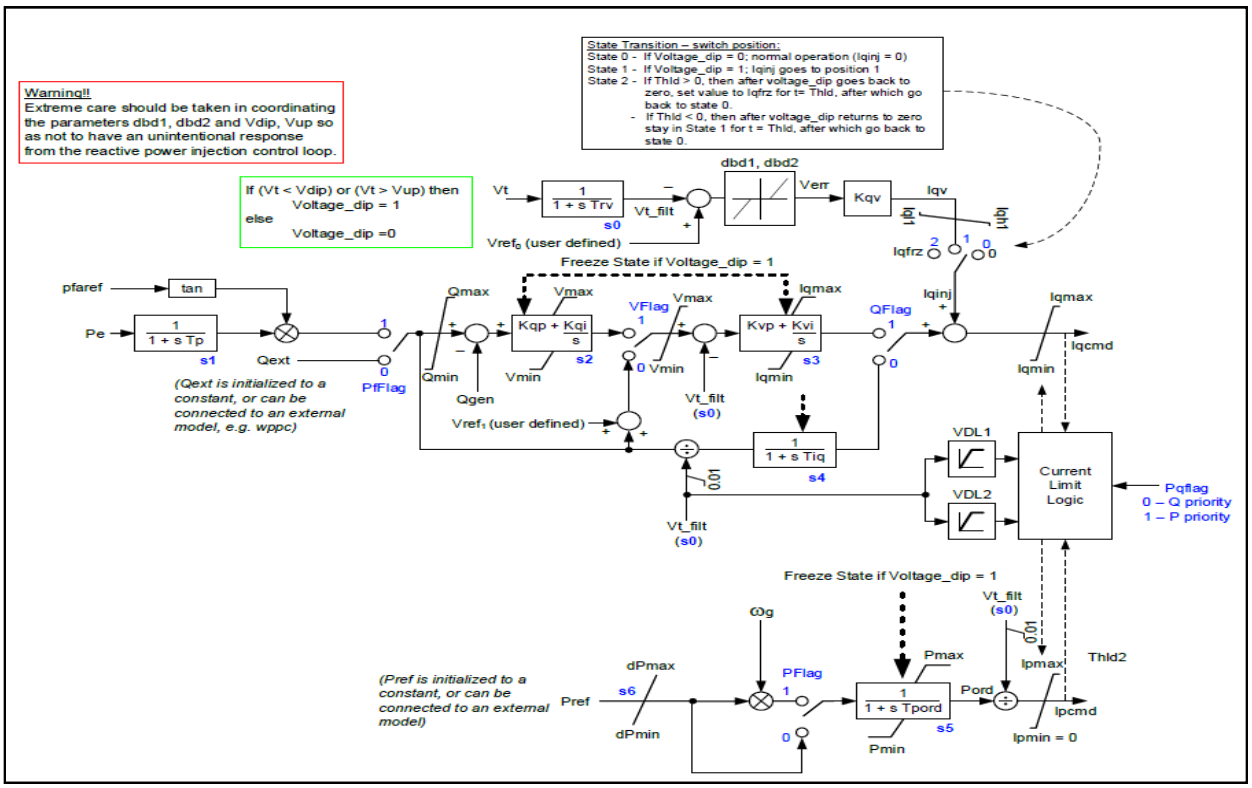
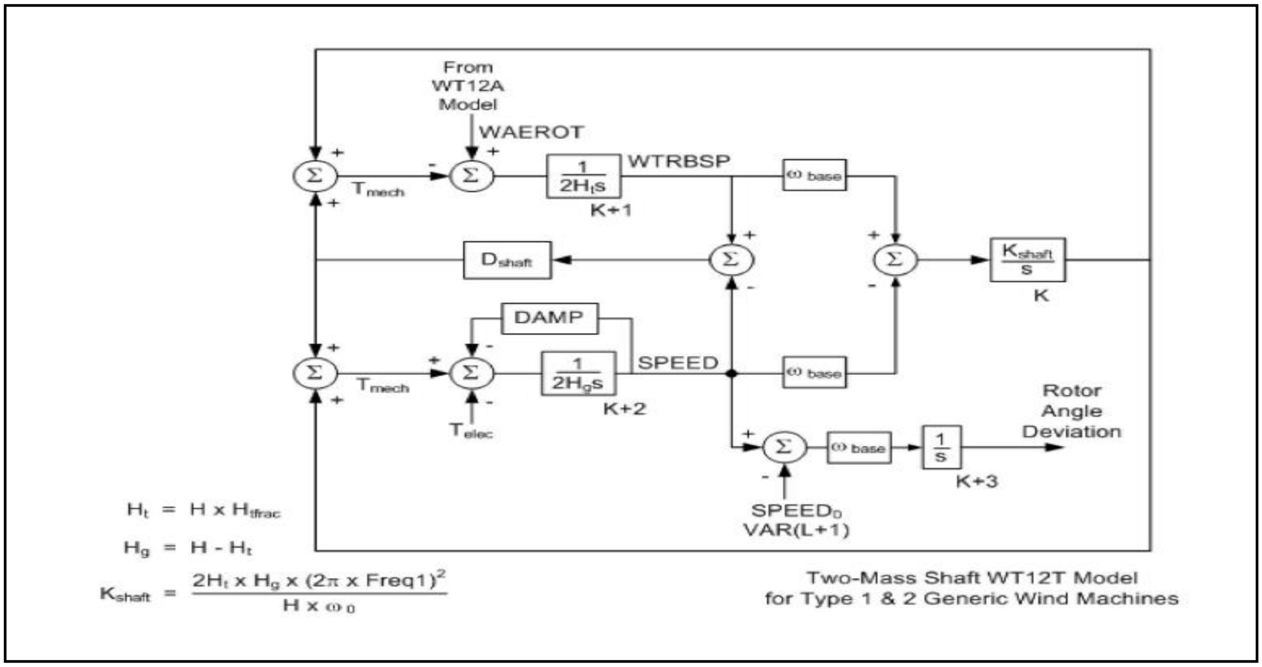


