FORMATs of Technical Data for Connectivity Agreement

Central Transmission Utility of India Limited

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General Information to the Applicants for submission of Technical Connection Data

i. Within 30 days of the final grant of Connectivity (through **FORMAT-CONN-INT-1C / FORMAT-CONN-INT-2 / FORMAT-CONN-INT-TRANS-3)**, the entity shall submit the Technical Data (indicating Tentative or Final) as per **FORMAT-CONN-TD-1** for RE Generator / BESS, **FORMAT-CONN-TD-2** for Thermal/ Hydro/ Nuclear generating stations including Pumped Storage Projects (PSP), and **FORMAT-CONN-TD-3** for Bulk Consumer/Distribution Licensee.

The Transmission Licensee for physical connection to ISTS, shall submit the requisite technical Connection data and shall sign the Connectivity Agreement as per IEGC.

ii. If the submitted Technical Data is tentative, then the Connectivity Agreement as per **FORMAT-CONN-CA-5** shall be signed within thirty (30) days of submission of tentative Technical Connection Data between the Nodal Agency and the entity which has been intimated final grant of Connectivity. On signing of the Connectivity Agreement such entity shall become the Connectivity grantee. In such case, final Technical Data shall be submitted by entity at least one (1) year prior to physical connection. CTU shall scrutinize the submitted data within thirty (30) days, and inform regarding discrepancies (if any). Upon rectification of all discrepancies by entity, CTU within thirty (30) days shall intimate the connection details, inter alia, details of protection equipment, system recording, SCADA and communication equipment, under Regulation 10.1 as per **FORMAT-CONN-TD-4** based on the inputs provided by the connectivity grantee. The **FORMAT-CONN-TD-4** shall automatically become an integral part of already signed **FORMAT-CONN-CA-5**. Physical connection to ISTS shall be permitted only after issuance of **FORMAT-CONN-TD-4.**

iii. If the submitted Technical Data is final, CTU shall scrutinize the submitted data within thirty (30) days, and inform regarding discrepancies (if any). Upon rectification of all discrepancies by the entity, CTU within thirty (30) days shall intimate the connection details, inter alia, details of protection equipment, system recording, SCADA and communication equipment, under Regulation

10.1 as per **FORMAT-CONN-TD-4** based on the inputs provided by the connectivity grantee. The Connectivity Agreement as per **FORMAT-CONN-CA-5** shall be signed between the Nodal Agency and the entity which has been issued **FORMAT-CONN-TD-4** within thirty (30) days. In such case, physical connection to ISTS shall be permitted only after signing of **FORMAT-CONN-CA-5**.

iv. Subsequent to issuance of **FORMAT-CONN-TD-4**, if there is any change in technical data provided by the applicant, the revised technical data shall be submitted to CTU with full justification, following which CTU shall process the same for revision in **FORMAT-CONN-TD-4** within thirty (30) days after receipt of complete data. Such request shall be allowed only once at least three (3) months prior to physical connection to ISTS. However, upon physical interconnection with ISTS, revised technical data, if any, shall be provided to CTU for information and record.

FORMAT-CONN-TD-1

TECHNICAL CONNECTION DATA TO BE FURNISHED BY RE GENERATOR / BESS FOR SIGNING OF CONNECTIVITY AGREEMENT FOR INTERCONNECTION WITH THE INTER-STATE TRANSMISSION SYSTEM

A. Introduction

This document is designed to act as a guideline for exchange of technical connection data for the purpose of interconnection of the generation plant with ISTS alongwith exchange of accurate modelling data. Availability of accurate modelling data shall enable assessment of compliances of applicable regulations, adequacy of power system & assessment of equipment performance for secure and reliable interconnection with the ISTS Grid.

B. Regulation

CEA Technical Standards for Connectivity to Grid, 2007 and its amendments thereof: Clause 6.4d

"Provided that in order to carry out the said study, the requester shall present the mathematical model of the equipment in accordance with the requirements as stipulated by the Appropriate Transmission Utility or distribution licensee, as the case may be."

C. Compliance with existing rules and regulations

All applicants seeking connection to the grid shall comply with all the applicable regulations as enacted or amended thereof from time to time, including the following:

a) Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007;

b) Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010.

c) Central Electricity Authority (Measures Relating to Safety & Electric Supply) Regulations, 2010;

d) Central Electricity Regulatory Commission (Communication System for Inter State Transmission of Electricity) Regulations,2017;

e) Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006;

f) Central Electricity Regulatory Commission (Connectivity and General Network Access to the inter-State Transmission System) Regulations, 2022;

g) Central Electricity Regulatory Commission (Fees and Charges for Regional Load Despatch Centres) Regulations, 2019;

h) Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020;

i) Central Electricity Regulatory Commission (Furnishing of Technical Details by the Generating Companies) Regulations, 2009.

j) Central Electricity Authority (Cyber Security in Power Sector) Guidelines, 2021

k) Any other regulations and standards as specified from time to time

D. General considerations

i. RE generating station shall take due consideration of external variables including temperature extremes, wind, elevation, pollution, floods, lightning, earthquake and containments in the design and operation of the connected facilities. Considering all due factors, the proposed generator should be able to deliver active & reactive power at POI without any degradation.

ii. The applicant shall follow the industry best practices and applicable industry standards in respect of the equipment installation and its operation and maintenance

iii. **Point of Interconnection (POI)** may be defined as the point of interconnection of the RE generating station with the ISTS Grid as depicted in Figure-1. The POI would be the reference point for assessment of compliance to CEA standards(viz. data/studies/all performance capabilities, etc) and the generator pooling station & dedicated transmission line & system of the RE shall be considered as a part of the RE Generator.

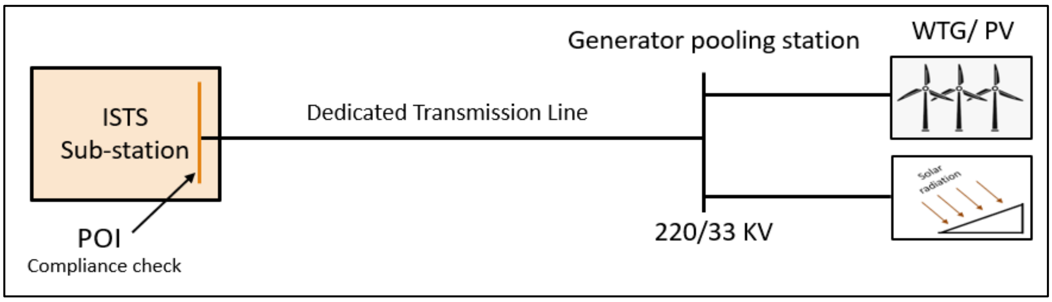


Figure-1: POI of RE Generating Station

iv. The Solar/ Wind power plant shall be required to demonstrate performance under steady-state and dynamic state at the Point of Interconnection and hence provisions shall be enabled for the PPC to take voltage and current of POI as a reference to Power Plant Controller for giving command to individual WTG/Inverter.

v. The RE developer should optimize the micro-siting of each WTG/PV Inverter during early design stage of power plant so that voltage, ampacity and other key electrical parameters of the plant remains within permissible operating limits during steady state operations (Voltage control mode, PF mode, Reactive Control Mode). It is expected that all the machines should remain in service during steady state conditions and should be capable of delivering the rated active and reactive power subject to availability of fuel source (Solar/Wind).

vi. Transformer tap changing is generally considered as a voltage regulation tool meant for controlling voltage variations that arise due to seasonal variations in the operational regime. Hence, during the planning stage, the system should be optimized in such a way that voltages are be kept within limits without the use of transformer tap changers [Ref. CEA Manual on Transmission Planning Criteria].

E. Reactive power response from wind power plant

As per CEA Technical Standards for Connectivity to Grid, the RE Generating station should have a capability of supplying dynamically varying reactive power at POI at least up to 0.95pf lag & lead operation. The voltage dependence of reactive power shall be as per the PQ and QV curve (*Figure-2*) depicted below:

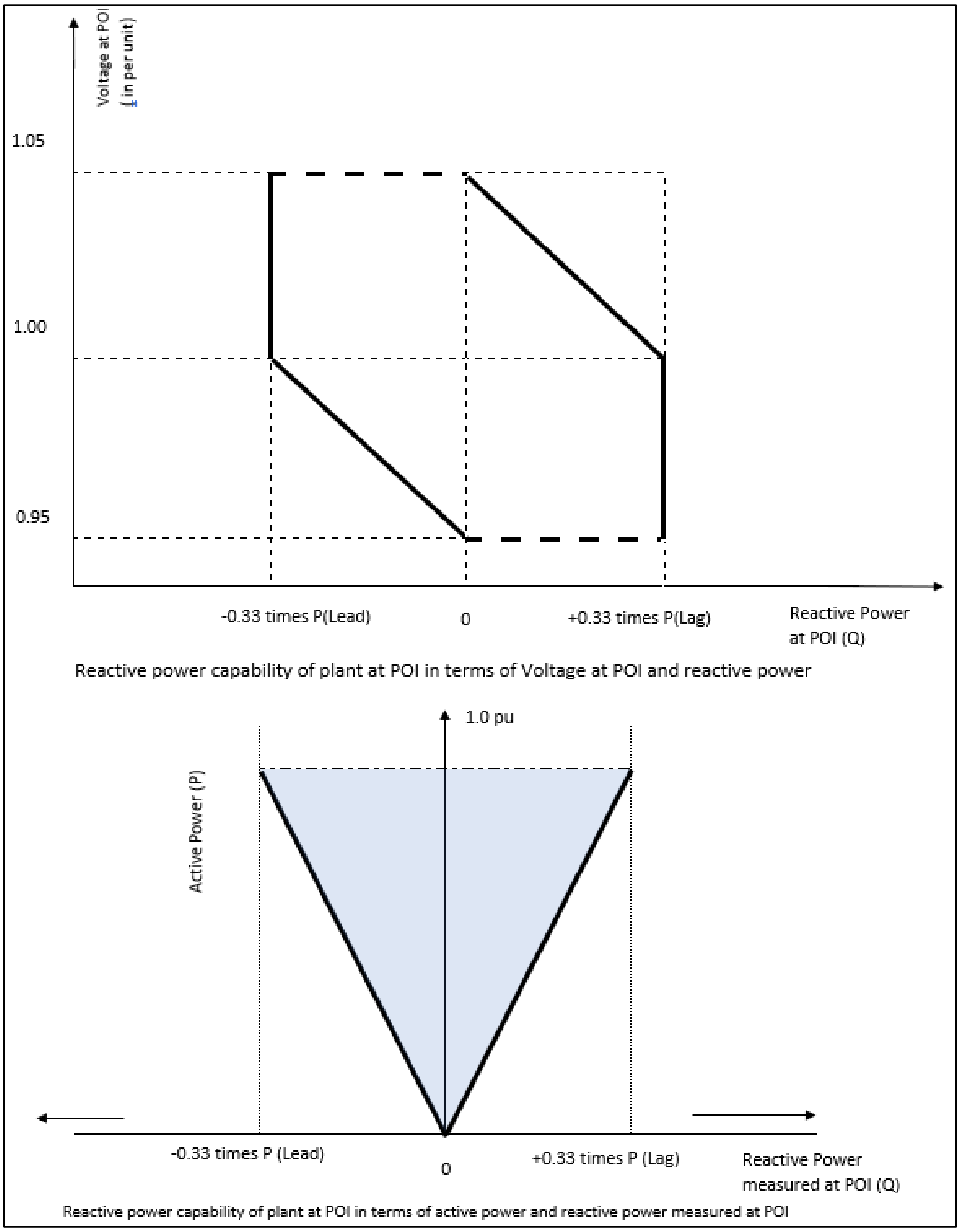


Figure-2: PQ and QV curve to be followed by RE Generators

For the purpose of qualifying dynamically varying reactive, the following shall be considered:

i. **Dynamically varying reactive power:**

The reactive power (or reactance) is considered to be dynamically variable in nature if the emulated reactance is variable in nature and is achieved through an automatic control mechanism having adequate response time [Ref. IEC TS 63042-101:2019]. Power apparatus like STATCOM & SVC emulate the dynamically varying reactance at the point of measurement. Whereas, power apparatus like mechanically switched capacitors & fixed capacitors are covered under the category of Static reactive compensation device considering long switching (mechanical) time and uncontrolled magnitude of reactance being provided, WTG (Type-III & IV) and PV Inverter (Type-IV) at its terminal generally give dynamically variable reactive power support almost instantaneously through its control mechanism. The RE Generators shall adopt appropriate measures for enabling such dynamic reactive response.

ii. **Formulation of Plant level model using the unit-level simulation model**

The plant-level Wind/Solar power plant model shall be constructed using the unit level WTG/PV model. The Unit level WTG/PV inverter model of OEM should be accurate enough so that the simulations results should closely match with the machine performance achieved during actual tests. In order to check the correctness, the benchmarking is done both for machine PSS/E and PSCAD models. The number of such WTGs shall be interconnected as per the design of the reticulation system. After constructing the plant level model, the steady-state studies shall be carried out in the first phase. The fully converged steady state case shall be used for performing the dynamic simulation. Typical flowchart to be followed for formulation of plant level simulation level is depicted in Figure-3.

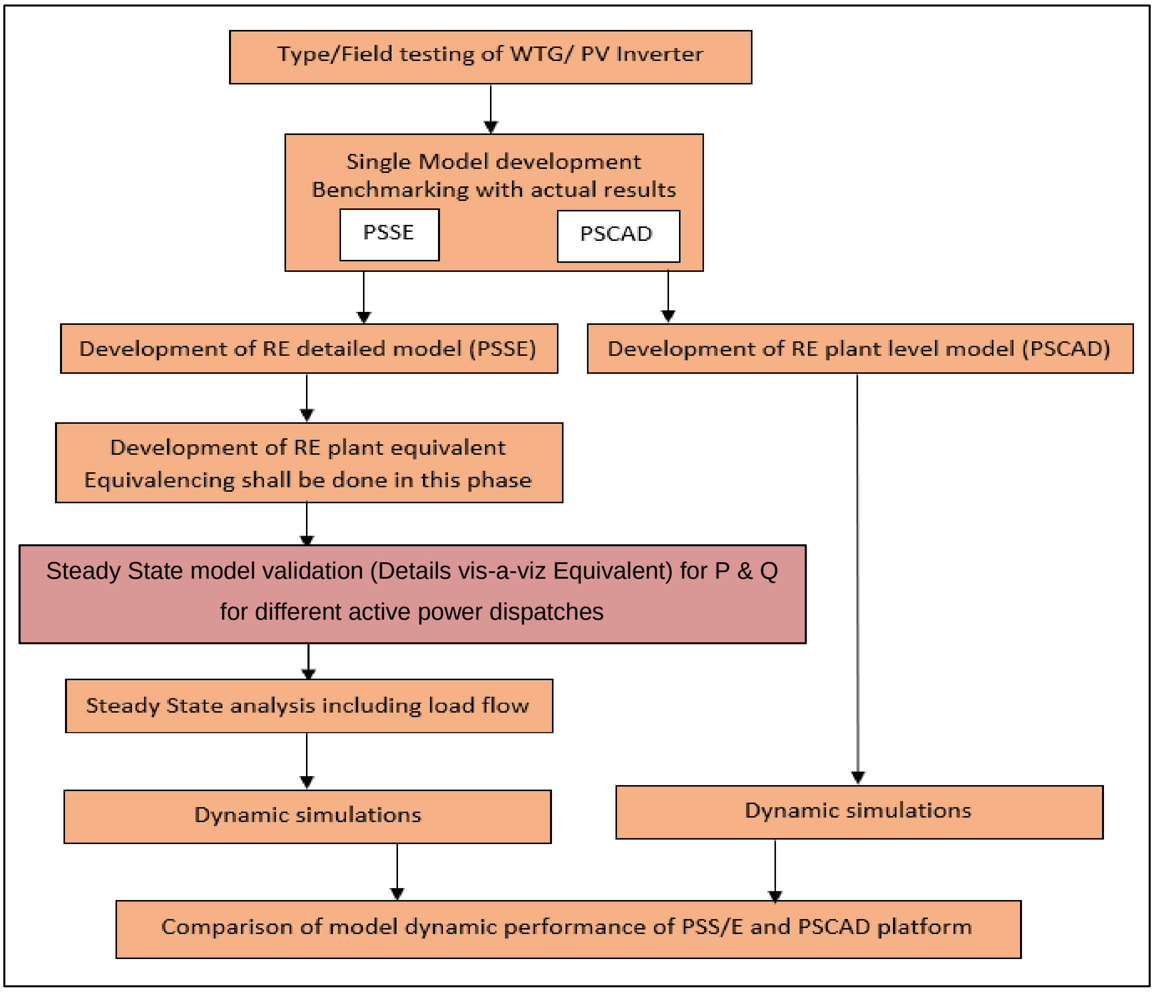


Figure-3: Flow chart depicting formulation of plant level simulation model

F. Solar Power Plant (SPP)

i. General Description:

In a typical Solar Power Plant, arrays of Solar PV panels are connected to an inverter (Power Conditioning System / Power Conversion Station – PCS) through DC cables. Inverters convert DC input from PV arrays into AC power, which is stepped up to form part of the MV reticulation system (typically at 33 kV or less) with the help of the Inverter Duty Transformer. A number of inverters are pooled and then stepped up to the voltage of 220 kV / 400 kV prior to connection to the EHV grid. A Power Plant controller (PPC) is usually installed at the generator pooling station and gives the higher-order reference of Active Power (P) and Reactive Power (Q) to individual inverters so as to meet the requirements at POI. PPC communicates with individual inverters through any mode of communication system. The PPC control behavior of solar power plant is to be enabled to act in accordance with grid codes.

The major components of a solar power project consist of the following elements (illustrated in the Figure-4):

1. Generator or Converter
2. Inverter Duty Transformer (IDT)
3. Power Transformer
4. Dedicated Transmission Line
5. Reticulation system
6. Reactive compensation device, if applicable

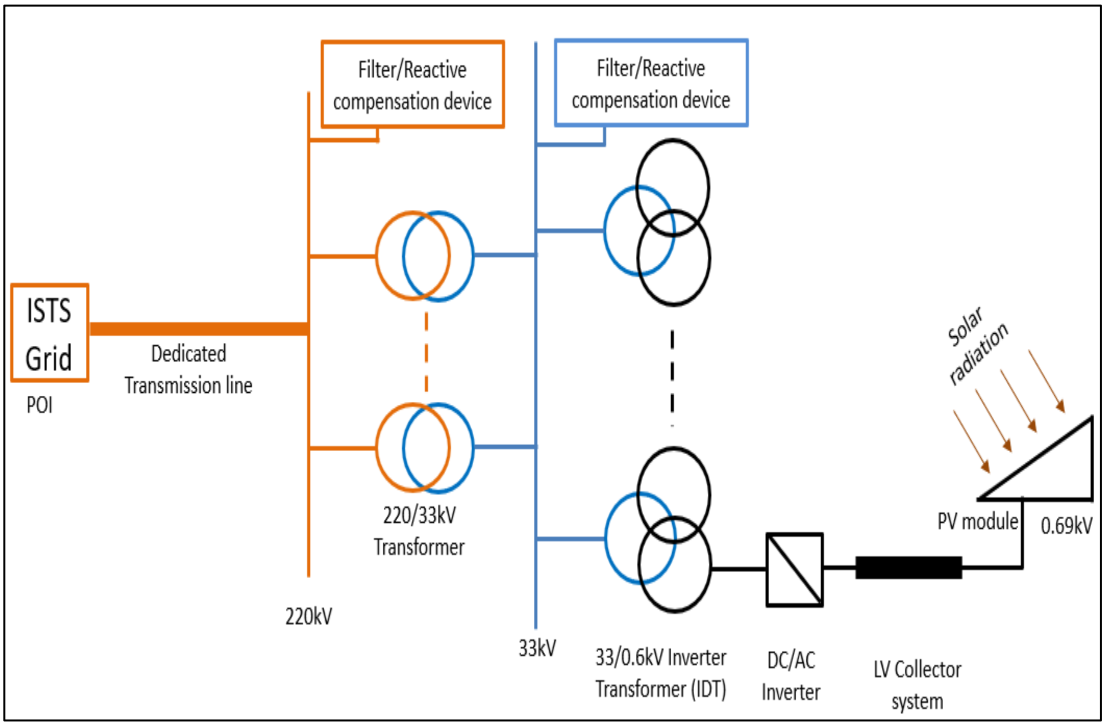


Figure-4: Typical layout of Solar Power Plant

Based on the technology used is respect to PV inverters, solar power plants can be classified broadly into two types:

a) Grid following: Grid following technology comprises of current source based generation wherein the generator (Solar) shall act as a current source and shall inject current at POI considering it as a reference. The generic grid following technology does not have the black start facility because it cannot emulate voltage reference from itself.

b) Grid forming: In grid forming technology, the generator (PV Inverter) acts as a voltage source and injects active power as a function of voltage deviation similar to STATCOM. They have black start capability and have a faster response time. Grid forming technology in the context of Renewable is the latest one and has more advantages as compared to current source-based technology.

c) Operating mode: Depending on the nature of technology and operation of PV inverter, the requirements for steady-state and dynamic modeling evolves. Solar power plants are generally equipped with Solid State converters having simultaneous fast de-coupled control on active as well as reactive power. Solar Power plants can work in any of the following operating modes:

1) **Voltage control mode:** Converters track the reference POI voltage and based on error function (deviation), they inject suitable reactive power so as to maintain the voltage within limits.

2) **Reactive Power (Q) Control:** Solar power plant operated under Q-control shall inject/absorb the fixed set point reactive power. In this control mode, priority is given to supply reactive power irrespective of active power (within apparent power limit).

3) **Power factor (PF) Control:** Solar power plants inject/absorb reactive power so as to maintain the requisite power factor at POI. In the PF mode, the PV inverter shall be operated at set point on the PF locus.

ii. **Response of Solar RE Generators during fault/under voltage conditions**

The solar generators are essentially fully controllable machines wherein the active and reactive power control at terminals are completely de-coupled. Therefore, the machine behavior is completely characterized at transformer terminals by its controls. Typically, Type-IV Solar PV Inverter contributes within 1.1pu - 1.2pu current limits during balanced and un-balanced fault cases. The ratings of protection and switchgear, in this case, shall be governed considering 1.1pu - 1.2pu current level. The equivalent short circuit phase domain analysis can be done considering sub-transient reactance (X_d"~0.8-0.9) corresponding to 1.1pu -1.2pu current level [*Ref:* ***Modification of Commercial Fault Calculation programs for Wind Turbine Generator*** *- A Report prepared by the IEEE Power System and Control Committee, WG C24 IEEE Power and Energy Society, 2020*]. The complete response of Type-IV machines can be realized using Voltage-Current characteristics and current-time characteristics.

iii. **Modelling of Solar Power Plant:**

Solar power plant for the purpose of Connection details, shall be modeled using the built-in generic models available with PSS/E software. No part of the model should contain the special model/setting. The list of generic models used for modeling a complete Solar power plant are given hereunder. The changes which need to be made for different simulation studies for the simulation model shall be indicated to represent close to the actual behavior of the SPP in different scenarios/conditions. A typical interaction of different components is given in Figure-5.

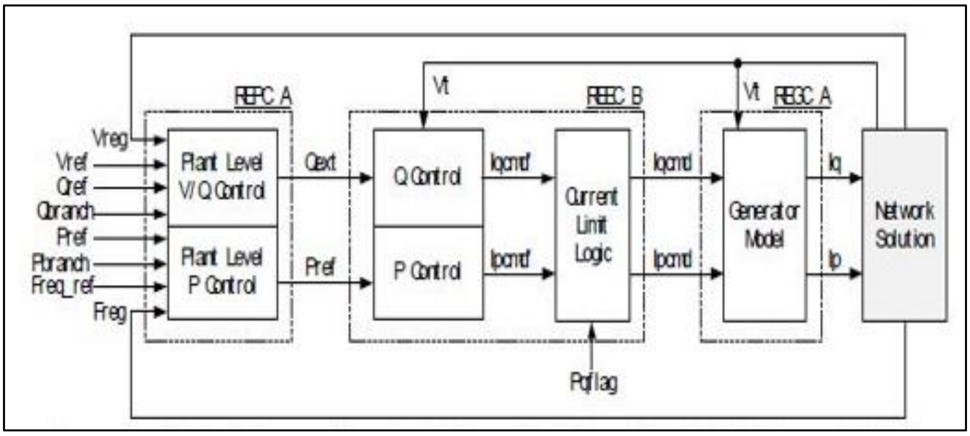


Figure-5: Interaction of different models within Solar Power Plant

Generic models in PSS/E for Solar Power Plant:

The mathematical simulation models of PSS/E generic models to be used for demonstrating RE plant (Solar) behavior are given in Table-1. The changes (parameter setting/ICONs) which need to be made for different simulation studies for the simulation models shall be indicated.

Table-1: PSS/E Generic models in respect of Solar Power Plants

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)

The block diagrams for the above simulation models are given in Appendix-A. The above list is indicative in nature and is not exhaustive. Applicants can also submit the plant model using other PSS/E based generic models updated from time to time.

G. Wind Power Plant (WPP):

i. General Description:

A typical Wind Power Plant has a Wind Turbine Generator (WTG) as a source of electrical power. The power generation is usually carried out at 0.69kV (nearly) level which is further stepped up to 33kV level with the help of pad mounted 0.69/33kV transformer. Usually pad mounted transformers are housed within Wind turbine structures. Number of such WTGs are connected in a daisy chain / other topologies based on the geography of such area. Common 33kV lines are pooled at a common generator pooling station wherein voltage level is steeped up to 220 or 400kV level using 33/220kV transformer. Power Plant Controller (PPC) is usually installed at Generator Pooling Station and is connected to each

WTG using appropriate communication medium. Since the compliances are to be met at POI, PPC takes reference of voltage/current of the POI. WTGs considering the POI reference, dispatch their Active and Reactive current during steady state conditions as per the set control mode. Typical configuration of a WPP is shown in Figure-6.

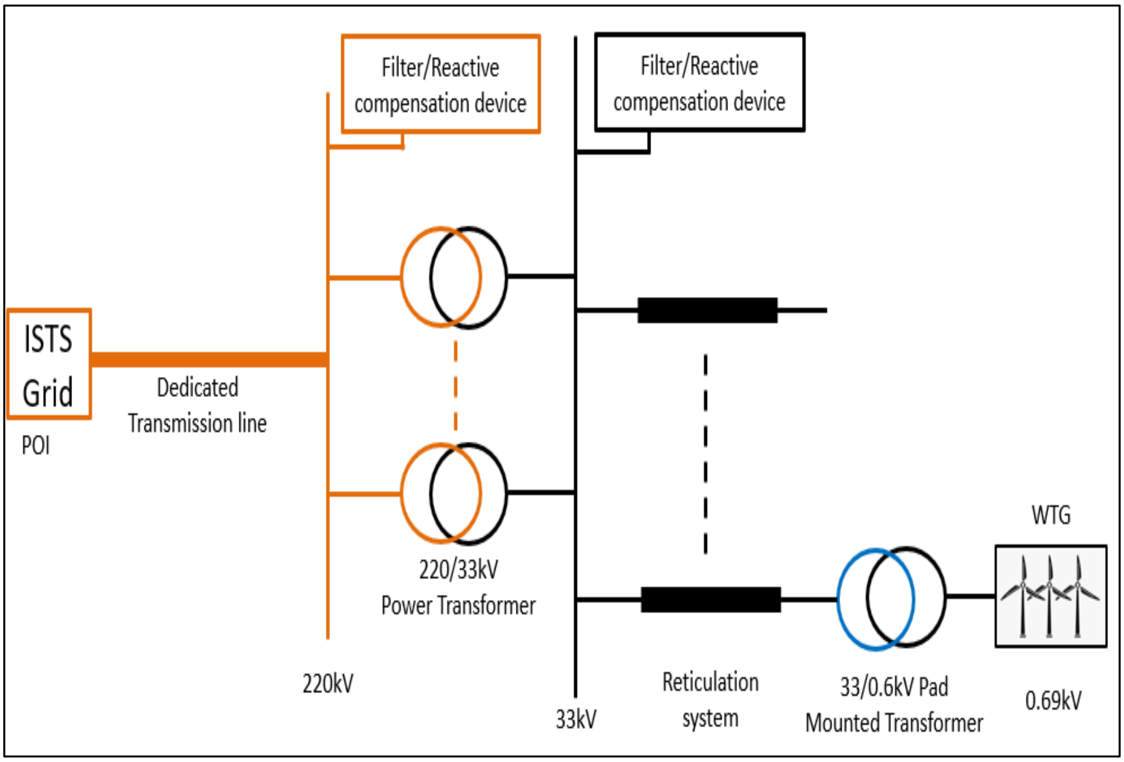


Figure-6: Typical layout of Wind Power Plant

All of the above components may or may not be present, as the same depends upon the nature of the technology used for wind power generation (i.e. type of turbine). Depending on the nature of technology, usage/configuration of components at the site, the requirements for steady-state and dynamic modeling is evolved.

ii. **Models for Wind generators:**

The typical wind farm consists of the following elements:

1. Generator or Converter

2. Electrical control

3. Drive-Train model

4. Aerodynamics

5. Pitch controller

6. Torque controller

7. Power Plant Controller (PPC)

Interaction of various function blocks within a Wind power plant is given in Figure-7.

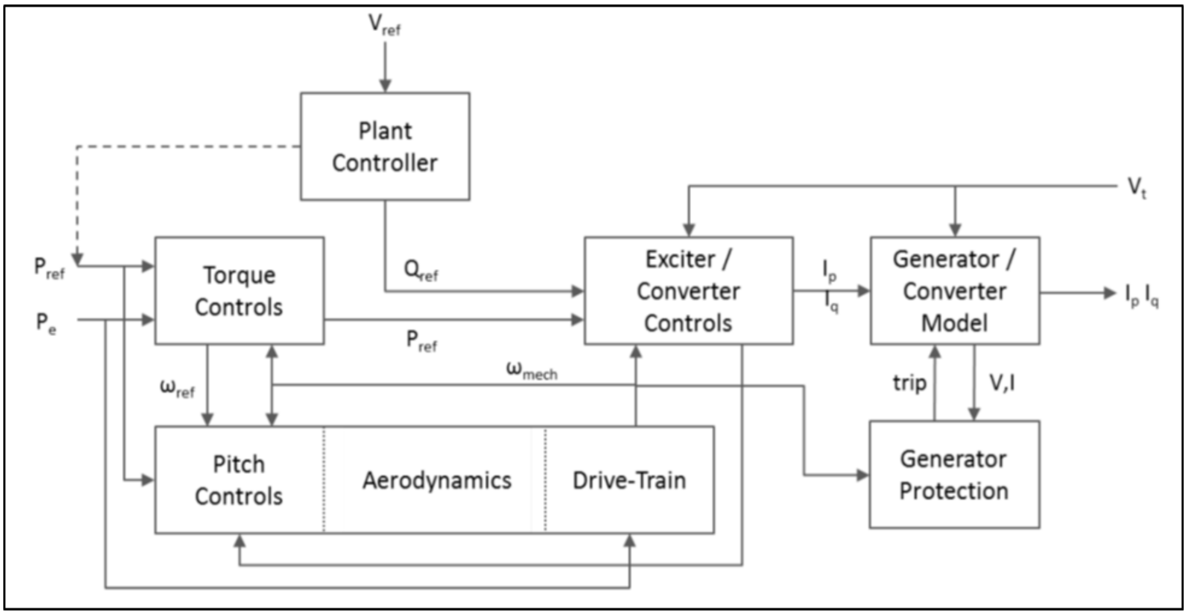


Figure-7: Typical interaction among various models within Wind power plant

1. Types of WTGs based on construction:

Type-I WTG: Type I WTG is a form of squirrel cage induction generator whose rotor is solidly die casted. The rotor reactance is fixed due to its construction. Type-I machines draw reactive power for their operation and capacitor banks are generally installed to compensate the losses. Configuration of Type-I WTG is shown in Figure-8.

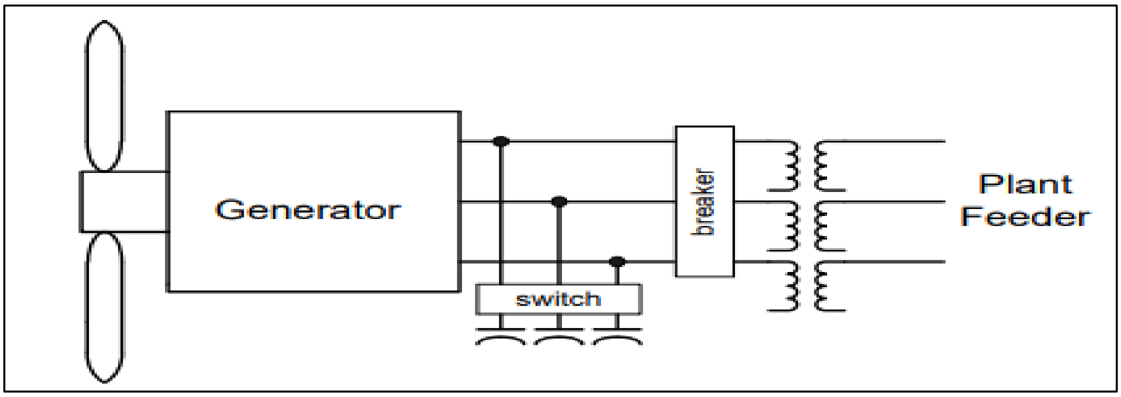


Figure-8: Type-I WTG configuration

Type-II WTG: Type II WTG is a wound rotor induction generator whose rotor reactance can be varied and hence has better slip characteristics than Type-I WTG. Type-II machines are also generally equipped with capacitor bank to improve power factor of the machine. Configuration of Type-II WTG is shown in Figure-9.

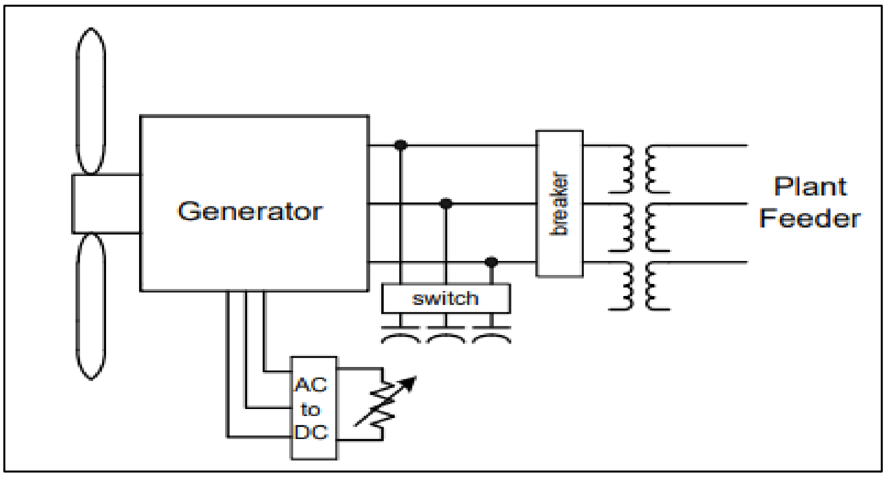


Figure-9: Type-II WTG configuration

Type-III WTG: In Type-III WTG, the rotor is coupled through AC-DC-AC solid state converter. By use of converters in rotor circuit, nearly 30% power control can be achieved. Type-III machines are technically more superior considering steady state and dynamic state performance. Configuration of Type-III WTG is shown in Figure-10.

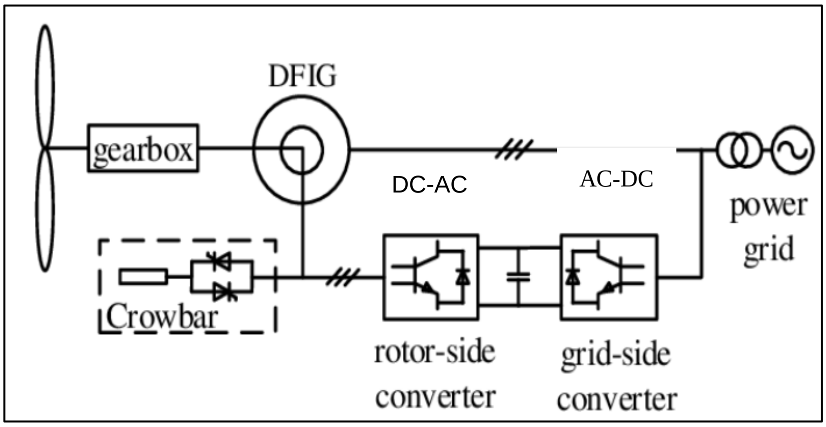


Figure-10: Type-III WTG Configuration

Type-IV WTG: Type IV WTG is a fully controllable machine where the machine mechanical performance is completely de-coupled from the terminal viewpoint. The Stator output is converted to DC using AC-DC converter which is further converted to AC using DC-AC inverter. Type-IV machine is more superior in terms of operability as compared to Type-III machines. Configuration of Type-IV WTG is shown in Figure-11.

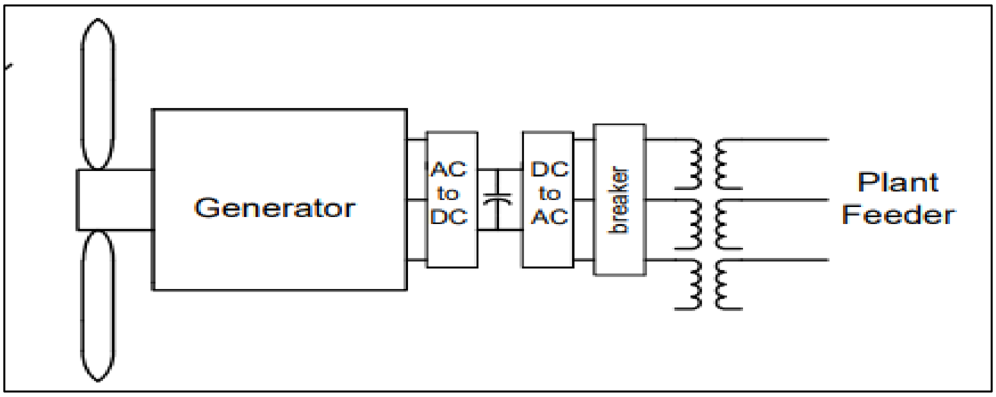


Figure-11: Type-IV WTG Configuration

2. Short circuit characteristics of Wind Turbine Generators and Wind Farms

Presently, WTG of type-III & IV configuration are mostly used due to the improved performance as compared to earlier Type I & II machines. Type-III WTGs are having converter control on its rotor side thus enabling de-coupled control over active and reactive power with adequate response time. The rating of both rotor side and grid side converter is limited to nearly 30% of machine apparent power. During fault conditions, higher magnitude stator currents shall be observed at its terminals alongwith higher rotor currents. In order to protect converters from high rotor currents and thus high voltage in DC link, OEMs generally provide a "Crowbar" in the rotor circuit. The crowbar can be kept in service during fault period or as specified by OEM and converters are electrically bypassed. Alternatively, or in conjunction with Crowbar, a DC chopper can also be employed to maintain DC link voltage within the permissible range.

The operation of a crowbar essentially converts Type-III machine i.e Doubly Fed Induction Generator to work as Type-I/II machine i.e induction generator and high fault currents can be realized at terminals. Further, due to the presence of converters, the effect of machine dynamics cannot be fully realized by phase domain short circuit tools. Therefore, the terms like Time Constants & Reactance (Transient, Sub-transient) shall not remain valid due to the presence of converter control instead of flux controls in conventional machines.

The planning of ratings of switchgear and protection philosophy are based on the peak current requirements of the system. For the purpose of calculating the fault current, peak values at the machine terminal, the response of the machine during crowbar in service can be considered. The typical value of sub-transient reactance of **0.2pu (X_d'')** can be considered in the short circuit performance with phase domain short circuit tools [**Ref: "Fault Current Contributions from Wind Plants"** A report prepared by the Joint Working Group of the **IEEE Power and Energy Society**, 2015].

Generally, Type-III machines contribute 1.1-1.2pu current during fault conditions with crowbar bypass conditions. During such conditions, the active and reactive power response is governed as per control structures and operating regimes. During LVRT conditions, the reactive power injection at the fault point is given priority in order to help the system in maintaining voltage and hence stability. For giving priority to deliver of reactive power, active power needs to be compromised within the apparent power limits of the WTG. Considering the above, the response of WTG (Type-III &IV) during fault conditions is described by **Voltage-Current characteristics** and **current-time characteristics**. Generally, the factor (K) determining the contribution of reactive current during low voltage or fault conditions is a function of voltage deviation and as a result, WTGs deliver more reactive current during severe voltage dips.

The Type-IV machines (WTGs) are fully controllable machines wherein the active and reactive power at terminals are completely de-coupled with respect to stator and rotor dynamics. Therefore, the machines characteristics are completely characterized at transformer terminals by its controls. Typically, Type-IV WTGs contribute within 1.1-1.2 pu current limits during balance and un-balanced cases. The ratings of protection and switchgear, in this case, shall be governed considering 1.1-1.2pu current level. The equivalent short circuit phase domain analysis can be done considering sub-transient reactance corresponding to 1.1pu -1.2pu current level. The complete response of Type-IV machines can be realized using Voltage-Current characteristics and current-time characteristics. Typical Voltage-Current characteristics and current-time characteristics are shown in Figure-12.

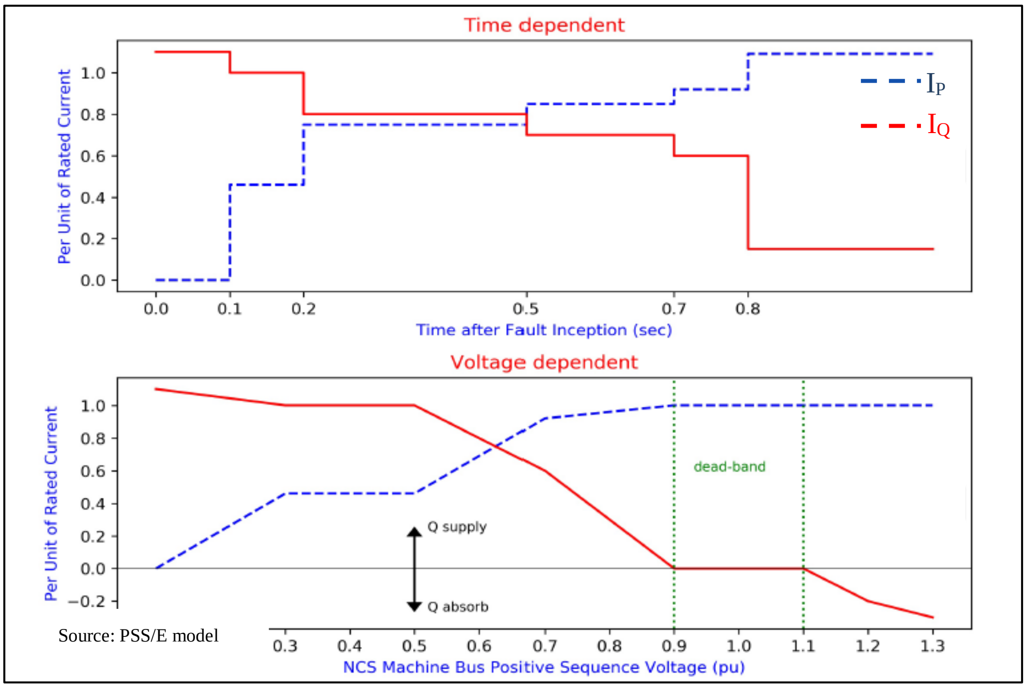


Figure-12: Typical Fault characteristics of WTG

3. Generic Models of WTGs / Wind farms

Wind power plant for the purpose of Connection details, shall be modeled using the built-in generic models available with PSS/E software. No part of the model should contain any special model/setting. The list of generic models used for modelling a complete Wind power plant is given hereunder. The changes (parameter setting/ICONs) which need to be made for different simulation studies for the simulation models shall be indicated.

The block diagrams for above simulation models are given in Appendix-1. The above list is indicative in nature. Applicant can also submit the plant model using other PSS/E based generic models updated from time to time.

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	REGCA1	Renewable energy generator converter model
		REECA1	Renewable energy controls model
		WTDTA1	Drive train model
		WTARA1	Wind turbine aerodynamic model

Wind Turbine type	Technology	Generic model	Model Description
	side converter	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)

Technical Connection Data and compliance Report submission by RE Generators / Battery Energy Storage System

A General Details:

1.	Name of the Applicant Company	:	
2.	URN No	:	
3.	Details of Grant of Connectivity (a) Connectivity Intimation No. (b) Date	:	
4.	Quantum of Connectivity Granted (MW) (Maximum injection & Maximum drawal to be indicated for BESS)	:	
5.	Location of Generation Plant Latitude Longitude	:	(Applicant shall attach Survey of India Toposheet indicating RE Station/ BESS alongwith DTL)
6.	Installed capacity of Generating station (MW) (For BESS, capacity in MWh indicating number of injection hours corresponding to quantum at Sl. No. 3)	:	
7.	Fuel Source (Solar/Wind/Hybrids/ other RE Technologies)/BESS	:	
8.	Address for Correspondence	:	

9.	Contact Person		
	9.1 Primary Contact Person (a) Name (b) Designation (c) Phone No. (d) E-mail	:	
	9.2 Alternate Contact Person (a) Name (b) Designation (c) Phone No. (d) E-mail	:	
10.	Expected Date of Commercial Operation	:	

B Technical Connection data (to be filled by applicant):

1. Wind turbine generator details

Parameter Description		Data
WTG Model Name	:	
Type of Generator	:	Type-I, II, III, IV
Terminal Voltage (kV)	:	
Turbine- Rated MVA	:	
Turbine – Rated active power (P_{MAX}) in MW	:	
Converter technology (Grid following/ Grid forming)	:	
Total number of WTGs	:	
Power Factor – Options	:	
MAX/ MIN reactive power capability (KVAR) at temperature extreme	:	
Minimum SCR of WTG	:	

Note: *Applicant shall attach GTP/ Technical documentation of each type of generator*

2. PV Inverter details

Parameter Description		Data
Inverter rating (kVA/MVA)	:	
DC/AC ratio	:	
Terminal Voltage (kV)	:	
Total number of PV Inverters	:	
Technology type (Grid following/ Grid forming)	:	
Power Factor – Options	:	
MAX/ MIN reactive power capability (KVAR) at temperature extreme	:	
Minimum SCR rating of PV Inverter	:	

Note: *Applicant shall attach GTP/ Technical documentation of each type of PV inverter*

3. Power Transformer (Generation Pooling station)

Parameter Description		Data
Transformer Rating (MVA)	:	MVA
Voltage rating (kV)	:	
Number of Power Transformers	:	
Cooling Type	:	
Transformer rating with different cooling	:	
Transformer vector Group	:	
Tap changer (ON/OFF Load Tap changer)	:	
% Resistance at 75ºC with normal tap	:	
% Reactance at 75ºC with normal tap	:	
% Impedance at 75° C with normal tap	:	
Positive sequence resistance between HV/LV in pu	:	
Positive sequence reactance between HV/LV in pu	:	
Zero sequence resistance between HV/LV in pu	:	
Zero sequence reactance between HV/LV in pu	:	
Neutral earthing (solid or through reactance)	:	

Note: *Applicant shall attach the GTP of Power Transformer*

4. Pad mounted WTG/Inverter Duty Transformer

Parameter Description		Data
Transformer Rating (MVA)	:	MVA
Voltage rating	:	
Number of Transformers	:	
Cooling Type	:	
Voltage Ratio	:	
Transformer Vector Group	:	
Tap changer (ON/OFF Load Tap changer)	:	
%Resistance at 75ºC	:	
% Reactance at 75ºC	:	
Neutral earthing (solid or through reactance)	:	
Positive sequence reactance in pu	:	
Positive sequence resistance(pu)		
Zero sequence reactance(pu)		
Zero sequence resistance(pu)	:	

Note: *Applicant shall attach GTP of WTG/Inverter Duty Transformer*

5. DTL details

Parameter Description		Data		
Name of Sending End S/s	:			
Name of Receiving End S/s (ISTS end)	:			
Voltage level (kV)	:			
Length of DTL (Kms)	:			
Tower Configuration (S/c, D/c, M/c)	:			
Type of Conductor	:			
OPGW available (Yes/No)	:			
No. of Fibre in OPGW (24/48F)	:			
OPGW/Line Shared with another GenCo or another plant of same owner	:			
	R (pu)		**X (pu)**	**B (pu)**
Conductor positive sequence R X B parameters in pu/km/ckt (considering 100MVA base)				
DTL positive sequence R X B parameters in pu/km/ckt (considering 100MVA base)				
DTL zero sequence R X B parameters in pu/km/ckt (considering 100MVA base)				

Note: *Applicant shall submit the details of DTL as per* ***Annexure-A***

6. Reticulation system details

Parameter Description		Data		
Voltage level (kV)	:			
Length of Reticulation System(Kms)	:			
Tower/Pole Configuration (S/c, D/C, M/c) or Cable (type/sq.mm/core)	:			
Type of Conductor (ACSR/ AAAC/ HTLS/ etc.,)	:			
Conductor Configuration (Single/ Twin/ Triple, Quad, etc.,)	:			
Ampacity of Conductor (in Amps) at ambient temp:--- ^{0}C and Temperature Rise: -----^{0}C)	:			
		R (pu)	**X (pu)**	**B (pu)**
Conductor R X B parameters in pu/km/ckt (considering 100MVA base)	:			
Reticulation system R X B parameters in pu/km/ckt (considering 100MVA base)	:			
Equivalent reticulation system R X B parameters in pu/km/ckt (considering 100MVA base)	:			

7. Generator Pooling Station

Parameter Description		Data
Name of Substation	:	
Substation type (AIS/ GIS/Hybrid)	:	
Voltage level	:	
Design Fault level of substation (---kA for ---sec)	:	
Transformation Capacity (MVA)	:	
Bus Switching Scheme	:	
Switchyard Configuration (I/D type etc.)	:	
Bus Capacity (Main / Transfer) (in Amps)	:	
Basic System Parameter	:	Applicant shall attach basic system parameters details as per Annexure-B

8. Battery Energy Storage System (BESS)

Parameter Description		Data
Rated power output(MW)	:	
Storage Capacity of BESS (MWh)	:	
Type of Battery (Li-ion, Lead-acid, etc)	:	
Max Power Rating (MW)	:	
Discharge time (Hrs)	:	
Depth of Discharge (DoD)(%) permissible	:	
Efficiency (%)	:	
Inverter technology (Grid following/forming)	:	
Inverter Rated output Voltage(AC)		
Rating of one battery cell (Voltage & Amp-Hour) & No. of Units	:	
Maximum number of cycles in BESS life span (One cycle is construed as a complete charging and discharging of the BESS keeping in view the specified DoD)	:	
Total Harmonic Distortion(THD)	:	
Temperature Range	:	

9. PSS/E Single Line Diagram (Single Machine Infinite Bus Model)

Note: *Applicant shall attach herewith equivalent PSS/E based SLD of generation plant wherein grouping of each type of machine shall be done. For machine with* *different rating equivalencing shall be done separately*.

10. Model Validation (Steady State):

Note: *Applicant shall validate the performance of plant level equivalent and detailed PSS/E model using the comparison of steady state Active power and reactive power with the help of following table*:

Active Power (pu) dispatch	**Active Power (MW) at POI**		**Reactive Power (MVAR) at POI**	
	Detailed model	**Equivalent model**	**Detailed model**	**Equivalent model**
1.0pu (Q=0)				
1.0pu (Q=max)				
0.75pu (Q=0)				
0.75pu (Q=max)				
0.5pu (Q=0)				
0.5pu (Q=max)				
0.25pu (Q=0)				
0.25pu (Q=max)				

Note: *After validation, the equivalent model shall be used for conducting all tests as stipulated in CEA Technical Standards for Connectivity to Grid*

11. Fault Characteristics

Note: *Applicant shall submit the short-circuit characteristics of each WTG/PV type as per the following table alongwith curve:*

Voltage dependent characteristics:

Voltage (pu)	Active power (pu)	Reactive power (pu)	Active Current (pu) (I_p)	Reactive Current (pu) (I_q)
1.0				
0.9				
0.8				
0.7				
0.6				
0.5				
0.4				
0.3				
0.2				
0.1				

Time dependent characteristics	
Current (pu)	**Time (sec)**
1.2	
1.1	
1.0	
0.9	
0.8	
0.7	
0.6	
0.5	
0.4	
0.3	
0.2	
0.1	

Note: *The applicant can add the upper limit of machine as per its design above 1.2 pu current.*

12. Type-III DFIG Machine parameters

DFIG Machine parameters		
Number of poles	no.	
Stator winding resistance (R_s)	pu	
Stator leakage inductance (L_{ls})	pu	
Magnetizing inductance (L_{md})	pu	
Magnetizing inductance (L_{mq})	pu	
Rotor resistance (R_r)	pu	
Rotor leakage inductance (L_{lr})	pu	
Inertia Constant (H_{gen})	s	

Wind park controller	
V-Control (K_v)	
Q-Control (K_p)	
Q-Control (K_i)	

Rotor side converter control		
Fault current limit	pu	
Fault d-axis current limit	pu	
Fault q-axis current limit	pu	
FRT voltage deviation	pu	

Grid side converter control		
Fault current limit	pu	
Fault d-axis current limit	pu	
Fault q-axis current limit	pu	

13. Data and voice communication

Parameter Description		Data
Type Data Gateway (Remote Terminal Unit/ Substation Automation System Gateway)	:	(Whether RTU/ Substation Automation System Gateway; and Number of data ports)
Data Communication connectivity Standard followed (As per interface requirement and other guideline made available by the respective RLDC)	:	(Type of Communication Protocol, i.e. 104(Ethernet), etc.)
Write here the communication media, interface and capacity being targeted for Connectivity for Data and voice Communication	:	(Communication media: For example, fibre optics, PLCC, etc. Interface : Ethernet, G.703 etc. Capacity : 1200 baud, 64 Kbps, 2MBPS, etc.)

C Applicant has attached a copy of the affidavit towards the fulfillment of terms and conditions as specified in the CEA (Technical Standards for Connectivity to the

Grid) Regulations, 2007 and its amendments thereof as per Annexure-C alongwith OEM undertaking as per **Annexure-D**

D Dynamic simulation data: Applicant has attached the dynamic simulation data of each component used in PSS/E as per **Annexure-E.**

E Applicant has submitted the details of terminal bay equipment under its scope as per **Annexure-F**.

F Applicant has submitted the simulation studies for compliance of CEA Technical Standards for Connectivity to Grid, 2007 and its amendments thereof, as per list of studies mentioned in **Annexure-G.**

G Applicant has further attached the following drawings (soft copy) alongwith application:

1) Site plan in appropriate scale indicating Generators, Transformer, Site building (pdf & autocad copy)

2) Site plan of the ISTS substation at which connectivity granted (pdf and/or autocad copy)

3) General Arrangement (GA) drawing indicating proposed facility

4) Electrical Single Line Diagram (SLD) of the proposed facility detailing all significant items of plant (pdf & autocad copy)

5) Electrical Single Line Diagram (SLD) of ISTS substation at which connectivity granted (pdf & autocad copy)

6) Sub-Station Automation System (SAS) ring diagram indicating interconnections of various IEDs/Engg PC/Gateway etc.

7) Equipment drawings for confirming the ratings

8) CRP (Control & Relay Panel) & scheme drawings containing protection details of the transmission line

9) PLCC/FOTE drawings for the transmission lines under the scheme

10) Details of Communication System

11) Detailed calculation sheet for deriving the maximum ampacity of the conductor as per IEEE-738 Standards, Central Electricity Authority (Technical Standards for Connectivity to Grid), Regulations 2007 and its amendments thereof, Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 & CEA Transmission Planning Criteria, 2013 as amended.

H Applicant has undertaken studies including voltage stability, protection co-ordination, machine dynamics, resonance, sub-station grounding and fault duties of equipment to be installed at Generating Station (as the case may be) so that the overall system performance is not constrained during steady state and contingency conditions. The sub-station grounding design should be such that the earth fault factor of the system should remain below 1.4. Sub-station grounding should be in line with provisions of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010.

Resonance including ferro-resonance studies has been carried out by applicant covering possible network topologies for excitation of series/parallel resonant point by network impedance scanning and they shall implement the remedial measure at their end in this context.

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

Authorized Signatory of Applicant

Name:

Designation:

Seal:

Place:

Date:

Annexure-A

Data Pertaining to Dedicated Transmission Line

A.	**Conductor**	
i.	Name of conductor	
ii.	Outside diameter	
iii.	DC Resistance (ohm/km)	
iv.	Number of conductors in bundle	
v.	Bundle spacing (mm)	
vi.	Maximum operating Temperature (degree C)	
vii.	Ampacity at maximum operating Temperature (A) with calculation sheet as per IEEE 738 & CEA Technical standard/CEA Planning criteria)	
B.	**Earth Wire**	
i.	Diameter of Earthwire	
ii.	DC Resistance (ohm/km)	
C.	**OPGW**	
(i)	OPGW diameter (mm)	
(ii)	OPGW cross-section area (mm^2)	
(iii)	Number of Strands	
(iv)	Diameter of each strands	

(v)	DC Resistance (Ohms/km)	
(vi)	Short Circuit Current (kA)	
(vii)	OPGW Sag - Tension chart	
(viii)	Fiber type considered in OPGW	
(ix)	No. of fibers available for use	
(x)	Fiber loss (dB) Attenuation Chromatic Dispersion	
(xi)	FODP terminations capacity	
D.	**Communication Equipment**	
(i)	Transmission Equipment (SDH) capacity (STM4/16)	
(ii)	Optical Directions supported	
(iii)	Make and model of Transmission Equipment	
(iv)	Ethernet card/ ports details and availability for use	

Annexure-B

Basic System Details

Sl. No.	Description	Values
1	System operating voltage	
2	Maximum voltage of the system (rms)	
3	Rated frequency	
4	Nos. of phases	
5	Rated insulation levels	
i)	Impulse withstand voltage for (1.25/50micro second) - Transformer and Reactors - For other equipment - For insulator string	
ii)	Switching impulse withstand voltage (250/2500 micro second) dry and wet	
iii)	One-minute power frequency dry withstand voltage (rms)	
iv)	One-minute power frequency dry and wet withstand voltage (rms)	
6.	Corona extinction voltage	
7.	Max. radio interference voltage for frequency between 0.5MHz and 2MHz	
8.	Minimum creepage distance for insulator string/longrod insulators/ outdoor bushings	
9.	Minimum creepage distance for switchyard equipment	
10.	Max. fault current capacity (kA for …sec)	

Annexure-C

Affidavit to be submitted by the grantee (on non-judicial Stamp Paper of Rs. 10/-) towards fulfilment of various compliances as specified in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof (to be provided by company authorized signatory duly authorized vide board resolution)

Date: ………………….

Connectivity Application No. & Date: ……………

I…………..(Name)………S/o Shri …………..(Father's name) working as ………………….. (designation) in ……………… (Name of the Applicant organization / entity) ……..….., having its registered office at …………… (Address of the Applicant organization / entity) …………, do solemnly affirm that ..…..…… (name of generating station along with Installed capacity & location of connectivity granted by CTU) complies with the following conditions as laid out in the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof and CERC (Connectivity and General Network Access to Inter State Transmission System) Regulations, 2022 and directions through various orders including the following:

1. Harmonic current injections from the generating station does not exceed the limits specified in Institute of Electrical and Electronics Engineers (IEEE) Standard 519.

2. The Generating station does not inject DC current greater than 0.5 % of the full rated output at the interconnection point

3. The generating station does not introduce flicker beyond the limits specified in IEC 61000.

4. The Items 1, 2 and 3 shall be tested with calibrated meters once a year and indicative month for the same is ……….

5. The generating station is capable of supplying dynamically varying reactive

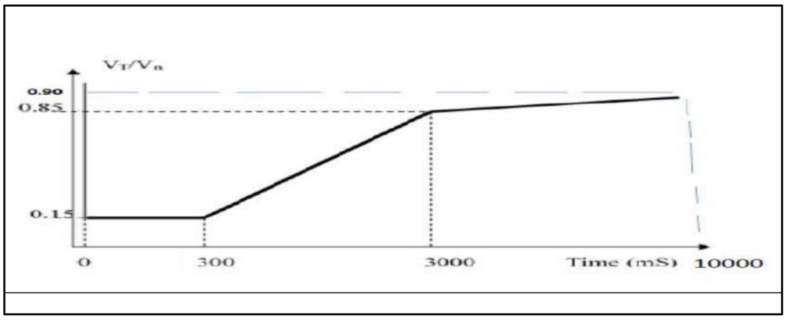
power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading.

6. The generating unit is capable of operating in the frequency range 47.5 to 52Hz and is able to deliver rated output in the frequency range of 49.5Hz to 50.5Hz.

   Further, in the frequency range below 49.90 Hz and above 50.05 Hz, or, as prescribed by the Central Commission, from time to time, it is possible to activate the control system to regulate the output of the generating unit as per frequency response requirement as provided in sub-clause (4) of clause B2 of the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended.

   The generating unit is able to maintain its performance contained in this subclause even with voltage variation of up to ± 5% subject to availability of commensurate wind speed in case of wind generating stations and solar insolation in case of solar generating stations.

7. The generating station shall remain connected to the grid when voltage at the interconnection point on any or all phases dips up to the level depicted by the thick lines in the curve at Annexure-I. During the voltage dip, the supply of reactive power has first priority, while the supply of active power has second priority and the active power shall preferably be maintained during voltage drops, provided, a reduction in active power within the plant’s design specifications is acceptable and active power be restored to at least 90% of the pre-fault level within 1 sec of restoration of voltage.



8. The generating station shall remain connected to the grid when voltage at the interconnection point, on any or all phases (symmetrical or asymmetrical

overvoltage conditions) rises above the specified

Over voltage (pu)	Minimum time to remain connected (Seconds)
1.30 < V	0 Sec (Instantaneous trip)
1.30 ≥ V > 1.20	0.2 Sec
1.20 ≥ V > 1.10	2 Sec
V ≤ 1.10	Continuous

The generating station shall be equipped with facilities to control active power injection in accordance with a set point, frequency controller, rate of change of power output etc in accordance with sub-clause 4 of clause B2 of the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended.

I am submitting the test reports along-with compliance certificate for all applicable provisions under the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 (and its amendments thereof) including each of the above requirements from labs accredited by Govt./NABL/other recognized agencies along with detailed modelling data for RE generation units as available on CTU website. I am aware that in case any discrepancies / incompleteness are found in the documents / test reports submitted to CTU, the connection details (CON-5) / Connectivity agreement (CON-6) shall not be processed further. I am also aware that if at any stage any falsity / inaccuracy / incorrectness is detected in the documents / statements …….. (name of generator) shall be solely liable for disconnection from the Grid along with all associated liabilities / consequences in this regard.

Name of the Authorised Signatory:

Signature:

Company Stamp (mandatory):

Annexure-D

Compliance Certificate to be submitted by the Inverter / WTG / other control equipment manufacturer towards fulfilment of terms and conditions as specified in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof (to be provided on manufacturer's company letter head)

Certificate No: …………..

Name of Manufacturer: …………………… Date: ………………

Generation Capacity supplied for (in MW): ………….

Name of Generation Developer (to whom supplied): ……… for ……. (location) Generating station

……………… (Name of the Manufacturer) ………., having its registered office at ……… (Address of the Manufacturer)………, do solemnly affirm that the inverters / WTG / other control equipment supplied to ……………..(Name of the renewable generating station) complies with the various conditions as laid out in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof.

