पावर सिस्टम ऑपरेशन कॉर्पोरेशन लिमिटेड
(भारत सरकार का उद्यम)
POWER SYSTEM OPERATION CORPORATION LIMITED
(A Govt. of India Enterprise)
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संदर्भ: NLDC/FTC/ **दिनांक:** 03rd June 2020

From: ED, NLDC

To: ED, NRLDC/WRLDC/SRLDC/ ERLDC/NERLDC
Copy to: CMD, POSOCO
Dir.(SO), POSOCO

विषय: Consolidated Procedure for First Time Charging/Energization (FTC) and Integration of New or Modified Power System Element-Regarding

Indian Electricity Grid Code provides for formulation of operating procedure by NLDC/RLDCs. Also, Regulation 5(2) of CERC (Terms and Condition of Tariff) Regulation,2019 provides for certification of charging element by RLDC. In line with the above provisions, a procedure has been formulated to enable NLDC/RLDCs to facilitate integration of a new or modified power system element. This consolidated First time Charging(FTC) procedure is applicable to all the generating station those are regional entities (as defined in IEGC) as well as all the Power system elements belongs to 400kV level and above irrespective of ownership, 220 kV lines emanating from ISGS /ISTS substations, Inter Regional/ Inter-state/Transnational transmission lines irrespective of voltage level/ownership, HVDC links/poles irrespective of ownership, FACTS devices (TCSC/FSC/STATCOM/SVC), Station Transformers (STs) connected at generating station those are regional entities.

The procedure is divided into five sections as follows:

Section 1:- Provides the details of requirement for Integration of conventional generating plants (Thermal, Gas & Hydro), Bulk Consumers or Load Serving Entities and Combined (Load & Captive) generation complex

Section 2:- Provides the requirement for Integration of Solar, Wind or Hybrid Power Plant/Wind or Solar Power Parks, WPD/SPD/HPD those are regional entities

Section 3:- Describes the requirement for integration of a new or modified HVDC transmission elements and issue of certificate of successful trial operation by National Load Despatch Centre (NLDC)/ Regional Load Despatch Centres (RLDCs)

Section 4:- Provides the requirement for integration of a STATCOM/SVC and issue of certificate of successful trial operation by Regional Load Despatch Centres (RLDCs)

Section 5:- Provides the requirement for integration of a new or modified power system elements and issue of certificate of successful trial operation by National Load Despatch Centre (NLDC)/ Regional Load Despatch Centres (RLDCs).

Procedure for First Time Charging (FTC) is available at following link:

https://drive.google.com/file/d/1fp7eFttUfbrn5ZmaUARhJiJHQsteanvG/view?usp=sharing

This procedure supersedes all other FTC procedures issued earlier by NLDC/RLDCs. All concerned are requested to follow this procedure for the smooth operation of the all India electricity grid. RLDCs are requested to further circulate this procedure.

Thanking you,

Yours sincerely,

03/06/2020

(Debasis De)

ED, NLDC

Power System Operation Corporation Ltd.

(A Government of India Enterprise)

Procedure for First Time Charging/Energization (FTC) and Integration of New or Modified Power System Element

[As per CERC (Terms and Conditions of Tariff) Regulations, 2019 (dated 07.03.2019)]

<table>
<tr><td colspan="2">Document Name:</td><td colspan="2">NLDC/FTC</td></tr>
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INTRODUCTION

This First time Charging(FTC) procedure is applicable to all the generating station those are regional entities (as defined in IEGC) as well as all the Power system elements belongs to 400kV level and above irrespective of ownership, 220 kV lines emanating from ISGS /ISTS substations, Inter Regional/ Inter-state/Transnational transmission lines irrespective of voltage level/ownership, HVDC links/poles irrespective of ownership, FACTS devices (TCSC/FSC/STATCOM/SVC) , Station Transformers (STs) connected at generating station those are regional entities.

Indian Electricity Grid Code provides for formulation of operating procedure by NLDC/RLDCs. The same is quoted below:

"A set of detailed operating procedures for the National grid shall be developed and maintained by the NLDC in consultation with the RLDCs, for guidance of the staff of the NLDC and it shall be consistent with IEGC to enable compliance with the requirement of this IEGC.

A set of detailed operating procedures for each regional grid shall be developed and maintained by the respective RLDC in consultation with the regional entities for guidance of the staff of RLDC. and shall be consistent with IEGC to enable compliance with the requirement of this IEGC."

In accordance with the above provisions and as a part of NLDC/RLDC operating procedure, the first time charging procedure for energization and integration of new or modified power system element has been prepared. This procedure specifies the requirements to be fulfilled by the connectivity grantees prior to obtaining the permission of the RLDC/NLDC. This procedure specifies operational and study requirements for integration of new or modified power system elements with the grid.

For integrating the new or modified power system elements in the grid, the following are prerequisite before First time charging of Power system elements.

a) Power purchase Agreements(PPA), connectivity details and agreements
b) Statutory clearances as per CEA or as per respective State government authorities which ever applicable
c) PTCC clearance Certificate
d) Compliances of various regulation/standards of CERC and CEA
e) Ensure to correct and appropriate settings of protection as per RPC

approved protection philosophy

f) Provides Real time SCADA data and telemetry at NLDC/RLDCs
g) Installation of meters as per provisions of CEA regulations
h) Dedicated Voice/Data communication from generating /substation in redundant and alternate path.
i) Static and dynamic modelling data for system studies
j) Compliances of relevant clauses of IEGC and operating procedures of RLDCs
k) Compliance to any other regulations and standards specified from time to time

Based on the requirements, First Time Charging (FTC) procedure is prepared by NLDC/RLDCs to follow uniformly in all region and is divided into five sections as follows:

Section 1:- Provides the details of requirement for Integration of conventional generating plants (Thermal, Gas & Hydro), Bulk Consumers or Load Serving Entities and Combined (Load & Captive) generation complex

Section 2:- Provides the details of requirement for Integration of Solar, Wind or Hybrid Power Plant/Wind or Solar Power Parks, WPD/SPD/HPD those are regional entities

Section 3:- Describes the details of requirement for integration of a new or modified HVDC transmission elements and issue of certificate of successful trial operation by National Load Despatch Centre (NLDC)/ Regional Load Despatch Centres (RLDCs)

Section 4:- Provides the details of requirement for Procedure for integration of a STATCOM/SVC and issue of certificate of successful trial operation by Regional Load Despatch Centres (RLDCs)

Section 5:- Provides the details of requirement for integration of a new or modified power system elements and issue of certificate of successful trial operation by National Load Despatch Centre (NLDC)/ Regional Load Despatch Centres (RLDCs).

For integrating new or modified power system elements in the grid , all concerned shall have to submit the Annexures (A1-A6), (B1-B5) and (C1-C4) as per the time line mentioned in Section 5 of this document in addition to the requirement described in the respective Sections. Jurisdiction of NLDC/RLDCs for issuing charging code and trial certificate is as follows:

a) First time Charging code, subsequent testing codes will be issued as follows:

NLDC- Power system elements belongs to 765kV level, Inter Regional transmission lines irrespective of voltage level/ownership, inter regional HVDC transmission element, Intra-Regional ISTS HVDC transmission element and all transnational lines.

RLDC- Power system elements belongs to 400kV level irrespective of ownership, 220 kV lines emanating from ISGS /ISTS substations, Inter-state transmission lines irrespective of voltage level/ownership, Intra-State Non ISTS HVDC transmission element, FACTS devices(TCSC/FSC/STATCOM/SVC) , Station Transformers (STs) at generating station those are regional entities.; Generating station, Bulk Consumers or Load Serving Entities and Combined (Load & Captive) generation complex those are regional entities.

b) Trial Certificate will be issued as follows:

NLDC- Inter Regional transmission lines designated as ISTS irrespective of voltage level, inter regional HVDC links/Poles irrespective of ownership and all transnational lines.

RLDC- Transmission lines designated as ISTS irrespective of voltage level/ownership, Intra Regional HVDC links/poles connected as designated ISTS network, FACTS devices (TCSC/FSC/STATCOM/SVC) associated with designated ISTS; Generating station, Bulk Consumers or Load Serving Entities and Combined (Load & Captive) generation complex those are regional entities.

For Issuance of Trial operation certificate by NLDC/RLDC the following shall be ensured by all concerned

a. Compliance all the documents / sharing of data & information stated in respective Sections
b. Completion of trial operation as per CERC regulation/ procedure.
c. Submitting the Annexure (C1-C4) as per FTC procedure.

SLDCs may follow a similar procedure for intra state elements too. This will help in bringing uniformity throughout the country for smooth operation of power system and in the interest of grid security

This procedure supersedes all other FTC procedures issued earlier by NLDC/RLDCs.

Definitions and Interpretation (As defined in the Indian Electricity Grid Code)

1.1. In this procedure, unless the context otherwise requires,

a. "Act˝ means the Electricity Act, 2003 (36 of 2003) and subsequent amendments thereof;

b. "actual drawal˝ in a time-block means electricity drawn by a buyer, as the case may be, measured by the interface meters;

c. "actual injection˝ in a time-block means electricity generated or supplied by the seller, as the case may be, measured by the Interface meters;

d. "beneficiary˝ means a person who has a share in an Inter-State Generating Station;

e. "Commission" means the Central Electricity Regulatory Commission referred to in sub-section (1) of section 76 of the Act;

f. "Deviation˝ in a time-block for a seller means its total actual injection minus its total scheduled generation and for a buyer means its total actual drawal minus its total scheduled drawal;

g. "Disturbance Recorder (DR)" means a device provided to record the behaviour of the pre-selected digital and analog values of the system parameters during an Event;

h. "Event Logging Facilities" means a device provided to record the chronological sequence of operations, of the relays and other equipment;

i. "Grid Code˝ means the Grid Code specified by the Commission under clause (h) of sub-section (1) of Section 79 of the Act;

j. "Inter-State GeneratingSt ation (ISGS)" means a Central generating station or other generating station, in which two or more states have Shares;

k. "interface meters˝ means interface meters as defined by the Central Electricity Authority under the Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006, as amended from time to time;

l. "Inter State Transmission System (ISTS)" means
   i) Any system for the conveyance of electricity by means of a main transmission line from the territory of one State to another State
   ii) The conveyance of electricity across the territory of an intervening State as well as conveyance within the State which is incidental to such inter-state transmission of energy
   iii) The transmission of electricity within the territory of State on a system built, owned, operated, maintained or controlled by CTU;

m. "Licensee" means a person who has been granted a license under Section 14 of the Act;

n. "Load Despatch Centre˝ means National Load Despatch Centre, Regional Load

Despatch Centre or State Load Despatch Centre, as the case may be, responsible for coordinating scheduling in accordance with the provisions of Grid Code;

o. "regional entity″ means a person whose metering and energy accounting is done at the regional level;

p. "Scheduled generation″ at any time or for a time block or any period means schedule of generation in MW or MWh ex-bus given by the concerned Load Despatch Centre;

q. “Transmission License” means a License granted under Section 14 of the Act to transmit electricity;"time-block″ means a time block of 15 minutes each for which special energy meters record values of specified electrical parameters with first time block starting at 00.00 hrs;

Section 1

Procedure for obtaining first time charging/clearance from RLDC & commencement of Grid Access for drawal of start-up power for conventional generating plants (Thermal, Gas & Hydro),Bulk Consumers or Load Serving Entities and Combined (Load & Captive) generation complex

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<u>Procedure for obtaining first time charging/clearance from RLDC & commencement of Grid Access for drawal of start-up power for conventional generating plants (Thermal, Gas & Hydro), Bulk Consumers or Load Serving Entities and Combined (Load and Captive) generation complex</u>

References:

1. CERC (Indian Electricity Grid Code Regulations) 2010 & subsequent amendments
2. CERC Approved Procedure for Drawl of Start-up power dated 12.08.2014
3. CERC (Deviation Settlement Mechanism) Regulation 2014 & amendments thereof
4. CERC (Fees and Charges of Regional Load Despatch Centre) Regulation 2019
5. CERC (Grand of Connectivity, Long Term Access and Medium Term Open Access in Inter State Transmission) Regulation 2009 and amendments thereof
6. CEA (Installation of Operation of Meters) Regulation 2006 and any Amendments thereof.
7. CEA (Technical standard for Connectivity to the Grid) Regulation, 2007& amendments
8. CEA(Measures relating to safety & electric supply) Regulations-2015 & amendments

1. Documents Submission to RLDC

The following documents shall be submitted by conventional generating plants (Thermal, Gas & Hydro), Bulk Consumers / Load Serving entitles (having min load of 100 MW and connected to ISTS) and Combined (load + captive generation(having an exportable capacity of 250MW into ISTS grid)) complex to respective RLDC before commencement of any startup activities of any Unit:

1. **<u>Control Area</u>:** Control Area jurisdiction of Generating station, Bulk Consumers or Load Serving Entities and Combined (Load & Captive) generation complex shall be in accordance with clause 6.4.2 of Chapter- 6 of IEGC-2010.

2. **<u>Connectivity Details:</u>** As per clause 4.1 of Indian Electricity Grid Code (IEGC) -2010, Central Transmission Utility (CTU) , State Transmission Utility (STU) and Users connected to, or seeking connection to Inter State Transmission System (ISTS) shall comply with the following:
   i. Central Electricity Authority (Technical Standards for connectivity to the Grid) Regulations, 2007 which specifies the minimum technical and design criteria
   ii. Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations,2009 and subsequent amendments thereof.
   iii. CERC Approved Procedure for grant of connectivity to Inter State transmission system vide order dated 31.12.2009. <u>A copy of the Connection agreement</u>

(CON-6) shall be submitted to RLDC along with formats CON-3, CON-4, CON-5 as provided in the CERC approved Procedure.

iv. Similarly, any information on Long Term Access, Medium Term Open Access availed from CTU shall be submitted to RLDC along with copy of LTA/MTOA agreements, etc.

v. Copy of signed power purchase agreement as applicable to be submitted to the respective RLDC.

vi. As per clause 6.3 of the *CERC Approved procedure* dated 31.12.2009, the generating stations including captive generating station shall submit the likely date of synchronization, likely quantum and period of injection of infirm power before being put into commercial operation to the RLDC concerned at least ***one month*** in advance.

3. User Registration with RLDC & related modalities:

Generating Station, Bulk Consumers or Load Serving Entities and Combined (Load & Captive) generation complex is required to register as a **'User '** of RLDC for commencement of Grid Access as per Regulation-4(1) of *CERC (Fees and Charges of Regional Load Despatch Centre & other related matters) Regulations-2019* which is applicable for the control period 1.4.2019 to 31.3.2024. Relevant clauses are quoted below.

Quote:

*"**4.** Registration : **(**1) The users shall register with the respective Regional Load Despatch Centre for commencement of Grid Access for availing system operation services of RLDC or NLDC as under:*

a) All generating stations, distribution licensees and inter-State transmission licensees intending to avail the Grid Access shall register themselves with concerned Regional Load Despatch Centre responsible for scheduling, metering, energy accounting and switching operations, not less than 30 days prior to intended date of commencement of grid access, by filing an application in the format prescribed as Appendix-IV to these regulations:

Provided that when a unit is added to a generating station or an element is added to a transmission system, the generating company or transmission licensee, as the case may be, shall send an intimation to the concerned RLDC(s) for updating its records;

(2) The Regional Load Despatch Centre and the National Load Despatch Centre, as the case may be, after scrutinizing applications for registration and on being satisfied with correctness of the information furnished in the application shall register the applicant and send a written intimat''ion to an applicant.

(3) The generating companies, distribution licensees, inter-State transmission licensees, power exchanges, traders, sellers and buyers shall pay the registration fees as specified in these Regulations.

(4) Regional Load Despatch Centres and National Load Despatch Centre shall maintain a list of registered users, licensees and Power Exchanges on their website along with their date of registration.”

Unquote:

The user registration form (***Appendix-IV*** of the above regulation) is enclosed at **Annex-1**.

(i) Registration Fee: As per Regulation 29(2) Chapter-8 of the *CERC (Fees and Charges of Regional Load Despatch Centre & other related matters) Regulations-2019*, generating station is required to pay the applicable **one time Registration fee** for getting registered with Regional Load Despatch Centre (RLDC). The Relevant section of the above regulation [29(2)] is quoted below.

Quote:

“*2) The generating companies shall pay registration fee as under:*

a) For generating station upto 10 MW installed capacity: Rs 0.50 Lakh ;

b) Generating stations having installed capacity of not less than 10 MW and upto 100 MW:

Rs 1.0 Lakh ;

c) Generating stations having installed capacity of not less than 100 MW and up to 2000 MW: Rs 5.0 Lakh ;

d) Generating stations having capacity of 2000 MW and above: Rs 10.0 Lakh, and

Provided that the entire capacity of the generating station or stage thereof whose scheduling, metering and energy accounting is done separately shall be considered for the purpose of registration fee at the time of the initial registration;

Provided further that the generating companies shall intimate RLDC concerned about the additional capacity commissioned in case of generating station or stage thereof.”

Unquote:

The bank details for payment of ‘one time registration fee’ will be provided by RLDC.

(ii) Monthly Billing of RLDC Fees & Charges: As per Regulation 34 of Chapter 10 of CERC (RLDC Fees & Charges) Regulations 2019, RLDC will raise monthly ‘RLDC fees and charge bills’ to generating station. Accordingly, generating station shall make the monthly payments through RTGS to the bank account of RLDC.

4. **Energy Metering:**

As per clause 6.4.21 of IEGC-2010, CTU, POWERGRID shall install special energy meters (SEMs) on all the inter connection between the regional entities and other identified points. Accordingly, RLDC shall work out the requirement of SEMs in line CEA (Installation & Operation of Meters)-Regulation-2006 & subsequent amendments after receipt of the Single Line switching Diagram of generating station indicating proposed path for drawal of start-up power. Subsequent to intimation from RLDC on the requirement of SEMs. Generating station shall coordinate with Regional HQ, POWERGRID, for procurement of the SEMs along with Data Collecting Device (DCD).

5. **Telemetry & SCADA integration:**

As per clause 4.6.2 of IEGC-2010, All Users, STUs and CTU shall provide Systems to telemeter power system parameter such as flow, voltage and status of switches/ transformer taps etc. in line with interface requirements and other guideline made available by RLDC. The associated communication system to facilitate data flow up to appropriate data collection point on CTU's system, shall also be established by concerned User, as specified by CTU in the connection agreement.

6. **Integration of Bulk Consumers or Load Serving Entities and Combined (Load and Captive) generation complex:**

System security to be ensured during the integration of Bulk Consumers or Load Serving Entities and Combined (Load and Captive) generation complex. Additional requirement to be fulfilled by Bulk Consumers or Load Serving Entities and Combined (Load and Captive) generation complex, other than the information mentioned in this procedure. Notarized Undertaking to be submitted to the owner of the of above-mentioned entities as per ***Annex-2.***

7. **Statutory approval & first-time charging**

Statutory approval for energization from the Central Electricity Authority; Govt. of India in line with the CEA(Measures relating to safety & electric supply) Regulations-2015 & amendments) is to be submitted to RLDC before energization of any Electrical Installation at your end.

First time charging of any new or modified power system element is carried out as per the procedure for integration of a new or modified power system elements. Charging will be allowed only after submission of the information mentioned in Procedure for integration of a new or modified power system elements & after obtaining necessary approval from respective RLDC.

8. **Start-up power drawal under DSM**:

As per the Hon'ble CERC Notification dated 12^{th} Aug 2014 on 4^{th} Amendment to CERC(Grant of Connectivity, Long-term Access(LTA) and Medium-term Open Access (MTOA) in inter-state transmission and related matters) Regulations, 2014 and the *CERC Approved Procedure for availing start-up power* from the grid by generating stations under commissioning phase through deviation settlement mechanism (DSM), Generating station has to follow the enclosed procedure at **Annex-3,** before commencement of any activity. All the documents to be submitted as mentioned in the enclosed procedure at **Annex-3** including the duly filled "**Application form seeking start up power**" which is a part of the procedure.

9. Modelling data for simulation study:

Modelling data for simulation study for the Thermal, Gas and Hydro generating station to be submitted as per **Annex-4(A),Annex-4(B)** and **Anne4(C)** respectively.

For the Bulk Consumers / Load Serving entitles and Combined (load +captive Generation) complex, Mathematical model (if any) shared with CTU for carrying out interconnection study to be shared with respective RLDC.

Hydro plants reservoir details such as FRL, MDDL, monthly design energy/10 daily energy, rated cumecs and rated head, energy content of reservoir and water content details to be provided as per **Annex-5**.

Further a *check list of items/information* has to be submitted by any new regional entity generator as per the format enclosed at **Annex-6**.

10. Drawal & Injection of Infirm Power

As per clause Regulation 8(7) of the CERC(Grant of Connectivity, LTA and MTOA in ISTS and related matters)Regulations-2009, and amendments thereof, any generating station, including captive generating plant which has been granted connectivity to the grid shall be allowed to undertake testing including full load testing by injecting infirm power into the grid before being put into commercial operation, even before availing any type of open access, after obtaining permission of the concerned RLDC, which shall keep the grid security in view while granting such permission and the power injected into the grid as a result of this testing. It shall be charged at the rate specified in CERC (Deviation Settlement Mechanism & related matters)-Regulations-2014 as amended from time to time.

a) During the period of drawal / injection of infirm power, RLDC Control Room should be intimated in advance, the scheduled pattern of quantum of drawl / infirm injection and tripping and synchronization of the unit.

b) For any switching operation necessary codes have to be exchanged with RLDC control room

11. Declaration of Commercial Operation Date (COD)

CoD declaration of units of generating station shall be in line with 6.3A of the Grid Code (IEGC) 4th amendment regulations. Accordingly, after completion of the trial run, details to be forwarded to RLDC along with the CoD declaration letter. Relevant clauses/definitions are given under for ready reference.

i. **IEGC 6.3A.1: "Date of Commercial Operation (CoD)(Thermal Generating Unit)**-In case of a unit of thermal Central Generating Stations or inter-State Generating Station shall mean the date declared by the generating company after demonstrating the unit capacity corresponding to its Maximum Continuous Rating (MCR) or the Installed Capacity (IC) or Name Plate Rating on designated fuel through a successful trial run and after getting clearance from the respective RLDC or SLDC, as the case may be, and in case of the generating station as a whole, the date of commercial operation of the last unit of the generating station".
ii. **IEGC 6.3A.2: "Date of Commercial Operation (CoD)(Hydro Generating Unit)-**In case of a unit of hydro generating station including pumped storage hydro generating station shall mean the date declared by the generating company after demonstrating peaking capability corresponding to the Installed Capacity of the generating station through a successful trial run, and after getting clearance from the respective RLDC or SLDC, as the case may be, and in relation to the generating station as a whole, the date of commercial operation of the last generating unit of the generating station.
iii. **IEGC 6.3A.3: Trial Run** in relation to a thermal Central Generating Station or inter-State Generating Station or a unit thereof shall mean the successful running of the generating station or unit thereof at maximum continuous rating or installed capacity for continuous period of 72 hours in case of unit of a thermal generating station or unit thereof and 12 hours in case of a unit of a hydro generating station or unit thereof.
iv. The Generating company shall issue a certificate in compliance to clause 6.3A.1.(iii) or clause 6.3A.2.(iii) of IEGC (whichever applicable), signed by CMD/CEO/MD of the company with a copy to Member Secretary of the concerned Regional Power Committee (RPC) and Head of Concerned Regional Load Despatch Centre.
v. The generating company shall submit approval of Board of Directors to the certificates as required under IEGC clause 6.3A.1.(iii) or clause 6.3A.2.(iii)(whichever applicable) within a period of 3 months of the COD of its unit.
vi. Trial Certificate of conventional generating plants (Thermal, Gas & Hydro) will be issued by respective RLDC.

12. Compliance to Ministry of Power order on Payment Security Mechanism –

Generating station shall comply with the orders of Ministry of Power pertaining to Payment Security Mechanism. As per the orders generating station shall provide status of LC opened by its beneficiaries to RLDC. Further, the daily status shall be provided on web link https://psa.posoco.in/. Appropriate login credentials for providing status of availability of Payment security will be provided after registration with RLDC.

13. Weekly Energy Accounting:

As per CERC (Deviation Settlement Mechanism and related matters) Regulations (as amended) generating station shall become the RLDC DSM pool member after commencement of commissioning activities of its first generating unit. RPC Secretariat, would release weekly bills for DSM through their respective web site. Transfer of DSM receivable/payable amount for beneficiaries without any additional charges is through Regional DSM Pool Account. The Regional DSM Pool account fund is operated by RLDC. The weekly DSM payment to be made by generating station (if any) after commencement of the commissioning activities of its 1st unit, shall be credited to the account.

Generating station has to furnish the requisite details about their bank account where DSM charges receivable (if any) by generating station shall be made from the Regional DSM pool account fund.

Weekly meter data collection and sending the same to RLDC is the responsibility of the utility in whose premises the SEMs are installed. Since commercial accounting is carried out on weekly basis, generating station shall collect the data on every Monday and the same shall be transmitted to RLDC by every Monday through e-mail to the respective RLDC's e-mail addresses.

14. Congestion Charge:

Congestion charges has been defined in cl. 2 (d) of the CERC (Measures to relieve congestion in real time operation" Regulation-2009 (and amendments thereof) as under:

Quote

"*Congestion charge" means the supplementary charge kicked in on one or more Regional entities in one or more Regions for transmission of power from one Region to another Region or from one State to another State within the a Region when deviations from the schedule cause the net drawal of power in the inter-regional or intra-regional transmission links to go beyond the Total Transfer Capability limit*.

Unquote

RPC Secretariat, would release statement for the purpose of payment of congestion charge through their web site as and when congestion charge would be imposed. RLDC has made necessary arrangement with bank for implementation of RTGS system for quick transfer of congestion charges for beneficiaries without any additional charges. The congestion charge payment, to be made by generating station (if any), after synchronization of its 1st unit with Regional grid, shall be credited to the RLDC congestion charge account.

Generating station has to furnish the requisite details about their bank account, where congestion charge receivable (if any) by generating station is to be made from the RLDC Congestion Charge (pool) account.

Generating station has to Nominate representatives (with contact number and e-mail details) for co-ordination of daily scheduling and weekly data transmission to RLDC.

Enclosures.

Annex-1: RLDC User Registration Form (Appendix-IV of RLDC fees & charge regulation)

Annex-2: Undertaking by Bulk Consumers or Load Serving Entities and Combined (Load and Captive) generation complex

Annex-3: CERC Approved Procedure for drawal of start-up power under DSM
Annex-4(A): Procedure for Collection of Modelling data from Coal fired station
Annex-4(B): Procedure for Collection of Modelling data from Gas power station
Annex-4(C): Procedure for Collection of Modelling data from Hydro Power Station
Annex-5: Details of Hydro plant
Annex-6: Check-List of information to be submitted by a new regional entity to RLDC

Other than the documents mentioned above the formats for first time charging of power system elements (Format A1-A6, B1-B5 and C1-C4) to be submitted to RLDC.

Annex-1

Appendix-IV

[in Compliance of Regulation-4 of CERC (RLDC Fees & Charges) Regulations 2015]

1. **Name of the entity** (in bold letters):
2. **Registered office address**:
3. **Region in which registration is sought**:
    i. North-eastern
    ii. North
    iii. East
    iv. West
    v. South
4. **User category**:
    i. Generating Station
    ii. Seller
    iii. Buyer
    iv. Transmission Licensee
    v. Distribution Licensee
5. **User details** (as on 31st March of last financial year):

i. **Category – Generating Station**

i. Total Installed Capacity

ii. Maximum Contracted Capacity (MW) using ISTS

iii. Points of connection to the ISTS:

Sl.No.	**Point of connection**	**Voltage level (kV)**	**Number of Special Energy Meters (Main) installed at this location**

ii. **Category – Seller/Buyer/Distribution Licensee**

i. Maximum Contracted Capacity (MW) using ISTS

ii. Points of connection to the ISTS:

Sl.No.	Point of connection	Voltage level (kV)	Number of Special Energy Meters (Main) installed at this location

iii. **Category – Transmission Licensee (inter-State)**

i. Sub-stations:

Sl.No.	Sub-station Name	Number of Transformer	Total Transformation Capacity or Design MVA handling capacity if switching station

ii. Transmission lines:

Sl.No.	Voltage Level(kV)	Number of Transmission lines	Total Circuit Kilometers

6. **Contact person(s) details for meters related to RLDC/NLDC**:

i. Name:

ii. Designation:

iii. Landline Telephone No.:

iv. Mobile No.:

v. E-mail address:

vi. Postal address:

The above information is true to the best of my knowledge and belief.

Signature of Authorised Representative

Place: Name:

Date:

Designation:

Contact number:

Undertaking by Bulk Consumers or Load Serving Entities and Combined (Load and Captive) generation complex

This Undertaking is executed by MR. ……….**[Name of authorized personal]** on behalf of M/s ……………**[Name of company]** having its registered address at………**[registered address of company]**, in favour of **XXXXX Regional Load Dispatch Centre (XRLDC), Place**, having its registered address at **RLDC Address**.

I, ………...**[Name of authorized personal]** working as ……………..**[designation of authorized personal]** at M/s …………….**[Name of company]** with an ultimate installed capacity of ..**[Installed Capacity]** MW and having connectivity to ISTS at ..**[Name of Station Name, voltage level and Transmission licensee],** do here by solemnly state and confirm as under:

1. Shall be capable of remaining connected to the network and operating at the frequency range between 47.5 Hz to 51.5 Hz.
2. Shall be capable of remaining connected to the network and operating at the voltage ranges and time periods for different voltage ranges as specified in CEA Grid Standards Regulations 2010 and discussed at RPC from time to time.
3. Shall furnish the data required by RLDC to evaluate the short circuit level at the interconnection point.
4. Shall be capable of maintaining their steady-state operation at their connection point within a reactive power range of 0.9 lagging to 0.9 leading power factor.
5. Shall prepare single line schematic diagrams in respect of its system facility and make the same available to the RLDC. A functional one-line diagram is required, including representation of the major components of the Interconnection (i.e. power transformers, circuit breakers, switches, reactive devices, etc) and the protective relaying including lockout relays.
6. Shall implement a protection system and share its settings with RLDCs prior to the connection. Protection system shall be designed to reliably detect faults on various abnormal conditions and provide an appropriate means and location to isolate the equipment or system automatically. The protection system must be able to detect power system faults within the protection zone. The protection system should also detect abnormal operating conditions such as equipment failures or open phase conditions. Bus Bar Protection and Breaker Fail Protection or Local Breaker Back Up Protection shall be provided.
7. Shall design suitable Special Protection Scheme such as under frequency relay for load shedding, voltage instability, angular instability, generation backing down or Islanding Schemes may also be required to be provided to avert system disturbances.
8. Shall furnish all the real time data required from RLDC with time stampings. Suitable SCADA (metering and telemetering) equipment shall be provided to meter and to transmit real-time information at the point of interconnection to the RLDC. Such metering typically includes all energy meters, current and potential transformers and associated equipment at each point of interconnection for system control. Additional SCADA data that may be required includes but is not limited to breaker status, bus voltage, transmission line and/or transformer MW, MVAR, and current flows, alarms, etc. PMU should be suitably placed to monitor parameters at point of interconnection.
9. Shall adhere to the existing regulations on frequency control. Disconnection scheme during low frequency conditions shall be implemented.
10. Shall implement the scheme for disconnection of complex during low voltage conditions.
11. Shall ensure that connection to the network does not result in a determined level of distortion or fluctuation of the supply voltage on the network, at the connection point. The level of distortion shall not exceed that mentioned in CEA Technical Standards to the Grid Regulations.

12. Shall submit the simulation modelling data to RLDC in the format required. Also carry out simulations and furnish the results whether interconnection is safe and reliable or not.

Place: Signature:

Date: Name of the authorized personal:
Designation of the authorized person:

210

No. L-1/(93)/2009-CERC Dated: 12th August, 2014

To,

Shri S.K. Sonee
Chief Executive Officer
Power System Operation Corporation Limited,
B-9, First Floor, Qutab Institutional Area,
Katwaria Sarai,
New Delhi-110 016

Sub: Approval of the procedure for drawal of startup power

Dear Sir,

I am directed to refer to your letter nos. POSCO/CERC dated 14.11.2013 and 13.3.2014 and to say that the Commission has approved the Procedure for drawal of startup power for new generating stations, 2014 as per the Annexure attached to this letter. It is requested that wide publicity to the Procedure be given by POSOCO for the information of all concerned.

Thanking you,

Yours faithfully

sd/-
(Shubha Sarma)

Secretary

Procedure for availing Start up power from the Grid by the Generating Stations under commissioning phase through Deviation Settlement Mechanism

This procedure is called Procedure for drawal of Start-up Power for new Generating Stations, 2014.

This procedure describes the methodology to be followed by the upcoming Generating Stations seeking to avail start-up power during commissioning period.

This procedure is applicable to Generating stations without an existing Unit under Commercial operation. Where one unit has been commissioned and if the startup power is required by subsequent unit(s), the same may be availed from the existing units of the same plant under Commercial operation. In such case, the existing units shall factor the requirement of startup power by the new upcoming units before contracting/scheduling the entire sent out capability under STOA so that there will not be any under injection by the existing unit(s).

However, in case power from the unit(s) of the generating station already commissioned is fully allocated or committed under Medium Term Open Access (MTOA)/Long Term Access (LTA), subsequent unit(s) shall be allowed to draw Start-up power under this procedure.

1. Scope :

This Procedure shall be followed by all Regional Load Despatch Centres (RLDCs), Regional Power Committees (RPCs) and Generating stations including Inter-state Generating Stations (ISGS) under Seller category.

2. Definitions:

(a) **Construction Power:** Power required for carrying out construction/erection works of plant and equipment of a new Generating Station **including services such as desalination of sea water, etc.**

(b) **Start-**Up Power: Power required for running the Auxiliary equipment for commissioning activities of a new Generating Station.

(c) **Auxiliary power:** Power required to keep the auxiliaries like Motor Driven Boiler Feed Pump (MDBFP), Induced Draft (ID) Fan, Forced Draft (FD) Fan, Cooling Water (CW) pumps, etc, running after tripping of a generating unit during its trial operation.

3. General :

The Generating station may avail Start-up power under Deviation Settlement Mechanism from Inter-State Transmission System.

4. Pre-conditions for availing Start-up power under Deviation Settlement Mechanism:

The Generating Station intending to avail Start-up power shall fulfil the following conditions:

(1) It has a valid Connectivity granted by CTU as per CERC (Grant of Connectivity, Long-term Access and Medium-term Open Access and related matters) Regulations, 2009 (hereinafter referred to as Connectivity Regulations)
(2) It has signed Connection Agreement as per Con-6 of the Connectivity Regulations
(3) It has established Connectivity with the ISTS
(4) It has commissioned all the switchyard equipments including Bus / Line reactor if any as per the grant of Connectivity (Con-3).
(5) It has established Data and Voice communication with the concerned RLDC as per clause 4.6.2 of IEGC
(6) It has put in place necessary system protection in place as specified by concerned Regional Power Committee (RPC).
(7) It shall coordinate Generation Transformer (GT) / Station Transformer (ST) tap positions as per the direction of concerned Regional Load Despatch Centre (RLDC).

5. Procedure for applying for Start-up power:

5.1 **The Generating Station shall submit a request for availing Start-up power to the concerned RLDC at least one month prior to the expected date of availing Start-up power i.e 16 months before the expected date of first synchronisation of the unit.**

5.2 While requesting for start-up power, the Generating Station shall furnish the following details to the concerned RLDC:

(1) A copy of Connectivity approval granted by CTU along with the details of arrangement for drawing start up power ,
(2) Connection Agreement signed with CTU and other ISTS licensees as the case may be
(3) Single line diagram of the Generating Station
(4) Inspection report of the Electrical Inspectorate of Central Electricity Authority (CEA).
(5) Details of electrical scheme for drawal of construction power clearly establishing the isolation between the schemes for construction power and start up power.
(6) Details of electrical scheme for drawal of start-up power by various phases of the Generating station.
(7) Unit details like Unit size, MCR, Auxiliaries & their rating etc.
(8) Schedule of activities and their requirement of power in terms of quantity and period etc.

5.3 The Generating Station shall submit an undertaking that :

(1) Drawal of power is only for the purpose of start-up power and not for the construction activity. **The onus of proving that the drawal of power is for startup of Auxiliaries, testing and commissioning activities and not for Construction power shall lie with the generating station alone.**
(2) There is no violation of any of the agreements made with the Distribution Licensee or any other agency.
(3) The Generating Station shall indemnify, defend and save the SLDCs/RLDCs harmless from any and all damages, losses, claims and actions including those relating to injury or death of any person or damage to property, demands, suits, recoveries, costs and expenses, court costs, attorney fees, and all other obligations by or to third parties, arising out of or resulting from this drawal.
(4) The Generating Station shall abide by IEGC and all prevailing Regulations and the directions of RLDC from time to time.
(5) The Generating Station shall reschedule the start up activities as directed by RLDC due to reasons such as staggering the simultaneous drawal of Start-up power by other Generating Stations.
(6) The Generating Station shall pay the charges for Deviation within due date and comply with Deviation Settlement Regulations, 2014

as amended from time to time or subsequent re-enactment thereof.

(7) The Generating Station shall send the Special Energy Meter (SEM) data to RLDC as per the provisions of IEGC for energy accounting.

(8) The Generating Station shall pay all incidental charges such as Transmission charges, RLDC Fee & Charges, etc., as applicable, within the due date.

(9) The Generator shall open a Revolving and Irrevocable Letter of Credit issued by a Scheduled Bank equivalent to 2 months transmission charges prior to drawal of Start-up power.

5.4 The Generator shall update the following information during the period of availing the Start-up Power and likely date of first synchronisation of the unit **and subsequent program for injection of infirm power :**

(1) The quantum of power to be availed on a weekly basis.

(2) The schedule is to be updated on a weekly basis, considering the deviations in the tentative schedule.

(3) Monthly Energy data of Construction power availed from the local licensee for the past 6 months period and monthly readings for the period subsequent to availing start-up power.

(4) Monthly details of start-up activities carried out during the month. The Generating Station shall also indicate whether all activities are as per commissioning schedule or not.

6. Procedure to be followed by RLDC during the period of availing Startup power :

6.1 The concerned RLDC shall convey the period, quantum and duration of the Start-up power with a copy to RPC and SLDC, if required.

6.2 RLDC may permit drawal of Start-up power for one or more units at a time within a generating station keeping grid security in view.

6.3 RLDC will issue suitable directions to the Generating Station on Real time basis for limiting / stopping the drawal of start-up power in case of Network constraint on grounds of threat to system security or frequency or Voltage falling below the limits specified in IEGC. Such direction shall be complied by the Generating Station promptly.

6.4 The generator is entitled to draw the start-up power under Deviation Settlement Mechanism, up to the maximum period of 21 months (Fifteen months prior to expected date of synchronization and six months after synchronization) from the date of commencement of drawal of start-up power from the grid. In case startup power is required beyond the specified period, the generator shall approach C.E.R.C at least two months in advance of the date up to which permission has been granted.

6.5 RLDC may direct the Generating Station to install under-frequency/under voltage relays to operate below a threshold value with suitable dead bands.

6.6 If simultaneous drawal of start-up power by more than one generating station is likely to cause system constraints, RLDC may stagger such drawal among various generators to relieve the constraint.

Application form seeking Startup power

Reference number :
Date :
Name of the Generating Station :
Unit number :
Unit size :
Details of Connectivity granted :
Details of Start up power requirement :

Sl. No.	From date	To date	Requirement of Power in MW	Details of Activities	Remarks

Enclosures:

- Details of Reactive Compensation Equipment
- Status of Commissioning works of Reactive Compensation Equipment
- A copy of grant of connectivity approval given by CTU,
- Connection Agreement signed with CTU and other ISTS licensees as the case may be
- Inspection report of the Electrical Inspectorate of CEA
- Single line diagram of the Generating station
- Details of electrical scheme for drawal of construction power clearly establishing the isolation between the schemes for construction power and start up power
- Details of electrical scheme for drawal of start-up power by various phases of the Generating station clearly establishing the isolation between the schemes for construction power and start-up power
- Unit details like Unit size, MCR, Auxiliaries & their rating, etc.

Undertaking

I ________ son of _______________ working as ____________________ in _______________________ (organisation name) am authorised to sign this undertaking. I hereby undertake that:

- Drawal of power by unit no._____ of ________________(name of Generating station) is only for the purpose of start up power and not for the construction activity. **(The onus of proving that the drawal of power is for start-up of auxiliaries, testing and commissioning activities and not for Construction Power shall lie with the generating company)**
- There is no violation of any of the agreements made with the Distribution Licensee or any other agency.
- (Organization name) shall indemnify at all times, defend and save the SLDCs/RLDCs harmless from any and all damages, losses, claims and actions including those relating to injury to or death of any person or damage to property, demands, suits, recoveries, costs and expenses, court costs, attorney fees, and all other obligations by or to third parties, arising out of or resulting from this drawal.
- (Organization name) will abide by IEGC and all prevailing regulations and the directions of RLDC from time to time.
- (Organization name) will reschedule the start up activities as directed by RLDC due to reasons such as staggering the simultaneous drawal of startup power by other Generating Stations
- (Organization name) will pay the charges for Deviations from schedules within due date and comply with Deviation Settlement Mechanism Regulations, 2014 as amended from time to time or subsequent re-enactment thereof.
- (Organization name) shall open a Revolving and Irrevocable LC issued by a Scheduled Bank equivalent to 2 months transmission charges prior to drawal of Start-up power.
- (Organization name) shall send the Special Energy Meter (SEM) data to RLDC as per the provisions of IEGC for energy accounting
- (Organization name) shall pay all incidental charges such as PoC charges, RLDC Fee & Charges, etc., as applicable within the due date.
- (Organization name) Shall coordinate GT/ST tap positions as per the direction of concerned Regional Load Despatch Centre (RLDC).
- (Organization name) has ensured the following before availing startup power

- Establishment of connectivity with the ISTS
- Commissioning of all the switchyard equipments including Bus/Line reactor, if any, as per the grant of Connectivity (Con-3)
- Establishing of data and voice communication with the concerned RLDC(s) as per clause 4.6.2 of IEGC
- Putting necessary system protection in place as specified by concerned Regional Power Committee (RPC)
- Installation of SEMs as per CEA's Metering Regulations.

Signature
(Name)
Designation

Enclosures: as above

Copy to : 1) __________RPC
2) __________ S.L.D.C

Grant of Startup Power by RLDC

Approval number : Date :

To :

____

____

____

Sub : Grant of Startup power through Deviation Settlement Mechanism

Sir,

With reference to your application number _______________ dated __________, permission is hereby accorded to draw Startup power under Deviation Settlement Mechanism as per following details:

Name of the Generating Station :
Unit number :
Unit size :
Details of Start-up power granted :

Sl. No.	From date	To date	Startup Power in MW granted	Remarks

You are requested to follow all the guidelines as per the Procedures.

Signature
(Name)
Designation

Copy to : 1) ___________RPC
2) ___________ S.L.D.C

Guideline for furnishing information for modelling Coal fired generation in Indian Grid

1.0 Introduction:

The purpose of this document is to act as a guideline for exchange of information for accurate modelling of coal fired thermal generation in India. Availability of fit-for-purpose steady state and dynamics models of coal fired thermal stations will enable secure operation of Indian power grid and enable identification of potential weak points in the grid so as to take appropriate remedial actions.

1.1 Applicability:

The guideline shall be applicable to all coal fired thermal generation in India that can have an impact on operation of the power grid of India, irrespective of connection at Intra-STS or ISTS (Inter-state Transmission System).

This document presents the desired information for collection of data for modelling of coal fired thermal generation in PSS/E software, a software suite being used pan-India at CEA, CTU, SLDCs, RLDCs, and NLDC for modelling of India's power grid. A systematic set of data and basic criteria for furnishing data are presented.

1.2 Need for a fit-for-purpose model:

There is a cost involved in developing and validating dynamic models of power system equipment. But there are much higher benefits for the power system if this leads to a functional, fit-for-purpose model, and arrangements that allow that model to be maintained over time.

A functional fit-for-purpose dynamic model will:

- Facilitate significant power system efficiencies by allowing power system operations to confidently identify the secure operating envelope and thereby manage security effectively
- Allow assessment of impact on grid elements due to connection of new elements (network elements, generators, or loads) for necessary corrective actions
- Permit power system assets to be run with margins determined on the basis of security assessments
- Facilitate the tuning of control systems, such as power system stabilizers, voltage- and frequency-based special control schemes etc.
- Improve accuracy of online security tools, particularly for unusual operating conditions, which in turn is likely to result in higher reliability of supply to power system users.

The power system model would enable steady state and electromechanical transient simulation studies that deliver reasonably accurate outcomes.

1.3 Regulation:

- **CEA Connectivity Standard 6.4.d :**

The requester and user shall cooperate with RPC and Appropriate Load Despatch Centre in respect of the matters listed below, but not limited to

furnish data as required by Appropriate Transmission Utility or Transmission Licensee, Appropriate Load Despatch Centre, Appropriate Regional Power Committee and any committee constituted by the Authority or appropriate Government for system studies or for facilitating analysis of tripping or disturbance in power system;

Here Requester and User Includes a generating company, captive generating plant, energy storage system, transmission licensee (other than Central Transmission Utility and State Transmission Utility), distribution licensee, solar park developer, wind park developer, wind-solar photovoltaic hybrid system, or bulk consumer *(2019 Amendment)*

- **IEGC 4.1 :**

CTU, STU and Users connected to, or seeking connection to ISTS shall comply with Central Electricity Authority (Technical Standards for connectivity to the Grid) Regulations, 2007 which specifies the minimum technical and design criteria and Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations,2009.

2.0 Coal fired thermal generation technologies:

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 (IEEE Power and Energy Society, 2013).