Figure: *Vp-Ip and Vq-Iq curves for REECA1 model*

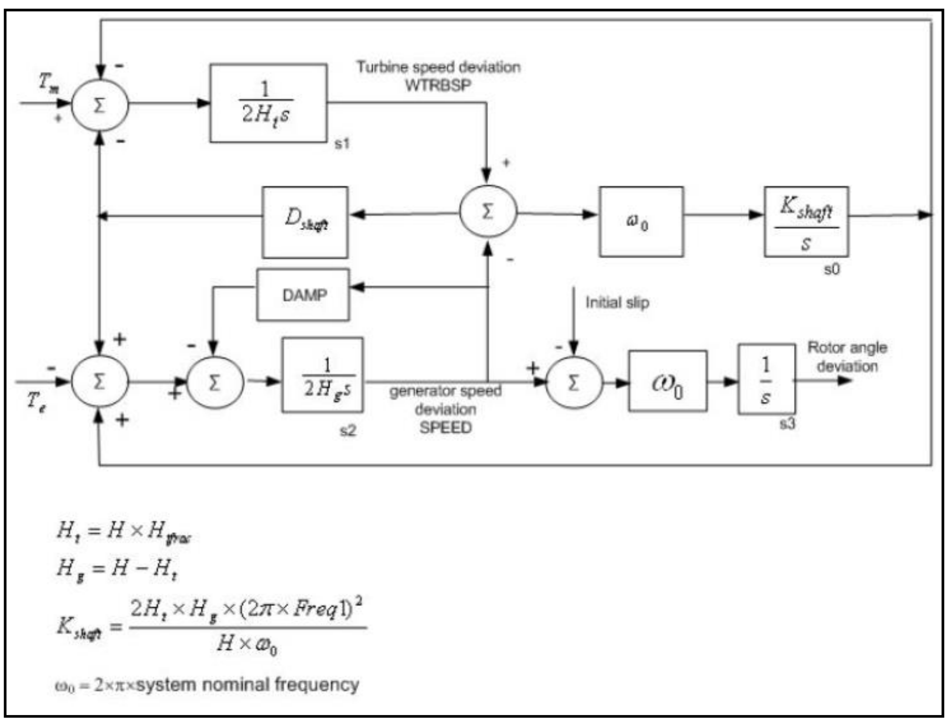


C. Drive Train Model:

- <u>Type-2 (WT12T1) : For Type 1 and Type-2 wind turbines</u>