Name of the Authorised Signatory:

Signature:

Company Stamp (mandatory):

Annexure-E

Generic Models for Utility Scale Solar-PV & Wind Power generation:

Category	Parameter Description	Data
GENERATOR model (Solar and Wind)		
Solar PV (REGCA1)	T_g, Converter time constant (s)	
	R_{rpwr}, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)	
	B_{rkpt}, LVPL characteristic voltage 2 (pu)	
	Zerox, LVPL characteristic voltage 1 (pu)	
	$L_{vpl}1$, LVPL gain (pu)	
	V_{olim}, Voltage limit (pu) for high voltage reactive current management	
	$L_{vpnt}1$, High voltage point for low voltage active current management (pu)	
	$L_{vpnt}0$, Low voltage point for low voltage active current management (pu)	
	I_{olim}, Current limit (pu) for high voltage reactive current management (specified as a negative value)	
	T_{fltr}, Voltage filter time constant for low voltage active current management (s)	
	K_{hv}, Overvoltage compensation gain used in the high voltage reactive current management	
	I_{qrmax}, Upper limit on rate of change for reactive	

Category	Parameter Description	Data
	current (pu)d	
	I_{qrmin}, Lower limit on rate of change for reactive current (pu)	
	Accel, acceleration factor (0 < Accel <= 1)	
Electrical Control model (Solar and Wind)		
Large Solar PV: (REECB1) [Refer Block Diagrams]	V_{dip} (pu), low voltage threshold to activate reactive current injection logic	
	V_{up} (pu), Voltage above which reactive current injection logic is activated	
	T_{rv} (s), Voltage filter time constant	
	dbd1 (pu), Voltage error dead band lower threshold (≤0)	
	dbd2 (pu), Voltage error dead band upper threshold (≥0)	
	K_{qv} (pu), Reactive current injection gain during over and undervoltage conditions	
	$I_{qh}1$ (pu), Upper limit on reactive current injection Iqinj	
	$I_{ql}1$ (pu), Lower limit on reactive current injection Iqinj	
	$V_{ref}0$ (pu), User defined reference (if 0, model initializes it to initial terminal voltage)	
	T_p (s), Filter time constant for electrical power	

Category	Parameter Description	Data
Electrical Control model (Solar and Wind)		
Large Solar PV : (REECB1) [Refer Block Diagrams]	Q_{Max} (pu), limit for reactive power regulator	
	Q_{Min} (pu) limit for reactive power regulator	
	V_{MAX} (pu), Max. limit for voltage control	
	V_{MIN} (pu), Min. limit for voltage control	
	K_{qp} (pu), Reactive power regulator proportional gain	
	K_{qi} (pu), Reactive power regulator integral gain	
	K_{vp} (pu), Voltage regulator proportional gain	
	K_{vi} (pu), Voltage regulator integral gain	
	T_{iq} (s), Time constant on delay s4	
	dP_{max} (pu/s) (>0) Power reference max. ramp rate	
	dP_{min} (pu/s) (<0) Power reference min. ramp rate	
	P_{MAX} (pu), Max. power limit	
	P_{MIN} (pu), Min. power limit	
	I_{max} (pu), Maximum limit on total converter current	
	T_{pord} (s), Power filter time constant	

Category	Parameter Description	Data
Power Plant Controller (PPC) model (Solar and Wind)		
Generic Power Plant Controller (PPC) model: (REPCA1)	T_{fltr}, Voltage or reactive power measurement filter time constant (s)	
	K_p, Reactive power PI control proportional gain (pu)	
	K_i, Reactive power PI control integral gain (pu)	
	T_{ft}, Lead time constant (s)	
	T_{fv}, Lag time constant (s)	
	V_{frz}, Voltage below which State s2 is frozen (pu)	
	R_c, Line drop compensation resistance (pu)	
	X_c, Line drop compensation reactance (pu)	
	K_c, Reactive current compensation gain (pu)	
	e_{max}, upper limit on deadband output (pu)	
	e_{min}, lower limit on deadband output (pu)	
	dbd1, lower threshold for reactive power control deadband (<=0)	
	dbd2, upper threshold for reactive power control deadband (>=0)	
	Q_{max}, Upper limit on output of V/Q control (pu)	
	Q_{min}, Lower limit on output of V/Q control (pu)	
	K_{pg}, Proportional gain for power control (pu)	

Category	Parameter Description	Data
Power Plant Controller (PPC) model (Solar and Wind)		
	K_{ig}, Proportional gain for power control (pu)	
	T_p, Real power measurement filter time constant (s)	
	$f_{dbd}1$, Deadband for frequency control, lower threshold (<=0)	
	$F_{dbd}2$, Deadband for frequency control, upper threshold (>=0)	
	fe_{max}, frequency error upper limit (pu)	
	fe_{min}, frequency error lower limit (pu)	
	P_{max}, upper limit on power reference (pu)	
	P_{min}, lower limit on power reference (pu)	
	T_g, Power Controller lag time constant (s)	
	D_{dn}, droop for over-frequency conditions (pu)	
	D_{up}, droop for under-frequency conditions (pu)	

Category	Parameter Description	Data
Electrical Control model: BESS		
Generic Electrical Control model for Utility Scale BESS: (REECCU1)	V_{dip} (pu), low voltage threshold to activate reactive current injection logic	
	V_{up} (pu), Voltage above which reactive current injection logic is activated	
	T_{rv} (s), Voltage filter time constant	
	dbd1 (pu), Voltage error dead band lower threshold (≤0)	
	dbd2 (pu), Voltage error dead band upper threshold (≥0)	
	K_{qv} (pu), Reactive current injection gain during over and undervoltage conditions	
	$I_{qh}1$ (pu), Upper limit on reactive current injection Iqinj	
	$I_{ql}1$ (pu), Lower limit on reactive current injection Iqinj	
	$V_{ref}0$ (pu), User defined reference (if 0, model initializes it to initial terminal voltage)	
	T_p (s), Filter time constant for electrical power	
	Q_{Max} (pu), limit for reactive power regulator	
	Q_{Min} (pu) limit for reactive power regulator	
	V_{Max} (pu), Max. limit for voltage control	
	V_{Min} (pu), Min. limit for voltage control	

Category	Parameter Description	Data
Electrical Control model: BESS		
	K_{qp} (pu), Reactive power regulator proportional gain	
	K_{qi} (pu), Reactive power regulator integral gain	
	K_{vp} (pu), Voltage regulator proportional gain	
	K_{vi} (pu), Voltage regulator integral gain	
	T_{iq} (s), Time constant on delay s4	
	dP_{max} (pu/s) (>0) Power reference max. ramp rate	
	dP_{min} (pu/s) (<0) Power reference min. ramp rate	
	P_{max} (pu), Max. power limit	
	P_{min} (pu), Min. power limit	
	I_{max} (pu), Maximum limit on total converter current	
	T_{pord} (s), Power filter time constant	
	V_q and I_q curve (Reactive Power V-I pair in p.u.) : 4 points	
	V_p and I_p curve (Active Power V-I pair in p.u.) : 4 points	
	T, battery discharge time (s) (<0)	
	SOC_{ini} (pu), Initial state of charge	

Category	Parameter Description	Data
Electrical Control model: BESS		
	SOC_{max} (pu), Maximum allowable state of charge	
	SOC_{min} (pu), Minimum allowable state of charge	

Category	Parameter Description	Data
Drive Train model		
WTDTA1	H, Total inertia constant, sec	
	DAMP, Machine damping factor, pu P/pu speed	
	Htfrac, Turbine inertia fraction (Hturb/H)1	
	F_{req}1, First shaft torsional resonant frequency, Hz	
	D_{shaft}, Shaft damping factor (pu)	

Category	Parameter Description	Data
Pitch Control model [for Type-3 only]		
Generic Pitch Control model for Type-3 : (WTPA1)	K_{iw}, Pitch-control Integral Gain (pu)	
	K_{pw}, Pitch-control proportional gain (pu)	
	K_{ic}, Pitch-compensation integral gain (pu)	

Category	Parameter Description	Data
	K_{pc}, Pitch-compensation proportional gain (pu)	
	K_{cc}, Gain (pu)	
	T_p, Blade response time constant (s)	
	$Teta_{Max}$, Maximum pitch angle (degrees)	
	$Teta_{Min}$, Minimum pitch angle (degrees)	
	$RTeta_{Max}$, Maximum pitch angle rate (degrees/s)	
	$RTeta_{Min}$, Minimum pitch angle rate (degrees/s) (< 0)	

Category	Parameter Description	Data
Aerodynamic model [For Type-3 only]		
(WTARA1)	K_a, Aerodynamic gain factor (pu/degrees)	
	Theta 0 Initial pitch angle (degrees)	

Category	Parameter Description	Data
Torque Controller model [For Type-3 only]		
Generic Torque Controller for Type-3 wind machines :	K_{pp}, Proportional gain in torque regulator (pu)	
	KIP, Integrator gain in torque regulator (pu)	
	T_p, Electrical power filter time constant (s)	
	TW_{ref}, Speed-reference time constant (s)	

Category	Parameter Description	Data
Torque Controller model [For Type-3 only]		
(WTTQA1)	Te_{max}, Max limit in torque regulator (pu)	
	Te_{min}, 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)	

Annexure-F

Data Format-I

A. Generation switchyard/Pooling Station end:

1.	Name of substation and ownership:	
2.	Name of the bay and bay identification number:	

B. Sub-station (ISTS) End at which Connectivity is granted:

1.	Name of substation and ownership:	
2.	Name of the bay and bay identification number:	

Data Format-II-A

Equipment to be provided in the allocated bay meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof

Bus switching scheme:

A. Generation/Pooling Station end: […………………………]

B. ISTS end: […………….]

Equipment Details:

Sl. No.	Name of Equipment	Generation Switchyard / Pooling Station end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/ MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
For GIS Substation							
1.	Circuit Breaker (with PIR /CSD if required))						
2.	Disconnecting Switch						
3.	Maintenance Earthing Switch						
4.	High speed Earthing switch						
5.	CT with core						

Sl. No.	Name of Equipment	Generation Switchyard / Pooling Station end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/MTS)	Nos	Ratings	Type (AIS/GIS/MTS)	Nos	Ratings
	details						
6.	Bus PT						
7.	Surge Arrester						
For AIS Substation							
1.	Circuit Breaker (with PIR /CSD if required)						
2.	Isolator (with no. of Earth Switch as required)						
3.	CT with core details						
4.	CT (Metering)						
5.	Line CVT						
6.	Bus CVT						
7.	PT (Metering)						
8.	Wave trap						

Sl. No.	Name of Equipment	Generation Switchyard / Pooling Station end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/ MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
9.	Surge Arrester						
10.	ICT						
11.	Bus Reactor						
12.	Line Reactor						
13.	NGR						
14.	NCT						
15.	ESS (Energy Storage System)						
16.	Any other equipment details (……)						

NOTE: *In case of more than two substations, the same shall be appended.*

Data Format-II(B)

Protection Equipment to be provided by applicant shall be meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof and shall be compatible & matching with the equipment installed at other end

(Please specify type, make and model of all main relays as applicable)

Name of Substation and Voltage level:

A. Generation end/Pooling substation end and Voltage Level:

B. Connectivity substation end and Voltage Level:

Name of Lines along with Tower Configuration (S/c, D/c, M/c**):**

Type of Conductor: (Bundle Configuration, Dia/ Type and Ampacity)

Protection Details:

Sl. No	Description	Generation Switchyard / Pooling station end	ISTS Substation End at which Connectivity is granted
		Protection Type, Make and Model	
1.	Line protection relay MAIN-I (Distance / Differential)		
2.	Line protection relay MAIN-II (Distance / Differential)		
3.	Auto reclose relays		
4.	Bay Control Unit		
5.	Any Other Protection		

Sl. No	Description	Generation Switchyard / Pooling station end	ISTS Substation End at which Connectivity is granted
		Protection Type, Make and Model	
	Equipment		

NOTE: *In case of more than two substations, the same shall be appended.*

Data Format-III(A)

System Recording Equipment to be provided in the allocated bay meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof

Sl No.	Name of Equipment's	Generation Switchyard / Pooling Station end		ISTS Substation End at which Connectivity is granted	
		Nos.	Ratings	Nos.	Ratings
1.	Event Logger				
2.	Disturbance recorder				
3.	Fault locator				
4.	PLCC details of transmission line				
5.	FOTE details				
6.	Any other equipment (Please indicate)				

NOTE:

1. *In case of more than two substations, the same shall be appended.*
2. *RE Generating station shall provide System Recording Equipment at each WTG/PV inverter with appropriate sampling frequency*

Data format-III(B)

Communication Equipment details upto Data Collection Point SCADA equipment shall be meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof and shall be compatible to facilitate exchange of data with the existing system installed in the ISTS network

Sl. No	Name of Equipment	Nos.	Description
1.	**Data Acquisition System** - Remote Terminal Unit/SAS/DAS Gateway		
2. a)	**Communication Equipment** SDH required if any i. At the Generating/Pooling station ii. At data collection point (DCP)		
b)	**Approach Cable & FODP** a) At the Generating/ Pooling station b) At data collection point (DCP)		
3.	**WAMS** Phasor Measurement Unit(s) for measuring three phase current of all the feeders and three phase bus voltage at *220kV and above Generator		

Note: *PMU locations shall be as per latest prevailing guidelines of CEA/Prevailing standards*

Data Format –III (C)

Cyber Security compliance as per CEA (Cyber Security in Power Sector) Guidelines 2021

Sl. No.	Name of Equipment	Nos.	Remarks
1.	**Perimeter security** Redundant Firewalls between SAS Gateway/RTU and FOTE		

Data Format –III (D)

Format for Communication inputs for Generator

A. Generator connectivity details with ISTS Station to be provided

1.	Generator location	
	Common Pooling Station (CPS) Location (if exists)	
2.	Generator Connectivity with CPS (33/220/400kV voltage)	
	Line length from Gen to CPS in kms	
3.	Provision of communication from pre pooling station to CPS (Fibre/ Leased Line/ Others)	

B. Communication Equipment details along with PMU

Sl. No.	Data Type	Gen End	ISTS S/s End	
		Installed/ Provisioned	Scope (With Gen or ISTS S/s Owner)	Installed /Provisioned
1.	Approach cable			
2.	FODP			
3.	PMU			
4.	FOTE			

C. FOTE Details

Sl. No.	Particulars	Gen End	ISTS S/s end
1.	Make		
2.	Model		
3.	Capacity (e.g. STM16)		
4.	No. of supported optical directions (e.g. 5 MSP)		

Data format-IV

Details of the modification/alteration to existing facilities for accommodating proposed connection and its estimated cost

Data format -V

Communication Link details up to ISTS Data Collection Point

Requirement of Channels:

(1) 2 Nos Data Channel (600Baud) /64 Kbps or Ethernet channel for RTU/SAS/DAS

(2) 1 No Speech channel

(3) 1 No. Data Channel (2 Mbps) for PMU

Data Collection Point for: Generating/Pooling Station Name

Data Collection Point (DCP): Name of ISTS Station

Wideband Link (Configuration of Data & Voice channel in wideband Link by Regional ULDC Team)**:**

Channel: DCP Name- Respective RLDC

Data format-VI

Site responsibility schedule

A. Principle & Procedure:

The responsibility of control, operation, maintenance & all matters pertaining to safety of equipment's and apparatus at the connection point shall lie with the connectivity grantee. The grantee may enter into a separate O&M contract with the owner of the substation based on mutually agreed terms and conditions for ease of day-to-day O&M of the equipment which are located in the premises of the substation.

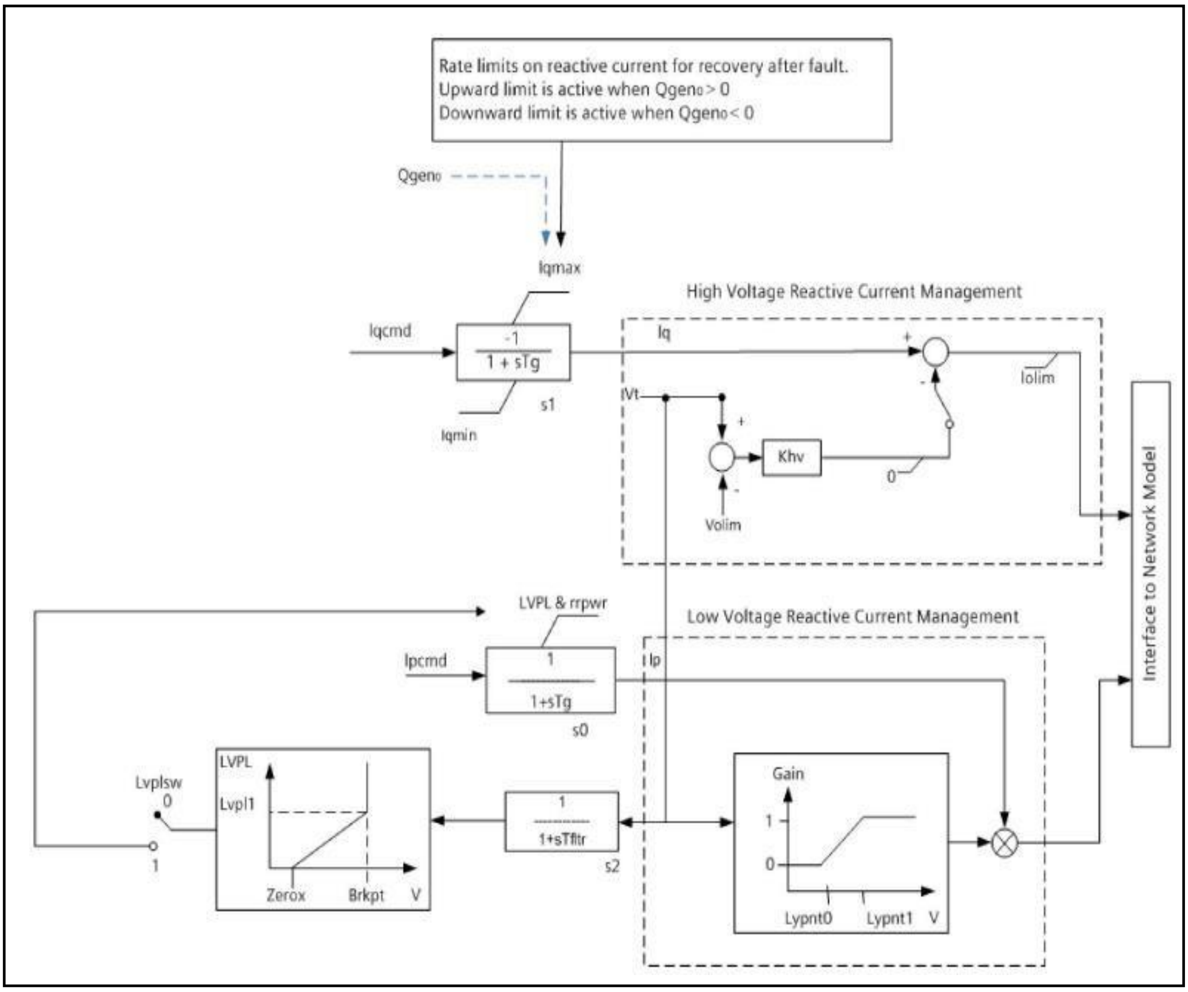
List of equipment and their ownership at the connection point:

Sl. No.	Name of Equipment	Ownership	
		Generation Switchyard / Pooling Station end	ISTS Substation end at which Connectivity is granted
1.	Circuit Breaker (with PIR/ CSD if required)		
2.	Isolator (with no. of Earth Switch as required)		
3.	Disconnecting Switch (For GIS)		
4.	Maintenance Earthing Switch (For GIS)		
5.	High speed Earthing switch (For GIS)		
6.	CT		
7.	CT (Metering)		

Sl. No.	Name of Equipment	Ownership	
		Generation Switchyard / Pooling Station end	**ISTS Substation end at which Connectivity is granted**
8.	Line CVT		
9.	Bus CVT		
10.	PT (Metering)		
11.	Wave trap		
12.	Surge Arrester		
13.	ICT		
14.	Bus Reactor		
15.	Line Reactor		
16.	NGR		
17.	NCT		
18.	ESS (Energy Storage System)		
19.	Any other Equipment (….)		

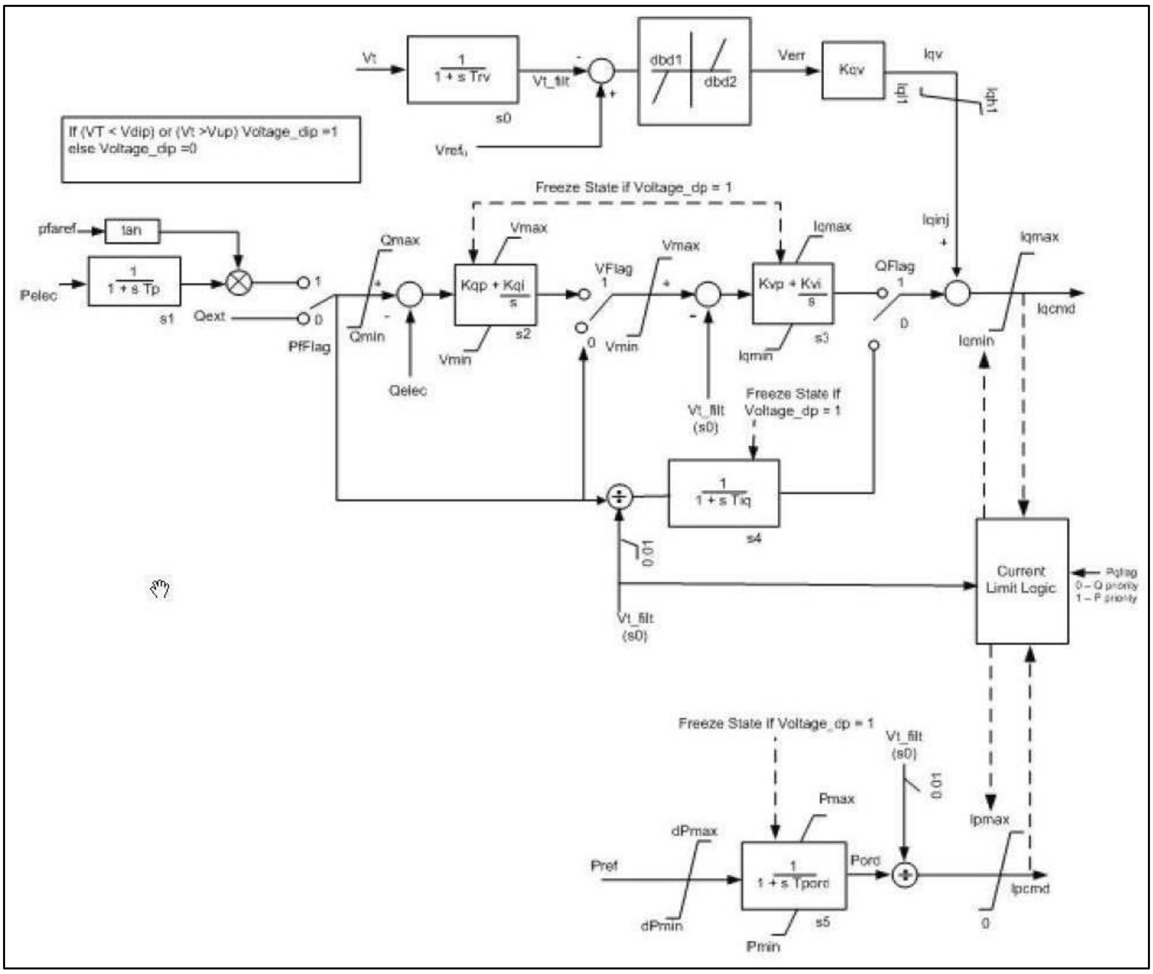
Appendix-1: Block Diagrams

- Generators: **REGCA1:** Generic Model for Utility Scale Solar PV/ Wind WTG



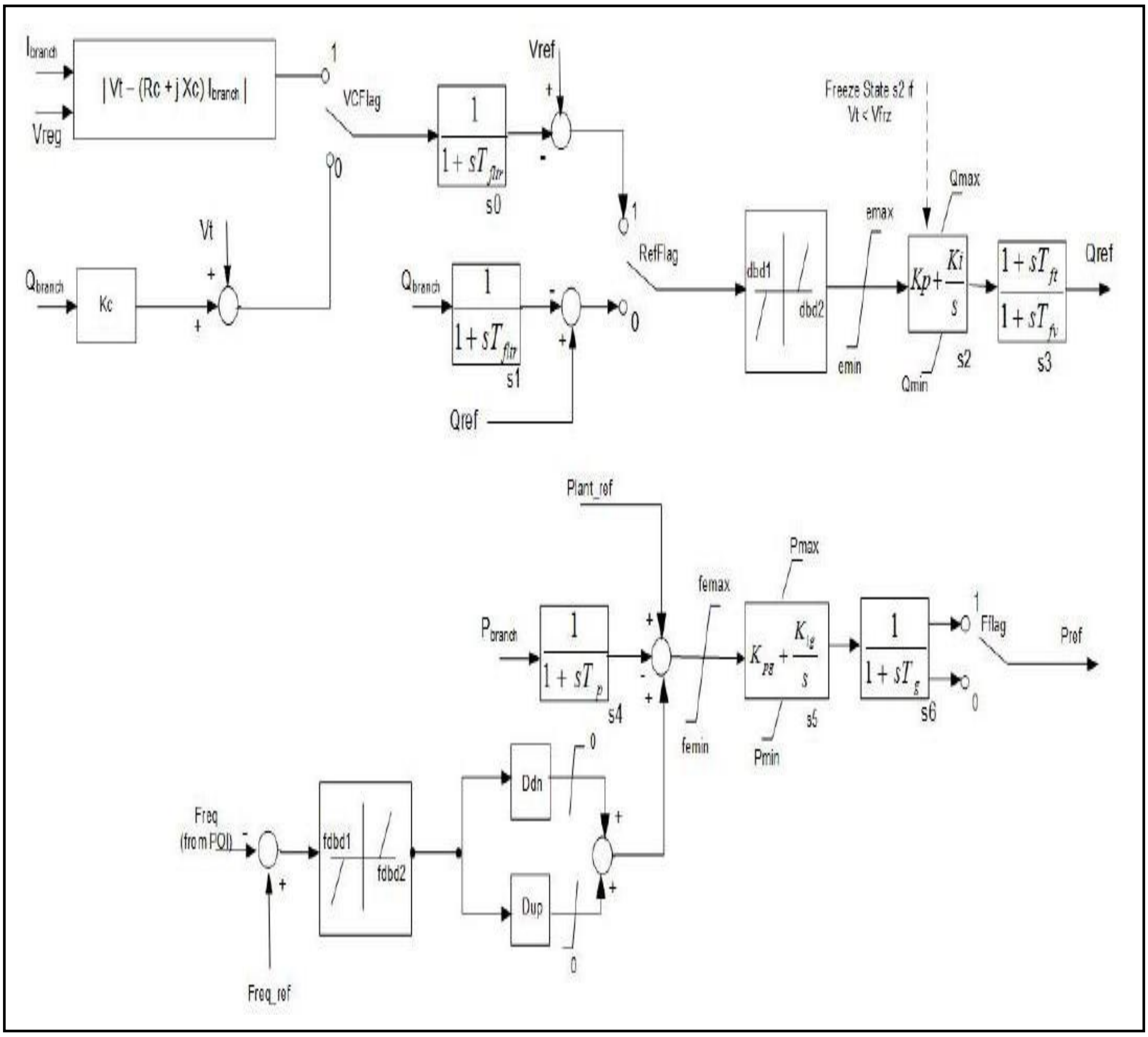
Electrical Control:

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

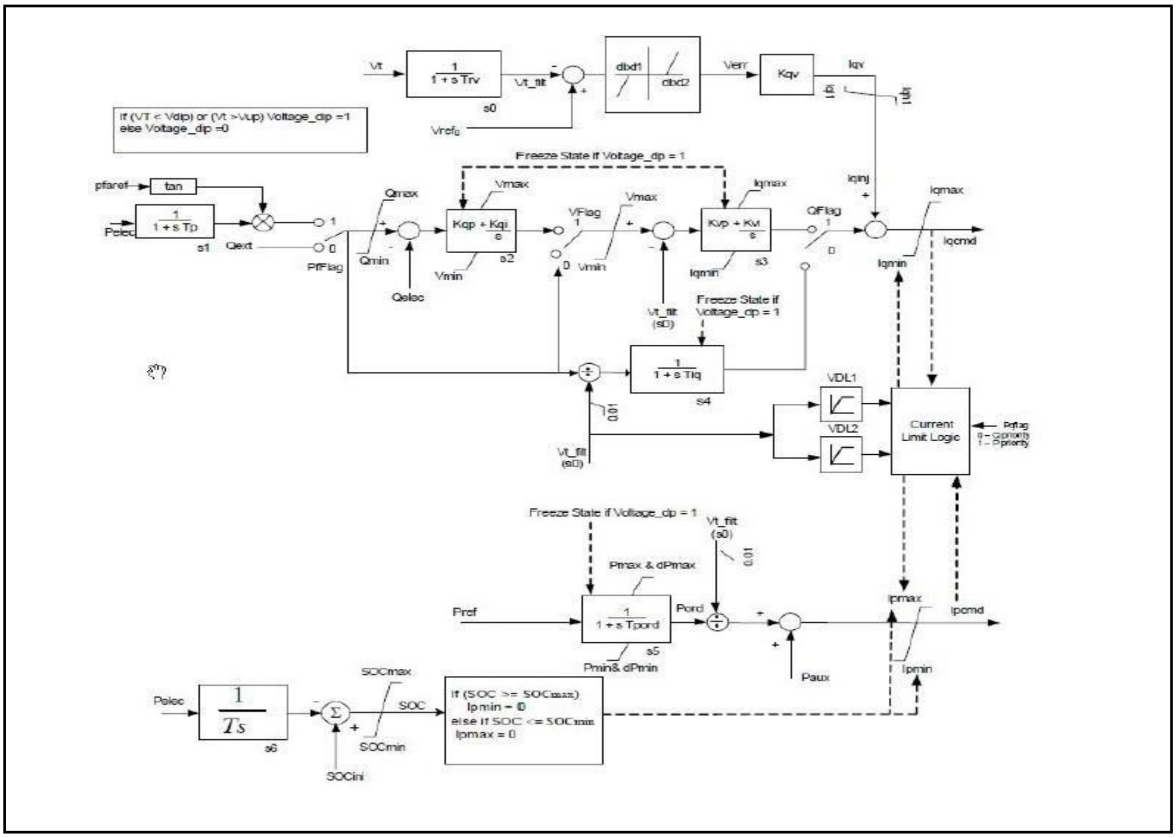


Power Plant Controller (PPC) Model:

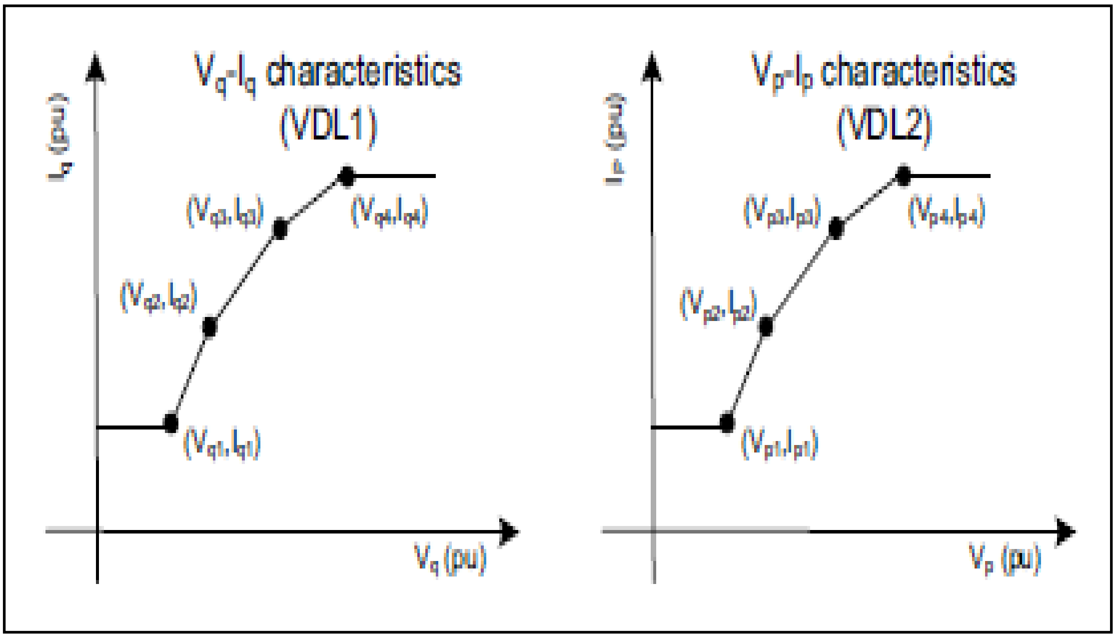
- REPCA1 for Utility scale Solar PV and Wind Power plants:



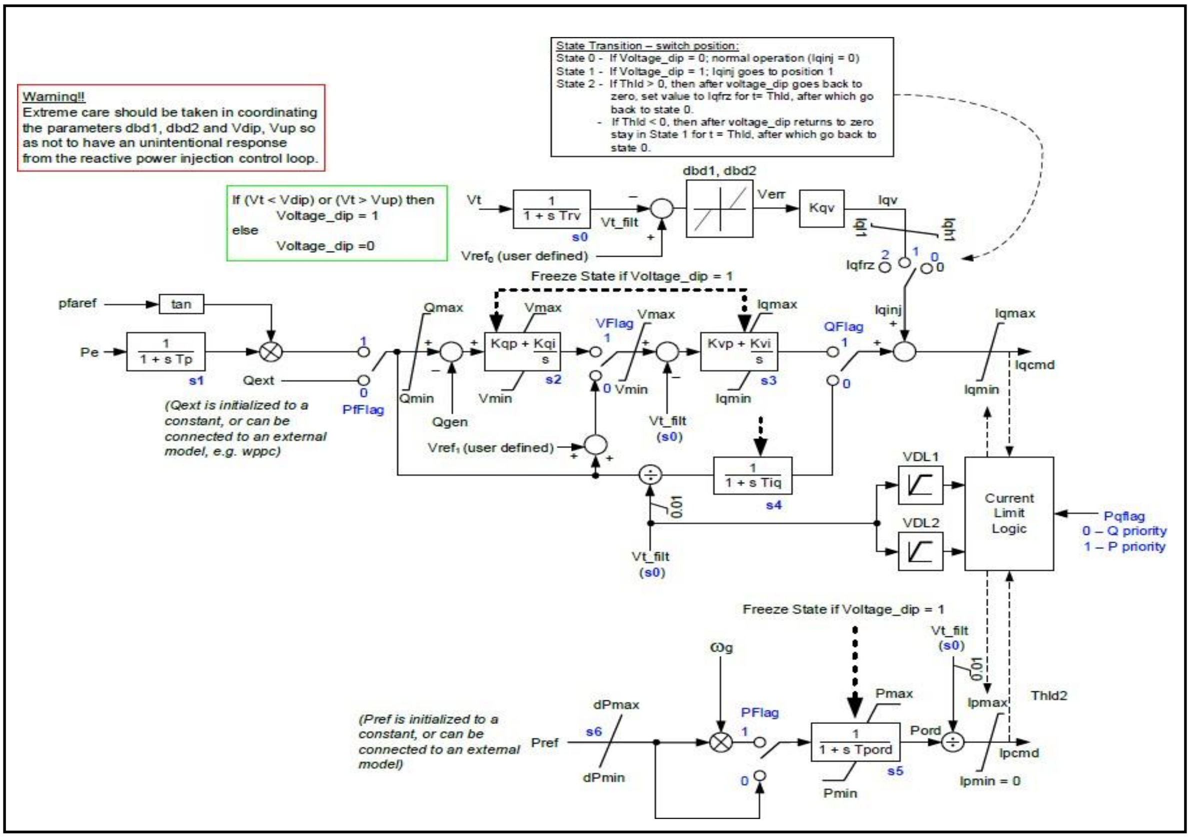
Electrical Control Model for Utility Scale Battery Energy Storage System (BESS):



- **Electrical Control:** Type-3 or Type-4 (REECA1):

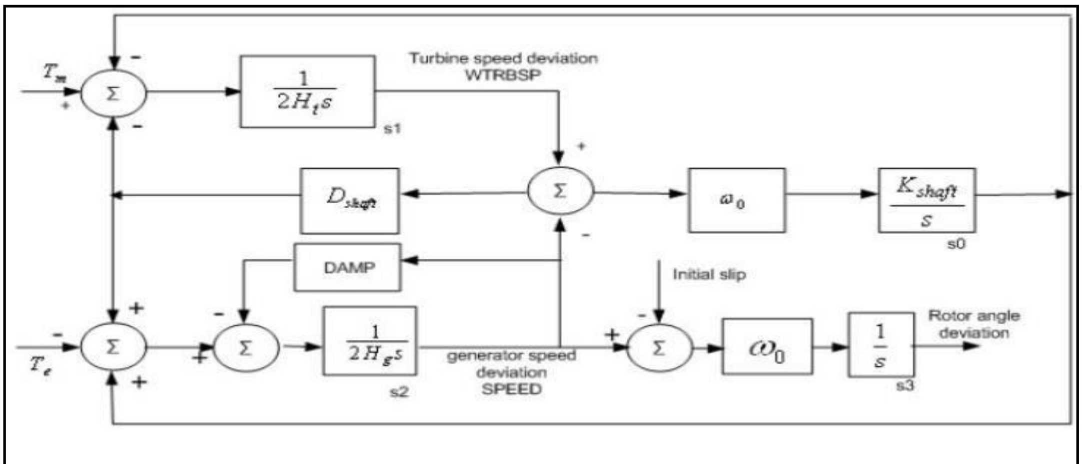


- V_p-I_p and V_q-I_q curves for REECA1 model:



➢ *Drive Train Model:*

- **WTDTA1:** Generic Drive Train model for Type-3 and Type-4 turbines

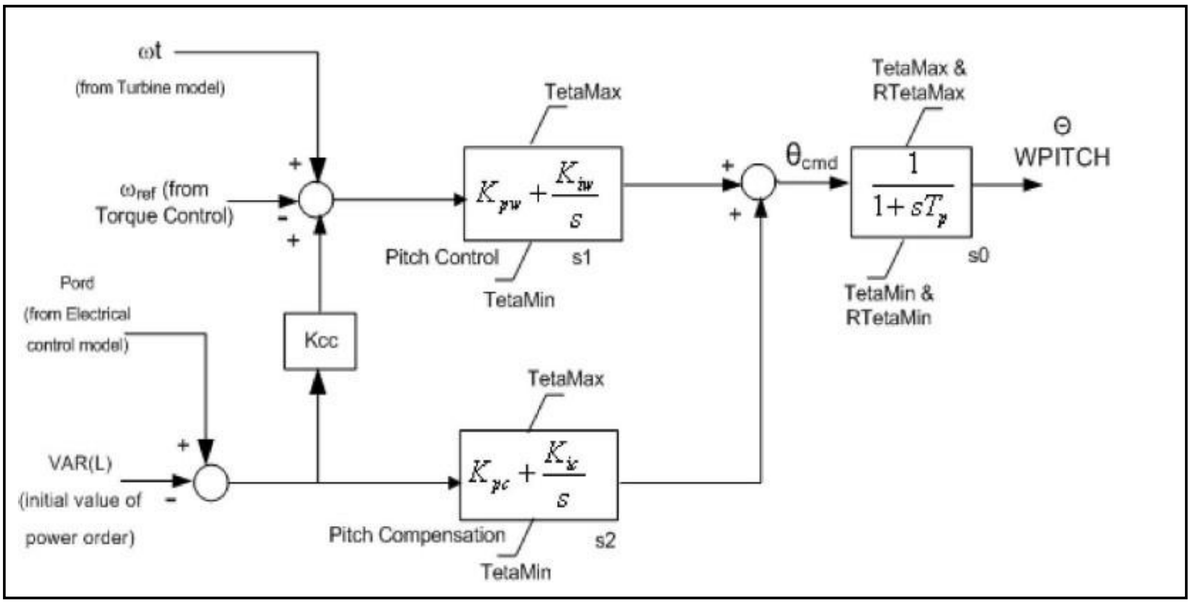


$$H_t = H \times H_{tfrac}$$
$$H_g = H - H_t$$
$$K_{shaft} = \frac{2H_t \times H_g \times (2\pi \times Freq1)^2}{H \times \omega_0}$$

$\omega_0 = 2\times\pi\times$system nominal frequency

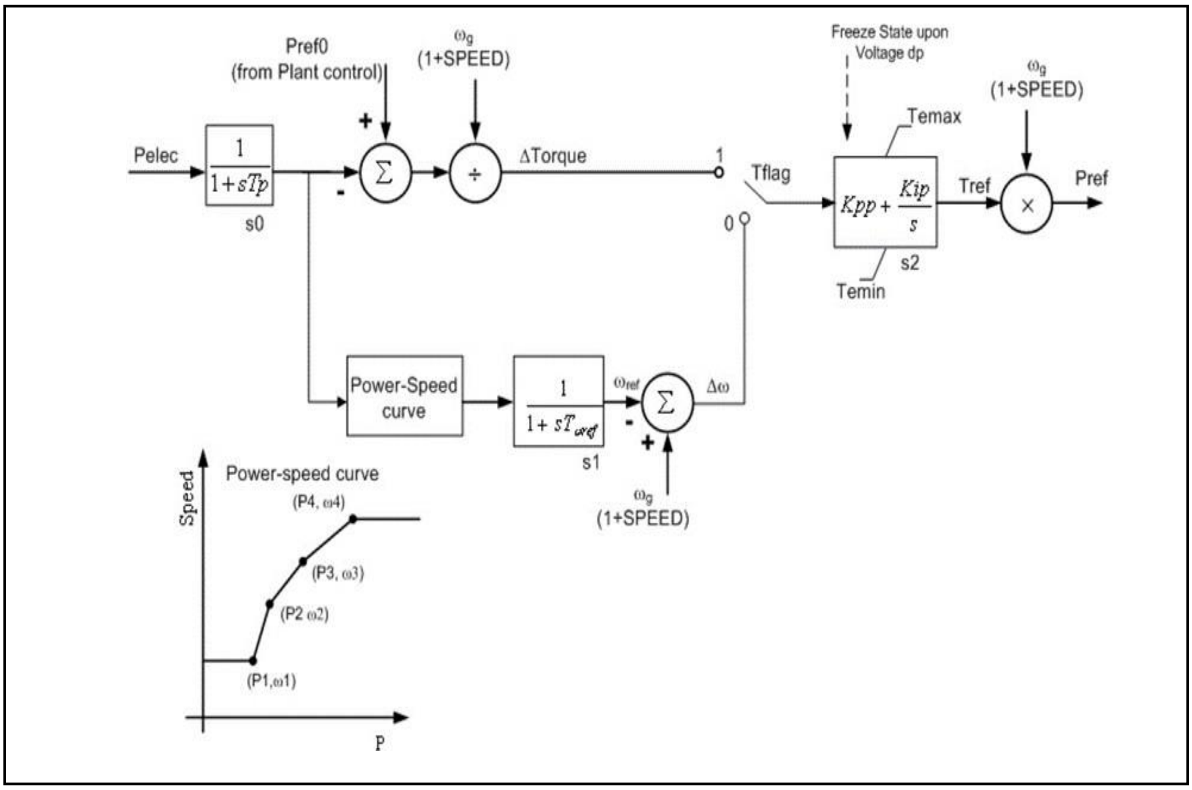
- *Pitch Control:*

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



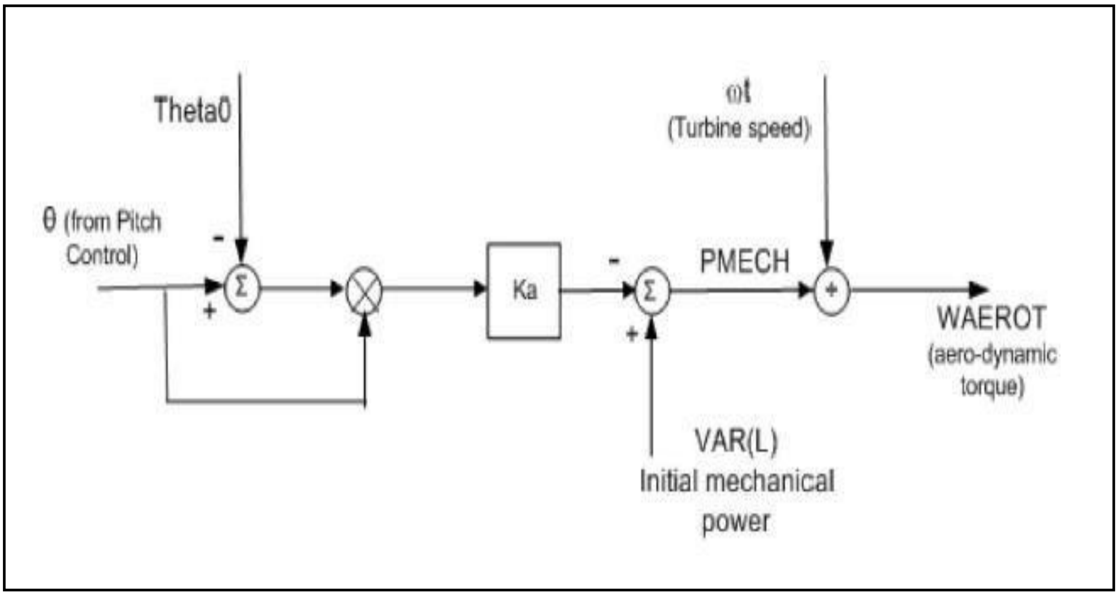
- *Torque Controller Model:*

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



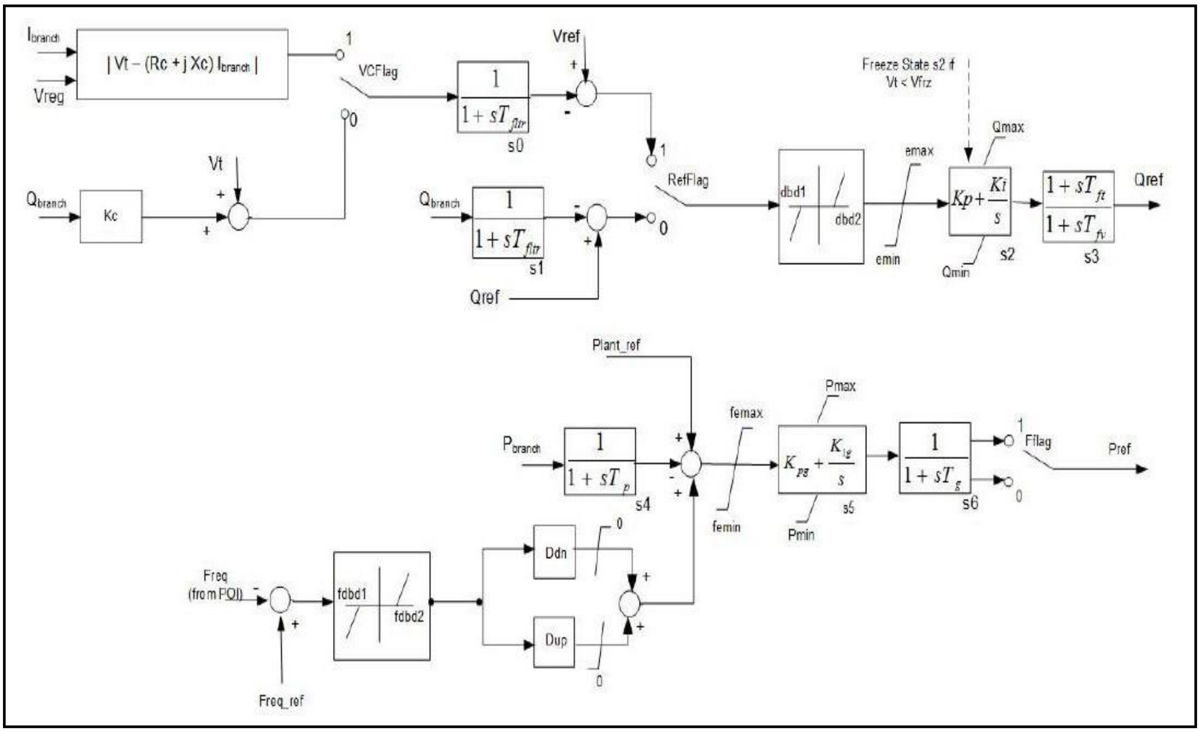
- *Aerodynamic Model:*

- **Type-3 (WTARA1):** Generic Aerodynamic model Type-3 WTG

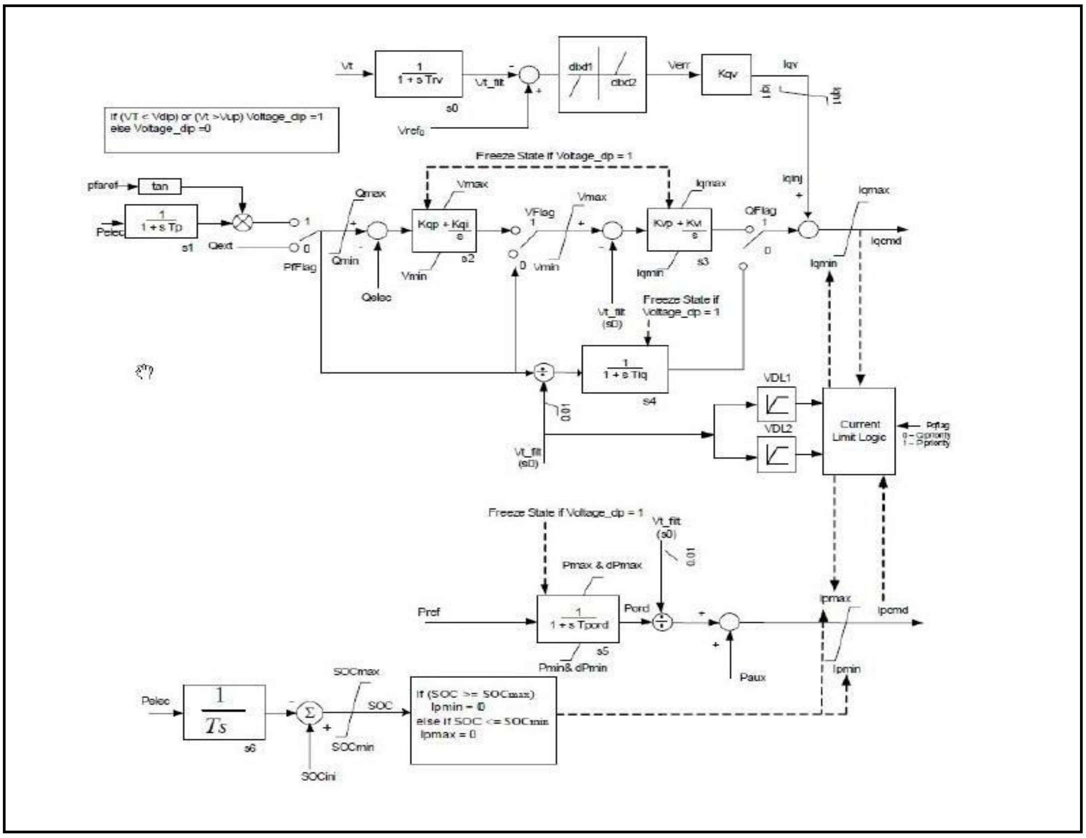


- *Power Plant Controller (PPC) Model:*

- **REPCTA1** for type 3, and REPCA1 for type 4 turbines



- *Electrical Control Model for Utility Scale Battery Energy Storage System (BESS):*



Annexure-G

List of Test/Study Reports required to be furnished by RE applicants in compliance of CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007

In support of compliance with Connectivity Standards, the RE applicant shall submit the following Test/Simulation Study Reports as part of CONN-4 documents as per the sequence indicated below. Other details such as model submission, test report (factory/lab/field) submission, benchmarking is provided at the end of this section

Power Quality test

1. Harmonic Current Injection at POI
2. DC Current Injection at POI
3. Flicker injection at POI

Reactive Capability test

4. Reactive power capability (0.95 lag - unity - 0.95 leading) at rated output

Voltage ride through test

5. Study analysis to demonstrate ride through capability for balance and unbalanced faults (LVRT & HVRT)

Frequency response & operational capability test within specified frequency/voltage band

6. Rated output for voltage (0.95pu -1.0 pu – 1.05 pu) and Freq. (49.5Hz – 50.5 Hz)
7. Frequency Response test

Active power control set point

8. Analysis to show capability to control active power injection in accordance with a set point

Ramping capability test

9. Study analysis for rate of change of power output

Note: *Power Quality Study is to be carried out on detailed EMT / Power Quality Assessment Model. Reactive Power Capability assessment shall be carried out on detailed RMS and Equivalent EMT model. Other tests are to be carried out in both equivalent RMS and EMT Model. Model compatibility guidelines are provided in subsequent pages.*

Details of the studies to be carried out as per CEA Connectivity Standard are as below:

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
Power quality	B.1(1)	Harmonic current injections from a generating station shall not exceed the limits specified in IEEE Standard 519	1. Harmonic Study report is required to be submitted considering complete Generating Station as a whole at POI (vide aggregation of individual PV inverter/ WTG/ Hybrid/ BESS unit test reports). 2. The harmonic current limits for voltage class **above 161kV** as depicted in IEEE Standard 519-2014 shall be applicable. In case of interface at 132kV level POI, Harmonic currents limit for voltage class above **69 kV to 161 kV** would be applicable. 3. Harmonic evaluation (Current) shall be done at 10% incremental

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
			active power levels starting from 0-100% of rated output.
	B.1(2)	Generating station shall not inject DC current greater than 0.5% of the full rated output at the interconnection point.	Study report is required to be submitted considering complete Generating Station as a whole at POI (vide aggregation of individual PV inverter/WTG/ Hybrid/BESS unit test reports)
	B.1(3)	Generating station shall not introduce flicker beyond the limits specified in IEC 61000	Study report for Flicker evaluation is required to be submitted considering complete Generating Station as a whole at POI (vide aggregation of individual PV inverter/WTG/ Hybrid/BESS unit test reports)
	B.1(4)	Measurement of harmonic content, DC current or flickers every year	Applicant shall indicate the month during which yearly measurement of harmonic content, DC current or flickers shall be done.
Reactive capability	B.2(1)	Generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within limits of 0.95 lagging and 0.95 leading.	Applicant shall submit study report indicating performance of power plant with the help of plant PQ capability curves considering different voltage levels (1.05, 1.0, 0.95) at POI under different power factors (0.95 lag- Unity-0.95 lead).

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
			List of studies to be provided are tabulated below: <table><tr><th>Voltage at POI</th><th>Unity PF</th><th>0.95 lagging</th><th>0.95 leading</th></tr><tr><td>1.0 pu</td><td>To be provided</td><td>To be provided</td><td>To be provided</td></tr><tr><td>0.95 pu</td><td>To be provided</td><td>To be provided</td><td>-</td></tr><tr><td>1.05 pu</td><td>To be provided</td><td>-</td><td>To be provided</td></tr></table> **Note:** • Generating station should able to deliver rated output (at POI for the above-mentioned conditions as per PQ curve attached at Annexure-A1. • The voltage dependence of reactive power capability of RE Generator shall be governed as per QV curve attached at Annexure-A1. • Additional study cases shall be required to demonstrate reactive capability at 1.025 and 0.975pu voltage (at POI) as per QV curve.

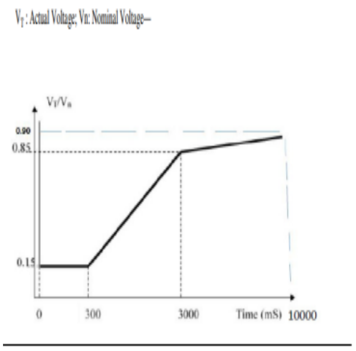
Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
			• For all cases, report should include details of both active and reactive power exchange by generation pooling station with the grid at point of interconnection (POI) • Plant PQ capability curve shall be demonstrated at the POI reflecting the effect of aggregated plant capacity along with contribution of dedicated transmission line • The applicant shall clearly indicate the details of additional reactive compensation as may be required to be installed, for compliance of the above, supported vide study reports.
Frequency response & operational capability within	B.2 (2)	The generating unit shall be capable of operating in the frequency range 47.5 to 52 Hz and be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz:	1. Study Analysis showing that generating station capable of operating in the frequency range 47.5 to 52 Hz. **Note:** The report should be tabulated as per following format:

<table>
<tr><th>Test Domain</th><th>Clause No. of Connectivity Regulation</th><th>Detailed clause</th><th>List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations</th></tr>
<tr><td>specified frequency /voltage band</td><td></td><td>Provided that in the frequency range below 49.90 Hz and above 50.05 Hz, or, as prescribed by the Central Commission, from time to time, it shall be possible to activate the control system to regulate the output of the generating unit as per frequency response requirement as provided in sub-clause (4):

Provided further that the generating unit shall be able to maintain its performance contained in this subclause even with voltage variation of up to +/- 5% subject to availability of commensurate wind speed in case of wind generating stations and solar insolation in case of solar generating stations.</td><td>
<table>
<tr><th rowspan="2">Voltage at PoI (pu)</th><th rowspan="2">Case*</th><th colspan="2">POI end</th><th colspan="2">Generator end</th></tr>
<tr><th>P (MW)</th><th>Q (MVAr)</th><th>P (MW)</th><th>Q (MVAr)</th></tr>
<tr><td rowspan="3">0.95 /1.0 /1.05</td><td>Unity pf</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Lagging pf</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Leading pf</td><td></td><td></td><td></td><td></td></tr>
</table>
**The above report shall be submitted for cases corresponding to frequency values of 47.5Hz and 52 Hz.

2. Study report demonstrating frequency response-based output power regulation in the range of 49.90Hz to 50.05Hz.</td></tr>
</table>

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
Frequency response & operational capability within specified frequency /voltage band	B.2 (4) (ii)	Frequency response test	Study analysis including at least following tests: 1. It shall have governors or frequency controllers of the units at a droop of 3 to 6% and a dead band not exceeding ±0.03 Hz. 2. Study analysis for real power freq. response (within 1 sec) of at least 10% of maximum AC active power capacity for frequency deviation excess of 0.3 Hz
	B.2(4) (iii)	Shall have the operating range of the frequency response and regulation system from 10% to 100% of the maximum Alternating Current active power capacity, corresponding to solar insolation or wind speed, as the case may be;	The test mentioned in B2 (4) (ii) shall be conducted for active power output at 10%, 50%, 100% of rated output.
Voltage Ride through	B.2 (3)	Generating station connected to the grid, shall remain connected	1. Study report to demonstrate LVRT capability of the power plant at POI considering full and

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
capabilities		to the grid when voltage at interconnection point on any or all phases dips up to the level depicted by the thick lines in curves.  Provided that during the voltage dip, the supply of reactive power has first priority, while the supply of active power has second priority and the active power preferably be maintained during voltage drops, provided, a reduction in active power within the plant's design specifications is acceptable and active power be restored to at	partial (25% and 50%) active power dispatch 2. The LVRT tests shall be carried out for balanced (Three phase) and non-balanced fault (L-G) case (PSSE/PSCAD) **Note:** i. During the voltage dip, the supply of reactive power has first priority, while the supply of active power has second priority and the active power preferably be maintained during voltage drops, provided, a reduction in active power within the plant's design specifications is acceptable and active power be restored to at least 90% of the pre-fault level within 1 sec of restoration of voltage. ii. Applicant shall provide relevant plots including active and reactive power plots during LVRT test.

<table>
<tr><th>Test Domain</th><th>Clause No. of Connectivity Regulation</th><th>Detailed clause</th><th>List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations</th></tr>
<tr><td></td><td></td><td>least 90% of the pre-fault level within 1 sec of restoration of voltage.</td><td></td></tr>
<tr><td></td><td>B.2(7)</td><td>The generating station connected to the grid, shall remain connected to the grid when voltage at the interconnection point, on any or all phases (symmetrical or asymmetrical overvoltage conditions) rises above the specified values given below for specified time
<table>
<tr><th>Over voltage (pu)</th><th>Minimum time to remain connected (Seconds)</th></tr>
<tr><td>1.30 < V</td><td>0 Sec (Instantaneous trip)</td></tr>
<tr><td>1.30 ≥ V > 1.20</td><td>0.2 Sec</td></tr>
<tr><td>1.20 ≥ V > 1.10</td><td>2 Sec</td></tr>
</table></td><td>1. Applicant shall submit the study report demonstrating the High voltage ride through capability of the power plant at POI considering cases of full (100% level) active power dispatch and partial (25% 50%level) power dispatch.
2. Applicant shall provide relevant plots including active and reactive power plots during HVRT test
3. The HVRT tests shall be carried out for balanced (Three phase) and non-balanced cases (PSSE/PSCAD)
4. The Protection setting at Generator, Generator PS & dedicated Trans. Line should be coordinated to enable HVRT compliance at POI</td></tr>
</table>

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
		V ≤ 1.10 | Continuous	
Active power control set point	B.2(4) (i)	Shall be equipped with the facility to control active power injection in accordance with a set point, capable of being revised based on directions of the State Load Dispatch Centre or Regional Load Dispatch Centre, as the case may be;	RE developers needs to submit declaration supported with OEM document depicting facility to comply active power set point capability along with details of design specification, with supporting documents, that generation plant: 1. is capable to control active power injection in accordance with a set point (to be done as a part of B2(4)(iv)) 2. capable of being revised set points based on directions of the State Load Dispatch Centre or Regional Load Dispatch Centre, as the case may be (OEM report showing this feature to be forwarded)
Ramping capability	B.2(4) (iv)	Shall be equipped with the facility for controlling the rate of change of power output at a rate not more than ±10% per minute.	Study report demonstrating rate of change of power output at a rate not more than ±10% per minute. The report shall include capability demonstration for both active power

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
			ramping up and ramping down scenario.

Note:

1. OEM technical datasheet of WTG/PV inverter/Hybrid/BESS module, IBR (Inverter Based Resource) Unit details, Unit transformer details, Power transformer details, conductor/cable details, SLD of the plant, PPC details, equivalent impedance calculation details for 33kV network etc. shall be provided by the RE developer

2. Dedicated transmission line originating from Generating station to ISTS point should be included in the study analysis and accordingly all study reports should be considering the POI reference point.

3. The RE generator shall submit Single Inverter/WTG/Equipment **Test Report (Type Characteristic Test/ Measurement Report[1])** from a Certified Testing Agency demonstrating compliance with CEA's "*Technical Standards for Connectivity to the Grid, 2007"* and subsequent amendments. The RE generator shall also submit **Statement of Compliance/Conformity certificate** along with the **evaluation report** from an "Accredited Certification Agency". Certificate of Accreditation of the certifying agency may also be asked for verification, if required.

[1] **Report indicating the electrical characteristic of single unit (inverter/WTG) and referred for the purpose of certification**

~~4.~~ WTG/Inverter model response shall be benchmarked with the actual test (Lab/Factory/Field test) reports of single WTG/Inverter for all the clauses as mentioned in the technical standards.

5. The RE Generator shall also submit the 'Benchmarking report' depicting performance comparison of actual test report Vs PSS/E and PSCAD simulation report (unit/single IBR level). The format for the same is given below:

Test Description	Field/Lab/Factory Test Result	RMS Mode Response	Model Response

Further, following shall be included in the benchmarking report:

a) For RMS models, provide a table of all simulation model STATEs, VARs, CONS, ICONs, their values as implemented in the dynamic data files and a description of each function.

b) For EMT models, provide a table of all user-definable settings and status code outputs for all plant within the generating system, a range of acceptable values for each user-changeable variable and a description of each entry's function.

c) Software version of controller & Firmware version of converter of IBR/WTG unit shall be mentioned.

d) Lab/factory/field test reports shall be referenced in the benchmarking report.

e) The settings kept in inverter/WTG unit during testing & actual unit installed at site must be same. If there is any mismatch in settings, justification for the same shall be included.

f) Table for inverter/WTG unit controller setting and RMS & EMT model parameter for different control parameters as specified (for both RMS & EMT).

6. RE developer shall submit the single inverter/WTG, aggregated and detailed RMS model of the RE plant in PSS/E alongwith PSCAD aggregated model. The guidelines to be followed for model submission is given below:

a) Generic RMS models shall be compatible with PSS/E version 34.4 and above.

b) EMT models shall be compatible with PSCAD version 4.6 and above with Intel Visual FORTRAN version 12 or higher compiler. Power quality assessment model shall also be submitted in PSCAD.

c) If user written/defined models (UDM) are being provided, then submission of the source code and compiling procedure along with the model is mandatory.

d) Model shall work for a range of dynamic simulation solution parameters rather than for specific settings only.

e) There shall be no initialization errors for the dynamic models and the warning messages are reviewed with resolution or explanation.

f) RE developer shall construct the detailed and equivalent plant model (at POI) using the benchmarked unit (single WTG/Inverter) model

7. For validation of study analysis results, applicants shall submit associated files (PSSE / PSCAD / Python / .sldfile / .dyr / .out / .plb etc.) including python recording/sequence of events simulated for a particular study/case. Model shall be validated by demonstrating that response obtained as per simulation, closely matches with the response obtained by testing under laboratory conditions.

8. In case of observation of deviations vis-à-vis submitted data/reports during real time field operations, the RE developer shall be required to carry out necessary modifications including installation of additional equipment as may be necessary to rectify such deviation.

9. The reactive power (or reactance) is considered to be dynamically variable in nature if the emulated reactance is variable in nature and is achieved through automatic control mechanism having adequate response time. Power apparatus like STATCOM & SVC emulates the dynamically varying reactance at the point

of measurement, whereas, Power apparatus like mechanically switched capacitors & fixed capacitors are covered under the category of Static reactive compensation device considering long switching (mechanical) time and uncontrolled magnitude of reactance provided. WTG (Type-III & IV) and PV Inverter (Type-IV) have the capability to provide at its terminals, dynamically variable reactive power support almost instantaneously through their control mechanism. The RE Generators shall adopt appropriate measures for enabling such dynamic reactive response.

10. In case of any change in the plant at a later stage due to installation of any additional equipment, changes in controller settings etc., the updated models along with the validation report shall be submitted within 03 month of any such activity from time to time. The undertaking certifying the same shall be submitted along with the final validated models.

11. In compliance to CEA's "Technical Standards for Connectivity to the Grid, 2007" and subsequent amendments, power quality (harmonic content, DC injection, flicker etc.) measurements shall be carried out at least once in a year and assessment report shall be submitted to CEA/RPC, CTU and POSOCO on an annual basis post commissioning of the plant.