Coal fired power plants constitute 54.70% of India's installed generation capacity as on 31.12.2018, and supply around 75% of energy as on 21.02.2019. The Indian Power Sector initially comprised of sub-100MW steam-driven generators in the 1970's, until the first 200 MW generating unit was introduced in 1977. This became almost the standard size and most generating units added during the next two decades were of 200/210 MW.

The first 500 MW unit was subsequently commissioned in 1984 and a number of 500 MW units have been commissioned since then. These 200/210 and 500 MW units form the backbone of Indian Power Sector. Meanwhile, 250 MW units have also evolved by upgrading the turbine design of existing 210 MW generating units. In last decade, super-critical plants have been commissioned of magnitude 600/660 MW and 800 MW size.

The majority of commercially available coal fired thermal generators use one of the three technologies depending upon the stream pressure within the boiler as listed below:

Technology	Temperature	Pressure
Sub-critical	537 °C / 565 °C	Below 225 kg/cm2
Super-critical	538/565 °C ~ Older units 565/593 °C ~ later commissioned	247kg/cm2
Ultra-supercritical	600/610 °C to 700°C	250-300 /cm2

**Figures taken from Standard Technical features of BTG system for subcritical and supercritical units issued by CEA 2013. Above values are typical values only.*

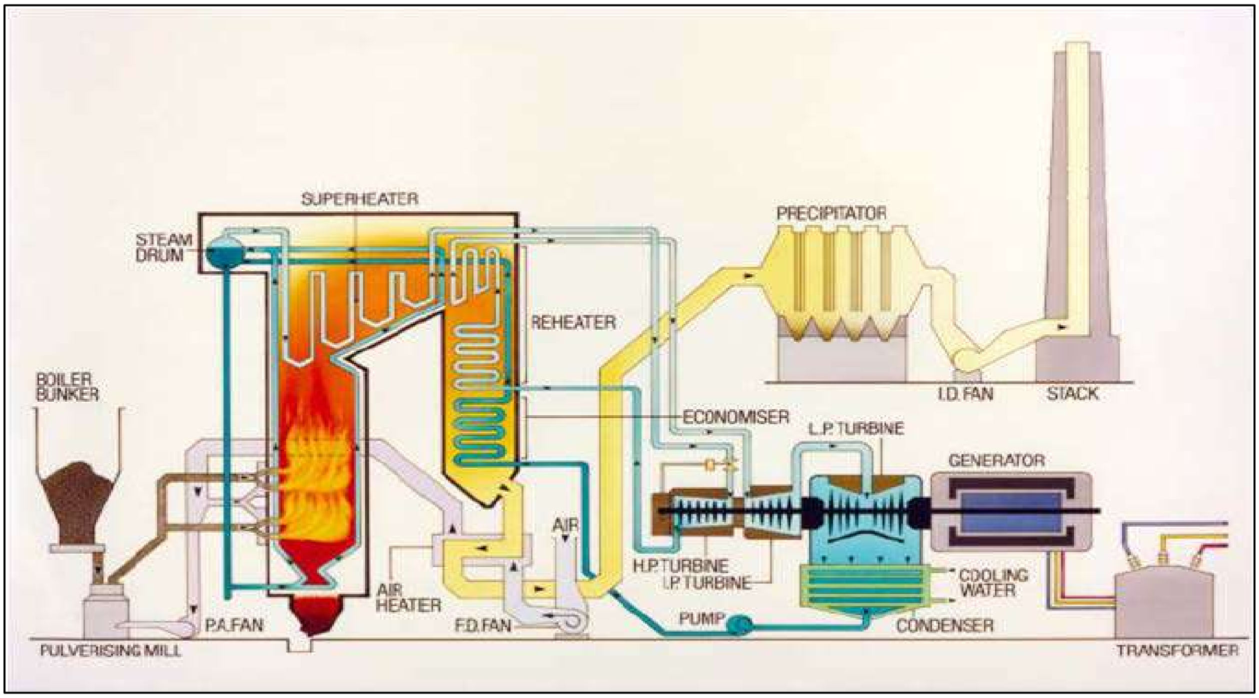


Figure 1: Schematic of a Typical Coal Fired Generator

For POSOCO to have access to verified fit-for-purpose models of coal fired thermal generation connected to Indian grid, following information is required:

1. Electrical Single Line Diagram of coal fired thermal station depicting;
   - **For individual generating units:** type of technology, **Complete Generator OEM Technical Datasheet** (which comprises namely generator parameters like impedances & time constants, generator capability curve, V-curve, generator open and short circuit characteristics, excitation system details, inertia of generator & exciter), generator name plate, generator SAT reports including Short circuit and open circuit test results during commissioning/recent overhauling.
   - **Generator step up transformer**: GT name plate/datasheet, details of LV, MV and HV, MVA rating, impedance, tap changer details, vector group, short-circuit parameters (actual positive & zero sequence impedance of GT, NGR nameplate with impedance).
   - **Excitation system :-** Type of excitation system (Direct Current Commutator Exciters (type DC), AC Excitation (Rotor or brushless excitation) Systems (type AC) and Static Excitation Systems (type ST), Excitation system schematics (Block diagram of AVR system), transfer function block

diagram of Excitation system, excitation transformer nameplate, saturation curves of the exciter (I_a versus I_f curve), IEEE standard model of excitation system, IEEE standard model and its parameter of subsystems such as Power system stabilizer (PSS), Under Excitation Limiter (UEL), Over Excitation Limiter (OEL), Voltage per Hz Limiter(V/Hz) control etc. and details thereof, factory acceptance test reports (FAT). Excitation system actual settings to be provided. AVR test report (excitation step response test).

- **Power System Stabilizer (PSS):** Transfer function block diagram of PSS, IEEE Standard Model, Actual PSS software settings, PSS commissioning report and **Recent PSS tuning report**.
- **Turbine-Governor system :** Type of turbine (Tandem/Cross compound), model of turbine and boiler (including details of boiler controls, technology, valves, valve characteristics), model of speed governor and turbine load (if applicable) control system (including details of technology, valves, valves characteristics) , mode of operation and control, ramp rates, **turbine inertia**, IEEE standard model of turbine governor system and its transfer function Block diagram and its parameters, details of control mode (boiler-follow, turbine-follow, or coordinated control), commissioning report of turbine-governor system or recent governor testing report.

2. Generic models of individual components (generator, exciter (including OEL, UEL), turbine-governor and PSS of coal fired thermal plants (refer sections 3.2 to section 3.5)
    - Model should be suitable for an integration time step between 1ms and 20ms, and suitable for operation up-to 100 s
    - Simulation results depicting validation of generic models against user-defined models (for P, Q, V, I) and against actual measurement (after commissioning) to be provided.
3. Encrypted user defined model (UDM) in a format suitable for latest PSSE release PSS/E (*.dll files) for electromechanical transient simulation for components coal fired thermal generators (in case non-availability of validated generic model)
    - User guide for Encrypted models to be provided including instructions on how the model should be set-up
    - Corresponding transfer function block diagrams to be provided
    - Simulation results depicting validation of User-Defined models against actual measurement to be provided
    - The use of black-box type representation is not preferred.

Annexure: Formats for submission of modelling data for coal fired thermal generation

Version History:

Version no.	Release Date	Prepared by*	Checked/Issued by*	Changes

***Mention Designation and Contact Details**

Details submitted:

Details pending:

3.1 Details of models in PSS/E for modelling coal fired thermal generation:

(a) Synchronous Machine

Category	Parameter Description	Data
Generator Nameplate	Rated apparent power in MVA	
	Rated terminal voltage	
	Rated power factor	
	Rated frequency (in Hz)	
	Rated speed (in RPM)	
	Rated excitation (in Amperes and Volts)	
Type of synchronous machine	Round rotor or salient pole No. of Poles:	-
Generator capability curve	The generator capability curve shows the reactive capability of the machine and should include any restrictions on the real or reactive power range like under/over excitation limits, stability limits, etc. Capability curve should have properly labelled axis and legible data	
Generator Open Circuit and Short Circuit Characteristic	Graph of excitation current versus terminal voltage and stator current	
	No load excitation current	
	Excitation current at rated stator current	
Generator vee-curves	Otherwise referred to as “V-curve”. A plot of the terminal (armature) current versus the generating unit field voltage.	
Resistance values	Resistance measurements of field winding and stator winding to a known temperature	
Generator Data sheet	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd’ in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd’’ in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xa in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq’ in p.u. (Unsaturated or saturated)	
	Quadrature axis sub-transient synchronous reactance Xq’’ in p.u. (Unsaturated or saturated)	
	Direct axis open circuit transient time constant Tdo’ in sec	
	Direct axis open circuit sub-transient time constant Tdo’’ in sec	
	Quadrature axis open circuit transient time constant Tqo’ in sec	
	Quadrature axis open circuit sub-transient time constant Tqo’’ in sec	
	Inertia constant of total rotating mass (generator, AVR, turbo-governor set) H in MW.s/MVA	
	Speed Damping D	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

Category	Parameter Description	Data
Generator step up transformer (GSUT)	Nameplate Rating - Rated primary and secondary voltage - Vector group - Impedance - Tap changer details (Number of taps, tap position, tap ratio etc.)	

(b) Site Load

	Low Output			High Output		
	kW	kvar	kVA	kW	kvar	kVA
Auxiliary Load						

(c) Excitation System

Category	Parameter Description	Data
Type of Automatic Voltage Regulator (AVR)	Manufacturer and product details	
	Type of control system :- Analogue or digital	
	Year of commissioning / Year of manufacture	
	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
Type of excitation system	Static excitation system OR	
	Indirect excitation system (i.e. rotating exciter) - AC exciter, or - DC exciter	
Details of AVR converter	Rated excitation current (converter rating in Amperes)	
	Six pulse thyristor bridge or PWM converter	
Source of excitation supply	Excitation transformer or auxiliary supply (Details thereof)	
	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.	
Schematics	Saturation curves of the exciter (if applicable – see Type AC and DC)	
	Drawings of excitation system, typically prepared and supplied by the OEM	
	Single line diagram (i.e. one-line diagram) for the excitation system	
Excitation limiters	What excitation limiters are commissioned?	
	Under Excitation Limiters settings	
	Over Excitation Limiters settings	
	Voltage/frequency limiter	
	Stator current limiter	
	Minimum excitation current limiter	
PSS	Is the AVR equipped with a PSS?	
	How many input Channels does the PSS have? (speed, real power output or both	

Category	Parameter Description	Data
	If the PSS uses speed, is this a derived speed signal (i.e. synthesized speed signal) or measured directly (i.e. actual rotor speed)?	
	Type of PSS Block Diagram of PSS and as commissioned parameters value (Gain, time constants, filter coefficients, output limits of the PSS)	

(d) Turbine Details

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	
	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)	

3.2 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 Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo'' in sec	
	Quadrature axis open circuit transient time constant Tqo' in sec	
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xl in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	
GENSAE OR **GENSAL**	Direct axis open circuit transient time constant Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo'' in sec	
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xl in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

While entering the values in above table, following relationship must be kept:

Xd>Xq>Xq’≥Xd’>Xq”≥Xd’’

Tdo’>Td’>Tdo’’>Td’’

Tqo’’>Tq’>Tqo’’>Tq’’

3.3 Excitation system model:

If a generic model is used, the first step must be to identify what type of exciter is present in the excitation system. The IEEE Std 421.5 (IEEE Recommended Practice for Excitation System Models for Power System Stability Studies published on 26th Aug 2016) has published several generic models, which are 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

Category	Parameter Description	Data
DC Exciter		
ESDC1A OR ESDC2A	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (> 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	TR regulator input filter time constant (sec)	
	KV (pu) limit on fast raise/lower contact setting	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	TRH (> 0) Rheostat motor travel time (sec)	
	TE (> 0) exciter time-constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	VEMIN (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)	

Category	Parameter Description	Data
DC Exciter		
ESDC4B	TR regulator input filter time constant (sec)	
	KP (pu) (> 0) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KD (pu) voltage regulator derivative gain	
	TD voltage regulator derivative channel time constant (sec)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KA (> 0) (pu) voltage regulator gain	
	TA voltage regulator time constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	VEMIN (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)	
AC Exciter		
ESAC1A	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (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)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	

Category	Parameter Description	Data
AC Exciter		
ESAC2A	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KB, Second stage regulator gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	KH, Exciter field current feedback gain	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (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)	
ESAC3A	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	KR (>0), Constant associated with regulator and alternator field power supply	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KN, Exciter feedback gain	
	EFDN, A parameter defining for which value of UF the feedback gain shall change from KF to KN	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	VFEMAX, 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)	

Category	Parameter Description	Data
AC Exciter		
ESAC4A	TR regulator input filter time constant (sec)	
	VIMAX, Maximum value of limitation of the integrator signal VI in p.u	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC, rectifier regulation factor (pu)	
ESAC5A	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (sec), Regulator stabilizing circuit time constant in seconds	
	TF2 (sec), Regulator stabilizing circuit time constant in seconds	
	TF3 (sec), Regulator stabilizing circuit time constant in seconds	
	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		
AC6A	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TK (sec), Lead time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFELIM, Exciter field current limit reference	
	KH, Damping module gain	
	VHMAX, damping module limiter	
	TH (sec), damping module lag time constant	
	TJ (sec), damping module lead time constant	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (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)	

Category	Parameter Description	Data
AC Exciter		
AC7B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KPA (pu) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KP (pu)	
	KL (pu)	
	KF1 (pu)	
	KF2 (pu)	
	KF3 (pu)	
	TF3 (sec) time constant (> 0)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) exciter field current limit (> 0)	
	VEMIN (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
AC Exciter		
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VPIDMAX (pu) PID maximum limit	
	VPIDMIN (pu) PID minimum limit	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
AC8B	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) max exciter field current limit (> 0)	
	VEMIN (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)	
Static Exciter		
	TR (sec) regulator input filter time constant	
	VIMAX, Controller Input Maximum	
	VIMIN, Controller Input Minimum	
	TC (s), Filter 1st Derivative Time Constant	
	TB (s), l Filter 1st Delay Time Constant	
	TC1 (s), Filter 2nd Derivative Time Constant	
	TB1 (s), Filter 2nd Delay Time Constant	
	KA (pu) voltage regulator proportional gain	
ST1A	TA (sec) voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KLR, Current Input Factor	
	ILR, Current Input Reference	

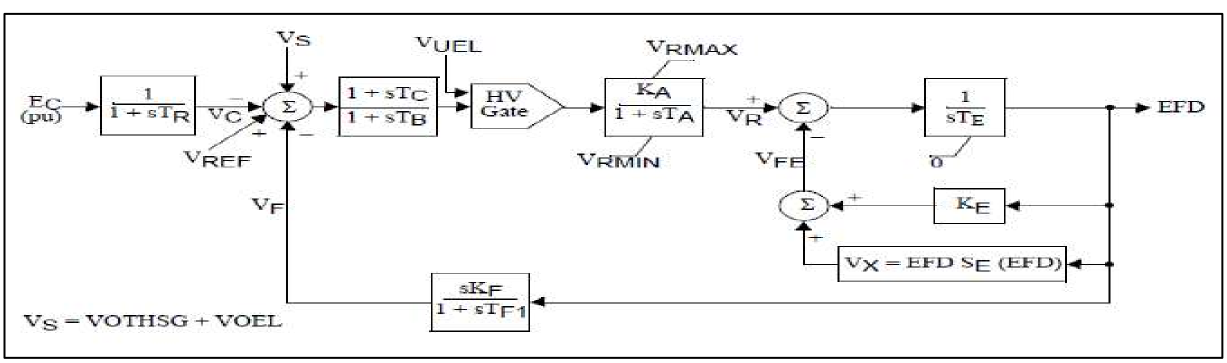
Category	Parameter Description	Data
Static Exciter		
ST2A	TR (sec) regulator input filter time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	EFDMAX	
ST3A	TR (sec) regulator input filter time constant	
	VIMAX, Maximum value of limitation of the signal VI in p.u.	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	KM, Forward gain constant of the inner loop field regulator	
	TC (s), lag time constant	
	TB (s), lead time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KG, Feedback gain constant of the inner loop field regulator	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX, Maximum value of limitation of the signal VB in p.u.	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL, Reactance associated with potential source	
	VGMAX, Maximum value of limitation of the signal VG in p.u	
	Θ_P (degrees)	
	TM (sec), Forward time constant of the inner loop field regulator	
	VMMAX, Maximum value of limitation of the signal VM in p.u	
	VMMIN, Minimum value of limitation of the signal VM in p.u.	

Category	Parameter Description	Data
Static Exciter		
ST4B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TA (sec) voltage regulator time constant	
	KPM, Regulator gain	
	KIM, Regulator gain	
	VMMAX, Maximum value of limitation of the signal in p.u.	
	VMMIN, Minimum value of limitation of the signal in p.u.	
	KG	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL	
	Θ_P (degrees)	
ST5B	TR regulator input filter time constant (sec)	
	TC1 lead time constant of first lead-lag block (voltage regulator channel) (sec)	
	TB1 lag time constant of first lead-lag block (voltage regulator channel) (sec)	
	TC2 lead time constant of second lead-lag block (voltage regulator channel) (sec)	
	TB2 lag time constant of second lead-lag block (voltage regulator channel) (sec)	
	KR (>0) (pu) voltage regulator gain	
	VRMAX (pu) voltage regulator maximum limit	
	VRMIN (pu) voltage regulator minimum limit	
	T1 voltage regulator time constant (sec)	
	KC (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)	
	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)	

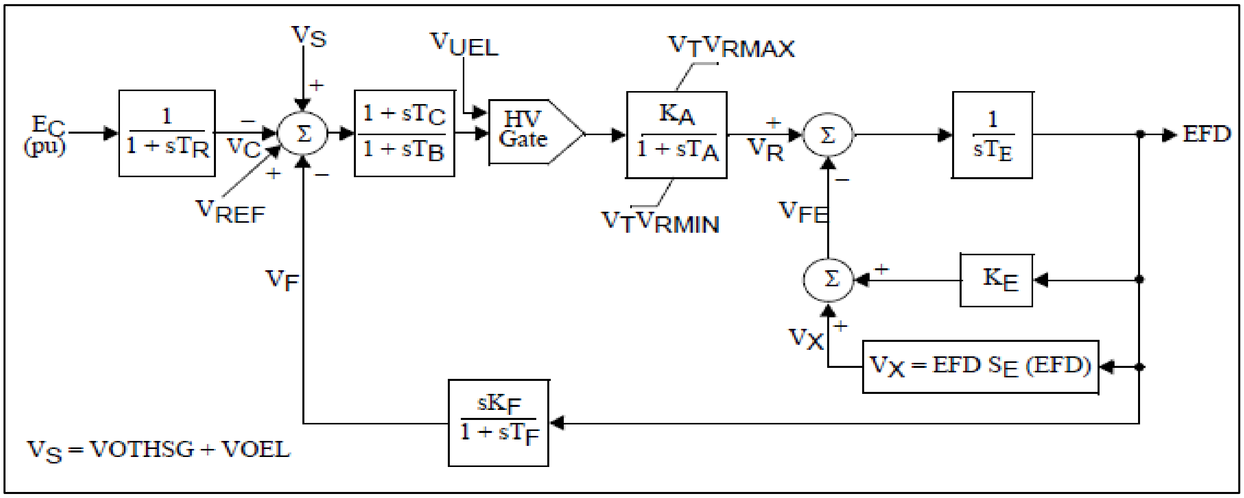
Category	Parameter Description	Data
Static Exciter		
ST6B	TR regulator input filter time constant (sec)	
	KPA (pu) (> 0) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	KDA (pu) voltage regulator derivative gain	
	TDA voltage regulator derivative channel time constant (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	
	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)	

(i) **DC Exciters Generic model:**

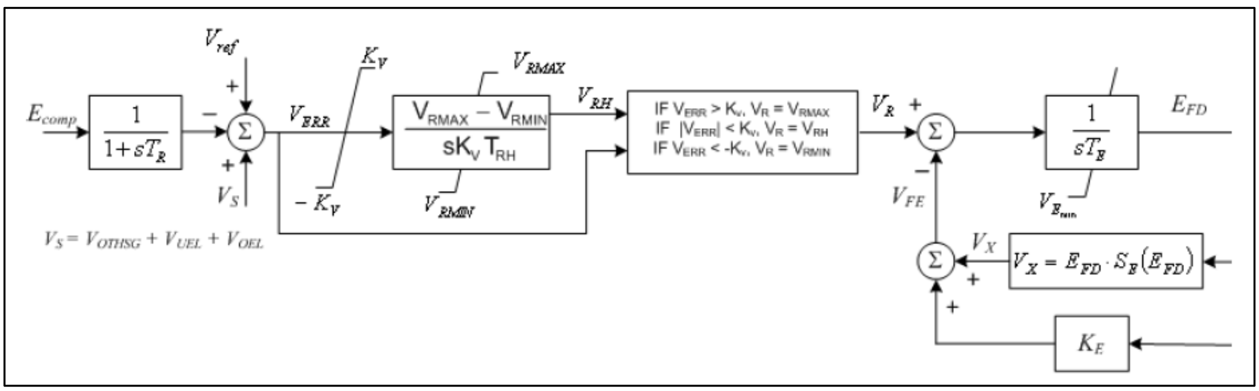
- **Type DC1A: 1992 IEEE type DC1A excitation system model**



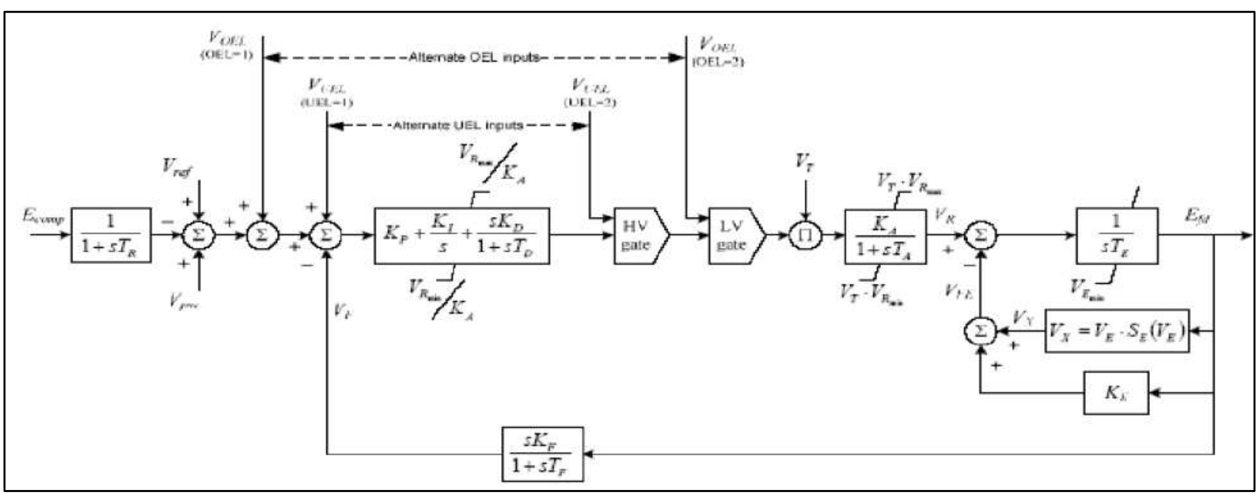
➢ **Type DC2A: 1992 IEEE type DC2A excitation system model**



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

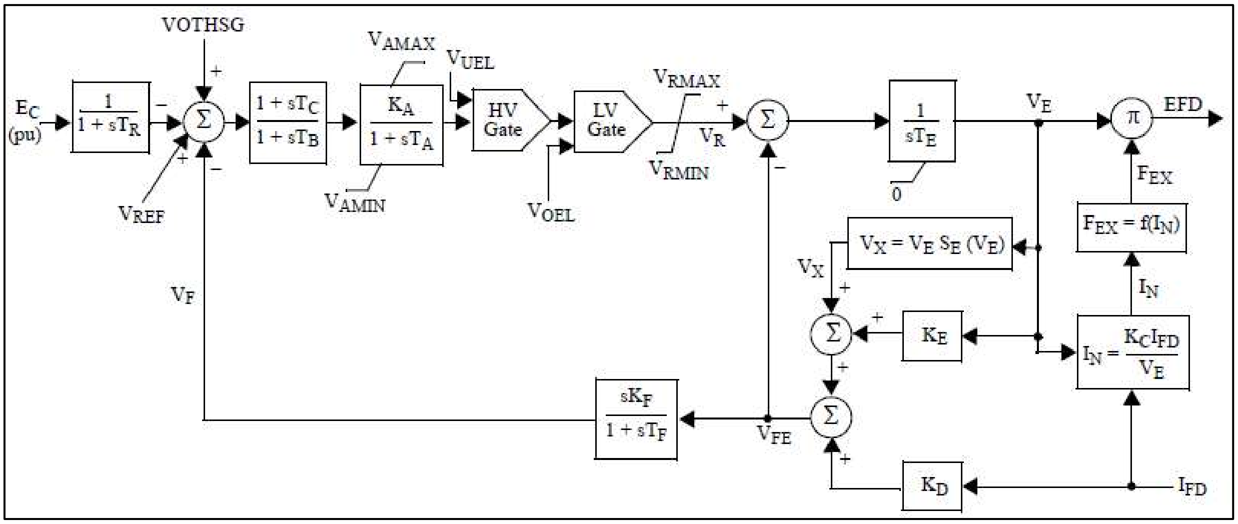


➢ **Type DC4B: IEEE 421.5 2005 DC4B excitation system**



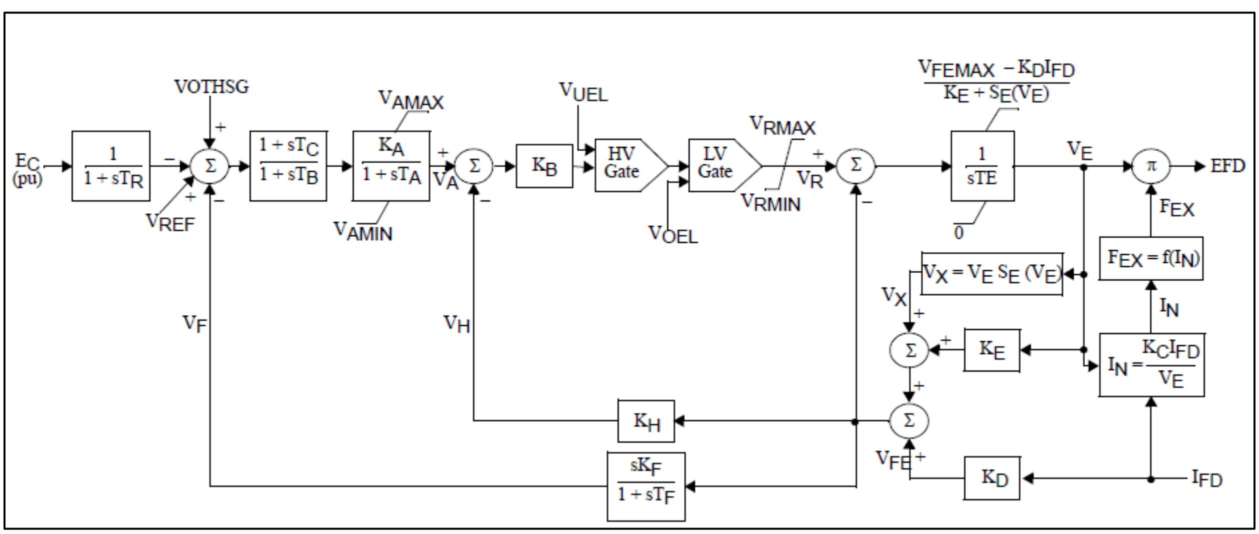
(ii) **AC Exciters Generic Models:**

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

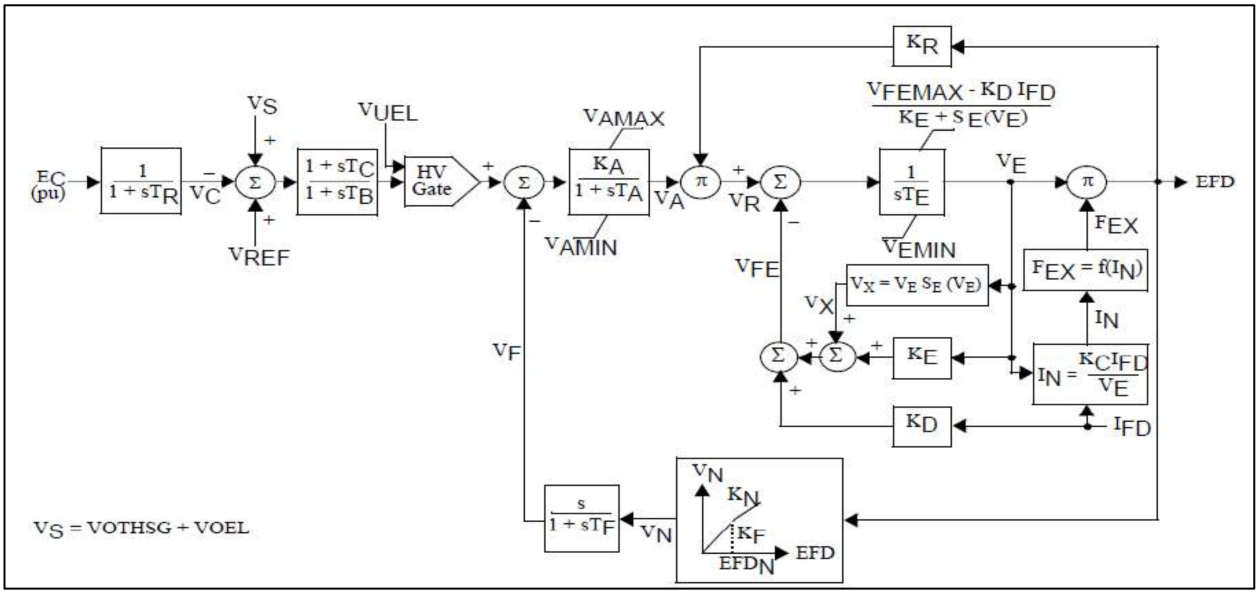


I_N →		→ FEX
	If $I_N \leq 0$	$F_{EX} = 1$
	If $I_N \leq 0.433$	$F_{EX} = 1 - 0.577\ I_N$
	If $0.433 < I_N < 0.75$	$F_{EX} = \sqrt{0.75 - I_N^2}$
	If $I_N \geq 0.75$	$F_{EX} = 1.732(1 - I_N)$
	If $I_N > 1$	$F_{EX} = 0$

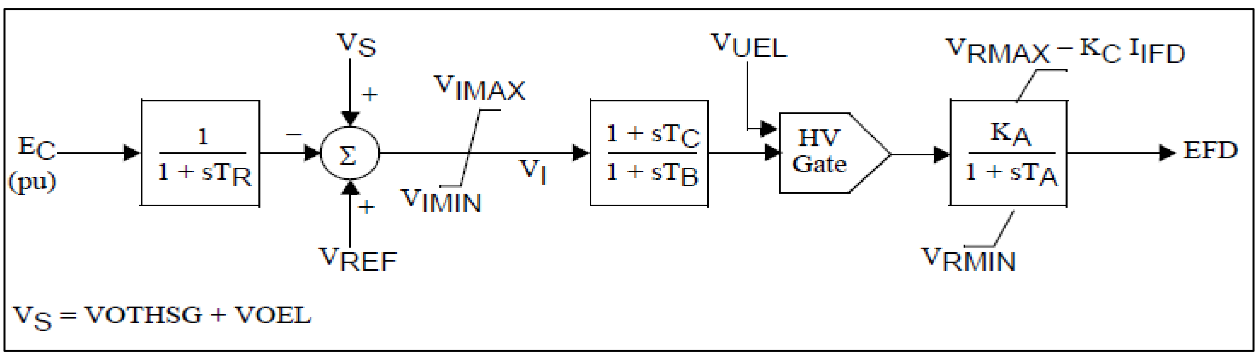
- **Type AC2A: 1992 IEEE type AC2A excitation system model**



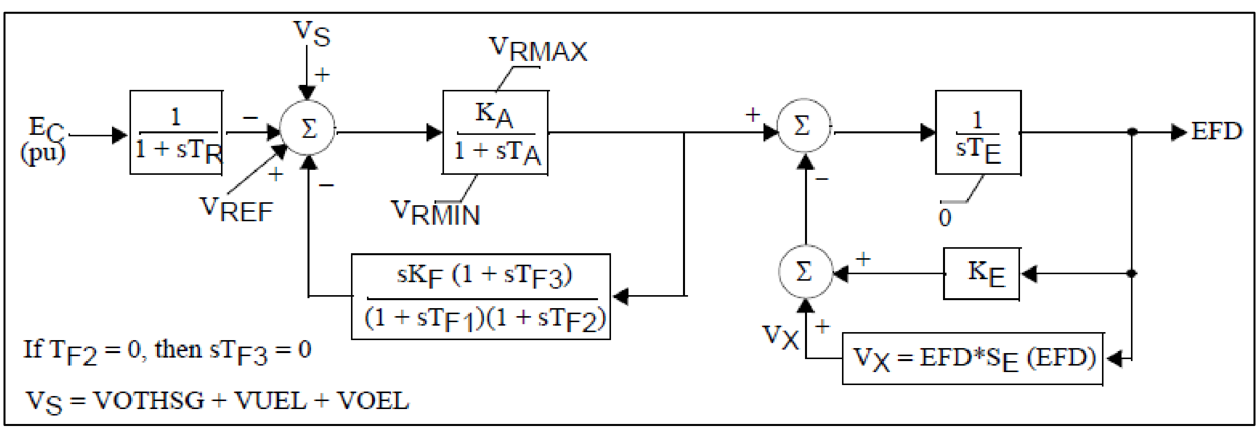
➢ **Type AC3A: 1992 IEEE type AC3A excitation system model**



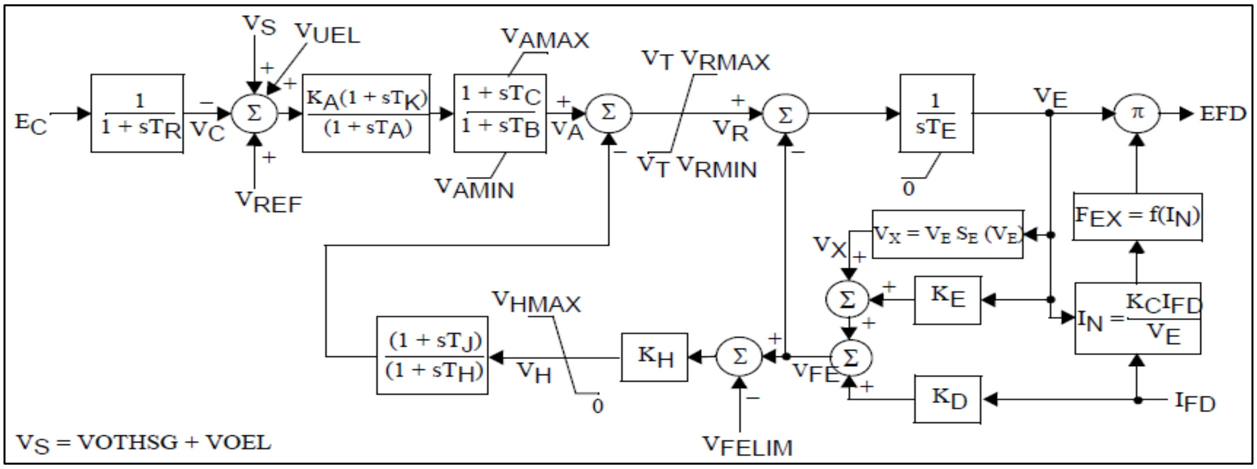
➢ **Type AC4A: 1992 IEEE type AC4A excitation system model**



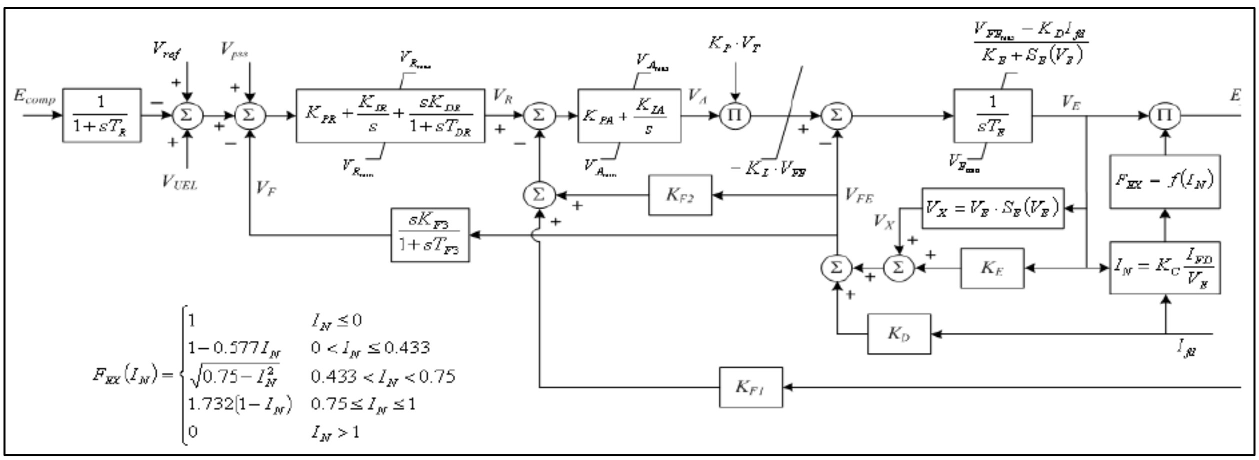
➢ **Type AC5A: 1992 IEEE type AC5A excitation system model**



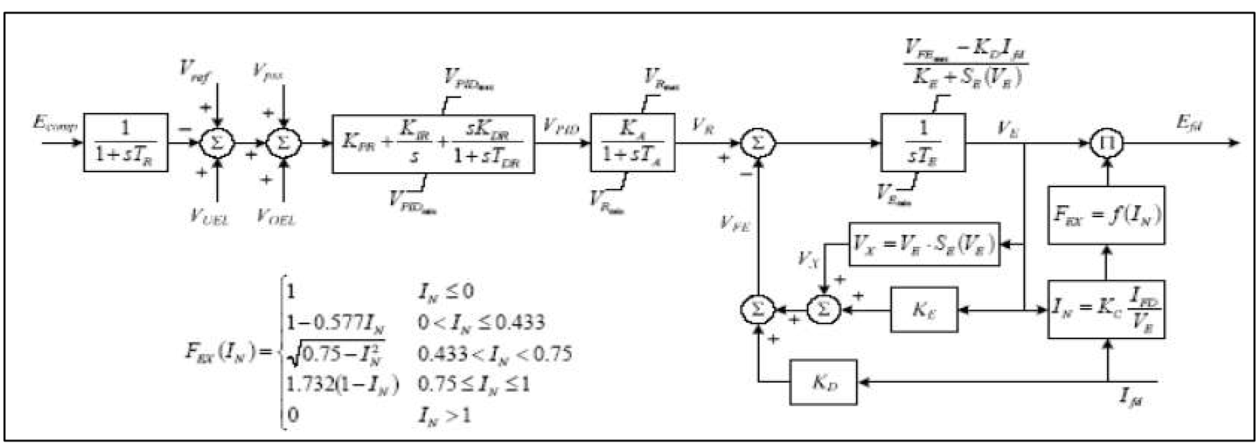
➢ **Type AC6A: IEEE 421.5 excitation system model**



➢ **Type AC7B: IEEE 421.5 2005 AC7B excitation system**

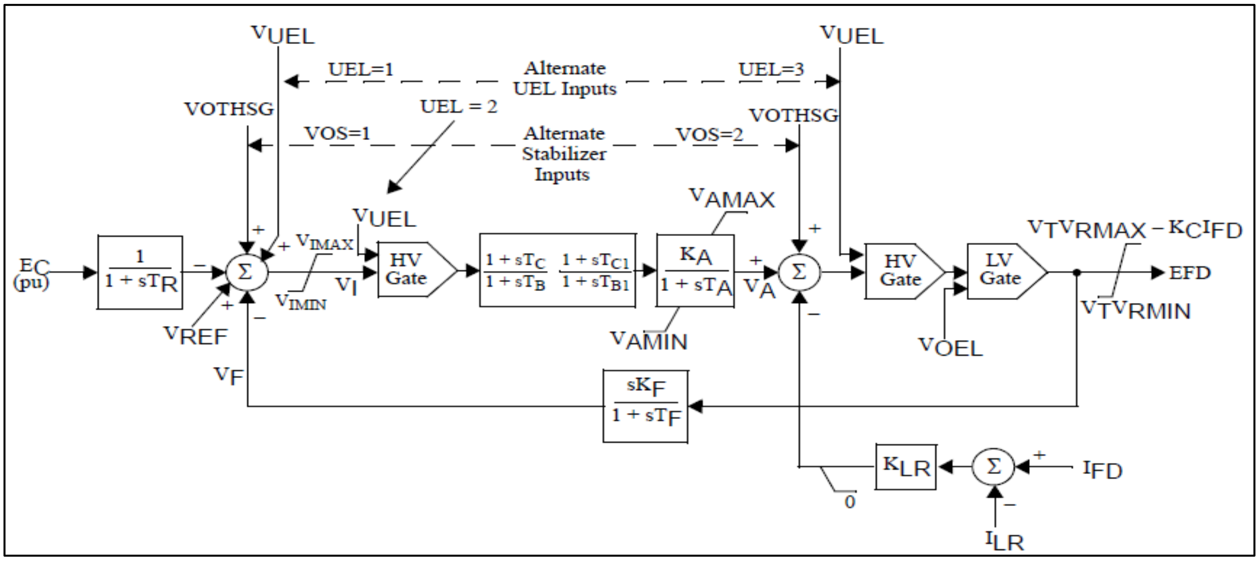


➢ **Type AC8B: IEEE 421.5 2005 AC8B excitation system**

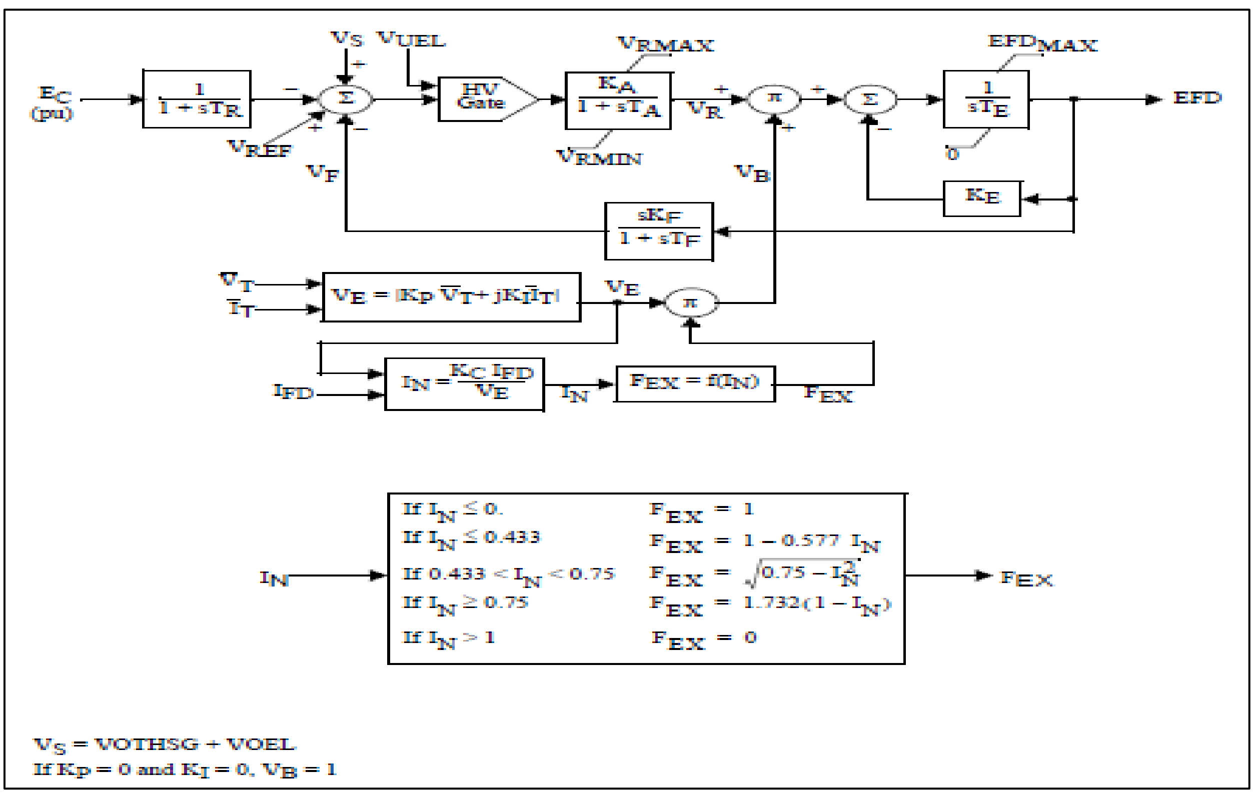


(iii) **Commonly Used Static Exciters Generic Models block diagrams:**

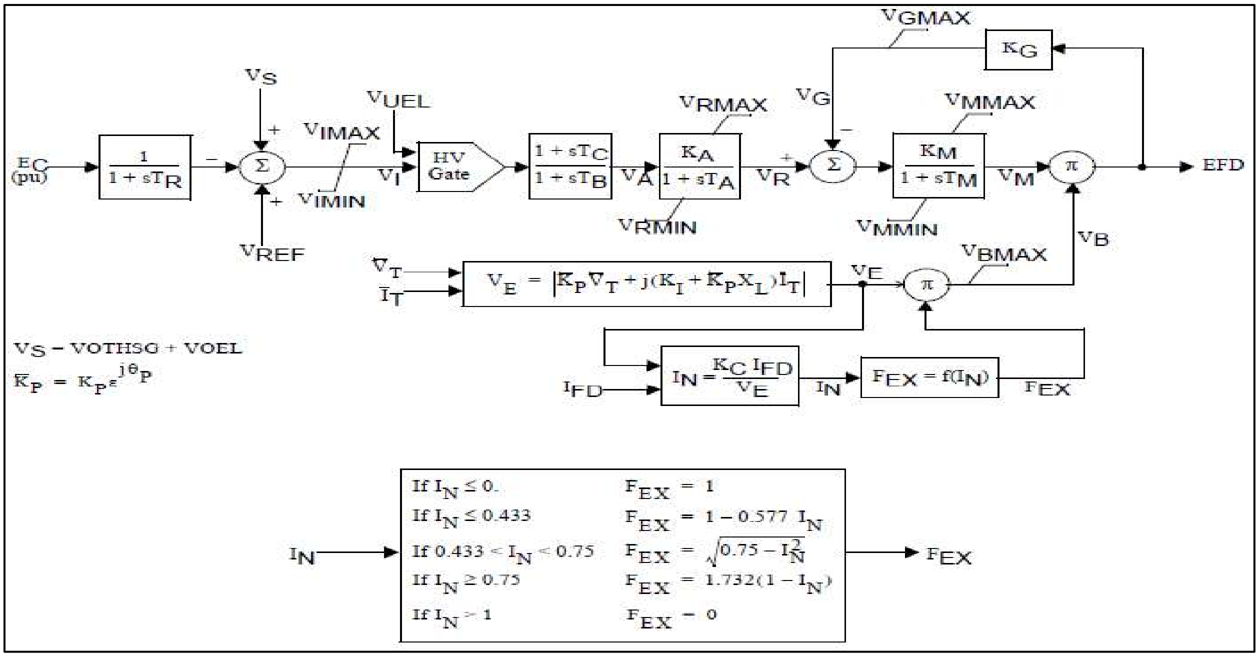
- **Type ST1A: 1992 IEEE type ST1A excitation system model**