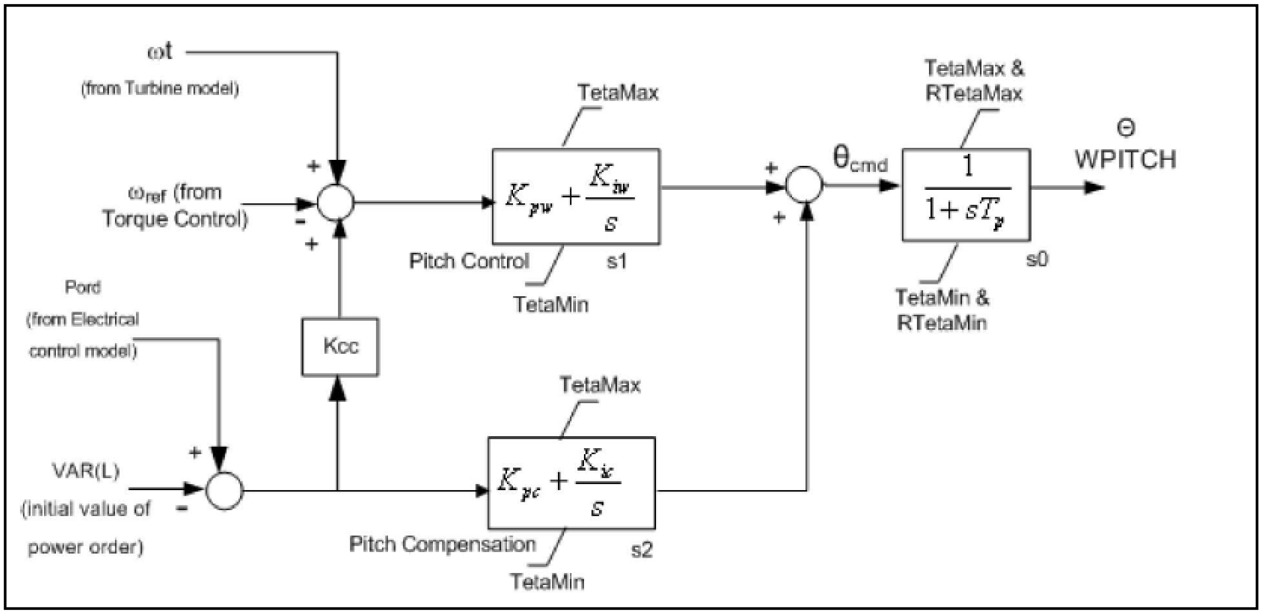


- <u>WTDTA1 : Generic Drive Train model for Type-3 and Type-4 turbines</u>



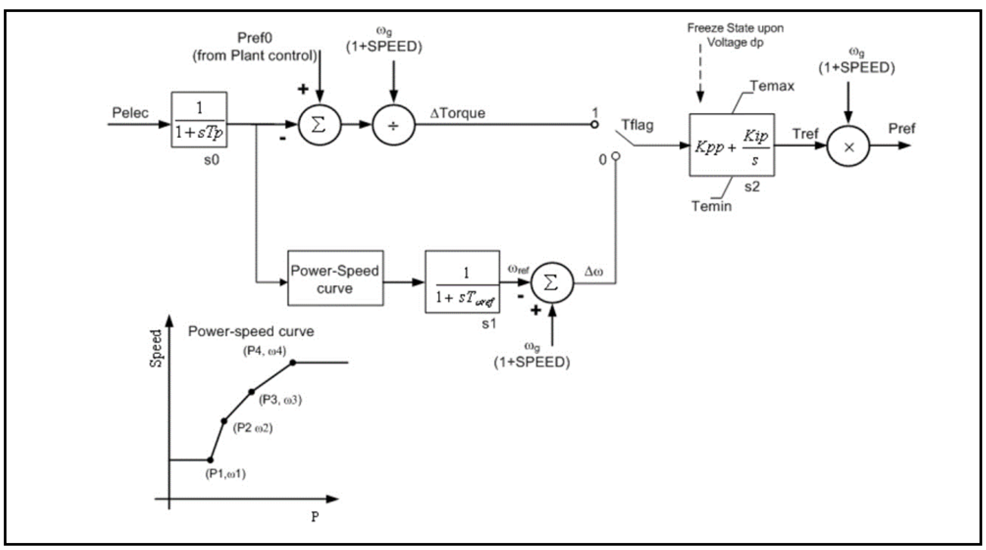
D. Pitch Control:

- Type-3 (WTPTA1) : Generic Pitch Control for Type-3 WTG



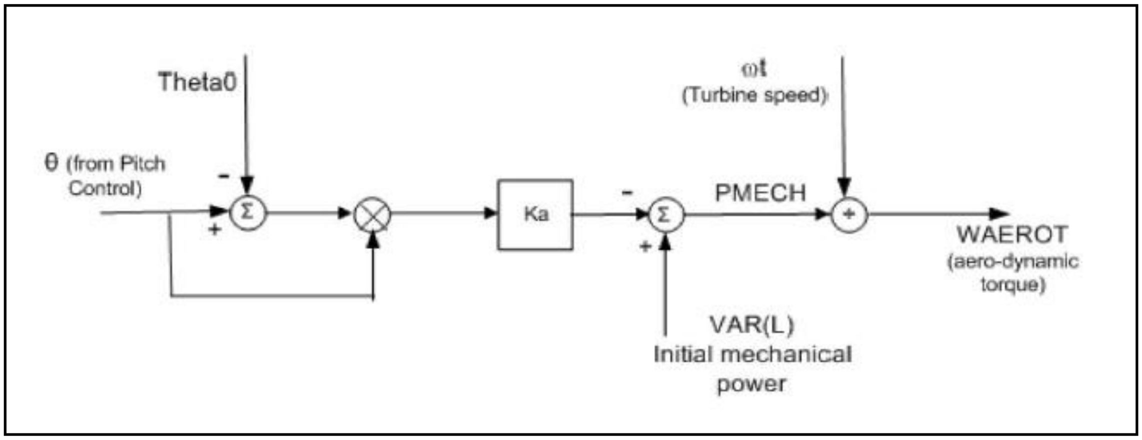
E. Torque Controller Model:

- Type-3 (WTTQA1) : Generic Torque Controller for Type-3 WTG



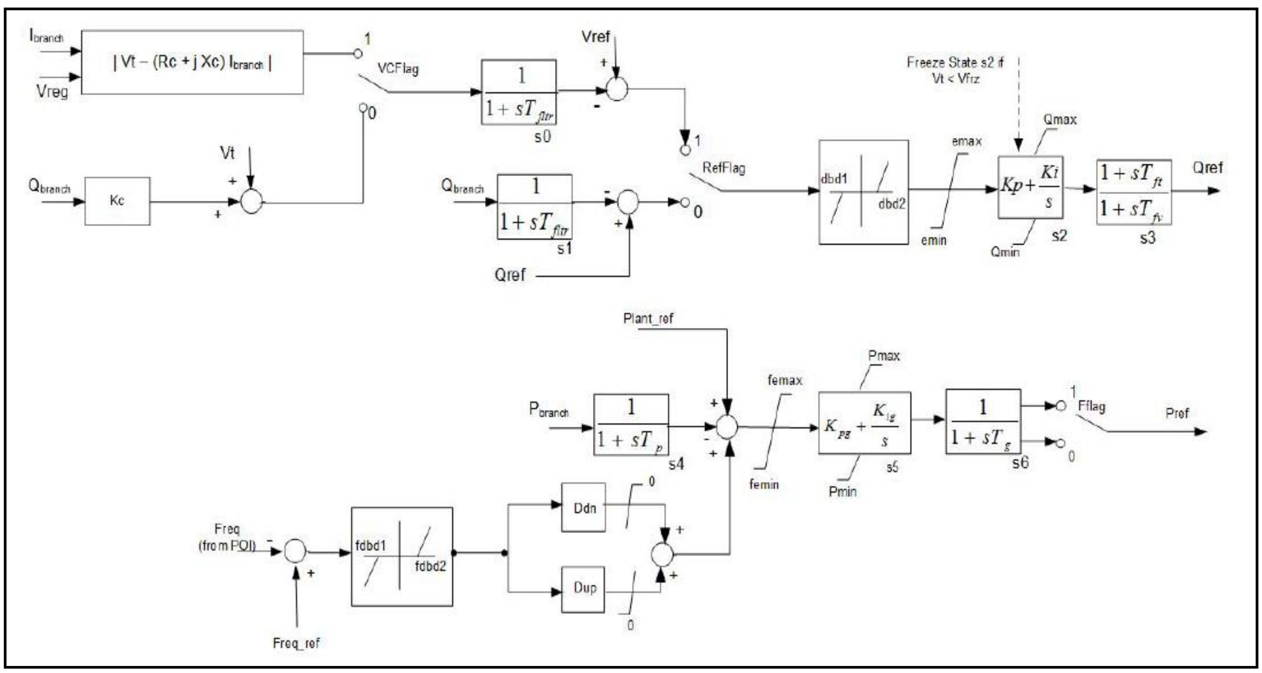
F. Aerodynamic Model:

- <u>Type-3 (WTARA1) : Generic Aerodynamic model Type-3 WTG</u>



G. Power Plant Controller (PPC) Model:

- <u>REPCTA1 for type 3, and REPCA1 for type 4 turbines</u>



H. Electrical Control Model for Utility Scale Battery Energy Storage System (BESS):