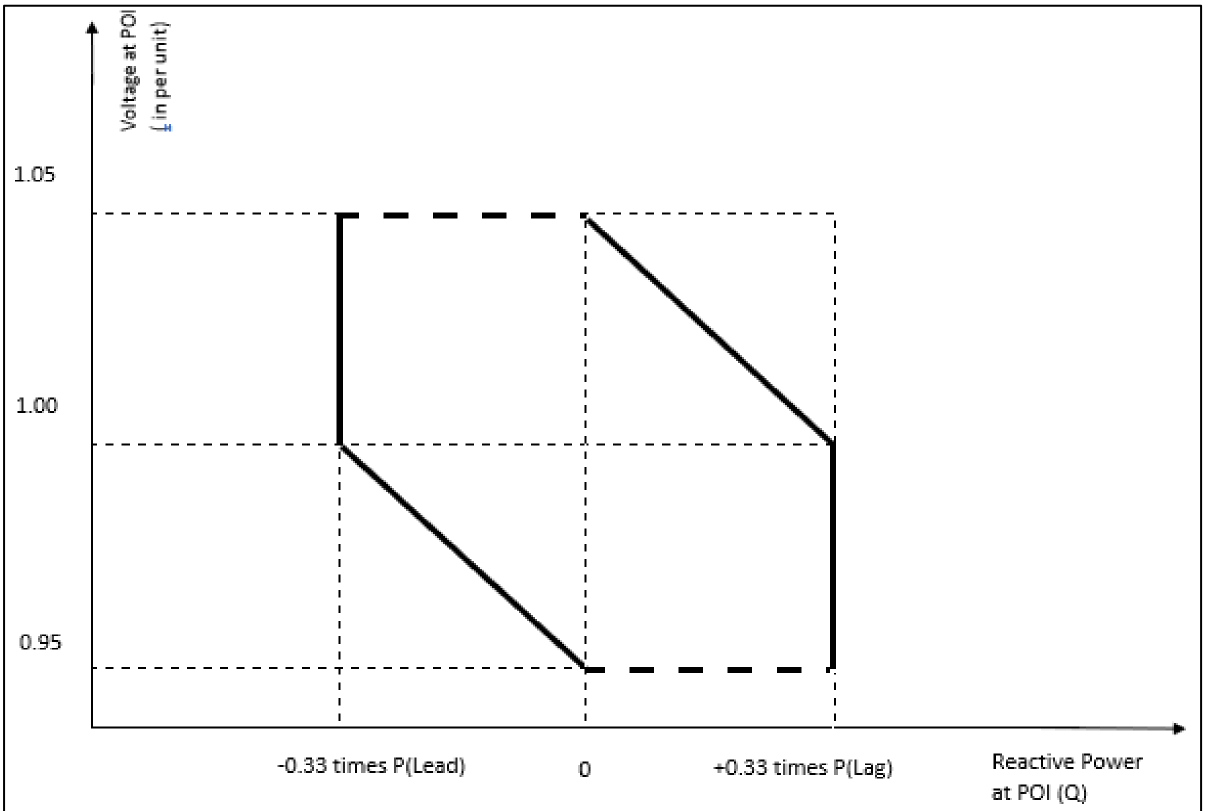
12. Total harmonic distortion (THD) - It is the ratio of the r.m.s value of the sum of all the harmonic components up to a specified order (H) to the r.m.s value of the fundamental component

$$\mathrm{THD} = \sqrt{\sum_{h=2}^{H} \left(\frac{Q_h}{Q_1}\right)^2}$$

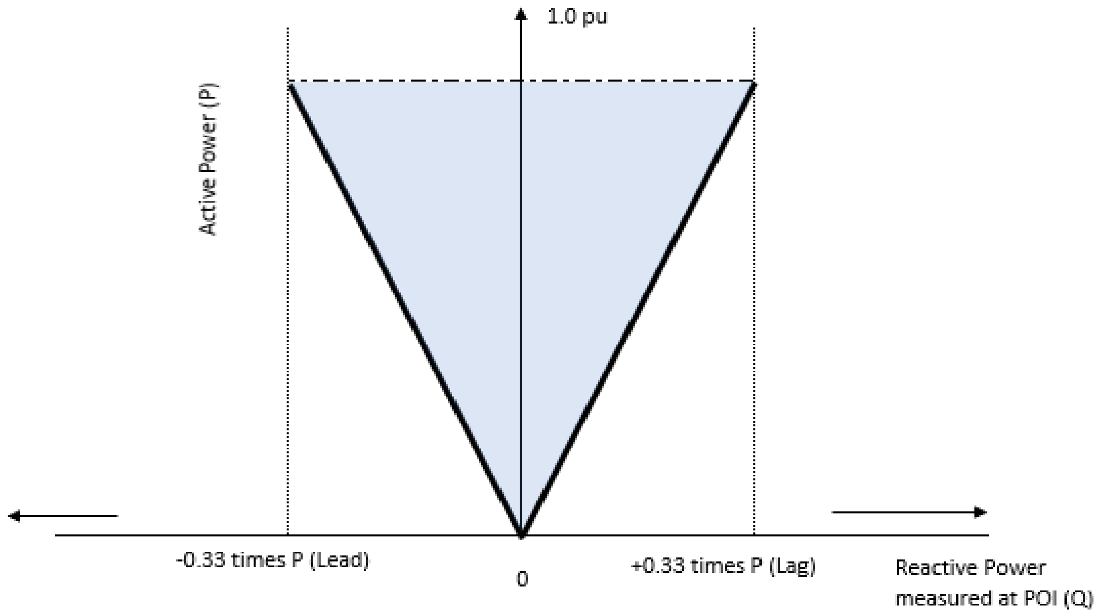
Q represents either current or voltage; Q_1 is the r.m.s. value of the fundamental component;

h is the harmonic order, Q_h is the r.m.s. value of the harmonic component of order h; H shall be considered 50.

Annexure-A1



Reactive power capability of plant at POI in terms of Voltage at POI and reactive power



Reactive power capability of plant at POI in terms of active power and reactive power measured at POI

FORMAT-CONN-TD-2

TECHNICAL CONNECTION DATA TO BE FURNISHED BY THERMAL/ HYDRO/ NUCLEAR GENERATING STATIONS INCLUDING PUMPED STORAGE PROJECTS(PSP) FOR SIGNING OF CONNECTIVITY AGREEMENT FOR INTERCONNECTION WITH THE INTER-STATE TRANSMISSION SYSTEM

A. Introduction

This document is designed to act as a guideline for exchange of technical connection data for the purpose of interconnection of the generation plant with ISTS along with exchange of accurate modelling data. Availability of accurate modelling data shall enable assessment of compliances of applicable regulations, adequacy of power system & assessment of equipment performance for secure and reliable interconnection with the ISTS Grid.

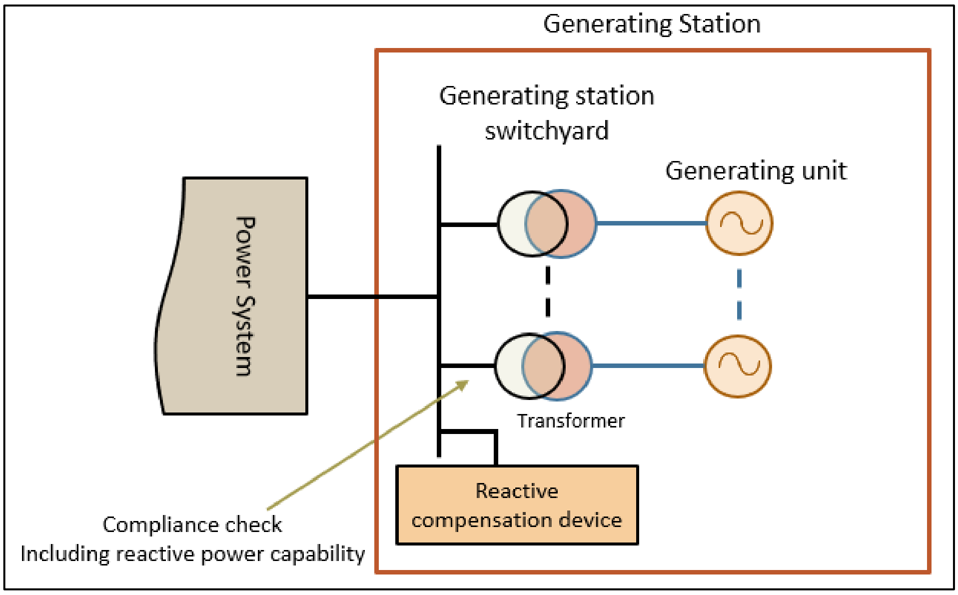
B. Regulation

CEA Technical Standards for Connectivity to Grid, 2007 and its amendments thereof: Clause 6.4d

"Provided that in order to carry out the said study, the requester shall present the mathematical model of the equipment in accordance with the requirements as stipulated by the Appropriate Transmission Utility or distribution licensee, as the case may be."

C. General Considerations

i. The compliances stipulated in CEA Technical Standards for Connectivity to Grid including reactive power capability of the unit shall be assessed at the unit level (high voltage terminal of generating unit).



ii. The applicant shall follow the industry best practices and applicable industry standards in respect of the equipment installation and its operation and maintenance.

D. Compliance with existing rules and regulations

All applicants seeking connection to the grid shall comply with all the applicable regulations as enacted or amended thereof from time to time, including the following:

i. Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007;

ii. Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010;

iii. Central Electricity Authority (Measures Relating to Safety & Electric Supply) Regulations, 2010;

iv. Central Electricity Regulatory Commission (Communication System for InterState Transmission of Electricity) Regulations,2017;

v. Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006;

vi. Central Electricity Regulatory Commission (Connectivity and General Network Access to the inter-State Transmission System) Regulations, 2022;

vii. Central Electricity Regulatory Commission (Fees and Charges for Regional Load Despatch Centres) Regulations, 2019;

viii. Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020;

ix. Central Electricity Regulatory Commission (Furnishing of Technical Details by the Generating Companies) Regulations, 2009;

x. Central Electricity Authority (Cyber Security in Power Sector) Guidelines, 2021;

xi. Any other regulations and standards as specified from time to time.

E. Description

i. Coal-fired thermal generation plant

Coal-fired power plants typically burn coal to heat a boiler that produces high-temperature, high-pressure steam that is passed through the turbine to produce mechanical energy. Synchronous machines coupled with the steam turbine convert mechanical energy into electrical energy at a suitable voltage level. Typical arrangement of coal-fired thermal generator is depicted in Figure-13.

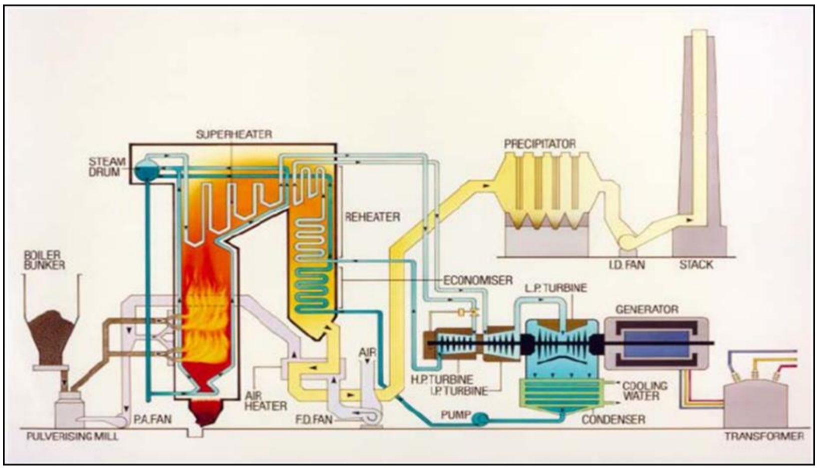


Figure-13: Typical schematic of coal fired thermal generation plant

Generally, coal-fired thermal generating units are high speed machines and therefore the construction of rotor is cylindrical in nature.

ii. Hydropower plant

Hydro Power Plant uses water as the source of energy wherein conversion of water kinetic energy is converted into mechanical energy by suitable turbines. The synchronous generator coupled with the turbine, in turn, converts mechanical energy into electrical energy at an appropriate voltage level. Typical arrangement of a hydro-power generating station is depicted in Figure 14. Based on the topology of quantum of water /storage, hydro-power plants are broadly classified into the following categories:

a. Run-of-river

Run of river hydropower projects have no, or very little, storage capacity behind the dam and generations are dependent on the timing and size of river flows.

b. Reservoir (HPP)

Reservoir-based hydropower schemes usually have dams for the storage of water and the large volume of water contained helps in regulating water flows during different seasonal conditions. A hydroelectric reservoir makes use of the potential energy of water for generating electricity. Water is held back by the dam, and released through a turbine, which in turn produces electricity. Reservoir capacities can be small or very large, depending on the characteristics of the site and the economics of dam construction.

c. Pumped storage (PSP)

Pumped-storage hydroelectricity (PSH), or pumped hydroelectric energy storage (PHES), is a type of hydroelectric energy storage used by electric power systems for load balancing. The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation. Low-cost surplus off-peak electric power is typically used to run the pumps. During periods of high electrical demand, the stored water is released through turbines to produce electric power.

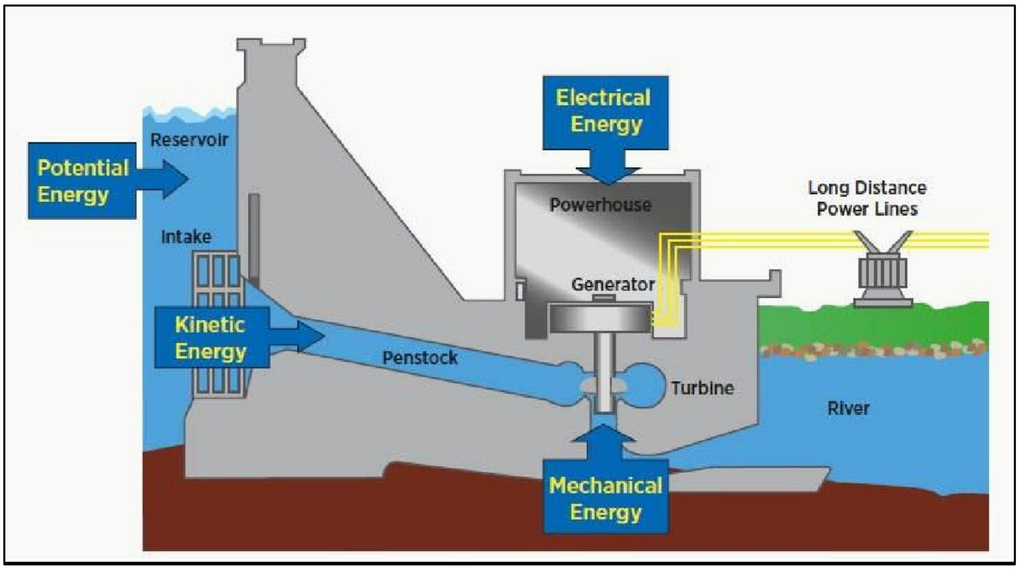


Figure-14: Typical schematic of a hydro power plant

Types of hydro- turbines

Based on the construction of turbines used within hydro-electric plants, it can be broadly classified into the following three types:

a) Pelton wheel turbine
b) Kaplan Turbine
c) Francis Turbine

iii. Gas power plant classification

The gas turbine power plants which are used in the electric power industry are classified into two main groups as per the cycle of operation and configuration:

a. Open cycle gas turbine (OCGT)

In the open cycle, air at the ambient condition is drawn into the compressor (either an axial-flow or centrifugal compressor) where its temperature and pressure are raised. The high-pressure air proceeds into the combustion chamber, where the fuel is burnt at constant pressure. The high-temperature gases then enter the turbine where they expand to the atmospheric pressure while producing power output. The exhaust gases leaving the turbine are thrown out (not recirculated), causing the cycle to be classified as an open cycle. All masses are typically on the same shaft (the compressor, combustion chamber, and turbine). This is also referred to as a "single-shaft" gas turbine as depicted in Figure-15.

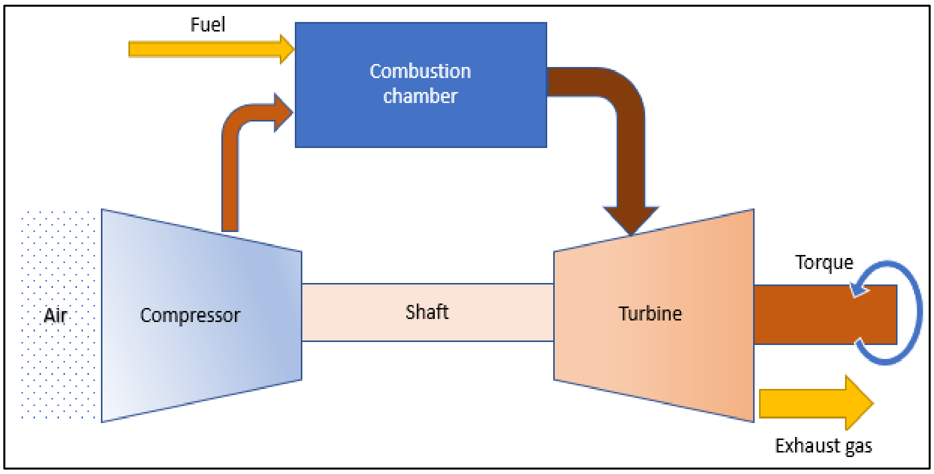


Figure-15: Open cycle gas turbine

b. Closed cycle gas turbine (CCGT)

In a closed cycle gas turbine, working fluid does not come in contact with atmospheric air. The compression and expansion process remain the same but the combustion process is replaced by a constant pressure heat addition process from an external source. The exhaust process is replaced by constant pressure heat rejection process to the ambient air. The exhaust gases leaving the turbine are cooled in heat exchanger called sink where it rejects heat. Therefore, in this cycle, the same working fluid is recirculated, causing cycle to be classified as close cycle as shown in Figure 16.

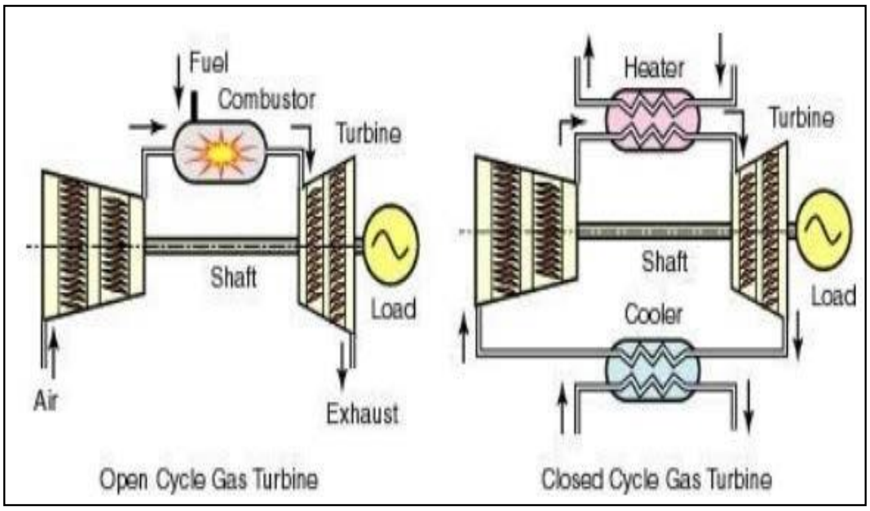


Figure 16: Typical Open and Close cycle Gas Turbine

iv. Reactive power capability of thermal generating unit

As per CEA Technical Standards for Connectivity to Grid, thermal generating unit shall be capable of operating at rated output for power factor varying 0.85 lagging (over-excited) to 0.95 leading (under-excited). Provided further that the above performance shall also be achieved with voltage variation of ± 5% of nominal, frequency variation of +3% and -5% and combined voltage and frequency variation of ±5%. However, for gas turbines, the above performance shall be achieved for voltage variation of ±5%.

During over-excited mode of operation (lagging power factor), the machine is required to deliver active and reactive power (Ex-Bus) simultaneously whereas during under-excited operation mode (leading power factor), the machine shall inject active power while absorbing reactive power (Ex-Bus). The convention to be followed in this regard is depicted in Figure-17.

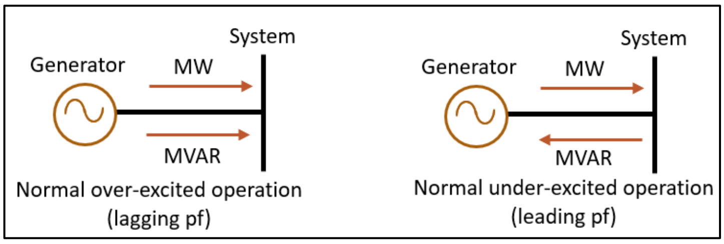


Figure-17: Leading and lagging operation of generator unit

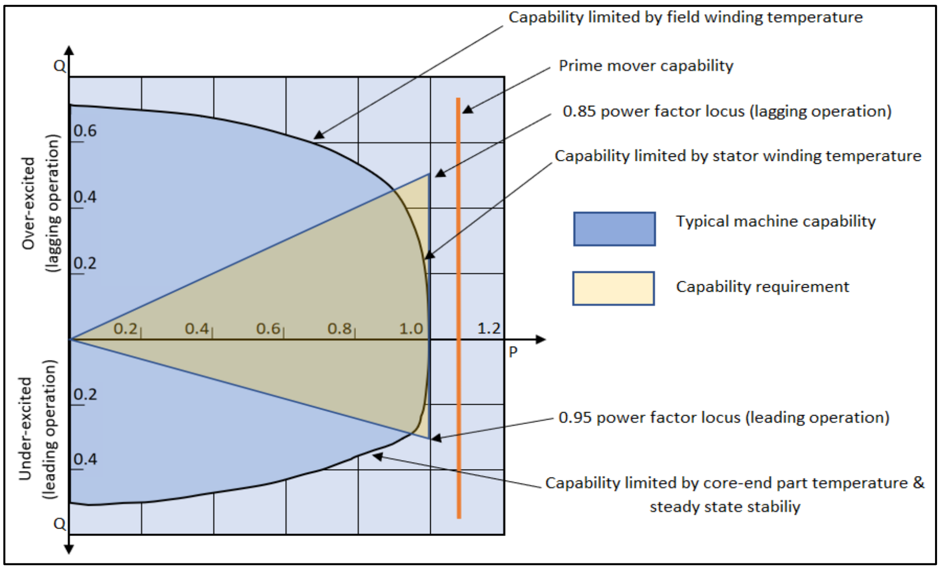


Figure-18: Typical reactive capability curve of thermal generating unit

The performance of machine is constrained due to rotor, stator & iron core parts temperature. Therefore, based on the limitations imposed due to rotor winding temperature, stator winding temperature, iron core parts temperature & stability limit, the final capability of the machines shall be arrived after considering such conditions. The reactive capability is expressed in terms of P-Q curve as depicted in Figure-18.

Synchronous machines shall be capable of demonstrating continuous rated output (active and reactive power) with the variations of ±5% voltage variations and frequency variations of + 3% and -5% alongwith combined voltage and frequency variations. The overall working envelope of machine considering both constraints (voltage and frequency) is shown in Figure-19. In addition to constraints indicated in the above P-Q curve, any other limitations including prime mover capability, Valve Wide Open Condition, etc. are also required for evaluating machine performance.

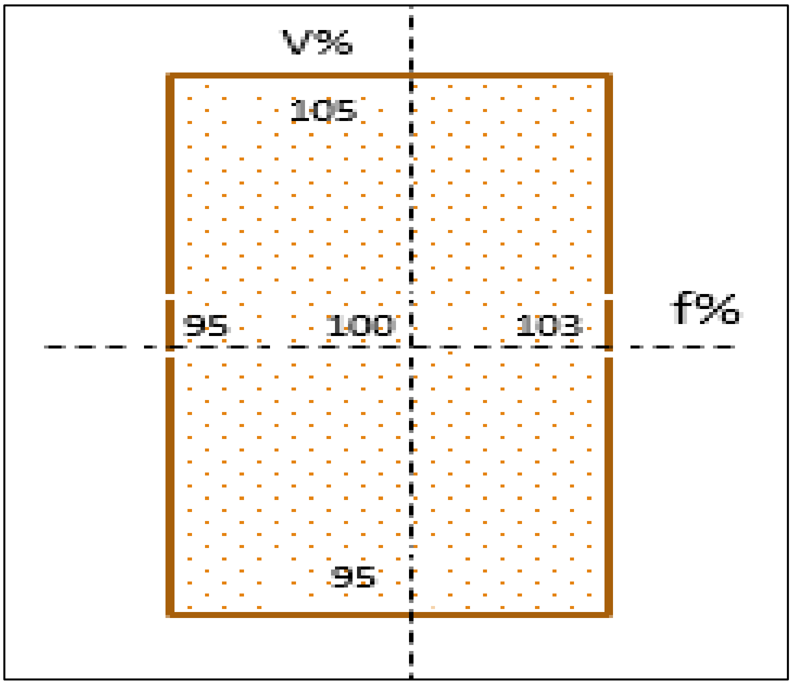


Figure-19: Combined voltage and frequency dependence on machine capability

v. Short circuit ratio (SCR) of Generating Unit

It is defined as the ratio of the field current required to generate rated voltage on an open circuit to the field current required to circulate rated armature current on sustained symmetrical short-circuit with the machine running at rated speed. It affects the physical size, operating characteristics and cost of the synchronous machine. For a lower value of SCR, the machine shall be very sensitive to the load variations and accordingly, the percentage variation in terminal voltage shall be higher. SCR is a measure of stability of an electromagnetic generator. Also, the synchronising power of machine with low SCR is less resulting in lower stability limit. The typical SCR derived from OCC and SCC are depicted in Figure-20.

$$SCR = \frac{I_f\ for\ rated\ open\ circuit\ voltage}{I_f\ for\ rated\ short\ circuit\ current} = \frac{oa}{od}$$

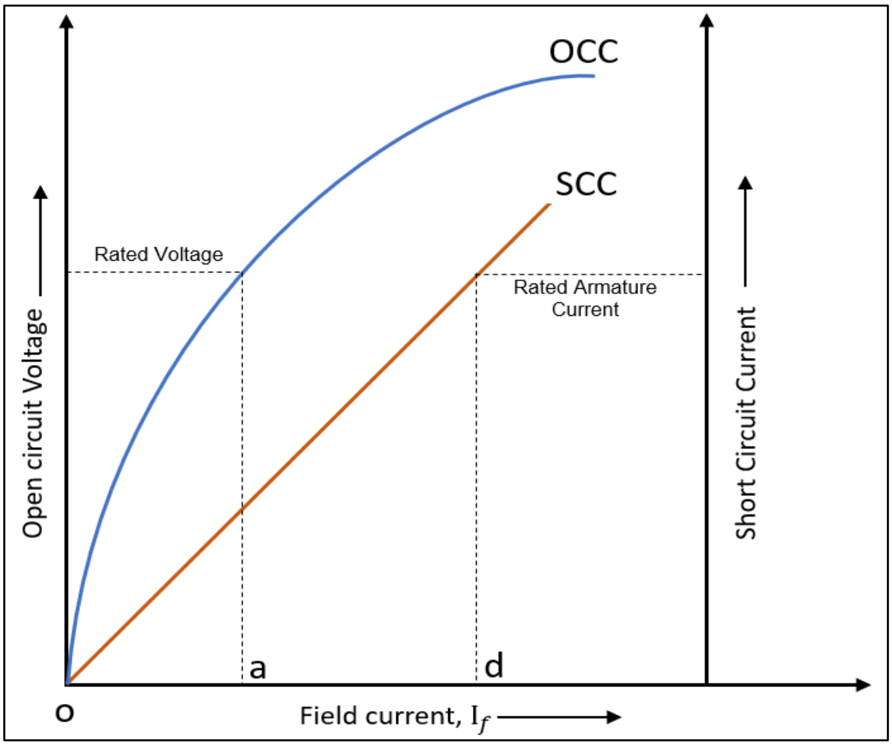


Figure-20: SCC and OCC characteristics

vi. Droop characteristics of Generating unit

Droop is one of the key parameter of the generating unit demonstrating the changes in active power in response to frequency changes outside the dead band as depicted in Figure-21. Droop corresponds to the deviation in frequency from the dead band *(*as a percentage of the nominal 50 Hz) that would result in a 100% change in generator MW output from the maximum level. Droop of a synchronous machine shall be evaluated using equation given hereunder.

$$\text{Droop \%} = 100\ \text{X} \frac{\Delta F / F}{\Delta P / P}$$

Δ is the frequency deviation beyond the upper or lower limit of generator's dead band (in Hz)

ΔP is active power change (in MW); P is the Maximum Operating Level (in MW)

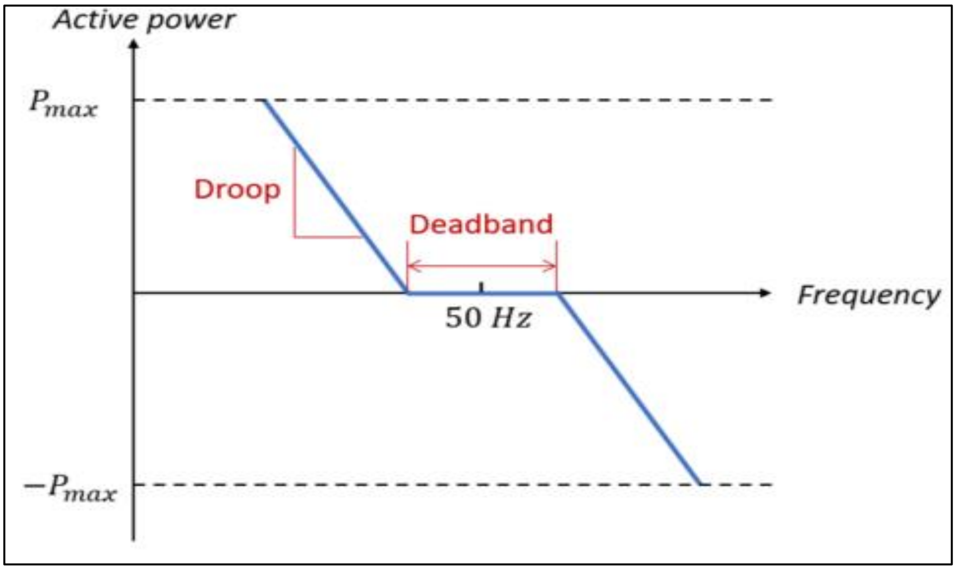


Figure-21: Droop characteristics of synchronous generator

vii. Simulation models for conventional generating stations

Conventional Generators shall be modelled using the generic model available in PSS/E model library. The applicable models for Synchronous machines, Excitation systems, Turbine-Governor and Power System Stabilizers are given hereunder *(Source: PSS/E model library)*. Applicants can also submit the model data corresponding to another PSS/E based generic model if the performance matches such model. Typical models used for simulating generating units are depicted in Figure-22.

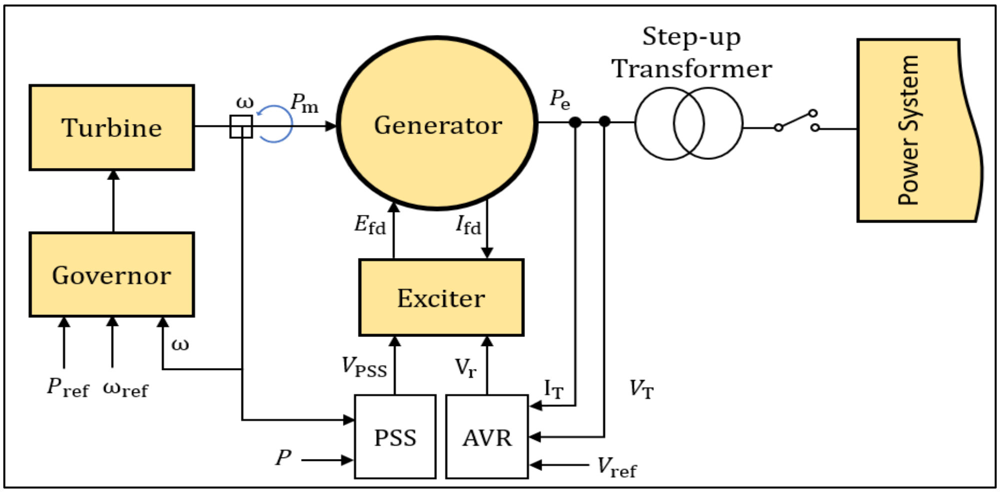


Figure-22: Components of conventional generating unit

(a) Generic Models for Synchronous machine

Hydro machines	Thermal, Gas, Diesel & Nuclear machines
GENSAL- Salient pole machine with quadratic saturation function GENSAE – Salient pole machine with exponential saturation function	**Round Rotor** GENROU –Machine model with quadratic saturation function GENROE – Machine model with exponential saturation function
	Salient Pole Machine GENSAL –Machine with quadratic saturation function GENSAE – Machine with exponential saturation function

(b) Excitation system model

PSS/E-based generic models for excitation systems are broadly classified into three groups:

- Type DC: for excitation systems with a DC exciter
- Type AC: for excitation systems with an AC exciter
- Type ST: for excitation systems with a static exciter

The following table shows the types of models separated into their respective groups.

DC exciter	AC exciter	Static excitation system
Type DC1A	Type AC1A	Type ST1A
Type DC2A	Type AC2A	Type ST2A
Type DC3A	Type AC4A	Type ST3A
Type DC4B	Type AC5A	Type ST4B
	Type AC6A	Type ST5B
	Type AC7B	Type ST6B
	Type AC8B	Type ST7B
		Type ST7C

(c) Power system stabilizer

Power System Stabilizer (PSS) is a control system applied at a generator that monitors variables such as current, voltage and shaft speed and sends the appropriate control signals to the voltage regulator to improve the damping of power system oscillations.

The most important aspect when considering a PSS model is the number of inputs. The following table shows the type of models separated based on the inputs:

Type	Inputs	Remarks
PSS1A	Single input	Two lead-lags

Type	Inputs	Remarks
		Inputs can either be speed, frequency, or power
PSS2B	Dual input	Rotational speed deviation and electrical power deviation as inputs Most common type Supersedes PSS2A (three versus two lead lags)
PSS3B	Dual input	Rotational speed deviation and bus frequency deviation as inputs Stabilizing signal is a vector sum of processed signals

(d) Generic models for steam turbine-governor

The following table is a list of generic models of steam turbines:

Type	Name	Remarks
BBGOV1	Brown – Boveri turbine governor model	Mainly used for a steam turbine with electrical damping feedback
IEEEG1	IEEE type 1 Speed-Governor Model	Used to represent non-reheat, tandem compound, and cross compound types.
IEEEG2	IEEE Type 2 Speed-Governing Model	Linearized model for representing a hydro turbine-governor and penstock dynamics
IEEEG3	IEEE type 3 turbine-governor model	Includes a more complex representation of the governor controls than IEEEG2
IEESGO	IEEE Standard Model	Simple model of reheat steam turbine
TGOV1	Steam-turbine governor	Mainly used for a steam turbine with reheater
TGOV2	Steam –turbine governor with fast valving	Fast valving model of steam turbine
TGOV3	Modified IEEE Type 1 Speed-Governing Model with fast	Modification of IEEEG1 for fast valving studies

Type	Name	Remarks
	valving	
TGOV4	Modified IEEE Type 1 Speed-Governing Model with PLU and EVA	Model of steam turbine and boiler, explicit action for both control valve (CV) and inlet valve (IV), main reheat and LP steam effects and boiler
TGOV5	IEEE Type 1 Speed-Governor Model Modified to Include Boiler Controls	Most common type of governor model, based on TGOV1 with boiler controls
TURCZT	Czech hydro or steam turbine governor model	General-purpose hydro and thermal turbine- governor model. Penstock dynamic is not included in the model
CRCMGV	Cross-compound turbine	-

(e) Generic models for hydro turbine-governor

The following table is a list of common generic models of hydro turbines:

Type	Name	Remarks
HYGOV	Hydro-turbine Governor	Simple hydro model with unrestricted head race and tail race, no surge tank
HYGOV2	Hydro-turbine Governor	Linearized hydro turbine governor model
HYGOVDU	Hydro turbine-governor model with speed dead band	Added asymmetrical deal band
HYGOVM	Hydro-Turbine Governor	Includes detailed representation of surge chamber
WEHGOV	Woodward Electric Hydro Governor Model	Woodward hydro governor with a non-linear model for penstock dynamics
HYGOVT	Hydro Turbine-Governor	Travelling-wave solution applied to

Type	Name	Remarks
	traveling wave model	penstock and tunnel
PIDGOV	Hydro Turbine Governor	Straight forward penstock configuration with PID governor
HYGOVR1	Fourth order lead-lag hydro-turbine	for a unit with digital controls, allows a nonlinear relationship between the gate position and power
TURCZT	Czech hydro or steam turbine governor model	General-purpose hydro and thermal turbine- governor model. Penstock dynamic is not included in the model
TWDM1T	Tail water depression hydro governor model 1	Same basic permanent and transient droop elements as the HYGOV model, but it adds a representation for a tail water depression protection system
TWDM2T	Tail water depression hydro governor model 2	Same as TWDM1T and uses a governor proportional-integral-derivative (PID) controller
WPIDHY	Woodward PID hydro governor model	Includes governor controls representing a Woodward PID hydro governor. The model includes a nonlinear gate/power relationship and a linearized turbine/penstock model.
WSHYDD	WECC double derivative hydro governor model	Double-derivative hydro turbine-governor mode. Includes two dead band, also includes a nonlinear gate/power relationship and a linearized turbine/ penstock model
WSHYGP	WECC GP hydro governor plus turbine model	WECC GP hydro turbine-governor model with a PID controller, penstock

Type	Name	Remarks
		dynamics are similar to those of the WECC WSHYDD

(f) Generic models for gas turbine-governor

The following table is a list of common generic models of gas turbines:

Type	Name	Remarks
GAST	Gas turbine governor	Simplified model for industrial gas turbine (i.e. OCGT)
GAST2A	Gas turbine governor	More detailed GT from GAST. Governor can beconfigured for droop or isochronous control. Includes temperature control
GASTWD	Woodward Gas Turbine-Governor model	Same detail of turbine dynamics as GAST2A but with a Woodward governor controls
WESGOV	Westinghouse Digital governor for GasTurbine	Westinghouse 501 combination turbine governor
GGOV1	GE General Governor/Turbine model	General purpose GE GT model (neglects ICV control)
PWTBD1	Pratt & Whitney Turboden turbine- governor	Turbine load PI control with valve and look-up table
URCSCT	Combined cycle, single shaft turbine- governor model	-
URGS3T	WECC gas turbine governor	-

Transfer function block diagrams of the above-mentioned generic models are given in **Annexure-6**.

Technical Connection Data and compliance Report submission by Generators (Thermal/Hydro/Nuclear) and PSP

A. General details

1.	Name of the Applicant Company	:	
2.	URN No.	:	
3.	Details of Grant of Connectivity (a) Connectivity Intimation No. (b) Date	:	
4.	Quantum of Connectivity Granted (MW) (Maximum injection & Maximum drawal to be indicated for PSP)	:	
5.	Location of Generation Plant Latitude Longitude	: : :	(The applicant shall also attach the Survey of India Toposheet indicating the location of the facility}
6.	Installed capacity of Generating station/PSP (MW)	:	
7.	Address for Correspondence	:	
8.	Contact Person 8.1 Primary Contact Person (a) Name (b) Designation (c) Phone No. (d) E-mail 8.2 Alternate Contact Person (a) Name (b) Designation (c) Phone No. (d) E-mail	:	
9.	Expected Date of Commercial Operation	:	

B. Technical Connection data

1. Details of Generation Plant /PSP

1.	Type of Generation Plant (Hydro, Thermal, Gas, Diesel, Nuclear, PSP, Nuclear)	:	
2.	Auxiliary Consumption (%)	:	
3.	Maximum Export Capacity Required (MW)	:	
4.	Maximum Import Capacity required This is the amount of import capacity that the site will require during startup (MVA)	:	
5.	Maximum power required by plant during motoring mode (in case of PSP) (MW) and duration of motoring mode considering reservoir size	:	
6.	Round trip Efficiency(%) for PSP	:	
7.	Rsesrvoir Details for PSP (MWL/ FRL/ MDDL) in Meters	:	
8.	Station house load during normal operating conditions (MW/MVAR)	:	
9.	Expected running regime e.g. base load, peaking, etc	:	
10.	Basic System details	:	The applicant shall submit the basic system details as per Annexure-1

2. Interconnecting Transmission Line (ITL)

1.	Name of Sending End S/s (Generator end)	:			
2.	Name of Receiving End S/s (ISTS end)	:			
3.	Voltage level (kV)	:			
4.	Length of ITL (Kms)	:			
5.	Tower Configuration (S/c, D/c, M/c)	:			
6.	Type of Conductor	:			
7.	OPGW available (Yes/No)	:			
8.	No. of Fibre in OPGW (24/48F)	:			
9.	OPGW/Line Shared with another GenCo or another plant of same owner	:			
		R (pu)		**X (pu)**	**B (pu)**
10.	Conductor positive sequence R X B parameters in pu/km/ckt (considering 100MVA base)				
11.	ITL positive sequence R X B parameters in pu/km/ckt (considering 100MVA base)				
12.	ITL zero sequence R X B parameters in pu/km/ckt (considering 100MVA base)				

Note: *Applicant shall attach the details of ITL as per* ***Annexure-2***

3. Generating Unit details

Sl. No.	Particulars	Unit – 1	Unit - 2	Unit – 3
1.	Unit Rating (MVA)			
2.	Rated terminal voltage (kV)			
3.	Rated power factor			
4.	Rated frequency (Hz)			
5.	Rated speed (rpm)			
6.	Rated excitation (in Amperes and Volts)			
7.	Type of synchronous machine (Round rotor or salient pole), Nos. of Poles			
8.	Type of Generator Cooling System (Water, Hydrogen, etc.)			
9.	Normal Max. Continuous Generation Capacity at Normal operating temperature (MW)			
10.	Normal Max. Continuous Export Capacity at Normal operating temperature (MW)			
11.	Maximum (Peaking) generating Capacity at min ambient air temperature (MW)			
12.	Maximum (Peaking) Export Capacity at min ambient air temperature (MW)			
13.	Minimum Continuous Generating Capacity (MW)			
14.	Minimum Export Generating Capacity (MW)			
15.	Normal Maximum Lagging MVAR at rated MW output			

16.	Normal Maximum Leading MVAR at rated MW output			

Note: *Applicant shall append unit nos. in case no. of units are more than 3*

4. Generator Data for Fault (Short Circuit Studies)

1.	Direct Axis Transient Reactance	X_d'	
2.	Sub-transient Reactance	X_d"	
3.	Synchronous Reactance	X_s	
4.	Zero Sequence Reactance	X_o	
5.	Negative Sequence Reactance	X_2	

5. Dynamic Simulation Data

1.	Direct Axis Positive Phase Sequence Synchronous Reactance in pu	X_d	
2.	Quadrature Axis Positive Phase Sequence Synchronous Reactance in pu	X_q	
3.	Direct Axis Transient Reactance (unsaturated) in pu	X_d'	
4.	Quadrature Axis Transient Reactance (unsaturated) in pu	X_q'	
5.	Sub-Transient Reactance (unsaturated) in pu	X_d"	
6.	Armature Leakage Reactance in pu	X_l	
7.	Direct Axis Transient open circuit Time Constant (Secs)	T_{do}'	
8.	Direct Axis Sub-transient open circuit Time Constant (Secs)	T_{do}"	
9.	Quadrature Axis Transient open circuit Time Constant (Secs)	T_{qo}"	

10.	Quadrature Axis Sub-transient open circuit Time Constant (Secs)	T_{qo}”	
11.	Inertia constant of total rotating mass (generator, AVR, turbo-governor set) H in MWs/MVA	sec	
12.	Speed Damping D		
13.	Saturation constant S (1.0) in p.u.		
14.	Saturation constant S (1.2) in p.u.		

Note:

1. *Applicant shall attach the **Generator open circuit and short circuit characteristics** indicating the following graphs:*

    a. *Graph of excitation current versus terminal voltage and stator current;*

    b. *No load excitation current;*

    c. *Excitation current at rated current.*

2. *Applicant shall attach the **Generator** V-curve indicating terminal (armature) current versus generating unit field voltage.*

3. *Applicant shall attach the Complete Generator OEM Technical Datasheet indicating generator parameters including impedance & time constants, etc*.

6. Excitation System

Type of Automatic Voltage Regulator (AVR)		
1.	Manufacturer and product details	
2.	Type of control system:- Analogue or digital	
3.	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
Type of excitation system		
4.	Static excitation system **OR** Indirect excitation system (i.e. rotating exciter) AC exciter, or DC exciter	
5.	**Details of AVR converter** - Rated excitation current (converter rating in Amperes)	
6.	Six pulse thyristor bridge or PWM converter	
Source of excitation supply		
7.	Excitation transformer or auxiliary supply (Details thereof)	
8.	If excitation transformer, nameplate information such as type of transformer, HV and HV winding ratings, positive and zero sequence impedance, tap positions, voltage step per tap is required.	
Excitation limiters		
9.	Under Excitation Limiters settings	
10.	Over Excitation Limiters settings	
11.	Voltage/frequency limiter	
12.	Stator current limiter	
13.	Minimum excitation current limiter	
Power System Stabilizer		

14.	Is the AVR equipped with a PSS (In accordance with CEA Technical Standards for Connectivity to Grid, 2007 as amended)	
15.	How many input Channels does the PSS have? (speed, real power output or both	
	If the PSS uses speed, is this a derived speed signal (i.e. synthesized speed signal) or measured directly (i.e. actual rotor speed)?	

Note:

1. *Applicant shall attach the drawings of the excitation system (supplied by OEM) along with excitation system SLD.*

2. *Applicant shall attach the saturation curves of the exciter (if applicable – see Type AC and DC)*

7. Two Winding Transformer Data

1.	Rating Capacity (HV-LV)	
2.	Voltage rating (kV) (Line to Line)	
3.	Number of Power Transformers	
4.	Cooling Type	
5.	Rating at different cooling as mentioned above	
6.	Type of Transformer (Constant Ohmic impedance/ Constant percentage Impedance)	
7.	Transformer vector Group	
8.	Tap changer (ON Load Tap changer)	
9.	Number of steps and step size	
10.	Neutral earthing (solid or through reactance)	
11.	% Impedance at 75ºC (HV-LV)	
12.	% Resistance at 75ºC (HV-LV)	
13.	% Reactance at 75ºC (HV-LV)	
14.	Transformer positive sequence resistance (R_1) in pu	
15.	Transformer positive sequence reactance (X_1) in pu	
16.	Transformer zero sequence resistance (R_0) in pu	
17.	Transformer zero sequence reactance (X_0) in pu	
18.	Nature of Tap Changer (on load/off load)	
19.	Number of steps and step size	

8. Three Winding Transformer Data

1.	Rating Capacity (HV-LV, HV-IV, IV-LV)	
2.	Voltage Ratio (Line to Line)	
3.	Number of Power Transformers	
4.	Cooling Type	
5.	Rating at above different cooling	
6.	Type of Transformer (Constant Ohmic impedance/ Constant percentage impedance)	
7.	Transformer Vector Group	
8.	Tap changer (ON/OFF Load Tap changer)	
9.	Number of steps and step size	
10.	Neutral earthing (solid or through reactance)	
11.	% Impedance at 75ºC (HV-IV)	
12.	% Resistance at 75ºC (HV-IV)	
13.	% Reactance at 75ºC (HV-IV)	
14.	% Impedance at 75ºC (HV-LV)	
15.	% Resistance at 75ºC (HV-LV)	
16.	% Reactance at 75ºC (HV-LV)	
17.	% Impedance at 75ºC (IV-LV)	
18.	% Resistance at 75ºC (IV-LV)	
19.	% Reactance at 75ºC (IV-LV)	
20.	Transformer Vector group	
21.	Positive sequence resistance (R_1HL_1) between HV/IV in pu	
22.	Positive sequence reactance (X_1HL_1) between HV/IV in pu	
23.	Zero sequence resistance (R_0HL_1) between HV/IV in pu	

24.	Zero sequence reactance (X_0HL_1) between HV/IV in pu	
25.	Positive sequence resistance (R_1HL_2) between HV/LV in pu	
26.	Positive sequence reactance (X_1HL_2) between HV/ LV in pu	
27.	Transformer zero sequence resistance (R_0HL_2) between HV/LV in pu	
28.	Zero sequence reactance (X_0HL_2) between HV/LV in pu	
29.	Positive sequence resistance ($R_1L_1L_2$) between IV/ LV in pu	
30.	Positive sequence reactance ($X_1L_1L_2$) between IV/LV in pu	
31.	Zero sequence resistance ($R_0L_1L_2$) between IV/LV in pu	
32.	Zero sequence reactance ($X_0L_1L_2$) between IV/LV in pu	
33.	Positive sequence resistance ($R_1HL_1//L_2$) between HV/(IV+LV) in pu	
34.	Positive sequence reactance ($X_1HL_1//L_2$) between HV/(IV+LV) in pu	
35.	Zero sequence resistance ($R_0HL_1//L_2$) between HV/(IV+LV) in pu	
36.	Zero sequence reactance ($X_0HL_1//L_2$) between HV/(IV+LV) in pu	

Note: *Applicant shall attach the OEM Technical datasheet for Generator step-up transformer indicating rating, impedance, short circuit parameters.*

9. Shunt Reactor

1.	Rated Voltage (Line to Line) (1.0 pu)	:	
2.	Rated capacity at rated voltage (MVAR)	:	
3.	Three phase unit or Single-phase unit	:	
4.	Cooling system	:	
5.	Rated current	:	
6.	Construction type (Core/Shell)	:	
7.	Neutral Grounding (Solidly earthed/ through reactor)	:	
8.	Range of constant impedance	:	Upto …… pu voltage
9.	Reactor knee point voltage (pu)	:	

***Note**: Applicant shall attach the OEM Technical datasheet for Shunt reactor indicating rating, impedance, knee point voltage.*

10. Technical particulars of Turbine:

Applicant shall submit the turbine details of the generating unit as per **Annexure-3.**

11. 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. 104 (Ethernet), etc.)

3.	Write here the communication media, interface and capacity being targeted for Connectivity for Data and voice Communication	:	(Communication media: For example fibre optics, PLCC, etc. Interface: Ethernet, G.703 etc Capacity: 1200baud, 64Kbps, 2 Mbps, etc)

12. Modeling details:

Applicant shall submit the model parameter data for each component of Generating Unit including Synchronous machine model, excitation system model, turbine governor (as per applicable configuration), power system stabilizer as per **Annexure-4**.

13. PSS/E Single Line Diagram (Single Machine Infinite Bus Model)

Note: Applicant shall attach herewith PSS/E based SLD of generation plant indicating each generating unit.

14. Open circuit magnetization curve

Note: Applicant shall attach herewith the Open circuit magnetization curve of generating unit.

15. Dynamic simulation test

Note: Applicant shall attach herewith the plant response with tables/ appropriate plots of electrical quantities including Voltage, Current, Active power, Reactive Power (Plant and Unit) for all compliances as per CEA Technical Standards for Connectivity to Grid as per **Annexure-5**.

C. The applicant has attached a copy of the affidavit towards the fulfillment of terms and conditions as specified in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended as per **Annexure-A.**

D. Applicant has submitted the details including terminal bay equipment data, Communication & metering data under its scope as per **Annexure-B.**

E. Applicant has undertaken studies including voltage stability, protection co-ordination, machine dynamics, resonance, sub-station grounding and fault duties of equipment to be installed at generating station premise (as the case may be) so that the overall system performance is not constrained during steady state and contingency conditions. The sub-station grounding design should be such that the earth fault factor of the system should remain below 1.4. Sub-station grounding should be in line with provisions of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010.

Resonance including ferro-resonance studies has been carried out by applicant covering possible network topologies for excitation of series/parallel resonant point by network impedance scanning and they shall implement the remedial measure at their end in this context.

F. Applicant has further attached the following drawings (soft copy) alongwith application:

1) Site plan in appropriate scale indicating Generators, Transformer, Site building (pdf & autocad copy)

2) Site plan of the ISTS substation at which connectivity granted (pdf and/or autocad copy)

3) General Arrangement (GA) drawing indicating proposed facility

4) Electrical Single Line Diagram (SLD) of the proposed facility detailing all significant items of plant (pdf & autocad copy)

5) Electrical Single Line Diagram (SLD) of ISTS substation at which connectivity granted (pdf & autocad copy)

6) Sub-Station Automation System (SAS) ring diagram indicating interconnections of various IEDs/Engg PC/Gateway etc.

7) Equipment drawings for confirming the ratings

8) CRP (Control & Relay Panel) & scheme drawings containing protection details of the transmission line

9) PLCC/FOTE drawings for the transmission lines under the scheme

10) Details of Communication System

11) Detailed calculation sheet for deriving the maximum ampacity of the conductor as per IEEE-738 Standards, Central Electricity Authority (Technical Standards for Connectivity to Grid), Regulations 2007 and its amendments thereof, Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 & CEA Transmission Planning Criteria, 2013 and its amendments thereof.

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

Authorized Signatory of Applicant

Name:

Designation:

Seal:

Place:

Date:

Annexure-A

Affidavit to be submitted by the grantee (on non-judicial Stamp Paper of Rs. 10/-) towards fulfilment of various compliances as specified in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof (to be provided by company authorized signatory duly authorized vide board resolution)

Date………………

Connectivity Intimation No: ……..… Connectivity intimation date: …..……

I …………(Name)……..…S/o Shri ……… (Father's name) working as ………………….. (designation) in ……………… (Name of the Applicant organization / entity) ……..….., having its registered office at …………… (Address of the Applicant organization / entity) …………, do solemnly affirm that ..…..…… (name of generating station along with Installed capacity & location of connectivity granted by CTU) complies with all applicable provisions as laid out in the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof and CERC (Connectivity and General Network Access to Inter State Transmission System) Regulations, 2022 and directions through various orders including the following:

1. The excitation system for every generating unit:

    a) have state of the art excitation system

    b) have Automatic Voltage Regulator (AVR) (for generators of 100MW rating and above)

    c) The Automatic Voltage Regulator of generator of 100 MW and above shall include Power System Stabilizer (PSS)

2. The short circuit ratio of generator is as per IEC-34

3. The generator transformer winding has delta construction on low voltage side and star connection on high voltage side. Star point of high voltage side is effectively(solidly) earthen so as to achieve earth fault factor of 1.4 or less

4. All generating machines irrespective of capacity have electronically controlled governing system with appropriate speed/load characteristics to regulate frequency. The governors of thermal generating units have a droop of 3 to 6% and those of hydro generating units 0 to 10%.

5. Generating Unit is capable of operating at rated output for power factor varying between 0.85 lagging (over-excited) to 0.95 leading (under-excited).

6. The above performance is also achieved with voltage variation of ± 5% of nominal, frequency variation of + 3% and -5% and combined voltage and frequency variation of ±5%. However, for gas turbines, the above performance shall be achieved for voltage variation of ±5%. Provided also that all hydro-electric generating units, where Techno-Economic Concurrence has been accorded by the Authority (CEA) under section 8 of the Act, shall be capable of operating at the rated output at the power factor as specified in such techno-economic concurrence.

7. The coal and lignite based thermal generating unit is capable of generating up to 105% of Maximum Continuous Rating (MCR) (subject to maximum load capability under Valve Wide Open Condition) for short duration to provide the frequency response.

8. The hydro generating units are capable of generating up to 110% of rated capacity (subject to rated head being available) on continuous basis.

9. Every generating unit have standard protections to protect the units not only from faults within the units and within the station but also from faults in transmission lines. For generating unit having rated capacity greater than 100 MW, two independent sets of protections acting on two independent sets of trip coils fed from independent Direct Current (DC) supplies shall be provided. The protections are not be limited to the Local Breaker Back-up (LBB) protection

10. Hydro generating units having rated capacity of 50 MW and above are capable of operation in synchronous condenser mode, wherever feasible. Provided that hydro generating units commissioned on or after 01.01.2014 and having rated capacity of 50 MW and above shall be equipped with facility to operate in

synchronous condenser mode, if necessity for the same is established by the: interconnection studies.

11. Bus bar protection has been provided at the switchyard of generating station.

12. Automatic synchronization facilities have been provided.

13. The station auxiliary power requirement, including voltage and reactive requirements, did not impose operating restrictions on the grid beyond those specified in the Grid Code.

14. In case of hydro generating units, self-starting facility has been provided. The hydro generating station also have a small diesel generator for meeting the station auxiliary requirements for black start.

15. The sub-station associated with the generating station is in conformity with the provisions specified in respect of “Sub-station” under Part III of CEA (Technical Standards for Connectivity to Grid) Regulations, 2007 and its amendments thereof.

I am aware that in case any discrepancies / incompleteness are found in the documents submitted to CTU, the connection offer (CONN-TD-5) / connectivity agreement (CONN-CA-6) shall not be processed further. I am also aware that if at any stage any falsity / inaccuracy / incorrectness is detected in the documents / statements …….. (name of generator) shall be solely liable for disconnection from the Grid along with all associated liabilities / consequences in this regard.

Name of the Authorised Signatory:

Signature:

Company Stamp (mandatory):

Annexure-B

Data Format-I

A. Generation switchyard/Pooling Station end:

1.	Name of substation and ownership:	
2.	Name of the bay and bay identification number:	

B. Sub-station (ISTS) End at which Connectivity is granted:

1.	Name of substation and ownership:	
2.	Name of the bay and bay identification number:	

Data Format-II-A

Equipment to be provided in the allocated bay meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof

Bus switching scheme:

A. Generation/Pooling Station end: [……………………….]

B. ISTS end: […………….]

Equipment Details:

Sl. No.	Name of Equipment	Generation Switchyard /Pooling Station end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/ MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
For GIS Substation							
1	Circuit Breaker (with PIR /CSD (if required))						
2	Disconnecting Switch						
3	Maintenance Earthing Switch						
4	High speed Earthing switch						
5	CT with core details						
6	Bus PT						

Sl. No.	Name of Equipment	Generation Switchyard /Pooling Station end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/ MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
7	Surge Arrester						
For AIS Substation							
1	Circuit Breaker (with PIR /CSD if required))						
2	Isolator (with no. of Earth Switch as required)						
3	CT with core details						
4	CT (Metering)						
5	Line CVT						
6	Bus CVT						
7	PT (Metering)						
8	Wave trap						
9	Surge Arrester						
10	ICT						
11	Bus Reactor						
12	Line Reactor						
13	NGR						
14	NCT						
15	ESS (Energy Storage System)						

Sl. No.	**Name of Equipment**	**Generation Switchyard /Pooling Station end**			**ISTS Substation End at which Connectivity is granted**		
		Type (AIS/GIS/ MTS)	**Nos**	**Ratings**	**Type (AIS/GIS/ MTS)**	**Nos**	**Ratings**
16	Any other equipment details (……)						

Note: *In case of more than two substations, the same shall be appended.*

Data Format-II (B)

Protection Equipment to be provided by applicant shall be meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof and shall be compatible & matching with the equipment installed at other end

(Please specify type, make and model of all main relays as applicable)

Name of Substation and Voltage level:

A. Generation end/Pooling substation end and Voltage Level:

B. Connectivity substation end and Voltage Level:

Name of Lines along with Tower Configuration (S/c, D/c, M/c**):**

Type of Conductor: (Bundle Configuration, Dia/ Type and Ampacity)

Protection Details:

Sl. No.	Description	Generation Switchyard / Pooling station end	ISTS Substation End at which Connectivity is granted
		Protection Type, Make and Model	
1.	Line protection relay MAIN-I (Distance / Differential)		
2.	Line protection relay MAIN-II (Distance / Differential)		
3.	Auto reclose relays		
4.	Bay Control Unit		
5.	Any Other Protection Equipment		

***Note**: In case of more than two substations, the same shall be appended.*

Data Format-III (A)

System Recording Equipment to be provided in the allocated bay meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof

Sl. No.	Name of Equipment's	Generation Switchyard / Pooling Station end		ISTS Substation End at which Connectivity is granted	
		Nos.	Ratings	Nos.	Ratings
1.	Event Logger				
2.	Disturbance recorder				
3.	Fault locator				
4.	PLCC details of transmission line				
5.	FOTE details				
6.	Any other equipment (Please indicate)				

***Note**: In case of more than two substations, the same shall be appended.*

Data format-III (B)

Communication Equipment details upto Data Collection Point SCADA equipment shall be meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof and shall be compatible to facilitate exchange of data with the existing system installed in the ISTS network

Sl. No	Name of Equipment	Nos.	Description
1.	**Data Acquisition System** - Remote Terminal Unit/SAS/DAS Gateway		
2(a)	**Communication Equipment** SDH required if any i. At the Generating/Pooling station ii. At data collection point (DCP)		
2(b)	**Approach Cable & FODP** i. At the Generating/ Pooling station ii. At data collection point (DCP)		
3	**WAMS** Phasor Measurement Unit(s) for measuring three phase current of all the feeders and three phase bus voltage at *220kV and above Generator		

***Note**: PMU locations shall be as per latest prevailing guidelines of CEA/Prevailing standards*

Data Format –III (C)

Cyber Security compliance as per CEA (Cyber Security in Power Sector) Guidelines 2021

Sl. No.	Name of Equipment	Nos.	Remarks
1.	**Perimeter security** Redundant Firewalls between SAS Gateway/RTU and FOTE		

Data Format –III (D)

Format for Communication inputs for Generator

A. Generator connectivity details with ISTS Station to be provided

1	Generator location	
	Common Pooling Station (CPS) Location (if exists)	
2	Generator Connectivity with CPS (33/220/400kV voltage)	
	Line length from Gen to CPS in km	
3	Provision of communication from pre pooling station to CPS (Fibre/ Leased Line/ Others)	

B. Bay details at ISTS S/s

Sl. No.	Description	
1	Ownership (Gen/ISTS S/s Owner)	
2	Voltage level (220/400kV/Other)	
3	ISTS Substation from where connectivity granted	
4	Bay Number/s	

C. Communication Equipment details along with PMU

Sl. No.	Data Type	Gen End	ISTS S/s End	
		Installed /Provisioned	Scope (With Gen or ISTS S/s Owner)	Installed /Provisioned
1	Approach cable			
2	FODP			
3	PMU			
4	FOTE			

D. FOTE Details

Sl. No.	Particulars	Gen End	ISTS S/s end
1	Make		
2	Model		
3	Capacity (e.g. STM16)		
4	No. of supported optical directions (e.g. 5 MSP)		

Data format-IV

Details of the modification/alteration to existing facilities for accommodating proposed connection and its estimated cost

Data format -V

Communication Link details up to ISTS Data Collection Point

Requirement of Channels:

i. 2 Nos Data Channel (600Baud) /64 Kbps or Ethernet channel for RTU/SAS/DAS

ii. 1 No Speech channel

iii. 1 No. Data Channel (2 Mbps) for PMU

Data Collection Point for: Generating/Pooling Station Name

Data Collection Point (DCP): Name of ISTS Station

Wideband Link (Configuration of Data & Voice channel in wideband Link by Regional ULDC Team)**: -**

Channel: DCP Name- Respective RLDC

Data format-VI

Site responsibility schedule

A. Principle & Procedure:

The responsibility of control, operation, maintenance & all matters pertaining to safety of equipment's and apparatus at the connection point shall lie with the connectivity grantee. The grantee may enter into a separate O&M contract with the owner of the substation based on mutually agreed terms and conditions for ease of day-to-day O&M of the equipment which are located in the premises of the substation.

List of equipment and their ownership at the connection point:

Sl. No.	Name of Equipment	Ownership	
		Generation Switchyard / Pooling Station end	ISTS Substation end at which Connectivity is granted
1.	Circuit Breaker (with PIR /CSD if required))		
2.	Isolator (with no. of Earth Switch as required)		
3.	Disconnecting Switch(For GIS)		
4.	Maintenance Earthing Switch (For GIS)		
5.	High speed Earthing switch (For GIS)		
6.	CT		
7.	CT (Metering)		
8.	Line CVT		

Sl. No.	Name of Equipment	Ownership	
		Generation Switchyard / Pooling Station end	**ISTS Substation end at which Connectivity is granted**
9.	Bus CVT		
10.	PT (Metering)		
11.	Wave trap		
12.	Surge Arrester		
13.	ICT		
14.	Bus Reactor		
15.	Line Reactor		
16.	NGR		
17.	NCT		
18.	ESS (Energy Storage System)		
19.	Any other Equipment (….)		