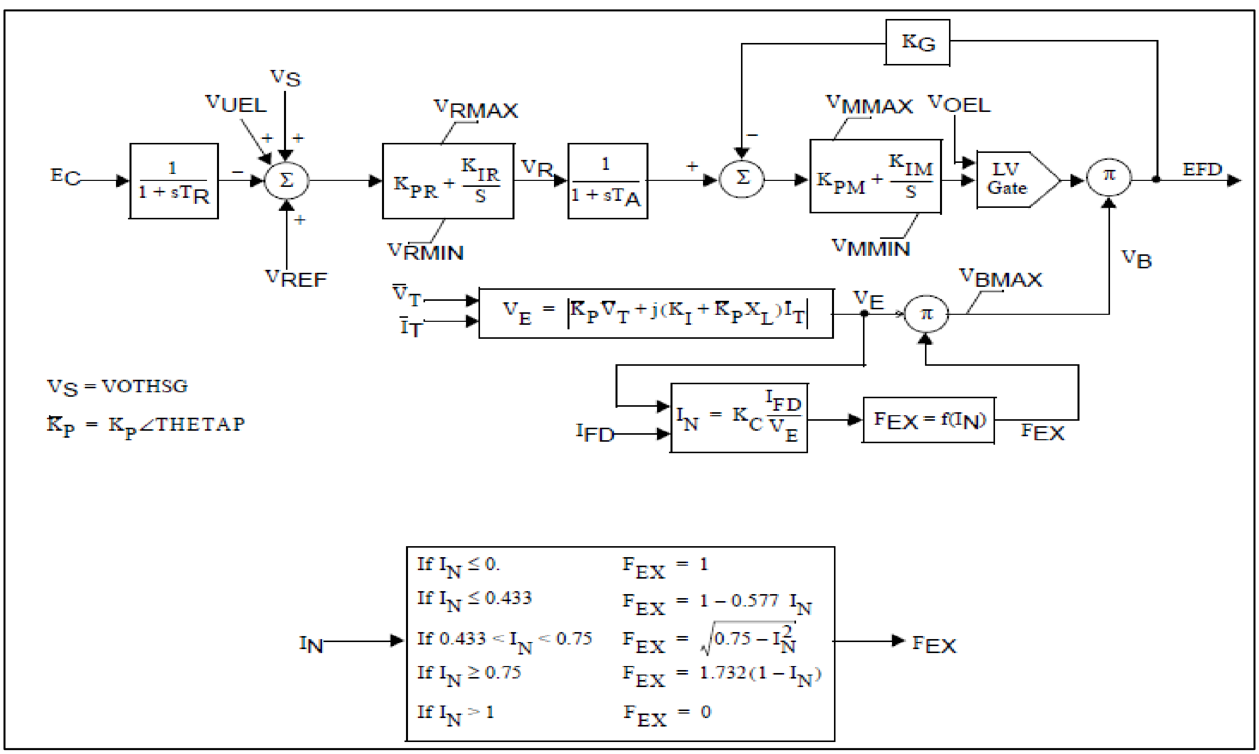
- **Type ST2A: 1992 IEEE type ST2A excitation system model**



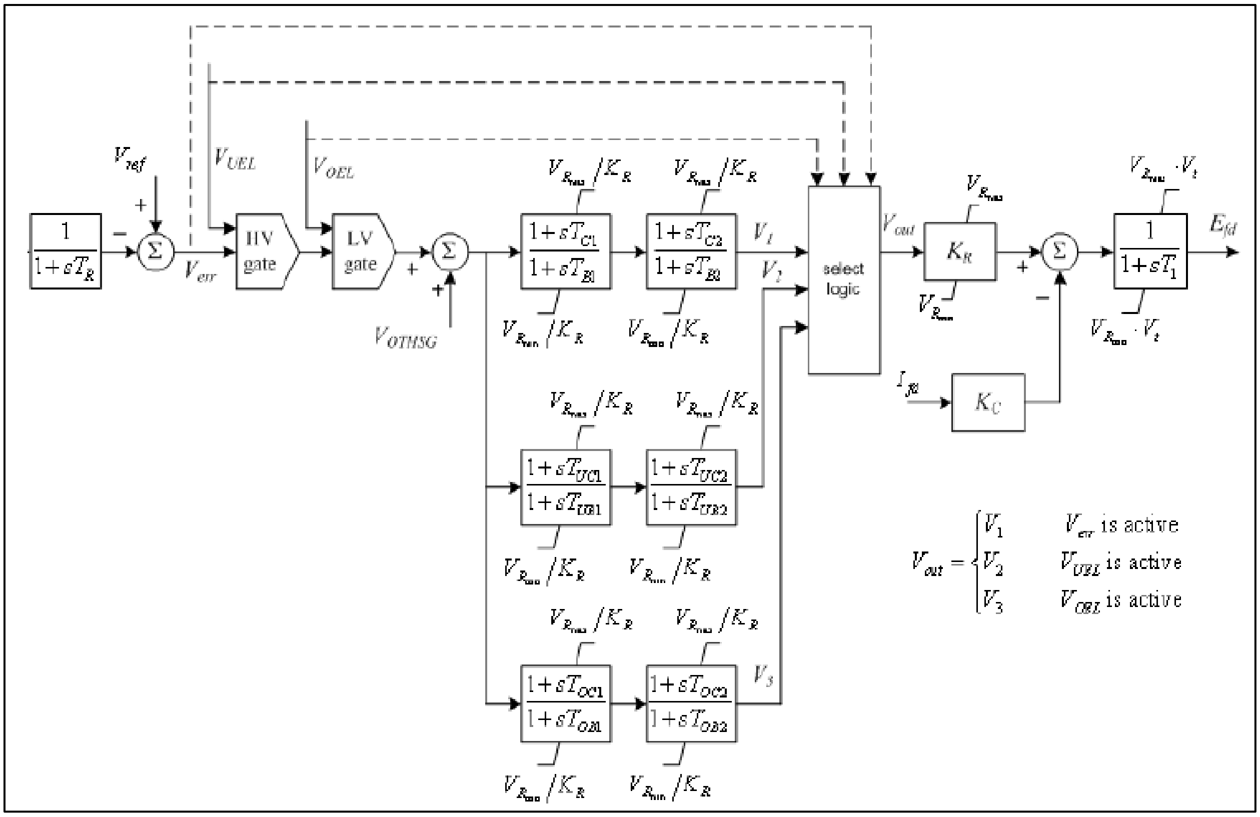
- **Type ST3A: 1992 IEEE type ST3A excitation system model**



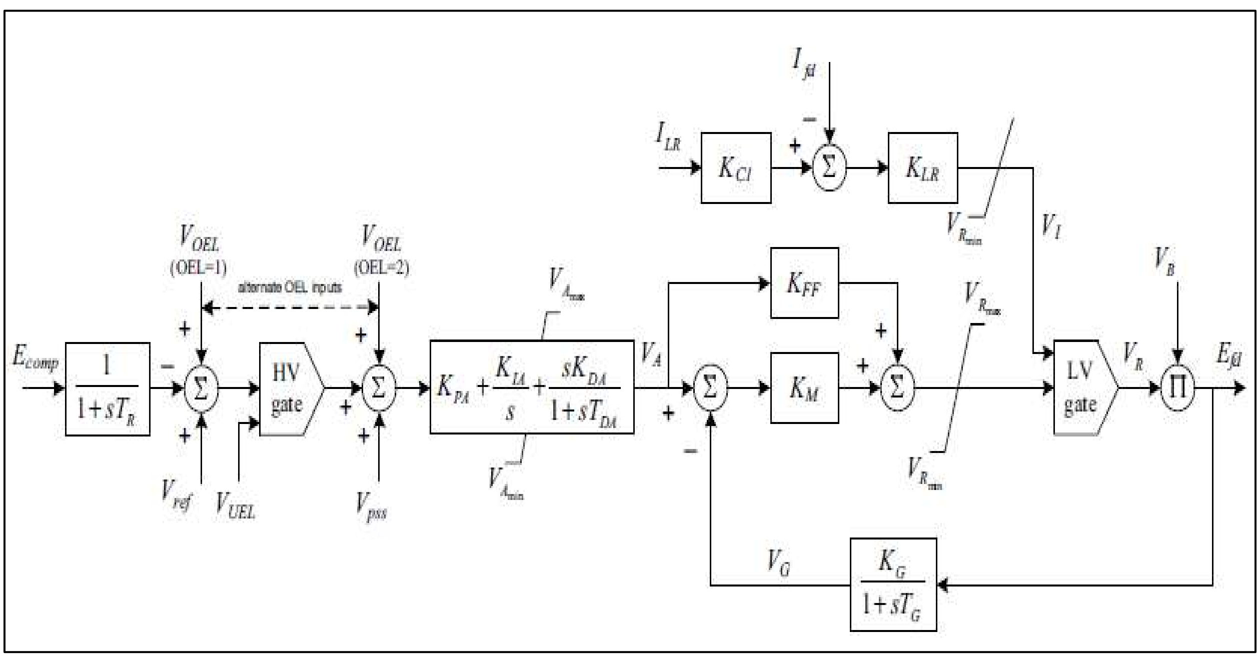
- **Type ST4B: IEEE type ST4B potential or compounded source-controlled rectifier exciter**



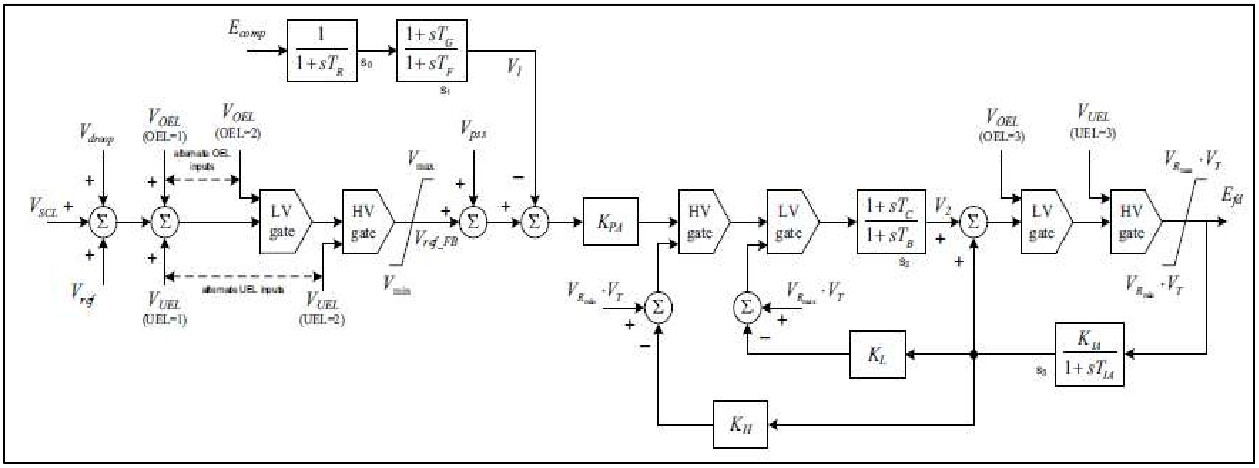
- **Type ST5B: IEEE 421.5 2005 ST5B excitation system**



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



- **Type ST7B: IEEE 421.5 2005 ST7B excitation system**



Source-PSSE Model Library

3.4 Power system stabilizer:

The function of the PSS is to add to the unit's characteristic electromechanical oscillations. This is achieved by modulating excitation to develop a component in electrical torque in phase with rotor speed deviations.

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:

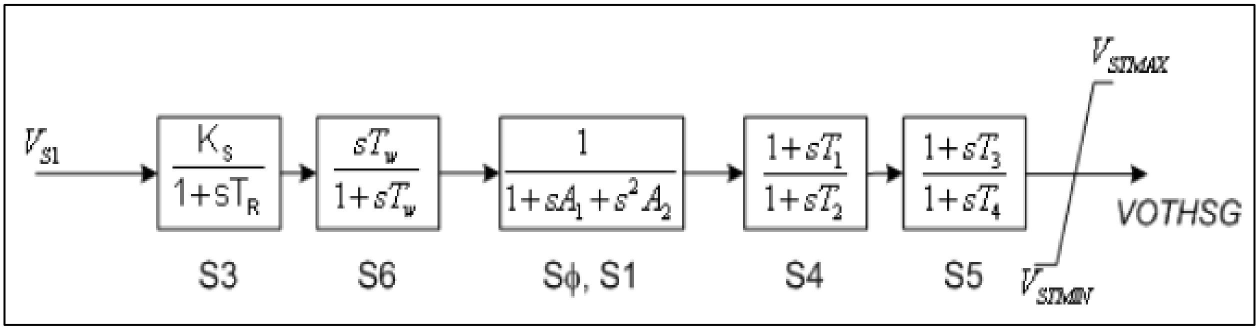
Type	Inputs	Remarks
PSS1A	Single input	Two lead-lags Input can either be speed, frequency or power
PSS2B	Dual input	Integral of accelerating power Speed and Power Most common type Supersedes PSS2A (three versus two lead lags)
PSS3B	Dual input	Power and rotor angular frequency deviation Stabilising signal is a vector sum of processed signals Not very common

Category	Parameter Description	Data
Stabilizer Models		
PSS1A	A1, Filter coefficient	
	A2, Filter coefficient	
	TR, transducer time constant	
	0	
	0	
	0	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	Tw, Washout Time Constant	
	Tw, Washout Time Constant	
	Ks, input channel gain	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	
	0	
	0	

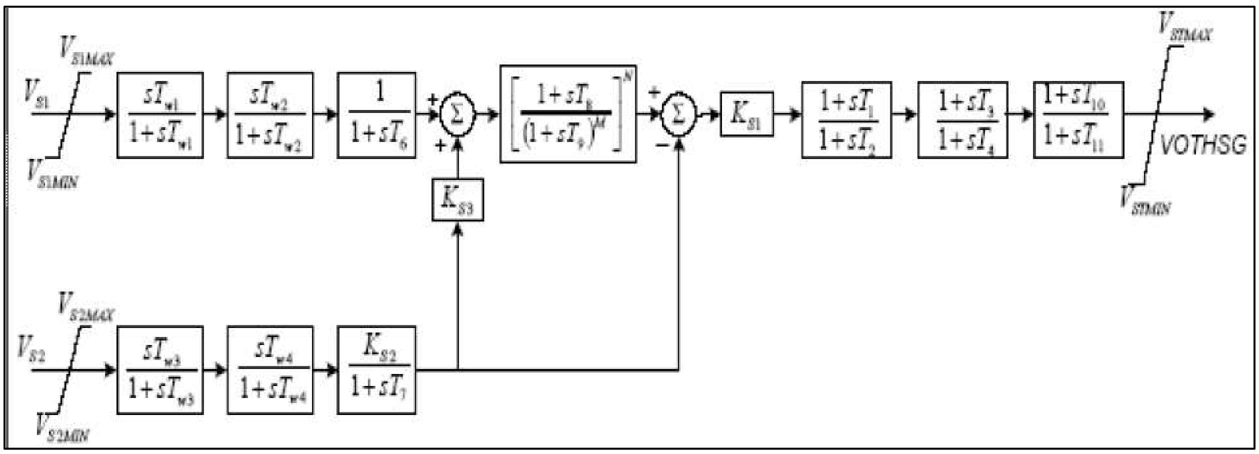
Category	Parameter Description	Data
Stabilizer Models		
PSS2B	TW1, 1st Washout 1th Time Constant	
	TW2, 1st Washout 2th Time Constant	
	T6, 1st Signal Transducer Time Constant	
	TW3, 2nd Washout 1th Time Constant	
	TW4, 2nd Washout 2th Time Constant	
	T7, 2nd Signal Transducer Time Constant	
	KS2, 2nd Signal Transducer Factor	
	KS3, Washouts Coupling Factor	
	T8, Ramp Tracking Filter Deriv. Time Constant	
	T9, Ramp Tracking Filter Delay Time Constant	
	KS1, PSS Gain	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	T10, 3rd Lead-Lag Derivative Time Constant	
	T11, 3rd Lead-Lag Delay Time Constant	
	VS1MAX, Input 1 Maximum limit	
	VS1MIN, Input 1 Minimum limit	
	VS2MAX, Input 2 Maximum limit	
	VS2MIN, Input 2 Minimum limit	
	VSTMAX, Controller Maximum Output	
	VSTMIN, Controller Minimum Output	
PSS3B	KS1 (pu) (≠0), input channel #1 gain	
	T1 input channel #1 transducer time constant (sec)	
	Tw1 input channel #1 washout time constant (sec)	
	KS2 (pu) (0), input channel #2 gain	
	T2 input channel #2 transducer time constant (sec)	
	Tw2 input channel #2 washout time constant (sec)	
	Tw3 (0), main washout time constant (sec)	
	A1, Filter coefficient	
	A2, Filter coefficient	
	A3, Filter coefficient	
	A4, Filter coefficient	
	A5, Filter coefficient	
	A6, Filter coefficient	
	A7, Filter coefficient	
	A8, Filter coefficient	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	

Commonly Used Power System Stabilizer generic models block diagrams:

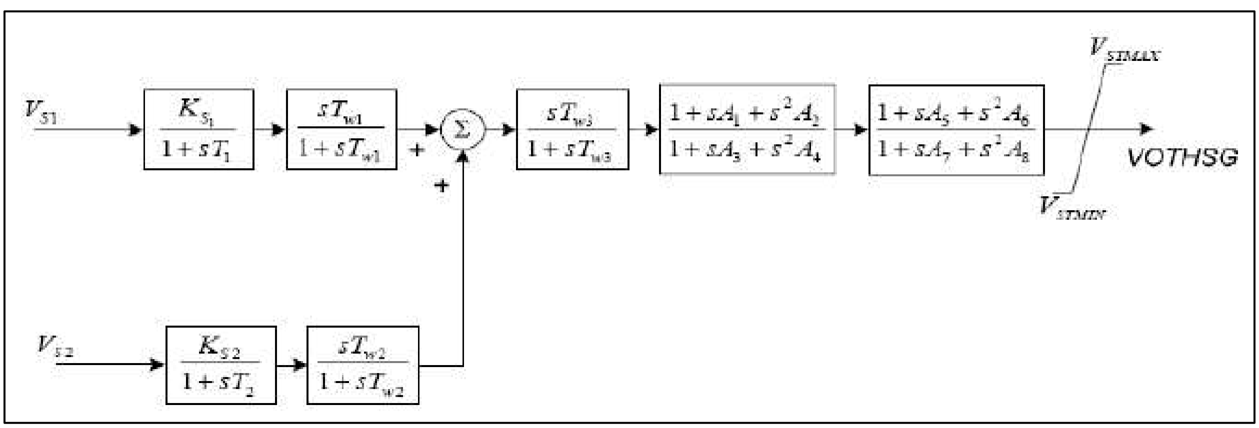
- **PSS1A: IEEE Std. 421.5-2005 PSS1A Single-Input Stabilizer model**



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



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



Source-PSSE Model Library

3.5 Generic models for turbine-governor:

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

Type	Name	Remarks
BBGOV1	Brown-Boveri turbine governor model	Mainly used for steam turbine with electrical damping feedback
TGOV1	Steam-turbine governor	Mainly used for steam turbine with reheater
CRCMGV	Cross-compound turbine	-
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 does
IEESGO	IEEE Standard Model	Simple model of reheat steam turbine
TGOV2	Steam –turbine governor with fast valving	Fast valving model of steam turbine
TGOV3	Modified IEEE Type 1 Speed-Governing Model with fast valving	Modification of IEEEG! For fast valving studies
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

Source: PSSE Model Library, for models other than the above list refer to

https://w3.usa.siemens.com/smartgrid/us/en/transmission-grid/products/grid-analysis-tools/transmission-system-planning/transmission-system-planning-tab/pages/user-support.aspx

Category	Parameter Description	Data
TURBINE GOVERNOR model		
BBGOV1	fcut (>=0) (pu), cut off frequency	
	KS, frequency gain	
	KLS (> 0)	
	KG	
	KP, power regulator gain	
	TN (sec) (> 0)	
	KD, damping gain	
	TD (sec) (> 0), damping time constant	
	T4 (sec), high pressure time constant	
	K2, intermediate pressure time constant	
	T5 (sec), intermediate re-heater time constant	
	K3, high pressure time constant	
	T6 (sec), re-heater time constant	
	T1 (sec), measuring transducer time constant	
	SWITCH	
	PMAX, maximum power output limiter	
	PMIN, minimum power output limiter	
TGOV1	R, Permanent Droop	
	T1 (>0) (sec), Steam bowl time constant	
	VMAX, Maximum valve position	
	VMIN, Minimum valve position	
	T2 (sec), Time constant	
	T3 (>0) (sec), reheater time constant	
	Dt, Turbine damping coefficient	
	VMAX, VMIN, Dt and R are in per unit on generator MVA base. *T2/T3 = high-pressure fraction.*	
CRCMGV	PMAX (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)	
	PMAX (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)	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
IEEEG1	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	
	Uc (< 0) (pu/sec), maximum valve closing rate	
	PMAX (pu on machine MVA rating)	
	PMIN (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	
	PMAX (pu on machine MVA rating), gate maximum	
	PMIN (pu on machine MVA rating), gate minimum	
	T4 (>0) (sec), water starting time	
IEEEG3	TG, (>0) (sec), gate servomotor time constant	
	TP (>0) (sec), pilot value time constant	
	Uo (pu per sec), opening gate rate limit	
	Uc (pu per sec), closing gate rate limit (< 0)	
	PMAX maximum gate position (pu on machine MVA rating)	
	PMIN minimum gate position (pu on machine MVA rating)	
	σ, permanent speed droop coefficient	
	δ, transient speed droop coefficient	
	TR, (>0) (sec), Dashpot time constant	
	TW (>0) (sec), water starting time	
	a11 (>0), Turbine coefficient	
	a13, Turbine coefficient	
	a21, Turbine coefficient	
	a23 (>0), Turbine coefficient	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
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	
	PMAX, Upper Power Limit	
	PMIN, Lower Power Limit	
TGOV2	R (pu), permanent droop	
	T1 (>0) (sec), Steam bowl time constant	
	VMAX (pu), Maximum valve position	
	VMIN (pu), Minimum valve position	
	K (pu), Governor gain	
	T3 (>0) (sec), Time constant	
	Dt (pu), Turbine damping coefficient	
	Tt (>0) (sec), Valve time constant	
	TA, Valve position at time 2 (fully closed after fast valving initialization)	
	TB, Valve position at time 3 (start to reopen after fast valving initialization)	
	TC, 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	
	PMAX, Maximum valve opening	
	PMIN, Minimum valve opening	
	T4 (sec), Inlet piping/steam bowl time constant	
	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	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
TGOV4	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)	
	K2	
	T6 (sec)	
	PRMAX	
	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	
	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)	

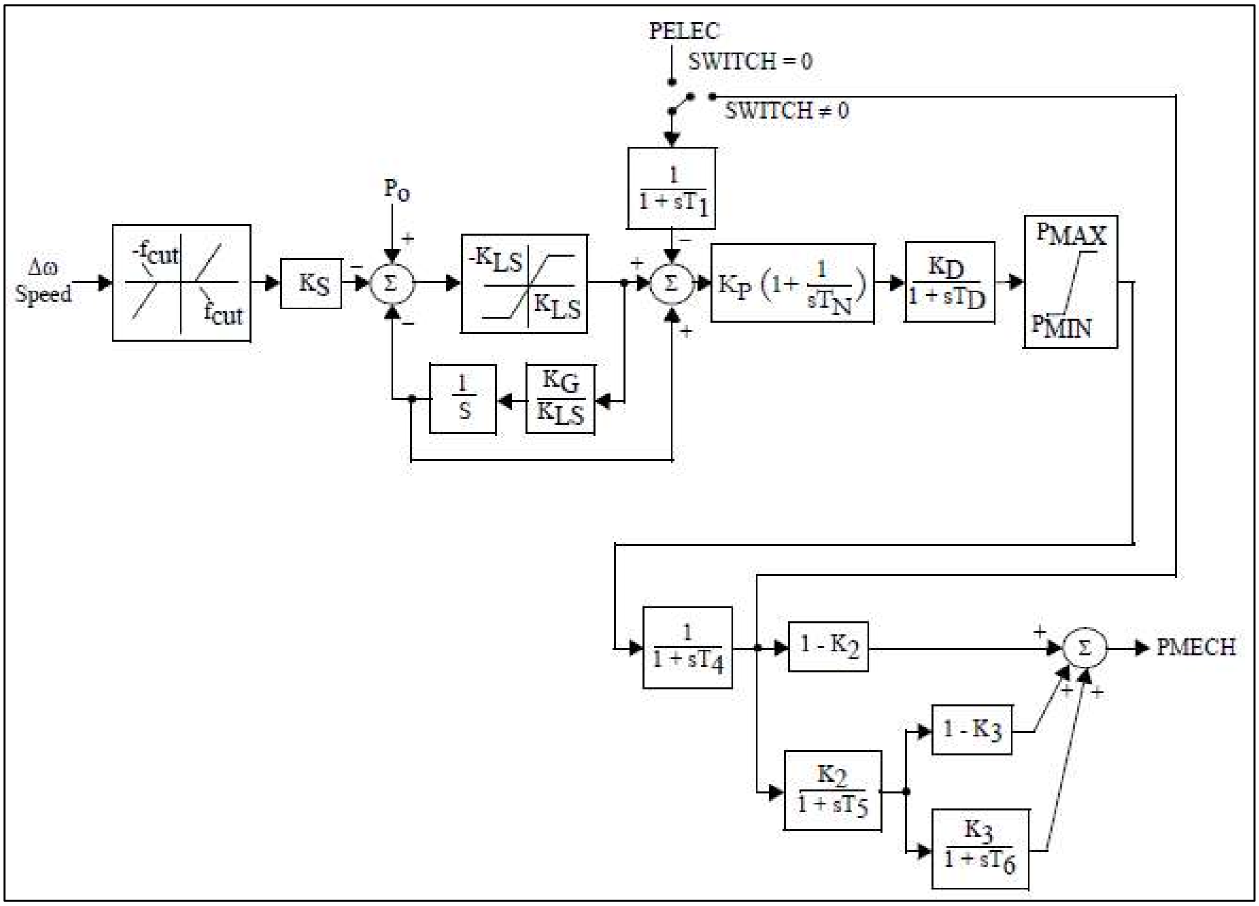
Category	Parameter Description	Data
TURBINE GOVERNOR model		
TGOV4	IV closing rate (pu/sec)	
	Time closed for IV #1 (sec)	
	Time closed for IV #2 (sec)	
	TRPLU (>0) (sec)	
	PLU rate level	
	Timer	
	PLU unbalance level	
	TREVA (>0) (sec)	
	EVA rate level	
	EVA unbalance level	
	Minimum load reference (pu)	
	Load reference ramp rate (pu/sec)	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
TGOV5	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	
	VMAX, The maximum valve area	
	VMIN, 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).	
	RMAX, The load reference positive rate of change limit	
	RMIN, The load reference negative rate of change limit	
	LMAX, The maximum load reference	
	LMIN, 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	
	TR (sec), The controller rate lead time constant	
	TR1 (sec), The inherent lag associated with lead TR (usually about TR/10)	
	CMAX, The maximum controller output	

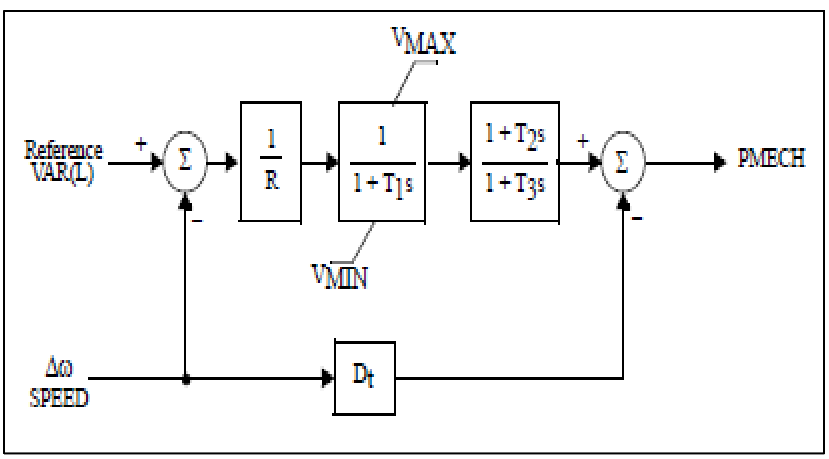
Category	Parameter Description	Data
TURBINE GOVERNOR model		
TGOV5	CMIN, The minimum controller output	
	TD (sec), The time delay in the fuel supply system	
	TF (sec), The fuel and air system time constant	
	TW (sec), The water wall time constant	
	Psp (initial) (>0), The initial throttle pressure set 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 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 andK7 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	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	
	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	

Commonly Used Steam Turbine Generic Models Block Diagrams:

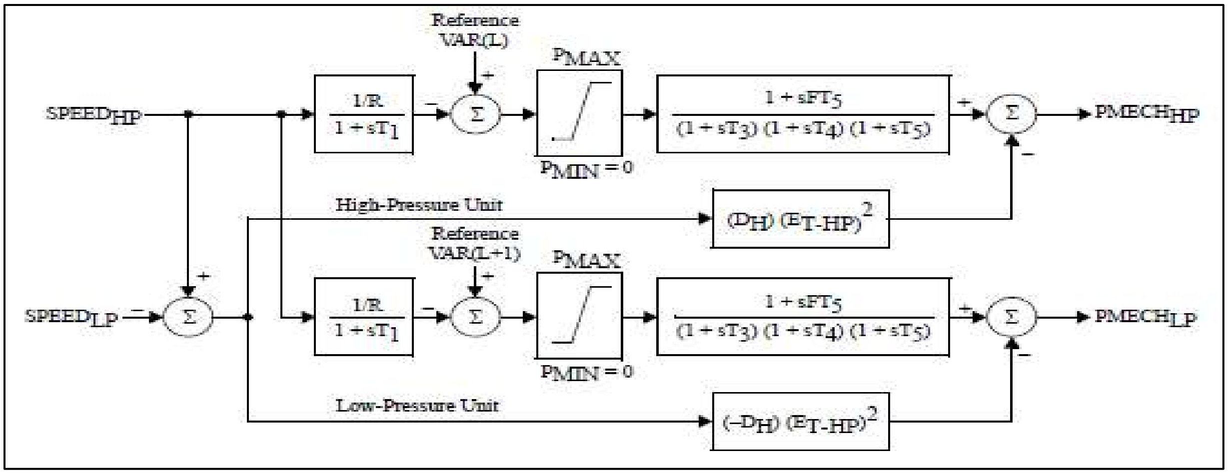
- **BBGOV1: Brown-Boveri turbine-governor model**



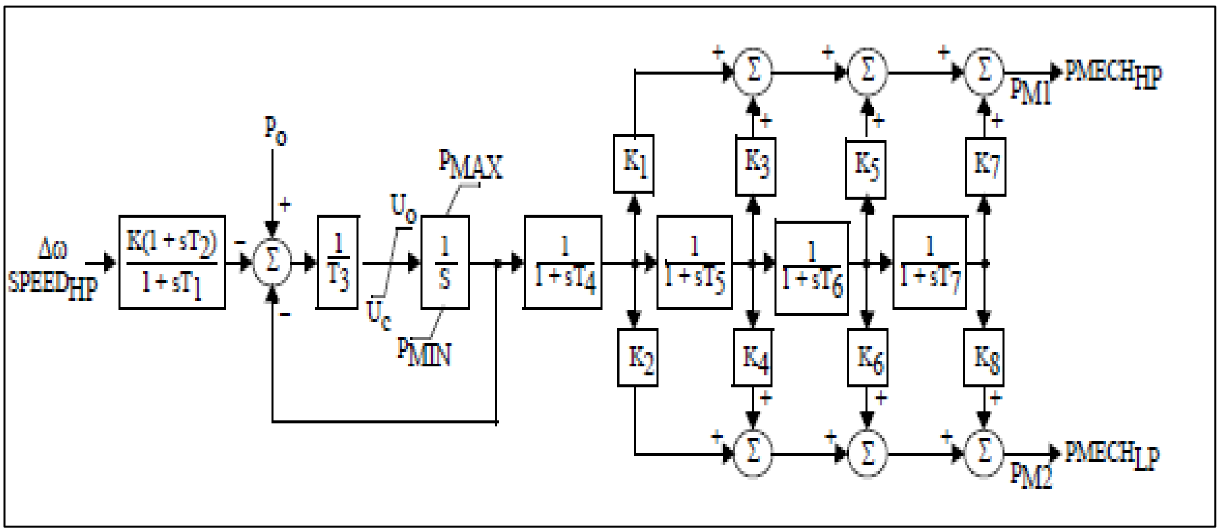
- **TGOV1: Steam turbine-governor model**



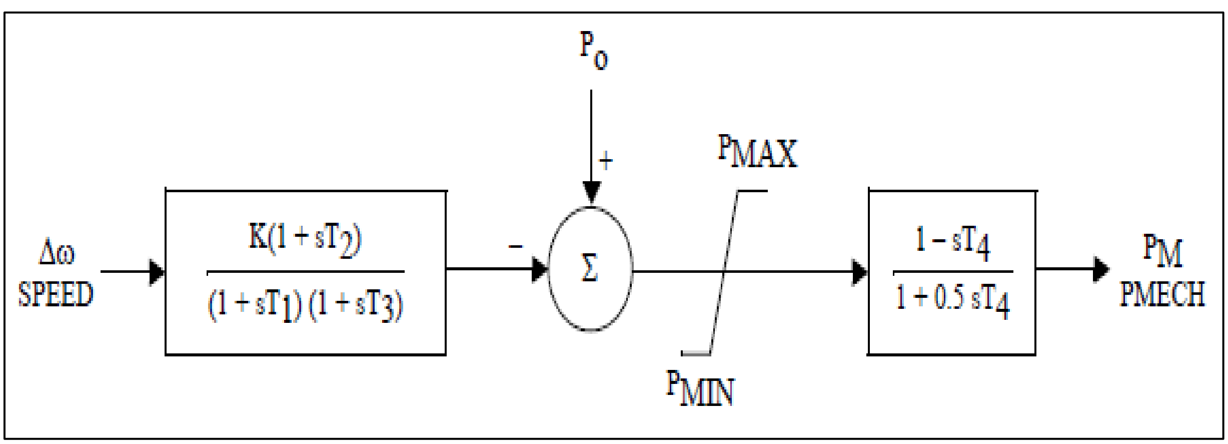
- **CRCMGV: Cross compound turbine-governor model**



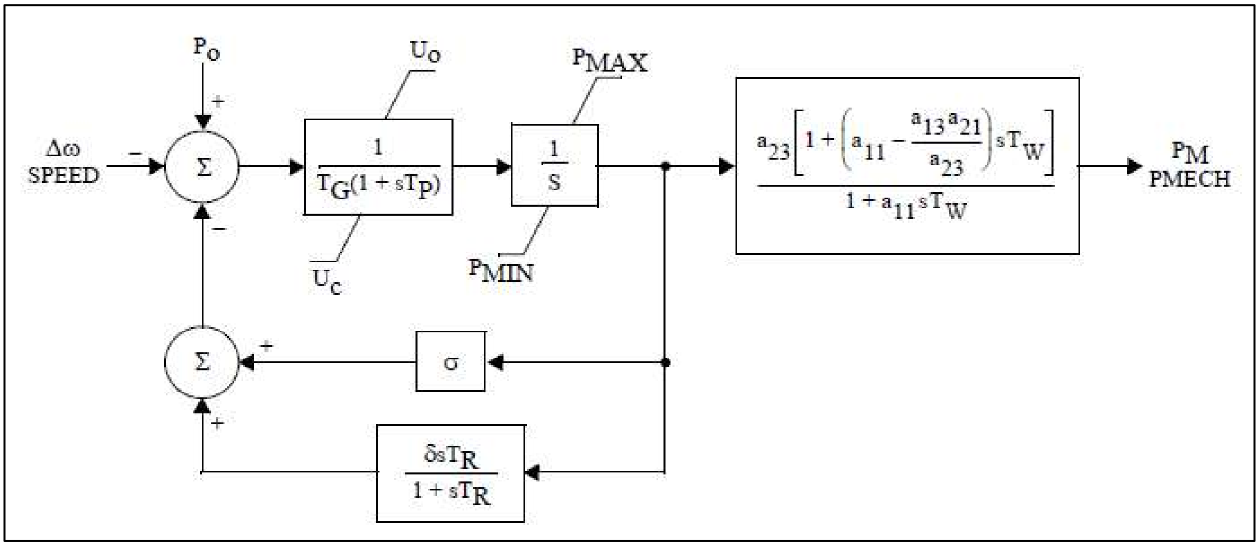
- **IEEEG1: 1981 IEEE type 1 turbine-governor model**



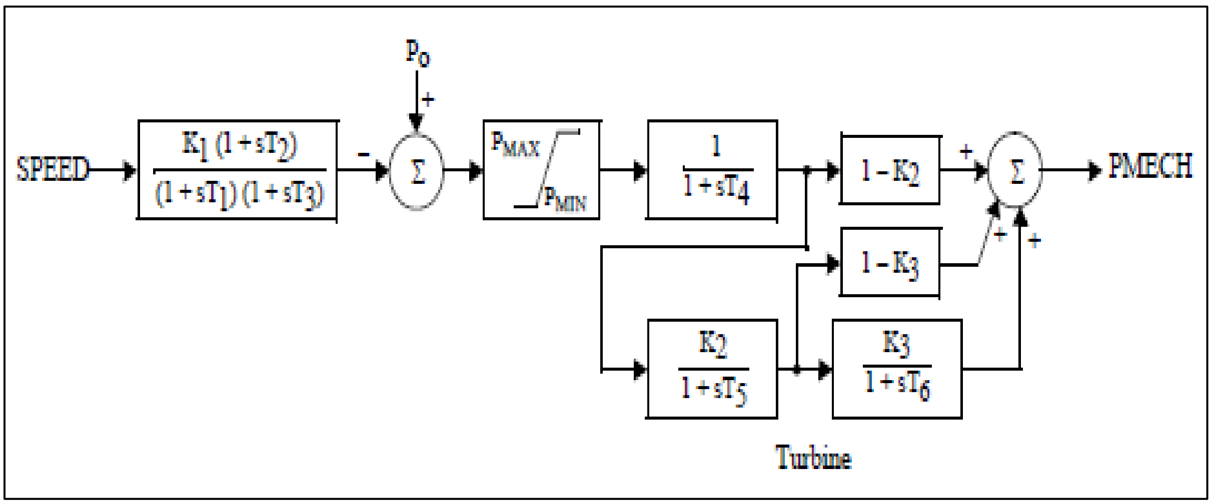
- **IEEEG2: 1981 IEEE Type 2 Speed-Governing Model**



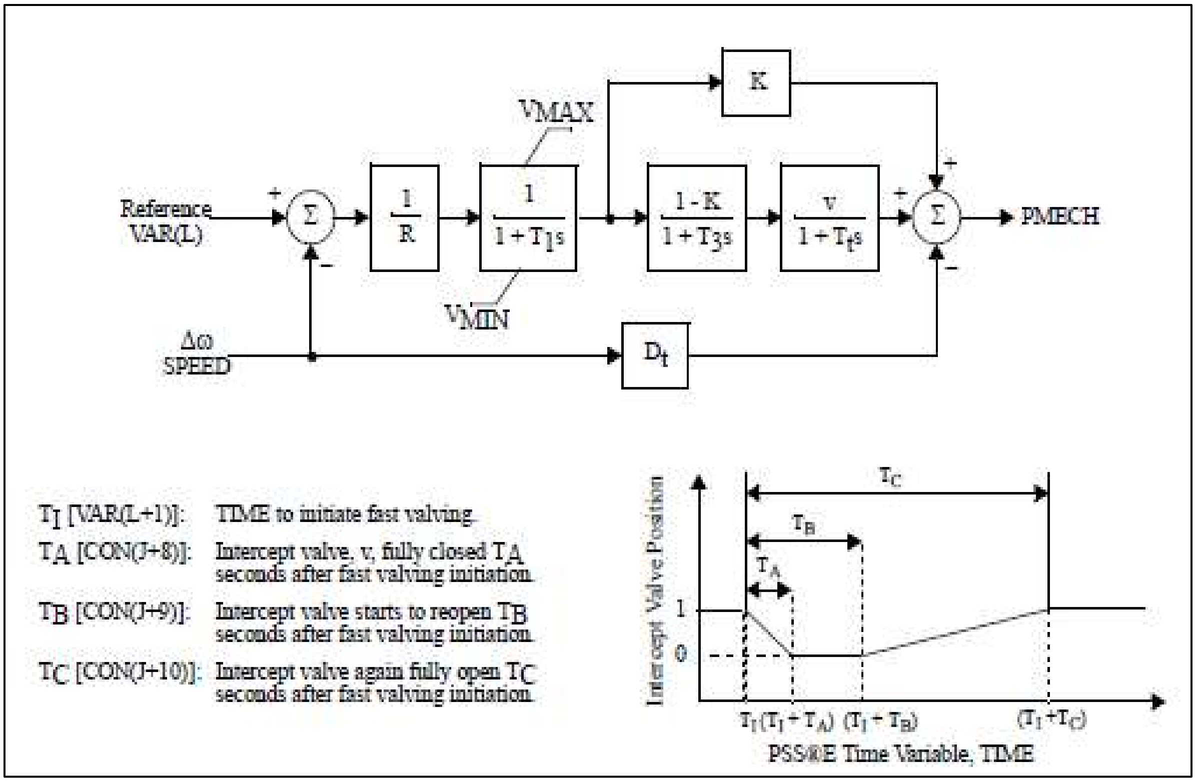
- **IEEEG3: 1981 IEEE Type 3 Speed-Governing Model**



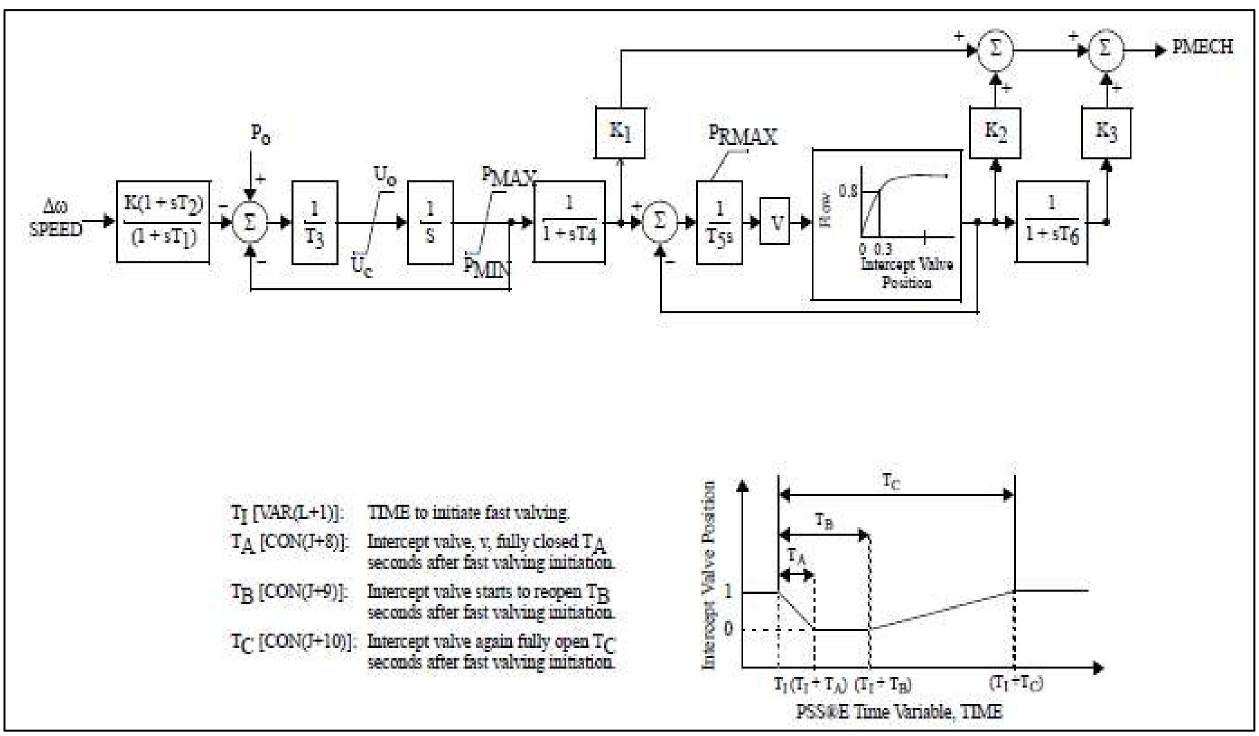
- **IEESGO: 1973 IEEE standard turbine-governor model**



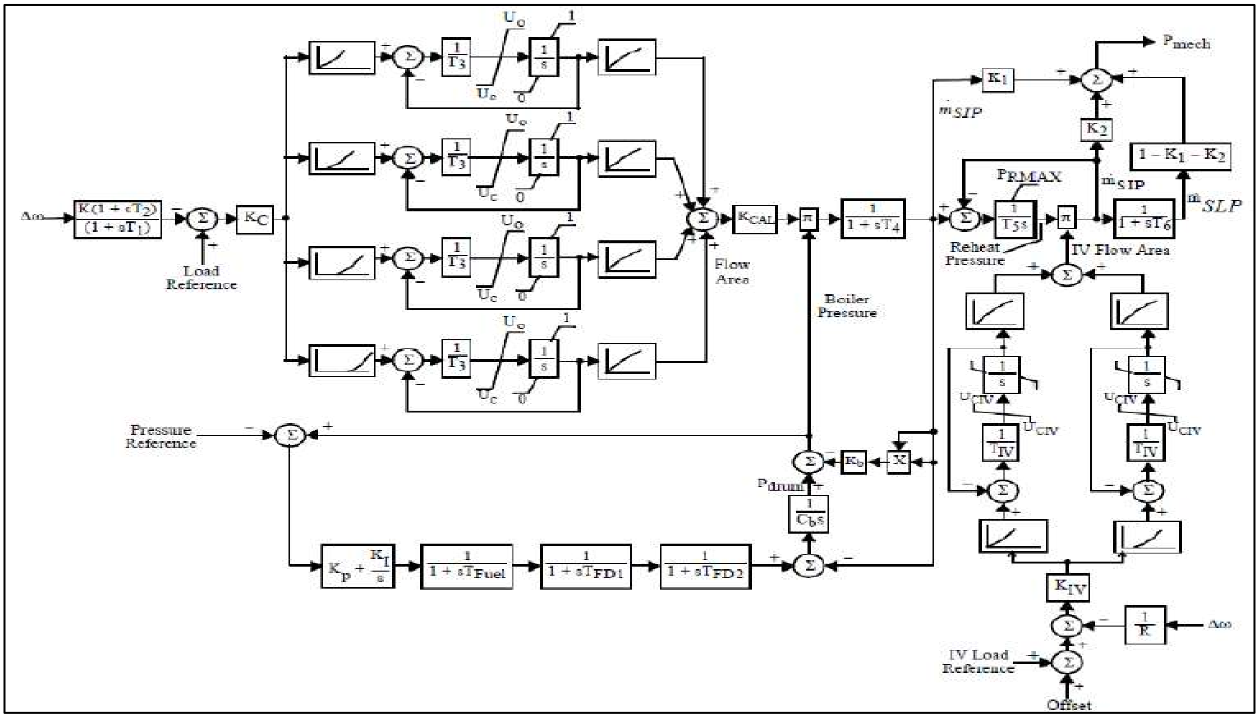
- **TGOV2: Steam turbine-governor model with fast valving**



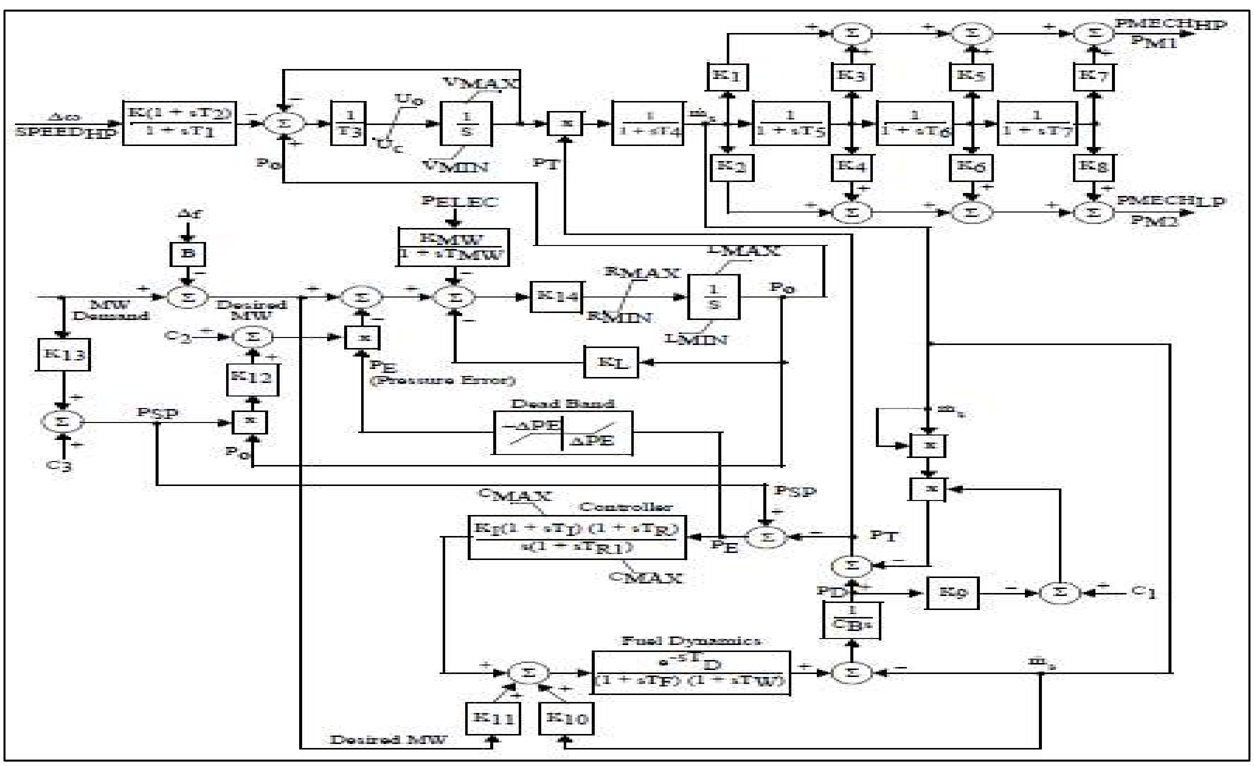
- **TGOV3: Modified IEEE type 1 turbine-governor model with fast valving**



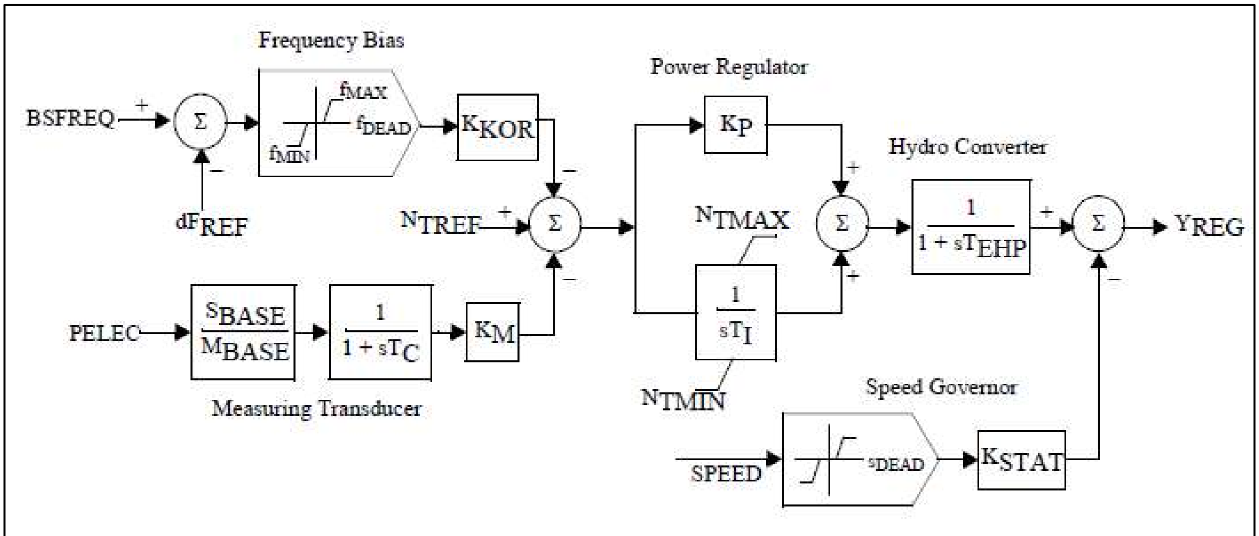
- **TGOV4: Modified IEEE type 1 speed governing model with PLU and EVA**



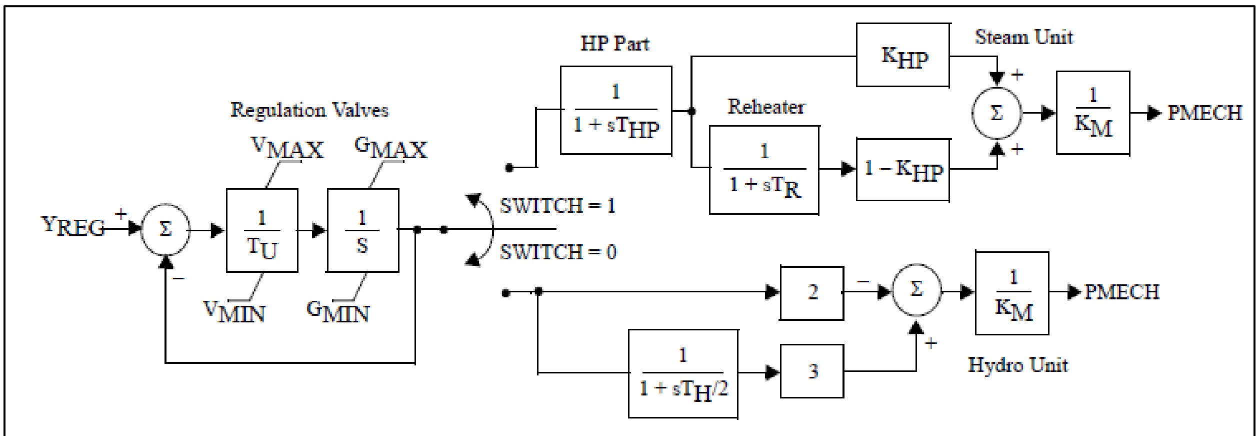
- **TGOV5: Modified IEEE type 1 turbine-governor model with boiler controls**



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



Governor



Turbine

Source-PSSE Model Library

Calculation of saturation parameters:

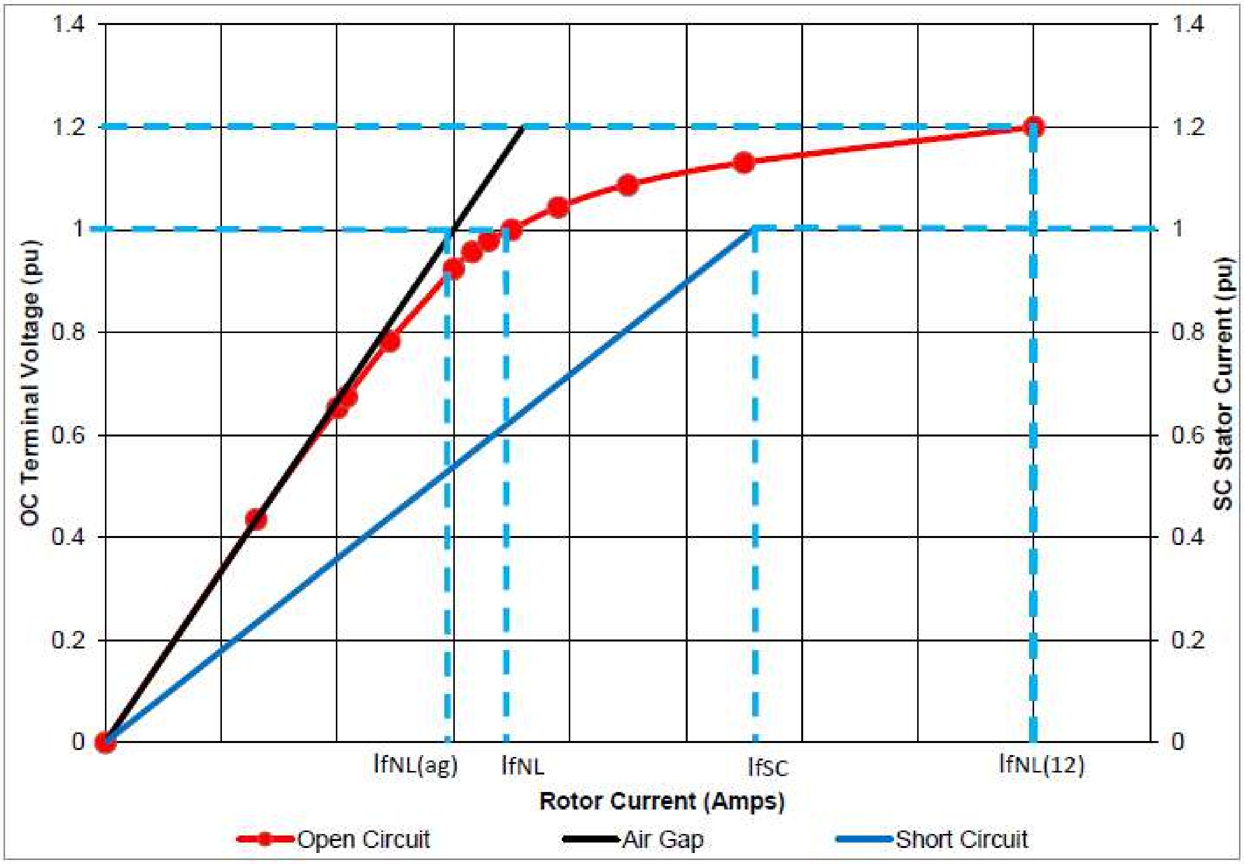


Figure 2: Open and short circuit characteristics

The saturation can be calculated using the following calculation:

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

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

Guideline for furnishing information for modelling Gas-fired Power generation in Indian Grid

1.0 Introduction:

The purpose of this document is to act as a guideline for exchange of information for accurate modelling of Gas-fired power generation in India. Availability of fit-for-purpose steady state and dynamics models of Gas-fired power generators will enable secure operation of Indian power grid and enable identification of potential weak points in the grid so as to take appropriate remedial actions.

1.1 Applicability:

The guideline shall be applicable to all Gas-fired power generation in India that can have an impact on operation of the power grid of India, irrespective of connection at Intra-STS or ISTS (Inter-state Transmission System).

This document presents the desired information for collection of data for modelling of Gas-fired power generators in PSS/E software, a software suite being used pan-India at CEA, CTU, SLDCs, RLDCs, and NLDC for modelling of India's power grid. A systematic set of data and basic criteria for furnishing data are presented.

1.2 Need for a fit-for-purpose model:

There is a cost involved in developing and validating dynamic models of power system equipment. But there are much higher benefits for the power system if this leads to a functional, fit-for-purpose model, and arrangements that allow that model to be maintained over time.

A functional fit-for-purpose dynamic model will:

- Facilitate significant power system efficiencies by allowing power system operations to confidently identify the secure operating envelope and thereby manage security effectively
- Allow assessment of impact on grid elements due to connection of new elements (network elements, generators, or loads) for necessary corrective actions
- Permit power system assets to be run with margins determined on the basis of security assessments
- Facilitate the tuning of control systems, such as power system stabilizers, voltage- and frequency-based special control schemes etc.
- Improve accuracy of online security tools, particularly for unusual operating conditions, which in turn is likely to result in higher reliability of supply to power system users.

The power system model would enable steady state and electromechanical transient simulation studies that deliver reasonably accurate outcomes.

1.3 Regulation:

- **<u>CEA Connectivity Standard 6.4.d :</u>**

The requester and user shall cooperate with RPC and Appropriate Load Despatch Centre in respect of the matters listed below, but not limited to

furnish data as required by Appropriate Transmission Utility or Transmission Licensee, Appropriate Load Despatch Centre, Appropriate Regional Power Committee and any committee constituted by the Authority or appropriate Government for system studies or for facilitating analysis of tripping or disturbance in power system;

Here Requester and User Includes a generating company, captive generating plant, energy storage system, transmission licensee (other than Central Transmission Utility and State Transmission Utility), distribution licensee, solar park developer, wind park developer, wind-solar photovoltaic hybrid system, or bulk consumer *(2019 Amendment)*

- **<u>IEGC 4.1 :</u>**

CTU, STU and Users connected to, or seeking connection to ISTS shall comply with Central Electricity Authority (Technical Standards for connectivity to the Grid) Regulations, 2007 which specifies the minimum technical and design criteria and Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations,2009.

2.0 Gas Power Plant Classification:

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

a. **Open cycle gas turbine (OCGT):**

In 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 into 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 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.

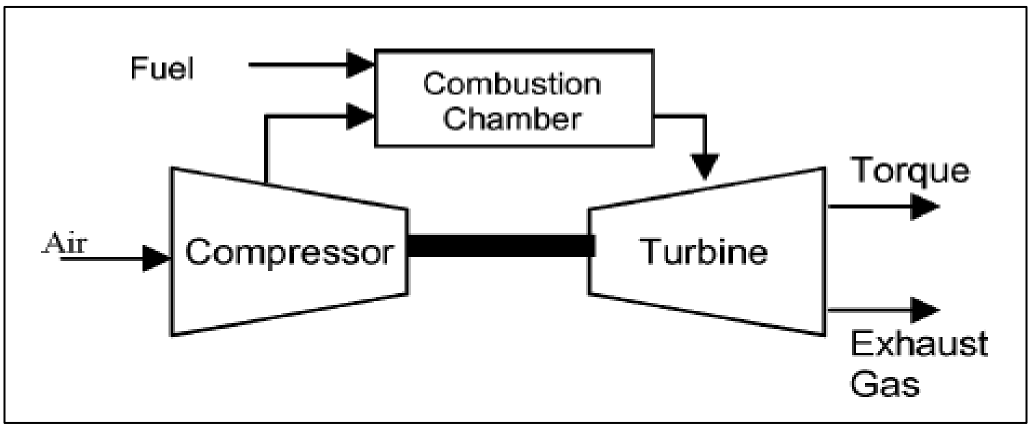


Figure 1: Single Shaft Gas Turbine

In aero-derivative type turbines, the gas generator (compressor and compressor turbine) are mechanically separated from the power turbine. The compressor can have different speed settings to achieve higher efficiency. However, the inertia will be lower than a "single-shaft" gas turbine.

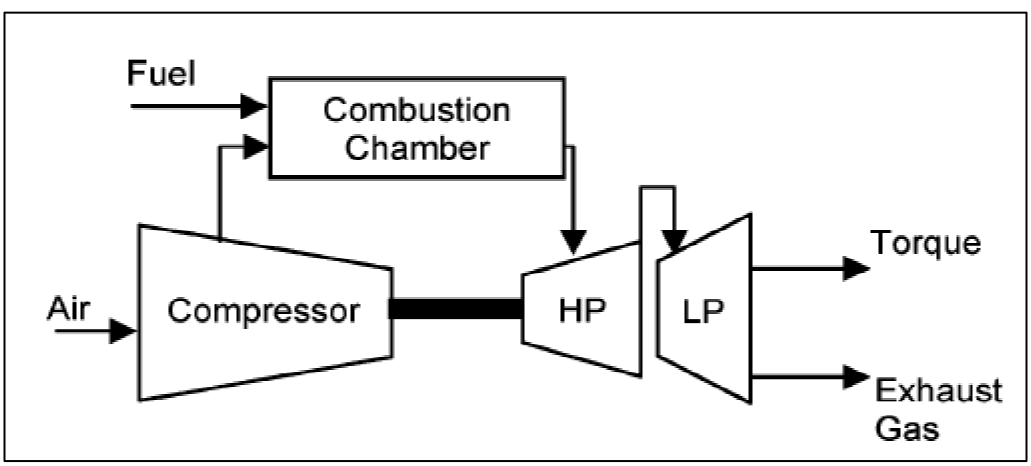


Figure 2: Aero-derivative Gas Turbine

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 remains the same but the combustion process is replaced by 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 reject heat. Therefore in this cycle, same working fluid is recirculated, causing the cycle to be classified as close cycle.

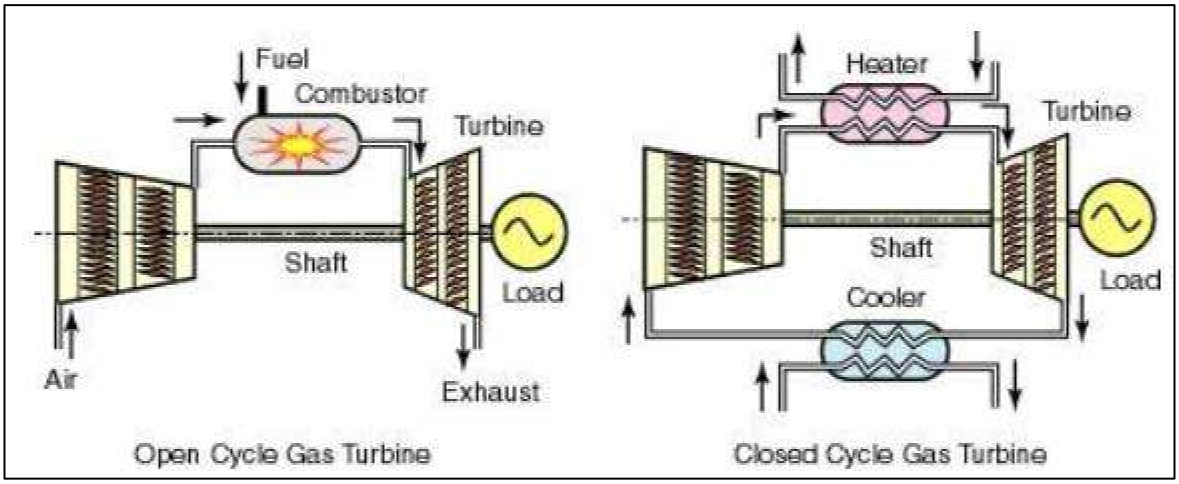


Figure 3: Typical Open and Close cycle Gas Turbine

For POSOCO to have access to verified fit-for-purpose models of gas power generator connected to Indian grid, following information is required:

1. Electrical Single Line Diagram of gas power station depicting;
   - For individual generating units: type of technology, Complete Generator OEM Technical Datasheet (which comprises namely generator parameters like impedances & time constants, generator capability curve, V-curve, generator open and short circuit characteristics, excitation system details, inertia of generator & exciter), generator name plate, generator SAT report including Short circuit and open circuit test results during commissioning/recent overhauling.
   - **Generator step up transformer**: GT name plate/datasheet, details of LV, MV and HV, MVA rating, impedance, tap changer details, vector group, short-circuit parameters (actual positive & zero sequence impedance of GT, NGR nameplate with impedance).
   - **Excitation system :-** Type of excitation system (Direct Current Commutator Exciters (type DC), AC Excitation (Rotor or brushless excitation) Systems (type AC) and Static Excitation Systems (type ST), Excitation system schematics (Block diagram of AVR system), transfer function block diagram of Excitation system, excitation transformer nameplate, saturation curves of the exciter (E_{fd} versus I_f curve), IEEE standard model of excitation system, IEEE standard model and its parameter of subsystems such as Power system stabilizer (PSS), Under Excitation Limiter (UEL), Over Excitation Limiter (OEL), Voltage per Hz Limiter(V/Hz) control etc. and details thereof, factory acceptance test reports (FAT). Excitation system actual settings to be provided. AVR test report (excitation step response test).

- **Power System Stabilizer (PSS):** Transfer function block diagram of PSS, IEEE Standard Model, Actual PSS software settings, PSS commissioning report and recent PSS tuning report.
- **Turbine-Governor system :-** Type of prime mover (open cycle, aero-derivative gas turbine or close cycle), droop and dead-band setting, characteristic of active power versus fuel valve position (or fuel stroke reference), size of steam turbine (ST), frequency control of ST, time lag and relationship of GT and ST, model of governor control system (including details of technology, valves, valves characteristics) , inlet guide vane (IGV) characteristic, ramp rates, base load/frequency control, details of heat recovery generator-HRSG (Block diagram, GT output vs heat relationship, Drum time constant, Pressure loss due to friction in boiler tubes), , turbine inertia, IEEE standard model of turbine governor system and its transfer function Block diagram and its parameters, details of control mode (boiler-follow, turbine-follow, or coordinated control), commissioning report of turbine-governor system or recent governor testing report.

2. Generic models of individual components (generator, exciter, turbine-governor and PSS of gas power generator (refer sections 3.2 to section 3.5)
    - Model should be suitable for an integration time step between 1ms and 20ms, and suitable for operation up-to 100 s
    - Simulation results depicting validation of generic models against user-defined models (for P, Q, V, I) and against actual measurement (after commissioning) to be provided.
3. Encrypted user defined model (UDM) in a format suitable for latest PSSE release PSS/E (*.dll files) for electromechanical transient simulation for components of gas power generators (in case non-availability of validated generic model)
    - User guide for Encrypted models to be provided including instructions on how the model should be set-up
    - Corresponding transfer function block diagrams to be provided
    - Simulation results depicting validation of User-Defined models against actual measurement to be provided
    - The use of black-box type representation is not preferred

Annexure: Formats for submission of modelling data for Gas-fired power generation

Version History:

Version no.	Release Date	Prepared by*	Checked/Issued by*	Changes

***Mention Designation and Contact Details**

Details submitted:

Details pending:

3.1 Details of models in PSS/E for modelling gas power generator:

(a) Synchronous Machine – To be filled separately for Gas turbine (GT) and steam turbine (ST)

Category	Parameter Description	Data
Generator Nameplate	Rated apparent power in MVA	
	Rated terminal voltage	
	Rated power factor	
	Rated speed (in RPM)	
	Rated frequency (in Hz)	
	Rated excitation (in Amperes and Volts)	
Type of synchronous machine	Round rotor or salient pole No. of poles	
Generator capability curve	The generator capability curve shows the reactive capability of the machine and should include any restrictions on the real or reactive power range like under/over excitation limits, stability limits, etc. Capability curve should have properly labelled axis and legible data	
Generator Open Circuit and Short Circuit Characteristic	Graph of excitation current versus terminal voltage and stator current	
	No load excitation current – used to derive per unit values	
	Excitation current at rated stator current	
Generator vee-curves	Otherwise referred to as “V-curve”. A plot of the terminal (armature) current versus the generating unit field voltage.	
Resistance values	Resistance measurements of field winding and stator winding to a known temperature	
Generator Data sheet	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd’ in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd’’ in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xa in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq’ in p.u. (Unsaturated or saturated)	
	Quadrature axis sub-transient synchronous reactance Xq’’ in p.u. (Unsaturated or saturated)	
	Direct axis open circuit transient time constant Tdo’ in sec	
	Direct axis open circuit sub-transient time constant Tdo’’ in sec	
	Quadrature axis open circuit transient time constant Tqo’ in sec	
	Quadrature axis open circuit sub-transient time constant Tqo’’ in sec	
	Inertia constant of total rotating mass (generator, AVR, turbo-governor set) H in MW.s/MVA	
	Speed Damping D	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

Category	Parameter Description	Data
Generator step up transformer (GSUT)	Nameplate Rating - Rated primary and secondary voltage - Vector group - Impedance - Tap changer details (Number of taps, tap position, tap ratio etc.)	
Auxiliary power (i.e. active and reactive auxiliary load)	Value of auxiliary load (MW and Mvar) at rated power of the generating unit.	
	Whether or not the load trips if the generating unit trips.	
Test Reports	Factory acceptance test (FAT) reports	

(b) Site Load

	Low Output			High Output		
	kW	kvar	kVA	kW	kvar	kVA
Auxiliary Load						

(c) Excitation System

Category	Parameter Description	Data
Type of Automatic Voltage Regulator (AVR)	Manufacturer and product details (for example ABB UNITROL or GE EX2100e)	
	Type of control system :- Analogue or digital	
	Year of commissioning / Year of manufacture	
	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
Type of excitation system	Static excitation system OR	
	Indirect excitation system (i.e. rotating exciter) - AC exciter, or - DC exciter	
Details of AVR converter	Rated excitation current (converter rating in Amperes)	
	Six pulse thyristor bridge or PWM converter	
Source of excitation supply	Excitation transformer or auxiliary supply (Details thereof)	
	If excitation transformer, nameplate information required	
Schematics	Saturation curves of the exciter (if applicable – see Type AC and DC)	
	Drawings of excitation system, typically prepared and supplied by the OEM	
	Single line diagram (i.e. one-line diagram) for the excitation system	
Excitation limiters	What excitation limiters are commissioned?	
	Under Excitation Limiters settings	
	Over Excitation Limiters settings	
	Voltage/frequency limiter	
	Stator current limiter	
	Minimum excitation current limiter	

Category	Parameter Description	Data
PSS	Is the AVR equipped with a PSS?	
	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)?	
	Type of PSS Block Diagram of PSS and as commissioned parameters value (Gain, time constants, filter coefficients, output limits of the PSS)	
Test Reports	Factory acceptance test (FAT) reports	

(d) Turbine Details (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)	

Category	Parameter Description	Data
Combine cycle plant	Details on heat recovery steam generator (HRSG) - 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	

3.2 Generic Models for synchronous machine

Gas turbine (GT) or steam turbines (ST) are generally round rotor machines however, salient pole Gas turbine (aero-derivative) with synchronous machine having four poles has also been installed at some of the places. Depending upon the saturation characteristic of the machine they are classified further:

- **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 Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo'' in sec	
	Quadrature axis open circuit transient time constant Tqo' in sec	
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xl in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	
GENSAE OR **GENSAL**	Direct axis open circuit transient time constant Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo'' in sec	
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xl in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

While entering the values in above table, following relationship must be kept:

Xd>Xq>Xq'≥Xd'>Xq"≥Xd''

Tdo'>Td'>Tdo''>Td''

Tqo''>Tq'>Tqo''>Tq''

3.3 Excitation system model:

If a generic model is used, the first step must be to identify what type of exciter is present in the excitation system. The IEEE Std 421.5 (IEEE Recommended Practice for Excitation System Models for Power System Stability Studies published on 26th Aug 2016) has published several generic models, which are 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

Category	Parameter Description	Data
DC Exciter		
ESDC1A OR ESDC2A	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (> 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	TR regulator input filter time constant (sec)	
	KV (pu) limit on fast raise/lower contact setting	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	TRH (> 0) Rheostat motor travel time (sec)	
	TE (> 0) exciter time-constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	VEMIN (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)	

Category	Parameter Description	Data
DC Exciter		
ESDC4B	TR regulator input filter time constant (sec)	
	KP (pu) (> 0) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KD (pu) voltage regulator derivative gain	
	TD voltage regulator derivative channel time constant (sec)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KA (> 0) (pu) voltage regulator gain	
	TA voltage regulator time constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	VEMIN (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)	
ESAC1A	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (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)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	

Category	Parameter Description	Data
DC Exciter		
ESAC2A	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KB, Second stage regulator gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	KH, Exciter field current feedback gain	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (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)	

Category	Parameter Description	Data
AC Exciter		
ESAC3A	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	KR (>0), Constant associated with regulator and alternator field power supply	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KN, Exciter feedback gain	
	EFDN, A parameter defining for which value of UF the feedback gain shall change from KF to KN	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	VFEMAX, 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)	
ESAC4A	TR regulator input filter time constant (sec)	
	VIMAX, Maximum value of limitation of the integrator signal VI in p.u	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC, rectifier regulation factor (pu)	

Category	Parameter Description	Data
AC Exciter		
ESAC5A	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (sec), Regulator stabilizing circuit time constant in seconds	
	TF2 (sec), Regulator stabilizing circuit time constant in seconds	
	TF3 (sec), Regulator stabilizing circuit time constant in seconds	
	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	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TK (sec), Lead time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFELIM, Exciter field current limit reference	
	KH, Damping module gain	
	VHMAX, damping module limiter	
	TH (sec), damping module lag time constant	
	TJ (sec), damping module lead time constant	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (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)	

Category	Parameter Description	Data
AC Exciter		
AC7B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KPA (pu) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KP (pu)	
	KL (pu)	
	KF1 (pu)	
	KF2 (pu)	
	KF3 (pu)	
	TF3 (sec) time constant (> 0)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) exciter field current limit (> 0)	
	VEMIN (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
AC Exciter		
AC8B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VPIDMAX (pu) PID maximum limit	
	VPIDMIN (pu) PID minimum limit	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) max exciter field current limit (> 0)	
	VEMIN (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)	
Static Exciter		
ST1A	TR (sec) regulator input filter time constant	
	VIMAX, Controller Input Maximum	
	VIMIN, Controller Input Minimum	
	TC (s), Filter 1st Derivative Time Constant	
	TB (s), l Filter 1st Delay Time Constant	
	TC1 (s), Filter 2nd Derivative Time Constant	
	TB1 (s), Filter 2nd Delay Time Constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KLR, Current Input Factor	
	ILR, Current Input Reference	

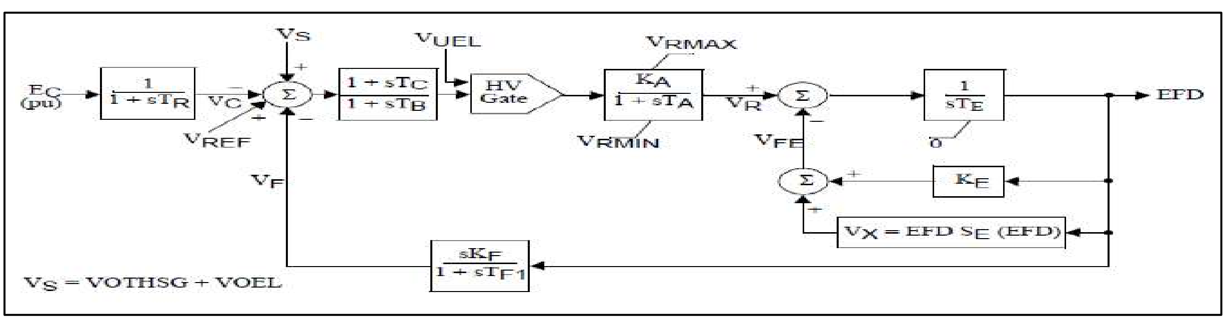
Category	Parameter Description	Data
Static Exciter		
ST2A	TR (sec) regulator input filter time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	EFDMAX	
ST3A	TR (sec) regulator input filter time constant	
	VIMAX, Maximum value of limitation of the signal VI in p.u.	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	KM, Forward gain constant of the inner loop field regulator	
	TC (s), lag time constant	
	TB (s), lead time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KG, Feedback gain constant of the inner loop field regulator	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX, Maximum value of limitation of the signal VB in p.u.	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL, Reactance associated with potential source	
	VGMAX, Maximum value of limitation of the signal VG in p.u	
	Θ_P (degrees)	
	TM (sec), Forward time constant of the inner loop field regulator	
	VMMAX, Maximum value of limitation of the signal VM in p.u	
	VMMIN, Minimum value of limitation of the signal VM in p.u.	

Category	Parameter Description	Data
Static Exciter		
ST4B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TA (sec) voltage regulator time constant	
	KPM, Regulator gain	
	KIM, Regulator gain	
	VMMAX, Maximum value of limitation of the signal in p.u.	
	VMMIN, Minimum value of limitation of the signal in p.u.	
	KG	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL	
	Θ_P (degrees)	
ST5B	TR regulator input filter time constant (sec)	
	TC1 lead time constant of first lead-lag block (voltage regulator channel) (sec)	
	TB1 lag time constant of first lead-lag block (voltage regulator channel) (sec)	
	TC2 lead time constant of second lead-lag block (voltage regulator channel) (sec)	
	TB2 lag time constant of second lead-lag block (voltage regulator channel) (sec)	
	KR (>0) (pu) voltage regulator gain	
	VRMAX (pu) voltage regulator maximum limit	
	VRMIN (pu) voltage regulator minimum limit	
	T1 voltage regulator time constant (sec)	
	KC (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)	
	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)	

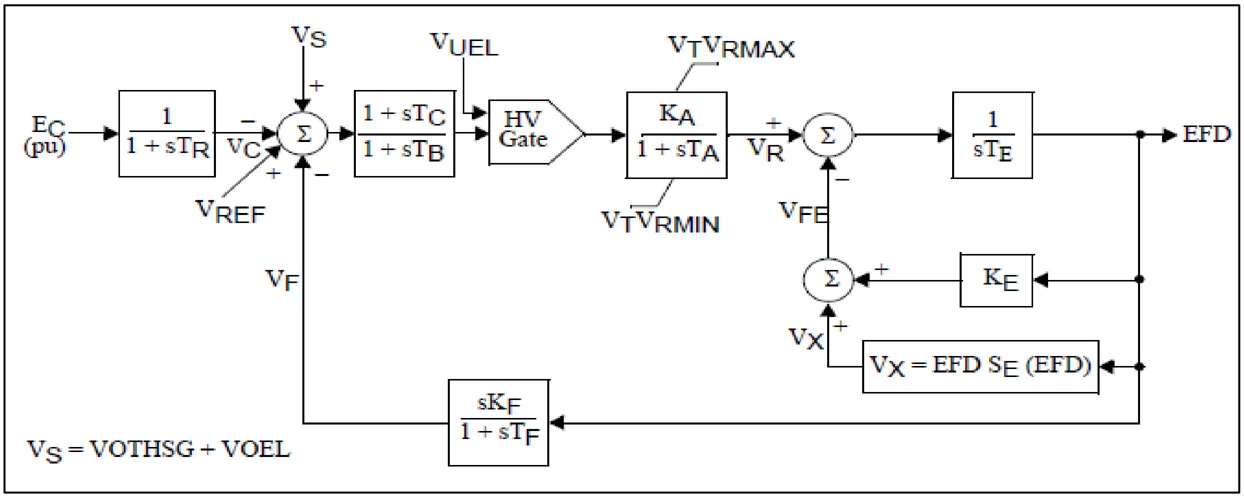
Category	Parameter Description	Data
Static Exciter		
	TR regulator input filter time constant (sec)	
	KPA (pu) (> 0) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	KDA (pu) voltage regulator derivative gain	
	TDA voltage regulator derivative channel time constant (sec)	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
ST6B	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	
	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)	
	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	
ST7B	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)	

(i) DC Exciters Generic model:

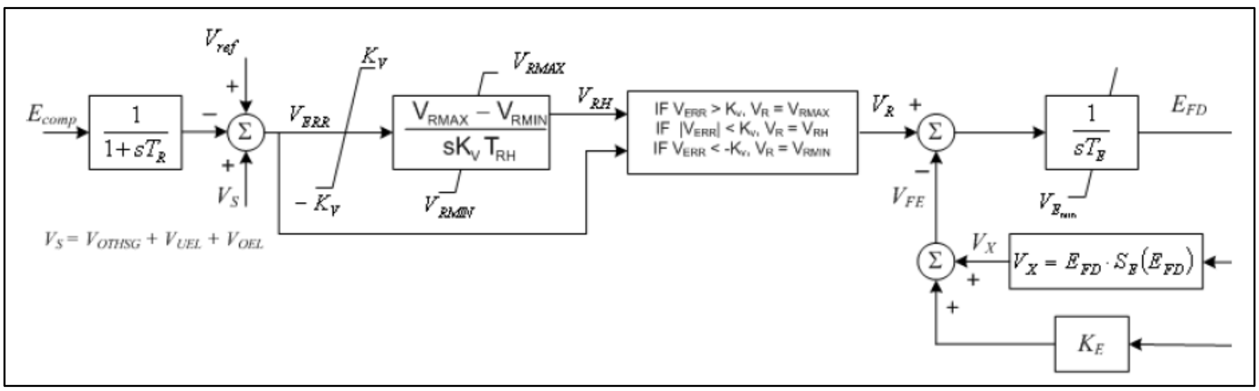
- **Type DC1A: 1992 IEEE type DC1A excitation system model**



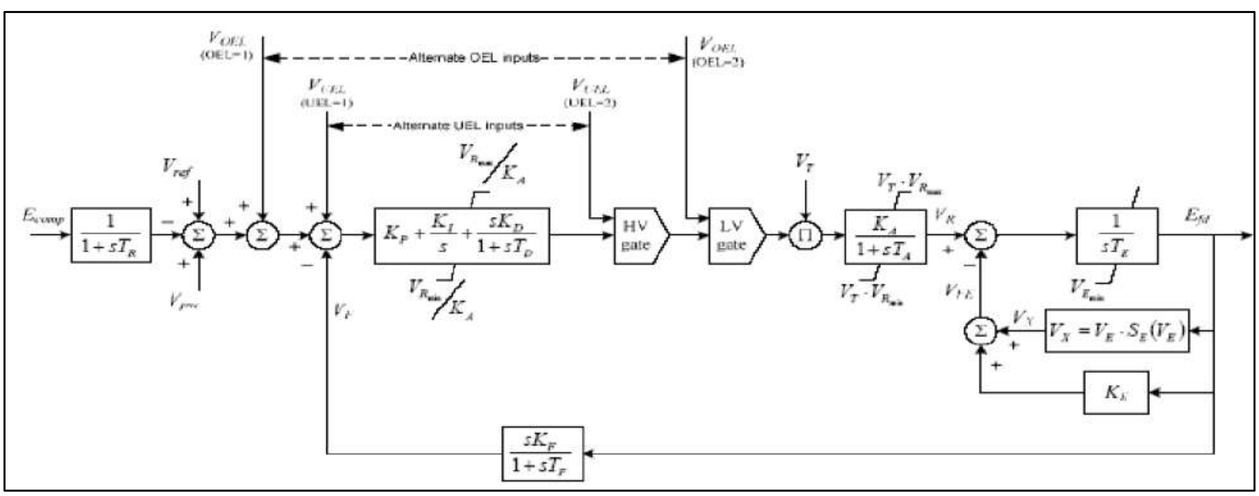
- **Type DC2A: 1992 IEEE type DC2A excitation system model**