Annexure-1

Basic System details

Sl. No.	Description	Values
1	System operating voltage	
2	Maximum voltage of the system (rms)	
3	Rated frequency	
4	Nos. of phases	
5	Rated insulation levels	
i.	Impulse withstand voltage for (1.25/50 micro second) - Transformer and Reactors - For other equipment - For insulator string	
ii.	Switching impulse withstand voltage (250/2500 micro second) dry and wet	
iii.	One-minute power frequency dry withstand voltage (rms)	
iv.	One-minute power frequency dry and wet withstand voltage (rms)	
6.	Corona extinction voltage	
7.	Max. radio interference voltage for frequency between 0.5MHz and 2MHz	
8.	Minimum creepage distance for insulator string/longrod insulators/ outdoor bushings	
9.	Minimum creepage distance for switchyard equipment	
10.	Max. fault current capacity (kA for …sec)	

Annexure-2

Data pertaining to interconnecting transmission line

A. Conductor		
i.	Name of conductor	
ii.	Outside diameter	
iii.	DC Resistance (ohm/km)	
iv.	Number of conductors in bundle	
v.	Bundle spacing (mm)	
vi.	Maximum operating Temperature (degree C)	
vii.	Ampacity at maximum operating Temperature (A) with calculation sheet as per IEEE 738 & CEA Technical standard/CEA Planning criteria)	
B. Earth Wire		
i.	Diameter of Earthwire	
ii.	DC Resistance (ohm/km)	
C. OPGW		
i.	OPGW diameter (mm)	
ii.	OPGW cross-section area (mm^2)	
iii.	Number of Strands	
iv.	Diameter of each strands	
v.	DC Resistance (Ohms/km)	
vi.	Short Circuit Current (kA)	
vii.	OPGW Sag - Tension chart	
viii.	Fiber type considered in OPGW	
ix.	No. of fibers available for use	
x.	Fiber loss (dB) Attenuation	

	Chromatic Dispersion	
xi.	FODP terminations capacity	
D. Communication Equipment		
i.	Transmission Equipment (SDH) capacity (STM4/16)	
ii.	Optical Directions supported	
iii.	Make and model of Transmission Equipment	
iv.	Ethernet card/ ports details and availability for use	

Annexure-3

1. Turbine Details (Thermal)

Category	Parameter Description	Data
Manufacturer of turbine	Manufacturer and name plate details Rating of turbine	
Type of Governor	Electro-mechanical governor	
	Digital electric governor	
	Block diagram of the speed governor	
Ramp rates	How fast can the turbine increase and/or decrease load, specified in MW/min	
	Stroke limits of speed changer (values of full stroke, full load and no-load in mm)	
Droop	Droop setting (% on machine base)	
	Frequency influence limiters - Maximum frequency deviation limiter (eg +/-2 Hz) - Maximum influence limiter (eg 10% of rating)	
Dead band	Details of frequency dead band (typically in Hz)	
Steam turbine	**Tandem compound**: all sections on one shaft with a single generator	
	Cross compound: consists of two shafts, each connected to a generator and driven by one or more turbine section	
	Turbine sections: High pressure (HP), intermediate pressure (IP) and low pressure (LP)	
	Reheat or non-reheat: In a reheat, steam upon leaving HP section returns to boiler where it passed through reheater before entering IP section	

Category	Parameter Description	Data
	Valves: - Main inlet stop valve (MSV) - Governor control valve (CV) - Reheater stop valve (RSV) - Intercept valves (IV)	
	Turbine control action: - Boiler follow mode - Turbine follow mode - Coordinated control	
	Fast valving /bypass operation	
	Block diagram of the turbine load control	
	Reheater volume (m^3), volume flow (kg/s), and average specific volume (m^3/kg)	

2. Turbine Details-Hydro (to be filled in for the HPP and PSP separately)

Category	Parameter Description	Data
Type of prime mover	Hydro-electric turbine Other (Pumped storage)	
Manufacturer of turbine	Manufacturer and name plate details	
Modes of operation	Type of modes of operation capable: - Generator - Pump storage - Synchronous condenser	
Governor	- Electro-mechanical governor (including settings and drawings) - Digital electric governor (including settings and drawings) - PID governor details and settings - Transient droop (dashpot) governor details and settings - Tacho-accelerometric governor details and settings - Input transducer details - Transfer function data	
	Digital electric governor	
Ramp rates	How fast can the turbine increase and/or decrease load, specified in MW/min Guide vane/wicket gate characteristic, including opening, closing rates/times and limits	
	Droop setting (% on machine base)	

Category	Parameter Description	Data
Droop	Frequency influence limiters - Maximum frequency deviation limiter (eg +/-2 Hz) - Maximum influence limiter (eg 10% of rating)	
Dead band	Details of frequency dead band (typically in Hz or RPM)	
Hydro-electric turbine	Type of hydro turbine	
	Impulse turbines : typical with high head plants (Pelton wheel) Reaction turbine : typical with low and medium head plants (such as Francis and Kaplan turbine	
	Head, water flow, velocity and pressure (e.g. intake and outtake/draft tube)	
Penstock	Length (m)	
	Area (m^2)	
	Internal penstock diameter	
	Pipe thickness, material or other characteristics (such as tapering)	
	Non-elastic or elastic	
	Linear or non-linear model (with or without relief valve) or Kaplan model	
	Flow of water through turbine (m^3/s) – with gates fully open	
	Number of penstocks supplied from common tunnel	
Pressure relief valve	Drawings/schematics	
	Settings	
	Operational descriptions	

Category	Parameter Description	Data
Surge tank, reservoir and tail water (i.e. head)	Vertical distance between the upper reservoir and level of turbine (in meters)	
	Head at turbine admission (lake head minus tailrace head) – (in meters)	
	Head loss due to friction in conduit (in meters)	
	Surge tank height, diameter and other characteristics (e.g. restricted inlet orifice)	
Pump characteristics	Active power draw vs head (table)	
	PSS status when pumping (on/off/not used)	
Synchronous condenser	Dewatered when operating as Syncon (yes/no)	
	Losses when operating as Syncon: • Mechanical loss (0 Mvar): …… MW • Copper loss (table) MW loss as a function of MVar output	
Other	Details of protection schemes that could influence dynamics (if any)	
	Details of resonance chamber for pipes (if any)	
	Temperature (e.g. water, ambient, unit)	
	Characteristic curve of blade versus gate (from 0MW to maximum MW)	

3. Turbine Details-Gas (to be filled in for the GT and ST separately)

Category	Parameter Description	Data
Type of prime mover	- Open cycle gas turbine - Aero-derivative (twin shaft) gas turbine - Combined cycle plant (closed cycle gas turbine)	
Manufacturer of turbine	Manufacturer and name plate details	
Governor	Electro-mechanical governor (including settings and drawings)	
	Digital electric governor (including settings and drawings)	
Ramp rates	How fast can the turbine increase and/or decrease load, specified in MW/min Guide vane/wicket gate characteristic, including opening, closing rates/times and limits	
Droop	Droop setting (% on machine base)	
	Frequency influence limiters - Maximum frequency deviation limiter (eg +/-2 Hz) - Maximum influence limiter (eg 10% of rating)	
Dead band	Details of frequency dead band (typically in Hz or RPM)	
Technology	- Open cycle - Close cycle	
Gas turbine	Does turbine operate in dual fuel (gas and liquid fuel)	
	Inlet guide vane (IGV) characteristic	
	Limit for exhaust gas temperature (EGT)	
	Base load/frequency control	
	Power output versus ambient temperature	
	No load fuel flow and turbine gain (determined by relationship of active power versus fuel valve position or fuel stroke reference)	
	Details on heat recovery steam generator (HRSG)	

Category	Parameter Description	Data
Combine cycle plant	- Block diagram - GT output vs heat relationship (look up table) - Drum time constant Pressure loss due to friction in boiler tubes	
	Size of steam turbine	
	Frequency control of ST	
	Time lag and relationship of GT and ST	
	Is the combined cycle plant a single shaft plant – i.e. the gas and steam turbine are on same shaft and drive same generator	

Annexure-4

Generic Models for synchronous machine

There are two typical groups of synchronous machine models, depending upon the type of machine:

- Round rotor machine (2 poles):
  - GENROU – Round rotor machine model with quadratic saturation function
  - GENROE – Round rotor machine model with exponential saturation function
- Salient pole machine (more than two poles):
  - GENSAL – Salient pole machine with quadratic saturation function
  - GENSAE – Salient pole machine with exponential saturation function

Category	Parameter Description	Data
GENERATOR model		
GENROU OR **GENROE**	Direct axis open circuit transient time constant T_{do}' in sec	
	Direct axis open circuit sub-transient time constant T_{do}'' in sec	
	Quadrature axis open circuit transient time constant T_{qo}' in sec	
	Quadrature axis open circuit sub-transient time constant T_{qo}'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance X_d in p.u. (Unsaturated)	
	Quadrature axis synchronous reactance X_q in p.u. (Unsaturated)	
	Direct axis transient synchronous reactance X_d' in p.u.	

Category	Parameter Description	Data
GENERATOR model		
	(Unsaturated)	
	Quadrature axis transient synchronous reactance X_q' in p.u. (Unsaturated)	
	Direct axis sub-transient synchronous reactance X_d'' in p.u. (Unsaturated)	
	Quadrature axis sub-transient synchronous reactance X_q'' in p.u. (Unsaturated)	
	Stator leakage reactance X_l in p.u.	
	Saturation constant S1 (1.0) in p.u.	
	Saturation constant S2 (1.2) in p.u.	
GENSAE OR **GENSAL**	Direct axis open circuit transient time constant T_{do}' in sec	
	Direct axis open circuit sub-transient time constant T_{do}'' in sec	
	Quadrature axis open circuit sub-transient time constant T_{qo}'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance X_d in p.u. (Unsaturated)	
	Quadrature axis synchronous reactance X_q in p.u. (Unsaturated)	
	Direct axis transient synchronous reactance X_d' in p.u. (Unsaturated)	
	Direct axis sub-transient synchronous reactance X_d'' in p.u. (Unsaturated) = Quadrature axis sub-transient synchronous reactance X_q'' in p.u. (Unsaturated)	

Category	Parameter Description	Data
GENERATOR model		
	Stator leakage reactance X_l in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

Category	Parameter Description	Data
DC Exciter		
ESDC1A OR ESDC2A	T_R regulator input filter time constant (sec)	
	K_A (> 0) (pu) voltage regulator gain	
	T_A (s), voltage regulator time constant	
	T_B (s), lag time constant	
	T_C (s), lead time constant	
	V_{RMAX} (pu) regulator output maximum limit or Zero	
	V_{RMIN} (pu) regulator output minimum limit	
	K_E (pu) exciter constant related to self-excited field	
	T_E (> 0) rotating exciter time constant (sec)	
	K_F (pu) rate feedback gain	
	T_{F1} (> 0) rate feedback time constant (sec)	
	Switch	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
ESDC3A	T_R regulator input filter time constant (sec)	
	K_V (pu) limit on fast raise/lower contact setting	
	V_{RMAX} (pu) regulator output maximum limit or Zero	
	V_{RMIN} (pu) regulator output minimum limit	
	T_{RH} (> 0) Rheostat motor travel time (sec)	
	T_E (> 0) exciter time-constant (sec)	
	K_E (pu) exciter constant related to self-excited field	

Category	Parameter Description	Data
DC Exciter		
	V_{EMIN} (pu) exciter minimum limit	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
ESDC4B	T_R regulator input filter time constant (sec)	
	K_P (pu) (> 0) voltage regulator proportional gain	
	K_I (pu) voltage regulator integral gain	
	K_D (pu) voltage regulator derivative gain	
	T_D voltage regulator derivative channel time constant (sec)	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	K_A (> 0) (pu) voltage regulator gain	
	T_A voltage regulator time constant (sec)	
	K_E (pu) exciter constant related to self-excited field	
	T_E (> 0) rotating exciter time constant (sec)	
	K_F (pu) rate feedback gain	
	T_F (> 0) rate feedback time constant (sec)	
	V_{EMIN} (pu) minimum exciter voltage output	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	

Category	Parameter Description	Data
AC Exciter		
ESAC1A	T_R regulator input filter time constant (sec)	
	T_B (s), lag time constant	
	T_C (s), lead time constant	
	K_A (> 0) (pu) voltage regulator gain	
	T_A (s), voltage regulator time constant	
	V_{AMAX} (pu) regulator output maximum limit	
	V_{AMIN} (pu) regulator output minimum limit	
	T_E (> 0) rotating exciter time constant (sec)	
	K_F (pu) rate feedback gain	
	T_F (> 0) rate feedback time constant (sec)	
	K_C (pu) rectifier loading factor proportional to commutating reactance	
	K_D (pu) demagnetizing factor, function of AC exciter reactances	
	K_E (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
ESAC2A	T_R regulator input filter time constant (sec)	
	T_B (s), lag time constant	
	T_C (s), lead time constant	

Category	Parameter Description	Data
AC Exciter		
	K_A (> 0) (pu) voltage regulator gain	
	T_A (s), voltage regulator time constant	
	V_{AMAX} (pu) regulator output maximum limit	
	V_{AMIN} (pu) regulator output minimum limit	
	K_B, Second stage regulator gain	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	T_E (> 0) rotating exciter time constant (sec)	
	V_{FEMAX}, parameter of VEMAX, exciter field maximum output	
	K_H, Exciter field current feedback gain	
	K_F (pu) rate feedback gain	
	T_F (> 0) rate feedback time constant (sec)	
	K_C (pu) rectifier loading factor proportional to commutating reactance	
	K_D (pu) demagnetizing factor, function of AC exciter reactances	
	K_E (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	T_R regulator input filter time constant (sec)	
	T_B (s), lag time constant	

Category	Parameter Description	Data
AC Exciter		
ESAC3A	T_C (s), lead time constant	
	K_A (> 0) (pu) voltage regulator gain	
	T_A (s), voltage regulator time constant	
	V_{AMAX} (pu) regulator output maximum limit	
	V_{AMIN} (pu) regulator output minimum limit	
	T_E (> 0) rotating exciter time constant (sec)	
	V_{EMIN} (pu) minimum exciter voltage output	
	K_R (>0), Constant associated with regulator and alternator field power supply	
	K_F (pu) rate feedback gain	
	T_F (> 0) rate feedback time constant (sec)	
	K_N, Exciter feedback gain	
	EFDN, A parameter defining for which value of UF the feedback gain shall change from KF to KN	
	K_C, rectifier regulation factor (pu)	
	K_D, exciter regulation factor (pu)	
	K_E (pu) exciter constant related to self-excited field	
	V_{FEMAX}, parameter of VEMAX, exciter field maximum output	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	T_R regulator input filter time constant (sec)	

Category	Parameter Description	Data
AC Exciter		
ESAC4A	V_{IMAX}, Maximum value of limitation of the integrator signal V_I in p.u	
	V_{IMIN}, Minimum value of limitation of the signal VI in p.u.	
	T_B (s), lag time constant	
	T_C (s), lead time constant	
	K_A (> 0) (pu) voltage regulator gain	
	T_A (s), voltage regulator time constant	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	K_C, rectifier regulation factor (pu)	
ESAC5A	T_R regulator input filter time constant (sec)	
	K_A (> 0) (pu) voltage regulator gain	
	T_A (s), voltage regulator time constant	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	K_E (pu) exciter constant related to self-excited field	
	T_E (> 0) rotating exciter time constant (sec)	
	K_F (pu) rate feedback gain	
	T_{F1} (sec), Regulator stabilizing circuit time constant in seconds	
	T_{F2} (sec), Regulator stabilizing circuit time constant in seconds	
	T_{F3} (sec), Regulator stabilizing circuit time constant in seconds	

Category	Parameter Description	Data
AC Exciter		
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
AC6A	T_R regulator input filter time constant (sec)	
	K_A (> 0) (pu) voltage regulator gain	
	T_A (s), voltage regulator time constant	
	T_K (sec), Lead time constant	
	T_B (s), lag time constant	
	T_C (s), lead time constant	
	V_{AMAX} (pu) regulator output maximum limit	
	V_{AMIN} (pu) regulator output minimum limit	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	T_E (> 0) rotating exciter time constant (sec)	
	VFELIM, Exciter field current limit reference	
	K_H, Damping module gain	
	V_{HMAX}, damping module limiter	
	T_H (sec), damping module lag time constant	
	T_J (sec), damping module lead time constant	
	K_C, rectifier regulation factor (pu)	
	K_D, exciter regulation factor (pu)	
	K_E (pu) exciter constant related to self-excited field	

Category	Parameter Description	Data
AC Exciter		
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
AC7B	T_R (sec) regulator input filter time constant	
	K_{PR} (pu) regulator proportional gain	
	K_{IR} (pu) regulator integral gain	
	K_{DR} (pu) regulator derivative gain	
	T_{DR} (sec) regulator derivative block time constant	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	K_{PA} (pu) voltage regulator proportional gain	
	K_{IA} (pu) voltage regulator integral gain	
	V_{AMAX} (pu) regulator output maximum limit	
	V_{AMIN} (pu) regulator output minimum limit	
	K_P (pu)	
	K_L (pu)	
	K_{F1} (pu)	
	K_{F2} (pu)	
	K_{F3} (pu)	
	T_{F3} (sec) time constant (> 0)	
	K_C (pu) rectifier loading factor proportional to commutating reactance	
	K_D (pu) demagnetizing factor, function of AC exciter	

Category	Parameter Description	Data
AC Exciter		
	reactances	
	K_E (pu) exciter constant related fo self-excited field	
	T_E (pu) exciter time constant (>0)	
	V_{FEMAX} (pu) exciter field current limit (> 0)	
	V_{EMIN} (pu)	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
AC8B	T_R (sec) regulator input filter time constant	
	K_{PR} (pu) regulator proportional gain	
	K_{IR} (pu) regulator integral gain	
	K_{DR} (pu) regulator derivative gain	
	T_{DR} (sec) regulator derivative block time constant	
	$VPID_{MAX}$ (pu) PID maximum limit	
	$VPID_{MIN}$ (pu) PID minimum limit	
	K_A (pu) voltage regulator proportional gain	
	T_A (sec) voltage regulator time constant	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	K_C (pu) rectifier loading factor proportional to commutating reactance	
	K_D (pu) demagnetizing factor, function of AC exciter reactances	

Category	Parameter Description	Data
	AC Exciter	
	K_E (pu) exciter constant related fo self-excited field	
	T_E (pu) exciter time constant (>0)	
	V_{FEMAX} (pu) max exciter field current limit (> 0)	
	V_{EMIN} (pu),	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	

Category	Parameter Description	Data
	Static Exciter	
ST1A	T_R (sec) regulator input filter time constant	
	V_{IMAX}, Controller Input Maximum	
	V_{IMIN}, Controller Input Minimum	
	T_C (s), Filter 1st Derivative Time Constant	
	T_B (s), l Filter 1st Delay Time Constant	
	T_{C1} (s), Filter 2nd Derivative Time Constant	
	T_{B1} (s), Filter 2nd Delay Time Constant	
	K_A (pu) voltage regulator proportional gain	
	T_A (sec) voltage regulator time constant	
	V_{AMAX} (pu) regulator output maximum limit	
	V_{AMIN} (pu) regulator output minimum limit	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	K_C (pu) rectifier loading factor proportional to commutating reactance	
	K_F (pu) rate feedback gain	
	T_F (> 0) rate feedback time constant (sec)	
	K_{LR}, Current Input Factor	
	I_{LR}, Current Input Reference	
	T_R (sec) regulator input filter time constant	
	K_A (pu) voltage regulator proportional gain	
	T_A (sec) voltage regulator time constant	
	V_{RMAX} (pu) regulator output maximum limit	

Category	Parameter Description	Data
Static Exciter		
ST2A	V_{RMIN} (pu) regulator output minimum limit	
	K_E (pu) exciter constant related fo self-excited field	
	T_E (pu) exciter time constant (>0)	
	K_F (pu) rate feedback gain	
	T_F (> 0) rate feedback time constant (sec)	
	K_P (pu) voltage regulator proportional gain	
	K_I (pu) voltage regulator integral gain	
	K_C (pu) rectifier loading factor proportional to commutating reactance	
	EFDMAX	
ST3A	T_R (sec) regulator input filter time constant	
	V_{IMAX}, Maximum value of limitation of the signal VI in p.u.	
	V_{IMIN}, Minimum value of limitation of the signal VI in p.u.	
	K_M, Forward gain constant of the inner loop field regulator	
	T_C (s), lag time constant	
	T_B (s), lead time constant	
	K_A (pu) voltage regulator proportional gain	
	T_A (sec) voltage regulator time constant	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	K_G, Feedback gain constant of the inner loop field regulator	
	K_P (pu) voltage regulator proportional gain	
	K_I (pu) voltage regulator integral gain	

Category	Parameter Description	Data
Static Exciter		
	V_{BMAX}, Maximum value of limitation of the signal VB in p.u.	
	K_C (pu) rectifier loading factor proportional to commutating reactance	
	X_L, Reactance associated with potential source	
	V_{GMAX}, Maximum value of limitation of the signal VG in p.u	
	Θ_P (degrees)	
	T_M (sec), Forward time constant of the inner loop field regulator	
	V_{MMAX}, Maximum value of limitation of the signal VM in p.u	
	V_{MMIN}, Minimum value of limitation of the signal VM in p.u.	
ST4B	T_R (sec) regulator input filter time constant	
	K_{PR} (pu) regulator proportional gain	
	K_{IR} (pu) regulator integral gain	
	V_{RMAX} (pu) regulator output maximum limit	
	V_{RMIN} (pu) regulator output minimum limit	
	T_A (sec) voltage regulator time constant	
	K_{PM}, Regulator gain	
	K_{IM}, Regulator gain	
	V_{MMAX}, Maximum value of limitation of the signal in p.u.	
	V_{MMIN}, Minimum value of limitation of the signal in p.u.	
	K_G	
	K_P (pu) voltage regulator proportional gain	
	K_I (pu) voltage regulator integral gain	

Category	Parameter Description	Data
Static Exciter		
	VBMAX	
	K_C (pu) rectifier loading factor proportional to commutating reactance	
	X_L	
	Θ_P (degrees)	
ST5B	T_R regulator input filter time constant (sec)	
	T_{C1} lead time constant of first lead-lag block (voltage regulator channel) (sec)	
	T_{B1} lag time constant of first lead-lag block (voltage regulator channel) (sec)	
	T_{C2} lead time constant of second lead-lag block (voltage regulator channel) (sec)	
	T_{B2} lag time constant of second lead-lag block (voltage regulator channel) (sec)	
	K_R (>0) (pu) voltage regulator gain	
	V_{RMAX} (pu) voltage regulator maximum limit	
	V_{RMIN} (pu) voltage regulator minimum limit	
	T_1 voltage regulator time constant (sec)	
	K_C (pu)	
	TUC1 lead time constant of first lead-lag block (under-excitation channel) (sec)	
	TUB1 lag time constant of first lead-lag block (under-excitation channel) (sec)	
	TUC2 lead time constant of second lead-lag block (under-excitation channel) (sec)	

Category	Parameter Description	Data
Static Exciter		
	TUB2 lag time constant of second lead-lag block (under-excitation channel) (sec)	
	TOC1 lead time constant of first lead-lag block (over-excitation channel) (sec)	
	TOB1 lag time constant of first lead-lag block (over-excitation channel) (sec)	
	TOC2 lead time constant of second lead-lag block (over-excitation channel) (sec)	
	TOB2 lag time constant of second lead-lag block (over-excitation channel) (sec)	
ST6B	TR regulator input filter time constant (sec)	
	KPA (pu) (> 0) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	KDA (pu) voltage regulator derivative gain	
	TDA voltage regulator derivative channel time constant (sec)	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KFF (pu) pre-control gain of the inner loop field regulator	
	KM (pu) forward gain of the inner loop field regulator	
	KCI (pu) exciter output current limit adjustment gain	
	KLR (pu) exciter output current limiter gain	
	ILR (pu) exciter current limit reference	
	VRMAX (pu) voltage regulator output maximum limit	

Category	Parameter Description	Data
Static Exciter		
	VRMIN (pu) voltage regulator output minimum limit	
	KG (pu) feedback gain of the inner loop field voltage regulator	
	TG (> 0) feedback time constant of the inner loop field voltage regulator (sec)	
ST7B	TR regulator input filter time constant (sec)	
	TG lead time constant of voltage input (sec)	
	TF lag time constant of voltage input (sec)	
	Vmax (pu) voltage reference maximum limit	
	Vmin (pu) voltage reference minimum limit	
	KPA (pu) (>0) voltage regulator gain	
	VRMAX (pu) voltage regulator output maximum limit	
	VRMIN (pu) voltage regulator output minimum limit	
	KH (pu) feedback gain	
	KL (pu) feedback gain	
	TC lead time constant of voltage regulator (sec)	
	TB lag time constant of voltage regulator (sec)	
	KIA (pu) (>0) gain of the first order feedback block	
	TIA (>0) time constant of the first order feedback block (sec)	

Category	Parameter Description	Data
Stabilizer Model		
PSS1A	A_1, Filter coefficient	
	A_2, Filter coefficient	
	T_R, transducer time constant	
	T_1, 1st Lead-Lag Derivative Time Constant	
	T_2, 1st Lead-Lag Delay Time Constant	
	T_3, 2nd Lead-Lag Derivative Time Constant	
	T_4, 2nd Lead-Lag Delay Time Constant	
	T_w, Washout Time Constant	
	T_w, Washout Time Constant	
	Ks, input channel gain	
	V_{STMAX}, Controller maximum output	
	V_{STMAX}, Controller minimum output	
PSS2B	T_{W1}, 1st Washout 1th Time Constant	
	T_{W2}, 1st Washout 2th Time Constant	
	T_6, 1st Signal Transducer Time Constant	
	T_{W3}, 2nd Washout 1th Time Constant	
	T_{W4}, 2nd Washout 2th Time Constant	
	T_7, 2nd Signal Transducer Time Constant	
	K_{S2}, 2nd Signal Transducer Factor	
	K_{S3}, Washouts Coupling Factor	
	T_8, Ramp Tracking Filter Deriv. Time Constant	
	T_9, Ramp Tracking Filter Delay Time Constant	
	K_{S1}, PSS Gain	

Category	Parameter Description	Data
Stabilizer Model		
	T_1, 1st Lead-Lag Derivative Time Constant	
	T_2, 1st Lead-Lag Delay Time Constant	
	T_3, 2nd Lead-Lag Derivative Time Constant	
	T_4, 2nd Lead-Lag Delay Time Constant	
	T_{10}, 3rd Lead-Lag Derivative Time Constant	
	T_{11}, 3rd Lead-Lag Delay Time Constant	
	V_{S1MAX}, Input 1 Maximum limit	
	V_{S1MIN}, Input 1 Minimum limit	
	V_{S2MAX}, Input 2 Maximum limit	
	V_{S2MIN}, Input 2 Minimum limit	
	V_{STMAX}, Controller Maximum Output	
	V_{STMIN}, Controller Minimum Output	
PSS3B	K_{S1} (pu) (≠0), input channel #1 gain	
	T_1 input channel #1 transducer time constant (sec)	
	T_{w1} input channel #1 washout time constant (sec)	
	K_{S2} (pu) , input channel #2 gain	
	T_2 input channel #2 transducer time constant (sec)	
	T_{w2} input channel #2 washout time constant (sec)	
	T_{w3} (0), main washout time constant (sec)	
	A_1, Filter coefficient	
	A_2, Filter coefficient	
	A_3, Filter coefficient	
	A_4, Filter coefficient	

Category	Parameter Description	Data
Stabilizer Model		
	A_5, Filter coefficient	
	A_6, Filter coefficient	
	A_7, Filter coefficient	
	A_8, Filter coefficient	
	V_{STMAX}, Controller maximum output	
	V_{STMAX}, Controller minimum output	

Category	Parameter Description	Data
Turbine Governor model		
BBGOV1	fcut (>=0) (pu), cut off frequency	
	K_S, frequency gain	
	K_{LS} (> 0)	
	K_G	
	K_P, power regulator gain	
	T_N (sec) (> 0)	
	K_D, damping gain	
	T_D (sec) (> 0), damping time constant	
	T_4 (sec), high pressure time constant	
	K_2, intermediate pressure time constant	
	T_5 (sec), intermediate re-heater time constant	
	K_3, high pressure time constant	
	T_6 (sec), re-heater time constant	
	T_1 (sec), measuring transducer time constant	
	SWITCH	
	P_{MAX}, maximum power output limiter	
	P_{MIN}, minimum power output limiter	
TGOV1	R, Permanent Droop	
	T1 (>0) (sec), Steam bowl time constant	
	V_{MAX}, Maximum valve position	
	V_{MIN}, Minimum valve position	
	T2 (sec), Time constant	
	T3 (>0) (sec), reheater time constant	

Category	Parameter Description	Data
Turbine Governor model		
	Dt, Turbine damping coefficient	
	V_{MAX}, V_{MIN}, D_t and R are in per unit on generator MVA base. T2/T3 = high-pressure fraction.	
CRCMGV	P_{MAX} (HP)1, maximum HP value position (on generator base)	
	R (HP), HP governor droop	
	T1 (HP) (>0), HP governor time constant	
	T3 (HP) (>0), HP turbine time constant	
	T4 (HP) (>0), HP turbine time constant	
	T5 (HP) (>0), HP reheater time constant	
	F (HP), fraction of HP power ahead of reheater	
	DH (HP), HP damping factor (on generator base)	
	P_{MAX} (LP), maximum LP value position (on generator base)	
	R (LP), LP governor droop	
	T1 (LP) (>0), LP governor time constant	
	T3 (LP) (>0), LP turbine time constant	
	T4 (LP) (>0), LP turbine time constant	
	T5 (LP) (>0), LP turbine time constant	
	F (LP), fraction of LP power ahead of reheater	
	DH (LP), LP damping factor (on generator base)	
	K, Governor gain, (1/droop) pu	
	T1 (sec), Lag time constant (sec)	
	T2 (sec), Lead time constant (sec)	
	T3 (> 0) (sec), valve position time constant	
	Uo (pu/sec), maximum valve opening rate	

Category	Parameter Description	Data
Turbine Governor model		
IEEEG1	Uc (< 0) (pu/sec), maximum valve closing rate	
	P_{MAX} (pu on machine MVA rating)	
	P_{MIN} (pu on machine MVA rating)	
	T4 (sec), time constant for steam inlet	
	K1, HP fraction	
	K2, LP fraction	
	T5 (sec), Time Constant for Second Boiler Pass [s]	
	K3, HP Fraction	
	K4, LP fraction	
	T6 (sec), Time Constant for Third Boiler Pass [s]	
	K5, HP Fraction	
	K6, LP fraction	
	T7 (sec), Time Constant for Fourth Boiler Pass [s]	
	K7, HP Fraction	
	K8, LP fraction	
IEEEG2	K, Governor gain	
	T1 (sec), Governor lag time constant	
	T2 (sec), Governor lead time constant	
	T3 (>0) (sec), Gate actuator time constant	
	P_{MAX} (pu on machine MVA rating), gate maximum	
	P_{MIN} (pu on machine MVA rating), gate minimum	
	T4 (>0) (sec), water starting time	
	T_G, (>0) (sec), gate servomotor time constant	

Category	Parameter Description	Data
Turbine Governor model		
IEEEG3	T_P (>0) (sec), pilot value time constant	
	Uo (pu per sec), opening gate rate limit	
	Uc (pu per sec), closing gate rate limit (< 0)	
	P_{MAX} maximum gate position (pu on machine MVA rating)	
	P_{MIN} minimum gate position (pu on machine MVA rating)	
	σ, permanent speed droop coefficient	
	δ, transient speed droop coefficient	
	T_R, (>0) (sec), Dashpot time constant	
	T_W (>0) (sec), water starting time	
	a11 (>0), Turbine coefficient	
	a13, Turbine coefficient	
	a21, Turbine coefficient	
	a23 (>0), Turbine coefficient	
IEESGO	T1, Controller Lag	
	T2, Controller Lead Compensation	
	T3, Governor Lag (> 0)	
	T4, Delay Due To Steam Inlet Volumes	
	T5, Reheater Delay	
	T6, Turbine, pipe, hood Delay	
	K1, 1/Per Unit Regulation	
	K2, Fraction	
	K3, fraction	
	P_{MAX}, Upper Power Limit	

Category	Parameter Description	Data
Turbine Governor model		
	P_{MIN}, Lower Power Limit	
TGOV2	R (pu), permanent droop	
	T1 (>0) (sec), Steam bowl time constant	
	V_{MAX} (pu), Maximum valve position	
	V_{MIN} (pu), Minimum valve position	
	K (pu), Governor gain	
	T3 (>0) (sec), Time constant	
	Dt (pu), Turbine damping coefficient	
	Tt (>0) (sec), Valve time constant	
	T_A, Valve position at time 2 (fully closed after fast valving initialization)	
	T_B, Valve position at time 3 (start to reopen after fast valving initialization)	
	T_C, Valve position at time 4 (again fully open after fast valving initializations)	
TGOV3	K, Governor gain	
	T1 (sec), Governor lead time constant	
	T2 (sec), Governor lag time constant	
	T3 (>0) (sec), Valve positioner time constant	
	Uo, Maximum valve opening velocity	
	Uc (< 0), Maximum valve closing velocity	
	P_{MAX}, Maximum valve opening	
	P_{MIN}, Minimum valve opening	
	T4 (sec), Inlet piping/steam bowl time constant	

Category	Parameter Description	Data
Turbine Governor model		
	K1, Fraction of turbine power developed after first boiler pass	
	T5 (> 0) (sec), Time constant of second boiler pass	
	K2, Fraction of turbine power developed after second boiler pass	
	T6 (sec), Time constant of crossover or third boiler pass	
	K3, Fraction of hp turbine power developed after crossover or third boiler pass	
	TA (sec), Valve position at time 2 (fully closed after fast valving initializations)	
	TB (sec), Valve position at time 3 (start to reopen after fast valving initializations)	
	TC (sec), Valve position at time 4 (again fully open after fast valving initializations)	
	PRMAX (pu), Max. pressure in reheater	
	K, The inverse of the governor speed droop	
	T1 (sec), The governor controller lag time constant	
	T2 (sec), The governor controller lead time constant	
	T3 (>0) (sec), The valve servomotor time constant for the control valves	
	Uo, The control valve open rate limit	
	Uc (<0), The control valve close rate limit	
	KCAL	
	T4 (sec), The steam flow time constant	
	K1	
	T5 (> 0) (sec)	

Category	Parameter Description	Data
Turbine Governor model		
TGOV4	K2	
	T6 (sec)	
	P_{RMAX}	
	KP	
	KI	
	TFuel (sec)	
	TFD1 (sec)	
	TFD2 (sec)	
	Kb	
	Cb (> 0) (sec)	
	TIV (> 0) (sec)	
	UOIV	
	UCIV	
	R (>0)	
	Offset	
	CV position demand characteristic	
	CV #2 offset	
	CV #3 offset	
	CV #4 offset	
	IV position demand characteristic	
	IV #2 offset	
	CV valve characteristic	
	IV valve characteristic	

Category	Parameter Description	Data
Turbine Governor model		
	CV starting time for valve closing (sec)	
	CV closing rate (pu/sec)	
	Time closed for CV #1 (sec)	
	Time closed for CV #2	
	Time closed for CV #3	
	Time closed for CV #4	
	IV starting time for valve closing (sec)	
	IV closing rate (pu/sec)	
	Time closed for IV #1 (sec)	
	Time closed for IV #2 (sec)	
	TRPLU (>0) (sec)	
	PLU rate level	
	Timer	
	PLU unbalance level	
	TREVA (>0) (sec)	
	EVA rate level	
	EVA unbalance level	
	Minimum load reference (pu)	
	Load reference ramp rate (pu/sec)	
	K, The inverse of the governor speed droop	
	T1 (sec), The governor controller lag time constant	
	T2 (sec), The governor controller lead time constant	
	T3 (>0) (sec), The valve servomotor time constant for the control valves	

Category	Parameter Description	Data
Turbine Governor model		
TGOV5	Uo, The control valve open rate limit	
	Uc (<0), The control valve close rate limit	
	V_{MAX}, The maximum valve area	
	V_{MIN}, The minimum valve area	
	T4 (sec), The steam flow time constant	
	K1, The fractions of the HP	
	K2, fractions of the LP	
	T5 (sec), The first reheater time constant	
	K3, The fractions of the HP	
	K4, fractions of the LP	
	T6 (sec), second reheater time constant	
	K5, The fractions of the HP	
	K6, fractions of the LP	
	T7 (sec), crossover time constant	
	K7, The fractions of the HP	
	K8, fractions of the LP	
	K9, The adjustment to the pressure drop coefficient as a function of drum pressure	
	K10, The gain of anticipation signal from main stream flow	
	K11, The gain of anticipation signal from load demand	
	K12, The gain for pressure error bias	
	K13, The gain between MW demand and pressure set point	
	K14, Inverse of load reference servomotor time constant (= 0.0 if load reference does not change).	

Category	Parameter Description	Data
Turbine Governor model		
	R_{MAX}, The load reference positive rate of change limit	
	R_{MIN}, The load reference negative rate of change limit	
	L_{MAX}, The maximum load reference	
	L_{MIN}, The minimum load reference	
	C1, The pressure drop coefficient	
	C2, The gain for the pressure error bias	
	C3, The adjustment to the pressure set point	
	B, The frequency bias for load reference control	
	CB (>0) (sec), The boiler storage time constant	
	KI, The controller integral gain	
	TI (sec), The controller proportional lead time constant	
	T_R (sec), The controller rate lead time constant	
	T_{R1} (sec), The inherent lag associated with lead TR (usually about TR/10)	
	C_{MAX}, The maximum controller output	
	C_{MIN}, The minimum controller output	
	T_D (sec), The time delay in the fuel supply system	
	T_F (sec), The fuel and air system time constant	
	TW (sec), The water wall time constant	
	Psp (initial) (>0), The initial throttle pressure set point	
	TMW (sec), The MW transducer time constant	
	KL (0.0 or 1.0), The feedback gain from the load reference	
	KMW (0.0 or 1.0), The gain of the MW transducer	
	DPE (pu pressure), The dead band in the pressure error signal	

Category	Parameter Description	Data
Turbine Governor model		
	for load reference control	
	• The fractions of the HP unit's mechanical power developed by the various turbine stages. The sum of K1, K3, K5 and K7 constants should be one for a non cross-compound unit. • Similarly fractions of the LP unit's mechanical power should be zero for a non cross- compound unit. For a cross-compound unit, the sum of K1 through K8 should equal one.	
TURCZT	f_{DEAD} (pu), Frequency Dead Band	
	f_{MIN} (pu), Frequency Minimum Deviation	
	f_{MAX} (pu), Frequency Maximum Deviation	
	KKOR (pu), Frequency Gain	
	$K_M > 0$ (pu), Power Measurement Gain	
	K_P (pu), Regulator Proportional Gain	
	S_{DEAD} (pu), Speed Dead Band	
	K_{STAT} (pu), Speed Gain	
	KHP (pu), High Pressure Constant	
	T_C (sec), Measuring transducer time constant	
	T 1 (sec), Regulator Integrator Time Constant	
	TEHP (sec), Hydro Converter Time Constant	
	TV > 0 (sec), Regulation Valve Time Constant	
	THP (sec), High Pressure Time Constant	
	T_R (sec), Reheater time constant	
	TW (sec), Water Time Constant	
	NT_{MAX} (pu), Power Regulator-Integrator Maximum Limiter	

Category	Parameter Description	Data
Turbine Governor model		
	NT_{MIN} (pu), Power Regulator-Integrator Minimum Limiter	
	G_{MAX} (pu), Valve Maximum Open	
	G_{MIN} (pu), Valve Minimum Open	
	V_{MIN} (pu/sec), Valve Maximum Speed Close	
	V_{MAX} (pu/sec), Valve Maximum Speed Open	
HYGOV	R, permanent droop	
	r, temporary droop	
	T_r (>0) governor time constant	
	T_f (>0) filter time constant	
	T_g (>0) servo time constant	
	+ VELM, gate velocity limit	
	G_{MAX}, maximum gate limit	
	G_{MIN}, minimum gate limit	
	TW (>0) water time constant	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
	R, permanent droop	
	r, temporary droop	
	Tr (>0) governor time constant	
	Tf (>0) filter time constant	
	Tg (>0) servo time constant	
	+ VELM, gate velocity limit	

Category	Parameter Description	Data
Turbine Governor model		
HYGOVDU	G_{MAX}, maximum gate limit	
	G_{MIN}, minimum gate limit	
	TW (>0) water time constant	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
	DBH (pu), droop for over-speed, (> 0)	
	DBL (pu), droop for under-speed, (< 0)	
	TRate (MW), turbine rating, if zero, then MBASE used	
	P_{rated}, rated turbine power (MW	
	Q_{rated}, rated turbine flow (cfs or cms)	
	H_{rated}, rated turbine head (ft or m)	
	G_{rated}, gate position at rated conditions (pu)	
	QNL, no power flow (pu of Qrated)	
	R, permanent droop (pu)	
	r, temporary droop (pu)	
	Tr, governor time constant (> 0) (sec)	
	Tf, filter time constant (> 0) (sec)	
	Tg, servo time constant (> 0) (sec)	
	MXGTOR, maximum gate opening rate (pu/sec)	
	MXGTCR, maximum gate closing rate (< 0) (pu/sec)	
	MXBGOR, maximum buffered gate opening rate (pu/sec)	
	MXBGCR, maximum buffered gate closing rate (< 0) (pu/sec)	

Category	Parameter Description	Data
Turbine Governor model		
HYGOVM	BUFLIM, buffer upper limit (pu)	
	GMAX, maximum gate limit (pu)	
	GMIN, minimum gate limit (pu)	
	RVLVCR, relief valve closing rate (< 0) (pu/sec) or MXJDOR, maximum jet deflector opening rate (pu/sec)	
	RVLMAX, maximum relief valve limit (pu) or MXJDCR, maximum jet deflector closing rate (< 0) (pu/sec)	
	HLAKE, lake head (ft or m)	
	HTAIL, tail head (ft or m)	
	PENL/A, summation of penstock, scroll case and draft tube lengths/ cross sections (> 0)(1/ft or 1/m)	
	PENLOS, penstock head loss coefficient (ft/cfs2 or m/cms2)	
	TUNL/A, summation of tunnel lengths/cross sections (>0) (1/ft or 1/m)	
	TUNLOS, tunnel head loss coefficient (ft/cfs^2 or m/cms^2)	
	SCHARE, surge chamber effective cross section (>0) (ft^2 or m^2)	
	SCHMAX, maximum water level in surge chamber (ft or m)	
	SCHMIN, minimum water level in surge chamber (ft or m)	
	SCHLOS, surge chamber orifice head loss coefficient (ft/cfs^2 or m/cms^2)	
	DAMP1, turbine damping under RPM1	
	RPM1, over speed (pu)	
	DAMP2, turbine damping above RPM2	
	RPM2, over speed (pu)	
	R-PERM-GATE (Feedback settings)	

Category	Parameter Description	Data
	Turbine Governor model	
WEHGOV	R-PERM-PE (Feedback settings)	
	TPE (sec), Power time constant	
	Kp, Proportional gain	
	KI, Integral gain	
	KD, Derivative gain	
	TD (sec), Derivative time constant	
	TP (sec), Gate servo time constant	
	TDV (sec), Time constant	
	Tg (sec), Gate servo time constant	
	GTMXOP (>0), Max gate opening velocity	
	GTMXCL (<0), Max gate closing velocity	
	GMAX, Maximum governor output	
	GMIN, Minimum governor output	
	DTURB, Turbine damping factor	
	TW (sec), Water inertia time constant	
	Speed Dead Band (DBAND)	
	DPV, Governor limit factor	
	DICN, Gate limiter modifier	
	GATE 1	
	GATE 2	
	GATE 3	
	GATE 4	
	GATE 5	

Category	Parameter Description	Data
Turbine Governor model		
	FLOW G1	
	FLOW G2	
	FLOW G3	
	FLOW G4	
	FLOW G5	
	FLOW P1	
	FLOW P2	
	FLOW P3	
	FLOW P4	
	FLOW P5	
	FLOW P6	
	FLOW P7	
	FLOW P8	
	FLOW P9	
	FLOW P10	
	PMECH1	
WEHGOV	PMECH2	
	PMECH3	
	PMECH4	
	PMECH5	
	PMECH6	
	PMECH7	
	PMECH8	

Category	Parameter Description	Data
Turbine Governor model		
	PMECH9	
	PMECH10	
HYGOVT	Prated, rated turbine power (MW)	
	Qrated, rated turbine flow (cfs or cms)	
	Hrated, rated turbine head (ft or m)	
	Grated, gate position at rated conditions (pu)	
	QNL, no power flow (pu of Qrated)	
	R, permanent droop	
	r, temporary droop (pu)	
	Tr, governor time constant (> 0) (sec)	
	Tf, filter time constant (> 0) (sec)	
	Tg, servo time constant (> 0) (sec)	
	MXGTOR, maximum gate opening rate (pu/sec)	
	MXGTCR, maximum gate closing rate (< 0) (pu/sec)	
	MXBGOR, maximum buffered gate opening rate (pu/sec)	
	MXBGCR, maximum buffered gate closing rate (< 0) (pu/sec)	
	BUFLIM, buffer upper limit (pu)	
	GMAX, maximum gate limit (pu)	
	GMIN, minimum gate limit (pu)	
	RVLVCR, relief valve closing rate (< 0) (pu/sec) or MXJDOR, maximum jet deflector opening rate (pu/sec)	
	RVLMAX, maximum relief valve limit (pu) or MXJDCR, maximum jet deflector closing rate (< 0) (pu/sec)	
	HLAKE, lake head (ft or m)	

Category	Parameter Description	Data
Turbine Governor model		
	HTAIL, tail head (ft or m)	
	PENLGTH, penstock length (ft or m)	
	PENLOS, penstock head loss coefficient (ft/cfs2 or m/cms2)	
	TUNLGTH, tunnel length (ft or m)	
	TUNLOS, tunnel head loss coefficient (ft/cfs2 or m/cms2)	
	SCHARE, surge chamber effective cross section (>0) (ft2 or m2)	
	SCHMAX, maximum water level in surge chamber (ft or m)	
	SCHMIN, minimum water level in surge chamber (ft or m)	
	SCHLOS, surge chamber orifice head loss coefficient (ft/cfs2 or m/cms2)	
	DAMP1, turbine damping under RPM1	
	RPM1, overspeed (pu)	
	DAMP2, turbine damping above RPM2	
	RPM2, overspeed (pu)	
	PENSPD, penstock wave velocity (>0) (ft/sec or m/sec)	
	PENARE, penstock cross section (>0) (ft2 or m2)	
	TUNSPD, tunnel wave velocity (>0) (ft/sec or m/sec)	
	TUNARE, tunnel cross section (>0) (ft2 or m2)	
	Rperm, permanent drop, pu	
	Treg (sec), speed detector time constant	
	Kp, proportional gain, pu/sec	
	Ki, reset gain, pu/sec	
	Kd, derivative gain, pu	

Category	Parameter Description	Data
Turbine Governor model		
PIDGOV	Ta (sec) > 0, controller time constant	
	Tb (sec) > 0, gate servo time constant	
	Dturb, turbine damping factor, pu	
	G0, gate opening at speed no load, pu	
	G1, intermediate gate opening, pu	
	P1, power at gate opening G1, pu	
	G2, intermediate gate opening, pu	
	P2, power at gate opening G2, pu	
	P3, power at full opened gate, pu	
	Gmax, maximum gate opening, pu	
	Gmin, minimum gate opening, pu	
	Atw > 0, factor multiplying Tw, pu	
	Tw (sec) > 0, water inertia time constant	
	Velmax, minimum gate opening velocity, pu/sec	
	Velmin < 0, minimum gate closing velocity, pu/sec	
HYGOVR1	db1, Intentional dead band width, Hz	
	Err, deadband hysteresis (p.u.)	
	Td (sec), Input filter time constant, s	
	T1 (sec), Lead time constant 1, s	
	T2 (sec) q, Lag time constant 1, s	
	T3 (sec), Lead time constant 2, s	
	T4 (sec), Lag time constant 2, s	
	T5 (sec), Lead time constant 3, s	

Category	Parameter Description	Data
Turbine Governor model		
	T6 (sec), Lag time constant 3, s	
	T7 (sec), Lead time constant 4, s	
	T8 (sec), Lag time constant 4, s	
	KP, proportional gain	
	R, Steady-state droop, p.u.	
	Tt, Power feedback time constant, s	
HYGOVR1	KG, Gate servo gain, p.u.	
	TP (sec), Gate servo time constant, s	
	VELOPEN, Maximum gate opening velocity, p.u./s	
	VELCLOSE, Maximum gate closing velocity, p.u./s (<0)	
	PMAX, Maximum gate opening, p.u. of mwcap	
	PMIN, Minimum gate opening, p.u. of mwcap	
	db2, Unintentional deadband, MW	
	TW (>0) water time constant	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
	Trate (Turbine MW rating)	
	fDEAD (pu), Frequency Dead Band	
	fMIN (pu), Frequency Minimum Deviation	
	fMAX (pu), Frequency Maximum Deviation	
	KKOR (pu), Frequency Gain	
	KM > 0 (pu), Power Measurement Gain	

Category	Parameter Description	Data
Turbine Governor model		
TURCZT	KP (pu), Regulator Proportional Gain	
	SDEAD (pu), Speed Dead Band	
	KSTAT (pu), Speed Gain	
	KHP (pu), High Pressure Constant	
	TC (sec), Measuring transducer time constant	
	T 1 (sec), Regulator Integrator Time Constant	
	TEHP (sec), Hydro Converter Time Constant	
	TV > 0 (sec), Regulation Valve Time Constant	
	THP (sec), High Pressure Time Constant	
	TR (sec), Reheater time constant	
	TW (sec), Water Time Constant	
	NTMAX (pu), Power Regulator-Integrator Maximum Limiter	
	NTMIN (pu), Power Regulator-Integrator Minimum Limiter	
	GMAX (pu), Valve Maximum Open	
	GMIN (pu), Valve Minimum Open	
	VMIN (pu/sec), Valve Maximum Speed Close	
	VMAX (pu/sec), Valve Maximum Speed Open	
TWDM1T	R, permanent droop	
	r, temporary droop	
	Tr, governor time constant (>0)	
	Tf, filter time constant (>0)	
	Tg, servo time constant (>0)	
	VELMX, open gate velocity limit (pu/sec)	

Category	Parameter Description	Data
Turbine Governor model		
	VELMN, close gate velocity limit (pu/sec) (<0)	
	GMAX, maximum gate limit	
	GMIN, minimum gate limit	
	TW, water time constant (sec) (>0)	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
TWDM1	F1, frequency deviation (pu)	
	TF1, time delay (sec)	
	F2, frequency deviation (pu)	
	sF2, frequency (pu/sec)	
	TF2, time delay (sec)	
	GMXRT, rate with which GMAX changes when TWD is tripped (pu/sec)	
	NREF, setpoint frequency deviation (pu)	
	Tft, frequency filter time constant (>0	
	TREG (sec), governor time constant (s)	
	Reg, permanent droop (p.u. on generator MVA rating)	
	KP, controller proportional gain (p.u.)	
	KI, controller integral gain (p.u./s)	
	KD, controller derivative gain (p.u.-s)	
	TA (sec) (> 0), controller time constant (s)	
	TB (sec) (> 0), controller time constant (s)	
	VELMX (pu/sec), open gate velocity limit (p.u./s)	

Category	Parameter Description	Data
Turbine Governor model		
TWDM2	VELMN (pu/sec) (> 0), close gate velocity limit (p.u./s)	
	GATMX (pu), maximum gate limit (p.u.)	
	GATMN (pu), minimum gate limit (p.u.)	
	TW (sec) (> 0), water time constant (s)	
	At, turbine gain	
	qNL, flow rate at no load (p.u.)	
	Dturb, turbine damping factor	
	F1, frequency deviation (pu)	
	TF1, time delay (sec)	
	F2, frequency deviation (pu)	
	sF2, frequency (pu/sec)	
	TF2, time delay (sec)	
	PREF, power reference (pu)	
	Tft, frequency filter time constant (sec) (>0)	
	TREG (sec), governor time constant (s)	
	REG1, permanent droop (p.u. on generator MVA base)	
	KP, controller proportional gain (p.u.)	
	KI, controller integral gain (p.u./s)	
	KD, controller derivative gain (p.u./s)	
	TA (>0) (sec), controller time constant (s)	
	TB (>0) (sec), controller time constant (s)	
	VELMX (>0), open gate velocity limit (p.u./s)	
	VELMN (<0), close gate velocity limit (p.u./s)	

Category	Parameter Description	Data
Turbine Governor model		
WPIDHY	GATMX, maximum gate limit (p.u.)	
	GATMN, minimum gate limit (p.u.)	
	TW (>0) (sec), water time constant (s)	
	PMAX, maximum gate position (p.u.)	
	PMIN, minimum gate position (p.u.)	
	D	
	G0, gate position at no load (p.u.)	
	G1, first gate intermediate position (p.u.)	
	P1, power at gate position G1 (p.u. on generator MVA rating)	
	G2, second gate intermediate position (p.u.)	
	P2, power at gate position G2 (p.u. on generator MVA rating)	
	P3, power at fully open gate (p.u. on generator MVA rating)	
WSHYDD	db1, deadband width (p.u.)	
	Err, deadband hysteresis (p.u.)	
	Td (sec), input filter time constant (s)	
	K1, derivative gain (p.u.)	
	Tf (sec), derivative time constant (s)	
	KD, double derivative gain (p.u.)	
	KP, integral gain (p.u.)	
	R, droop (p.u. on Trate)	
	Tt, power feedback time constant (s)	
	KG, gate servo gain (p.u.)	
	TP (sec), gate servo time constant (s)	

Category	Parameter Description	Data
Turbine Governor model		
WSHYDD	VELOPEN (>0), maximum gate opening rate (p.u./s)	
	VELCLOSE (>0), maximum gate closing rate (p.u./s)	
	PMAX, maximum gate opening (p.u.)	
	PMIN, minimum gate opening (p.u.)	
	db2, deadband (p.u.)	
	GV1, coordinate of power-gate look-up table (p.u. gate)	
	PGV1, coordinate of power-gate look-up table (p.u. power)	
	GV2, coordinate of power-gate look-up table (p.u. gate)	
	PGV2, coordinate of power-gate look-up table (p.u. power)	
	GV3, coordinate of power-gate look-up table (p.u. gate)	
	PGV3, coordinate of power-gate look-up table (p.u. power)	
	GV4, coordinate of power-gate look-up table (p.u. gate)	
	PGV4, coordinate of power-gate look-up table (p.u. power)	
	GV5, coordinate of power-gate look-up table (p.u. gate)	
	PGV5, coordinate of power-gate look-up table (p.u. power)	
	Aturb, turbine lead time constant multiplier	
	Bturb (> 0), turbine lag time constant multiplier	
	Tturb (> 0) (sec), turbine time constant (s)	
	Trate, turbine rating (MW)	
	db1, deadband width (p.u.)	
	Err, deadband hysteresis (p.u.)	
	Td (sec), input filter time constant (s)	
	K1, derivative gain (p.u.)	

Category	Parameter Description	Data
Turbine Governor model		
WSHYGP	Tf (sec), derivative time constant (s)	
	KD, double derivative gain (p.u.)	
	KP, integral gain (p.u.)	
	R, droop (p.u. on Trate)	
	Tt, power feedback time constant (s)	
	KG, gate servo gain (p.u.)	
	TP (sec), gate servo time constant (s)	
	VELOPEN (>0), maximum gate opening rate (p.u./s)	
	VELCLOSE (>0), maximum gate closing rate (p.u./s)	
	PMAX, maximum gate opening (p.u.)	
	PMIN, minimum gate opening (p.u.)	
	db2, deadband (p.u.)	
	GV1, coordinate of power-gate look-up table (p.u. gate)	
	PGV1, coordinate of power-gate look-up table (p.u. power)	
	GV2, coordinate of power-gate look-up table (p.u. gate)	
	PGV2, coordinate of power-gate look-up table (p.u. power)	
	GV3, coordinate of power-gate look-up table (p.u. gate)	
	PGV3, coordinate of power-gate look-up table (p.u. power)	
	GV4, coordinate of power-gate look-up table (p.u. gate)	
	PGV4, coordinate of power-gate look-up table (p.u. power)	
WSHYGP	GV5, coordinate of power-gate look-up table (p.u. gate)	
	PGV5, coordinate of power-gate look-up table (p.u. power)	
	Aturb, turbine lead time constant multiplier	

Category	Parameter Description	Data
	Turbine Governor model	
	Bturb (> 0), turbine lag time constant multiplier	
	Tturb (> 0) (sec), turbine time constant (s)	
	Trate, turbine rating (MW)	
GAST	R, permanent droop	
	T1 (>0) (sec), Governor mechanism time constant	
	T2 (>0) (sec), Turbine power time constant	
	T3 (>0) (sec), Turbine exhaust temperature time constant	
	Ambient temperature load limit, AT	
	KT, Temperature limiter gain	
	VMAX, Maximum turbine power	
	VMIN, Minimum turbine power	
	Dturb, Turbine damping factor	
	W, governor gain (1/droop) (on turbine rating)	
	X (sec) governor lead time constant	
	Y (sec) (> 0) governor lag time constant	
	Z, governor mode:1 Droop or 0 ISO	
	ETD (sec), Turbine exhausts time constant	
	TCD (sec), Gas turbine dynamic time constant	
	TRATE turbine rating (MW)	
	T (sec), Fuel control time constant	
	MAX (pu) limit (on turbine rating)	
	MIN (pu) limit (on turbine rating)	
	ECR (sec), Combustor time constant	

Category	Parameter Description	Data
Turbine Governor model		
GAST2A	K3, Fuel control gain	
	a (> 0) valve positioner	
	b (sec) (> 0) valve positioner	
	c valve positioner	
	Tf (sec) (> 0), Fuel system time constant	
	Kf, feedback gain	
	K5, Radiation shield	
	K4, Radiation shield	
	T3 (sec) (> 0), Radiation shield time constant	
	T4 (sec) (> 0), Thermocouple time constant, seconds	
	Tt (> 0), Temperature control time constant	
	T5 (sec) (> 0), Temperature control time constant	
	af1, describes the turbine characteristic	
	bf1, describes the turbine characteristic	
	af2, describes the turbine characteristic	
	bf2, describes the turbine characteristic	
	cf2, describes the turbine characteristic	
	TR (degree), Rated temperature	
	K6 (pu), Minimum fuel flow	
	TC (degree), Temperature control	
	KDROOP (on turbine rating)	
	KP, Proportional gain	
	KI, Integral gain	

Category	Parameter Description	Data
Turbine Governor model		
GASTWD	KD, Derivative gain	
	ETD (sec), Turbine exhaust time constant	
	TCD (sec), Gas turbine dynamic time constant	
	TRATE turbine rating (MW)	
	T (sec), Fuel control time constant	
	MAX (pu) limit (on turbine rating)	
	MIN (pu) limit (on turbine rating)	
	ECR (sec), Combustor time constant	
	K3, Fuel control gain	
	a (> 0) valve positioner	
	b (sec) (> 0) valve positioner	
	c valve positioner	
	tf (sec) (> 0), Fuel system time constant	
	Kf, feedback gain	
	K5, Radiation shield	
	K4, Radiation shield	
	T3 (sec) (> 0), Radiation shield time constant	
	T4 (sec) (> 0), Thermocouple time constant, seconds	
	tt (> 0), Temperature control time constant	
	T5 (sec) (> 0), Temperature control time constant	
	af1, describes the turbine characteristic	
	bf1, describes the turbine characteristic	
	af2, describes the turbine characteristic	

Category	Parameter Description	Data
Turbine Governor model		
	bf2 (>0), describes the turbine characteristic	
	cf2, describes the turbine characteristic	
	TR(degree), Rated temperature1	
	K6 (pu), Minimum fuel flow	
	TC (degree), Temperature control1	
	TD (sec) (> 0), Power transducer	
WESGOV	ΔTC (sec), Δt sample for controls	
	ΔTP (sec), Δt sample for PE	
	Power Droop	
	Kp, Trubine proportional gain	
	TI (> 0) (sec), Integral time constant	
	T1 (sec), Constant time	
	T2 (sec), Constant time	
	ALIM	
	Tpe (sec), Power time constant	
	R, Permanent droop, pu	
	Tpelec, Electrical power transducer time constant, sec	
	maxerr, Maximum value for speed error signal	
	minerr, Minimum value for speed error signal	
	Kpgov, Governor proportional gain	
	Kigov, Governor integral gain	
	Kdgov, Governor derivative gain	
	Tdgov, Governor derivative controller time constant, sec	

Category	Parameter Description	Data
Turbine Governor model		
GGOV1	vmax, Maximum valve position limit	
	vmin, Minimum valve position limit	
	Tact, Actuator time constant, sec	
	Kturb, Turbine gain	
	Wfnl, No load fuel flow, pu	
	Tb, Turbine lag time constant, sec	
	Tc, Turbine lead time constant, sec	
	Teng, Transport lag time constant for diesel engine, sec	
	Tfload, Load Limiter time constant, sec	
	Kpload, Load limiter proportional gain for PI controller	
	Kiload, Load limiter integral gain for PI controller	
	Ldref, Load limiter reference value pu	
	Dm, Mechanical damping coefficient, pu	
	Ropen, Maximum valve opening rate, pu/sec	
	Rclose, Maximum valve closing rate, pu/sec	
	Kimw, Power controller (reset) gain	
	Aset, Acceleration limiter setpoint, pu/sec	
	Ka, Acceleration limiter gain	
	Ta, Acceleration limiter time constant, sec (> 0)	
	Trate, Turbine rating (MW)1	
	db, Speed governor deadband	
	Tsa, Temperature detection lead time constant, sec	
	Tsb, Temperature detection lag time constant, sec	

Category	Parameter Description	Data
Turbine Governor model		
	Rup, Maximum rate of load limit increase	
	Rdown, Maximum rate of load limit decrease	
PWTBD1	Trate (MW), Turbine rating (MW)	
	K (pu), Proportional gain	
	Ki (pu), Integral gain	
	Vrmax (pu), Upper Limit of PI controller	
	Vrmin (pu), Lower Limit of PI controller	
	Tv (s) (>0), Control valve Time Constant	
	Lo (pu/sec) (>0), Control valve open rate limit	
	Lc (pu/sec) (>0), Control valve close rate limit	
	Vmax (pu), Maximum valve position	
	Vmin (pu), Minimum valve position	
	Tb1 (s), steam buffer time constant	
	Tb2 (s), steam buffer time constant	
	v1 (pu), valve position 1	
	p1 (pu), power output for valve position v1	
	v2 (pu), valve position 2	
	p2 (pu), power output for valve position v2	
	v3 (pu), valve position 3	
	p3 (pu), power output for valve position v3	
	v4 (pu), valve position 4	
	p4 (pu), power output for valve position v4	
	v5 (pu), valve position 5	

Category	Parameter Description	Data
Turbine Governor model		
PWTBD1	p5 (pu), power output for valve position v5	
	v6 (pu), valve position 6	
	p6 (pu), power output for valve position v6	
	v7 (pu), valve position 7	
	p7 (pu), power output for valve position v7	
	v8 (pu), valve position 8	
	p8 (pu), power output for valve position v8	
	v9 (pu), valve position 9	
	p9 (pu), power output for valve position v9	
	v10 (pu), valve position 10	
	p11 (pu), power output for valve position v11	
	v11 (pu), valve position 11	
	p11 (pu), power output for valve position v11	
	W, governor gain (1/droop) (on turbine rating)	
	X (sec) governor lead time constant	
	Y (sec) (> 0) governor lag time constant	
	Z, governor mode:1 Droop or 0 ISO	
	ETD (sec), Turbine exhausts time constant	
	TCD (sec), Gas turbine dynamic time constant	
	TRATE turbine rating (MW)	
	T (sec), Fuel control time constant	
	MAX (pu) limit (on turbine rating)	
	MIN (pu) limit (on turbine rating)	

Category	Parameter Description	Data
Turbine Governor model		
URCSCT	ECR (sec), Combustor time constant	
	K3, Fuel control gain	
	a (> 0) valve positioner	
	b (sec) (> 0) valve positioner	
	c valve positioner	
	Tf (sec) (> 0), Fuel system time constant	
	Kf, feedback gain	
	K5, Radiation shield	
	K4, Radiation shield	
	T3 (sec) (> 0), Radiation shield time constant	
	T4 (sec) (> 0), Thermocouple time constant, seconds	
	Tt (> 0), Temperature control time constant	
	T5 (sec) (> 0), Temperature control time constant	
	af1, describes the turbine characteristic	
	bf1, describes the turbine characteristic	
	af2, describes the turbine characteristic	
	bf2, describes the turbine characteristic	
	cf2, describes the turbine characteristic	
	TR (degree), Rated temperature	
	K6 (pu), Minimum fuel flow	
	TC (degree), Temperature control	
	K, Governor gain, (1/droop) pu	
	T1 (sec), Lag time constant (sec)	

Category	Parameter Description	Data
Turbine Governor model		
	T2 (sec), Lead time constant (sec)	
	T3 (> 0) (sec), valve position time constant	
	Uo (pu/sec), maximum valve opening rate	
	Uc (< 0) (pu/sec), maximum valve closing rate	
	PMAX (pu on machine MVA rating)	
	PMIN (pu on machine MVA rating)	
URSCT	T4 (sec), time constant for steam inlet	
	K1, HP fraction	
	K2, LP fraction	
	T5 (sec), Time Constant for Second Boiler Pass [s]	
	K3, HP Fraction	
	K4, LP fraction	
	T6 (sec), Time Constant for Third Boiler Pass [s]	
	K5, HP Fraction	
	K6, LP fraction	
	T7 (sec), Time Constant for Fourth Boiler Pass [s]	
	K7, HP Fraction	
	K8, LP fraction	
	ST Rating, Steam turbine rating (MW)	
	POUT A, Plant total, point A (MW)	
	STOUT A, Steam turbine output, point A (MW)	
	POUT B, Plant total, point B (MW)	
	STOUT B, Steam turbine output, point B (MW)	

Category	Parameter Description	Data
Turbine Governor model		
	POUT C, Plant total, point C (MW)	
	STOUT C, Steam turbine output, point C (MW)	
URGS3T	R	
	T1 (> 0) (sec)	
	T2 (> 0) (sec)	
	T3 (> 0) (sec)	
	Lmax	
	Kt	
	Vmax	
	Vmin	
	Dturb	
	Fidle	
	Rmax	
	Linc (> 0)	
	Tltr (>0) (sec)	
	Ltrat	
	a	
	b (> 0)	
	db1, dead band width (p.u.)	
	Err, deadband hysteresis (p.u.)	
	db2, dead band width (p.u.)	
	GV1, coordinate of power-gate look-up table (p.u. gate)	
	PGV1, coordinate of power-gate look-up table (p.u. power)	

Category	Parameter Description	Data
Turbine Governor model		
	GV2, coordinate of power-gate look-up table (p.u. gate)	
	PGV2, coordinate of power-gate look-up table (p.u. power)	
	GV3, coordinate of power-gate look-up table (p.u. gate)	
	PGV3, coordinate of power-gate look-up table (p.u. power)	
	GV4, coordinate of power-gate look-up table (p.u. gate)	
	PGV4, coordinate of power-gate look-up table (p.u. power)	
	GV5, coordinate of power-gate look-up table (p.u. gate)	
	PGV5, coordinate of power-gate look-up table (p.u. power)	
	Ka	
	T4	
	T5	
	MWCAP	

Annexure-5

List of Test/Study Reports required to be furnished by applicant in compliance of CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended

In compliance of Connectivity Standards, the applicant shall submit the following Test/Study Reports as part of CONN-4 documents as per the sequence indicated below:

1) Details of excitation system of generating unit

2) Short circuit ratio of generating unit

3) Reactive power capability

Clause No. of Connectivity Regulation	Detailed clause	Reports/data in compliance of CEA Technical Standards for Connectivity to the Grid for Conventional Generators
A1(1)	New Generating units The excitation system for every generating unit: a) shall have state of the art excitation system b) Shall have Automatic Voltage Regulator (AVR). Generators of 100 MW rating and above shall have Automatic Voltage Regulator with digital control and two separate channels having	1. Applicant shall submit the details of excitation system alongwith parameters of the proposed generating unit For the generator capacity exceeding 100MW, applicant shall submit the details of PSS and AVR alongwith parameters to be used.