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

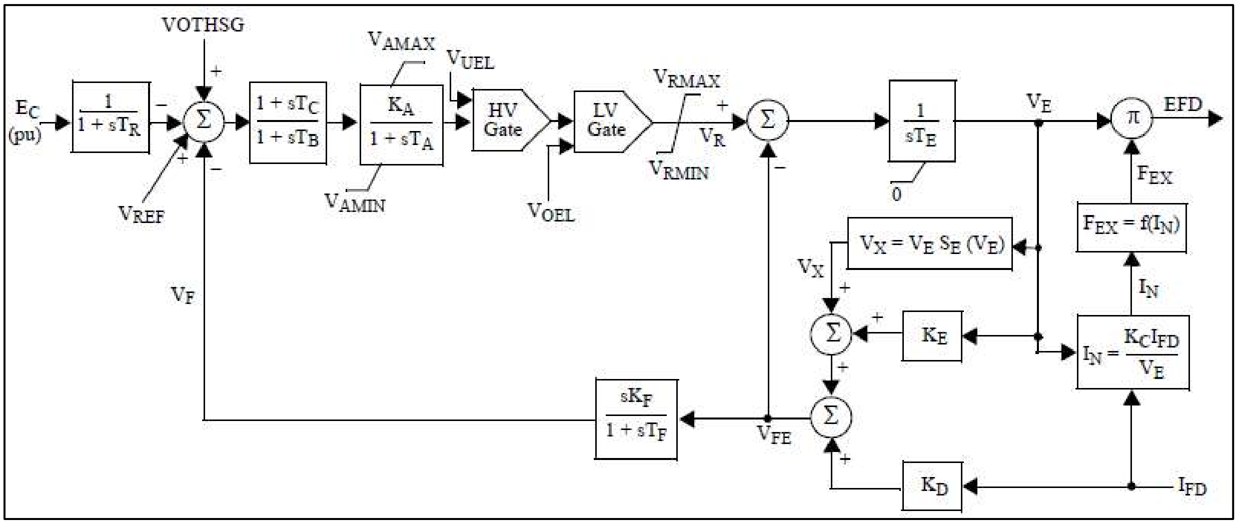


- **Type DC4B: IEEE 421.5 2005 DC4B excitation system**



(ii) **AC Exciters Generic Models:**

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

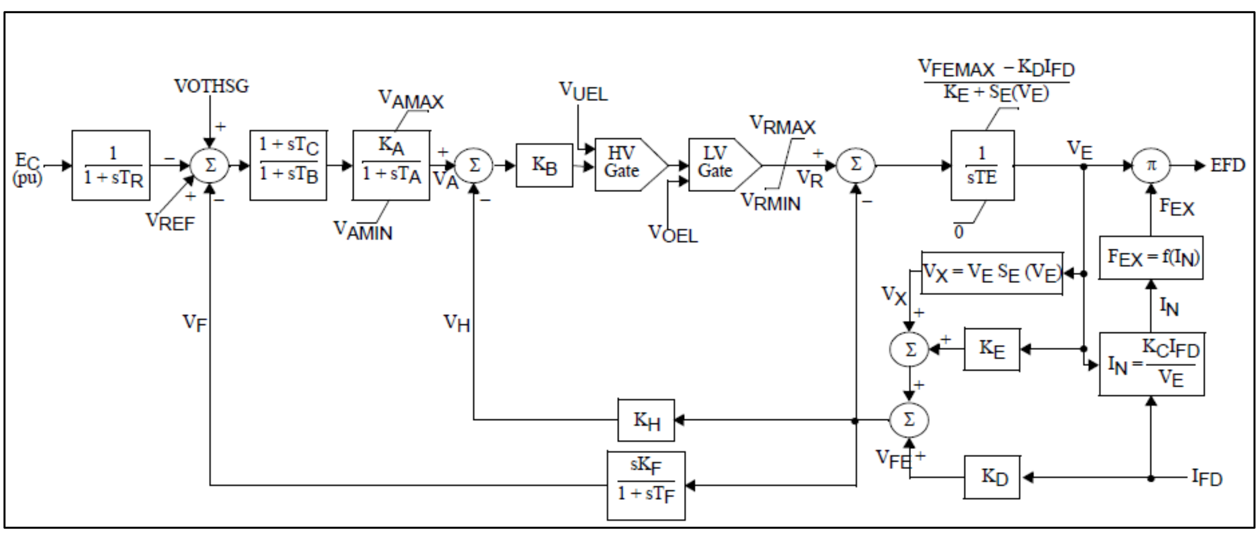


$I_N \rightarrow$

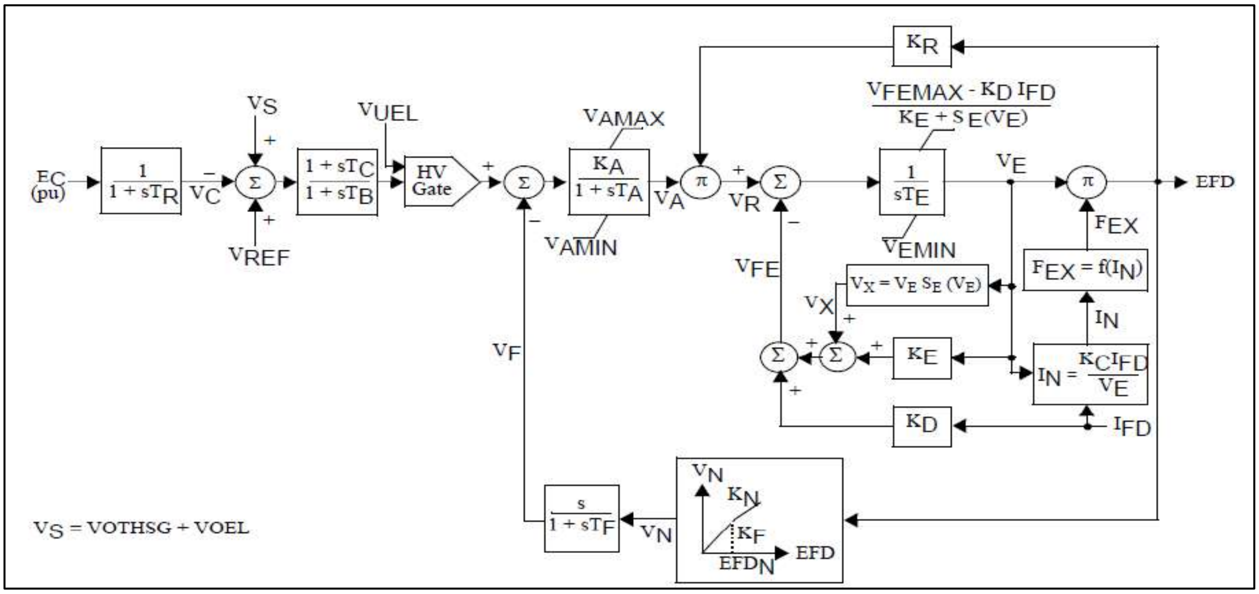
If $I_N \le 0$	$F_{EX} = 1$
If $I_N \le 0.433$	$F_{EX} = 1 - 0.577\, I_N$
If $0.433 < I_N < 0.75$	$F_{EX} = \sqrt{0.75 - I_N^2}$
If $I_N \ge 0.75$	$F_{EX} = 1.732(1 - I_N)$
If $I_N > 1$	$F_{EX} = 0$

$\rightarrow F_{EX}$

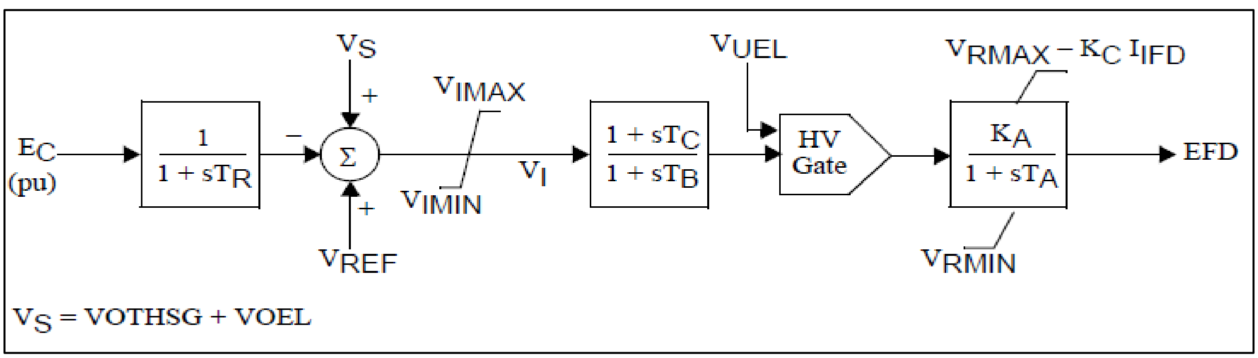
- **Type AC2A: 1992 IEEE type AC2A excitation system model**



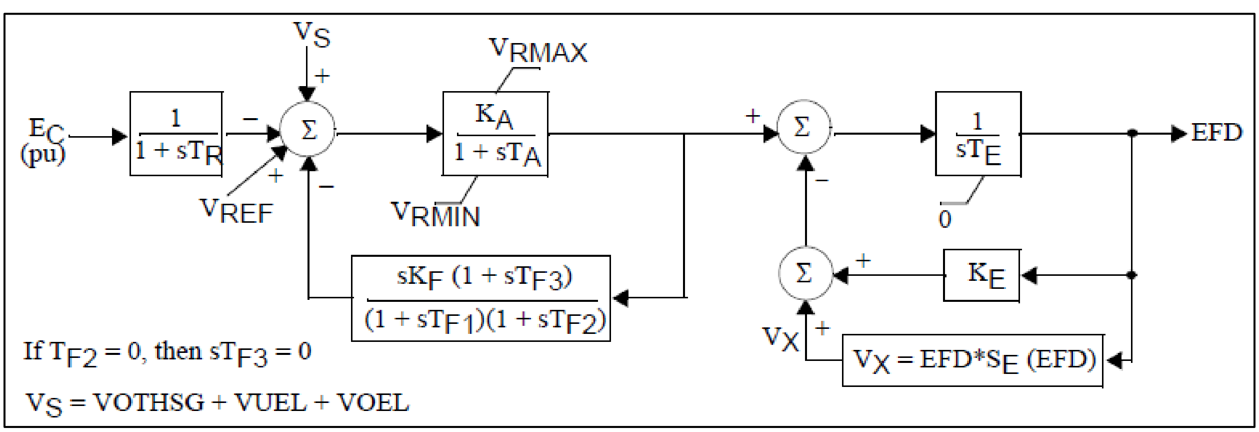
- **Type AC3A: 1992 IEEE type AC3A excitation system model**



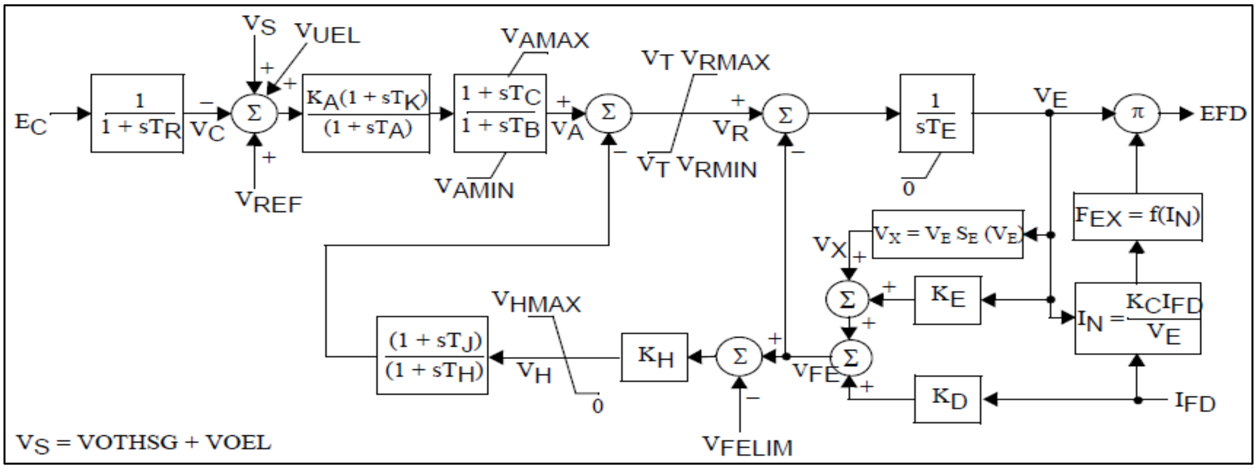
- **Type AC4A: 1992 IEEE type AC4A excitation system model**



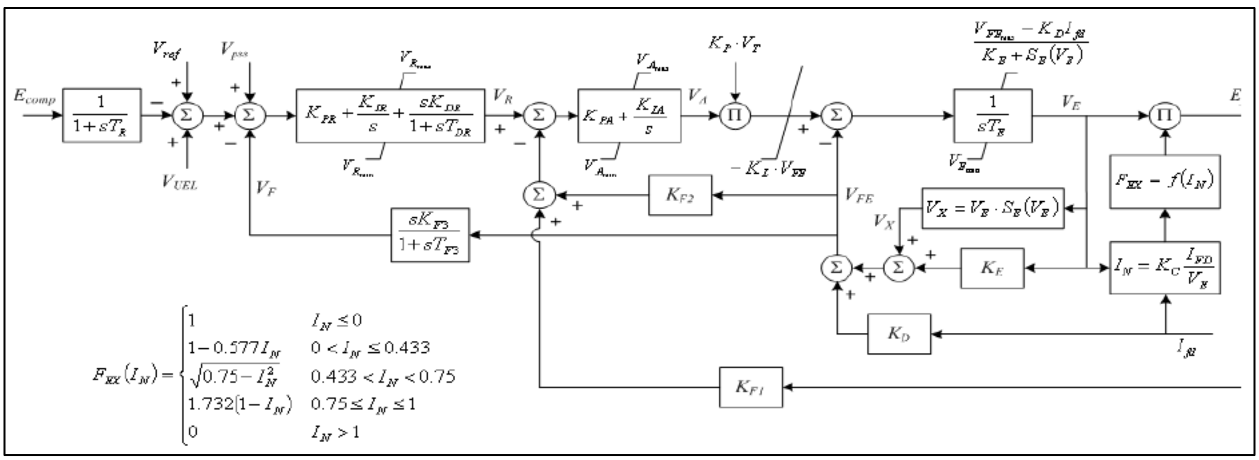
- **Type AC5A: 1992 IEEE type AC5A excitation system model**



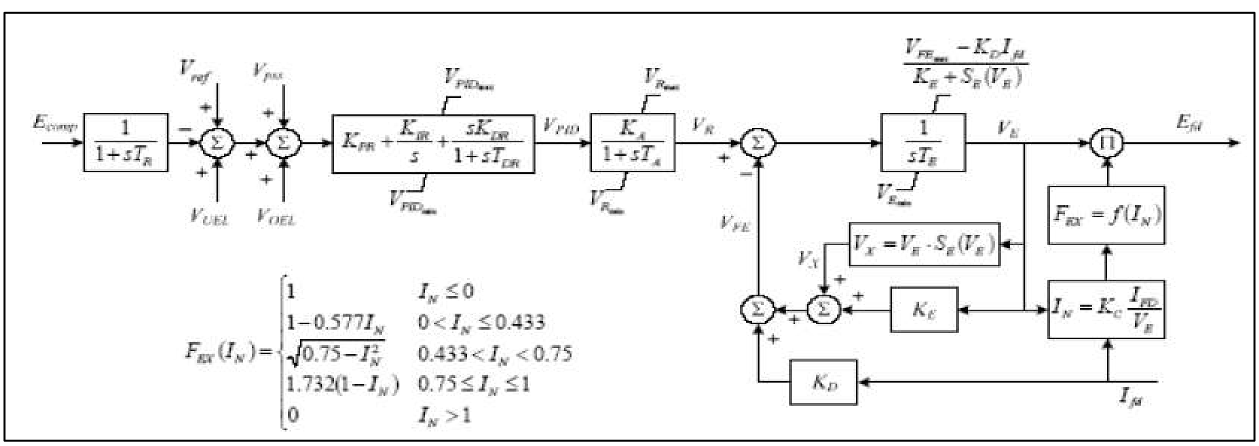
- **Type AC6A: IEEE 421.5 excitation system model**



- **Type AC7B: IEEE 421.5 2005 AC7B excitation system**

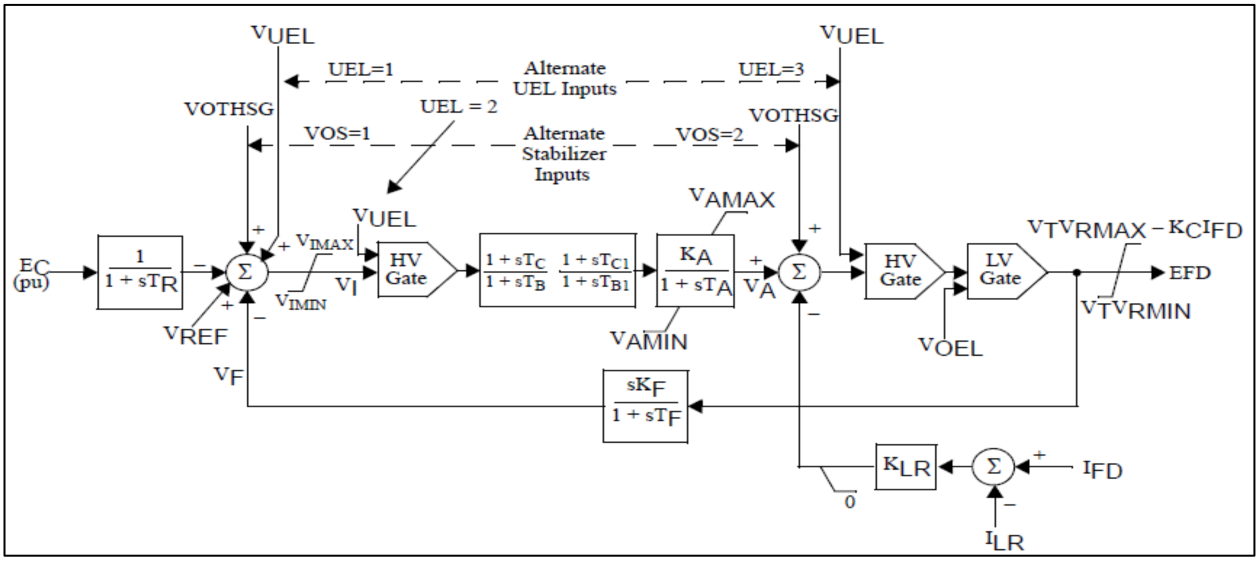


- **Type AC8B: IEEE 421.5 2005 AC8B excitation system**

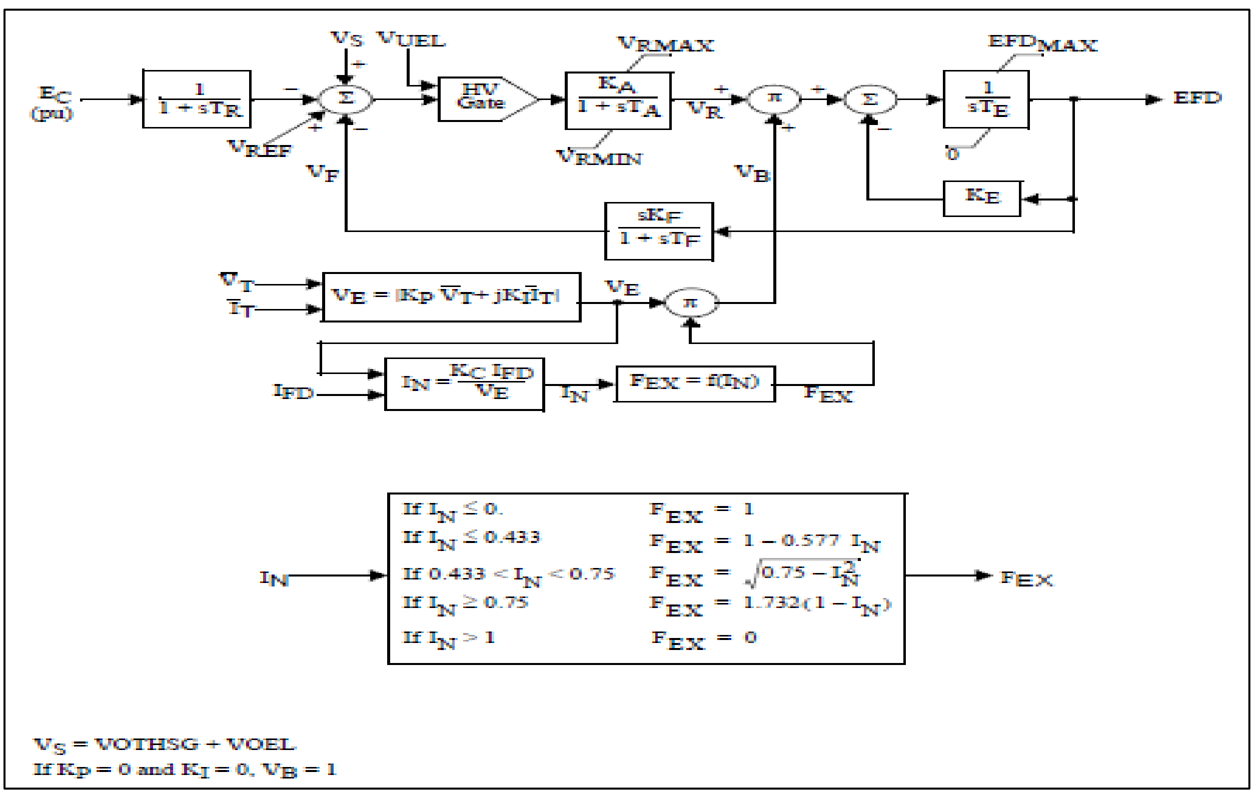


(iii) **Commonly Used Static Exciters Generic Models block diagrams:**

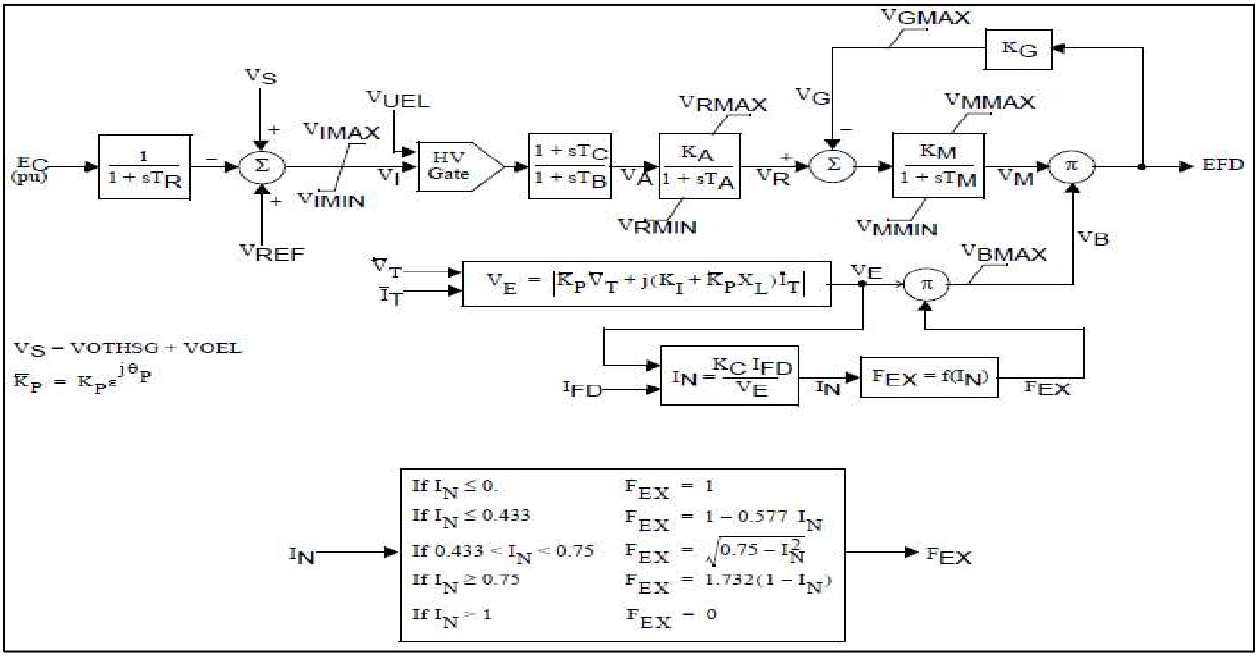
- **Type ST1A: 1992 IEEE type ST1A excitation system model**



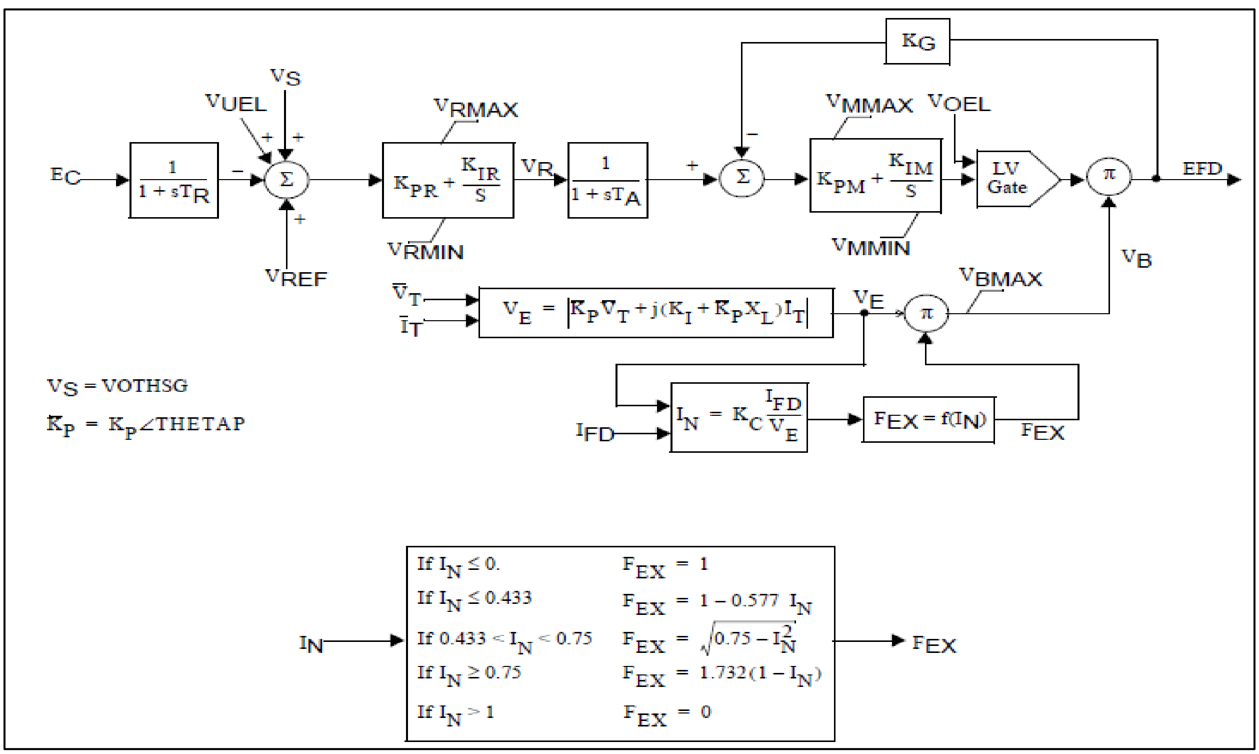
- **Type ST2A: 1992 IEEE type ST2A excitation system model**



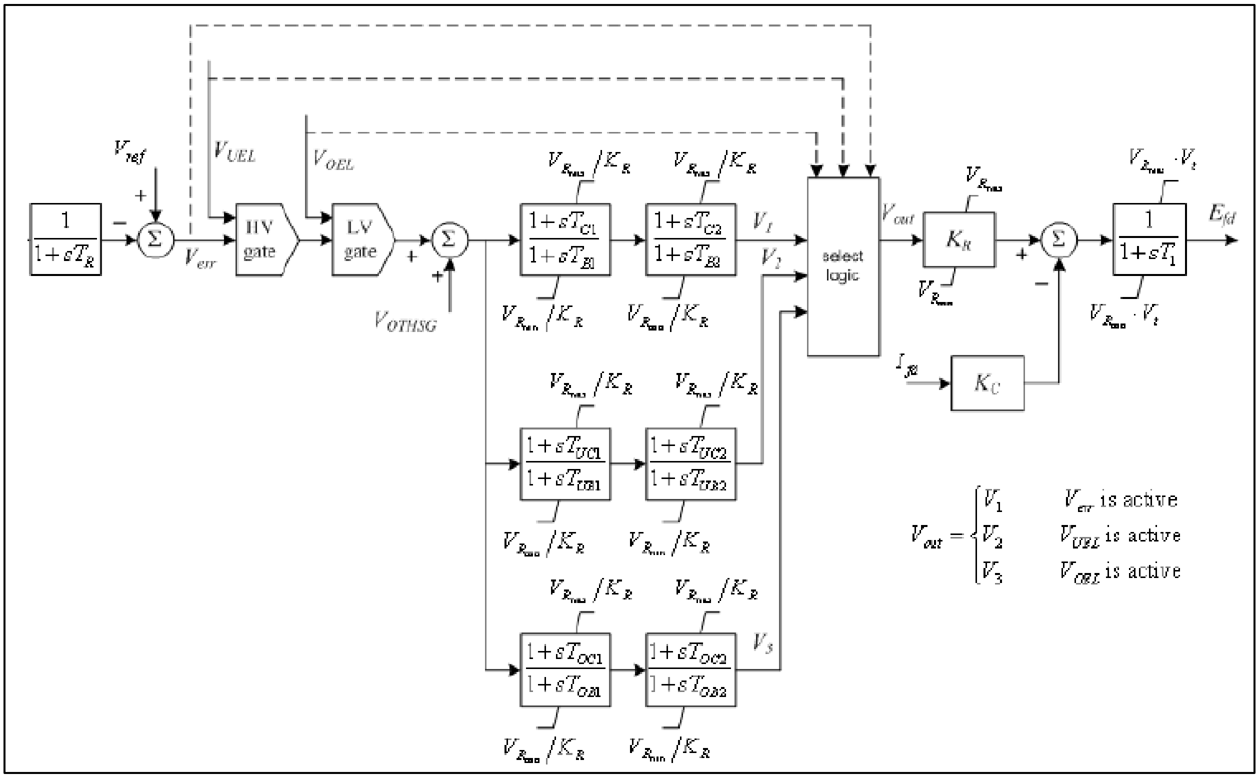
- **Type ST3A: 1992 IEEE type ST3A excitation system model**



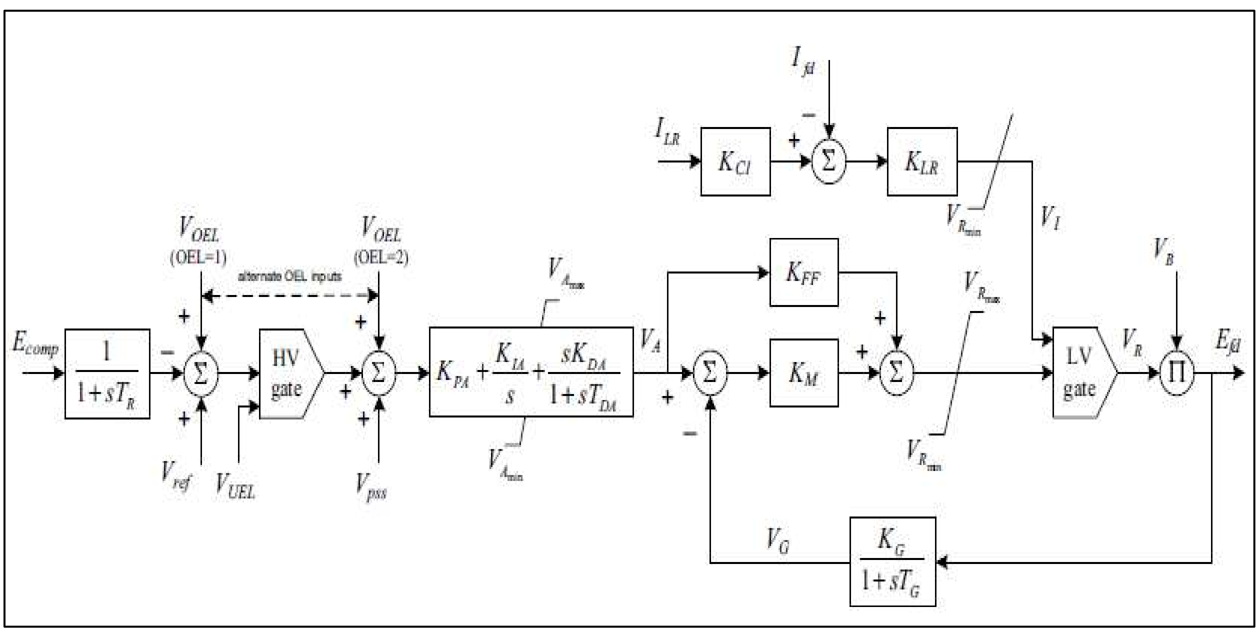
- **Type ST4B: IEEE type ST4B potential or compounded source-controlled rectifier exciter**



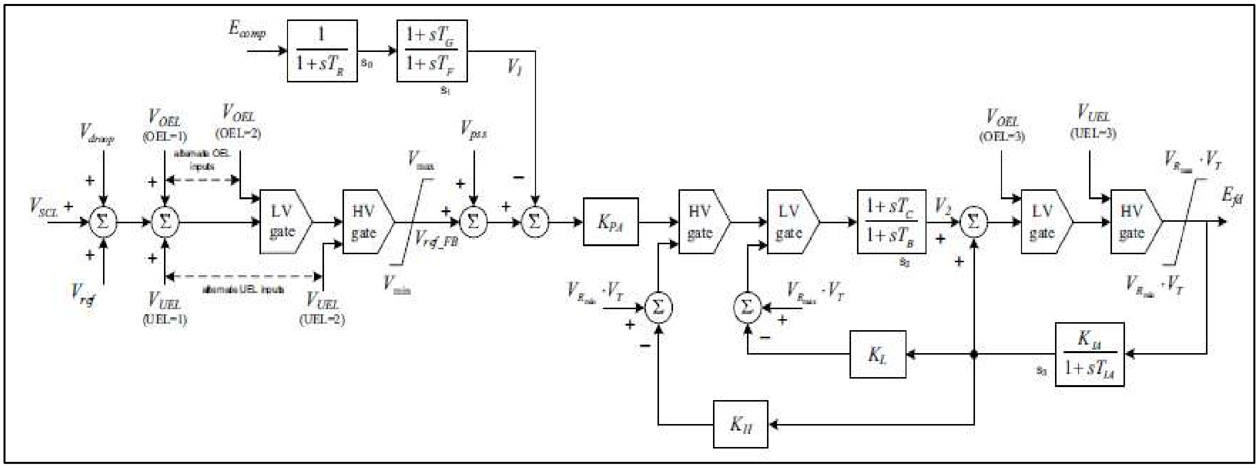
- **Type ST5B: IEEE 421.5 2005 ST5B excitation system**



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



- **Type ST7B: IEEE 421.5 2005 ST7B excitation system**



Source-PSSE Model Library

3.4 Power system stabilizer:

The function of the PSS is to add to the unit's characteristic electromechanical oscillations. This is achieved by modulating excitation to develop a component in electrical torque in phase with rotor speed deviations.

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:

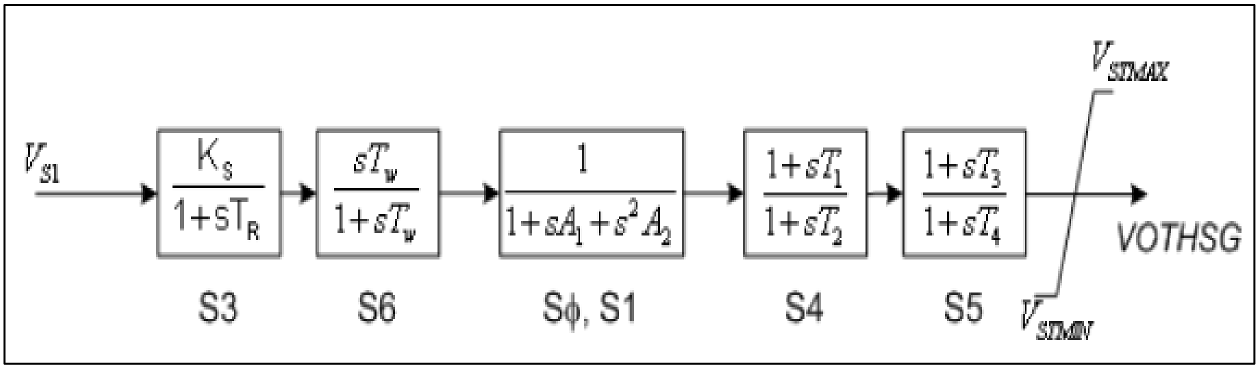
Type	Inputs	Remarks
PSS1A	Single input	Two lead-lags Input can either be speed, frequency or power
PSS2B	Dual input	Integral of accelerating power type stabiliser Speed and Power Most common type Supersedes PSS2A (three versus two lead lags)
PSS3B	Dual input	Power and rotor angular frequency deviation Stabilising signal is a vector sum of processed signals Not very common

Category	Parameter Description	Data
Stabilizer Models		
PSS1A	A1, Filter coefficient	
	A2, Filter coefficient	
	TR, transducer time constant	
	0	
	0	
	0	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	Tw, Washout Time Constant	
	Tw, Washout Time Constant	
	Ks, input channel gain	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	
	0	
	0	
PSS2B	TW1, 1st Washout 1th Time Constant	
	TW2, 1st Washout 2th Time Constant	
	T6, 1st Signal Transducer Time Constant	
	TW3, 2nd Washout 1th Time Constant	
	TW4, 2nd Washout 2th Time Constant	
	T7, 2nd Signal Transducer Time Constant	
	KS2, 2nd Signal Transducer Factor	
	KS3, Washouts Coupling Factor	
	T8, Ramp Tracking Filter Deriv. Time Constant	
	T9, Ramp Tracking Filter Delay Time Constant	
	KS1, PSS Gain	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	T10, 3rd Lead-Lag Derivative Time Constant	
	T11, 3rd Lead-Lag Delay Time Constant	
	VS1MAX, Input 1 Maximum limit	
	VS1MIN, Input 1 Minimum limit	
	VS2MAX, Input 2 Maximum limit	
	VS2MIN, Input 2 Minimum limit	
	VSTMAX, Controller Maximum Output	
	VSTMIN, Controller Minimum Output	

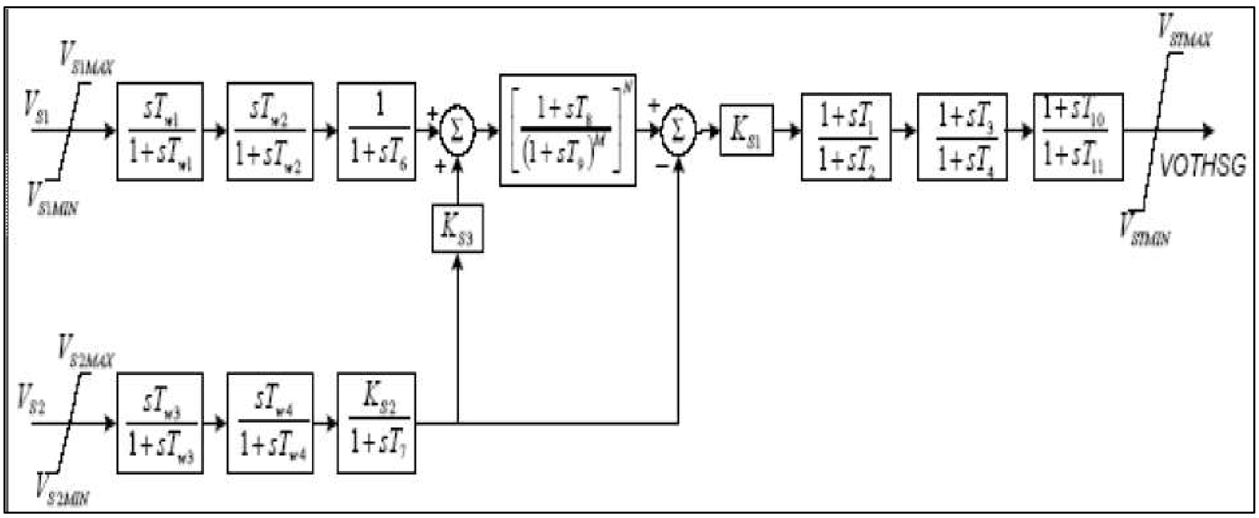
Category	Parameter Description	Data
Stabilizer Models		
PSS3B	KS1 (pu) (≠0), input channel #1 gain	
	T1 input channel #1 transducer time constant (sec)	
	Tw1 input channel #1 washout time constant (sec)	
	KS2 (pu) (□0), input channel #2 gain	
	T2 input channel #2 transducer time constant (sec)	
	Tw2 input channel #2 washout time constant (sec)	
	Tw3 (0), main washout time constant (sec)	
	A1, Filter coefficient	
	A2, Filter coefficient	
	A3, Filter coefficient	
	A4, Filter coefficient	
	A5, Filter coefficient	
	A6, Filter coefficient	
	A7, Filter coefficient	
	A8, Filter coefficient	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	

Commonly Used Power System Stabilizer generic models block diagrams:

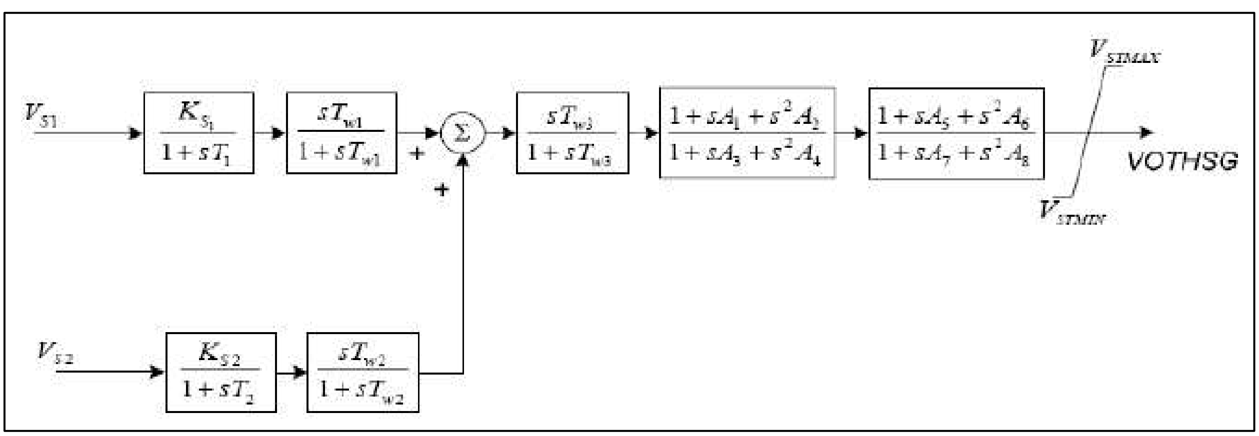
- **PSS1A: IEEE Std. 421.5-2005 PSS1A Single-Input Stabilizer model**



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



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



Source-PSSE Model Library

3.5 Generic models for gas turbine-governor:

The following table is a list for 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 be configured 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 Gas Turbine	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	

Source: PSSE Model Library, for models other than the above list refer to

https://w3.usa.siemens.com/smartgrid/us/en/transmission-grid/products/grid-analysis-tools/transmission-system-planning/transmission-system-planning-tab/pages/user-support.aspx

Category	Parameter Description	Data
TURBINE GOVERNOR model		
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	
GAST2A	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	
	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	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
GASTWD	KDROOP (on turbine rating)	
	KP, Proportional gain	
	KI, Integral gain	
	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	
	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	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
GGOV1	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	
	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	
	Rup, Maximum rate of load limit increase	
	Rdown, Maximum rate of load limit decrease	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
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	
	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	

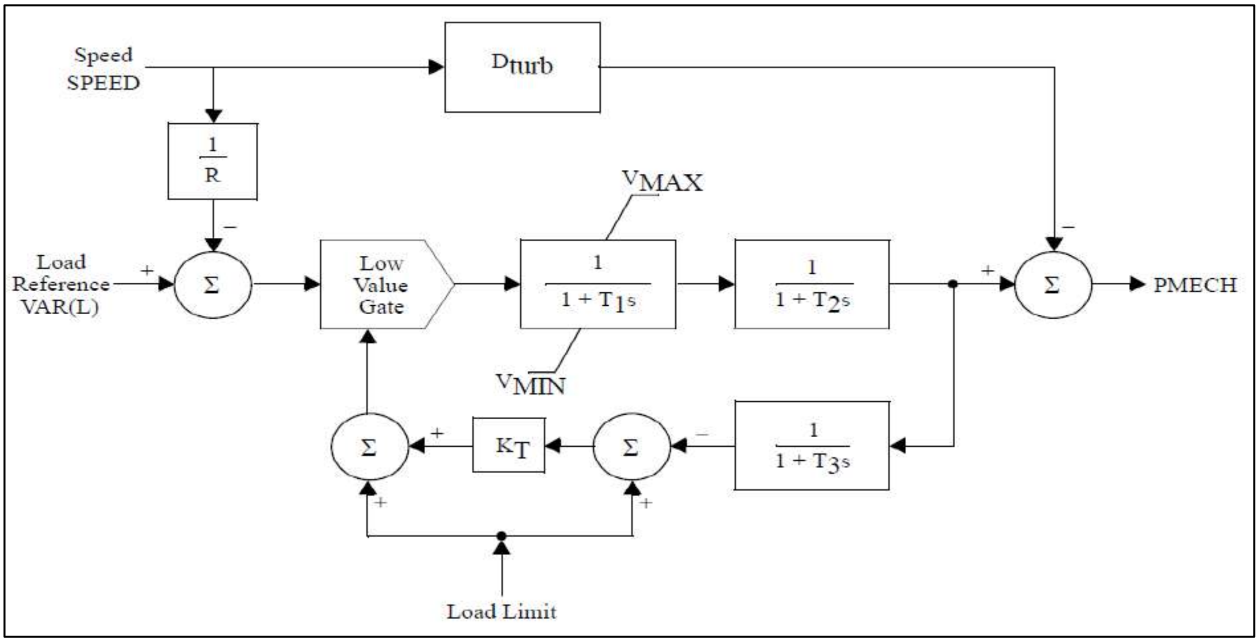
Category	Parameter Description	Data
TURBINE GOVERNOR model		
URCSCT	W, governor gain (1/droop) (on turbine rating)	
	X (sec) governor lead time constant	
	Y (sec) (> 0) governor lag time constant	
	Z, governor mode:1 Droop or 0 ISO	
	ETD (sec), Turbine exhausts time constant	
	TCD (sec), Gas turbine 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	
	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)	
	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)	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
URSCT (continued)	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)	
	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)	