Clause No. of Connectivity Regulation	Detailed clause	Reports/data in compliance of CEA Technical Standards for Connectivity to the Grid for Conventional Generators
	independent inputs and automatic changeover; The Automatic Voltage Regulator of generator of 100 MW and above shall include Power System Stabilizer (PSS)	
A1 (2)	The short circuit ratio for generator shall be as per IEC-34	Applicant shall be required to furnish the OEM document depicting SCR of generating unit.
A1 (3)	The generator transformer winding shall have delta construction on low voltage side and star connection on high voltage side. Star point of high voltage side shall be effectively(solidly) earthen so as to achieve earth fault factor of 1.4 or less	1. Applicant shall submit the SLD of station depicting connection configuration of Generator transformer and generating unit Applicant shall submit the earth fault factor at sub-station
A1 (4)	All generating machines irrespective of capacity shall have electronically controlled governing system with appropriate speed/load characteristics to regulate frequency. The governors of thermal generating units shall	Applicant shall submit the GTP/manual indicating droop characteristics of generating unit

<table>
<tr><th>Clause No. of Connectivity Regulation</th><th>Detailed clause</th><th>Reports/data in compliance of CEA Technical Standards for Connectivity to the Grid for Conventional Generators</th></tr>
<tr><td></td><td>have a droop of 3 to 6% and those of hydro generating units 0 to 10%.</td><td></td></tr>
<tr><td>A1 (5)</td><td>Generating Units located near load centre, shall be capable of operating at rated output for power factor varying between 0.85 lagging (over-excited) to 0.95 leading (under-excited) and Generating Units located far from load centres shall be capable of operating at rated output for power factor varying between 0.9 lagging (over-excited) to 0.95 leading (Under-excited).

The above performance shall also be achieved with voltage variation of ± 5% of nominal, frequency variation of + 3% and -5% and combined voltage and frequency variation of ±5%. However, for gas turbines, the above performance shall be achieved for voltage variation of ±5%.</td><td>Applicant shall submit report indicating performance of power plant with the help of unit PQ capability curves considering different voltage levels (1.05,1.0,0.95 pu) under different power factors (0.85 lag- unity-0.95 lead). List of studies to be provided are tabulated below:

a) With fixed frequency (50Hz)
<table>
<tr><th>Voltage</th><th>1.0 PF</th><th>0.95 lagging</th><th>0.95 leading</th></tr>
<tr><td>1.0 pu</td><td>To be provided</td><td>To be provided</td><td>To be provided</td></tr>
<tr><td>0.95 pu</td><td>To be provided</td><td>To be provided</td><td>-</td></tr>
<tr><td>1.05 pu</td><td>To be provided</td><td>-</td><td>To be provided</td></tr>
</table>
b) With fixed voltage (1pu)
<table>
<tr><th>Frequency</th><th>1.0 PF</th><th>0.95 lagging</th><th>0.95 leading</th></tr>
<tr><td>+ 3%</td><td>To be provided</td><td>To be provided</td><td>To be provided</td></tr>
<tr><td>-5%</td><td>To</td><td>To be</td><td>To be</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Clause No. of Connectivity Regulation</th><th>Detailed clause</th><th>Reports/data in compliance of CEA Technical Standards for Connectivity to the Grid for Conventional Generators</th></tr>
<tr><td></td><td>Provided also that all hydro-electric generating units, where Techno-Economic concurrence has been accorded by the Authority (CEA) under section 8 of the Act, shall be capable of operating at the rated output at the power factor as specified in such techno-economic concurrence</td><td>
<table>
<tr><td></td><td>be provided</td><td>provided</td><td>provided</td></tr>
</table>
c) With variable voltage and frequency
<table>
<tr><th></th><th>1.0 PF</th><th>0.85 lagging</th><th>0.95 leading</th></tr>
<tr><td>V:1.05pu, Δf:+5%</td><td>To be provided</td><td>To be provided</td><td>To be provided</td></tr>
<tr><td>V:1.05pu, Δf:-5%</td><td>To be provided</td><td>To be provided</td><td>To be provided</td></tr>
<tr><td>V: 0.95pu, Δf:+5%</td><td>To be provided</td><td>To be provided</td><td>To be provided</td></tr>
<tr><td>V: 0.95pu, Δf:-5%</td><td>To be provided</td><td>To be provided</td><td>To be provided</td></tr>
</table>
</td></tr>
<tr><td>A1 (6)</td><td>The coal and lignite based thermal generating units shall be capable of generating up to 105% of Maximum Continuous Rating (MCR) (subject to maximum load capability under Valve Wide Open Condition) for short duration to provide the frequency response.</td><td>Applicant shall submit the generator unit capability depicting MCR under valve wide open (VWO) condition</td></tr>
</table>

Clause No. of Connectivity Regulation	Detailed clause	Reports/data in compliance of CEA Technical Standards for Connectivity to the Grid for Conventional Generators
A1 (7)	The hydro generating units shall be capable of generating up to 110% of rated capacity (subject to rated head being available) on continuous basis	Applicant (Hydro) shall submit the generator unit capability depicting 110% generating capacity on continuous basis.
A1 (8)	Every generating unit shall have standard protections to protect the units not only from faults within the units and within the station but also from faults in transmission lines. For generating unit having rated capacity greater than 100 MW, two independent sets of protections acting on two independent sets of trip coils fed from independent Direct Current (DC) supplies shall be provided. The protections shall include but not be limited to the Local Breaker Back-up (LBB) protection	Applicant shall submit the protection schemes to be implemented for compliance of CEA Technical Standards
A1 (9)	Hydro generating units having rated capacity of 50 MW and above shall be capable of operation in synchronous condenser mode, wherever	Applicant (for unit capacity more than 50MW) shall submit generating unit OEM GTP indicating capability of operation hydro unit under synchronous condenser mode. In

Clause No. of Connectivity Regulation	Detailed clause	Reports/data in compliance of CEA Technical Standards for Connectivity to the Grid for Conventional Generators
	feasible. Provided that hydro generating units commissioned on or after 01.01.2014 and having rated capacity of 50 MW and above shall be equipped with facility to operate in synchronous condenser mode, if necessity for the same is established by the: interconnection studies	case of non-availability of the facility of synchronous condenser mode of operation, the detailed reasoning for the same should be furnished.
A1 (10)	Bus bar protection shall be provided at the switchyard of all generating station.	Applicant shall submit the bus bar scheme implemented in sub-station
A1 (11)	Automatic synchronization facilities shall be provided in the requester's Project.	Applicant shall submit the details of relay provided with synchronization facility at generating station
A1 (12)	The station auxiliary power requirement, including voltage and reactive requirements, shall not impose operating restrictions on the grid beyond those specified in the Grid Code or state Grid Code as the case may be.	Applicant shall submit declaration that station auxiliary power requirement, including voltage and reactive requirements, shall not impose operating restrictions on the grid beyond those specified in the Grid Code or State Grid Code as the case may be.
A1 (13)	In case of hydro generating units, self-starting facility may	Applicant shall submit the details of self-starting facilities implemented in

Clause No. of Connectivity Regulation	Detailed clause	Reports/data in compliance of CEA Technical Standards for Connectivity to the Grid for Conventional Generators
	be provided. The hydro generating station may also have a small diesel generator for meeting the station auxiliary requirements for black start.	respect of generating unit for hydro generating stations.
DA1 (14)	The standards in respect of the sub-stations associated with the generating stations shall be in accordance with the provisions specified in respect of 'Sub-station' under Part III of these Standards.	Applicant shall submit the details of sub-station equipment as a part of CON-4 data.

In order to check the performance of generating unit, applicant shall submit the plant model (Generic) compatible to PSS/E latest version with following information:

- SLD (Unit & Switchyard Sub-station)
- Generating OEM Technical datasheet
- Excitation system Technical datasheet
- Power System Stabilizer Technical datasheet
- Turbine governor system Technical datasheet

➢ PSS/E model shall demonstrate the steady state as well as dynamic state performance of the complete plant.

➢ Model should be suitable for an integration time step between 1ms and 20ms, and suitable for operation up-to 100s

List of simulation tests to be carried out in PSS/E software:

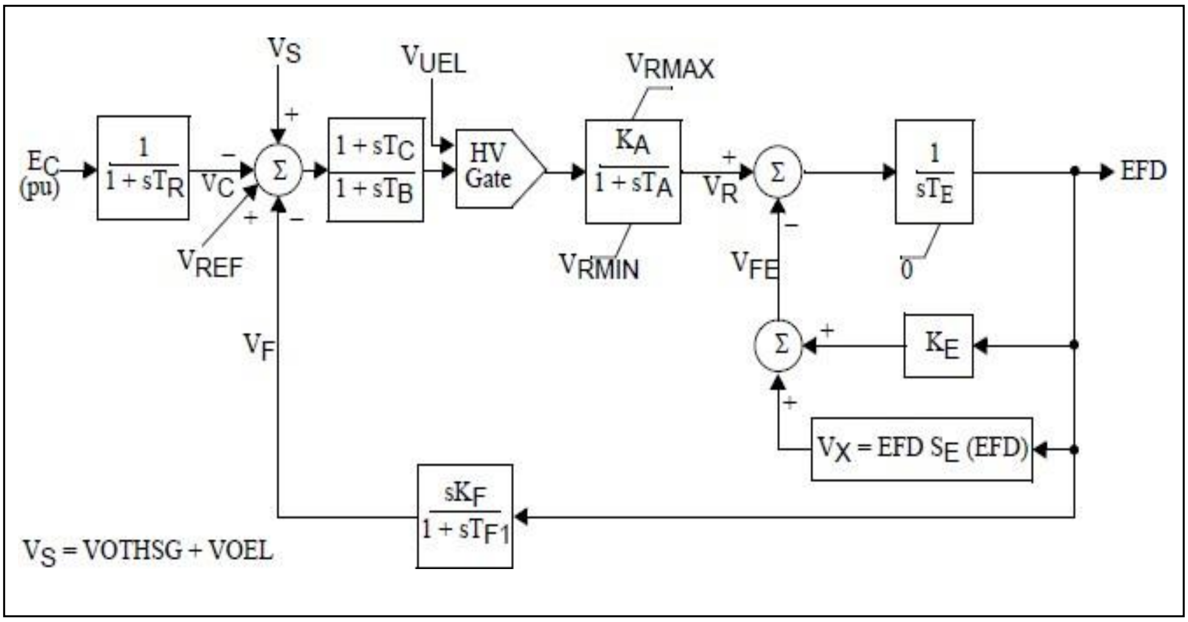
Sl. No.	Name of test	Remarks
1	Voltage Step (up/down) response of exciters of generator unit	Applicant shall submit the step response of exciter for following conditions: a) Change of POI voltage from 1.0 to 0.95pu b) Change of POI voltage from 1.0 to 1.05pu Report shall include relevant plots of electrical quantities including voltage, current, active power, reactive power, electrical angle of candidate Generator and balance units.
2	Generator response during Single line to ground fault (100ms) at its terminal (considering nil fault impedance)	Applicant shall submit the generator response during SLG fault at Generator terminal. Report shall include relevant plots of electrical quantities including voltage, current, active power, reactive power, angle of candidate Generator and balance units.
3	Generator response during Three phase fault (100ms) at its terminal (considering nil fault impedance)	Applicant shall submit the generator response during three phase fault at bus bar (including GT). Report shall include relevant plots of electrical quantities including voltage, current, active power, reactive power, electrical angle of candidate Generator and balance units.

Sl. No.	Name of test	Remarks
4	Generator droop test	Applicant shall demonstrate the droop characteristics of a Generating Unit
5	Reactive power capability of generator unit for voltage limits of ± 5%, frequency variations of + 3% and -5% and its combined effect	Applicant shall submit the reactive power absorption/injection capability of Generating unit as individual and aggregated response at HV bus bar through simulation. Applicant shall attach the plots of electrical quantities including terminal voltage, field voltage, stator current, field current, active power & reactive power, EFD.

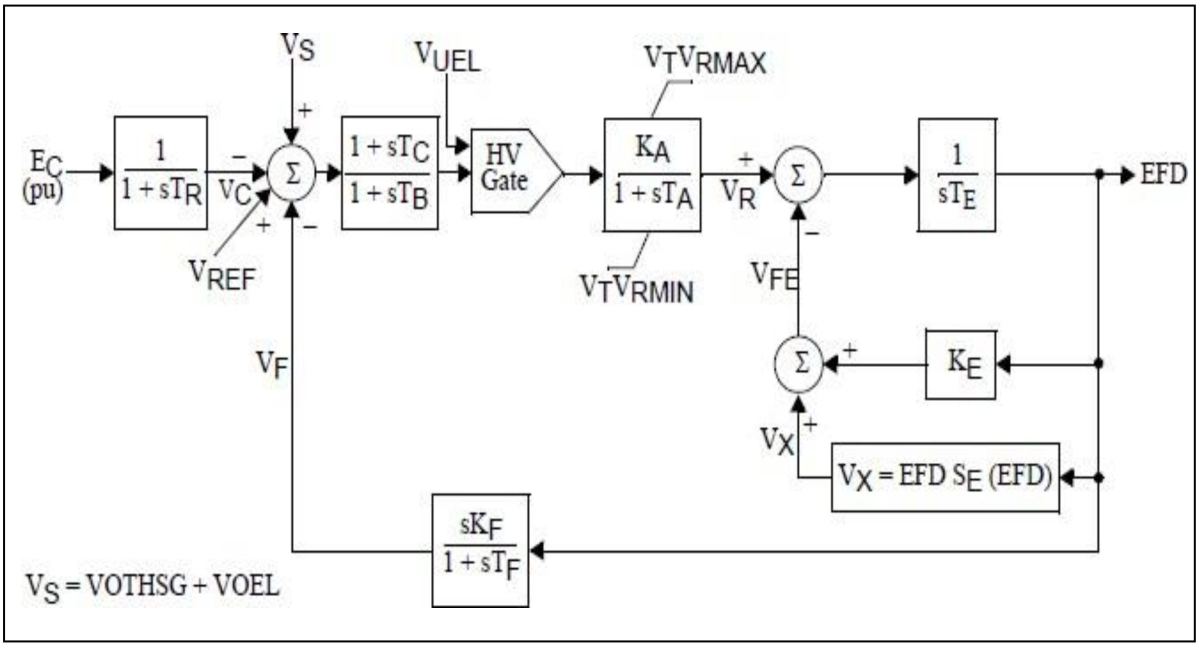
Annexure-6

1. DC Exciters Generic model:

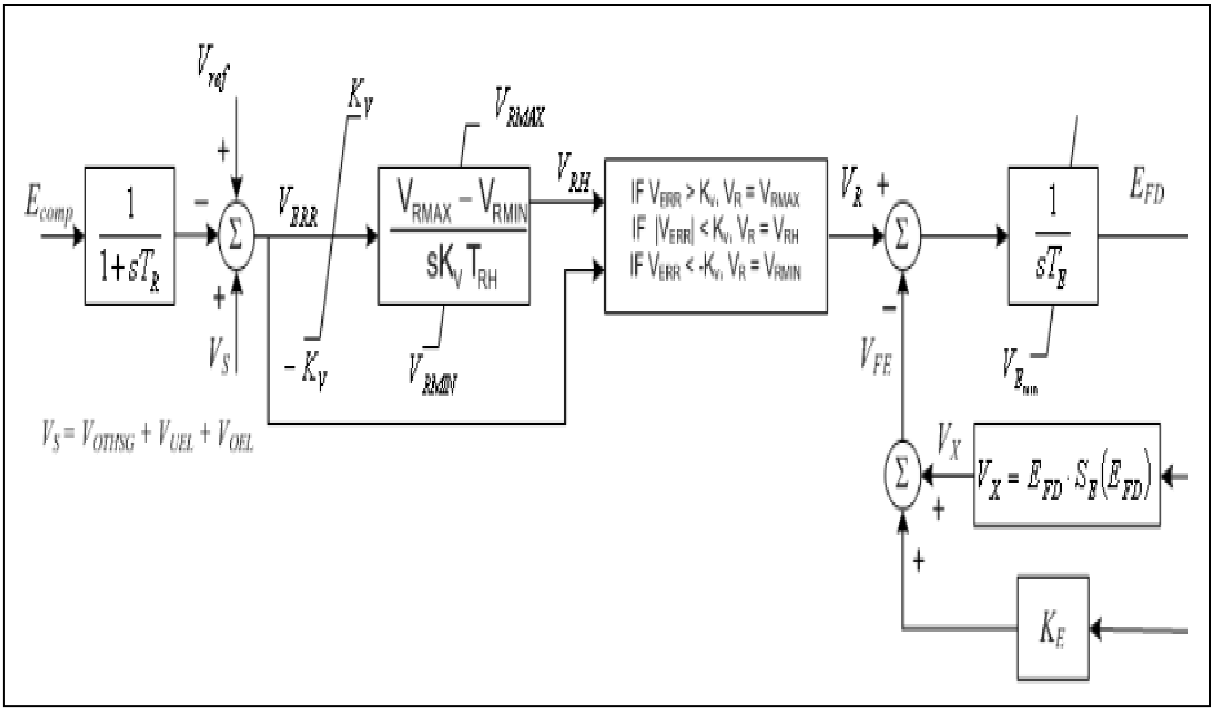
➢ Type DC1A: 1992 IEEE type DC1A excitation system model



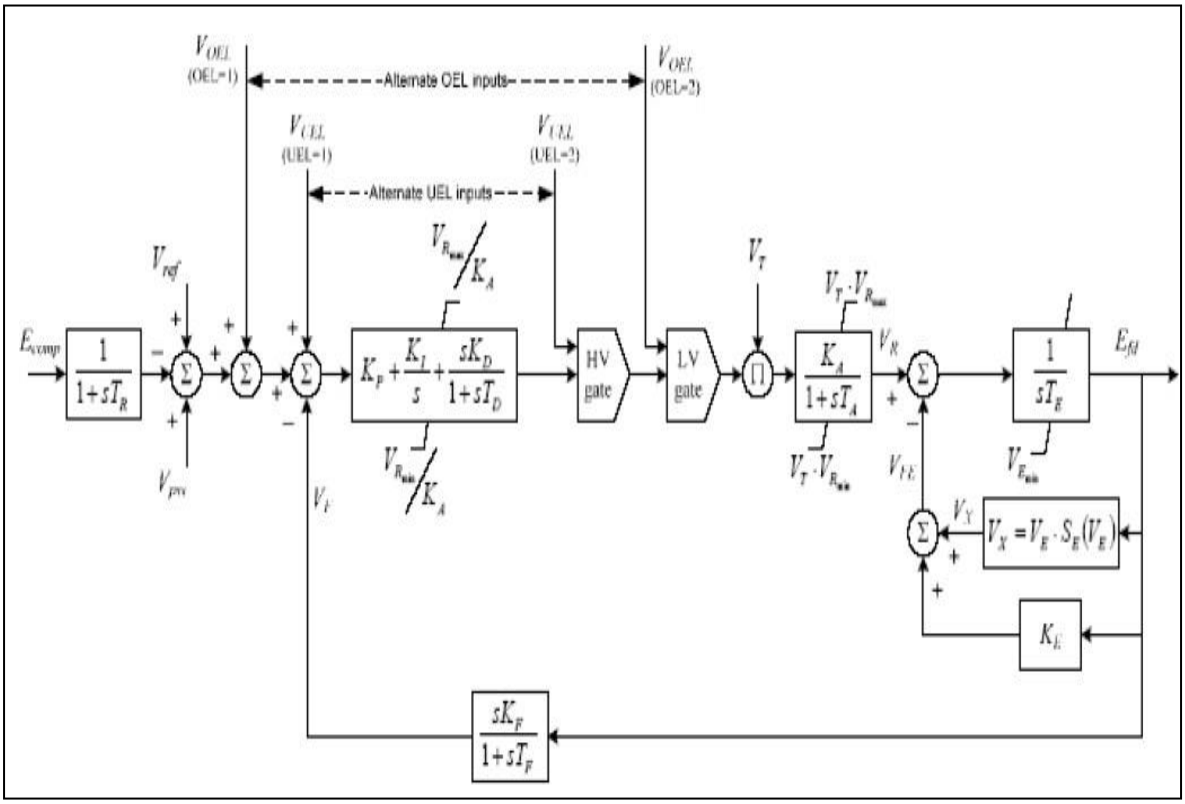
➢ Type DC2A: 1992 IEEE type DC2A excitation system model



- **Type DC3A: IEEE 421.5 2005 DC3A excitation system**

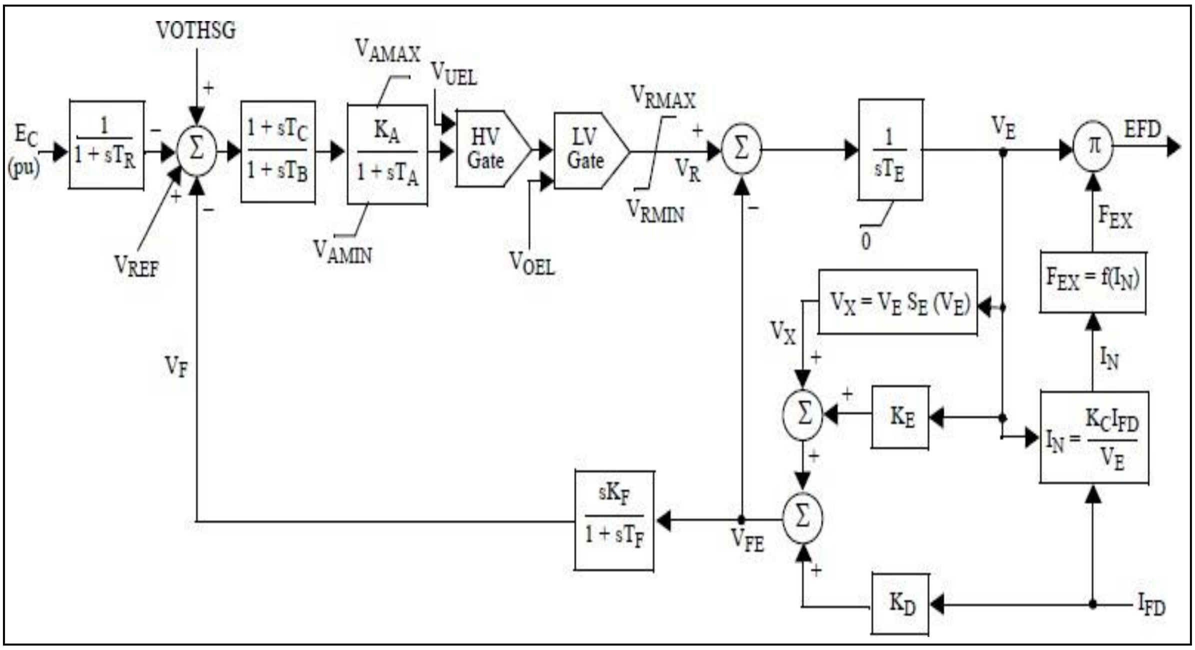


- **Type DC4B: IEEE 421.5 2005 DC4B excitation system**

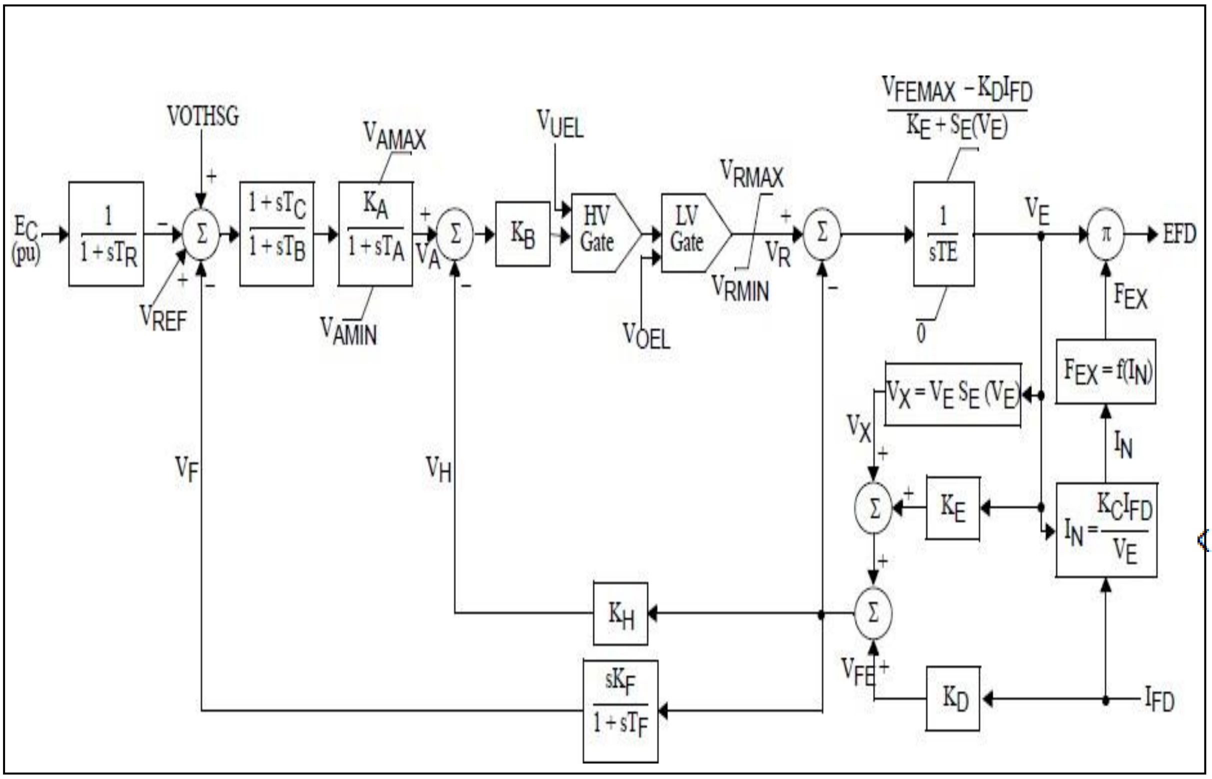


2. AC Exciters Generic Models:

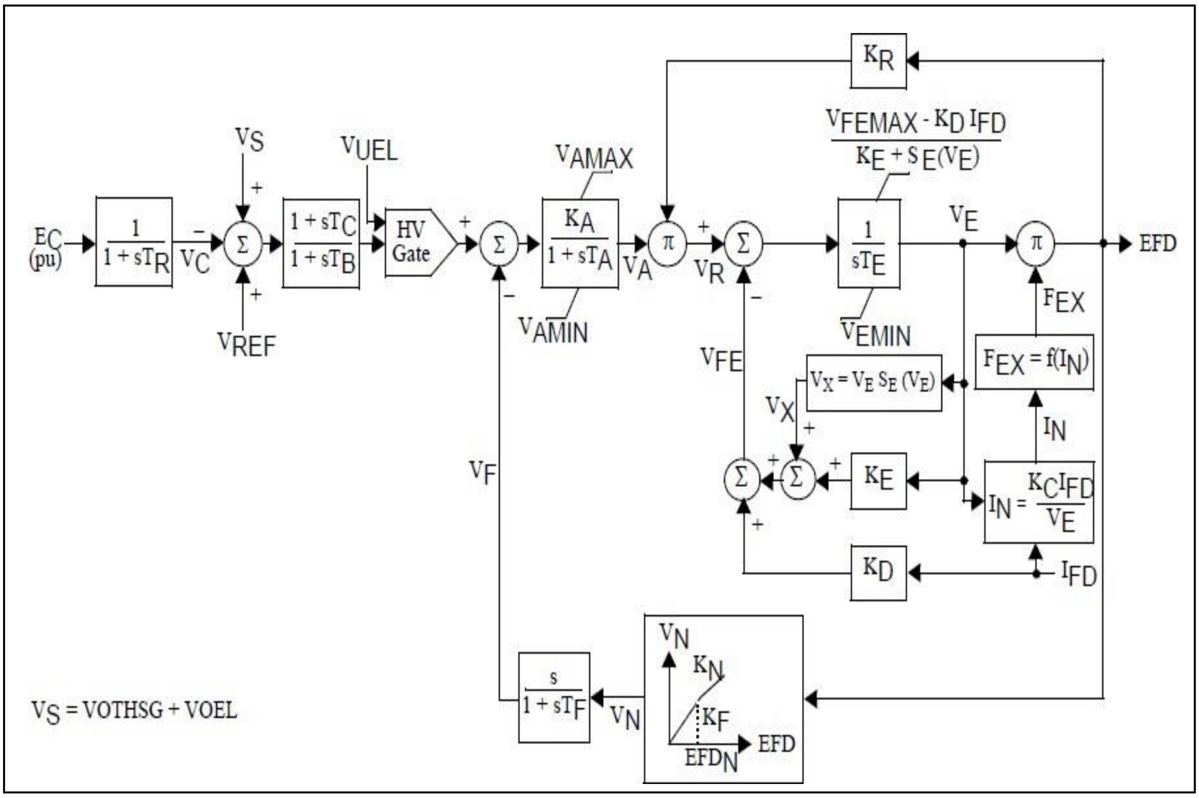
- **Type AC1A: 1992 IEEE type AC1A excitation system model**



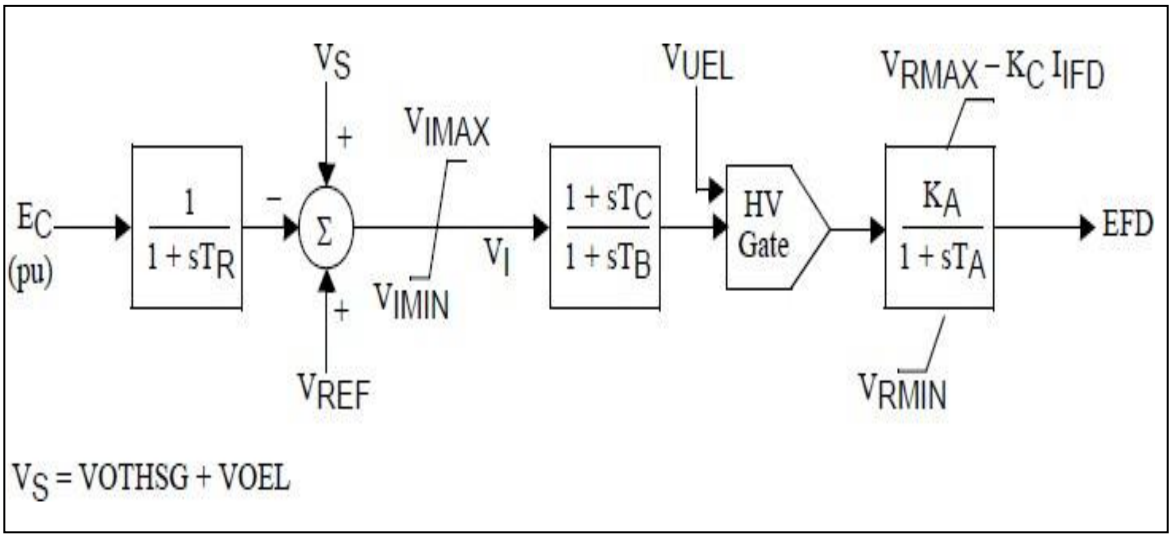
- **Type AC2A: 1992 IEEE type AC2A excitation system model**



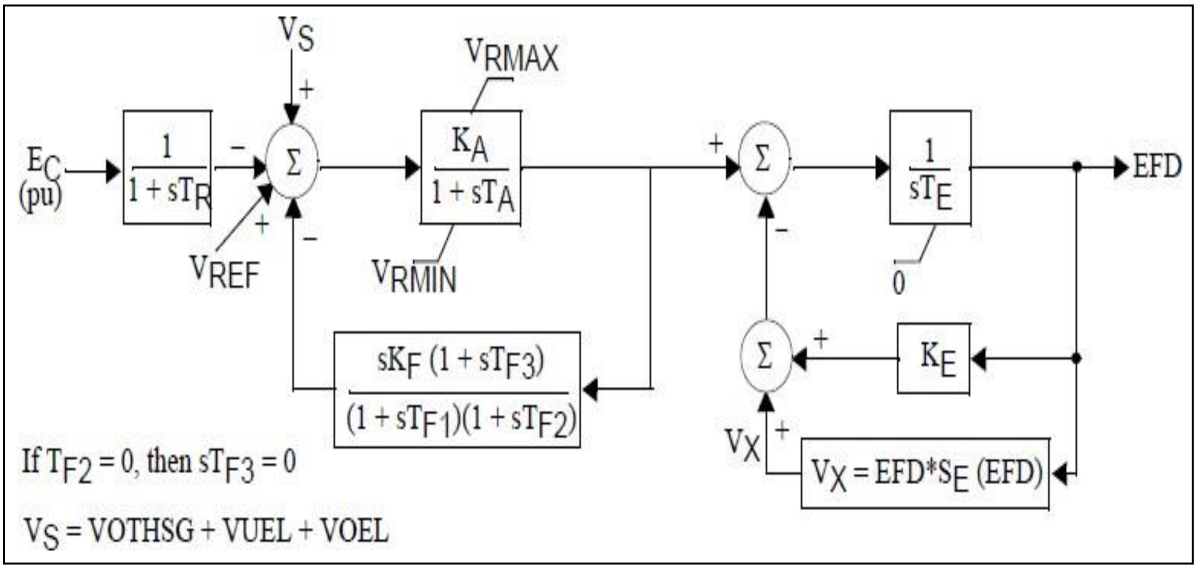
- **Type AC3A: 1992 IEEE type AC3A excitation system model**



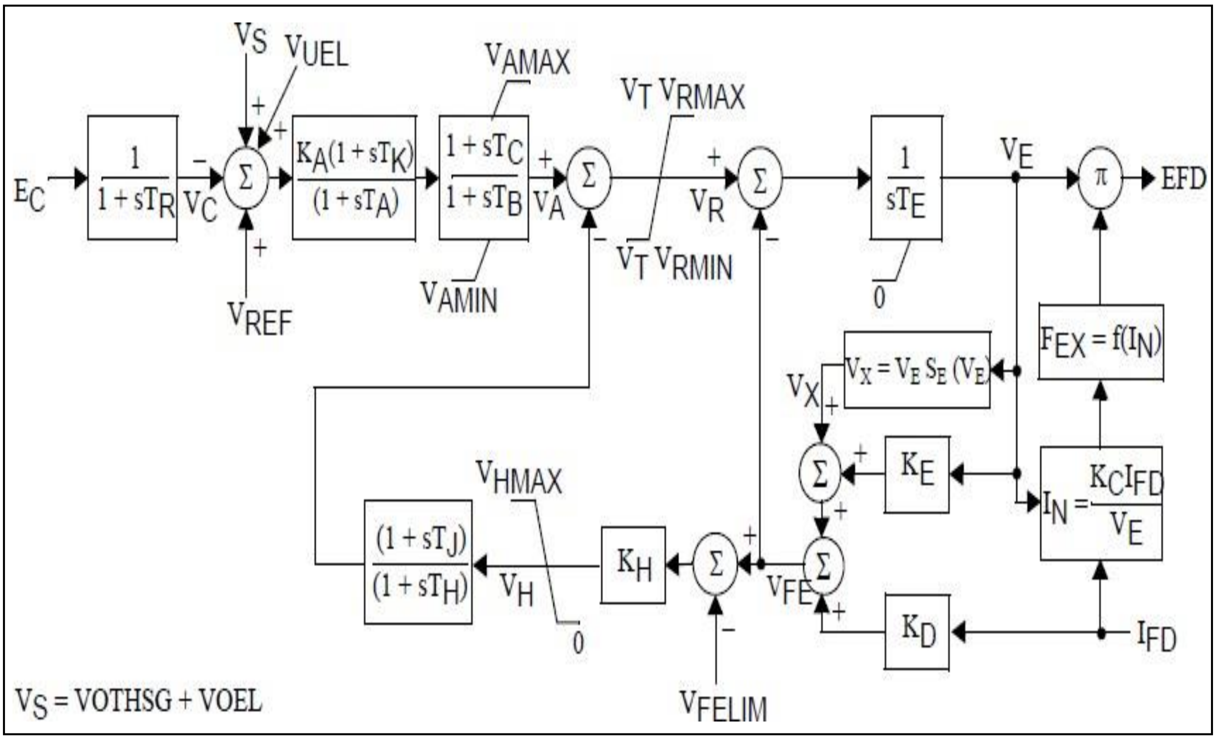
➢ **Type AC4A: 1992 IEEE type AC4A excitation system model**



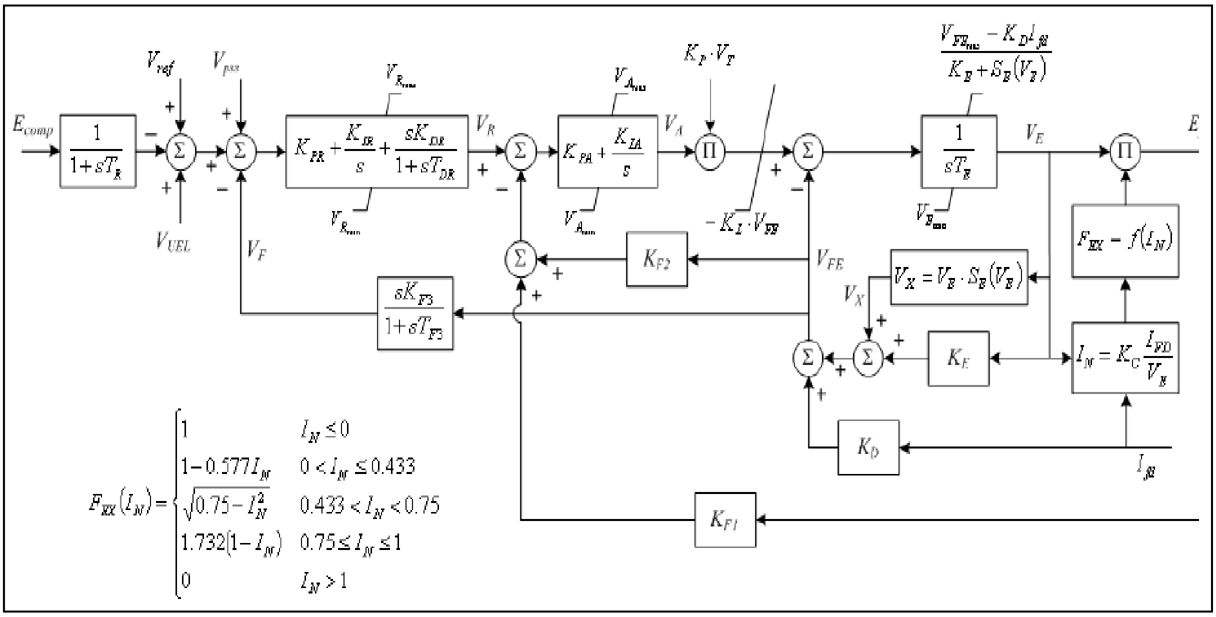
- **Type AC5A: 1992 IEEE type AC5A excitation system model**



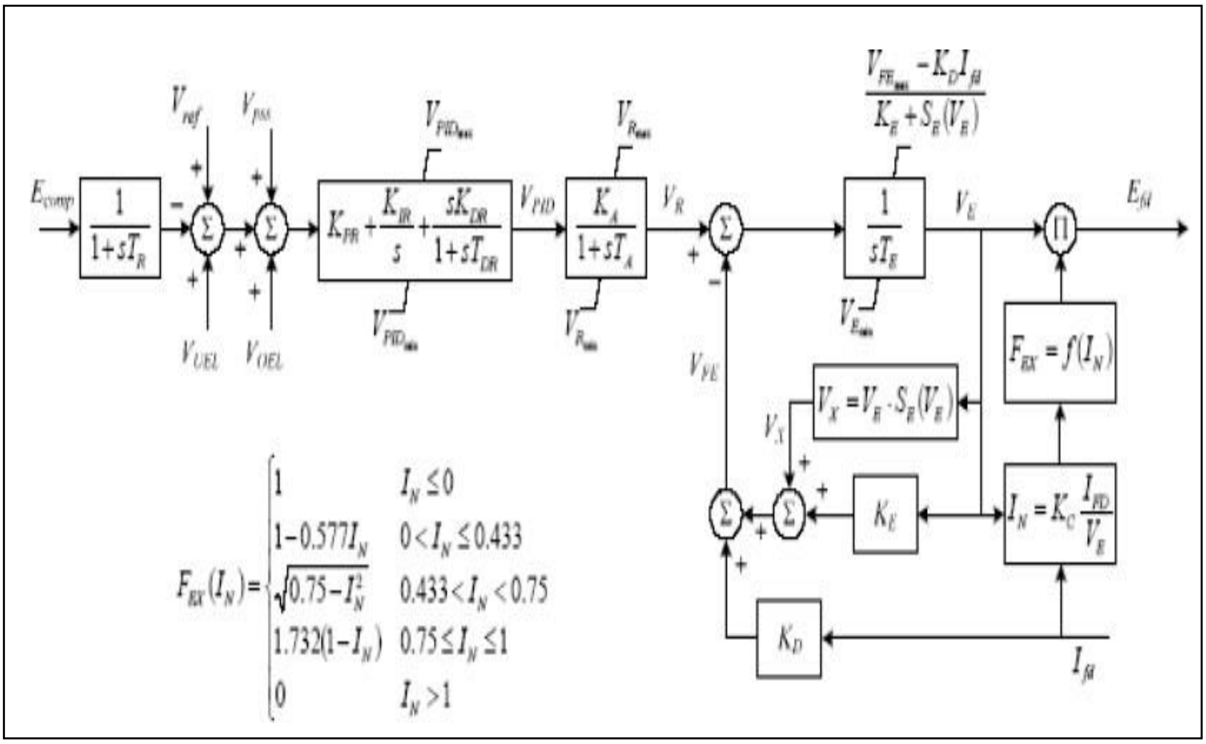
- **Type AC6A: IEEE 421.5 excitation system model**



➢ Type AC7B: IEEE 421.5 2005 AC7B excitation system

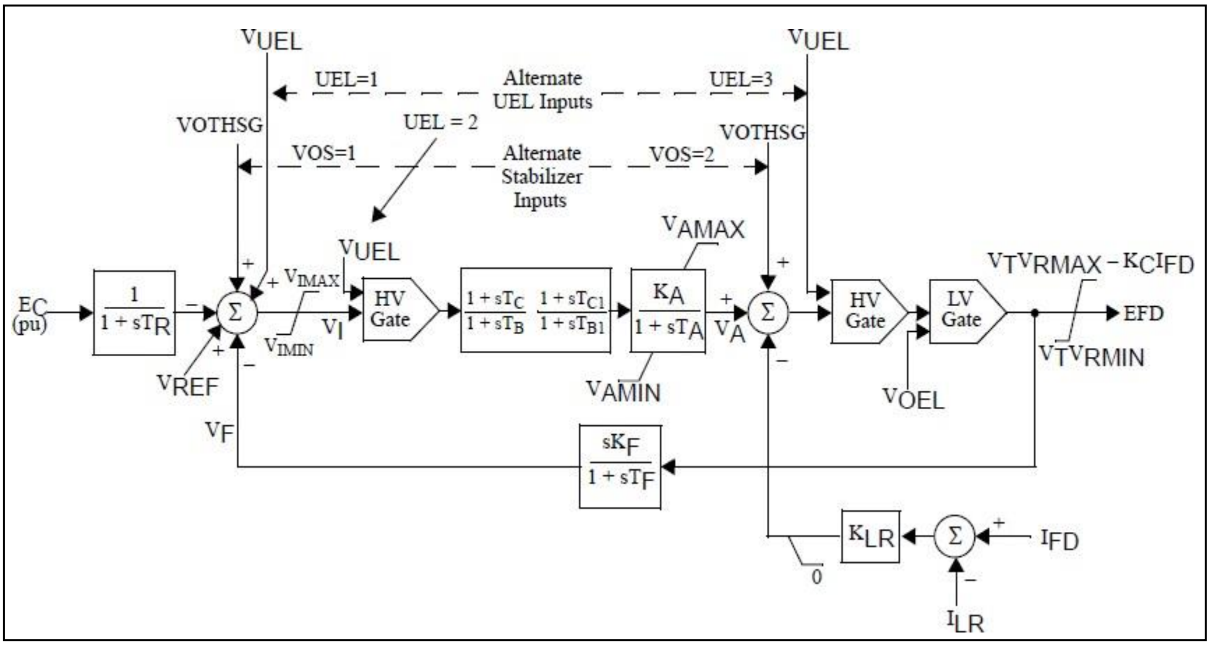


➢ Type AC8B: IEEE 421.5 2005 AC8B excitation system

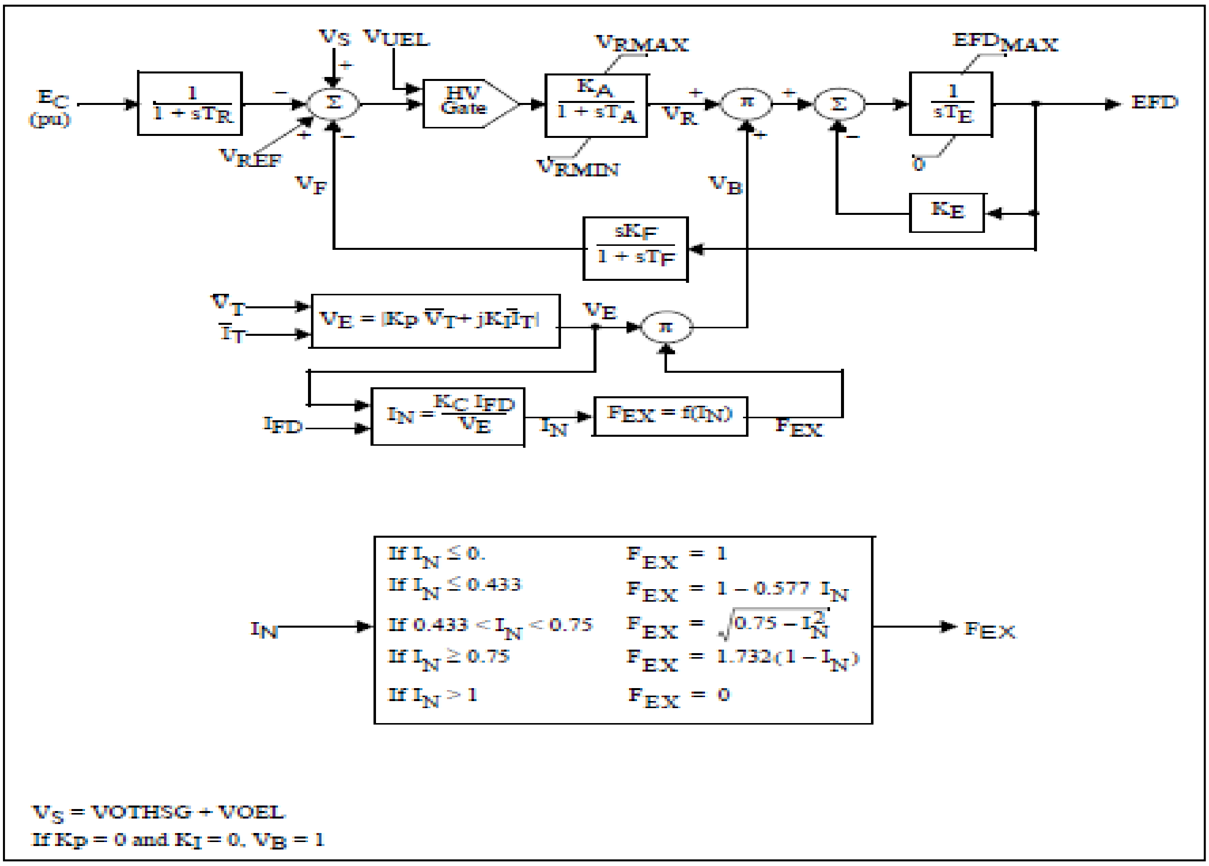


3. Commonly Used Static Exciters Generic Models block diagrams:

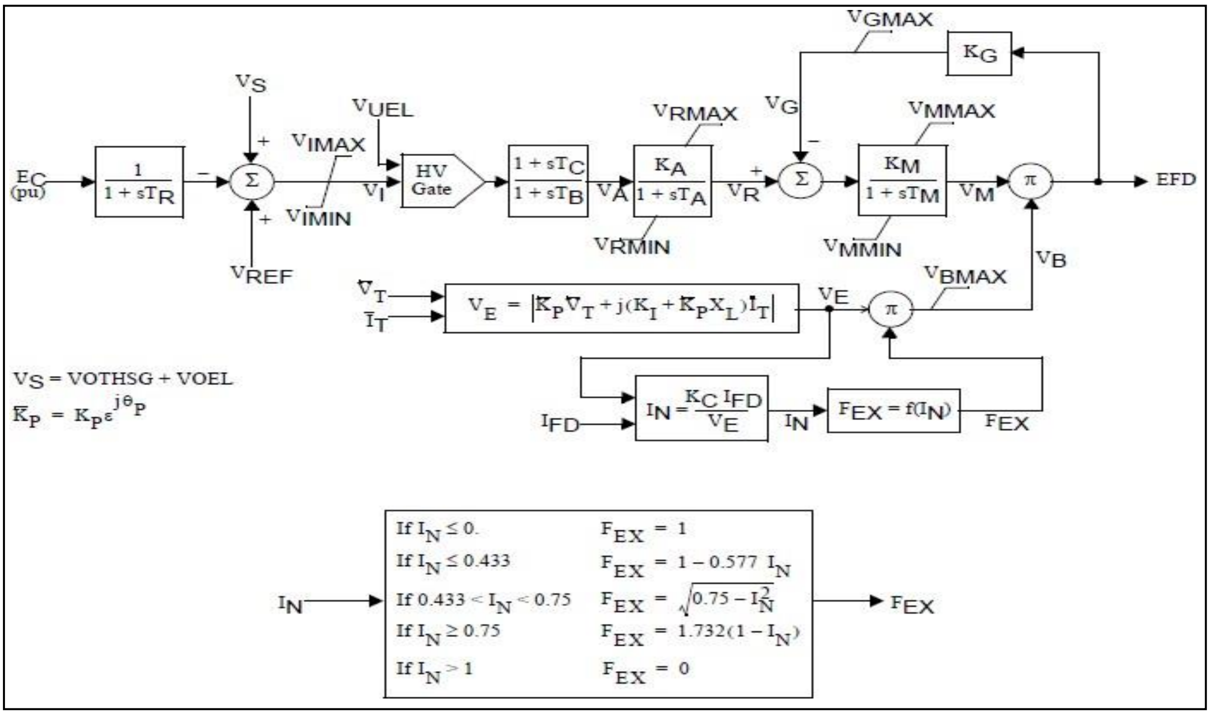
➢ Type ST1A: 1992 IEEE type ST1A excitation system model



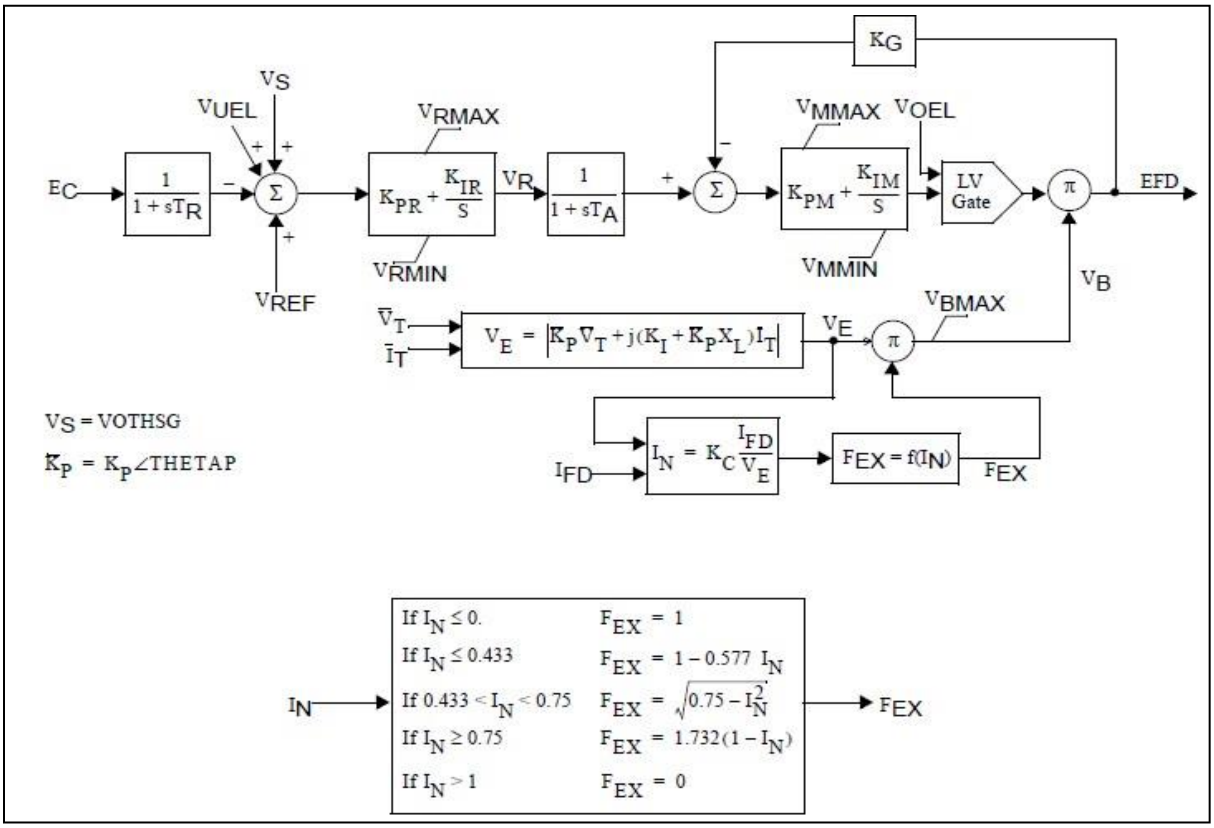
➢ Type ST2A: 1992 IEEE type ST2A excitation system model



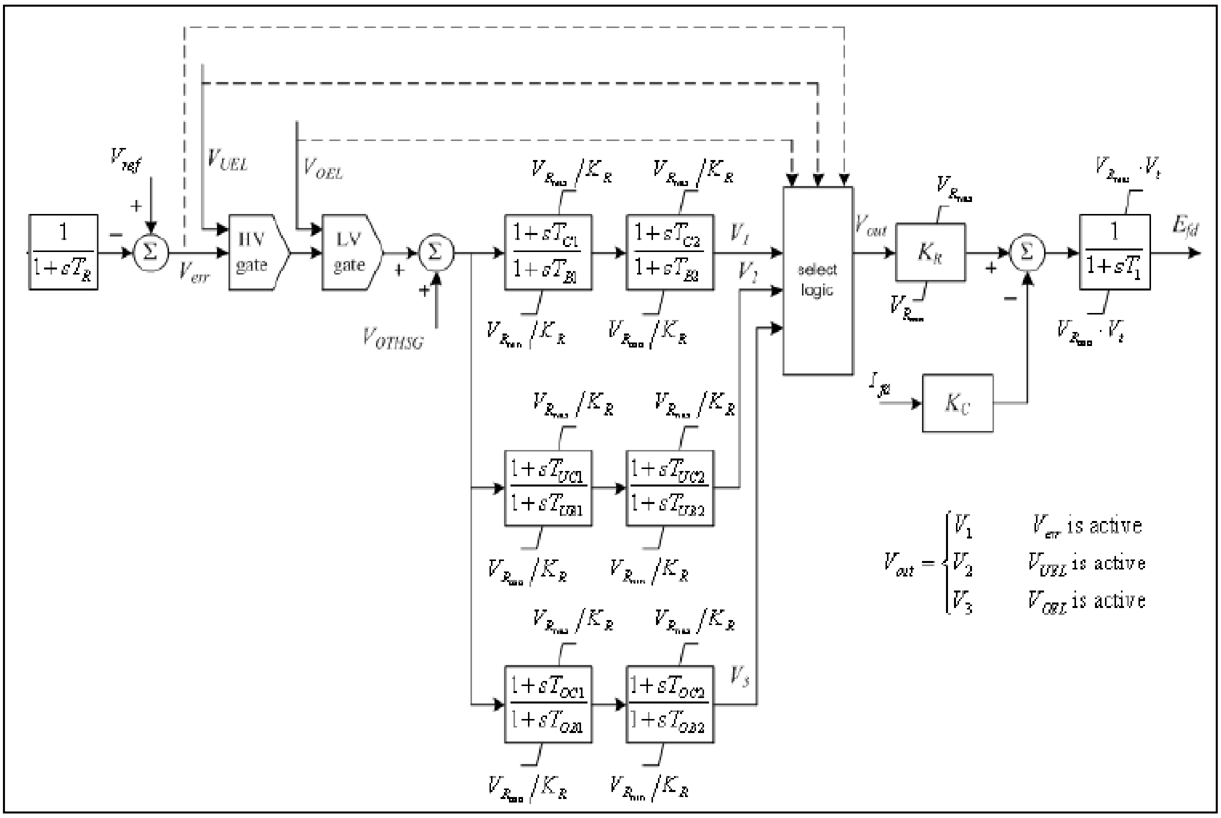
- **Type ST3A: 1992 IEEE type ST3A excitation system model**



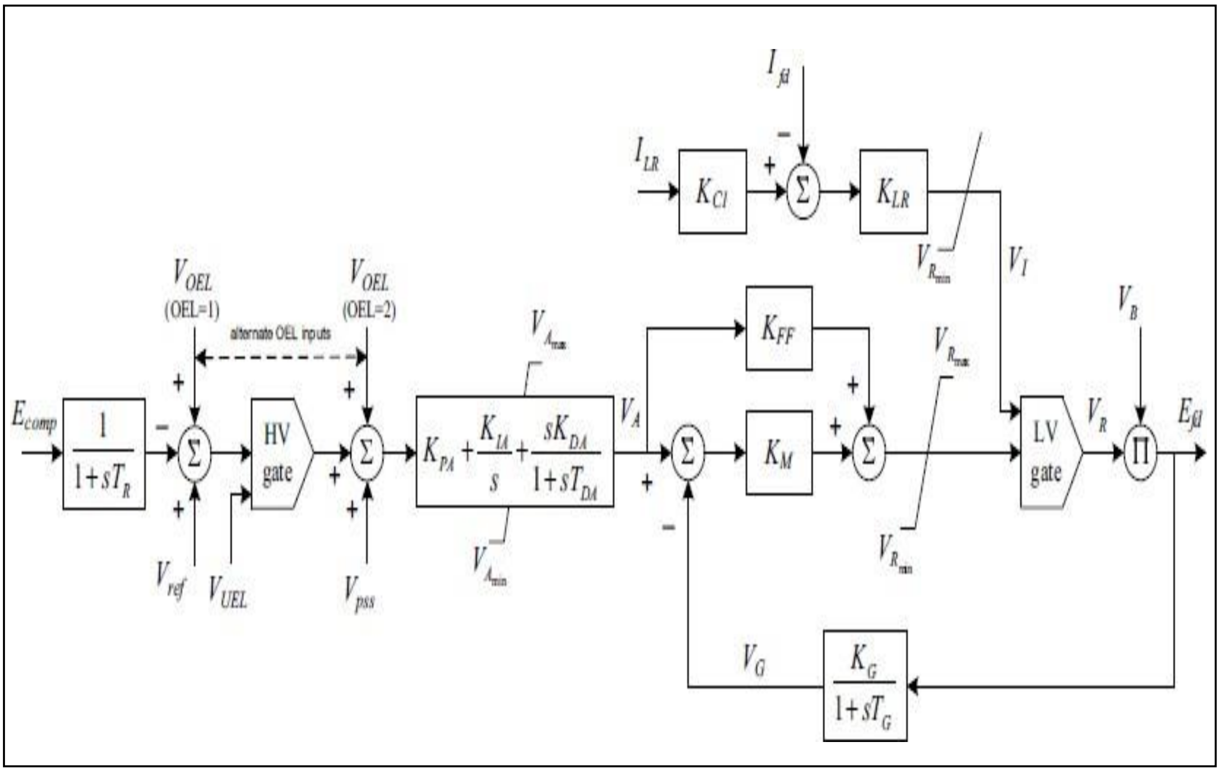
- **Type ST4B: IEEE type ST4B potential or compounded source-controlled rectifier exciter**



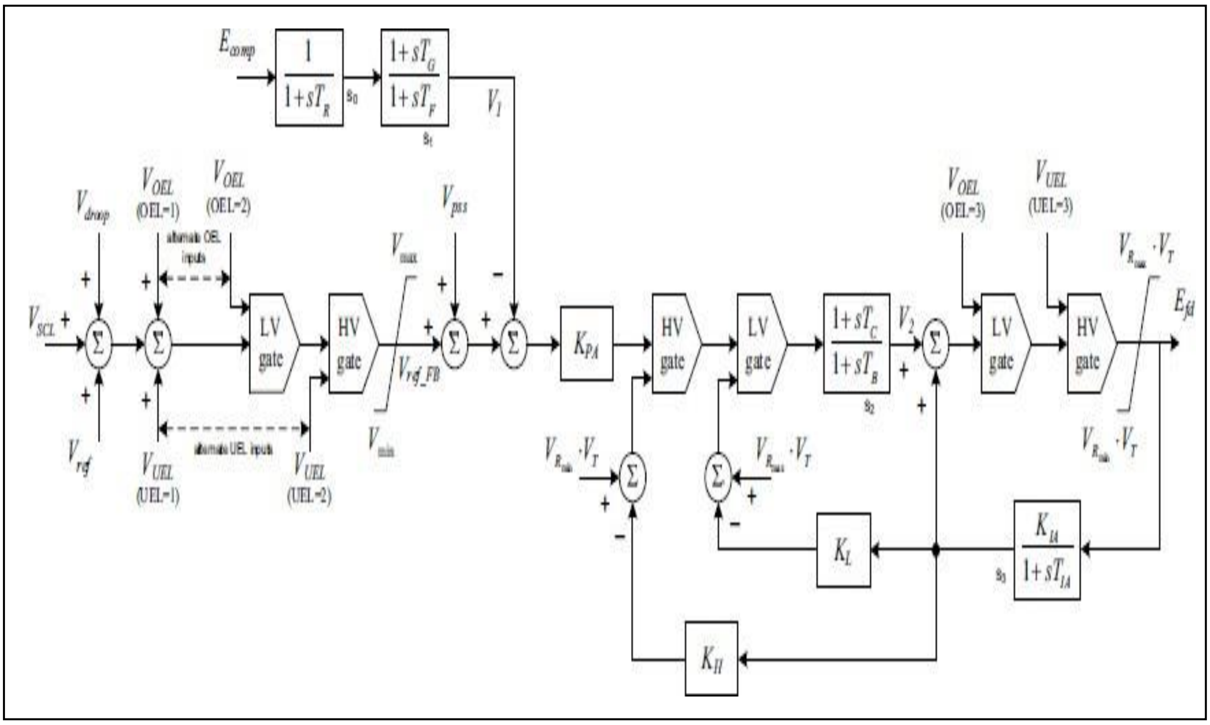
- **Type ST5B: IEEE 421.5 2005 ST5B excitation system**