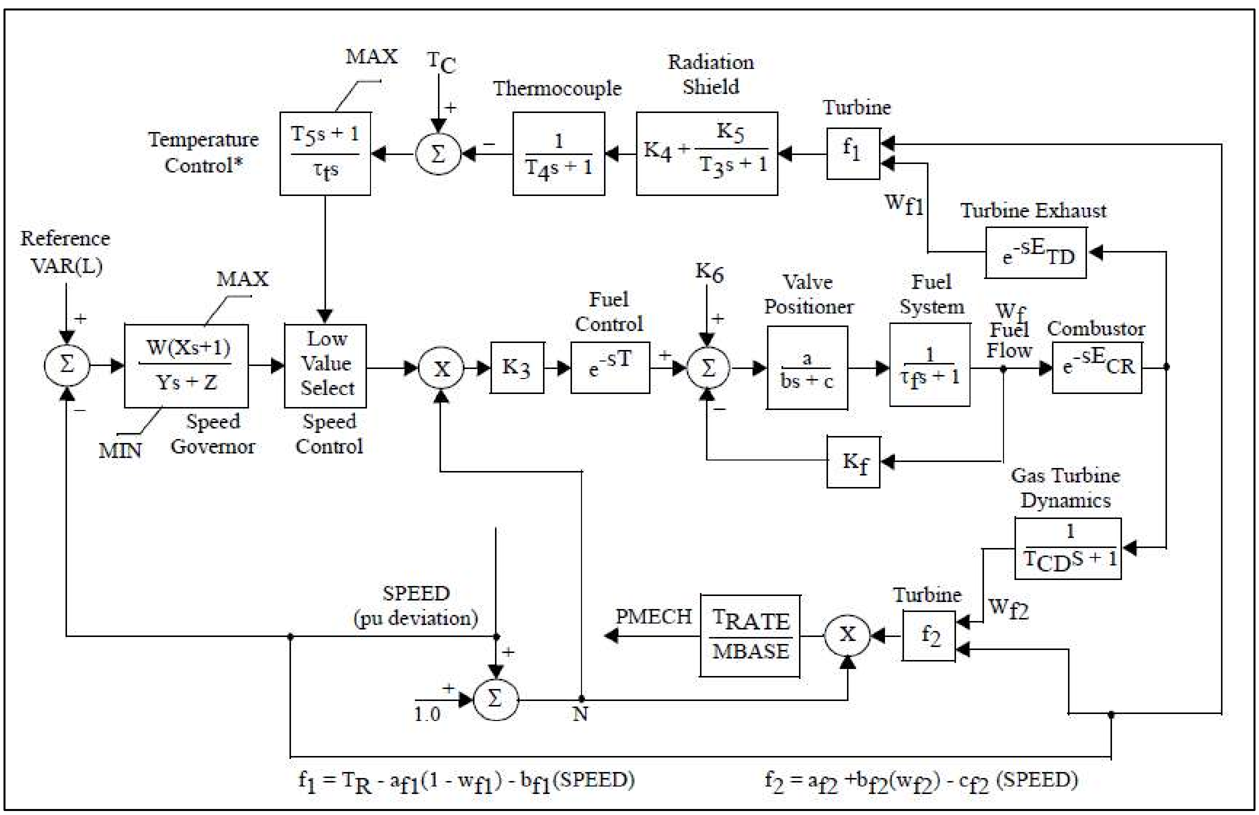
URGS3T (CONTINUED)	PGV1, coordinate of power-gate look-up table (p.u. power)	
	GV2, coordinate of power-gate look-up table (p.u. gate)	
	PGV2, coordinate of power-gate look-up table (p.u. power)	
	GV3, coordinate of power-gate look-up table (p.u. gate)	
	PGV3, coordinate of power-gate look-up table (p.u. 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)	
	Ka	
	T4	
	T5	
	MWCAP	

Commonly Used Gas Turbine Generic Models Block Diagrams:

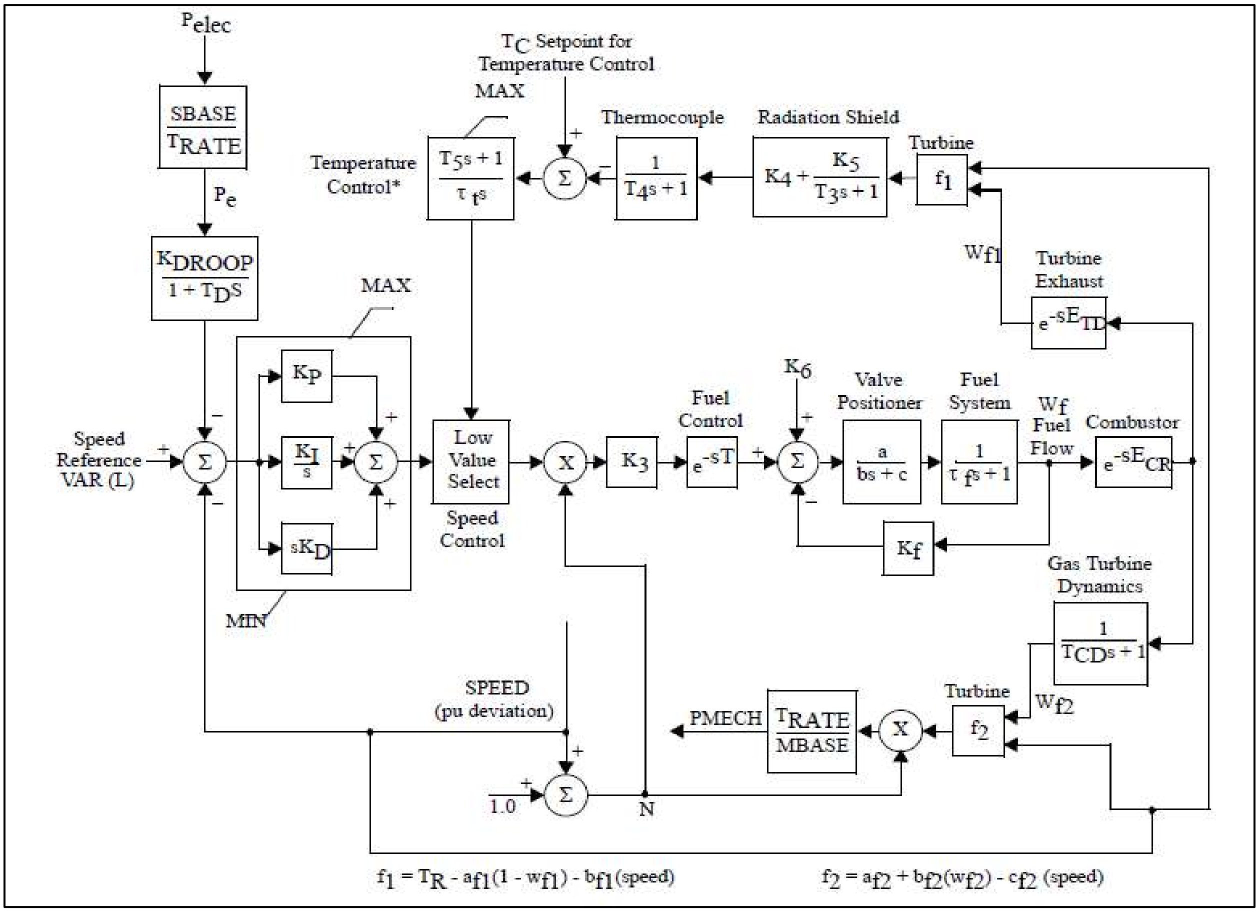
- **GAST: Gas Turbine-Governor**



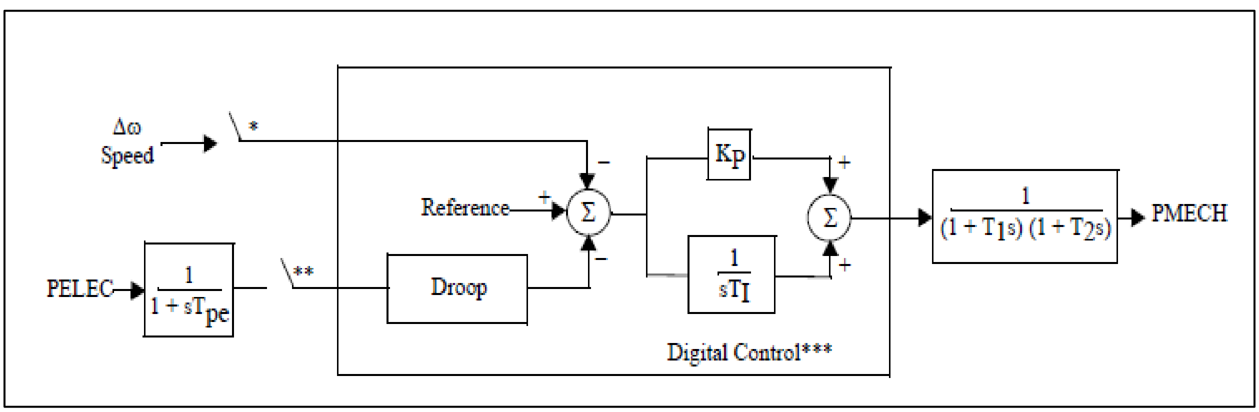
- **GAST2A: Hydro Turbine-Governor**



- **GASTWD: Woodward Gas Turbine-Governor Model**



- **WESGOV: Westinghouse Digital Governor for Gas Turbine**

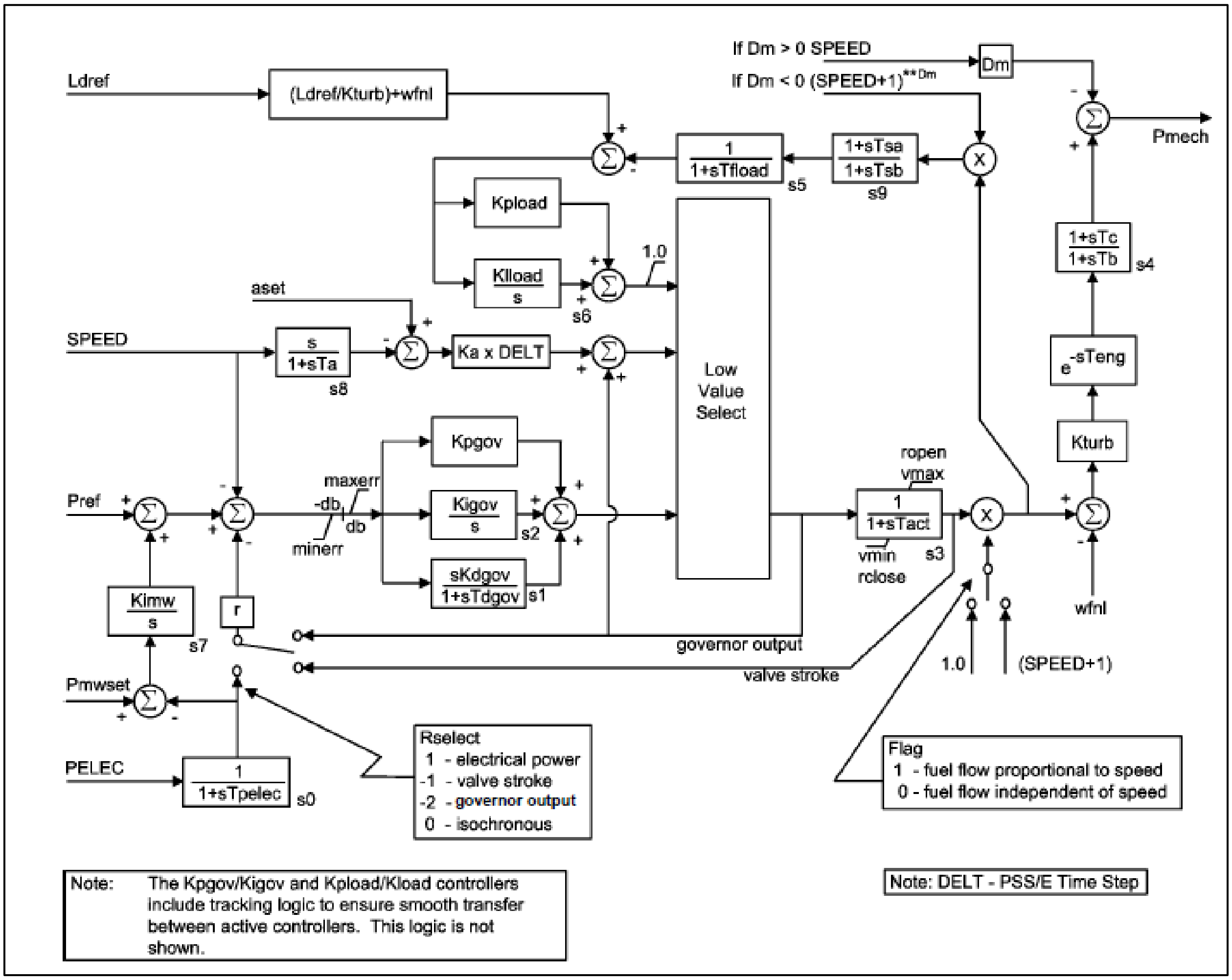


**Sample hold with sample period defined by ΔTC.*

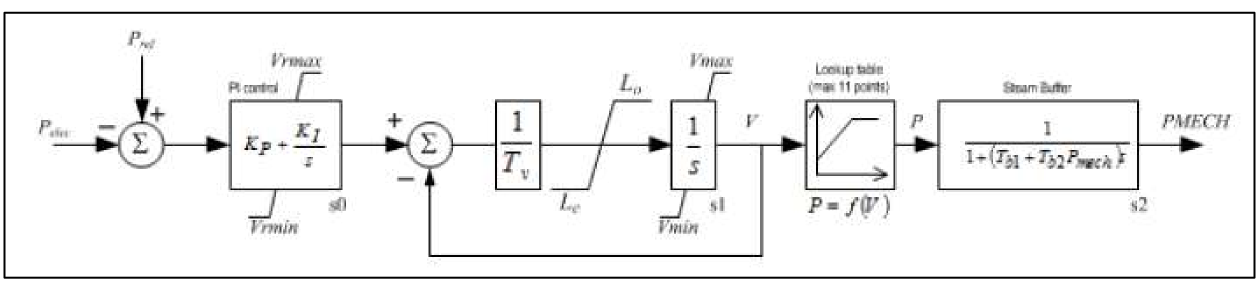
***Sample hold with sample period defined by ΔTP.*

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

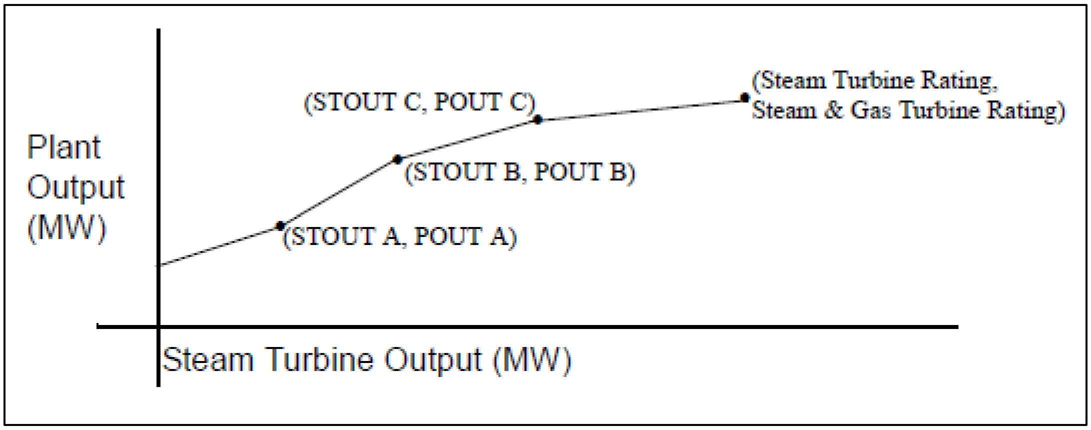
➢ GGOV1: GE General Governor/Turbine Model



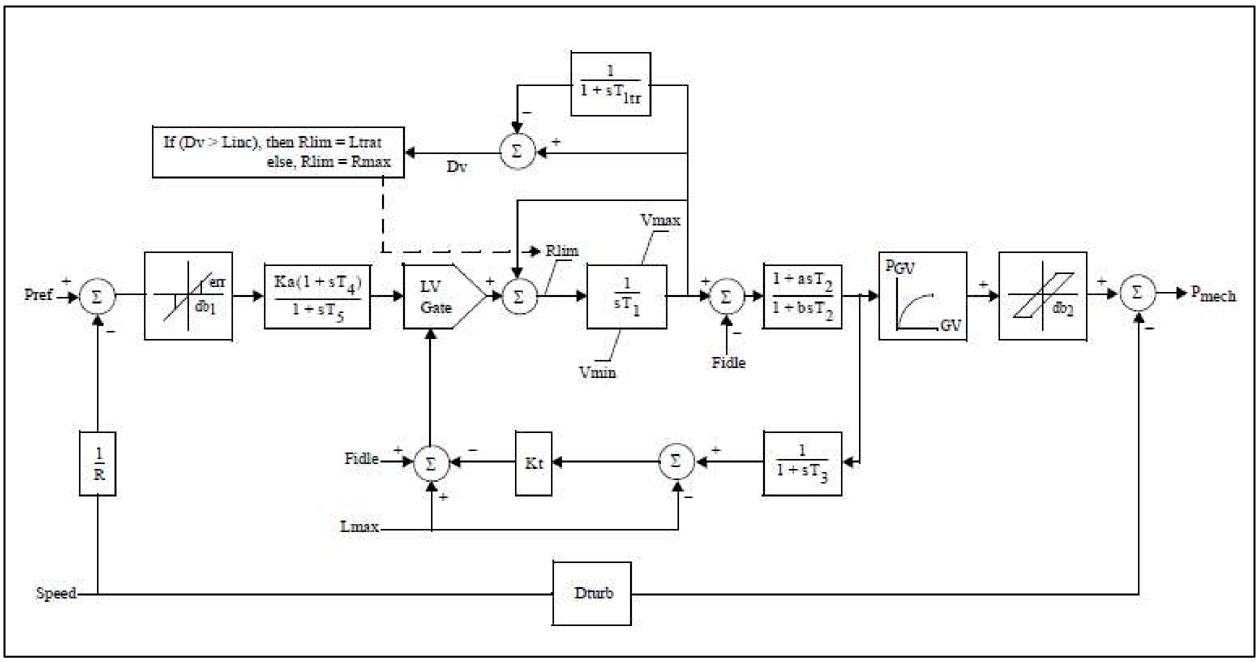
➢ PWTBD1: Pratt & Whitney Turboden Turbine-Governor Model



- **URCSCT: Combined Cycle on Single Shaft**



- **URGS3T: WECC Gas Turbine Model**



Source-PSSE Model Library

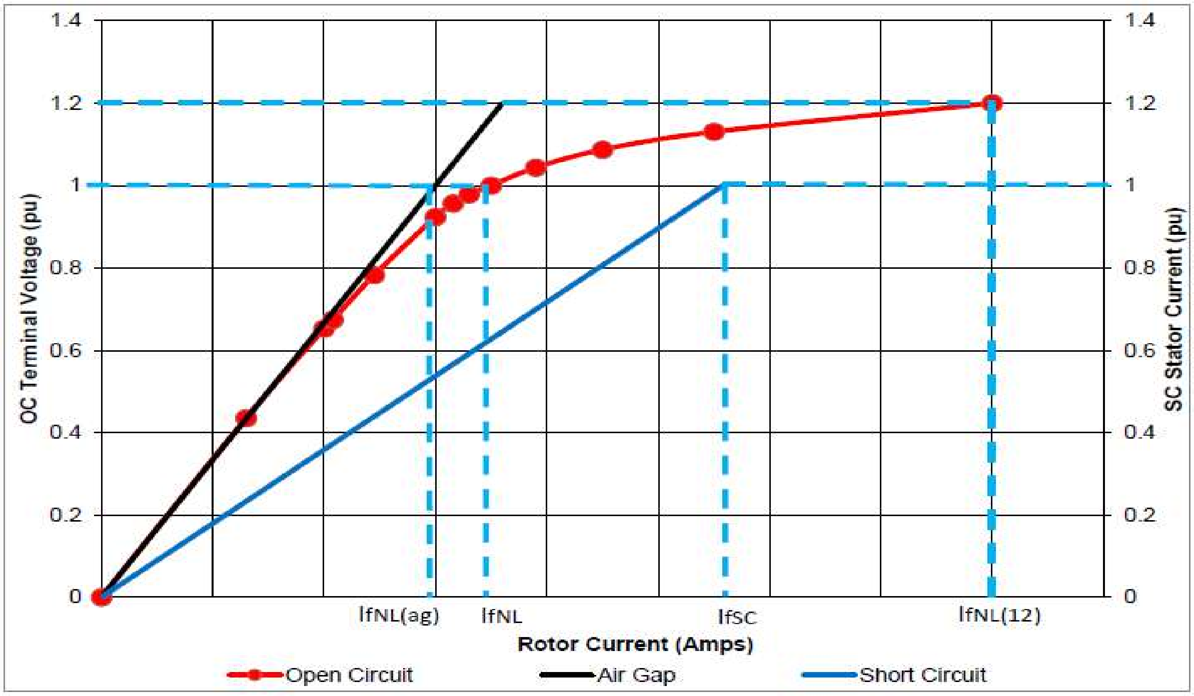


Figure 4: Open and short circuit characteristics

The saturation can be calculated using the following calculation:

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

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

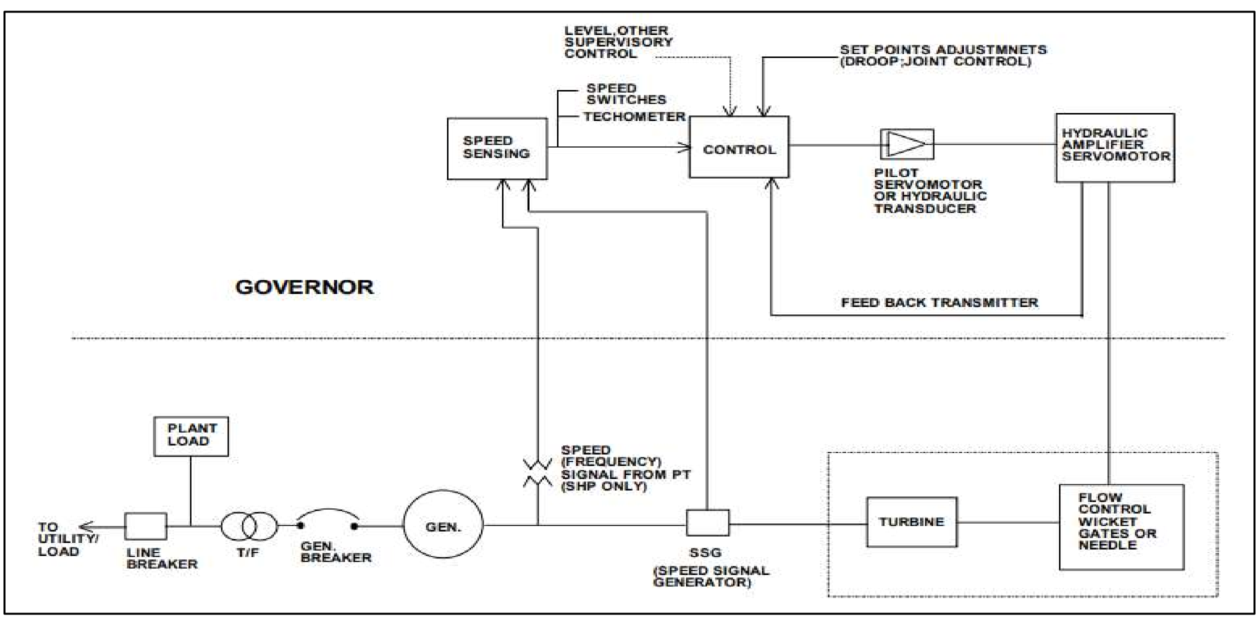


Figure 5: Governing system - Block Diagram (Typical) as per IEEE std. -75

Procedure for furnishing information for modelling Hydro Power Generation in Indian Grid

1.0 Introduction:

The purpose of this document is to act as a guideline for exchange of information for accurate modelling of hydro power generation in India. Availability of fit-for-purpose steady state and dynamics models of hydro power generation will enable secure operation of Indian power grid and enable identification of potential weak points in the grid so as to take appropriate remedial actions.

1.1 Applicability:

The guideline shall be applicable to all hydro power generation in India that can have an impact on operation of the power grid of India, irrespective of connection at Intra-STS or ISTS (Inter-state Transmission System).

This document presents the desired information for collection of data for modelling of hydro power generation in PSS/E software, a software suite being used pan-India at CEA, CTU, SLDCs, RLDCs, and NLDC for modelling of India's power grid. A systematic set of data and basic criteria for furnishing data are presented.

1.2 Need for a fit-for-purpose model:

There is a cost involved in developing and validating dynamic models of power system equipment. But there are much higher benefits for the power system if this leads to a functional, fit-for-purpose model, and arrangements that allow that model to be maintained over time.

A functional fit-for-purpose dynamic model will:

- Facilitate significant power system efficiencies by allowing power system operations to confidently identify the secure operating envelope and thereby manage security effectively
- Allow assessment of impact on grid elements due to connection of new elements (network elements, generators, or loads) for necessary corrective actions
- Permit power system assets to be run with margins determined on the basis of security assessments
- Facilitate the tuning of control systems, such as power system stabilizers, voltage- and frequency-based special control schemes etc.
- Improve accuracy of online security tools, particularly for unusual operating conditions, which in turn is likely to result in higher reliability of supply to power system users.

The power system model would enable steady state and electromechanical transient simulation studies that deliver reasonably accurate outcomes.

1.3 Regulation:

- ❖ **CEA Connectivity Standard 6.4.d :**

The requester and user shall cooperate with RPC and Appropriate Load Despatch Centre in respect of the matters listed below, but not limited to

furnish data as required by Appropriate Transmission Utility or Transmission Licensee, Appropriate Load Despatch Centre, Appropriate Regional Power Committee and any committee constituted by the Authority or appropriate Government for system studies or for facilitating analysis of tripping or disturbance in power system;

Here Requester and User Includes a generating company, captive generating plant, energy storage system, transmission licensee (other than Central Transmission Utility and State Transmission Utility), distribution licensee, solar park developer, wind park developer, wind-solar photovoltaic hybrid system, or bulk consumer *(2019 Amendment)*

- ❖ **IEGC 4.1 :**

CTU, STU and Users connected to, or seeking connection to ISTS shall comply with Central Electricity Authority (Technical Standards for connectivity to the Grid) Regulations, 2007 which specifies the minimum technical and design criteria and Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations,2009.

2.0 Hydro Power Plant Classification:

a. **Run-of-river:**

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

b. **Reservoir (HPP):**

Reservoir based hydropower schemes have the ability to store water behind the dam in a reservoir in order to de-couple generation from hydro inflows. A hydroelectric reservoir makes use of 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 hydropower schemes use off-peak electricity to pump water from a reservoir located after the tailrace to the top of the reservoir, so that the pumped storage plant can generate electricity at peak times and provide grid stability and flexibility services

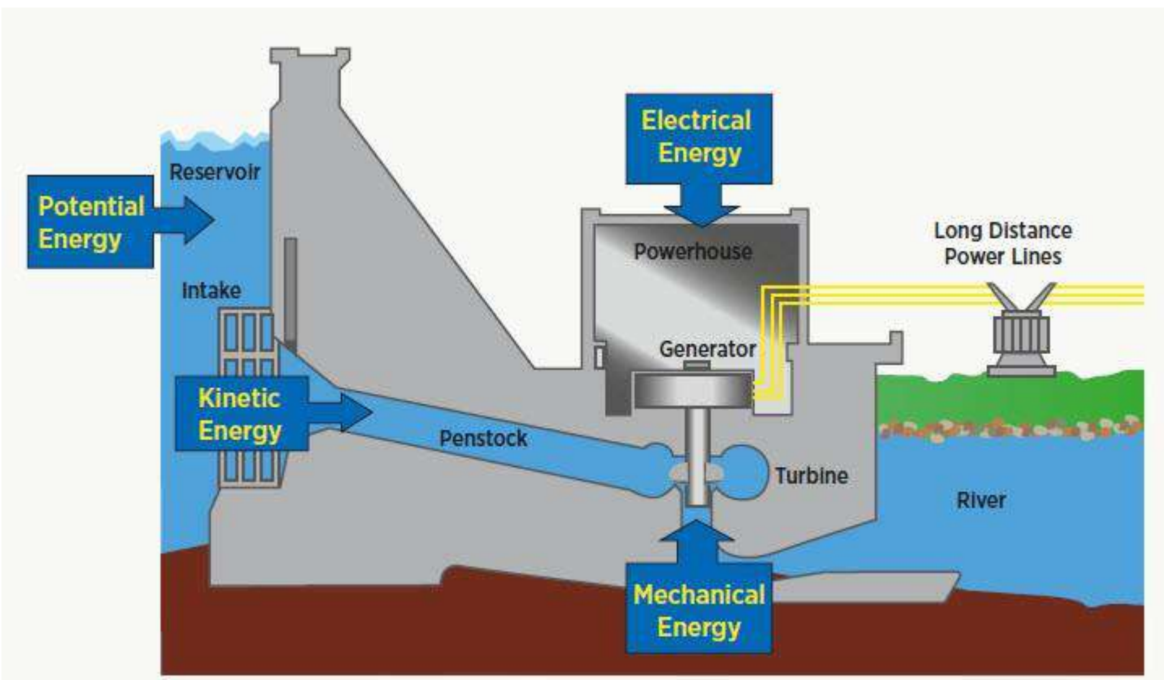


Figure 1: Typical "LOW HEAD" Hydro Power Plant with storage

Types of hydraulic turbines in regional grid:

The conventional hydroelectric generator can be classified broadly into three categories based on the hydraulic turbine type given as under:

1) Pelton wheel turbine
2) Kaplan Turbine
3) Francis Turbine
4) Bulb and other types of turbines

Pelton wheel turbine is an impulse turbine for high head and low discharges (flow rate) conditions. Kaplan wheel turbine is a reaction type turbine suitable for low head and high discharge (flow rate) conditions. Francis turbine is mix type of turbine that operates at medium head and flow rate.

Among the hydro generators the Francis turbine generators are characterized by unstable operation zone over a certain range of generation (typically 10-70%) where it experiences vibration due to cavitation. Cavitation is the resulting vibration caused by bubbles formed in water column due to pressure change and this causes loss of head and turbine efficiency. The Pelton wheel turbines on the other hand do have better load following characteristics and are capable of extended part load operation since they don't have any such forbidden zones.

Region wise distribution of different turbine types has been given below:

Region	Pelton	Capacity	Francis	Capacity	Kaplan	Capacity	Bulb	Capacity
	Number	MW	Number	MW	Number	MW	Number	MW
ER	6	1200	27	3014	13	534	0	0
NER	1	1.5	38	1260.5	0	0	0	0
NR	48	1580	103	10544	3	94	0	0
SR	68	4705	48	4096	12	426	20	594
WR	23	1047	56	5266	20	885	0	0
All India	**146**	**8534**	**272**	**24181**	**48**	**1939**	**20**	**594**

Source: Report on Operational Analysis for Optimization of Hydro resources – FOLD
https://posoco.in/hydro-committee-report/

For POSOCO to have access to verified fit-for-purpose models of hydro power generator connected to Indian grid, following information is required:

1. Electrical Single Line Diagram of coal fired thermal station depicting;
    - **For individual generating units:** type of technology, **Complete Generator OEM Technical Datasheet** (which comprises namely generator parameters like impedances & time constants, generator capability curve, V-curve, generator open and short circuit characteristics, excitation system details, inertia of generator & exciter), generator name plate, generator SAT report including short circuit and open circuit test results during commissioning/recent overhauling.
    - **Generator step up transformer**: GT name plate/datasheet, details of LV, MV and HV, MVA rating, impedance, tap changer details, vector group, short-circuit parameters (actual positive & zero sequence impedance of GT, NGR nameplate with impedance).
    - **Excitation system :-** Type of excitation system (Direct Current Commutator Exciters (type DC), AC Excitation (Rotor or brushless excitation) Systems (type AC) and Static Excitation Systems (type ST), Excitation system schematics (Block diagram of AVR system), transfer function block diagram of Excitation system, excitation transformer nameplate, saturation curves of the exciter (I_a versus I_f curve), IEEE standard model of excitation system, IEEE standard model and its parameter of subsystems such as Power system stabilizer (PSS), Under Excitation Limiter (UEL), Over Excitation Limiter (OEL), Voltage per Hz Limiter(V/Hz) control etc. and details thereof, factory acceptance test reports (FAT). Excitation system actual settings to be provided. AVR test report (excitation step response test).

- **Power System Stabilizer (PSS):** Transfer function block diagram of PSS, IEEE Standard Model, Actual PSS software settings, PSS commissioning report and **Recent PSS tuning report**.
- **Turbine-Governor system :-** Type of prime mover (hydro-electric or pumped storage), type of hydro turbine (impulse or reaction turbine) and details of head, model of turbine (including details of technology, valves, valve characteristics), model of governor control system (including details of technology, valves, valves characteristics) , penstock details (length, area, diameter, thickness, elastic or non-elastic, no of penstock supplied through common tunnel and flow of water through turbine) , mode of operation (hydro, pump storage or synchronous condenser) and control, surge tank details (height, diameter and restricted inlet orifice), pump characteristic (Active power Vs head) ramp rates, losses in case of synchronous condenser operation (Mechanical loss and copper loss as a function of MVAr output), Block diagram of turbine-governor system, IEEE standard model of turbine governor system and its transfer function diagram and its parameters, Turbine inertia, commissioning report of turbine-governor system or recent governor testing report.

2. Generic models of individual components (generator, exciter, turbine-governor and PSS of hydro power generator (refer sections 3.2 to section 3.5)
   - Model should be suitable for an integration time step between 1ms and 20ms, and suitable for operation up-to 100 s
   - Simulation results depicting validation of generic models against user-defined models (for P, Q, V, I) and against actual measurement (after commissioning) to be provided.
3. Encrypted user defined model (UDM) in a format suitable for latest PSSE release PSS/E (*.dll files) for electromechanical transient simulation for components of hydro power generators (in case non-availability of validated generic model)
   - User guide for Encrypted models to be provided including instructions on how the model should be set-up
   - Corresponding transfer function block diagrams to be provided
   - Simulation results depicting validation of User-Defined models against actual measurement to be provided
   - The use of black-box type representation is not preferred

Annexure: Formats for submission of modelling data for hydro power generator

Version History:

Version no.	Release Date	Prepared by*	Checked/Issued by*	Changes

***Mention Designation and Contact Details**

Details submitted:

Details pending:

3.1 Details of models in PSS/E for modelling hydro power generator:

(a) Synchronous Machine – HPP and PSP types

Category	Parameter Description	Data
Generator Nameplate	Rated apparent power in MVA	
	Rated terminal voltage	
	Rated power factor	
	Rated speed (in RPM)	
	Rated frequency (in Hz)	
	Rated excitation (in Amperes and Volts)	
Type of synchronous machine	Round rotor or salient pole No. of poles	
Generator capability curve	The generator capability curve shows the reactive capability of the machine and should include any restrictions on the real or reactive power range like under/over excitation limits, stability limits, etc. Capability curve should have properly labelled axis and legible data	
Generator Open Circuit and Short Circuit Characteristic	Graph of excitation current versus terminal voltage and stator current	
	No load excitation current – used to derive per unit values	
	Excitation current at rated stator current	
Generator vee-curves	Otherwise referred to as “V-curve”. A plot of the terminal (armature) current versus the generating unit field voltage.	
Resistance values	Resistance measurements of field winding and stator winding to a known temperature	
Generator Data sheet	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd’ in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd’’ in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xa in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq’ in p.u. (Unsaturated or saturated)	
	Quadrature axis sub-transient synchronous reactance Xq’’ in p.u. (Unsaturated or saturated)	
	Direct axis open circuit transient time constant Tdo’ in sec	
	Direct axis open circuit sub-transient time constant Tdo’’ in sec	
	Quadrature axis open circuit transient time constant Tqo’ in sec	
	Quadrature axis open circuit sub-transient time constant Tqo’’ in sec	
	Inertia constant of total rotating mass (generator, AVR, turbo-governor set) H in MW.s/MVA	
	Speed Damping D	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

Category	Parameter Description	Data
Generator step up transformer (GSUT)	Nameplate Rating - Rated primary and secondary voltage - Vector group - Impedance - Tap changer details (Number of taps, tap position, tap ratio etc.)	
Auxiliary power (i.e. active and reactive auxiliary load)	Value of auxiliary load (MW and Mvar) at rated power of the generating unit.	
	Whether or not the load trips if the generating unit trips.	
Test Reports	Factory acceptance test (FAT) reports	

(b) Site Load

	Low Output			High Output		
	kW	kvar	kVA	kW	kvar	kVA
Auxiliary Load						

(c) Excitation System

Category	Parameter Description	Data
Type of Automatic Voltage Regulator (AVR)	Manufacturer and product details (for example ABB UNITROL)	
	Type of control system :- Analogue or digital	
	Year of commissioning / Year of manufacture	
	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
Type of excitation system	Static excitation system OR	
	Indirect excitation system (i.e. rotating exciter) - AC exciter, or - DC exciter	
Details of AVR converter	Rated excitation current (converter rating in Amperes)	
	Six pulse thyristor bridge or PWM converter	
Source of excitation supply	Excitation transformer or auxiliary supply (Details thereof)	
	If excitation transformer, nameplate information required	
Schematics	Saturation curves of the exciter (if applicable – see Type AC and DC)	
	Drawings of excitation system, typically prepared and supplied by the OEM	
	Single line diagram (i.e. one-line diagram) for the excitation system	
Excitation limiters	What excitation limiters are commissioned?	
	Under Excitation Limiters settings	
	Over Excitation Limiters settings	
	Voltage/frequency limiter	
	Stator current limiter	
	Minimum excitation current limiter	

Category	Parameter Description	Data
PSS	Is the AVR equipped with a PSS?	
	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)?	
	Type of PSS Block Diagram of PSS and as commissioned parameters value (Gain, time constants, filter coefficients, output limits of the PSS)	
Test Reports	Factory acceptance test (FAT) reports	

(d) Turbine Details (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	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)	
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	
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)	

3.2 Generic Models for synchronous machine

Hydro machines are multi-pole machines and depending upon the saturation characteristic of the machine they are classified in two groups:

- GENSAL – Salient pole machine with quadratic saturation function
- GENSAE – Salient pole machine with exponential saturation function

Category	Parameter Description	Data
GENERATOR model		
GENSAE OR **GENSAL**	Direct axis open circuit transient time constant Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo'' in sec	
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xl	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

While entering the values in above table, following relationship must be kept:

Xd>Xq>Xq'≥Xd'>Xq''≥Xd''

Tdo'>Td'>Tdo''>Td''

Tqo''>Tq'>Tqo''>Tq''

3.3 Excitation system model:

If a generic model is used, the first step must be to identify what type of exciter is present in the excitation system. The IEEE Std 421.5 (IEEE Recommended Practice for Excitation System Models for Power System Stability Studies published on 26th Aug 2016) has published several generic models, which are 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

Category	Parameter Description	Data
	DC Exciter	
ESDC1A OR ESDC2A	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (> 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)	

Category	Parameter Description	Data
DC Exciter		
ESDC3A	TR regulator input filter time constant (sec)	
	KV (pu) limit on fast raise/lower contact setting	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	TRH (> 0) Rheostat motor travel time (sec)	
	TE (> 0) exciter time-constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	VEMIN (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	TR regulator input filter time constant (sec)	
	KP (pu) (> 0) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KD (pu) voltage regulator derivative gain	
	TD voltage regulator derivative channel time constant (sec)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KA (> 0) (pu) voltage regulator gain	
	TA voltage regulator time constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	VEMIN (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	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (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)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
ESAC2A	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KB, Second stage regulator gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	KH, Exciter field current feedback gain	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (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)	

Category	Parameter Description	Data
AC Exciter		
ESAC3A	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	KR (>0), Constant associated with regulator and alternator field power supply	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KN, Exciter feedback gain	
	EFDN, A parameter defining for which value of UF the feedback gain shall change from KF to KN	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	VFEMAX, 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)	
ESAC4A	TR regulator input filter time constant (sec)	
	VIMAX, Maximum value of limitation of the integrator signal VI in p.u	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC, rectifier regulation factor (pu)	

Category	Parameter Description	Data
AC Exciter		
ESAC5A	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (sec), Regulator stabilizing circuit time constant in seconds	
	TF2 (sec), Regulator stabilizing circuit time constant in seconds	
	TF3 (sec), Regulator stabilizing circuit time constant in seconds	
	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	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TK (sec), Lead time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFELIM, Exciter field current limit reference	
	KH, Damping module gain	
	VHMAX, damping module limiter	
	TH (sec), damping module lag time constant	
	TJ (sec), damping module lead time constant	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (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)	

Category	Parameter Description	Data
AC Exciter		
AC7B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KPA (pu) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KP (pu)	
	KL (pu)	
	KF1 (pu)	
	KF2 (pu)	
	KF3 (pu)	
	TF3 (sec) time constant (> 0)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) exciter field current limit (> 0)	
	VEMIN (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
AC Exciter		
AC8B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VPIDMAX (pu) PID maximum limit	
	VPIDMIN (pu) PID minimum limit	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) max exciter field current limit (> 0)	
	VEMIN (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)	
Static Exciter		
ST1A	TR (sec) regulator input filter time constant	
	VIMAX, Controller Input Maximum	
	VIMIN, Controller Input Minimum	
	TC (s), Filter 1st Derivative Time Constant	
	TB (s), l Filter 1st Delay Time Constant	
	TC1 (s), Filter 2nd Derivative Time Constant	
	TB1 (s), Filter 2nd Delay Time Constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KLR, Current Input Factor	
	ILR, Current Input Reference	

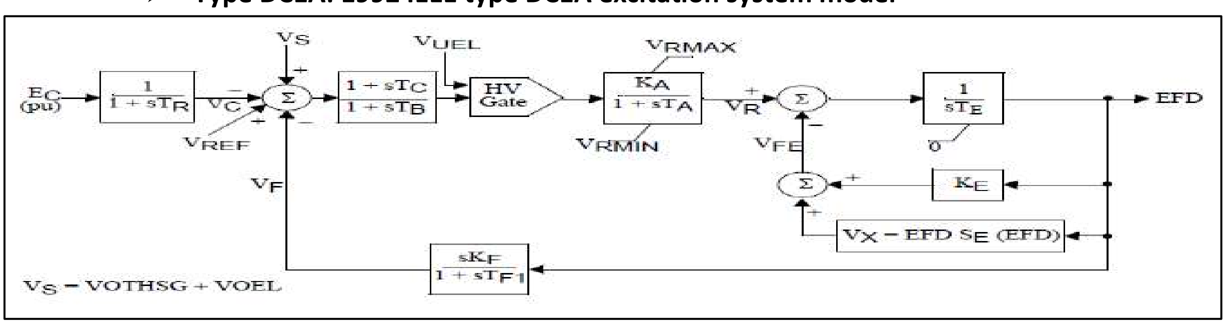
Category	Parameter Description	Data
Static Exciter		
ST2A	TR (sec) regulator input filter time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	EFDMAX	
ST3A	TR (sec) regulator input filter time constant	
	VIMAX, Maximum value of limitation of the signal VI in p.u.	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	KM, Forward gain constant of the inner loop field regulator	
	TC (s), lag time constant	
	TB (s), lead time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KG, Feedback gain constant of the inner loop field regulator	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX, Maximum value of limitation of the signal VB in p.u.	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL, Reactance associated with potential source	
	VGMAX, Maximum value of limitation of the signal VG in p.u	
	Θ_P (degrees)	
	TM (sec), Forward time constant of the inner loop field regulator	
	VMMAX, Maximum value of limitation of the signal VM in p.u	
	VMMIN, Minimum value of limitation of the signal VM in p.u.	

Category	Parameter Description	Data
Static Exciter		
ST4B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TA (sec) voltage regulator time constant	
	KPM, Regulator gain	
	KIM, Regulator gain	
	VMMAX, Maximum value of limitation of the signal in p.u.	
	VMMIN, Minimum value of limitation of the signal in p.u.	
	KG	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL	
	Θ_P (degrees)	
ST5B	TR regulator input filter time constant (sec)	
	TC1 lead time constant of first lead-lag block (voltage regulator channel) (sec)	
	TB1 lag time constant of first lead-lag block (voltage regulator channel) (sec)	
	TC2 lead time constant of second lead-lag block (voltage regulator channel) (sec)	
	TB2 lag time constant of second lead-lag block (voltage regulator channel) (sec)	
	KR (>0) (pu) voltage regulator gain	
	VRMAX (pu) voltage regulator maximum limit	
	VRMIN (pu) voltage regulator minimum limit	
	T1 voltage regulator time constant (sec)	
	KC (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)	
	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)	

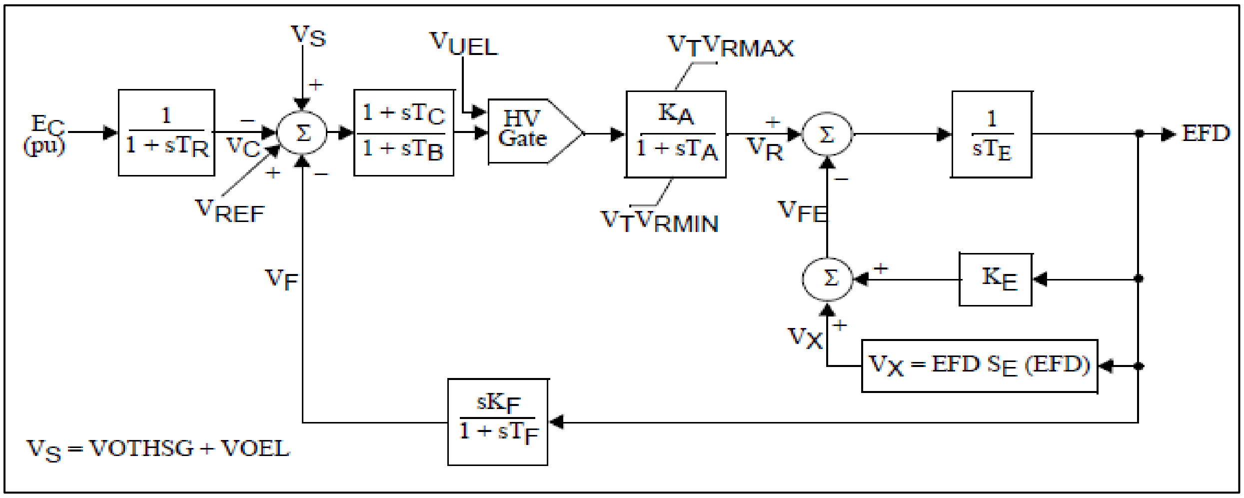
Category	Parameter Description	Data
Static Exciter		
ST6B	TR regulator input filter time constant (sec)	
	KPA (pu) (> 0) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	KDA (pu) voltage regulator derivative gain	
	TDA voltage regulator derivative channel time constant (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	
	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)	

(i) DC Exciters Generic model:

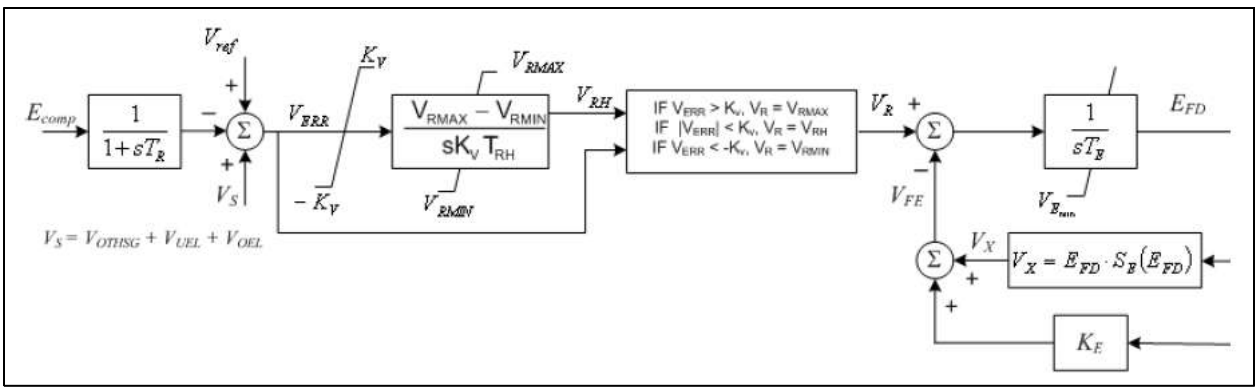
- **Type DC1A: 1992 IEEE type DC1A excitation system model**



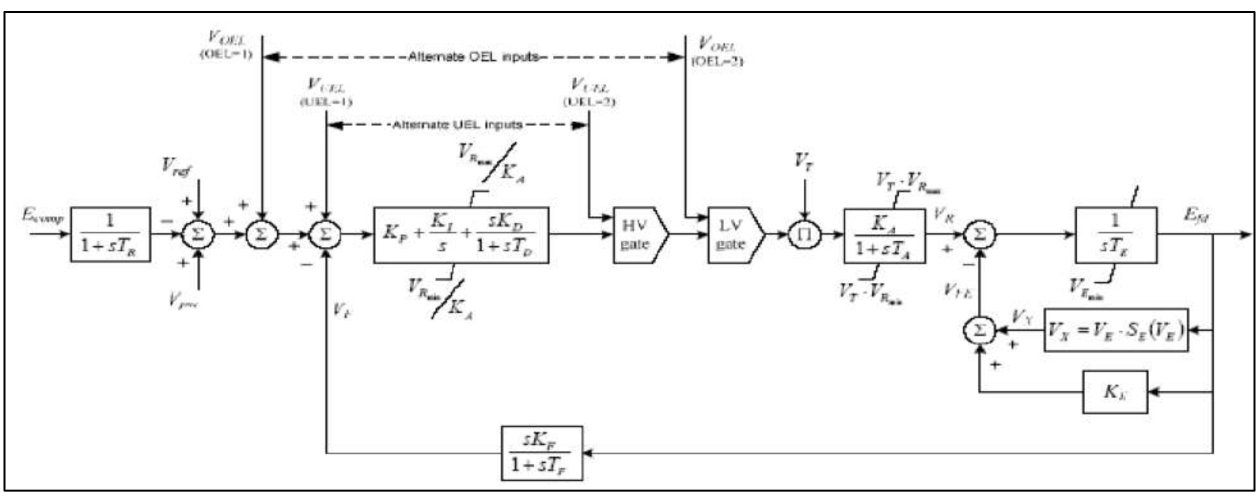
- **Type DC2A: 1992 IEEE type DC2A excitation system model**



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

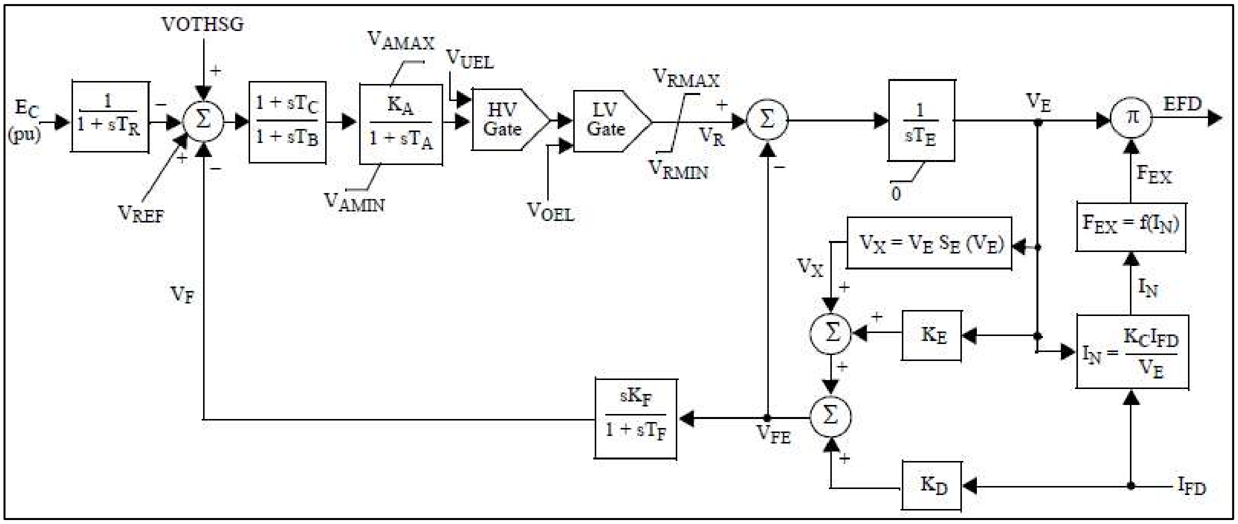


- **Type DC4B: IEEE 421.5 2005 DC4B excitation system**



(ii) **AC Exciters Generic Models:**

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

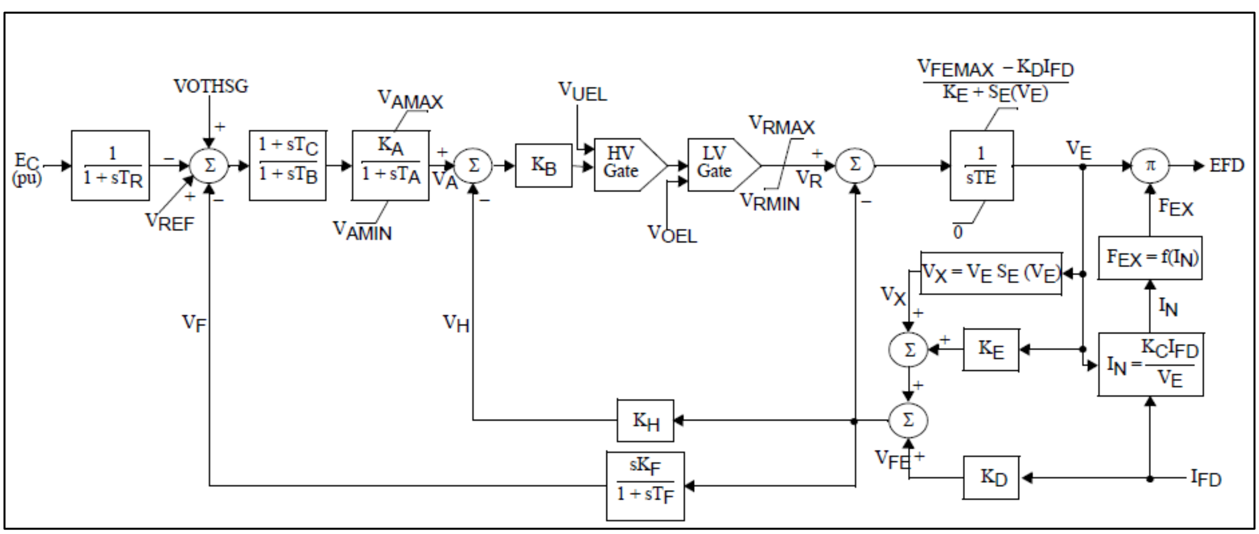


I_N →

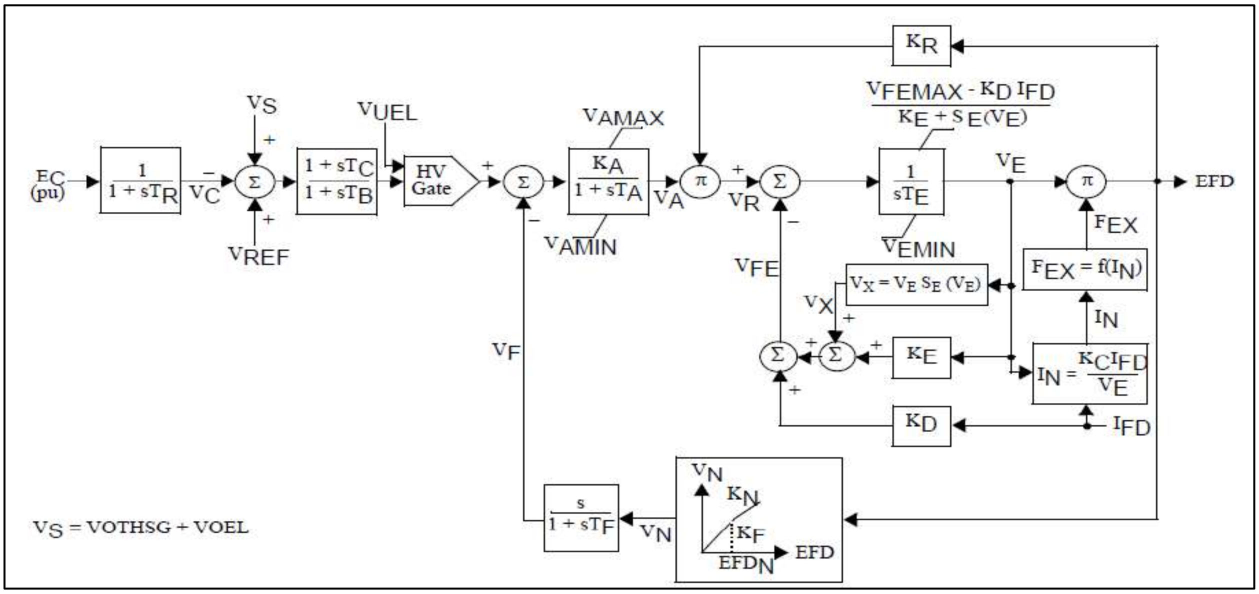
If $I_N \le 0$	$F_{EX} = 1$
If $I_N \le 0.433$	$F_{EX} = 1 - 0.577\ I_N$
If $0.433 < I_N < 0.75$	$F_{EX} = \sqrt{0.75 - I_N^2}$
If $I_N \ge 0.75$	$F_{EX} = 1.732(1 - I_N)$
If $I_N > 1$	$F_{EX} = 0$

→ FEX

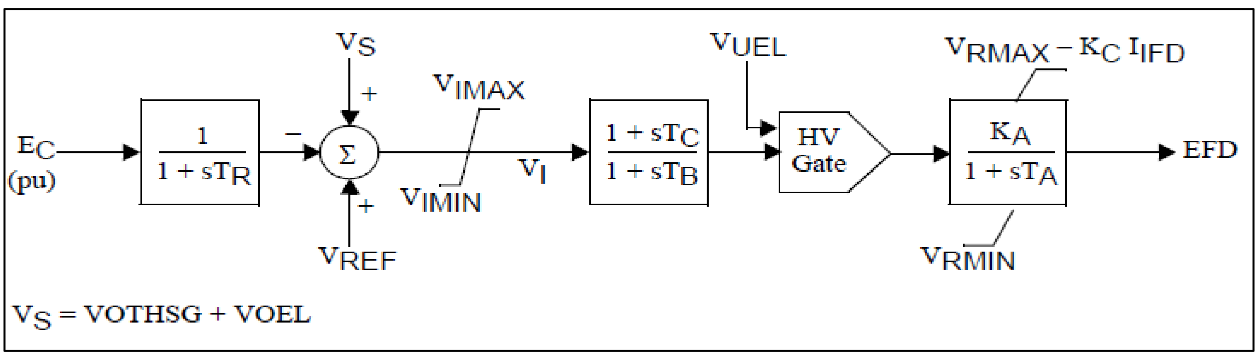
- **Type AC2A: 1992 IEEE type AC2A excitation system model**



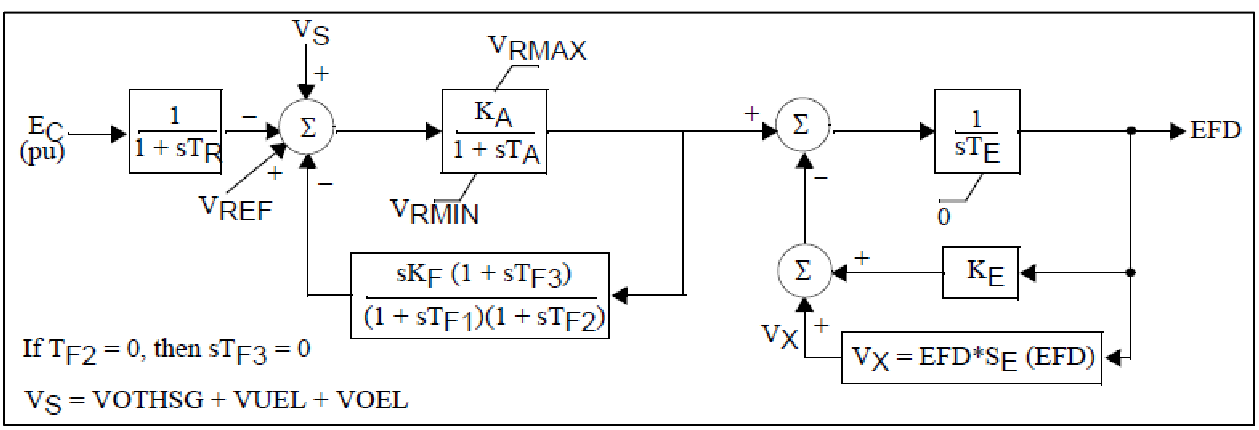
- **Type AC3A: 1992 IEEE type AC3A excitation system model**



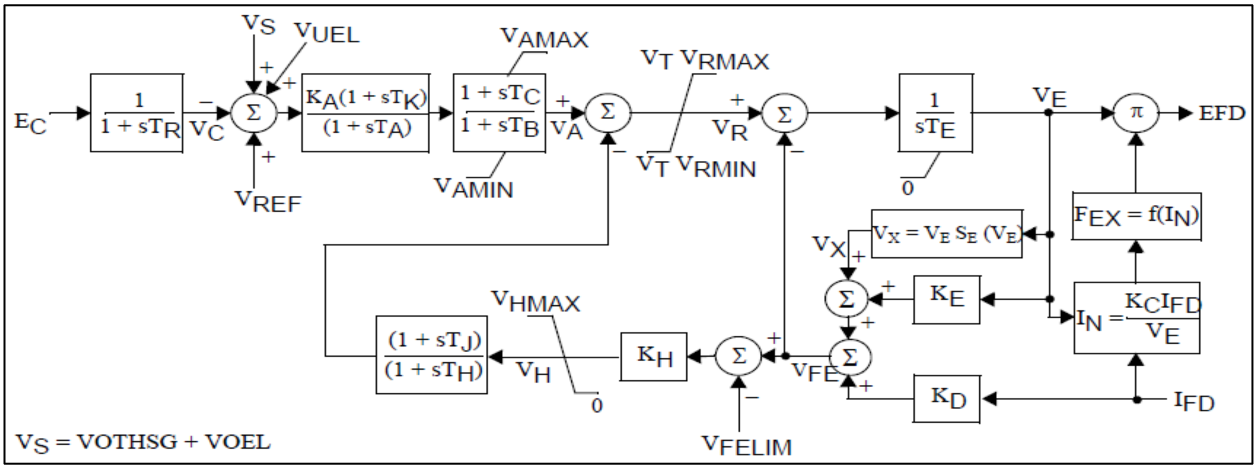
- **Type AC4A: 1992 IEEE type AC4A excitation system model**



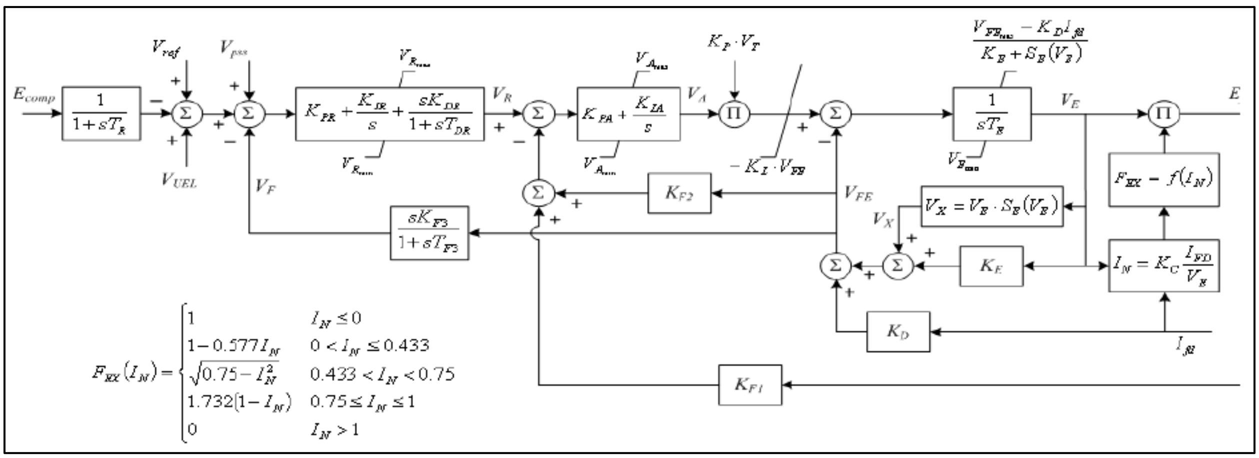
- **Type AC5A: 1992 IEEE type AC5A excitation system model**



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

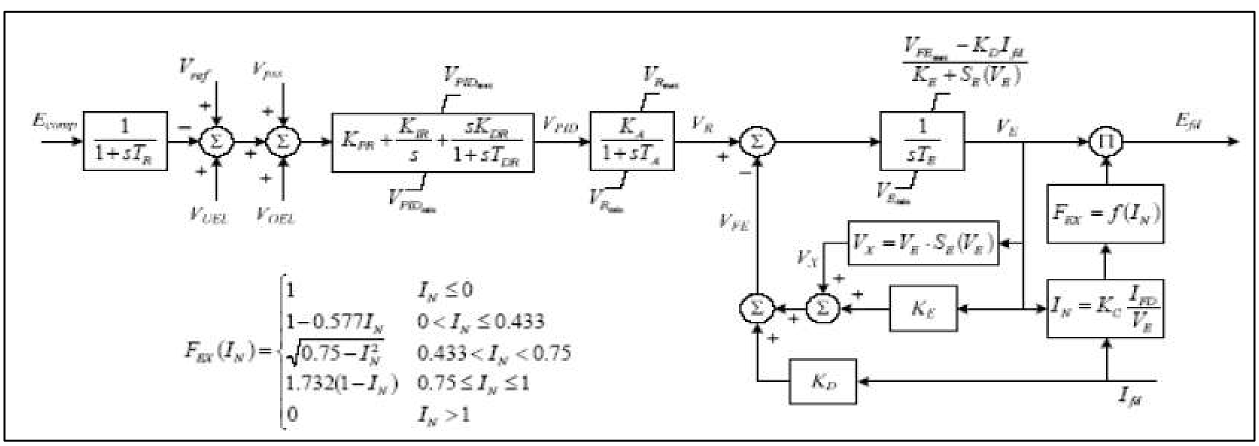


- **Type AC7B: IEEE 421.5 2005 AC7B excitation system**



$$F_{EX}(I_N)=\begin{cases}1 & I_N\le 0\\ 1-0.577I_N & 0<I_N\le 0.433\\ \sqrt{0.75-I_N^2} & 0.433<I_N<0.75\\ 1.732(1-I_N) & 0.75\le I_N\le 1\\ 0 & I_N>1\end{cases}$$

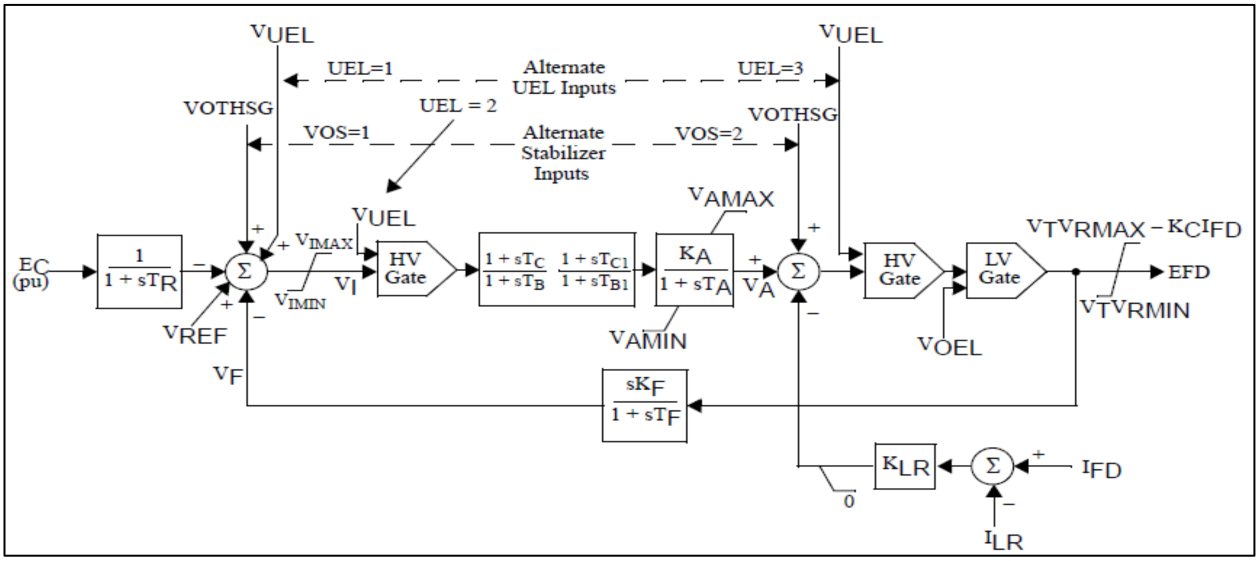
- **Type AC8B: IEEE 421.5 2005 AC8B excitation system**



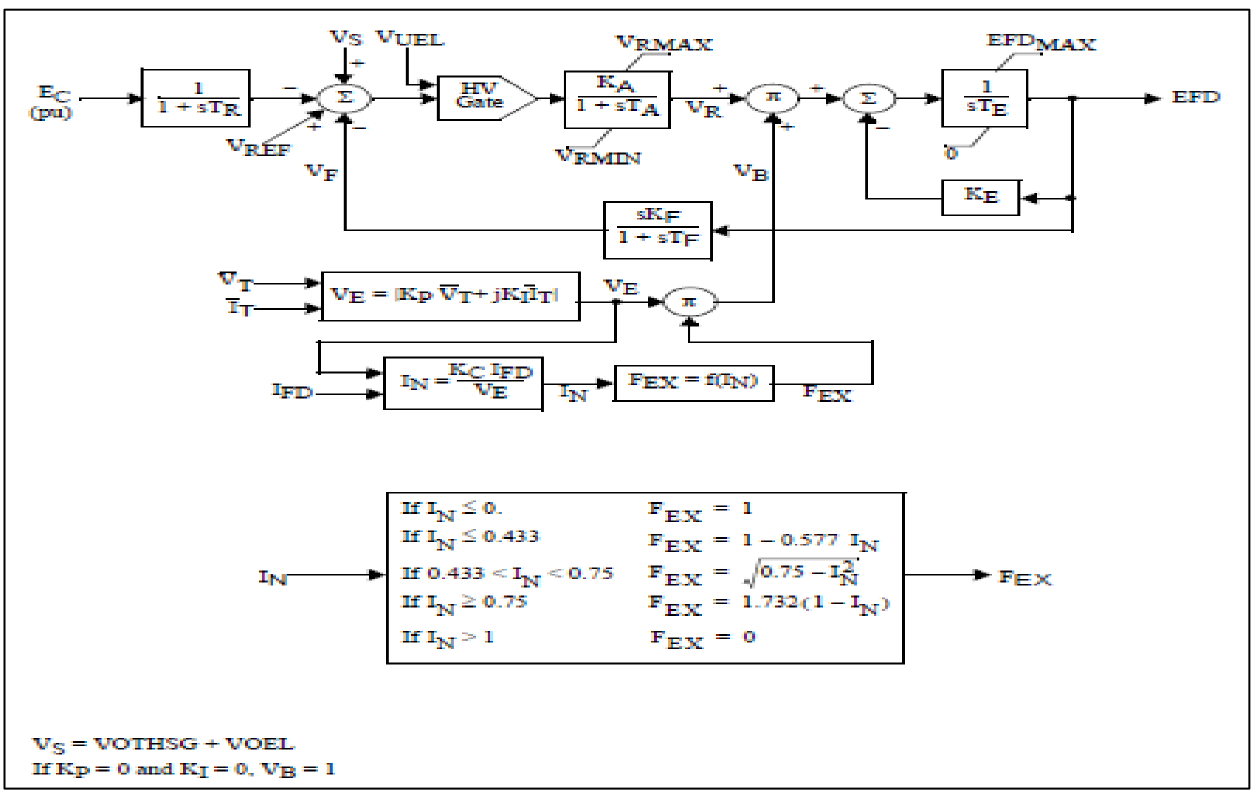
$$F_{EX}(I_N)=\begin{cases}1 & I_N\le 0\\ 1-0.577I_N & 0<I_N\le 0.433\\ \sqrt{0.75-I_N^2} & 0.433<I_N<0.75\\ 1.732(1-I_N) & 0.75\le I_N\le 1\\ 0 & I_N>1\end{cases}$$

(iii) **Commonly Used Static Exciters Generic Models block diagrams:**

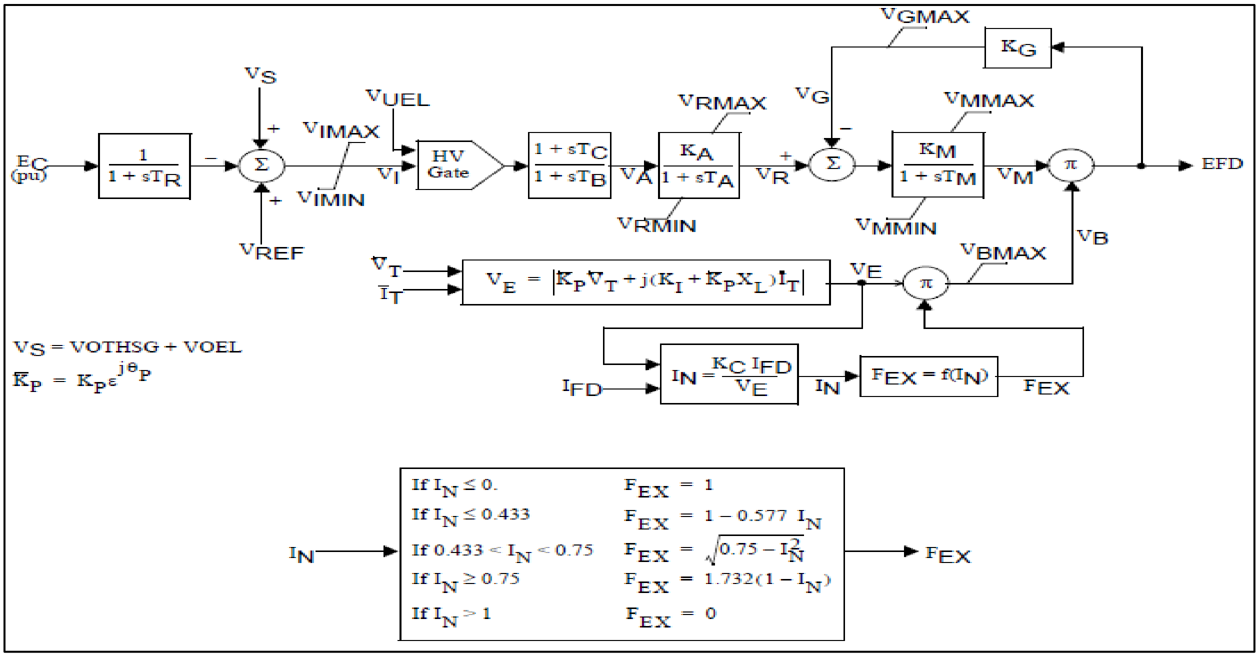
- **Type ST1A: 1992 IEEE type ST1A excitation system model**



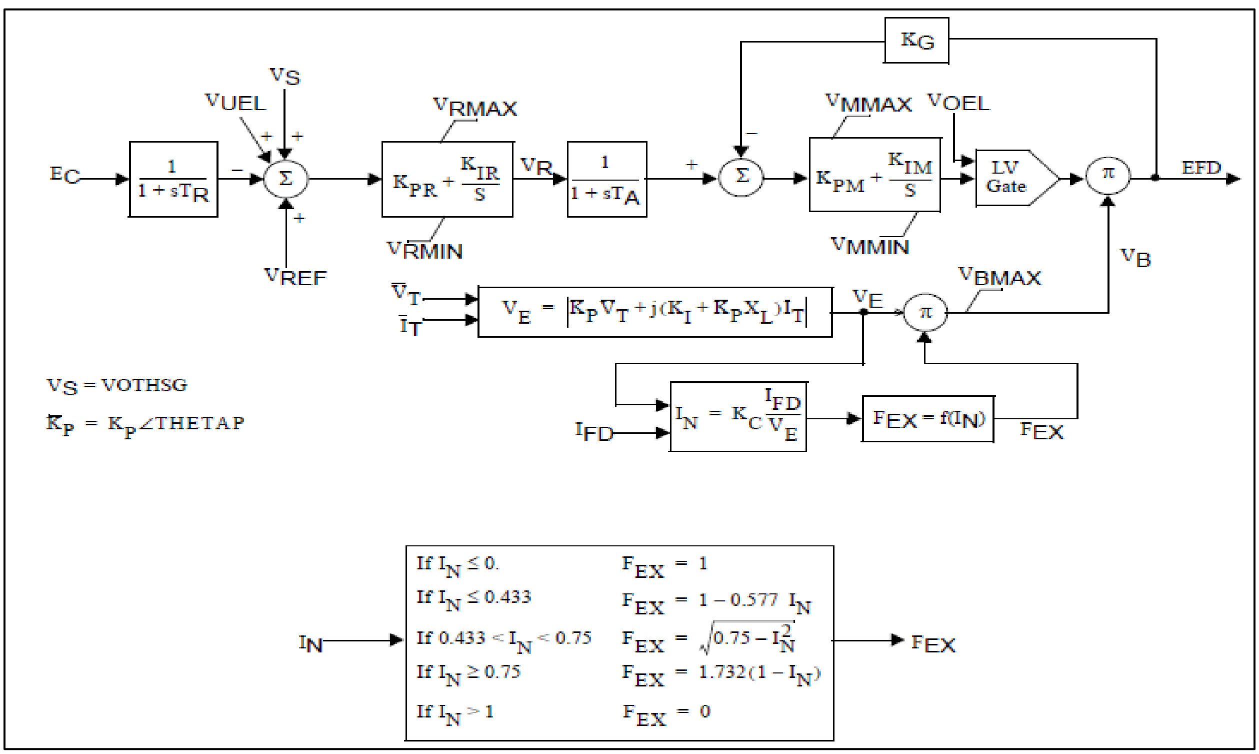
- **Type ST2A: 1992 IEEE type ST2A excitation system model**



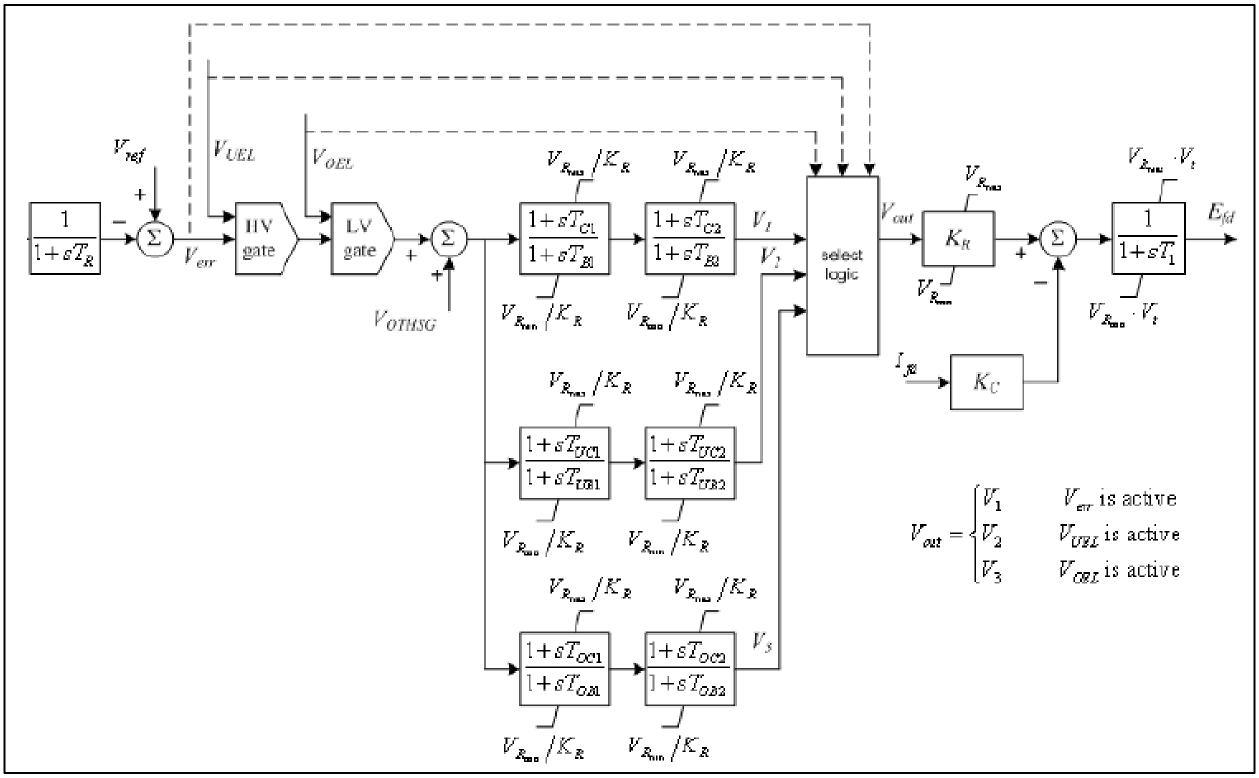
- **Type ST3A: 1992 IEEE type ST3A excitation system model**



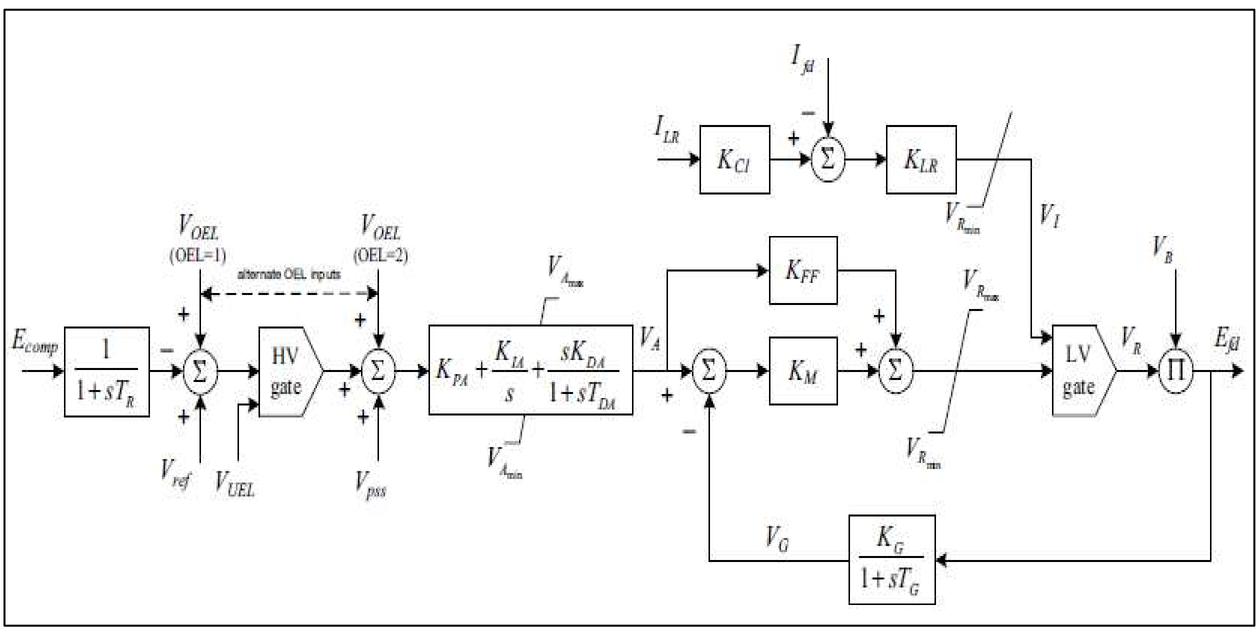
- **Type ST4B: IEEE type ST4B potential or compounded source-controlled rectifier exciter**



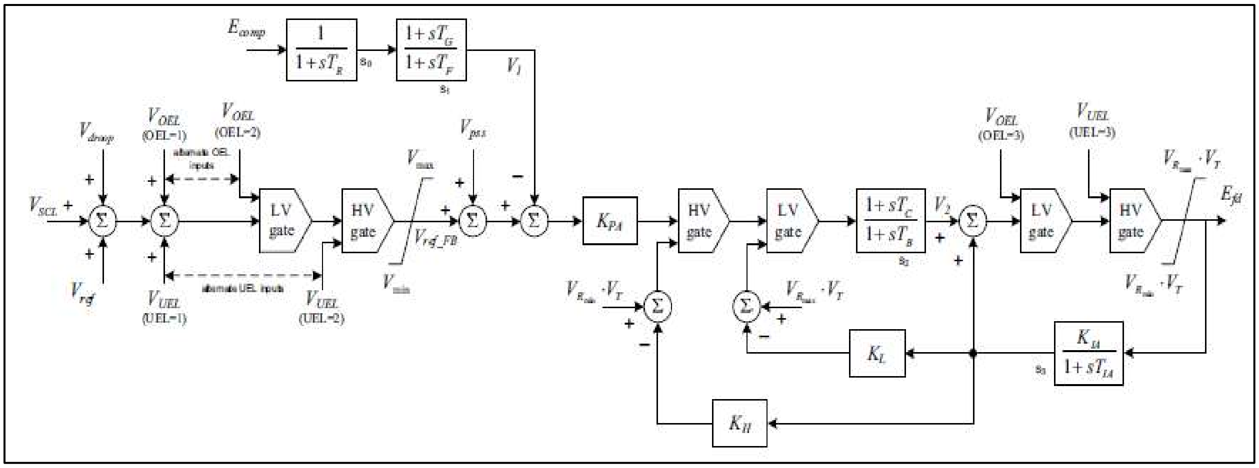
- **Type ST5B: IEEE 421.5 2005 ST5B excitation system**



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



- **Type ST7B: IEEE 421.5 2005 ST7B excitation system**



Source-PSSE Model Library

3.4 Power system stabilizer:

The function of the PSS is to add to the unit's characteristic electromechanical oscillations. This is achieved by modulating excitation to develop a component in electrical torque in phase with rotor speed deviations.