- **Type ST6B: IEEE 421.5 2005 ST6B excitation system**

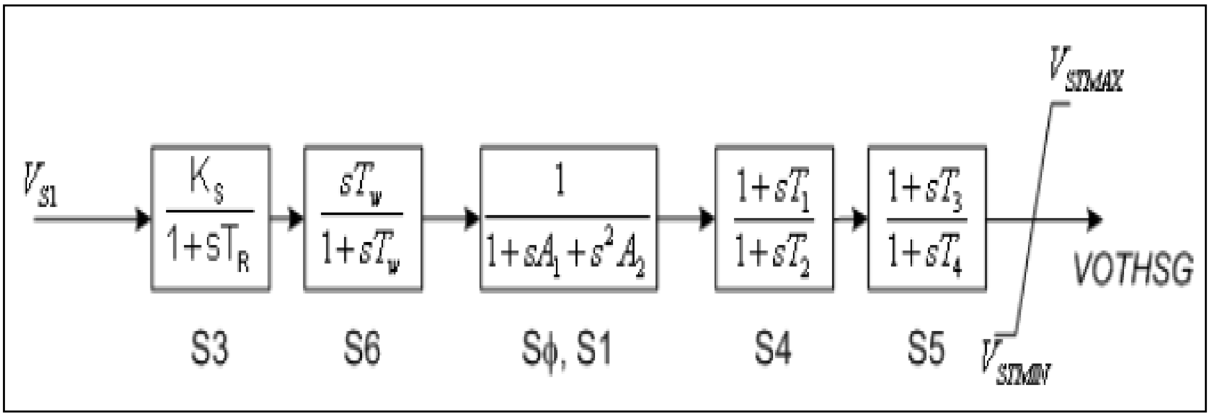


➢ Type ST7B: IEEE 421.5 2005 ST7B excitation system

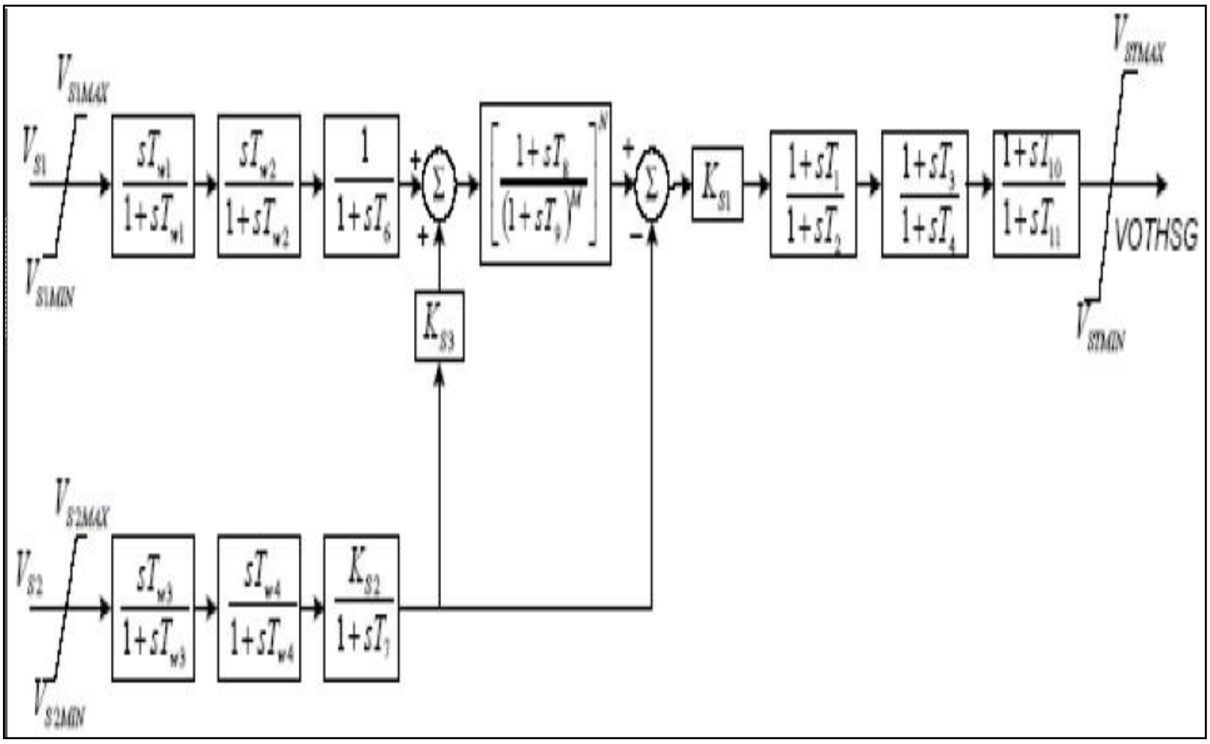


4. Commonly Used Power System Stabilizer generic models block diagrams:

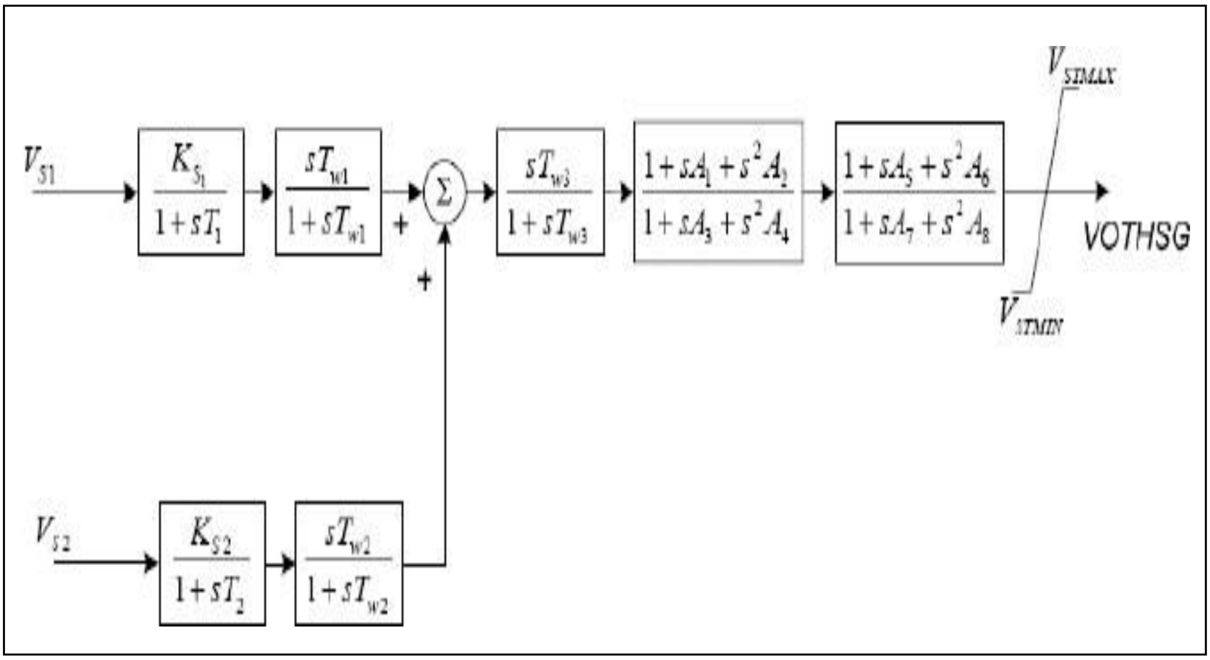
- **PSS1A: IEEE Std. 421.5-2005 PSS1A Single-Input Stabilizer model**



- **PSS2B: IEEE 421.5 2005 PSS2B IEEE dual-input stabilizer model**

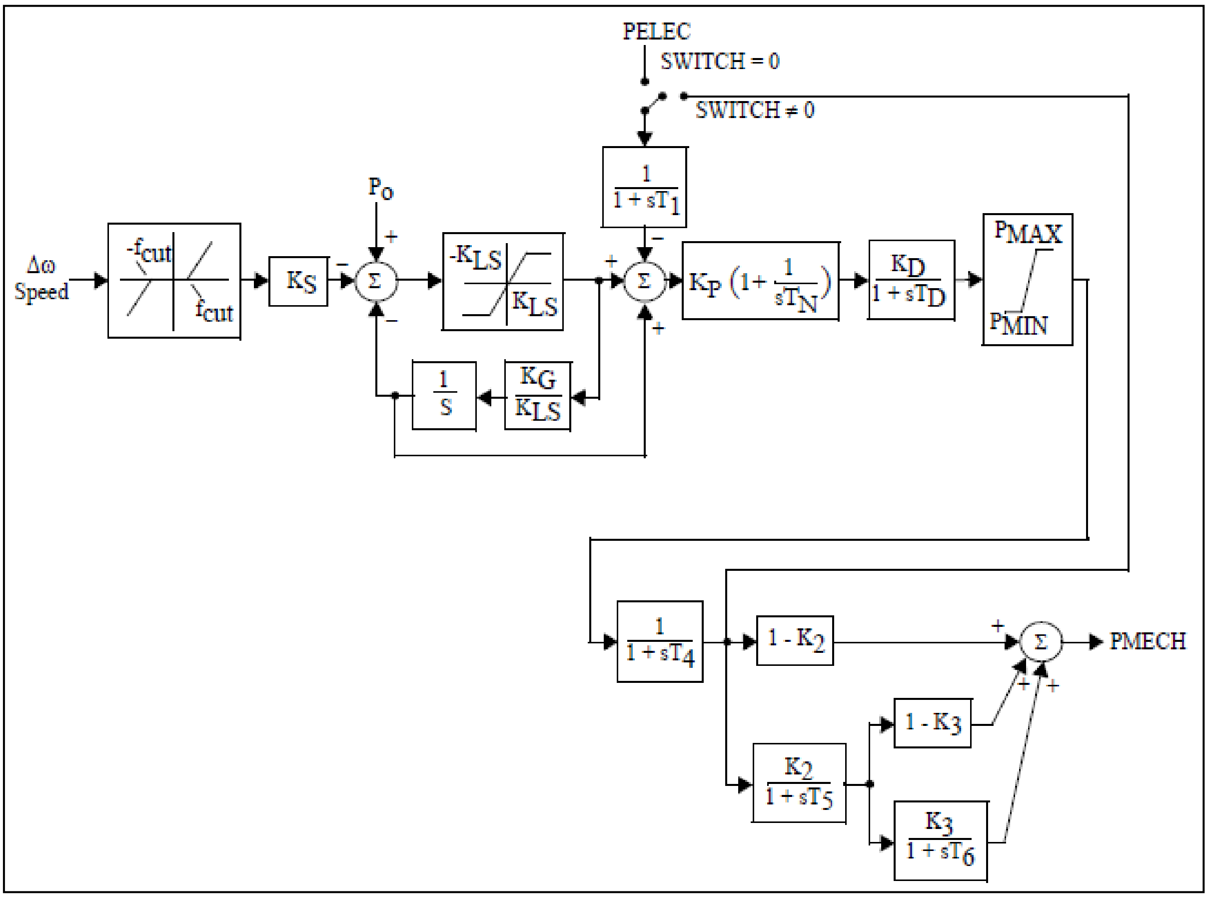


- **PSS3B: IEEE Std. 421.5 2005 PSS3B IEEE dual-input stabilizer model**

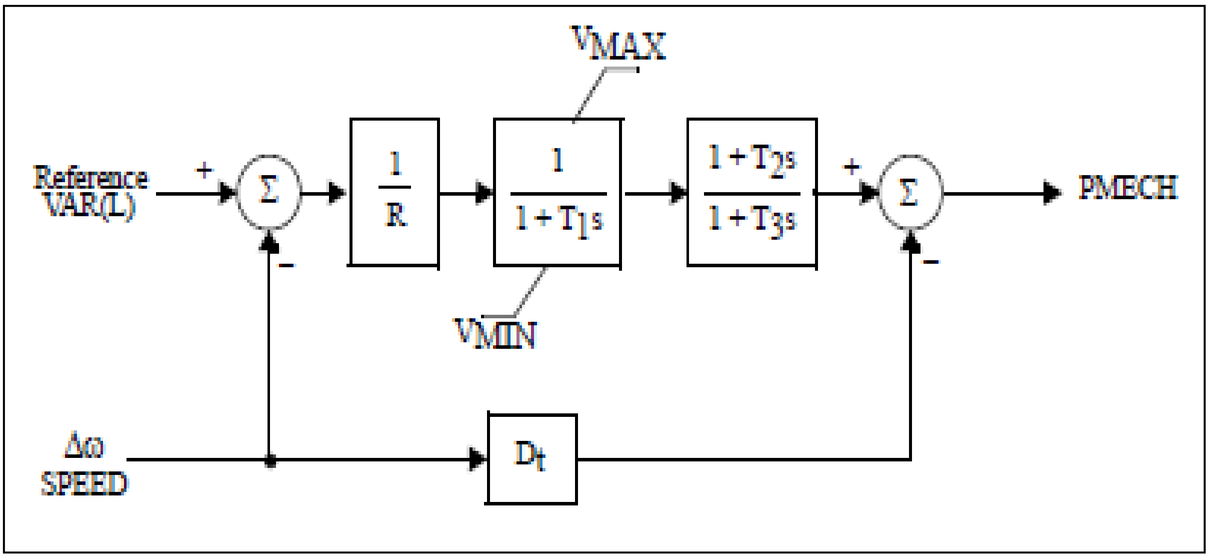


5. Commonly Used Steam Turbine Generic Models Block Diagrams:

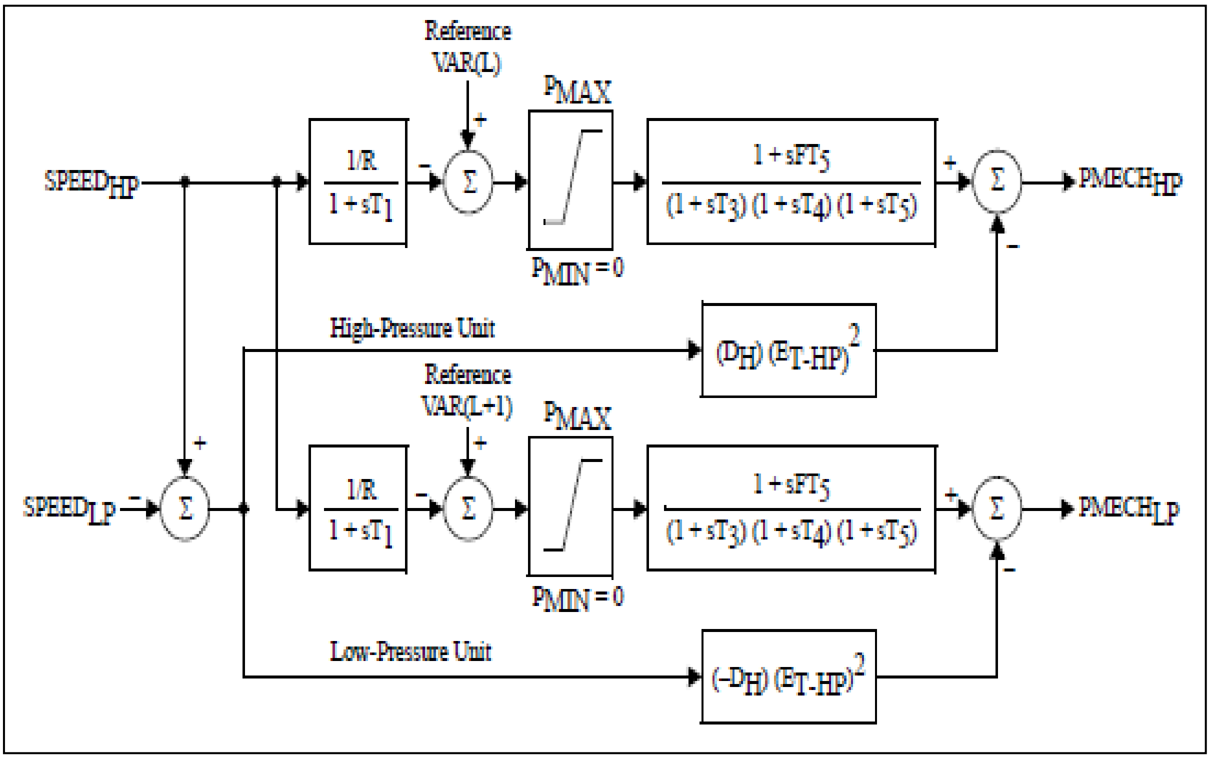
➢ **BBGOV1: Brown-Boveri turbine-governor model**



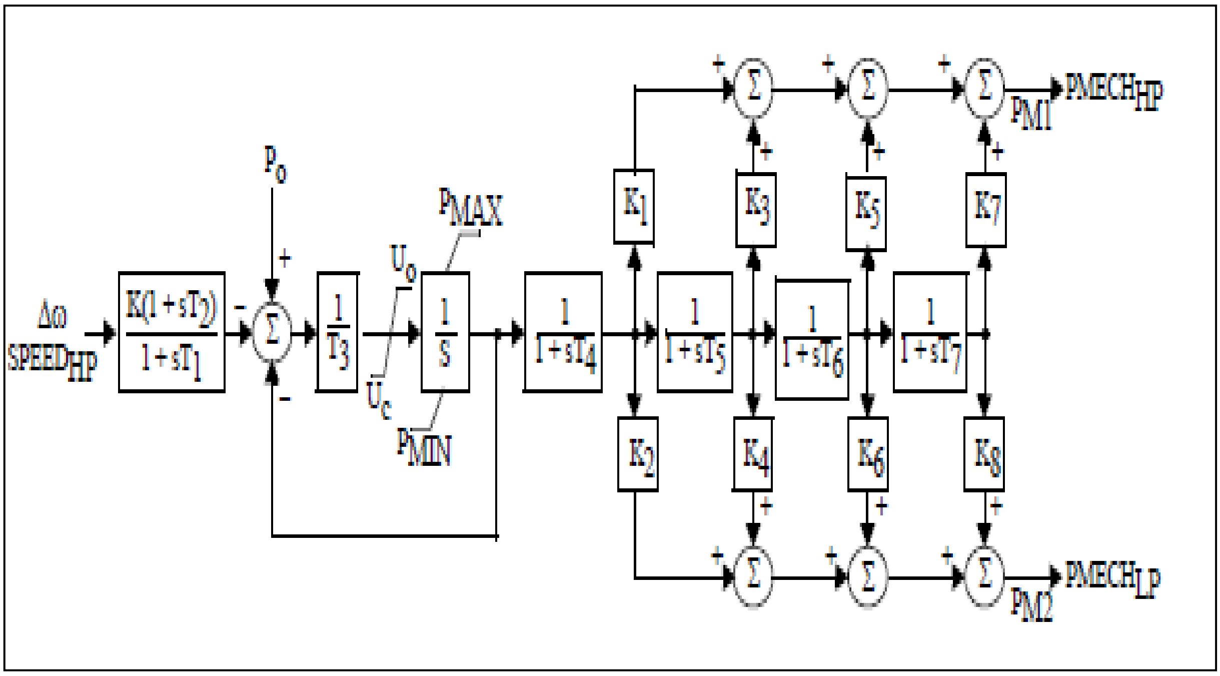
➢ **TGOV1: Steam turbine-governor model**



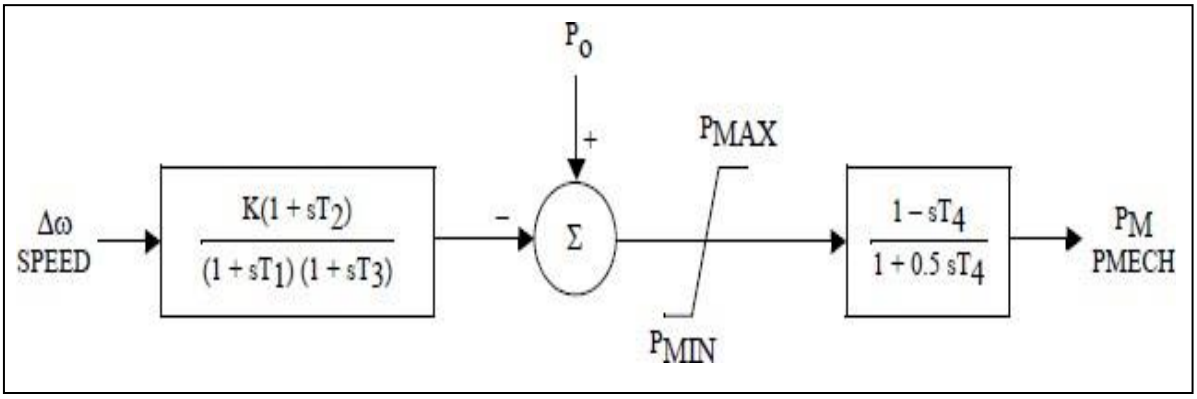
- **CRCMGV: Cross compound turbine-governor model**



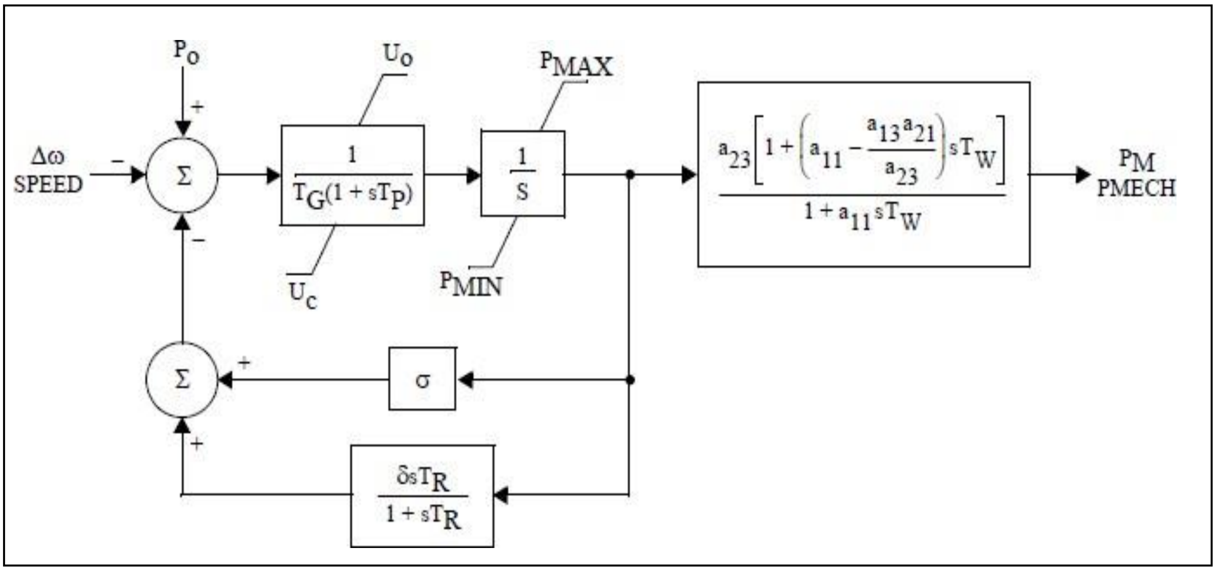
- **IEEEG1: 1981 IEEE type 1 turbine-governor model**



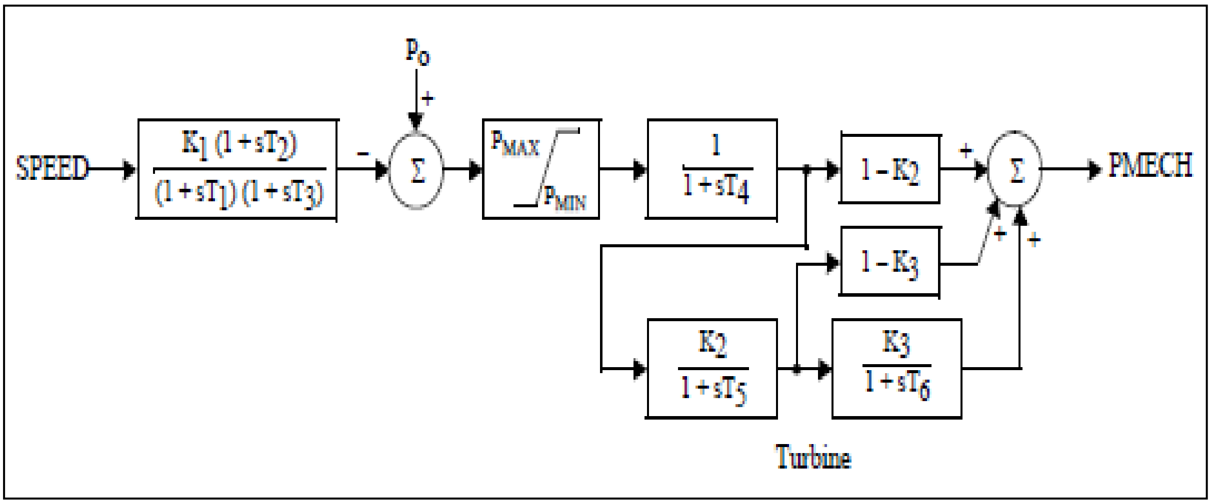
- **IEEEG2: 1981 IEEE Type 2 Speed-Governing Model**



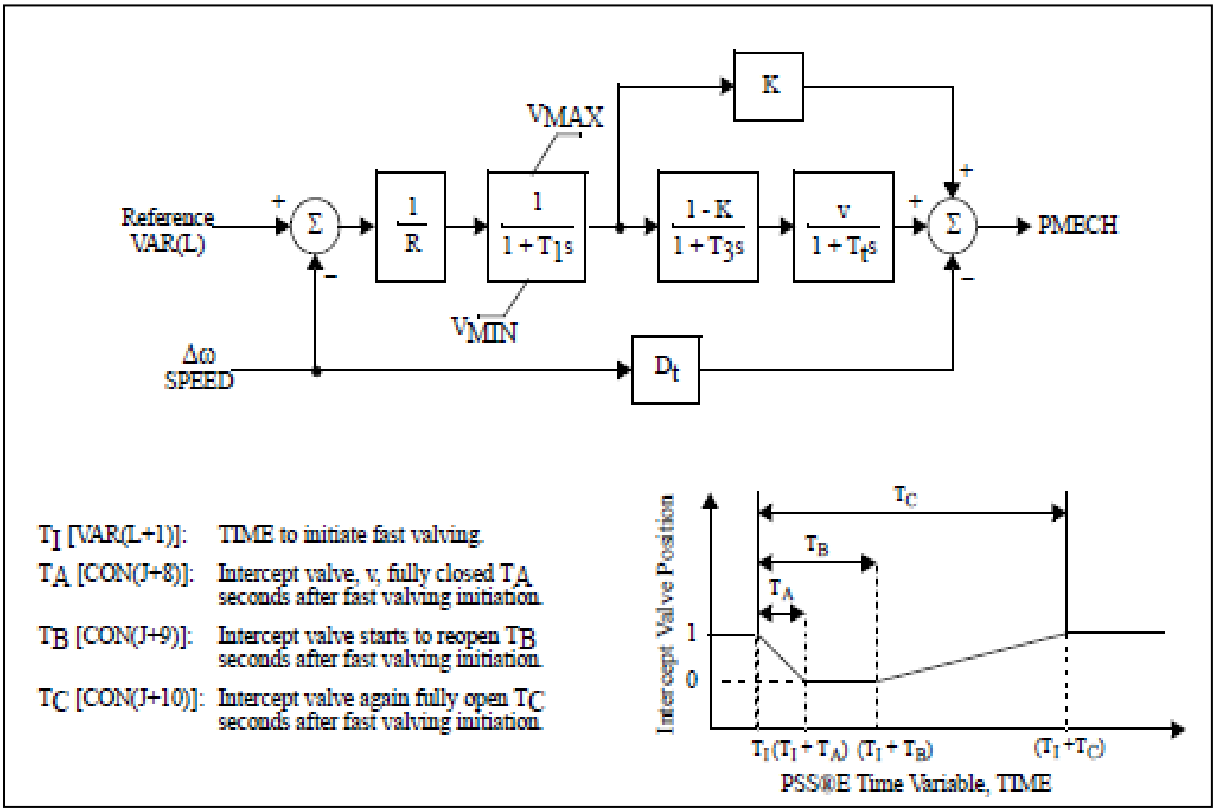
- **IEEEG3: 1981 IEEE Type 3 Speed-Governing Model**



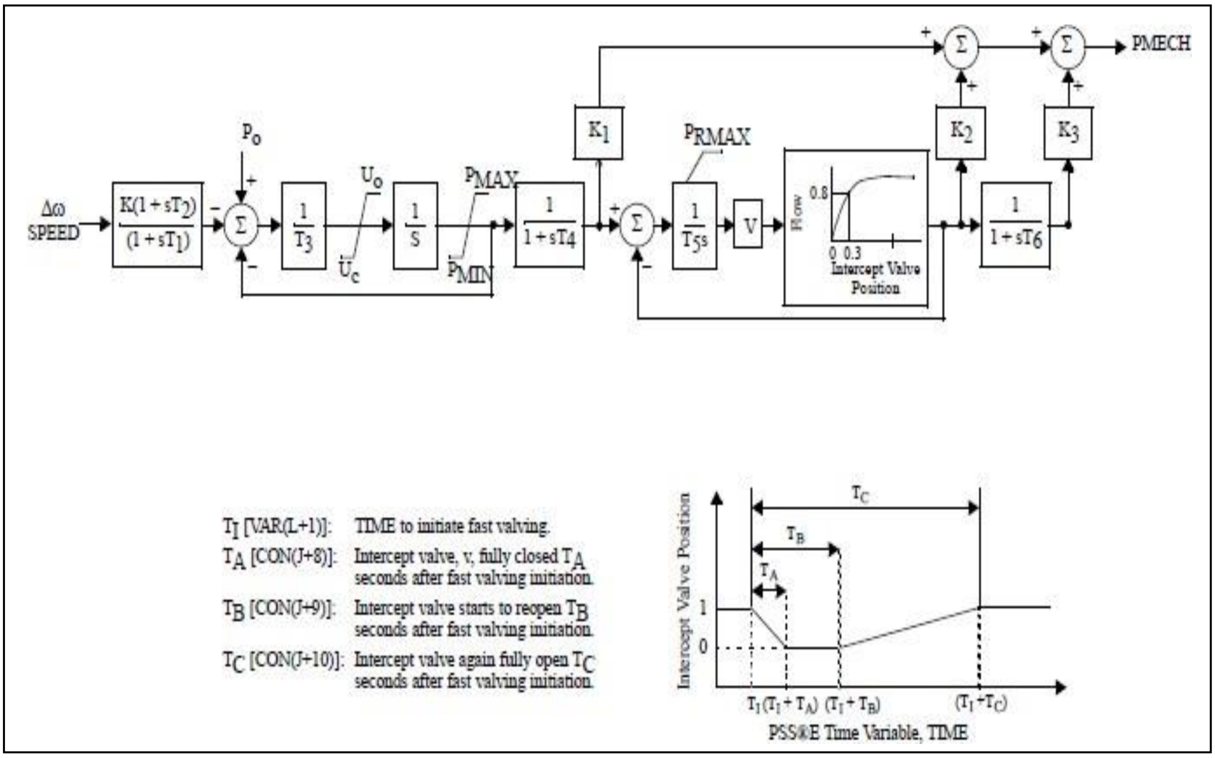
- **IEESGO: 1973 IEEE standard turbine-governor model**



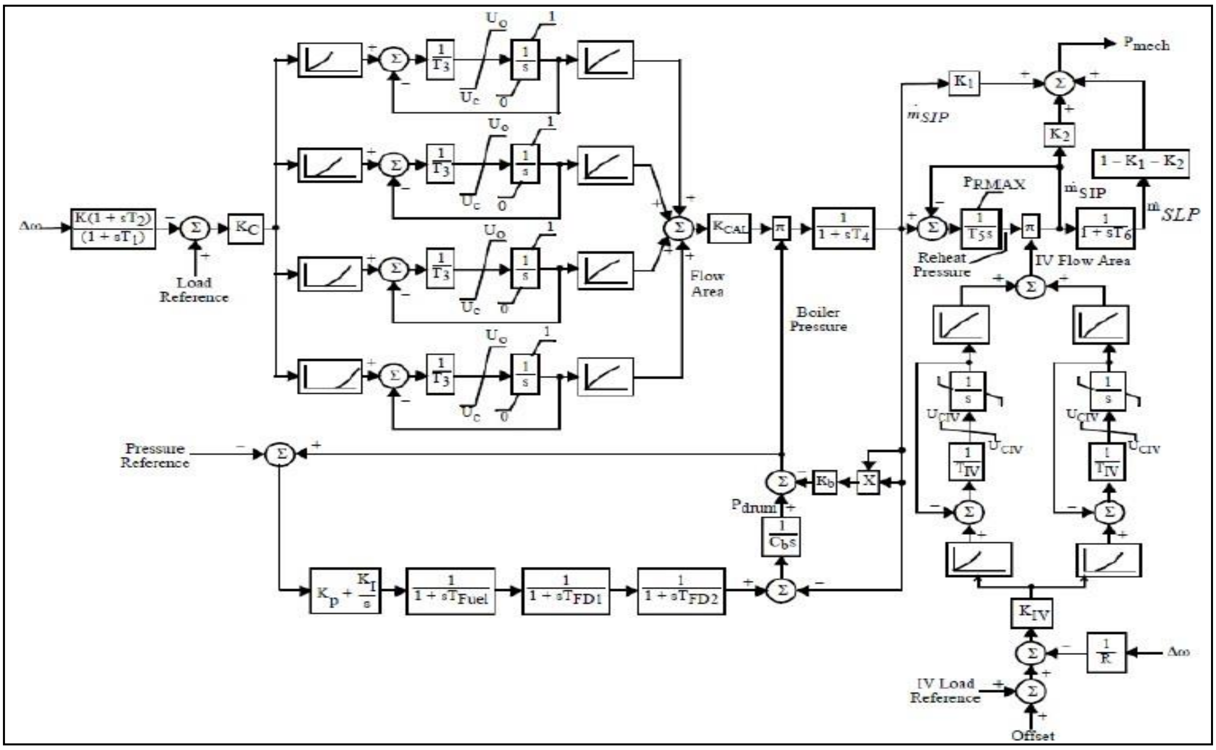
➢ TGOV2: Steam turbine-governor model with fast valving



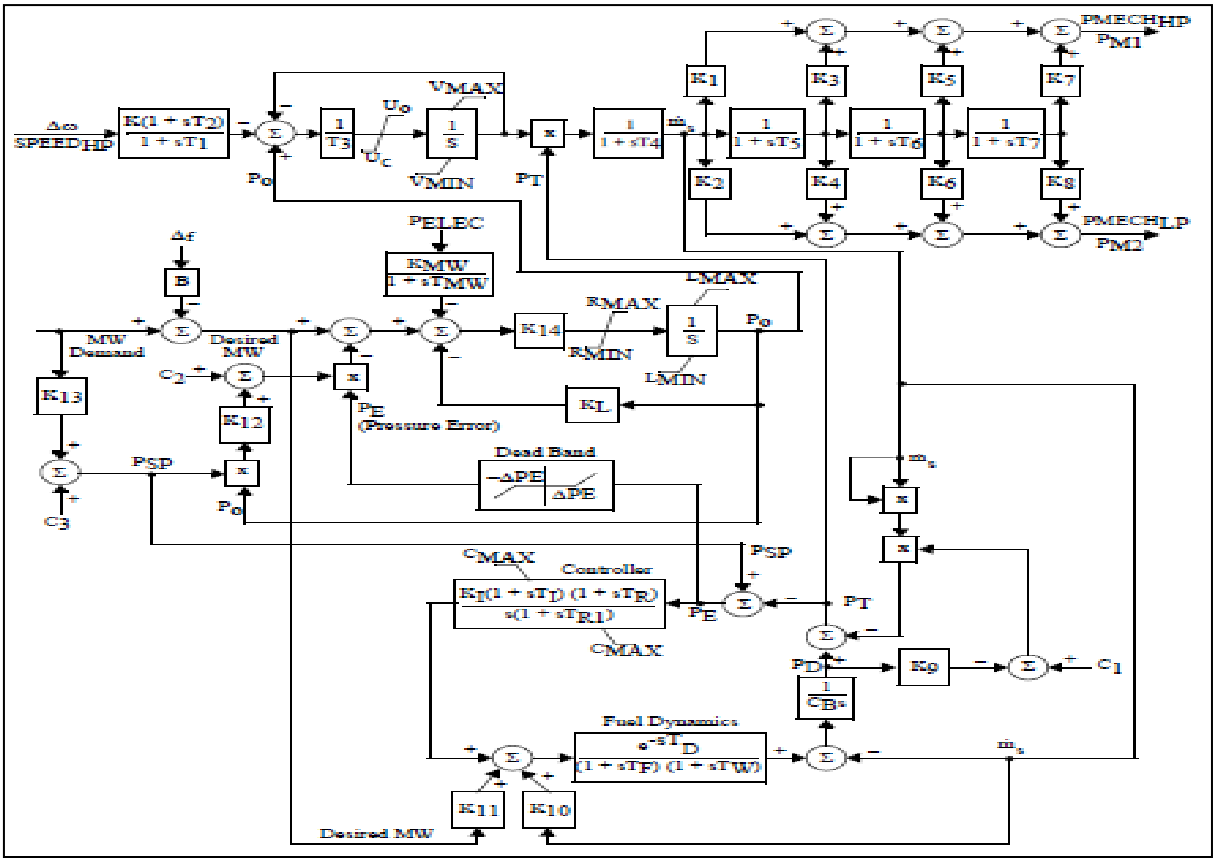
➢ TGOV3: Modified IEEE type 1 turbine-governor model with fast valving



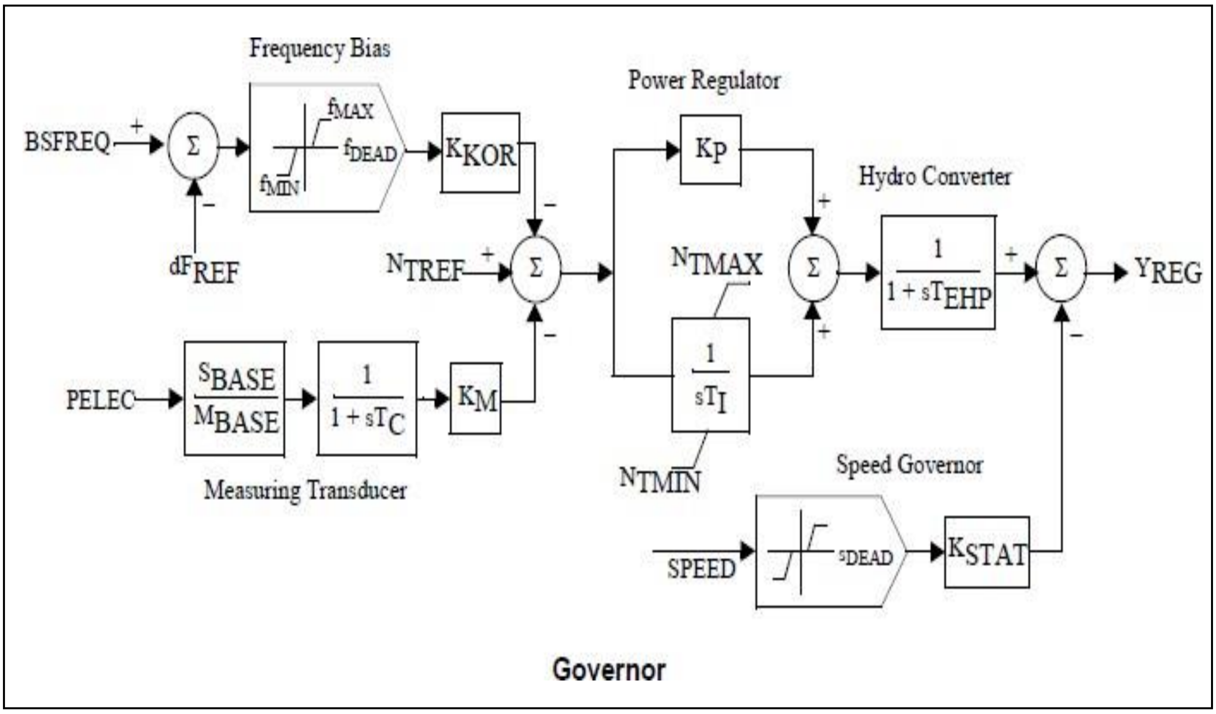
➢ TGOV4: Modified IEEE type 1 speed governing model with PLU and EVA

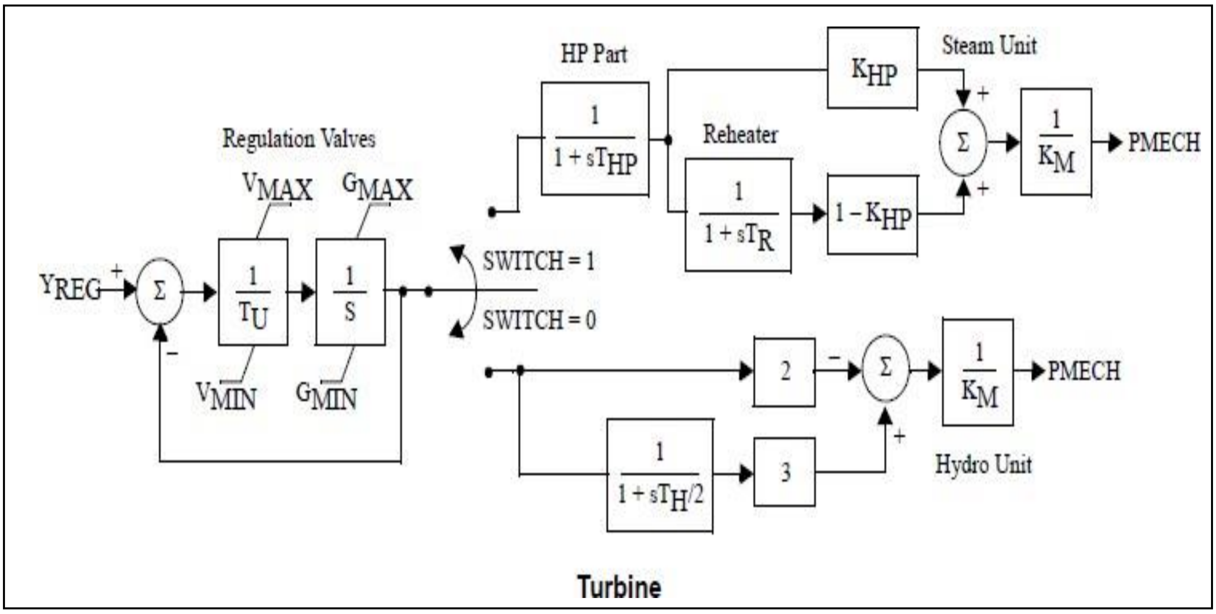


➢ TGOV5: Modified IEEE type 1 turbine-governor model with boiler controls

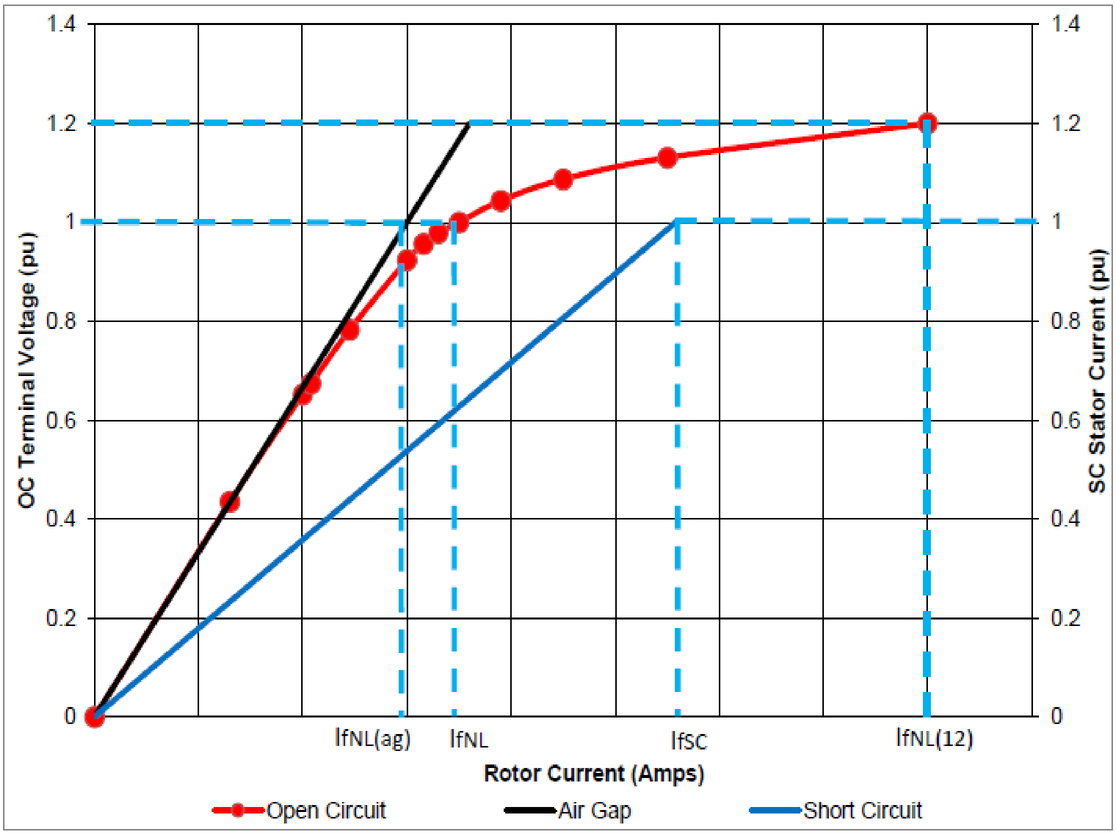


➢ TURCZT: Czech Hydro and Steam Governor





➢ **Calculation of saturation parameters:**



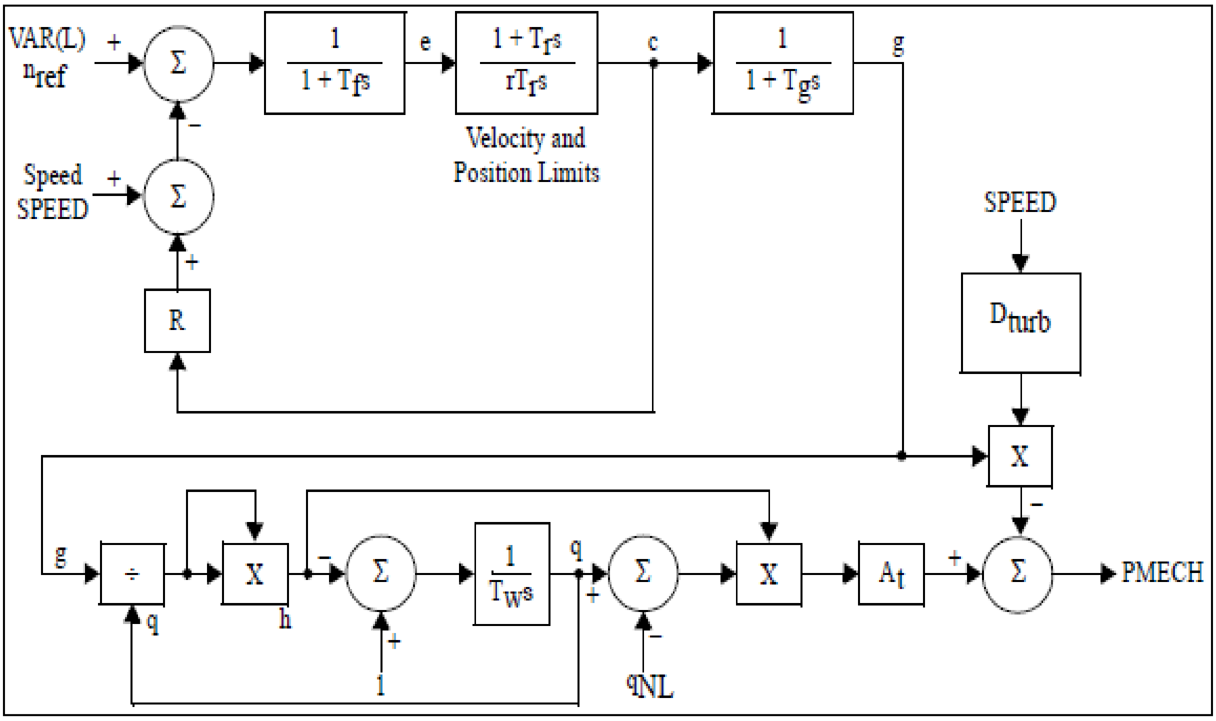
The saturation can be calculated using the following calculation:

$$S(1.0) = \frac{If_{NL} - If_{NL(AG)}}{If_{NL(AG)}}$$

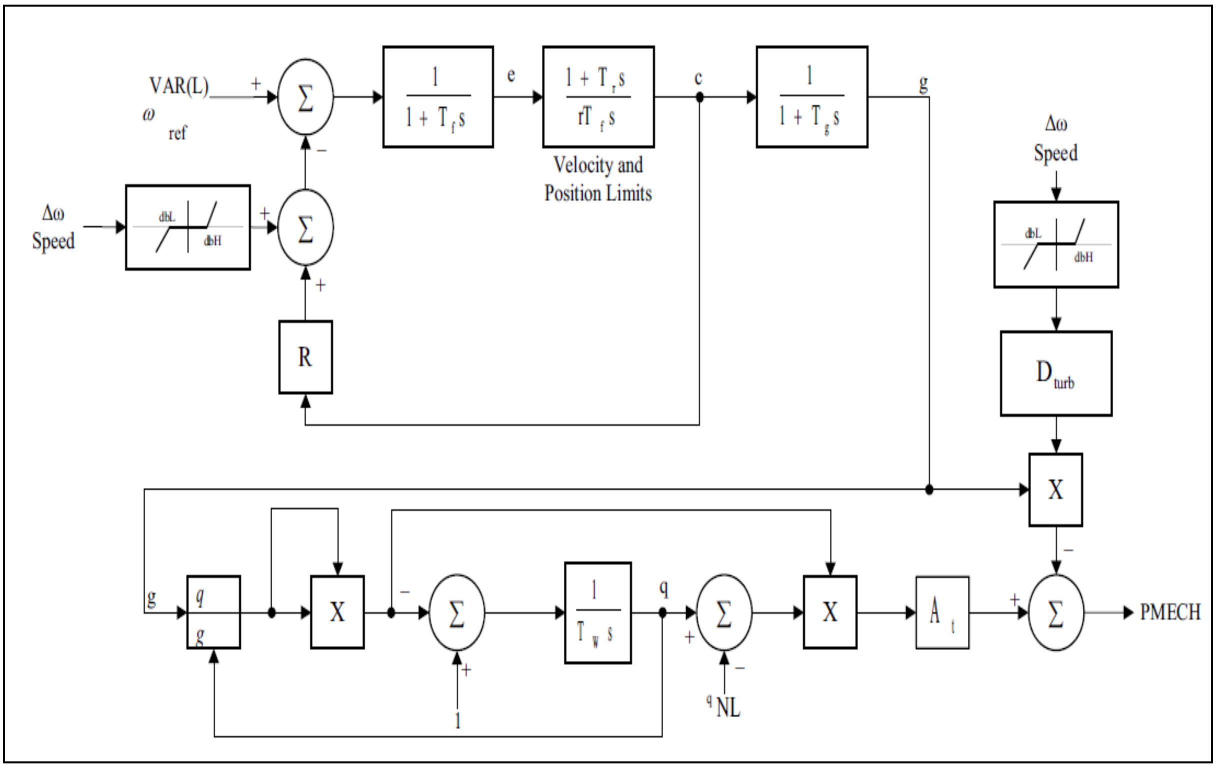
$$S(1.2) = \frac{If_{NL(12)} - 1.2 \times If_{NL(AG)}}{1.2 \times If_{NL(AG)}}$$

6. Commonly Used Hydro Turbine Generic Model Block Diagrams:

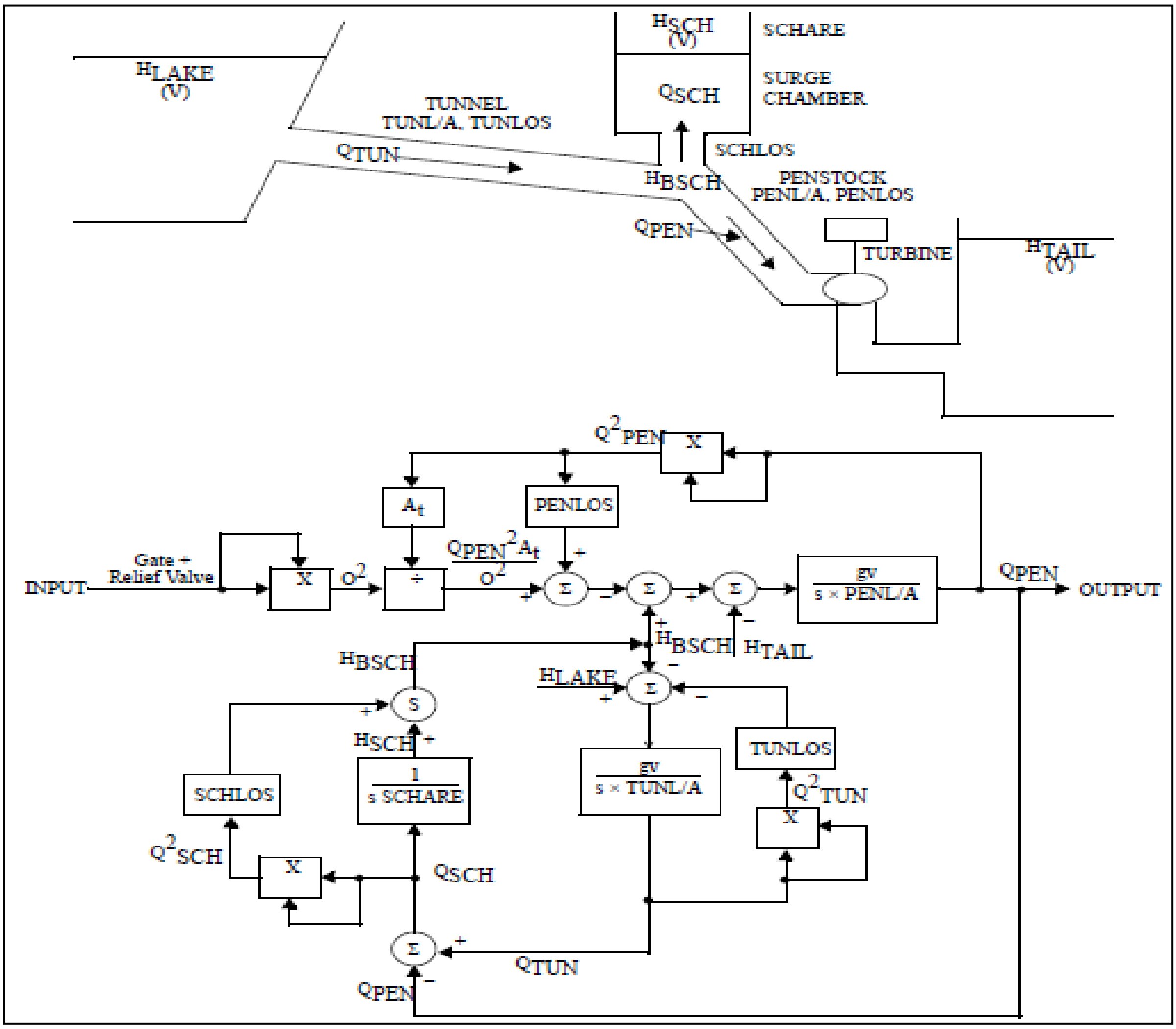
➢ HYGOV: Hydro Turbine-Governor



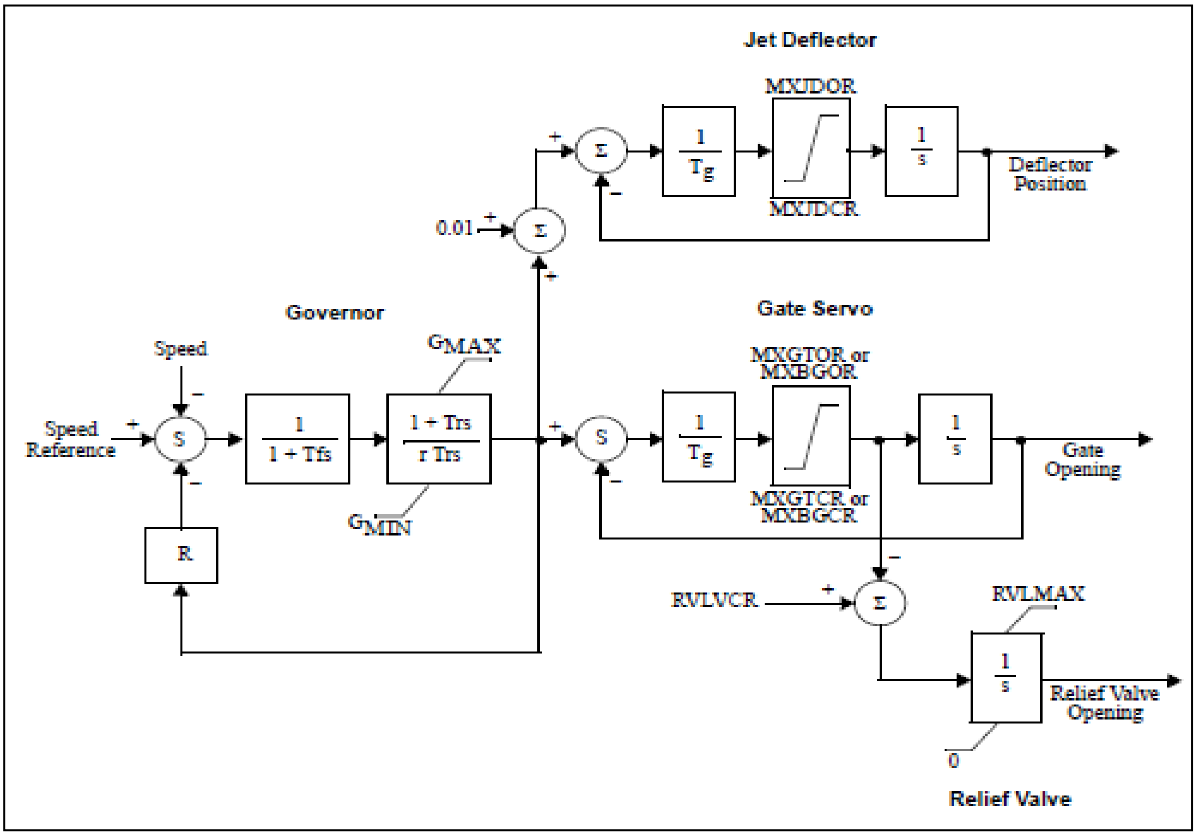
➢ HYGOVDU: Hydro Turbine-Governor



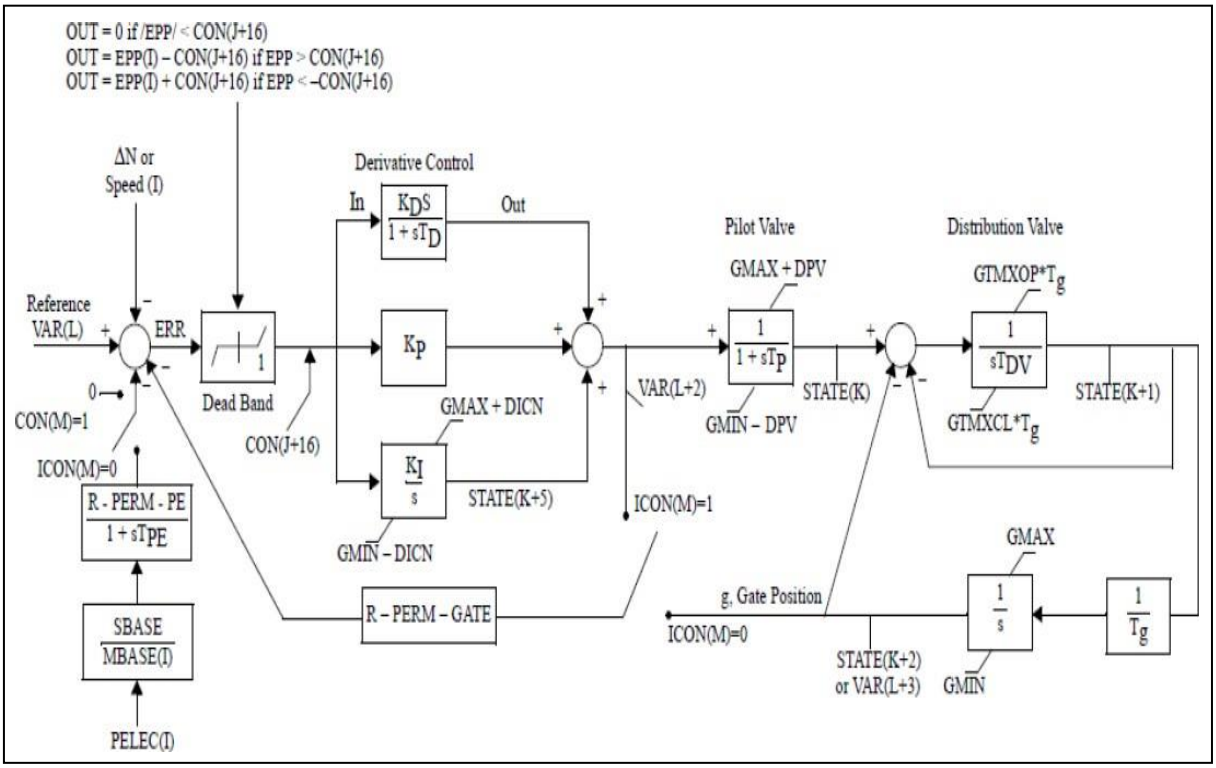
➢ HYGOVM: Hydro Turbine-Governor Lumped Parameter Model



gv	Gravitational acceleration	A_t	Turbine flow gain
TUNL/A	Summation of length/cross section of tunnel	O	Gate + relief valve opening
SCHARE	Surge chamber cross section	HSCH	Water level in surge chamber
PENLOS	Penstock head loss coefficient	QPEN	Penstock flow
TUNLOS	Tunnel head loss coefficient	QTUN	Tunnel flow
FSCH	Surge chamber orifice head loss coefficient	QSCH	Surge chamber flow
PENL/A	Summation of length/cross section of penstock, scroll case and draft tube		

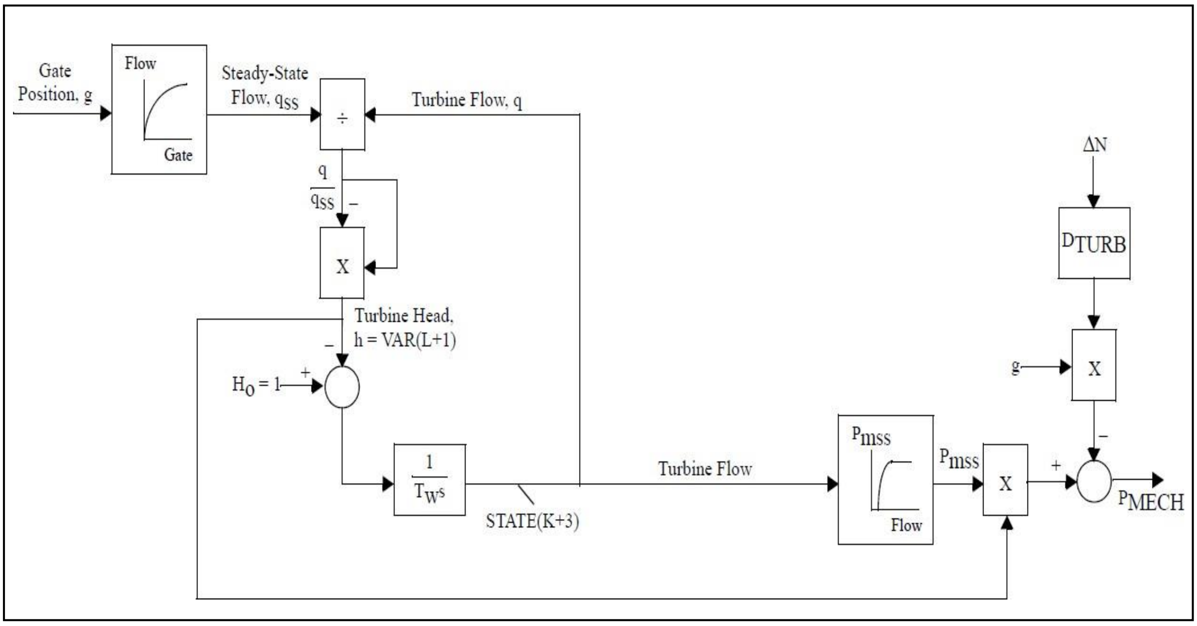


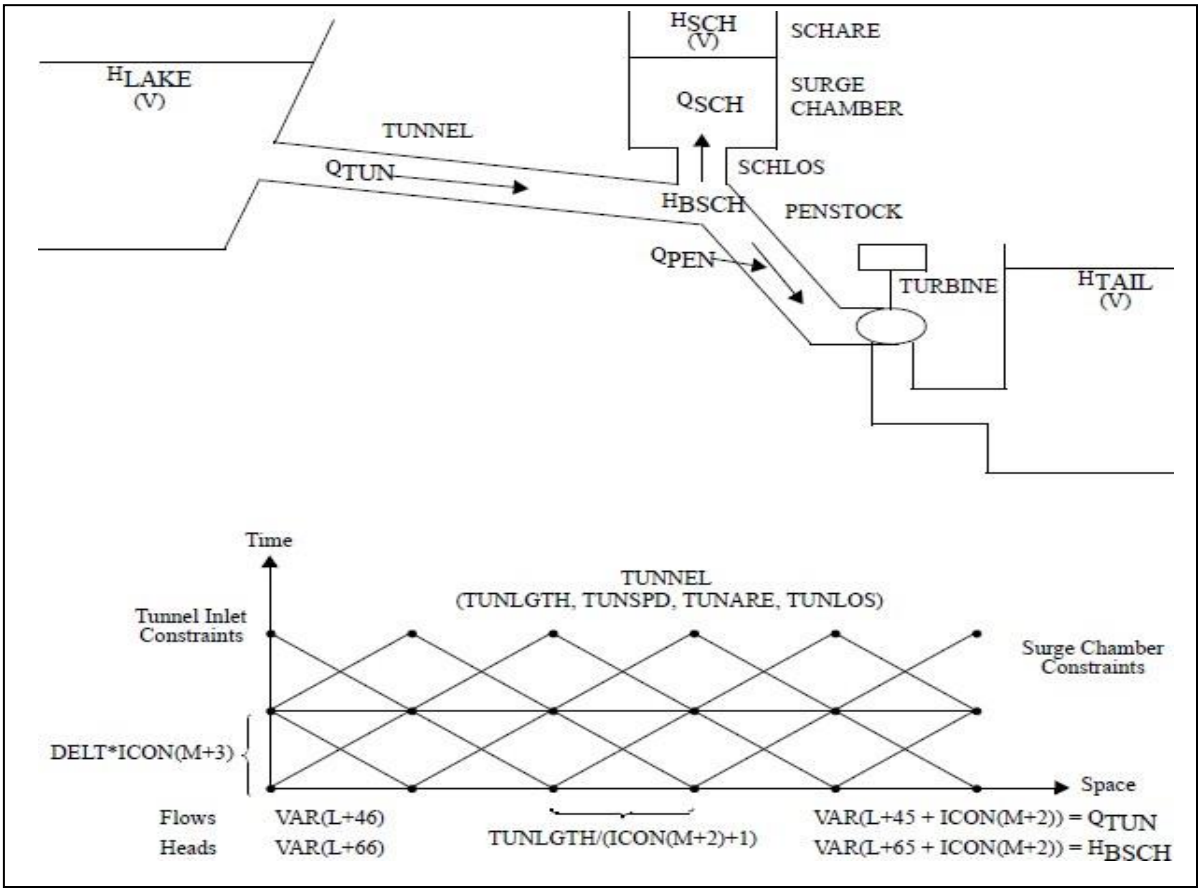
- **WEHGOV: Woodward Electric Hydro Governor Model**

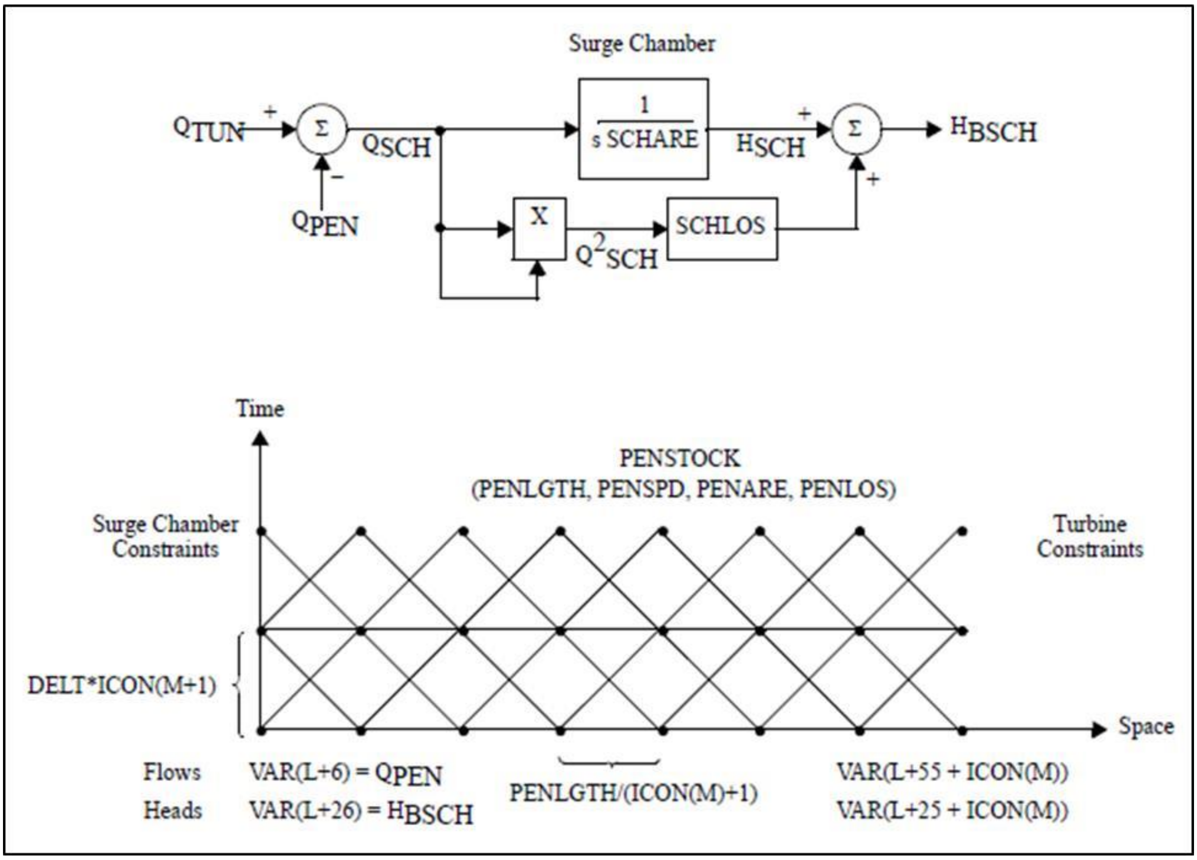


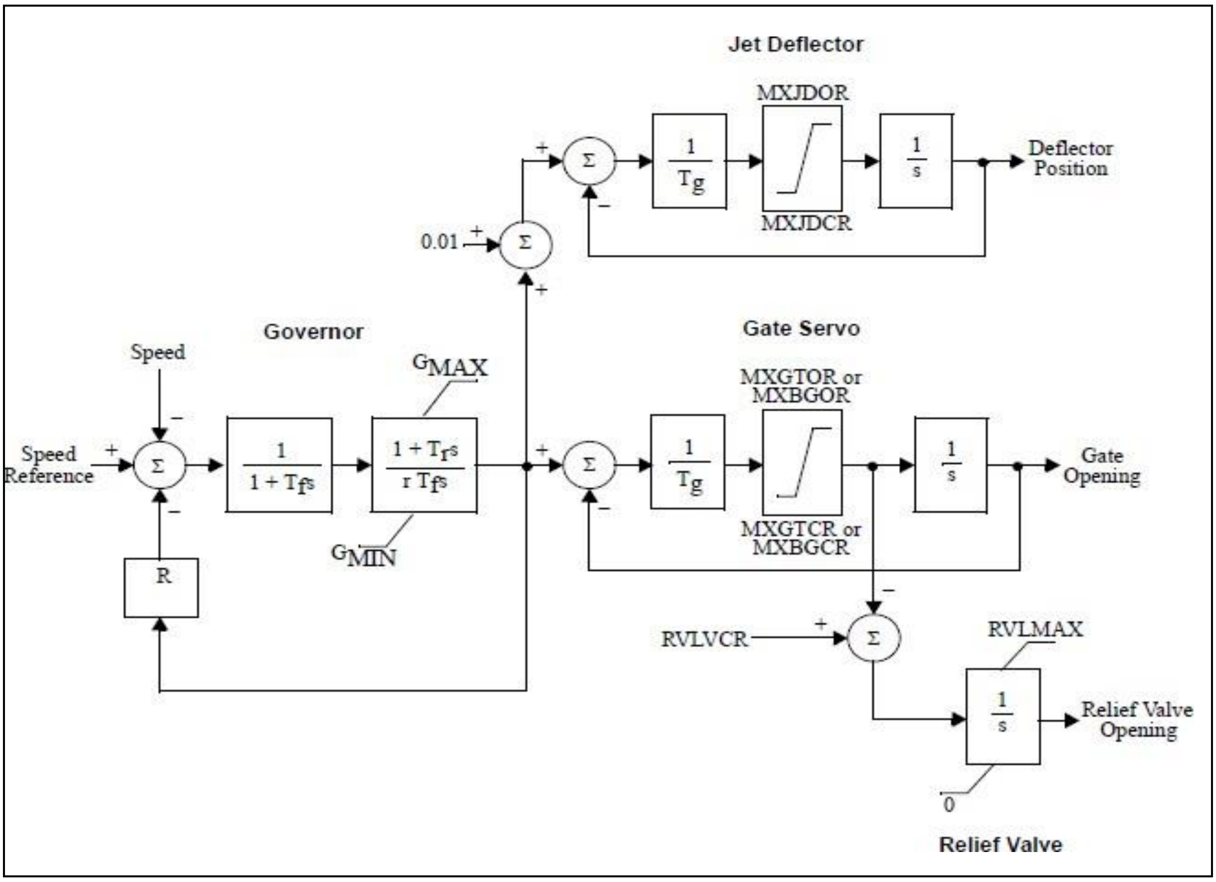
Governor and Hydraulic Actuators

- **HYGOVT: Hydro Turbine-Governor Traveling Wave Model**

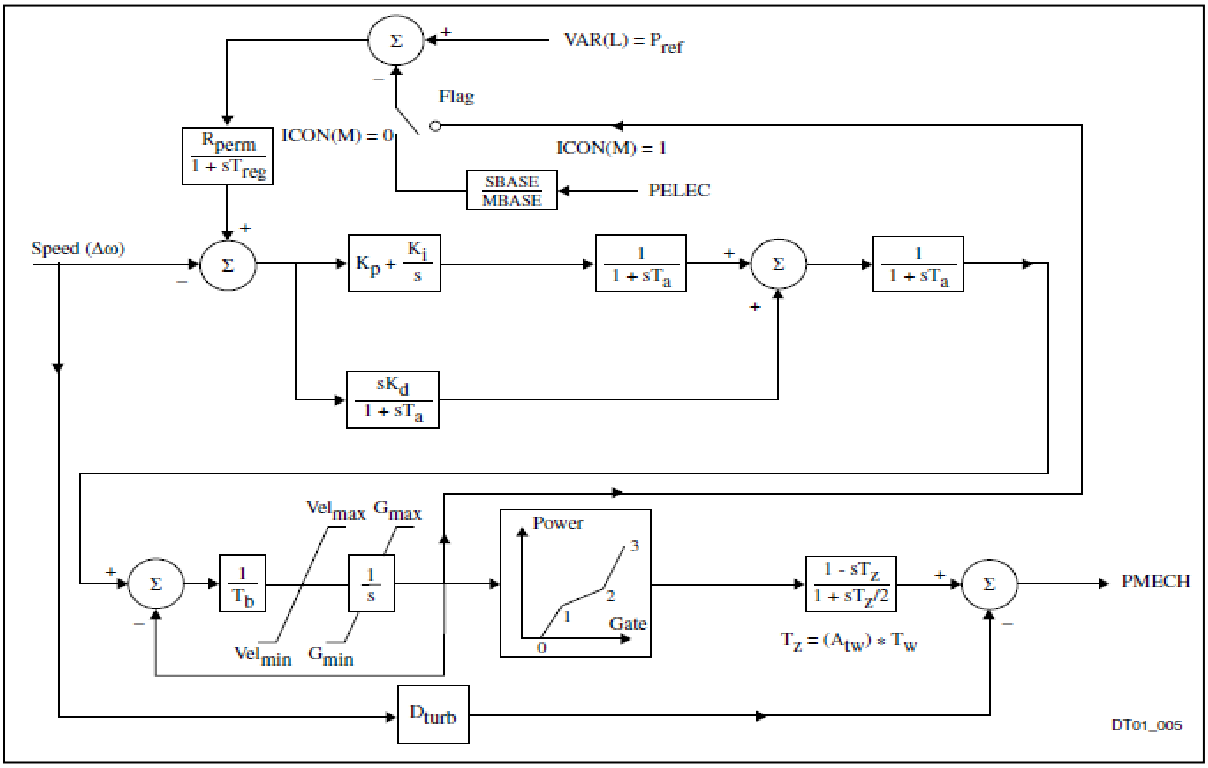




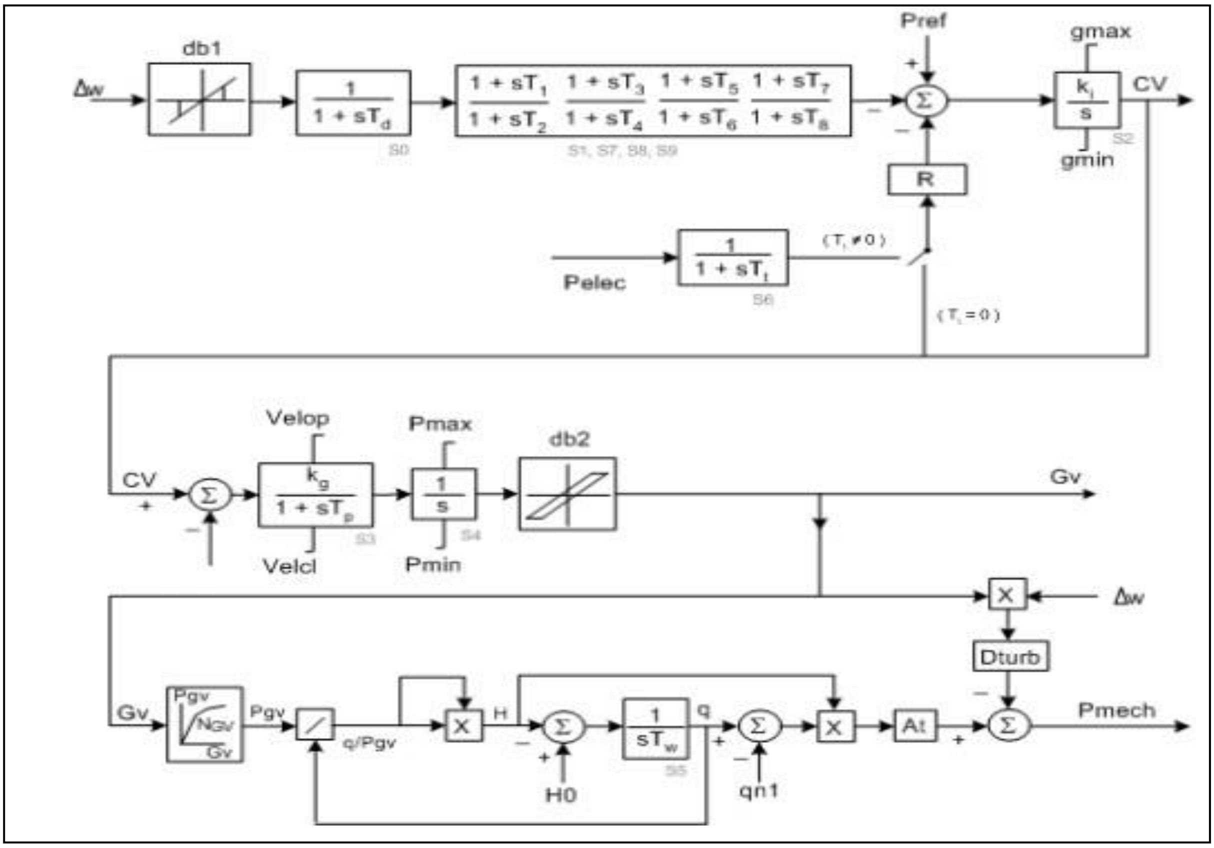

Surge Chamber
QTUN
QSCH
QPEN
1
s SCHARE
HSCH
HBSCH
X
Q2SCH
SCHLOS
Time
PENSTOCK
(PENLGTH, PENSPD, PENARE, PENLOS)
Surge Chamber
Constraints
Turbine
Constraints
DELT*ICON(M+1)
Space
Flows
Heads
VAR(L+6) = QPEN
VAR(L+26) = HBSCH
PENLGTH/(ICON(M)+1)
VAR(L+55 + ICON(M))
VAR(L+25 + ICON(M))


Jet Deflector
MXJDOR
MXJDCR
1
Tg
1
s
Deflector
Position
0.01
Governor
Gate Servo
Speed
Speed
Reference
1
1 + Tfs
GMAX
1 + Trs
r Tfs
GMIN
R
MXGTOR or
MXBGOR
MXGTCR or
MXBGCR
Gate
Opening
RVLVCR
RVLMAX
Relief Valve
Opening
0
Relief Valve

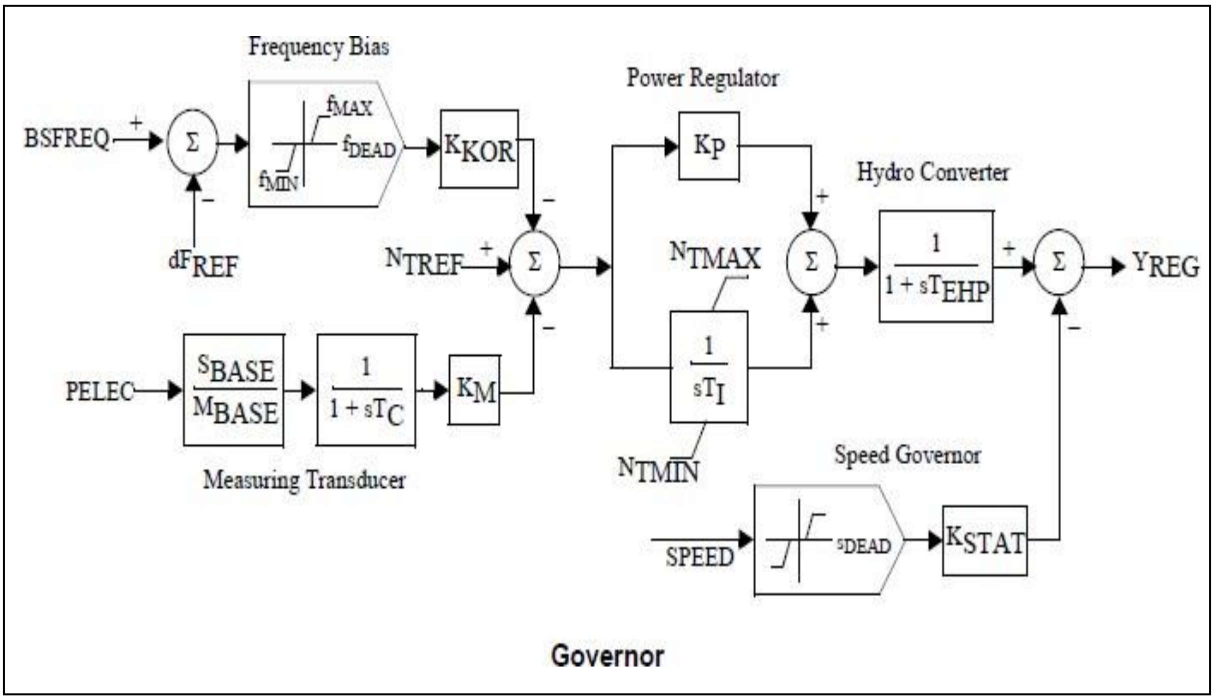
➢ PIDGOV: Hydro Turbine-Governor

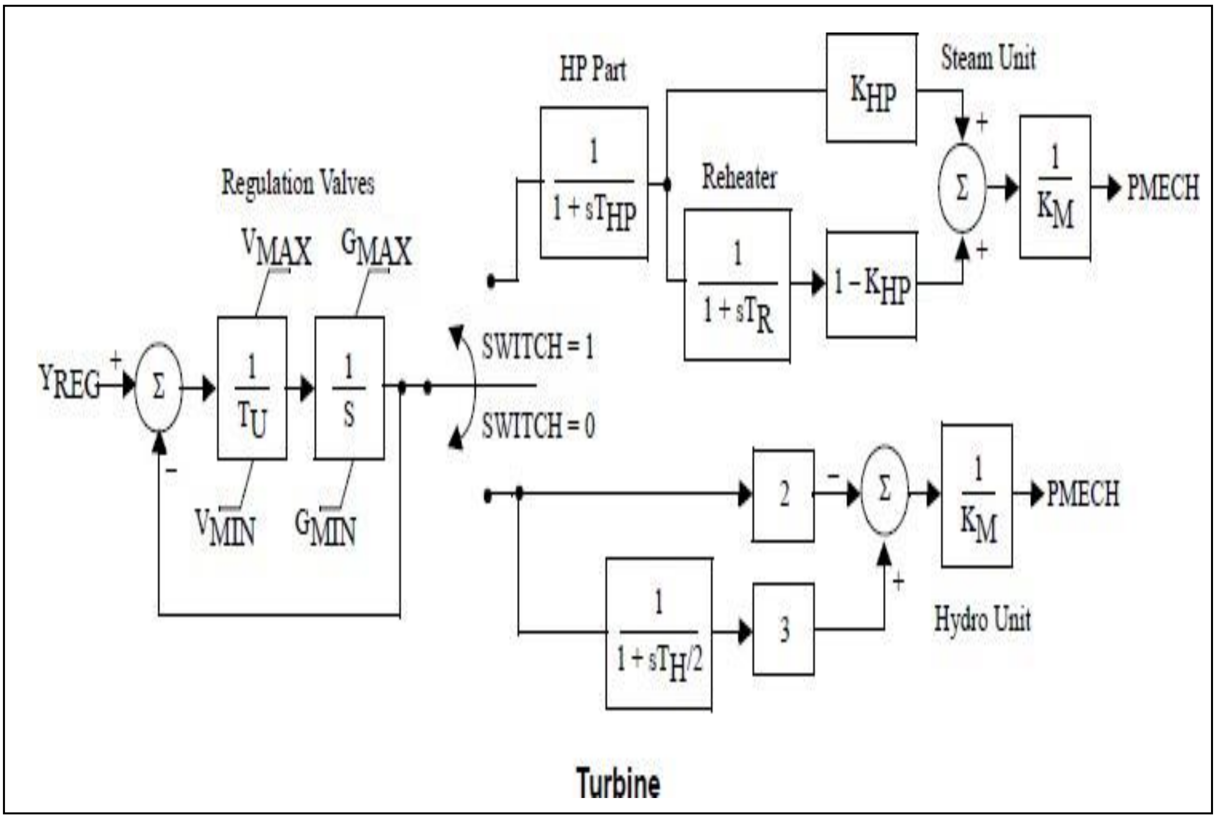


➢ HYGOVR1: Fourth order lead-lag hydro-turbine

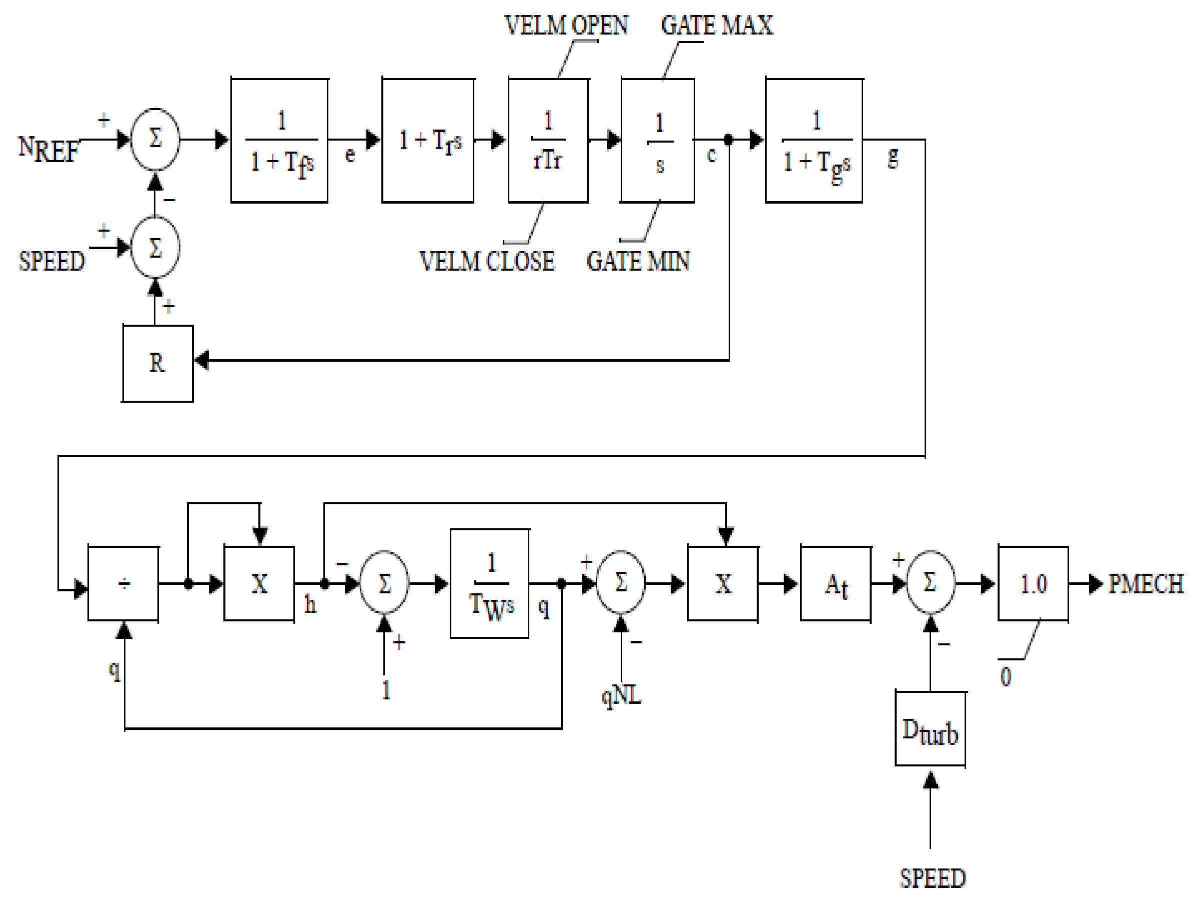


- **TURCZT: Czech Hydro and Steam Governor**

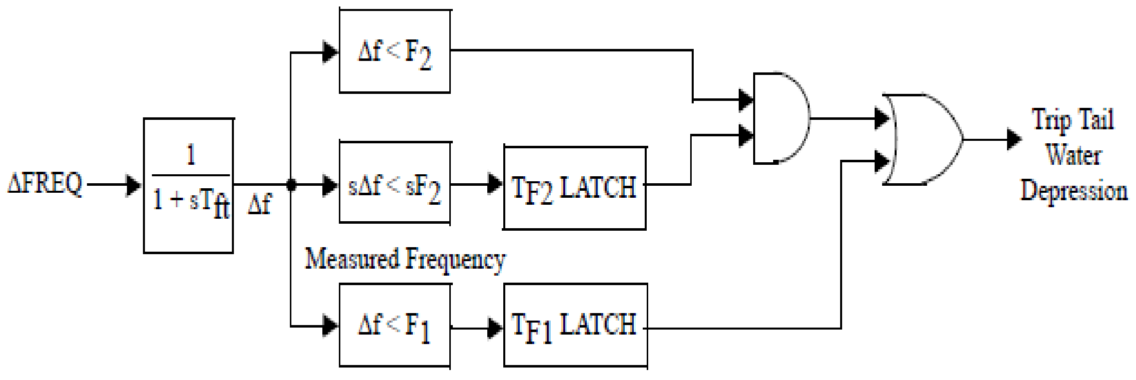




➢ **TWDM1T: Tail Water Depression Hydro Governor Model 1**

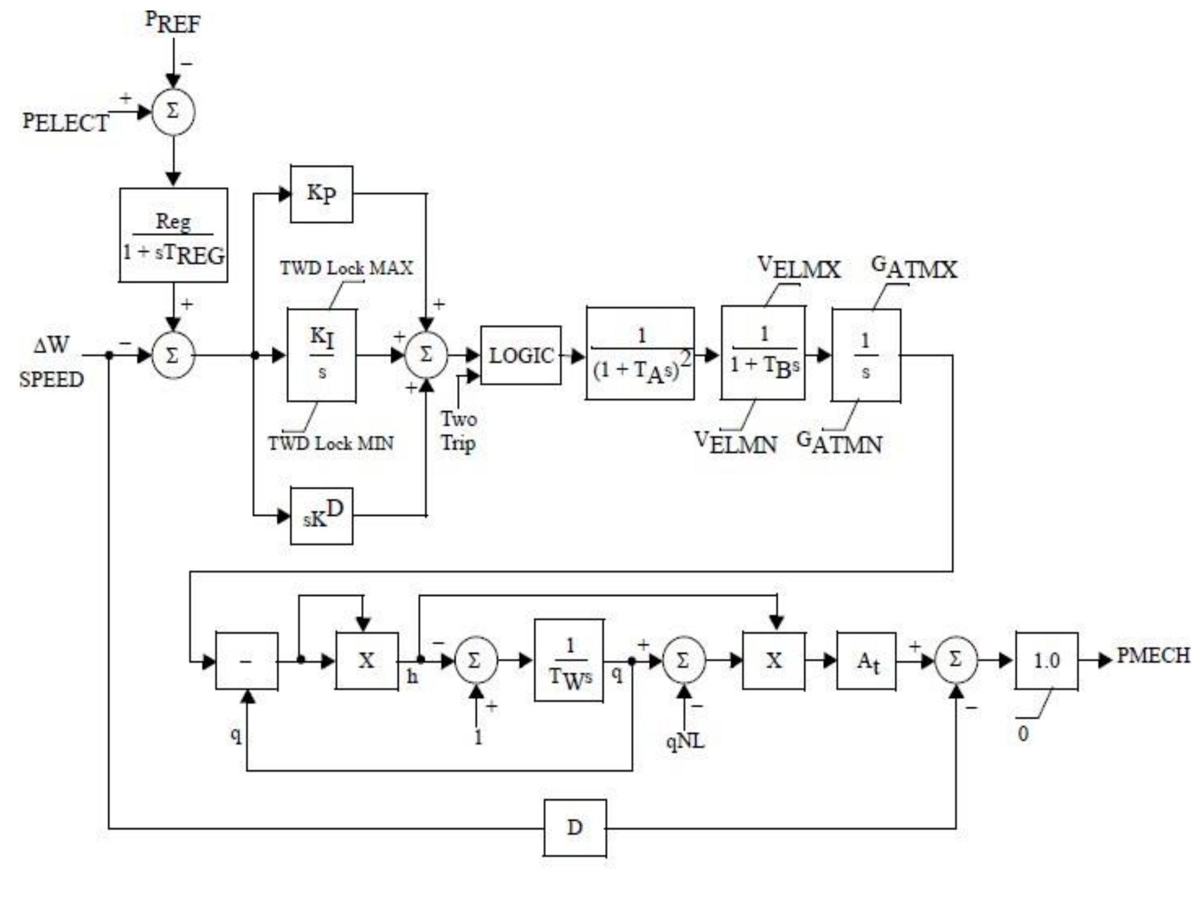


Tail Water Depression Model 1

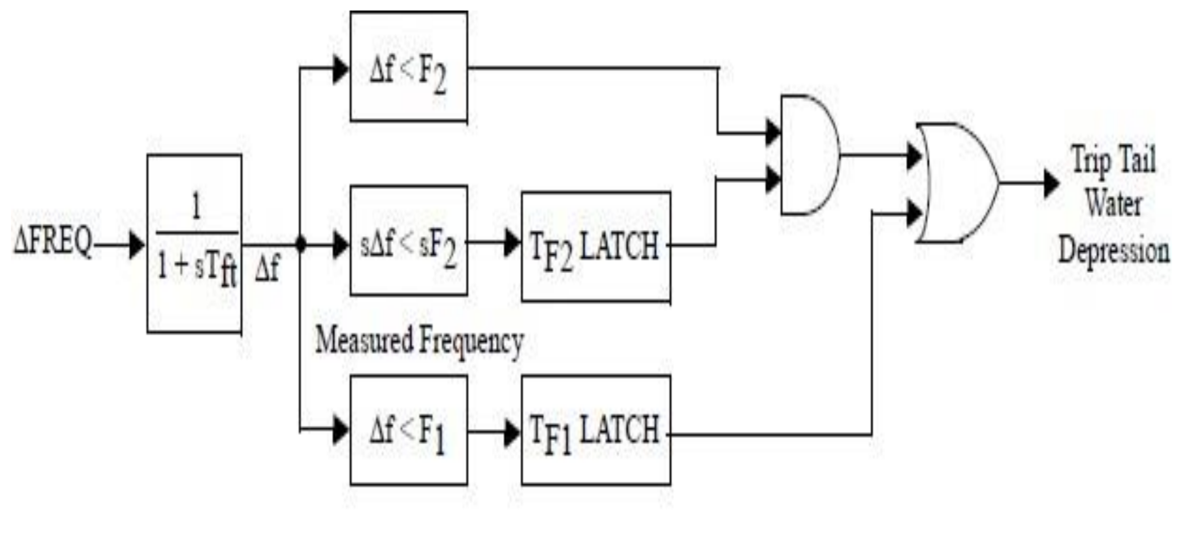


Tail Water Depression Trip Model

➢ **TWDM2T: Tail Water Depression Hydro Governor Model 2**

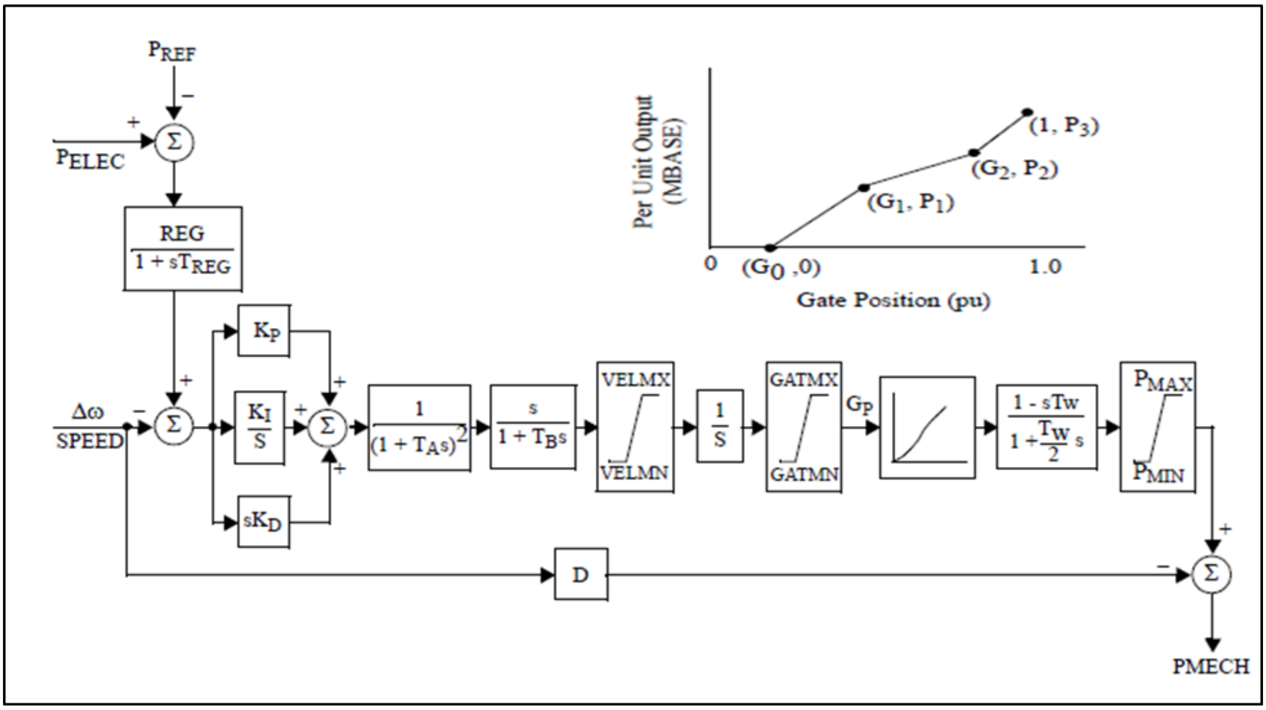


Tail Water Depression Model 2

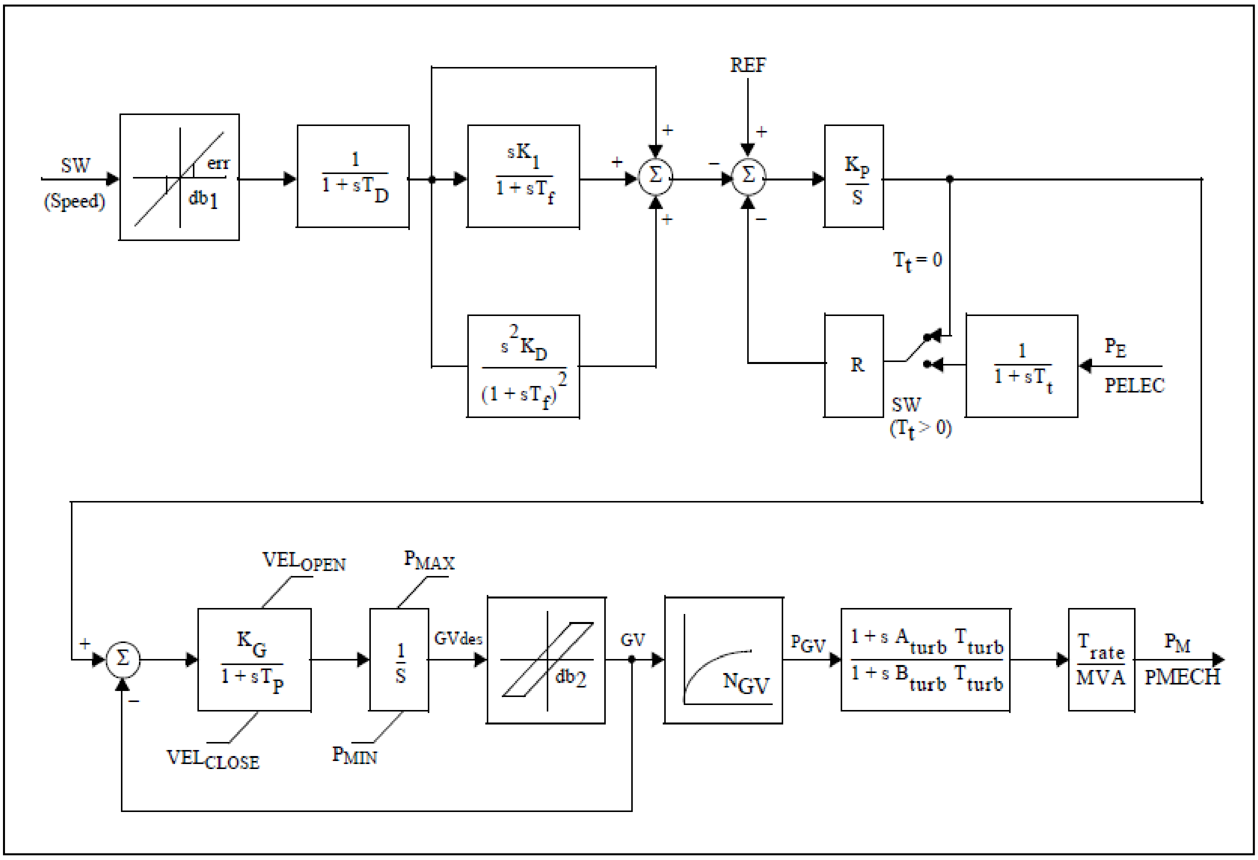


Tail Water Depression Trip Model

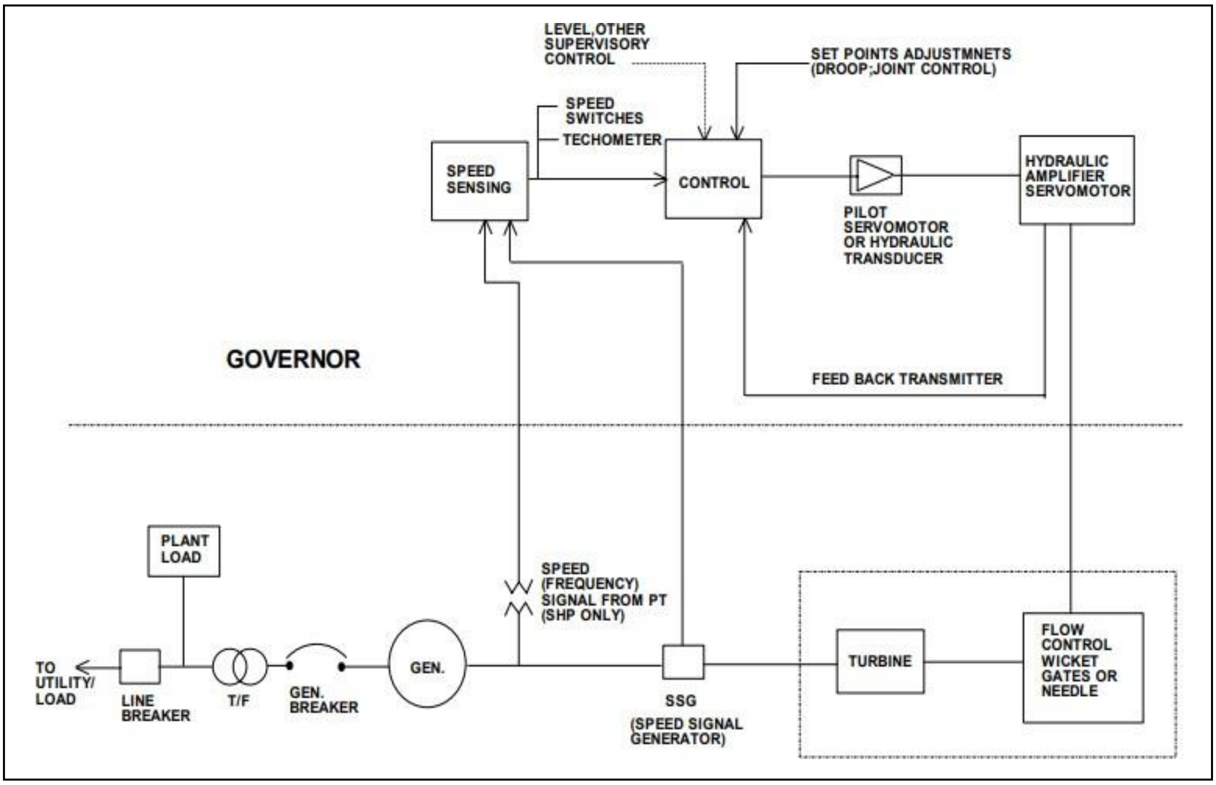
➢ **WPIDHY: Woodward PID Hydro Governor**



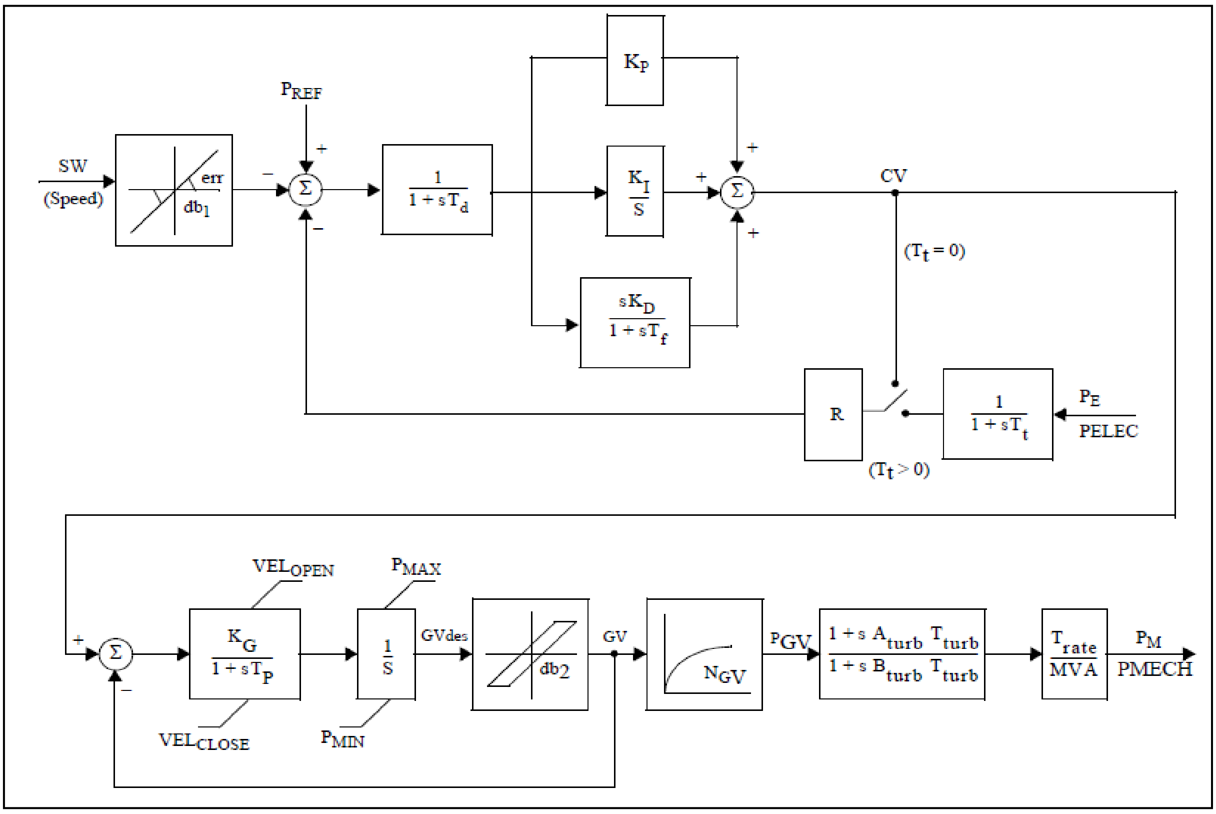
➢ **WSHYDD: WECC Double-Derivative Hydro Governor**



➢ WSHYGP: WECC GP Hydro Governor Plus Turbine

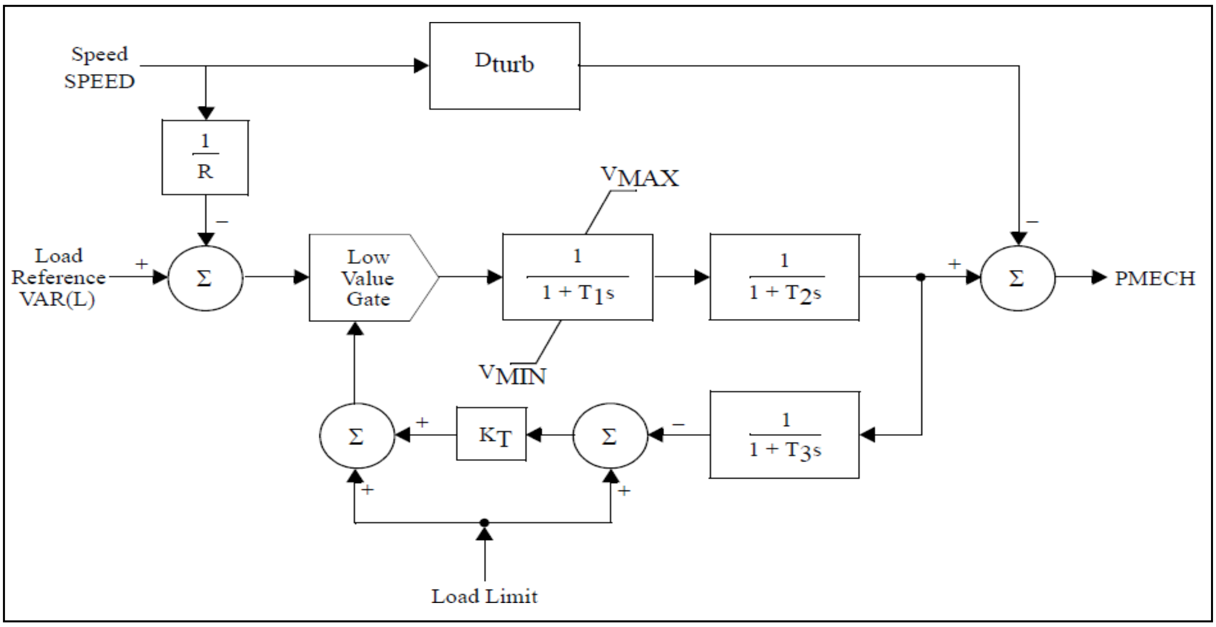


➢ Governing system - Block Diagram (Typical) as per IEEE std. -75

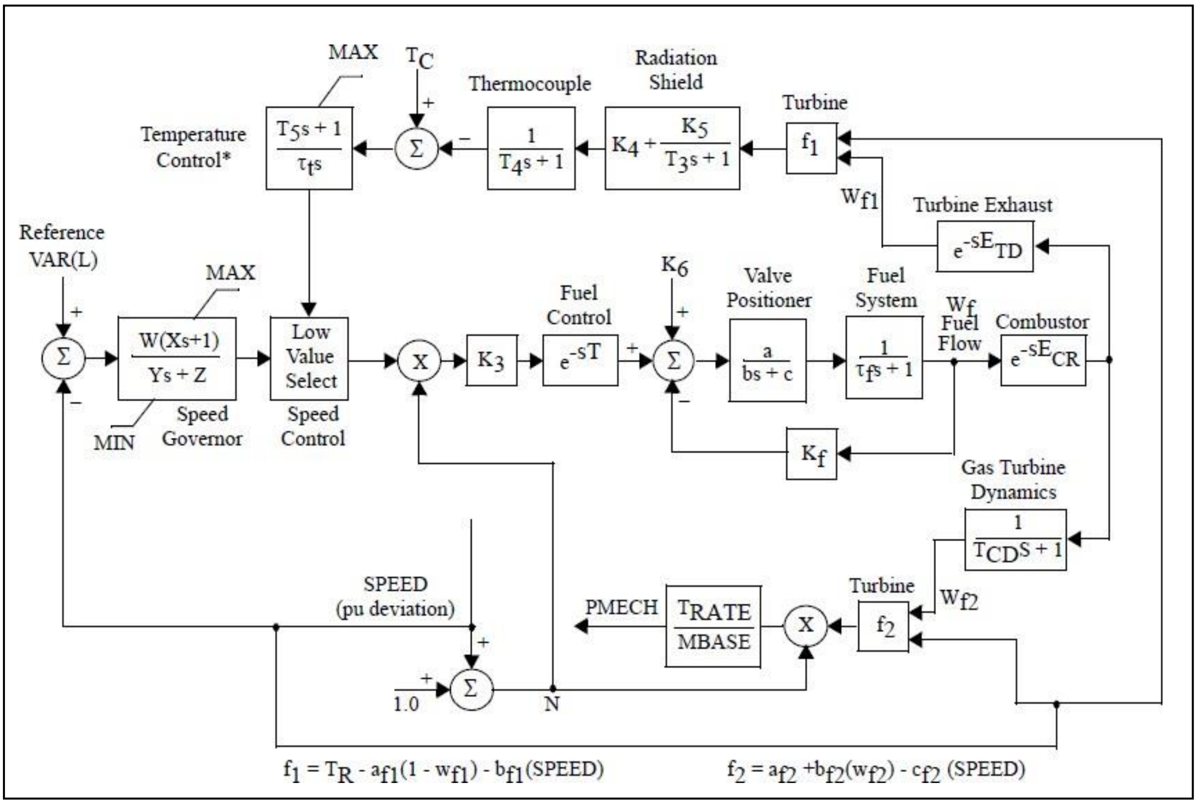


7. Commonly Used Gas Turbine Generic Models Block Diagrams:

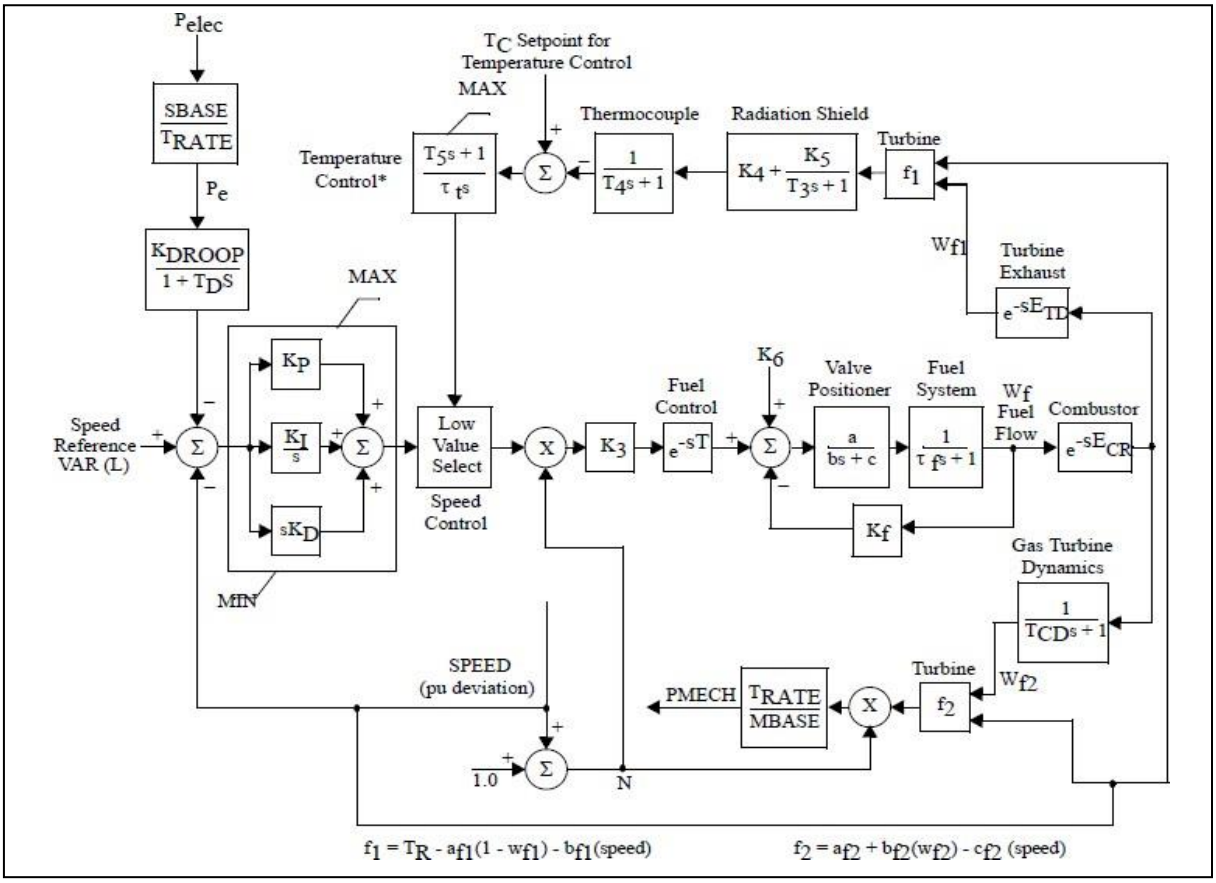
➢ GAST: Gas Turbine-Governor



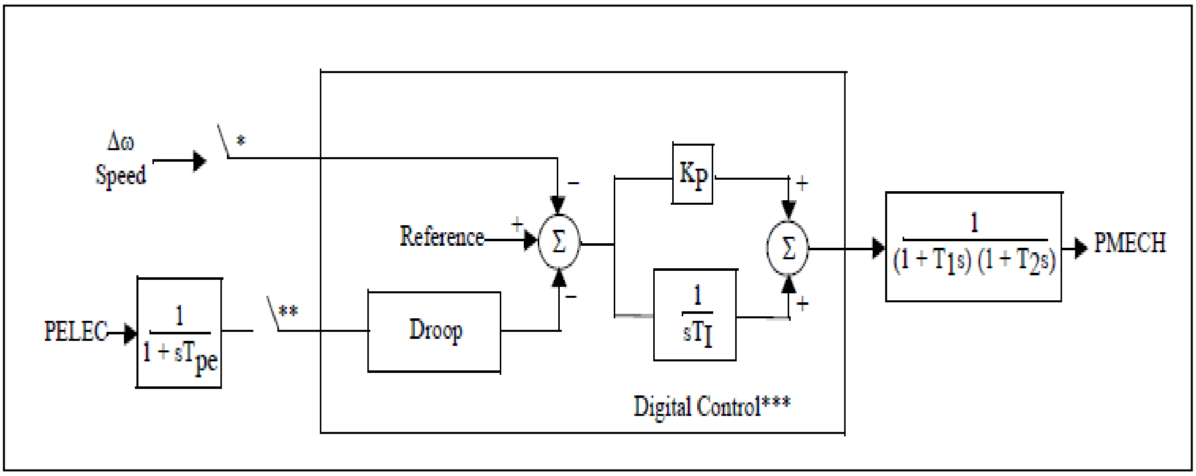
➢ GAST2A: Hydro Turbine-Governor



➢ GASTWD: Woodward Gas Turbine-Governor Model



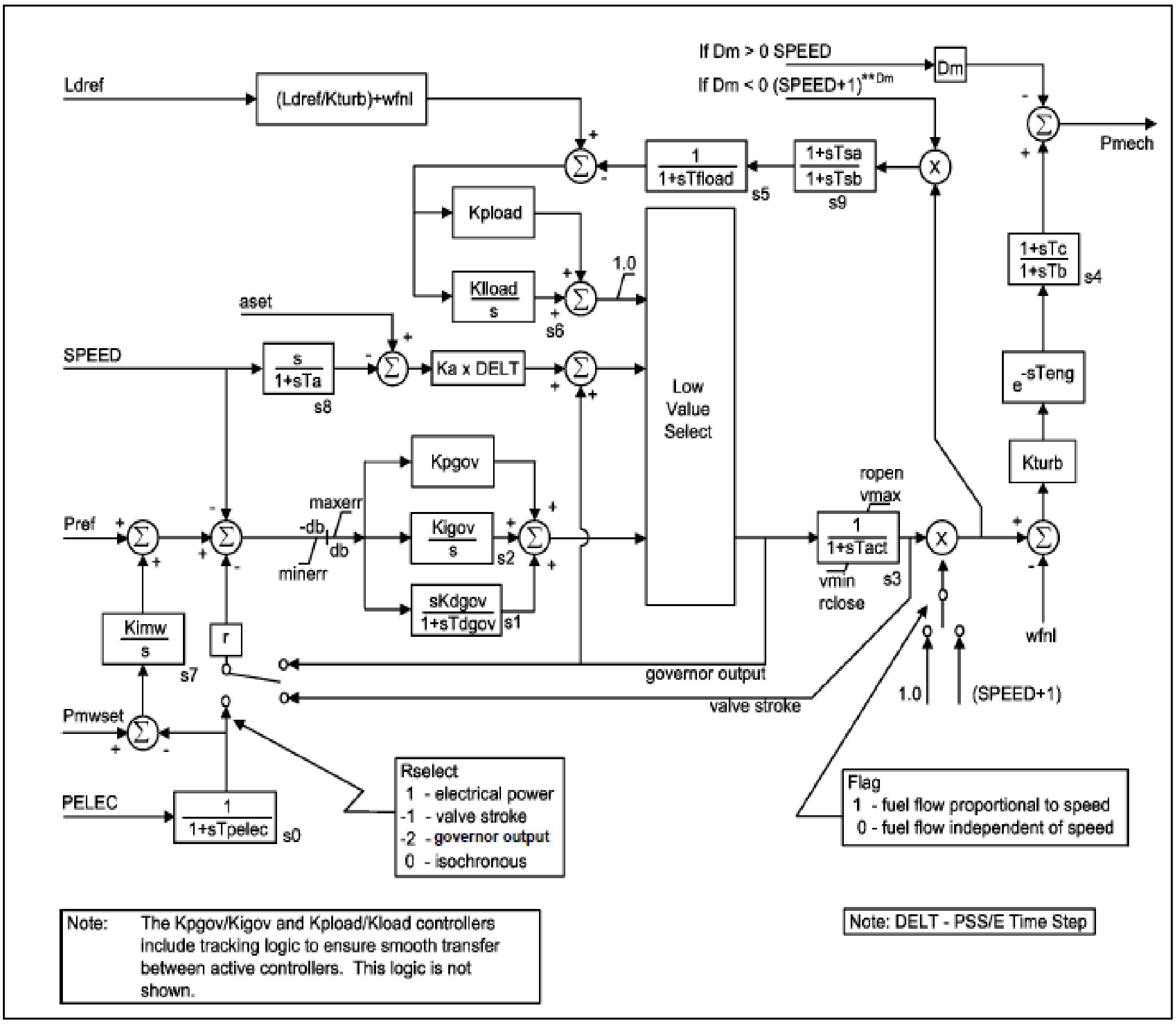
➢ WESGOV: Westinghouse Digital Governor for Gas Turbine



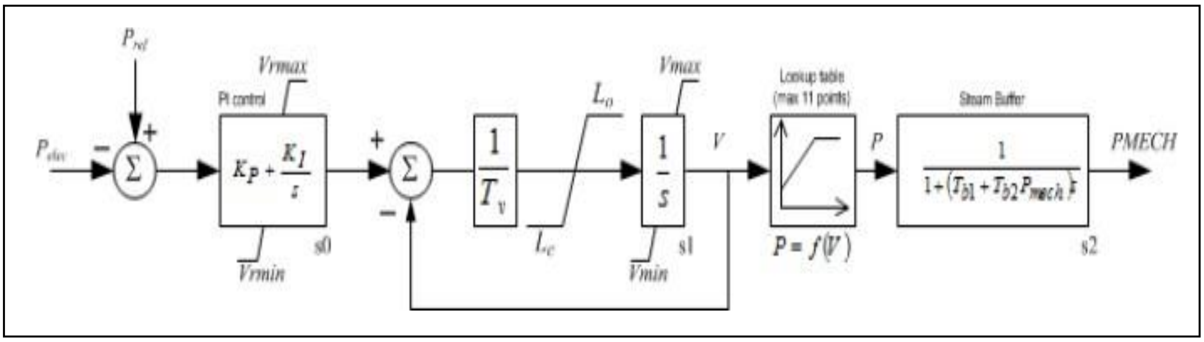
**Sample hold with sample period defined by ΔTC. **Sample hold with sample period defined by ΔTP.*

****Maximum change is limited to ALIM between sampling times.*

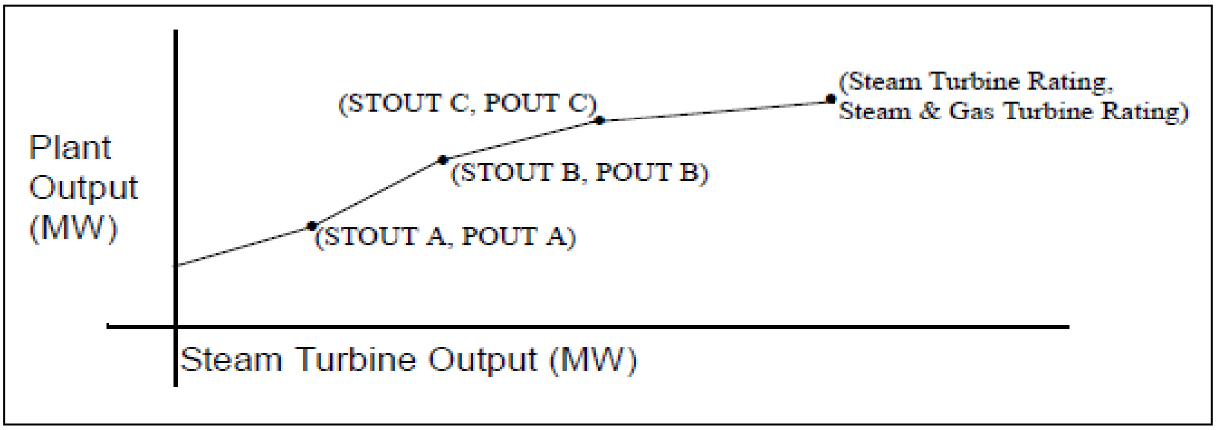
➢ GGOV1: GE General Governor/Turbine Model



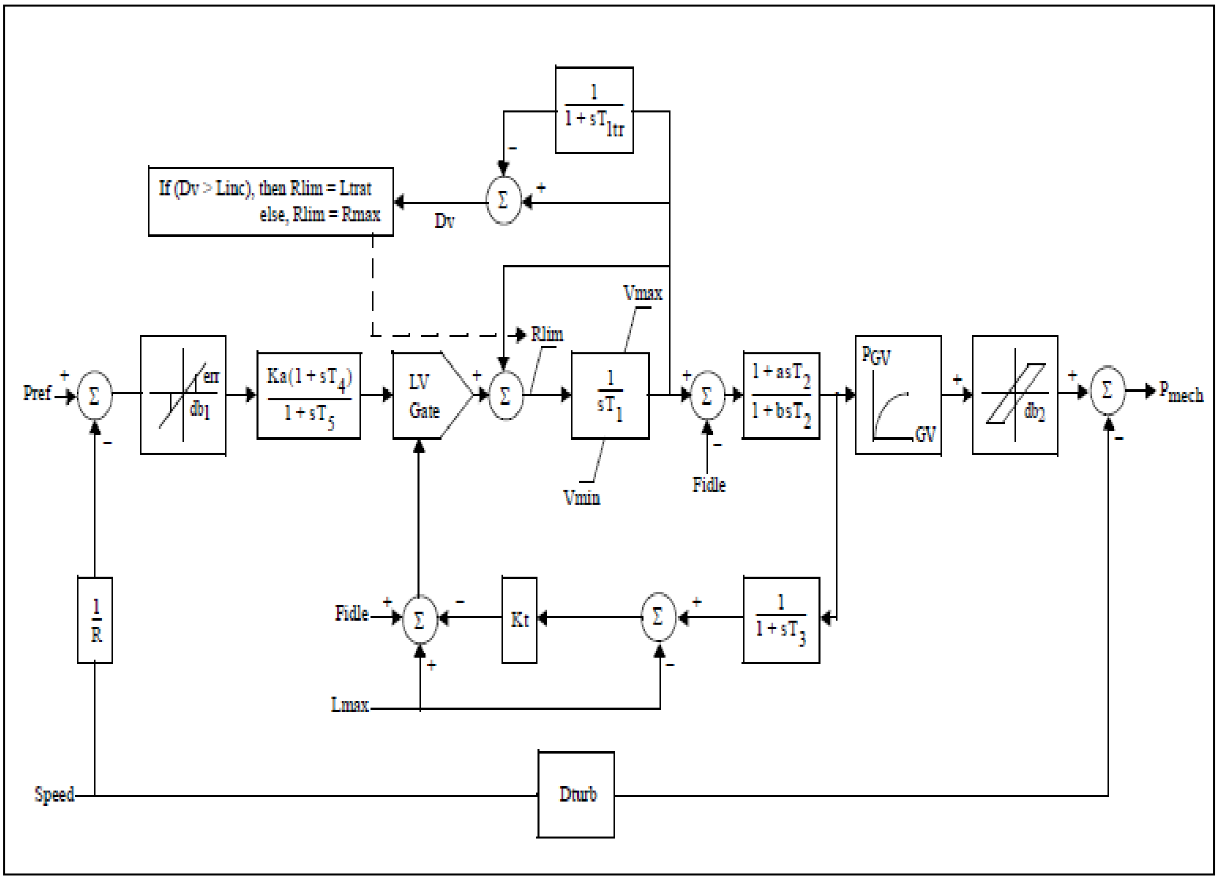
➢ PWTBD1: Pratt & Whitney Turboden Turbine-Governor Model



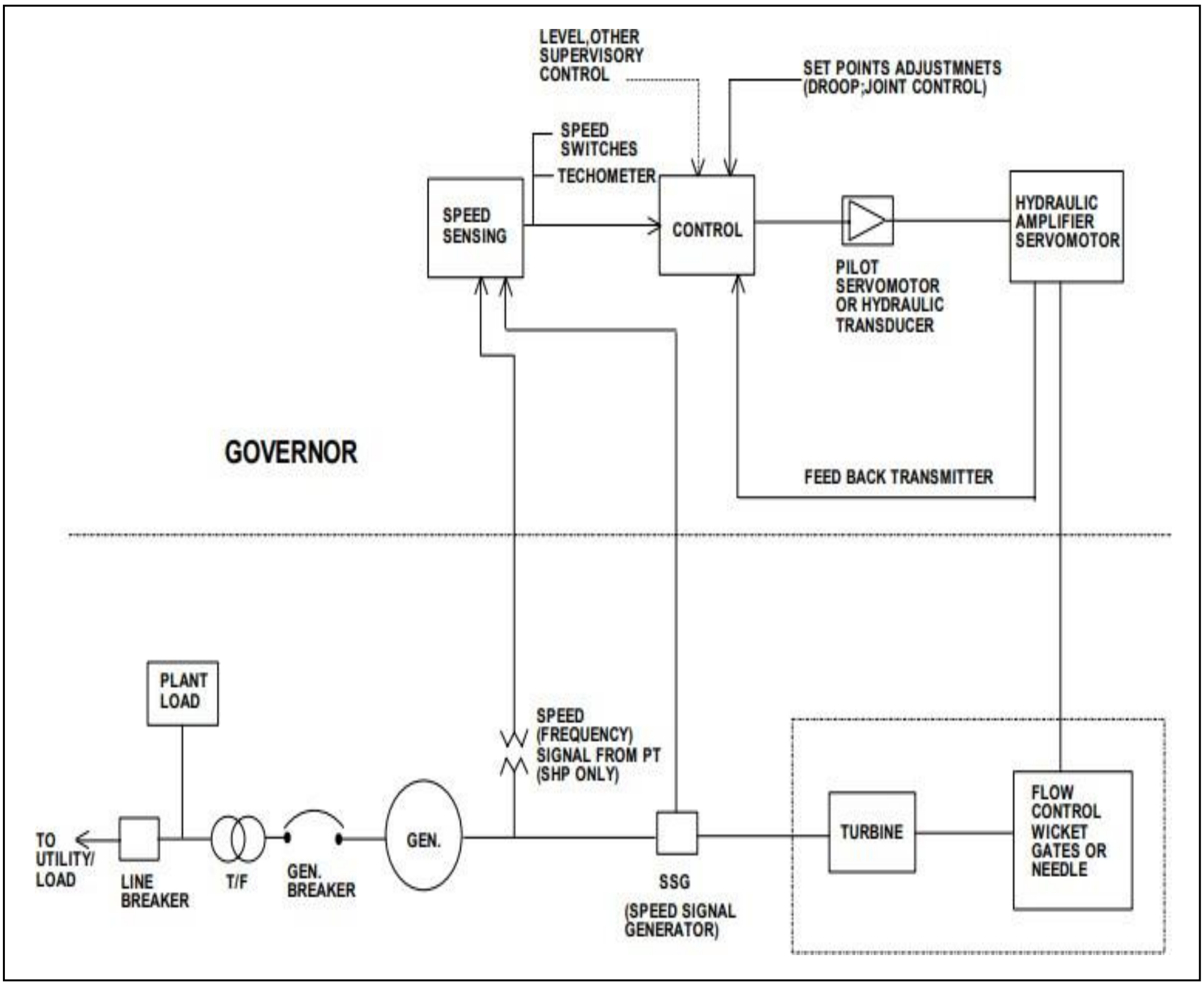
➢ URCSCT: Combined Cycle on Single Shaft



➢ URGS3T: WECC Gas Turbine Model



➢ **Governing system - Block Diagram (Typical) as per IEEE std. -75**



FORMAT-CONN-TD-3

TECHNICAL CONNECTION DATA TO BE FURNISHED BY BULK CONSUMER/ DISTRIBUTION LICENSEE FOR SIGNING OF CONNECTIVITY AGREEMENT FOR INTERCONNECTION WITH THE INTER-STATE TRANSMISSION SYSTEM

A. Introduction

This document is designed to act as a guideline for exchange of technical connection data for the purpose of interconnection of the Bulk consumer/ Distribution licensee with ISTS alongwith exchange of accurate modelling data. Availability of accurate modelling data shall enable assessment of compliances of applicable regulations, adequacy of power system & assessment of equipment performance for secure and reliable interconnection with the ISTS Grid.

B. Regulations

CEA Technical Standards for Connectivity to Grid, 2007 and its amendments thereof: Clause 6.4d:

"Provided that in order to carry out the said study, the requester shall present the mathematical model of the equipment in accordance with the requirements as stipulated by the Appropriate Transmission Utility or distribution licensee, as the case may be."

C. Compliance with existing rules and regulations

All applicants seeking connection to the grid shall comply with all the applicable regulations as enacted or amended thereof from time to time, including the following:

a) Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007;

b) Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010.

c) Central Electricity Authority (Measures Relating to Safety & Electric Supply) Regulations, 2010;

d) Central Electricity Regulatory Commission (Communication System for Inter State Transmission of Electricity) Regulations,2017;

e) Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006;

f) Central Electricity Regulatory Commission (Connectivity and General Network Access to the inter-State Transmission System) Regulations, 2022;

g) Central Electricity Regulatory Commission (Fees and Charges for Regional Load Despatch Centres) Regulations, 2019;

h) Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020;

i) Central Electricity Regulatory Commission (Furnishing of Technical Details by the Generating Companies) Regulations, 2009.

j) Central Electricity Authority (Cyber Security in Power Sector) Guidelines, 2021

k) Any other regulations and standards as specified from time to time.

D. General Consideration

i. Point of Interconnection (POI)

It may be defined as the point of interconnection of the bulk consumer facility with the Grid. The POI would be the reference point for an assessment of compliance to CEA standards (viz. data/studies/all performance capabilities, etc.) and the effect of the interconnecting transmission line shall be considered as an integral part of the bulk consumer as shown in Figure-23.

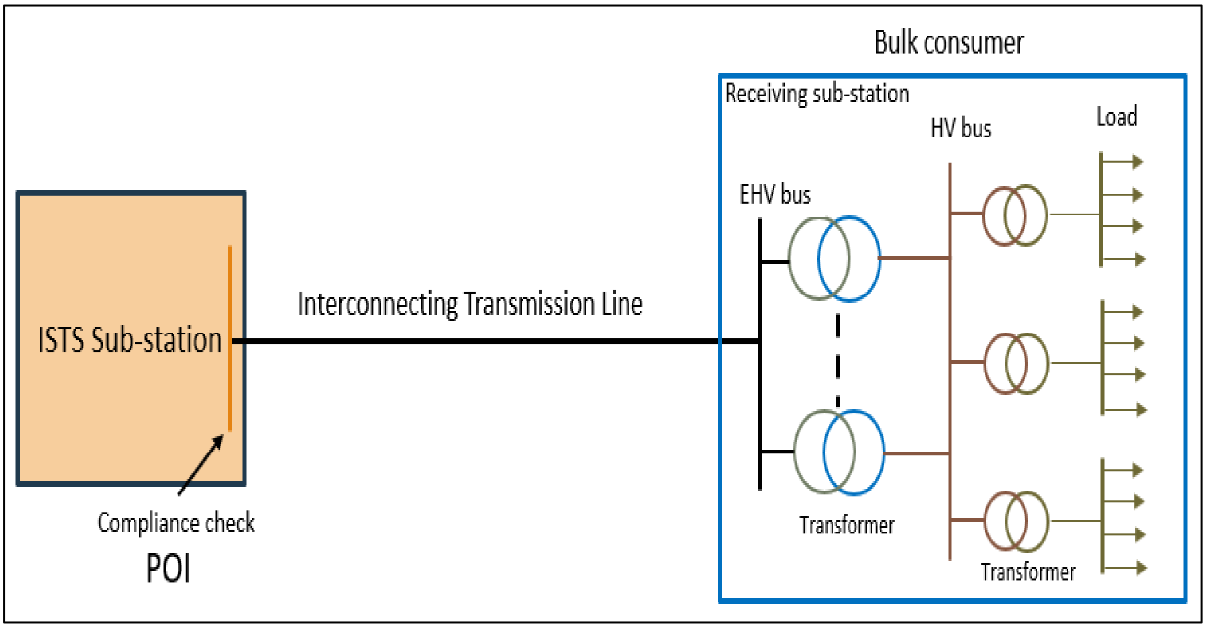


Figure-23: Point of Interconnection in respect of Bulk Consumer

ii. Description

Loads are one of the critical components in the power system governing the steady-state and dynamic state response of the system. Therefore, the modeling of loads with sufficient accuracy is of vital importance for analyzing the power system performance. By way of accurate modeling, the response of the system can be predicted for a set of pre-defined contingencies. Load modeling influences the system response during dynamic studies, fault-induced delayed voltage recovery, short-term voltage stability and inter-area oscillation analysis. Figure-2 shows the actual response of a typical load and its comparison with simulations carried out. From the figure, it can be inferred that the system oscillations during observed in a simulated disturbance which appeared as damped during simulations did not actually reacts in that way due to large approximations considered in modelling.

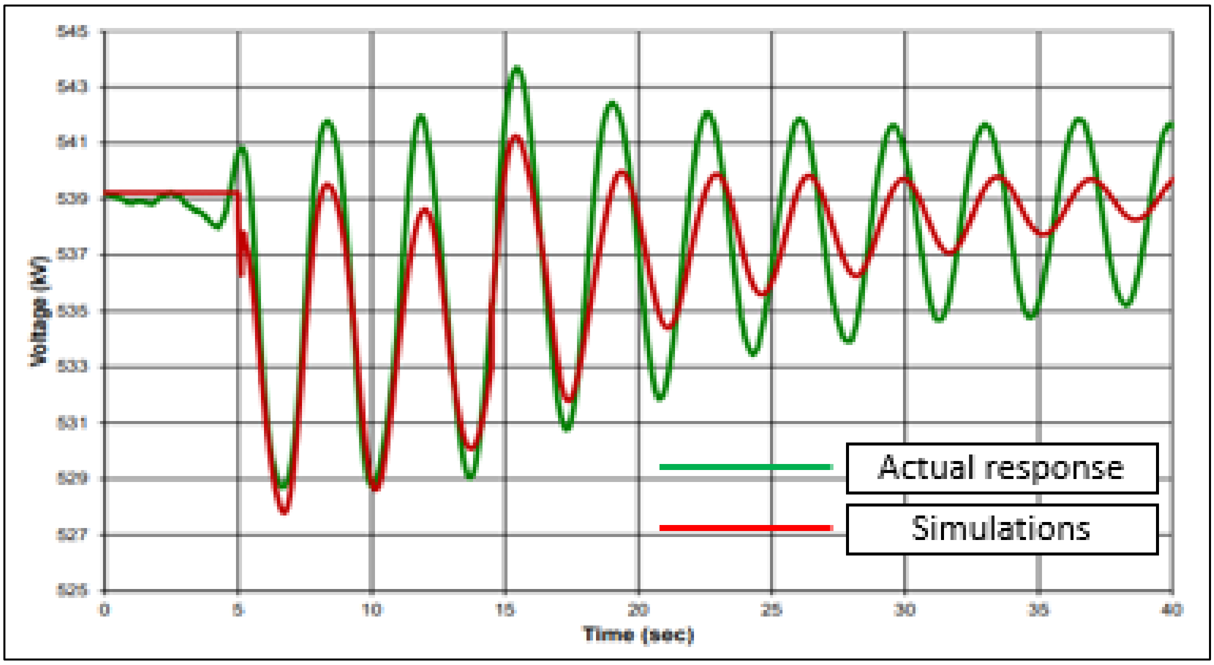


Figure-24: Typical characteristics of load behavior vs simulation

Bulk consumers draw power for its operations directly from Grid through transmission lines. Typically, bulk consumer contains motor loads of varied characteristics, reactive compensation devices, internal captive generation, static loads and distribution transformers as shown in Figure-25.

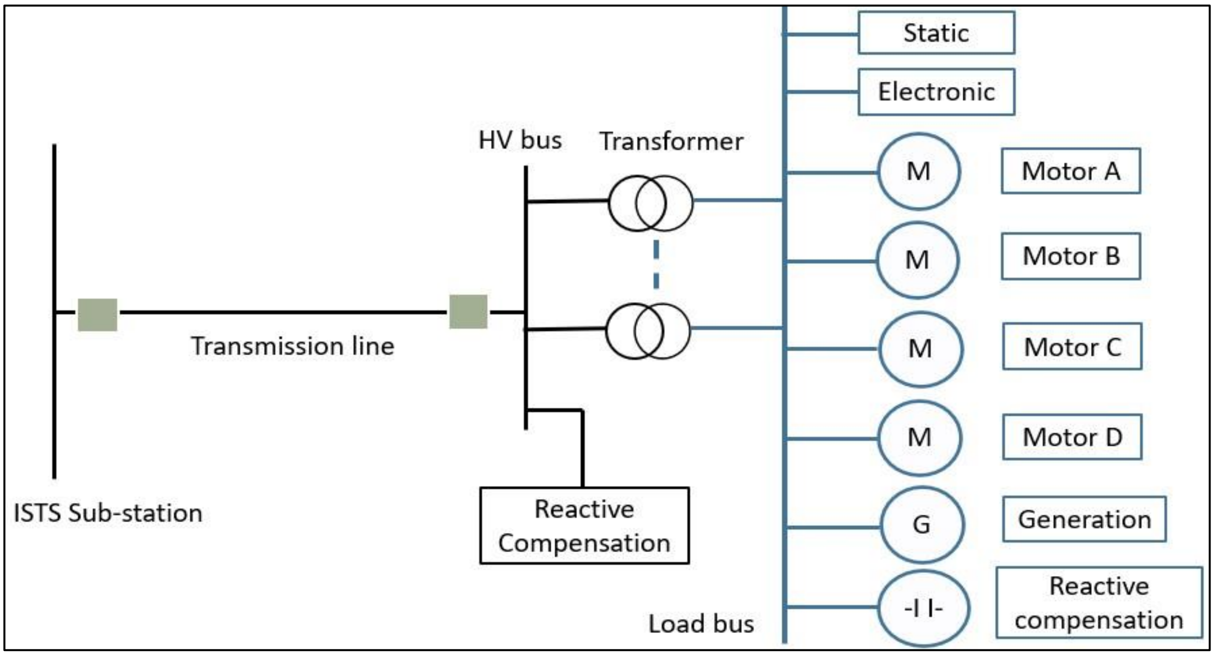


Figure-25: Typical layout of bulk consumer

iii. Load Modeling

Load modeling encompasses the mathematical representation of load physical characteristics and the physical behavior with the help of simulations. Load models can be classified as static and dynamic in nature. Static load models represent the load with time-invariant functions of the voltage and the frequency, i.e. the load behavior at every instant is given as a function of the voltage and frequency at that same instant. On the other hand, dynamic load models represents the dynamic response of system during perturbation or sudden change in variables (including voltage or frequency); these are well described using differential equations. Various load models are depicted in Figure-26.

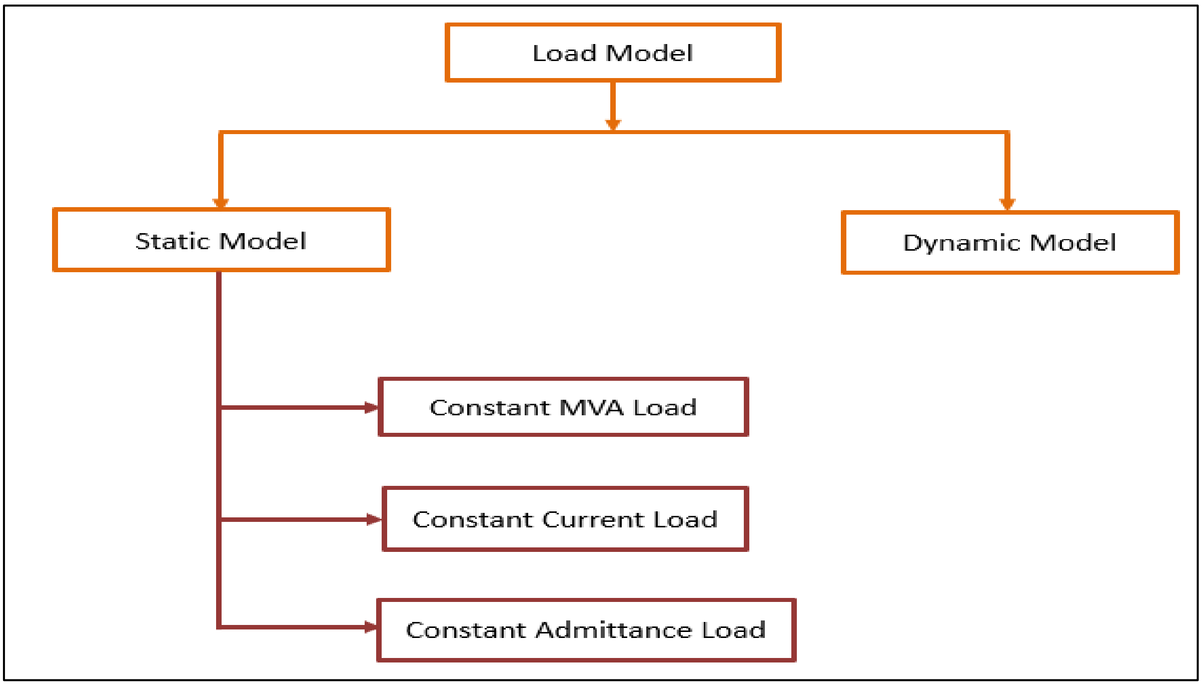


Figure-26: Different types of loads

a) Static load models:

Static models express the active and reactive power of load at any instant of time as functions of bus voltage magnitude and frequency. The changes in base quantities i.e P & Q can be evaluated with reasonable accuracy using the following expressions:

Voltage dependence:

$$P_{new} = P_{old}\left[\frac{V_{new}}{V_{Base}}\right]$$

$$Q_{new} = Q_{old}\left[\frac{V_{new}}{V_{Base}}\right]^2$$

Frequency dependence:

$$P_{new} = P_{old}\left[\frac{f_{new}}{f_{Base}}\right]$$

$$Q_{new} = Q_{old}$$

Q can be taken as independent of frequency variations for general approximations.

Static loads are broadly classified into three categories based on the nature of output:

i) Constant MVA Model:

In this model, the power is constant regardless of the magnitude of the voltage. Such type of load is designed to dynamically adjust the load current inversely with the load voltage so that the load power is constant, P = VI. If the voltage drops, more current will be drawn in order to maintain the amount of power. Most industrial electrical motors (with output controlled within narrow range) & data centers are of near-constant power load in nature. Typical characteristics of Constant MVA load are depicted in Figure-27.

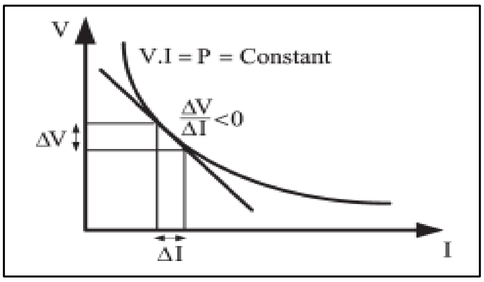


Figure-27: Typical characteristics of Constant MVA load

ii) Constant Current model:

In this model, the load current is held constant and power varies directly with the voltage magnitude. Such type of load is designed to dynamically adjust the power with the voltage changes so that the load current is constant, I=P/V.

iii) Constant Admittance Model: A static load model where the power varies directly with the square of the voltage magnitude. Incandescent lamps are one of many examples of this type of load

b) Dynamic Load Model:

A model that expresses the active and reactive powers of load at any instant of time as functions of the voltage magnitude and frequency at past instants of time and, usually, including the present instant. Differential equations can be used to represent such models.

i) Induction Motor: In dynamic models, the active and reactive power is represented as a function of the past and present voltage magnitude and frequency of the load bus. This type of model is commonly derived from the equivalent circuit of an induction motor. Typical characteristics of Induction motor is depicted in Figure 28.

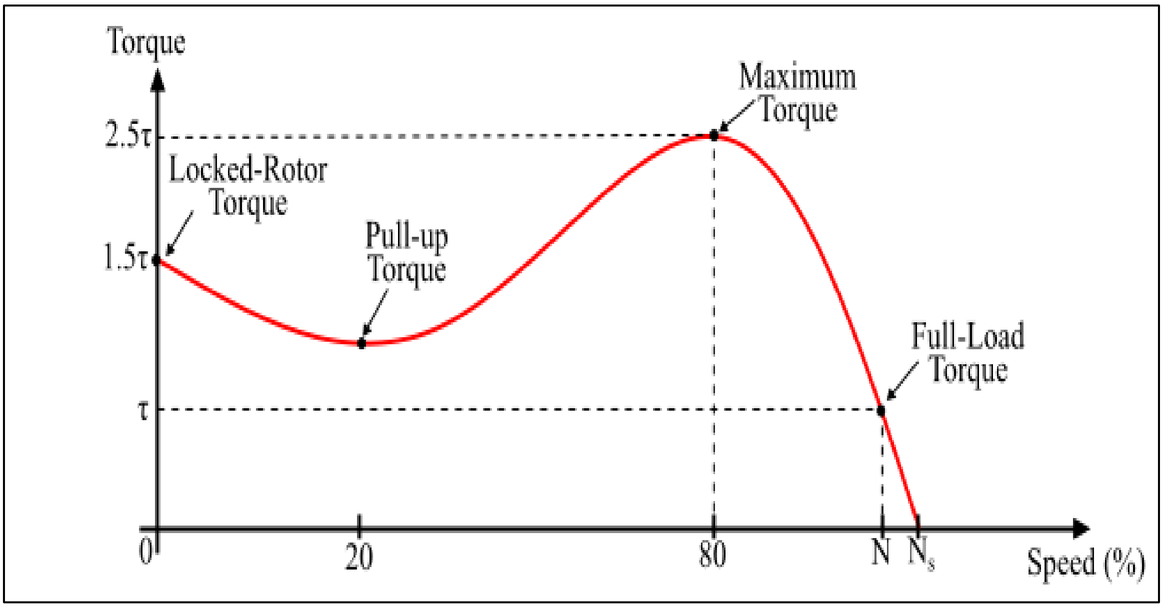


Figure 28: Typical characteristics of Induction motor

c) Composite Load Modelling:

Composite load model includes all constant MVA, current, and admittance load including induction motors. It is intended for representing load at the dynamic level as distinct from the algebraic characteristics level used in power flow, but where detailed dynamics data is not available. The model allows the user to specify a minimum amount of data stating the general character of the composite load. Typical topology of composite load model is depicted in Figure-29.

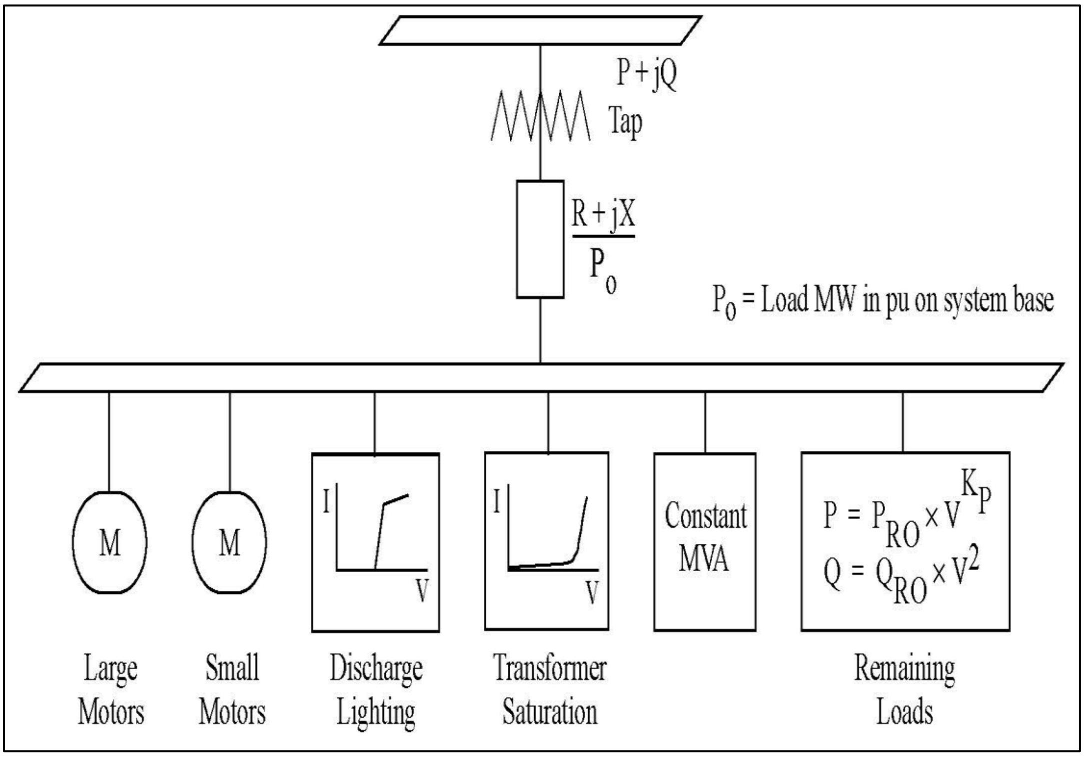


Figure-29: Configuration of Composite load

Composite load model (for the purpose of interconnection with ISTS) considers Inductions motors of two categories i.e. Large Induction Motor and Small Induction Motor. Typical characteristics of Large and Small Induction Motors are depicted in Figure-30 & Figure-31 respectively. The rational behind the classification of inductions (large and small) is based on the capacity of machine, accordingly the inertia constant of large motor (1.0) is higher than small induction motor (0.6).

For the purpose of processing technical connection detail, the steady state and dynamic state modelling of bulk consumer facility shall be carried out using generic models available on PSS/E software. Applicant shall submit the model parameters compatible to PSS/E composite load model (CLODBL). Applicant can also submit the data compatible to other PSS/E generic models, if the performance of facility matches to such model closely.

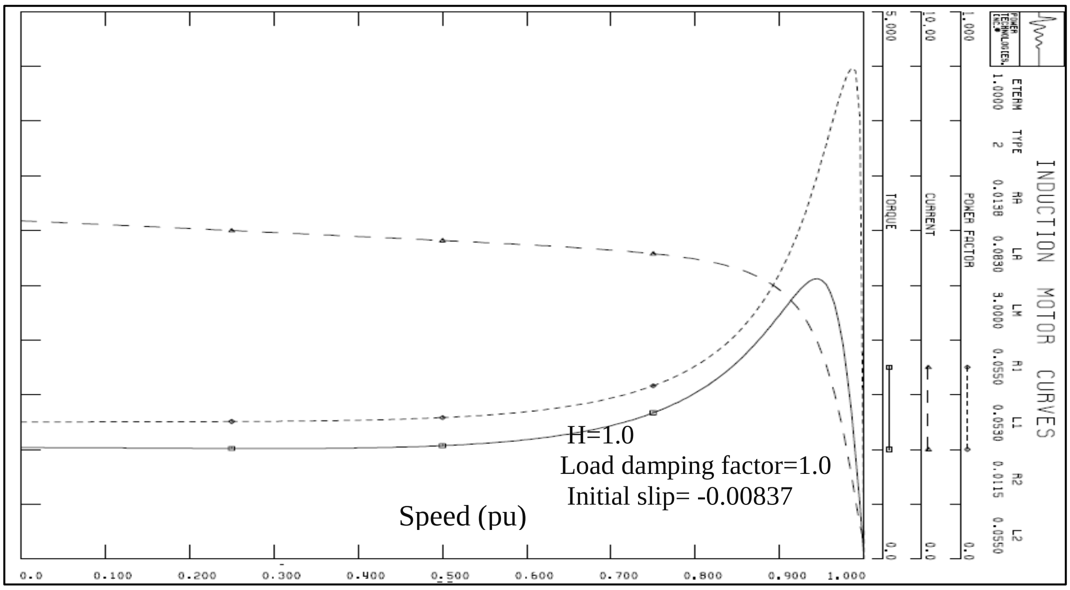


Figure-30: Typical characteristics of Large Induction Motor

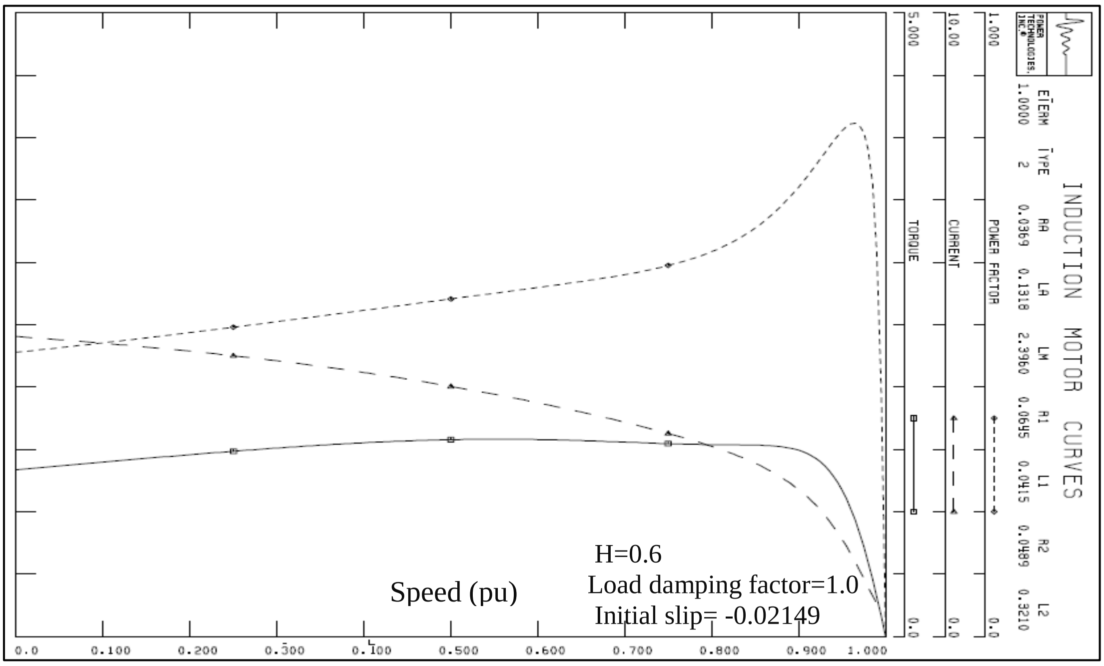


Figure-31: Typical characteristics of Small Induction Motor

d) Electric Arc Furnace (EAF) Load:

Electric arc furnace is one of the vital equipment used in Iron and Steel making industry, typical schematic is shown in Figure-32. In steel making process, electric arc is used to produce high temperature ranges from 3000ºC to 3500ºC required for smelting operation. The EAF is a housed structure wherein two graphite electrodes are spaced from other at a defined distance and is surrounded by metal scrap. In order to melt the scrap steel, electric supply is extended to graphite electrodes and electric arc is established. The electric energy shall result in very high temperature within EAF; typical arc current ranges from 40kA to 63kA operated on a typical voltage range of 500V. For a system with sufficient dielectric strength, the electric arc is considered to be resistive in nature. Electrically, the electric arc conduction process within EAF is a complete or partial short circuit phenomenon, the terminal voltage can drop to zero for a time duration as per operation.

EAF is characterized by large variations in current and voltage during the operation. Due to the highly non-linear nature of load, the performance of transmission system is affected to a large extend. Such operations shall result in low-frequency fluctuations in the system voltage, known as flicker and the injection of integral and fractional multiples of fundamental frequency harmonic components of supply voltage. Further, the operating power factor of the EAF can reduce to a large extend during its operation.

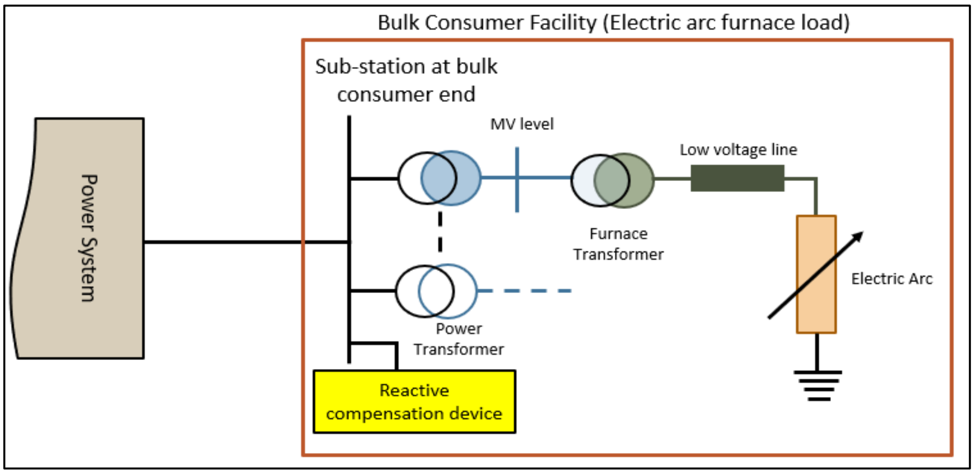


Figure-32: Typical layout of electric arc furnace smelter load

The voltage variations during EAF operation are cyclic or sub-cyclic in nature and hence large amount of reactive power is required with adequate response time. In order to operate the system within permissible voltage levels (steady state and transient state), the reactive power compensation of dynamic nature is required to be provided at the facility itself. Further, in order to mitigate harmonics produced due to arc operation, adequate filter is required to be installed at bulk consumer sub-station

Clause 84 (3) of CEA (Technical Standards for Construction of Electric Plants and Electric Lines), Regulations, 2010 as amended is reproduced below:

……………

84. ***Reactive Compensation-***

1) Where the power factor is low, reactive compensation shall be provided on the distribution transformers by fixed or automatic switched type capacitors of adequate rating.

2) In case of fixed capacitors, it shall be ensured that the rating of the capacitors is such as to prevent over compensation during off peak period.

3) In cases where loads fluctuate very fast, a suitable dynamic compensation like static compensator (STATCOM)/ thyristor switched capacitors shall be considered.

4) In loads which are rich in harmonics, suitable harmonics filters or detuned filter banks shall be considered.

………………..

Technical Connection Data and compliance Report submission by Bulk Consumer/ Distribution Licensee

A. General details:

1	Name of the Applicant Company	:	
	Category of Applicant (Bulk Consumer/ Distribution Licensee)	:	
2	Details of Grant of Connectivity (a) Connectivity Intimation No. (b) Date	 : :	
3	Quantum of Connectivity Granted (MW)	:	
4	Location of facility: Latitude Longitude	:	(Applicant shall also attach the Survey of India of India Toposheet clearly indicating the location of facility)
5	Address for Correspondence	:	
6	Contact Person 6.1 Primary Contact Person (a) Name (b) Designation (c) Phone No. (d) E-mail 6.2 Alternate Contact Person (a) Name (b) Designation (c) Phone No. (d) E-mail	:	
7	Estimated time of completion of project	:	

B. Technical Connection data:

1. Load Details:

1.	<u>For Bulk Consumer:</u> Type of Load including type of industry, i.e. electric furnace, rolling mills, manufacturing, assembly line, etc. <u>For Distribution Licensee:</u> Nature of load i.e. domestic, commercial, industrial, etc.	:	
2	Peak requirement of load in MVA, MW and MVAR of the facility	:	
3	Peak requirement of load in MVA, MW and MVAR from ISTS	:	
4	Peak import required in MVA, MW and MVAR from ISTS	:	
5	Month-wise Peak import required in MVA, MW and MVAR from ISTS.	:	
6	Month-wise Energy requirement in MUs.	:	
7	Installed internal generation capacity of the facility (MW)	:	
8	Voltage level(s) of internal generation capacity	:	

2. Bulk Consumer/ Distribution Licensee receiving Sub-station details

1	Name of Substation	:	
2	Substation type (AIS/ GIS/Hybrid)	:	
3	Voltage level (kV)	:	
4	Design Fault level of substation (---kA for ---sec)	:	
5	Transformation Capacity (MVA, voltage ratio)	:	
6	Bus Switching Scheme	:	
7	Switchyard Configuration (I/D type etc.)	:	
8	Bus Capacity (Main/Transfer) (in Amps)	:	
9	Reactive compensation equipment (if any) Type: (Fixed reactor/capacitor or FACTS devices) Capacity:	:	
10	Basic System details	:	Applicant shall submit the basic system details as per **Annexure-1**

3. Interconnecting Transmission Line (ITL) details

1.	Name of Sending End S/s	:			
2.	Name of Receiving End S/s (ISTS end)	:			
3.	Voltage level (kV)				
4.	Length of ITL (Kms)	:			
5.	Tower Configuration (S/c, D/c, M/c)	:			
6.	Type of Conductor	:			
7.	OPGW available (Yes/No)	:			
8.	No. of Fibre in OPGW (24/48F)	:			
9.	OPGW/Line Shared with another GenCo or another plant of same owner	:			
		R (pu)		**X (pu)**	**B (pu)**
10.	Conductor positive sequence R X B parameters in pu/km/ckt (considering 100MVA base)				
11.	ITL positive sequence R X B parameters in pu/km/ckt (considering 100MVA base)				
12.	ITL zero sequence R X B parameters in pu/km/ckt (considering 100MVA base)				

Note: *Applicant shall submit the details of ITL as per* ***Annexure-2.***

4. Autotransformer data

1	Rating Capacity (HV-LV, HV-IV, IV-LV)	:	
2	Voltage rating (Line to Line)	:	
3	Number of Power Transformers	:	
4	Cooling Type	:	
5	Rating at different cooling above	:	
6	Type of Transformer (Constant Ohmic impedance/ Constant percentage impedance)	:	
7	Transformer Vector Group	:	
8	Tap changer (ON/OFF Load Tap changer)	:	
9	Number of steps and step size	:	
10	Neutral earthing (solid or through reactance)	:	
11	% Impedance at 75ºC (HV-IV)	:	
12	% Resistance at 75ºC (HV-IV)	:	
13	% Reactance at 75ºC (HV-IV)	:	
14	% Impedance at 75ºC (HV-LV)	:	
15	% Resistance at 75ºC (HV-LV)	:	
16	% Reactance at 75ºC (HV-LV)	:	
17	% Impedance at 75ºC (IV-LV)	:	

18	% Resistance at 75ºC (IV-LV)	:	
19	% Reactance at 75ºC (IV-LV)	:	
20	Positive sequence resistance (R1HL1) between HV/IV in pu	:	
21	Positive sequence reactance (X1HL1) between HV/IV in pu	:	
22	Zero sequence resistance (R0HL1) between HV/IV in pu	:	
23	Zero sequence reactance (X0HL1) between HV/IV in pu	:	
24	Positive sequence resistance (R1HL2) between HV/LV in pu	:	
25	Positive sequence reactance (X1HL2) between HV/ LV in pu	:	
26	Zero sequence resistance (R0HL2) between HV/LV in pu	:	
27	Zero sequence reactance (X0HL2) between HV/LV in pu	:	
28	Positive sequence resistance (R1L1L2) between IV/ LV in pu	:	
29	Positive sequence reactance (X1L1L2) between IV/LV in pu	:	
30	Zero sequence resistance (R0L1L2) between IV/LV in pu	:	

31	Zero sequence reactance (X0L1L2) between IV/LV in pu	:	
32	Positive sequence resistance (R1HL1//L2) between HV/(IV+LV) in pu	:	
33	Positive sequence reactance (X1HL1//L2) between HV/(IV+LV) in pu	:	
34	Zero sequence resistance (R0HL1//L2) between HV/(IV+LV) in pu	:	
35	Zero sequence reactance (X0HL1//L2) between HV/(IV+LV) in pu	:	

5. Two Winding Transformer Data

1	Rating Capacity (HV-LV)	:	
2	Voltage Ratio (Line to Line)	:	
3	Number of Power Transformers	:	
4	Cooling Type	:	
5	Rating at above different coolings	:	
6	Type of Transformer (Constant Ohmic impedance/ Constant	:	
7	Transformer Vector Group	:	
8	Tap changer (ON/OFF Load Tap changer)	:	
9	Number of steps and step size	:	
10	Neutral earthing (solid or through reactance)	:	
11	% Impedance at 75ºC (HV-LV)	:	
12	% Resistance at 75ºC (HV-LV)	:	
13	% Reactance at 75ºC (HV-LV)	:	
14	Positive sequence resistance (R1) in pu	:	
15	Positive sequence reactance (X1) in pu	:	
16	Zero sequence resistance (R0) in pu	:	
17	Zero sequence reactance (X0) in pu	:	

6. Three Winding Transformer Data

1	Rating of transformer (MVA) (HV-IV & HV-LV)	:	
2	Voltage Ratio (Line to Line)	:	
3	Construction type (Three phase or single-phase units)	:	
4	Number of transformers	:	
5	Cooling Type	:	
6	Rating at above different cooling	:	
7	Type of Transformer (Constant Ohmic impedance/ Constant percentage impedance)	:	
8	Transformer Vector group	:	
9	Tap changer (ON/OFF Load Tap changer)	:	
10	Number of steps and step size	:	
11	Neutral earthing (solid or through reactance)	:	
12	% Impedance at 75ºC (HV-IV)	:	
13	% Resistance at 75ºC (HV-IV)	:	
14	% Reactance at 75ºC (HV-IV)	:	
15	% Impedance at 75ºC (HV-LV)	:	
16	% Resistance at 75ºC (HV-LV)	:	

17	% Reactance at 75ºC (HV-LV)	:	
18	% Impedance at 75ºC (IV-LV)	:	
19	% Resistance at 75ºC (IV-LV)	:	
20	% Reactance at 75ºC (IV-LV)	:	
21	Positive sequence resistance (R1HL1) between HV/LV1 in pu	:	
22	Positive sequence reactance (X1HL1) between HV/LV1 in pu	:	
23	zero sequence resistance (R0HL1) between HV/LV1 in pu	:	
24	zero sequence reactance (X0HL1) between HV/LV1 in pu	:	
25	Positive sequence resistance (R1HL2) between HV/LV2 in pu	:	
26	Positive sequence reactance (X1HL2) between HV/LV2 in pu	:	
27	Zero sequence resistance (R0HL2) between HV/LV2 in pu	:	
28	Zero sequence reactance (X0HL2) between HV/LV2 in pu	:	
29	Positive sequence resistance (R1L1L2) between LV1/LV2 in pu	:	
30	Positive sequence reactance (X1L1L2) between LV1/LV2 in pu	:	

31	zero sequence resistance (R0L1L2) between LV1/LV2 in pu	:	
32	Zero sequence reactance (X0L1L2) between LV1/LV2 in pu	:	
33	Positive sequence resistance (R1HL1//L2) between HV/(LV1+LV2) in pu	:	
34	Positive sequence reactance (X1HL1//L2) between HV/(LV1+LV2) in pu	:	
35	Zero sequence resistance (R0HL1//L2) between HV/(LV1+LV2) in pu	:	
36	Zero sequence reactance (X0HL1//L2) between HV/(LV1+LV2) in pu	:	

7. Shunt Reactor

1.	Rated Voltage (Line to Line) (1.0 pu)	:	
2.	Rated capacity at rated voltage (MVAR)	:	
3.	Three phase unit or Single-phase unit	:	
4.	Cooling system	:	
5.	Rated current (A)	:	
6.	Construction type (Core/Shell)	:	
7.	Neutral Grounding (Solidly earthed/ through reactor)	:	
8.	Range of constant impedance	:	Upto …… pu voltage
9.	Reactor knee point voltage (pu)	:	

Note: *Applicant shall attach the OEM Technical datasheet for Shunt reactor indicating rating, impedance, knee point voltage.*

8. Generator Data for Fault (Short Circuit Studies)

1.	Direct Axis Transient Reactance	X_d’	
2.	Sub-transient Reactance	X_d”	
3.	Synchronous Reactance	X_s	
4.	Zero Sequence Reactance	X_o	
5.	Negative Sequence Reactance	X_2	

9. 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. 104(Ethernet), etc.)
3.	Write here the communication media, interface and capacity being targeted for Connectivity for Data and voice Communication	:	(Communication media: For example fibre optics, PLCC, etc. Interface: Example, Ethernet, G.703) Capacity: 1200 baud, 64 Kbps, 2Mbps, etc)

10. PSS/E Single Line Diagram (Single Machine Infinite Bus Model)

Note: Applicant shall attach herewith the PSS/E based Plant SLD aggregated upto 132kV level. If 132 kV transformation level is not available then the applicant may submit the modelling details at 220 kV level.

11. Dynamic simulation test

Note: Applicant shall attach herewith the plant/distribution licensee response for voltage and frequency step changes at POI with appropriate data /plots of Voltage, Current, Active power, Reactive Power (for both POI and Plant) in order observe the load sensitivity. Voltage & Frequency step changes (with step size 0.005pu) at POI includes following tests:

a) Voltage at POI changed from 1.0 to 0.95pu

b) Voltage at POI changed from 1.0 to 1.05pu

c) Frequency at POI changed from 50Hz to 49.5Hz

d) Frequency at POI changed from 50Hz to 50.5Hz

12. Model Parameter list (CLODBL)

Note: Applicant shall submit the model parameters of the facility corresponding to steady state and dynamic state condition as per table given hereunder:

Steady state parameters			
1	Active Power (MW)- Constant Power Load	:	
2	Reactive Power (MVAr)- Constant Power Load	:	
3	Active Power (MW)- Constant Current Load	:	
4	Reactive Power (MVAr)- Constant Current Load	:	
5	Active Power (MW)- Constant Admittance Load	:	
6	Reactive Power (MVAr)- Constant Admittance Load	:	
Dynamic State parameters (CLODBL)			
1	Percentage of large motor (%)	:	
2	Percentage of small motor (%)	:	
3	Percentage of transformer excitation current (%)	:	
4	Percentage of discharge lighting (%)	:	
5	Percentage of Constant Power (%)	:	
6	K_p of remaining load	:	
7	Branch R (pu on load MW base)	:	
8	Branch X (pu on load MW base)	:	

C. Applicant has attached a copy of the affidavit towards the fulfillment of terms and conditions as specified in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof as per Annexure-A.

D. Applicant has further submitted documents/study reports as per Annexure-3 for compliance of CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007.

E. Applicant has submitted the details of terminal bay equipment including communication details under its scope as per Annexure-4.

F. Applicant has further attached the following drawings (soft copy) alongwith application:

1) Site plan in appropriate scale indicating Loads, Generators, Transformer, Site building (pdf & autocad copy)

2) Site plan of the ISTS substation at which connectivity granted (pdf and/or autocad copy)

3) General Arrangement (GA) drawing indicating proposed facility

4) Electrical Single Line Diagram (SLD) of the proposed facility detailing all significant items of plant (pdf & autocad copy)

5) Electrical Single Line Diagram (SLD) of ISTS substation at which connectivity granted (pdf & autocad copy)

6) Sub-Station Automation System (SAS) ring diagram indicating interconnections of various IEDs/Engg PC/Gateway etc.

7) Equipment drawings for confirming the ratings

8) CRP (Control & Relay Panel) & scheme drawings containing protection details of the transmission line

9) PLCC/FOTE drawings for the transmission lines under the scheme

10) Details of Communication System

11) Detailed calculation sheet for deriving the maximum ampacity of the conductor as per IEEE-738 Standards, Central Electricity Authority (Technical Standards for Connectivity to Grid), Regulations 2007 and its amendments thereof, Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 & CEA Transmission Planning Criteria, 2013 and its amendments thereof.

G. Applicant has undertaken studies including voltage stability, protection co-ordination, machine dynamics, resonance, sub-station grounding and fault duties of equipment to be installed at bulk consumer premise (as the case may be) so that the overall system performance is not constrained during steady state and contingency conditions. The sub-station grounding design should be such that the earth fault factor of the system should remain below 1.4. Sub-station grounding should be in line with provisions of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010.

Resonance including ferro-resonance studies has been carried out by applicant covering possible network topologies for excitation of series/parallel resonant point by network impedance scanning and they shall implement the remedial measure at their end in this context.

This is to certify that the above data submitted with the application are pertaining to Connectivity 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:

Annexure-A

Affidavit to be submitted by the grantee (on non-judicial Stamp Paper of Rs. 10/-) towards fulfilment of various compliances as specified in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof (to be provided by company authorized signatory duly authorized vide board resolution)

Date: …………….

Connectivity Intimation No: ………… Connectivity Intimation date: ………….

I ………….. (Name)….….…S/o Shri ……… (Father's name) working as ………………….. (designation) in ……………… (Name of the Applicant organization / entity) ……..….., having its registered office at …………… (Address of the Applicant organization / entity) …………, do solemnly affirm that ..…..…… (name of bulk consumer facility/ distribution licensee & location of connectivity granted by CTU) complies with the following conditions as laid out in the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof and CERC (Connectivity and General Network Access to Inter State Transmission System) Regulations, 2022 and directions through various orders including the following:

1. Under frequency and df/dt (rate of change of frequency with time) relays has been employed for automatic load control in a contingency to ensure grid security under conditions of falling grid frequency in accordance with the decision taken in the Regional Power Committee.

2. Reactive Power:

(i) The applicant has provided adequate reactive compensation to compensate reactive power requirement in their system so that they do not depend upon the grid for reactive power support.

(ii) The power factor for the bulk consumer is within ± 0.95.

3. Voltage and Current Harmonics

(i) The Voltage harmonics and current harmonics at POI is within permissible limits as stipulated in IEEE-519-2014;

(ii) The applicant has installed power quality meter complying with provisions of IEC 61000-4-30 Class A for the measurement of harmonics.

(iii) In addition to harmonics, periodic measurement of other power quality parameters such as voltage sag, swell, flicker, disruptions have been done as per relevant International Electrotechnical Commission Standards.

4. Voltage Unbalance

The Voltage Unbalance at POI is not exceeding 3.0%.

5. Voltage Fluctuations

(i) The voltage fluctuation for step changes which may occur repetitively is less than 1.5%.

(ii) For occasional fluctuations other than step changes the maximum voltage fluctuations is 3%.

6. Back energization

The applicant shall not energize transmission or distribution system by injecting supply from his generators or any other source either by automatic controls or manually unless specifically provided for in the Connectivity agreement with the Transmission or Distribution Licensee

I am aware that in case any discrepancies / incompleteness are found in the documents submitted to CTU, the Connection data (CONN-TD-5) / Connectivity agreement (CONN-CA-6) shall not be processed further. I am also aware that if at any stage any falsity / inaccuracy / incorrectness is detected in the documents / statements …………….. (name of bulk consumer/ distribution licensee), shall be solely liable for disconnection from the Grid along with all associated liabilities / consequences in this regard.

Name of the Authorised Signatory:

Signature:

Company Stamp (mandatory):

Annexure-1

Basic System details

Sl. No.	Description	Values
1	System operating voltage (kV)	
2	Maximum voltage of the system (rms) (kV)	
3	Rated frequency (Hz)	
4	Nos. of phases	
5	Rated insulation levels	
5 i)	Impulse withstand voltage for (1.25/50micro second) - Transformer and Reactors - For other equipment - For insulator string	
5 ii)	Switching impulse withstand voltage (250/2500 micro second) dry and wet	
5 iii)	One-minute power frequency dry withstand voltage (rms)	
5 iv)	One-minute power frequency dry and wet withstand voltage (rms) (kV)	
6.	Corona extinction voltage (kV)	
7.	Max. radio interference voltage for frequency between 0.5MHz and 2MHz	
8.	Minimum creepage distance for insulator string/longrod insulators/ outdoor bushings	
9.	Minimum creepage distance for switchyard equipment	
10.	Max. fault current capacity (kA for …sec)	

Annexure-2

Data pertaining to interconnected transmission line

A.	**Conductor**	
i.	Name of conductor	
ii.	Outside diameter	
iii.	DC Resistance (ohm/km)	
iv.	Number of conductors in bundle	
v.	Bundle spacing (mm)	
vi.	Maximum operating Temperature (degree C)	
vii.	Ampacity at maximum operating Temperature (A) with calculation sheet as per IEEE 738 & CEA Technical standard/CEA Planning criteria)	
B.	**Earth Wire**	
i.	Diameter of Earthwire	
ii.	DC Resistance (ohm/km)	
C.	**OPGW**	
i.	OPGW diameter (mm)	
ii.	OPGW cross-section area (mm^2)	
iii.	Number of Strands	
iv.	Diameter of each strands	
v.	DC Resistance (Ohms/km)	
vi.	Short Circuit Current (kA)	
vii.	OPGW Sag - Tension chart	
viii.	Fiber type considered in OPGW	
ix.	No. of fibers available for use	
x.	Fiber loss (dB) Attenuation Chromatic Dispersion	
xi.	FODP terminations capacity	
D.	**Communication Equipment**	
i.	Transmission Equipment (SDH) capacity (STM4/16)	
ii.	Optical Directions supported	
iii.	Make and model of Transmission Equipment	
iv.	Ethernet card/ ports details and availability for use	

Annexure-3

List of Test/Study Reports required to be carried out by bulk consumer/ distribution licensee in compliance of CEA (Technical Standards for Connectivity to the Grid), Regulations 2007 and its amendments thereof

Clause No. of Connectivity Regulation	Detailed clause	Reports in compliance of CEA Technical Standards for Connectivity to the Grid for Bulk Consumer and Distribution Licensee
Part-IV (1)	**Under Frequency/ df/dt Relays** Under frequency and df/dt (rate of change of frequency with time) relays shall be employed for automatic load control in a contingency to ensure grid security under conditions of falling grid frequency in accordance with the decision taken in the Regional Power Committee	Applicant shall submit the details of under frequency and df/dt relays in their system along with settings.
Part-IV (2)	**Reactive Power** (i) The distribution licensee and bulk consumer shall provide adequate reactive compensation to compensate reactive power	(i) Applicant shall submit the study report alongwith file in PSS/E format depicting reactive power requirement and compensation to be provided (if required) so that they should not depend on the ISTS Grid for reactive power support.

<table>
<tr><th>Clause No. of Connectivity Regulation</th><th>Detailed clause</th><th>Reports in compliance of CEA Technical Standards for Connectivity to the Grid for Bulk Consumer and Distribution Licensee</th></tr>
<tr><td></td><td>requirement in their system so that they do not depend upon the grid for reactive power support.

(ii) The power factor for distribution system and bulk consumer shall be within ± 0.95</td><td>(ii) The study shall be carried out considering three different voltage conditions at POI (0.95,1.0 & 1.05pu). The requisite response from the bulk consumer is given below:

<table>
<tr><th>Voltage at POI</th><th>Reactive power requirement (at POI)</th></tr>
<tr><td>Above 1.0pu</td><td>Bulk consumer shall not inject reactive power into the ISTS Grid</td></tr>
<tr><td>1.0pu</td><td>Bulk consumer shall ensure that reactive power exchange with the Grid remains under balanced conditions</td></tr>
<tr><td>0.95 to 1.0pu</td><td>Bulk consumer shall not draw reactive power from the ISTS Grid</td></tr>
</table>
(iii) Applicant it its report shall provide confirmation that power factor of</td></tr>
</table>

Clause No. of Connectivity Regulation	Detailed clause	Reports in compliance of CEA Technical Standards for Connectivity to the Grid for Bulk Consumer and Distribution Licensee
		the distribution system is within ± 0.95 range. (iv) Applicant shall indicate reactive power compensation equipment required (if any) to make the plant compliant to CEA Technical Standard for Connectivity to Grid, 2007.
Part-IV (3)	**Voltage and Current Harmonics** (i) The limits of voltage harmonics by the distribution licensee in its electricity system, the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the	(i) Applicant shall submit the study report depicting harmonic injection (Current and Voltage) from the facility at POI as per IEEE 519-2014 standard. For the purpose harmonic evaluation at the POI, the interconnecting transmission line and reactive compensation devices (if planned) shall also be considered as an internal part of the facility. (ii) Applicant shall submit details of power quality meter to be installed in the facility conforming IEC 61000-4-30 Class A.

Clause No. of Connectivity Regulation	Detailed clause	Reports in compliance of CEA Technical Standards for Connectivity to the Grid for Bulk Consumer and Distribution Licensee
	IEEE 519-2014 standard, as amended from time to time; (ii) Measuring and metering of harmonics shall be a continuous process with meters complying with provisions of IEC 61000-4-30 Class A. The bulk consumer shall install power quality meter for the measurement of harmonics. In addition to harmonics, periodic measurement of other power quality parameters such as voltage sag, swell, flicker, disruptions shall be done as per relevant International Electrotechnical Commission Standards.	*Note: The voltage level as mentioned in the grant of connectivity shall be considered for comparison of harmonics w.r.t IEEE-519-2014 limits.* (iii) Applicant shall submit the EMT model of facility for harmonic study. Applicant shall also submit the study report for evaluation of other power quality parameters including Voltage sag, swell, flicker, disruption at POI as per relevant IEC standards.
Part-IV (4)	**Voltage Unbalance**	Applicant shall submit the study report depicting voltage unbalance at voltage specified in the grant of connectivity.

Clause No. of Connectivity Regulation	Detailed clause	Reports in compliance of CEA Technical Standards for Connectivity to the Grid for Bulk Consumer and Distribution Licensee
	The Voltage Unbalance at 33 kV and above shall not exceed 3.0%.	
Part-IV (5)	**Voltage Fluctuations** (i) The permissible limit of voltage fluctuation for step changes which may occur repetitively is 1.5%. (ii) Far occasional fluctuations other than step changes the maximum permissible limit is 3%.	(i) Applicant shall submit the study report (alongwith file) depicting the following: a) Voltage fluctuation at POI remains below 1.5% for repetitive step changes. b) Voltage fluctuation at POI remains below 3% for occasional changes. (ii) Applicant in their study report shall indicate the maximum step changes & occasional fluctuations and the mitigation measures (if required)
Part-IV (6)	**Back energization** The bulk consumer shall not energize transmission or distribution system by injecting supply from his generators or any other source either by automatic controls or manually unless	Applicant shall submit undertaking on their letter head mentioning that "I/We (Name of applicant), have applied for Connectivity agreement to ISTS Grid as a Bulk consumer/Distribution Licensee. I/We (Name of applicant), hereby undertake that, they shall not energize transmission or distribution system by injecting supply from his

Clause No. of Connectivity Regulation	Detailed clause	Reports in compliance of CEA Technical Standards for Connectivity to the Grid for Bulk Consumer and Distribution Licensee
	specifically provided for in the Connectivity agreement with the Transmission or Distribution Licensee	generators or any other source either by automatic controls or manually unless specifically provided for in the Connectivity agreement with the Transmission or Distribution Licensee”

Note:

i. The bulk consumer/distribution licensee shall comply with the provisions of CEA Technical Standards for Connectivity to Grid, Regulations 2007 as amended at the POI (Point of Inter Connection). The Point of Interconnection (POI) shall be considered as a voltage level (of ISTS Sub-Station) mentioned in the grant of Connectivity which includes the interconnecting transmission line.

ii. **Total harmonic distortion (THD)-**It is the ratio of the r.m.s value of the sum of all the harmonic components up to a specified order (H) to the r.m.s value of the fundamental component

$$\mathrm{THD} = \sqrt{\sum_{h=2}^{H}\left(\frac{Q_h}{Q_1}\right)^2}$$

Q represents either current or voltage; Q_1 is the r.m.s. value of the fundamental component;

h is the harmonic order, Q_h is the r.m.s. value of the harmonic component of order h; H shall be considered 50

Annexure-4

Data Format-I

A. Bulk consumer/ distribution licensee end:

1.	Name of substation and ownership:	
2.	Name of the bay and bay identification number:	

B. Sub-station (ISTS) End at which Connectivity is granted:

1.	Name of substation and ownership:	
2.	Name of the bay and bay identification number:	

***Note**: In case of more than two substations, the same shall be appended.*

Data Format-II-A

Equipment to be provided in the allocated bay meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof

Bus switching scheme:

A. Bulk Consumer/ Distribution Licensee end: [……………………….]

B. ISTS end: […………….]

Name of Lines along with Tower Configuration (S/c, D/c, M/c**):**

Type of Conductor: (Bundle Configuration, Dia/ Type and Ampacity)

Equipment Details:

Sl. No.	Name of Equipment	Bulk Consumer/ Distribution Licensee end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/ MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
For GIS Substation							
1	Circuit Breaker (with PIR /CSD if required))						
2	Disconnecting Switch						
3	Maintenance Earthing Switch						
4	High speed Earthing switch						
5	CT with core details						
6	Bus PT						

Sl. No.	Name of Equipment	Bulk Consumer/ Distribution Licensee end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/ MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
7	Surge Arrester						

Note: *In case of more than two substations, the same shall be appended.*

Sl. No.	Name of Equipment	Bulk Consumer/ Distribution Licensee end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
For AIS Substation							
1	Circuit Breaker (with PIR /CSD if required))						
2	Isolator (with no. of Earth Switch as required)						
3	CT with core details						
4	CT (Metering)						
5	Line CVT						
6	Bus CVT						
7	PT (Metering)						
8	Wave trap						
9	Surge Arrester						
10	ICT						

Sl. No.	**Name of Equipment**	**Bulk Consumer/ Distribution Licensee end**			**ISTS Substation End at which Connectivity is granted**		
		Type (AIS/GIS/MTS)	**Nos**	**Ratings**	**Type (AIS/GIS/ MTS)**	**Nos**	**Ratings**
11	Bus Reactor						
12	Line Reactor						
13	NGR						
14	NCT						
15	ESS (Energy Storage System)						
16	Any other equipment details (……)						

Note: *In case of more than two substations, the same shall be appended.*

Data Format-II (B)

Protection Equipment to be provided by applicant shall be meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof and shall be compatible & matching with the equipment installed at other end

(Please specify type, make and model of all main relays as applicable)

Name of Substation and Voltage level:

A. Bulk Consumer/ Distribution Licensee end and Voltage Level:

B. Connectivity substation end and Voltage Level:

Protection Details:

Sl. No.	Description	Bulk Consumer/ Distribution Licensee end	ISTS Substation End at which Connectivity is granted
		Protection Type, Make and Model	
1)	Line protection relay MAIN-I (Distance / Differential)		
2)	Line protection relay MAIN-II (Distance / Differential)		
3)	Auto reclose relays		
4)	Bay Control Unit		
5)	Any Other Protection Equipment		

***Note**: In case of more than two substations, the same shall be appended.*

Data Format-III (A)

System Recording Equipment to be provided in the allocated bay meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof

Sl. No.	Name of Equipment's	Bulk Consumer/ Distribution Licensee end		ISTS Substation End at which Connectivity is granted	
		Nos.	Ratings	Nos.	Ratings
1.	Event Logger				
2.	Disturbance recorder				
3.	Fault locator				
4.	PLCC details of transmission line				
5.	FOTE details				
6.	Any other equipment (Please indicate)				

***Note**: In case of more than two substations, the same shall be appended.*

Data format-III (B)

Communication Equipment details upto Data Collection Point SCADA equipment shall be meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof and shall be compatible to facilitate exchange of data with the existing system installed in the ISTS network

Sl. No	Name of Equipment	Nos.	Ratings
1.	**Data Acquisition System** - Remote Terminal Unit/SAS/DAS Gateway		
2(a)	**Communication Equipment** SDH required if any i. At the Generating/Pooling station ii. At data collection point (DCP)		
2(b)	**Approach Cable & FODP** i. At the Generating/ Pooling station ii. At data collection point (DCP)		
3	**WAMS** Phasor Measurement Unit(s) for measuring three phase current of all the feeders and three phase bus voltage at *220kV and above Generator		

***Note:** *PMU locations shall be as per latest prevailing guidelines of CEA/Prevailing standards*

Data Format –III(C)

Cyber Security compliance as per CEA (Cyber Security in Power Sector) Guidelines 2021

Sl. No	Name of Equipment	Nos.	Remarks
1.	**Perimeter security** Redundant Firewalls between SAS Gateway/RTU and FOTE		

Data Format –III (D)

Format for Communication inputs for Bulk Consumer/ Distribution Licensee

A. Communication Equipment details along with PMU

Sl. No.	Data Type	Bulk Consumer/ Distribution Licensee end	ISTS S/s End	
		Installed/ Provisioned	Scope (With Gen or ISTS S/s Owner)	Installed/ Provisioned
1	Approach cable			
2	FODP			
3	PMU			
4	FOTE			

B. FOTE Details

Sl. No.	Particulars	Bulk Consumer/ Distribution Licensee end	ISTS S/s end
1	Make		
2	Model		
3	Capacity (e.g. STM16)		
4	No. of supported optical directions (e.g. 5 MSP)		

Data format-IV

Details of the modification/alteration to existing facilities for accommodating proposed connection and its estimated cost

Data format -V

Communication Link details up to ISTS Data Collection Point

Requirement of Channels:

(i) 2 Nos Data Channel (600Baud) /64 Kbps or Ethernet channel for RTU/SAS/DAS

(ii) 1 No Speech channel

(iii) 1 No. Data Channel (2 Mbps) for PMU

Data Collection Point for: Bulk Consumer/ Distribution Licensee end

Data Collection Point (DCP): Name of ISTS Station

Wideband Link (Configuration of Data & Voice channel in wideband Link by Regional ULDC Team)**:**

Channel: DCP Name- Respective RLDC

Data format-VI

Site responsibility schedule

A. Principle & Procedure:

The responsibility of control, operation, maintenance & all matters pertaining to safety of equipment's and apparatus at the connection point shall lie with the connectivity grantee. The grantee may enter into a separate O&M contract with the owner of the substation based on mutually agreed terms and conditions for ease of day-to-day O&M of the equipment which are located in the premises of the substation.

List of equipment and their ownership at the connection point:

Sl. No.	Name of Equipment	Ownership	
		Bulk Consumer/ Distribution Licensee end	ISTS Substation end at which Connectivity is granted
1.	Circuit Breaker (with PIR /CSD if required)		
2.	Isolator (with no. of Earth Switch as required)		
3.	Disconnecting Switch(For GIS)		
4.	Maintenance Earthing Switch (For GIS)		
5.	High speed Earthing switch (For GIS)		
6.	CT		
7.	CT (Metering)		
8.	Line CVT		
9.	Bus CVT		

Sl. No.	Name of Equipment	Ownership	
		Bulk Consumer/ Distribution Licensee end	**ISTS Substation end at which Connectivity is granted**
10.	PT (Metering)		
11.	Wave trap		
12.	Surge Arrester		
13.	ICT		
14.	Bus Reactor		
15.	Line Reactor		
16.	NGR		
17.	NCT		
18.	ESS (Energy Storage System)		
19.	Any other Equipment (….)		