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:

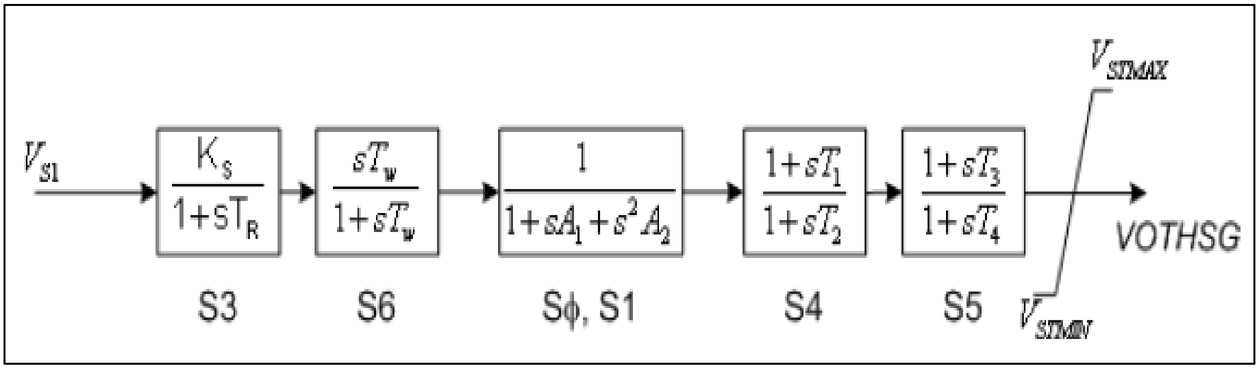
Type	Inputs	Remarks
PSS1A	Single input	Two lead-lags Input can either be speed, frequency or power
PSS2B	Dual input	Integral of accelerating power type stabiliser Speed and Power Most common type Supersedes PSS2A (three versus two lead lags)
PSS3B	Dual input	Power and rotor angular frequency deviation Stabilising signal is a vector sum of processed signals Not very common

Category	Parameter Description	Data
Stabilizer Models		
PSS1A	A1, Filter coefficient	
	A2, Filter coefficient	
	TR, transducer time constant	
	0	
	0	
	0	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	Tw, Washout Time Constant	
	Tw, Washout Time Constant	
	Ks, input channel gain	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	
	0	
	0	
PSS2B	TW1, 1st Washout 1th Time Constant	
	TW2, 1st Washout 2th Time Constant	
	T6, 1st Signal Transducer Time Constant	
	TW3, 2nd Washout 1th Time Constant	
	TW4, 2nd Washout 2th Time Constant	
	T7, 2nd Signal Transducer Time Constant	
	KS2, 2nd Signal Transducer Factor	
	KS3, Washouts Coupling Factor	
	T8, Ramp Tracking Filter Deriv. Time Constant	
	T9, Ramp Tracking Filter Delay Time Constant	
	KS1, PSS Gain	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	T10, 3rd Lead-Lag Derivative Time Constant	
	T11, 3rd Lead-Lag Delay Time Constant	
	VS1MAX, Input 1 Maximum limit	
	VS1MIN, Input 1 Minimum limit	
	VS2MAX, Input 2 Maximum limit	
	VS2MIN, Input 2 Minimum limit	
	VSTMAX, Controller Maximum Output	
	VSTMIN, Controller Minimum Output	

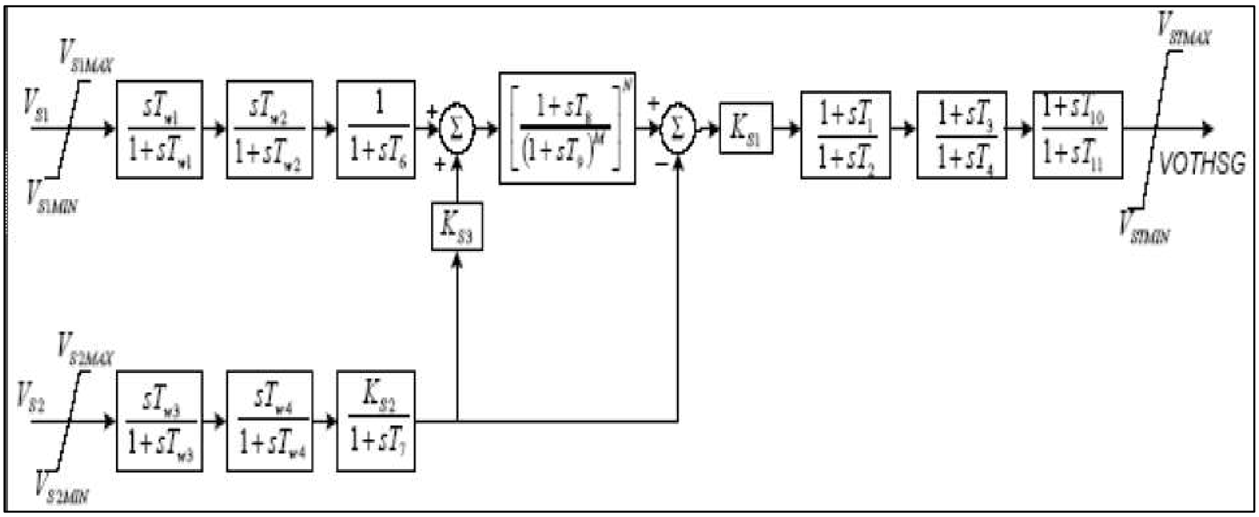
Category	Parameter Description	Data
	Stabilizer Models	
PSS3B	KS1 (pu) (≠0), input channel #1 gain	
	T1 input channel #1 transducer time constant (sec)	
	Tw1 input channel #1 washout time constant (sec)	
	KS2 (pu) (□0), input channel #2 gain	
	T2 input channel #2 transducer time constant (sec)	
	Tw2 input channel #2 washout time constant (sec)	
	Tw3 (0), main washout time constant (sec)	
	A1, Filter coefficient	
	A2, Filter coefficient	
	A3, Filter coefficient	
	A4, Filter coefficient	
	A5, Filter coefficient	
	A6, Filter coefficient	
	A7, Filter coefficient	
	A8, Filter coefficient	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	

Commonly Used Power System Stabilizer generic models block diagrams:

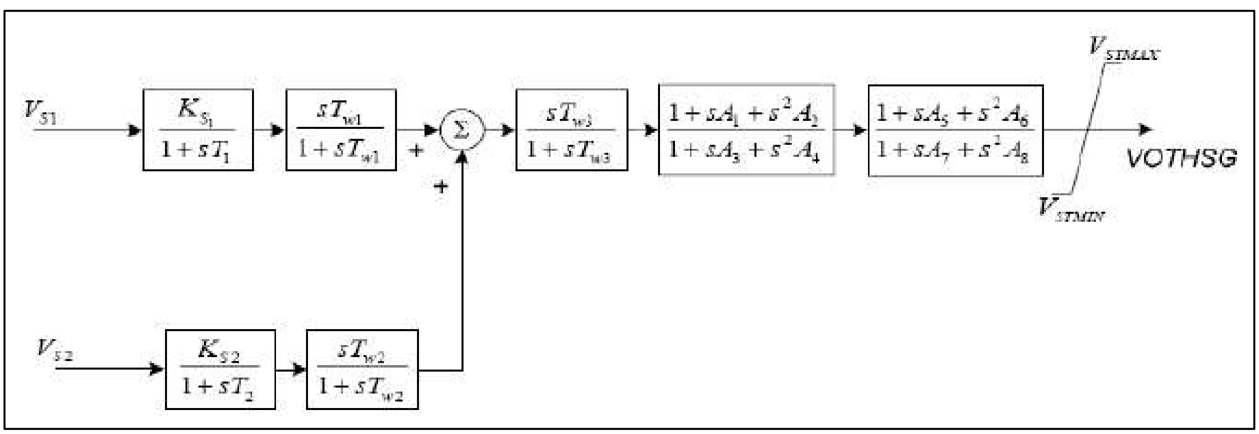
- **PSS1A: IEEE Std. 421.5-2005 PSS1A Single-Input Stabilizer model**



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



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



Source-PSSE Model Library

3.5 Generic models for turbine-governor:

The following table is a list for 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
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 non-linear model for penstock dynamics
HYGOVT	Hydro Turbine-Governor traveling wave model	Travelling-wave solution applied to 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 dynamics are similar to those of the WECC WSHYDD

Source: PSSE Model Library, for models other than the above list refer to

https://w3.usa.siemens.com/smartgrid/us/en/transmission-grid/products/grid-analysis-tools/transmission-system-planning/transmission-system-planning-tab/pages/user-support.aspx

Category	Parameter Description	Data
TURBINE GOVERNOR model		
HYGOV	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	
	GMAX, maximum gate limit	
	GMIN, minimum gate limit	
	TW (>0) water time constant	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
HYGOVDU	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	
	GMAX, maximum gate limit	
	GMIN, 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	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
HYGOVM	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 (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)	
	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)	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
WEHGOV	R-PERM-GATE (Feedback settings)	
	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	
	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	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
WEHGOV	PMECH2	
	PMECH3	
	PMECH4	
	PMECH5	
	PMECH6	
	PMECH7	
	PMECH8	
	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)	
	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)	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
HYGOVT	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)	
PIDGOV	Rperm, permanent drop, pu	
	Treg (sec), speed detector time constant	
	Kp, proportional gain, pu/sec	
	Ki, reset gain, pu/sec	
	Kd, derivative gain, pu	
	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	
	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	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
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)	
TURCZT	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	
	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)	

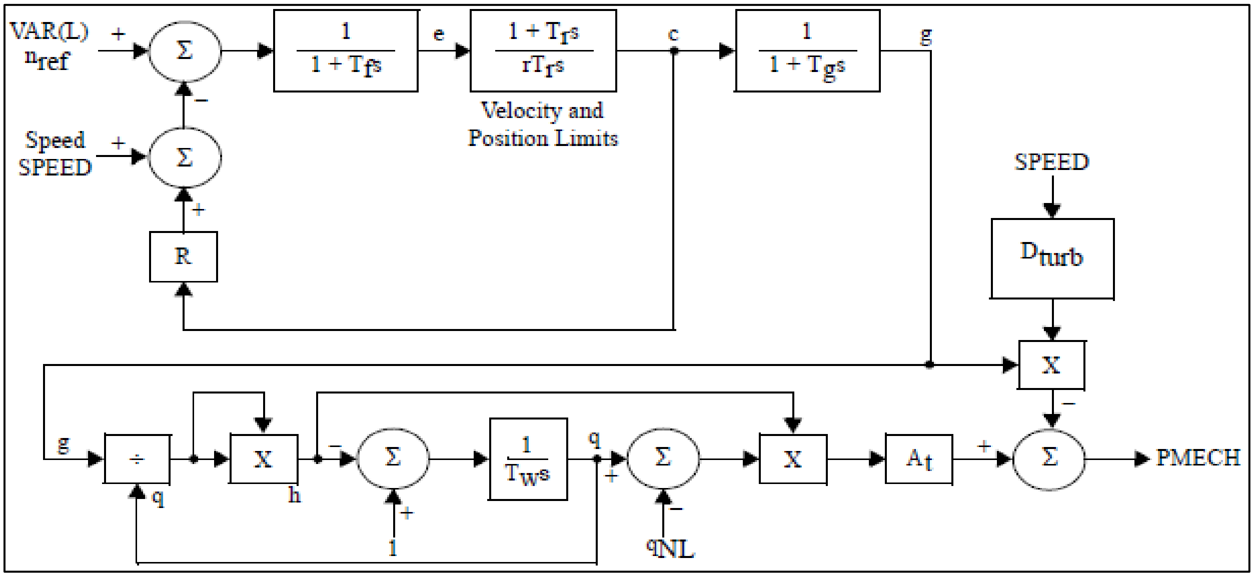
Category	Parameter Description	Data
TURBINE GOVERNOR model		
TWDM1	VELMN, close gate velocity limit (pu/sec) (<0)	
	GMAX, maximum gate limit	
	GMIN, minimum gate limit	
	TW, water time constant (sec) (>0)	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
	F1, frequency deviation (pu)	
	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	
TWDM2	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)	
	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)	

Category	Parameter Description	Data
TURBINE GOVERNOR model		
WPIDHY	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)	
	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)	
	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)	

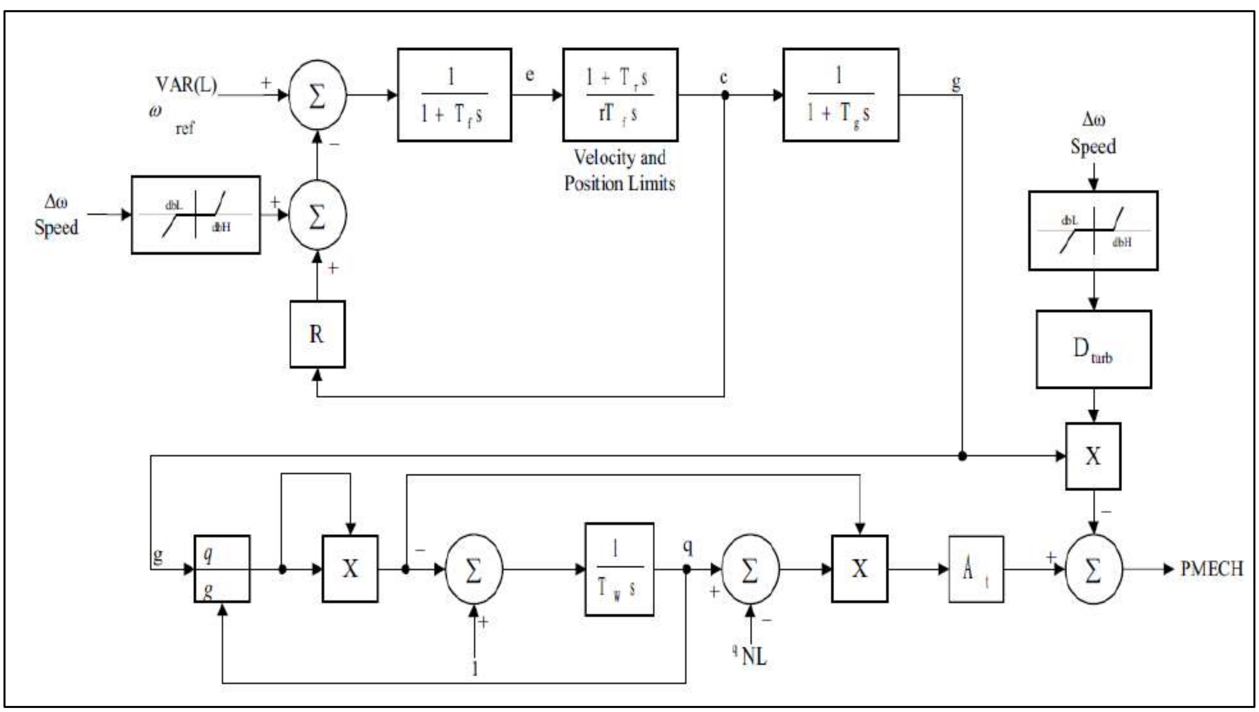
Category	Parameter Description	Data
TURBINE GOVERNOR model		
WSHYDD	PGV2, coordinate of power-gate look-up table (p.u. power)	
	GV3, coordinate of power-gate look-up table (p.u. gate)	
	PGV3, coordinate of power-gate look-up table (p.u. power)	
	GV4, coordinate of power-gate look-up table (p.u. gate)	
	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)	
WSHYGP	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)	
	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)	

Commonly Used Hydro Turbine Generic Models Block Diagrams:

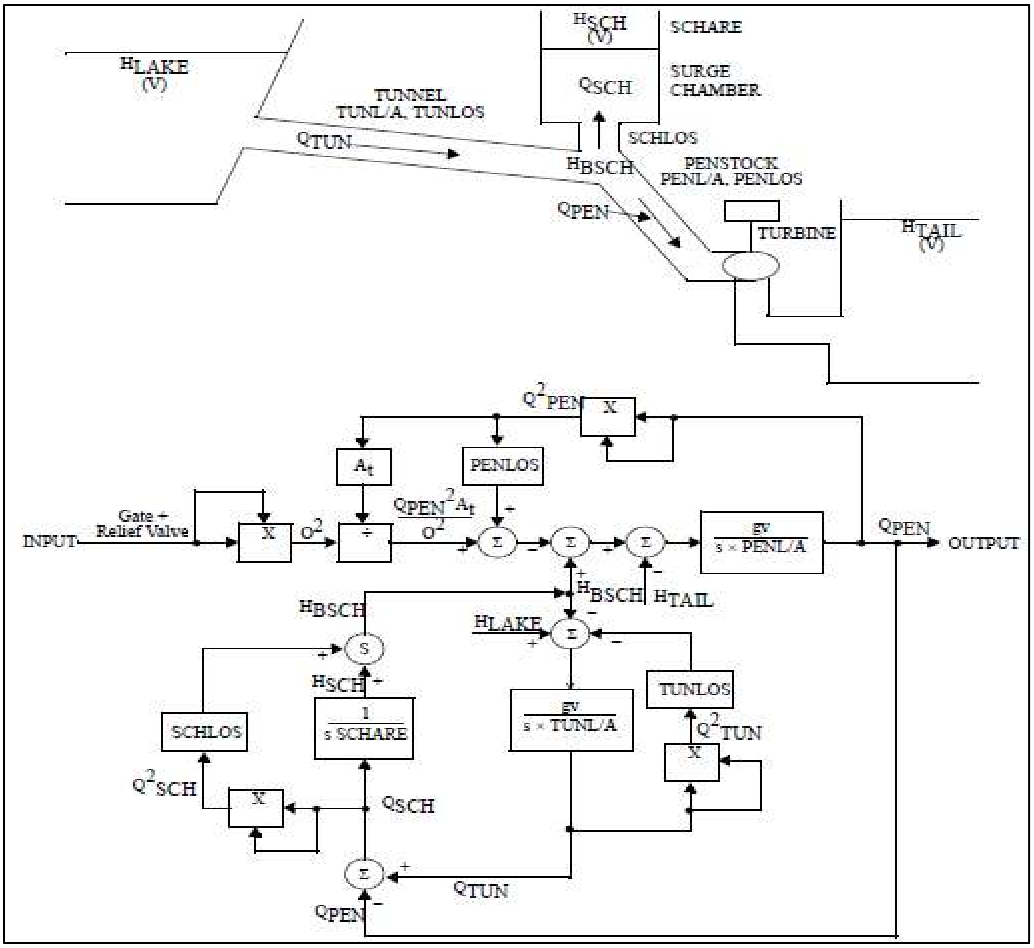
- **HYGOV: Hydro Turbine-Governor**



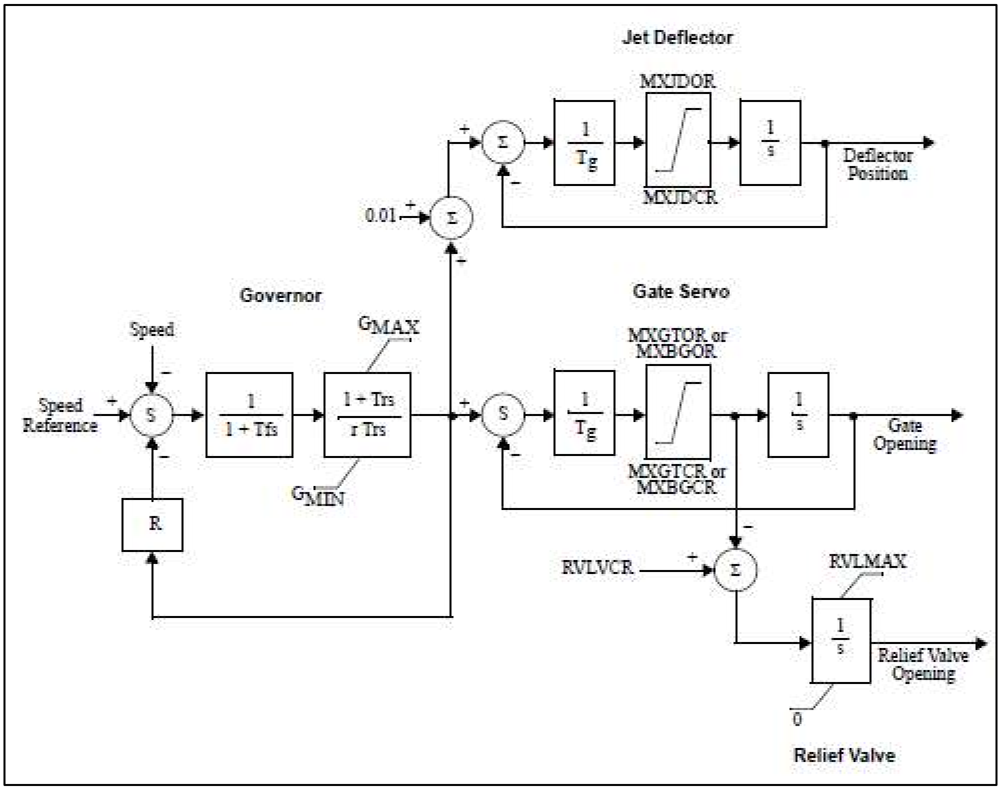
- **HYGOVDU: Hydro Turbine-Governor**



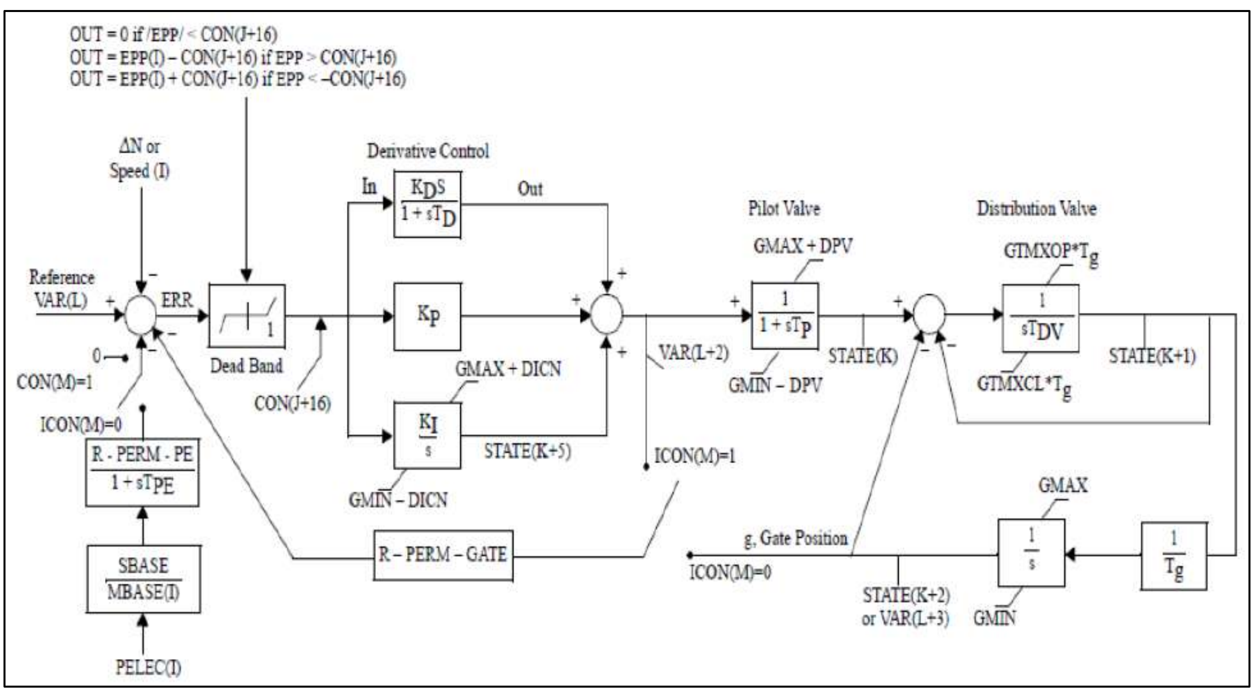
- **HYGOVM: Hydro Turbine-Governor Lumped Parameter Model**



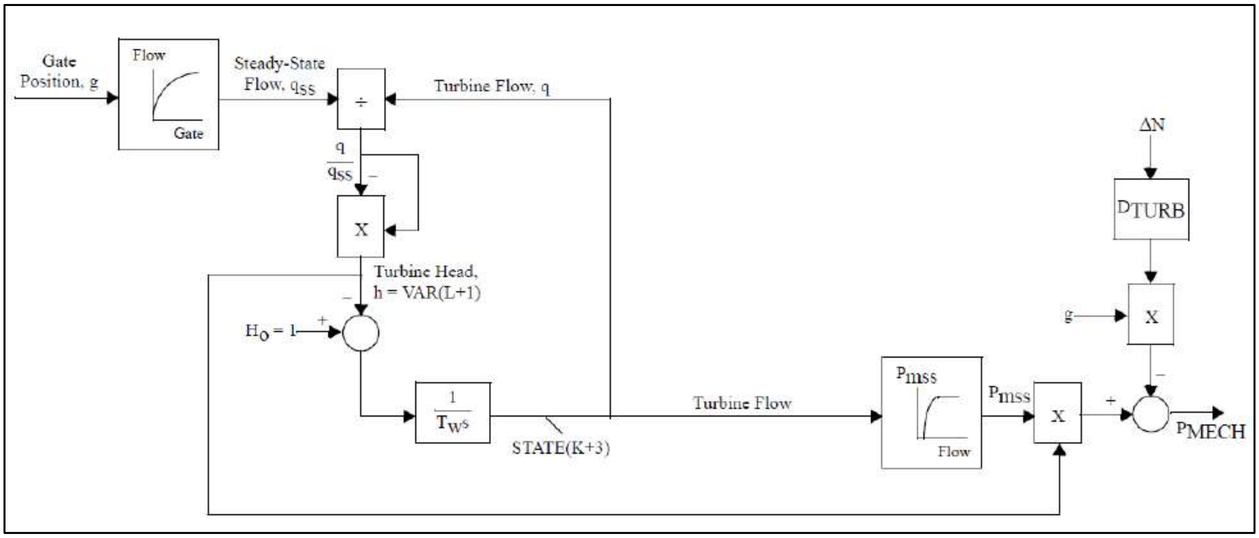
gv	Gravitational acceleration	A_t	Turbine flow gain
TUNL/A	Summation of length/cross section of tunnel	O	Gate + relief valve opening
SCHARE	Surge chamber cross section	HSCH	Water level in surge chamber
PENLOS	Penstock head loss coefficient	QPEN	Penstock flow
TUNLOS	Tunnel head loss coefficient	QTUN	Tunnel 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**

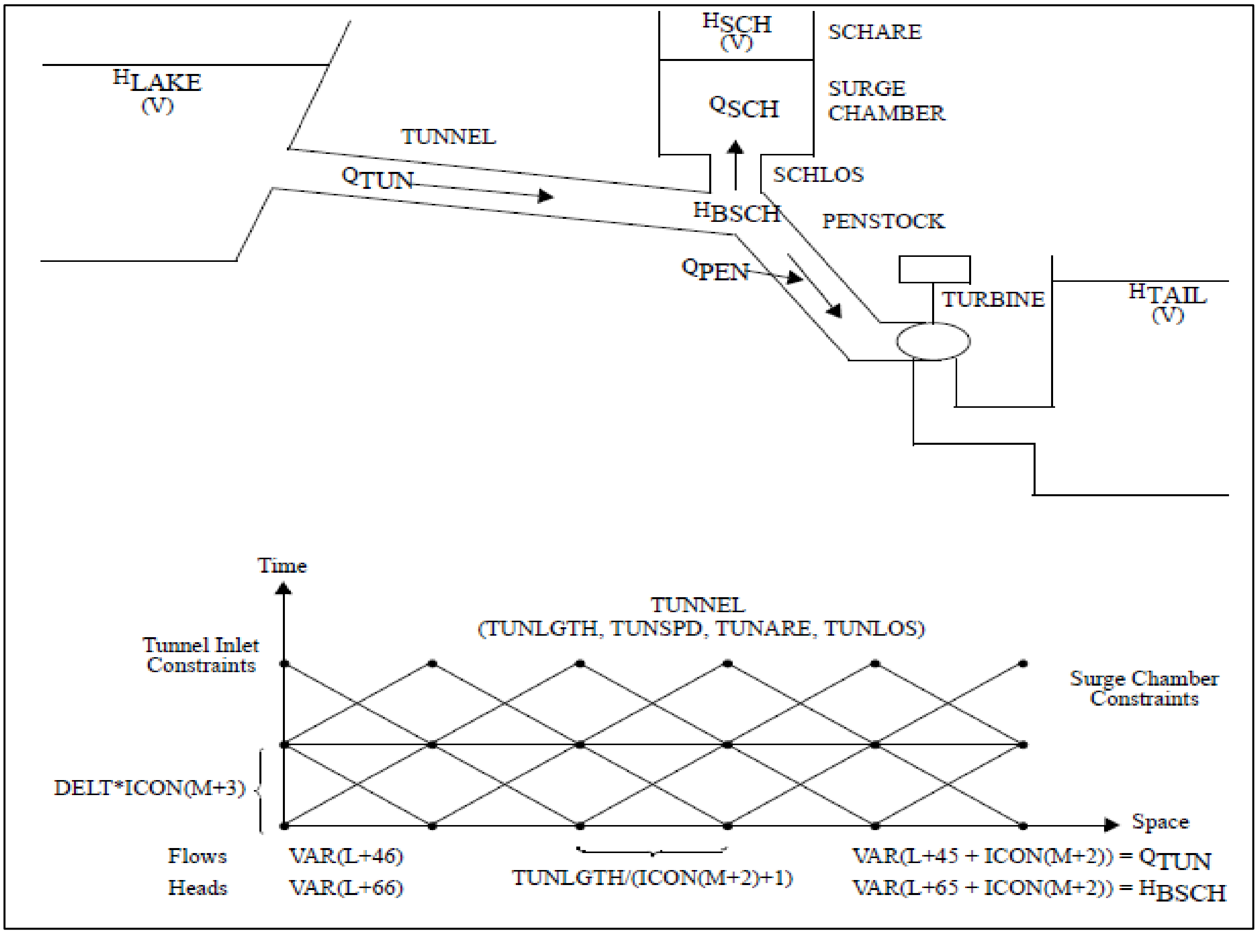


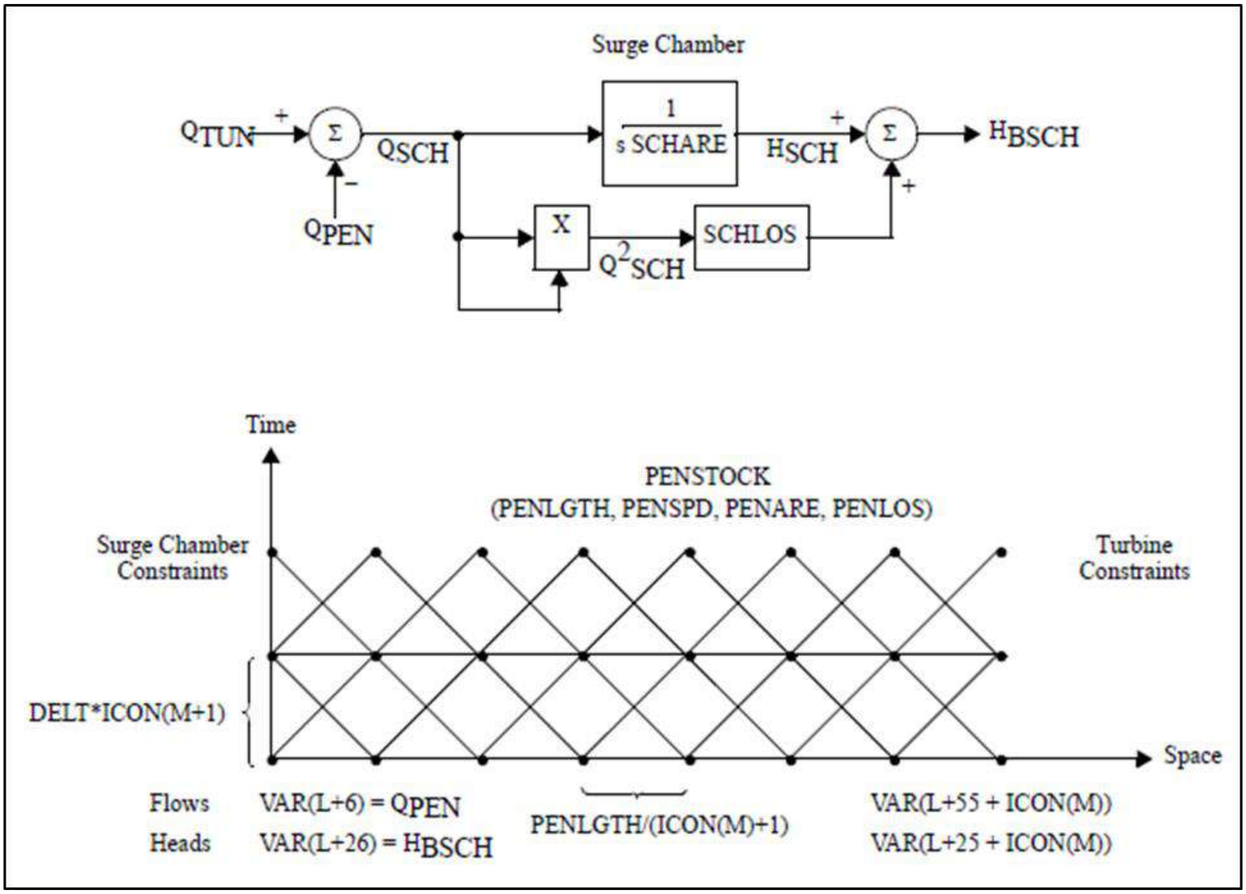
Governor and Hydraulic Actuators

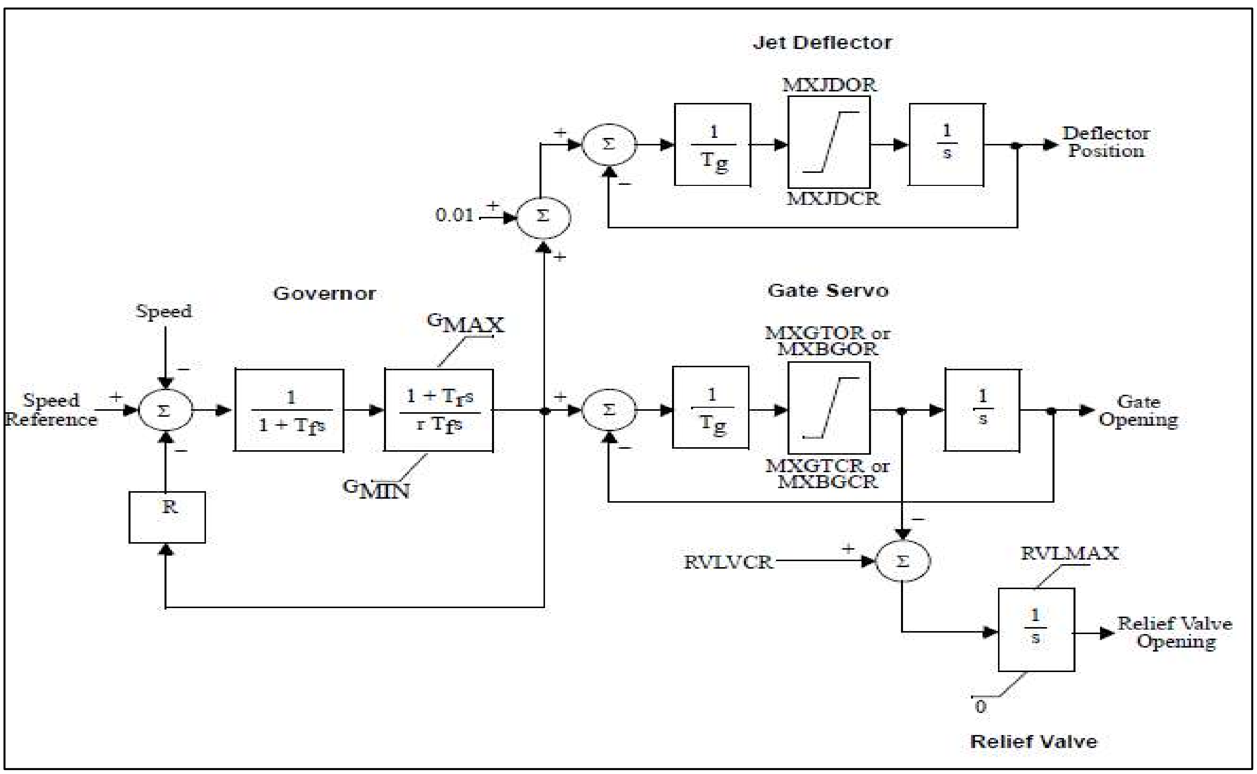


Turbine Dynamics

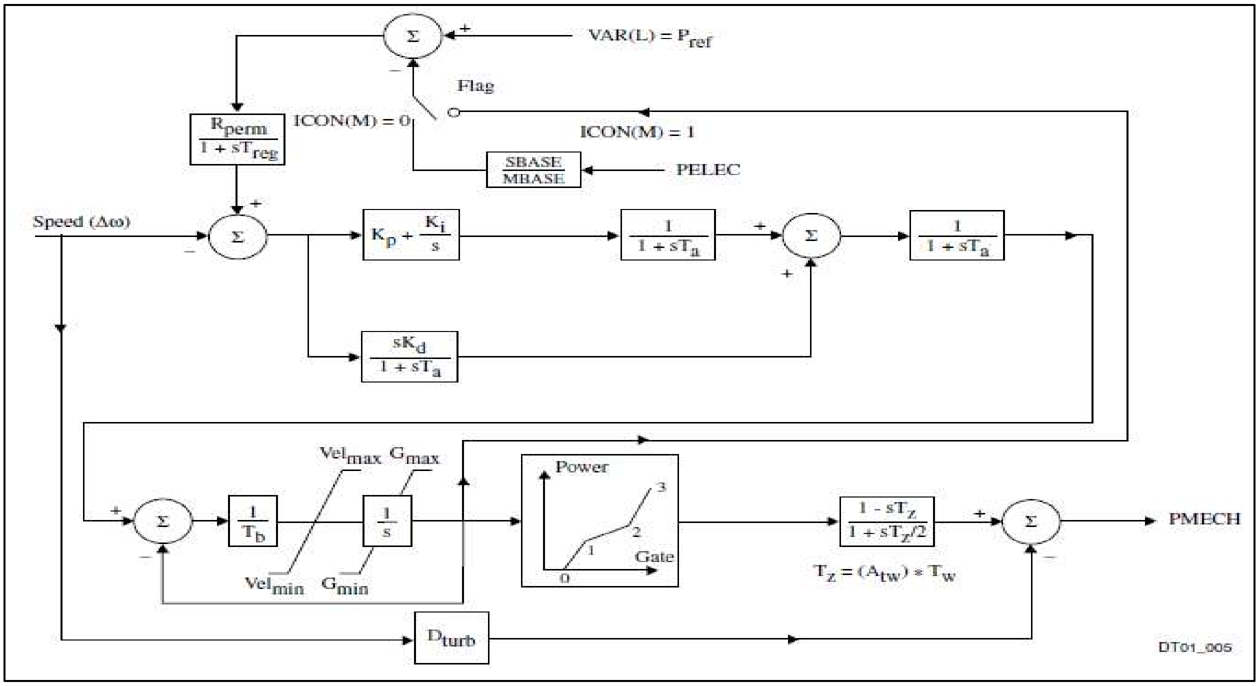
- **HYGOVT: Hydro Turbine-Governor Traveling Wave Model**



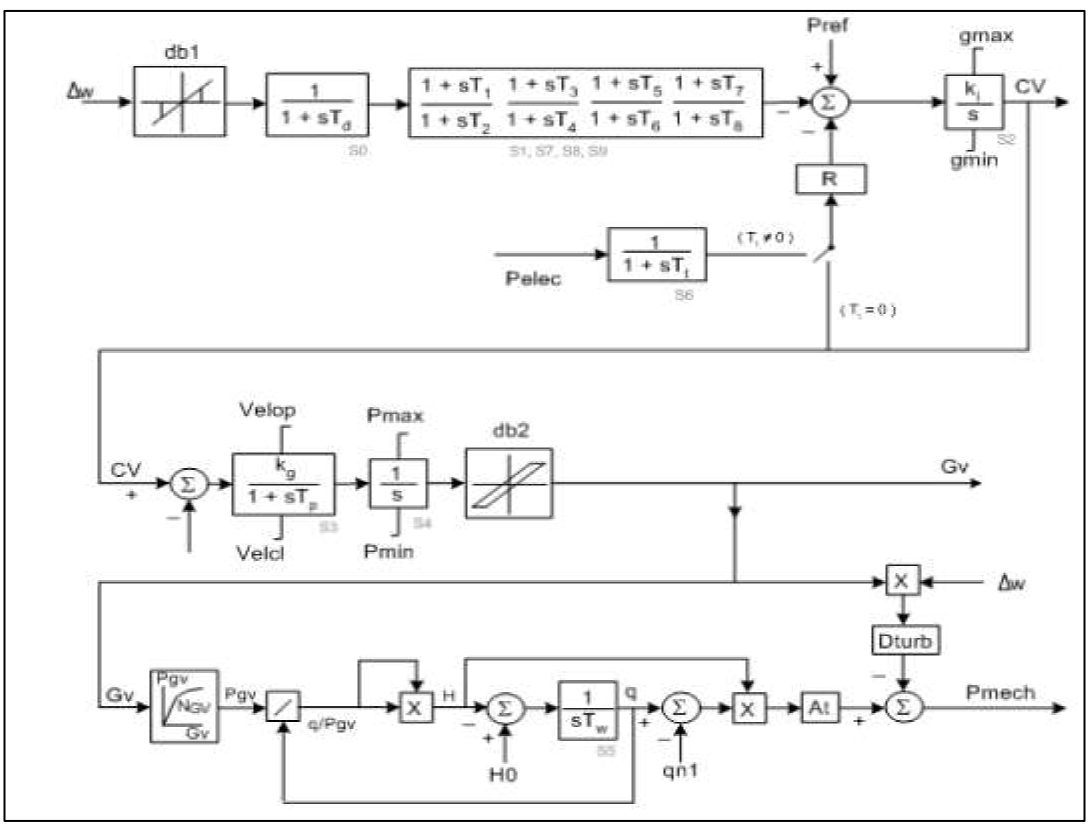

Surge Chamber
QTUN
QSCH
QPEN
1
s SCHARE
HSCH
HBSCH
X
Q^2SCH
SCHLOS
Time
PENSTOCK
(PENLGTH, PENSPD, PENARE, PENLOS)
Surge Chamber Constraints
Turbine Constraints
DELT*ICON(M+1)
Space
Flows
Heads
VAR(L+6) = QPEN
VAR(L+26) = HBSCH
PENLGTH/(ICON(M)+1)
VAR(L+55 + ICON(M))
VAR(L+25 + ICON(M))


Jet Deflector
MXJDOR
MXJDCR
Deflector Position
0.01
Governor
Speed
Speed Reference
R
GMAX
GMIN
Gate Servo
MXGTOR or MXBGOR
MXGTCR or MXBGCR
Gate Opening
RVLVCR
RVLMAX
Relief Valve Opening
0
Relief Valve

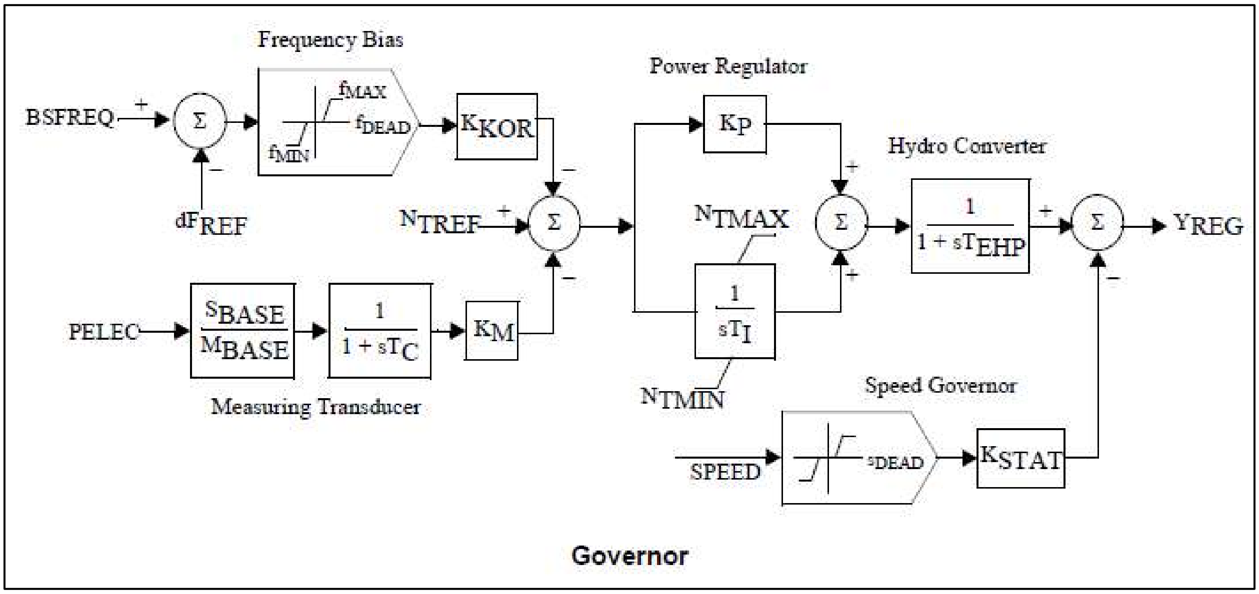
- **PIDGOV: Hydro Turbine-Governor**



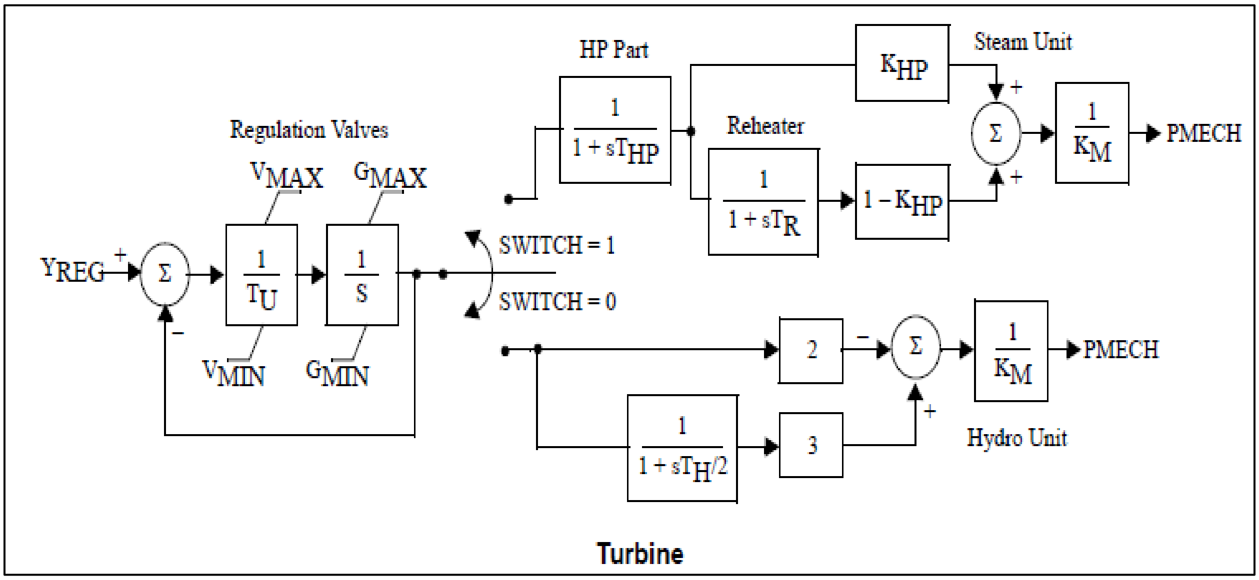
- **HYGOVR1: Fourth order lead-lag hydro-turbine**



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

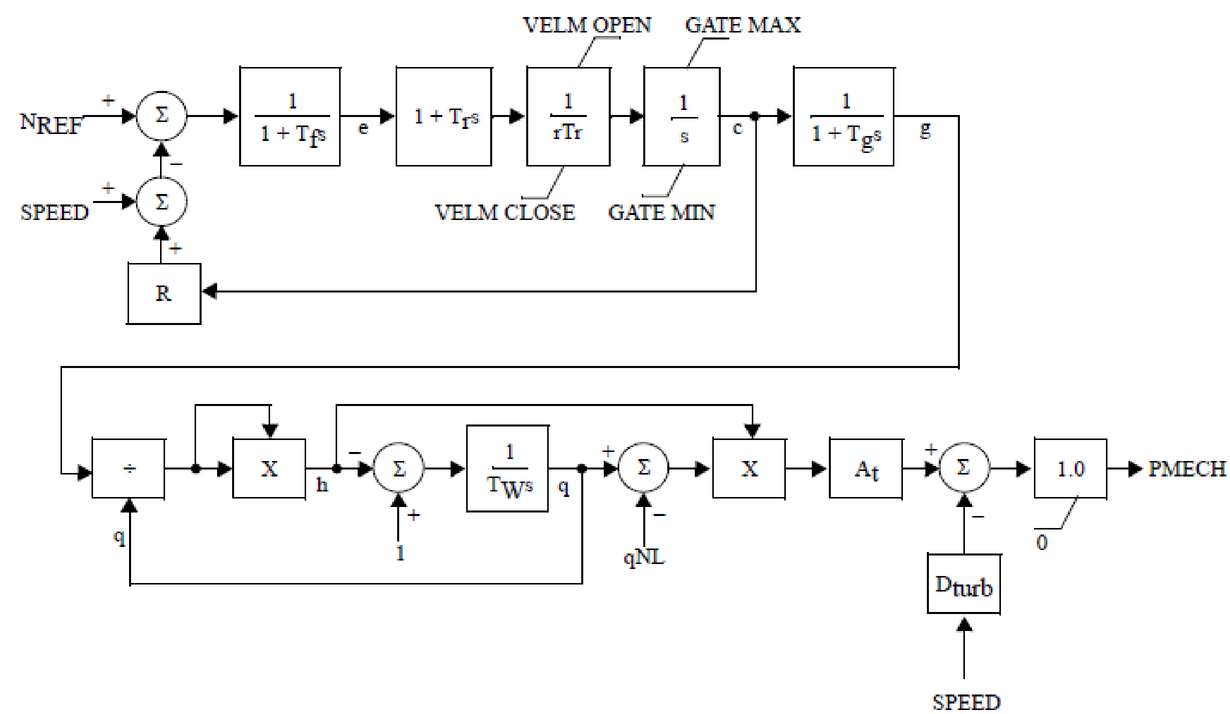


Governor

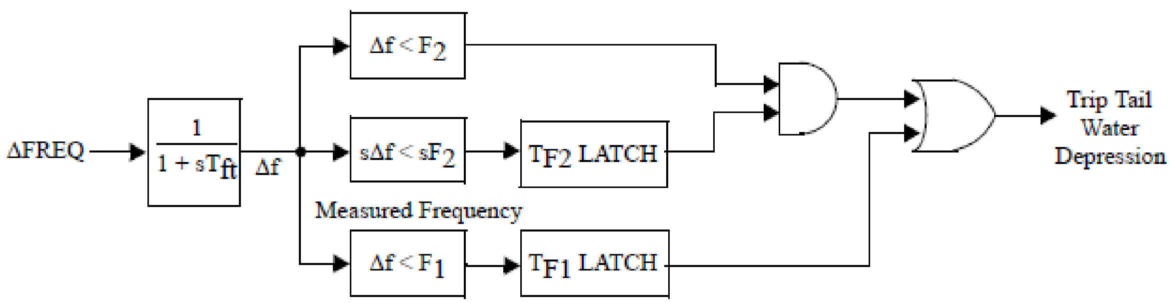


Turbine

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

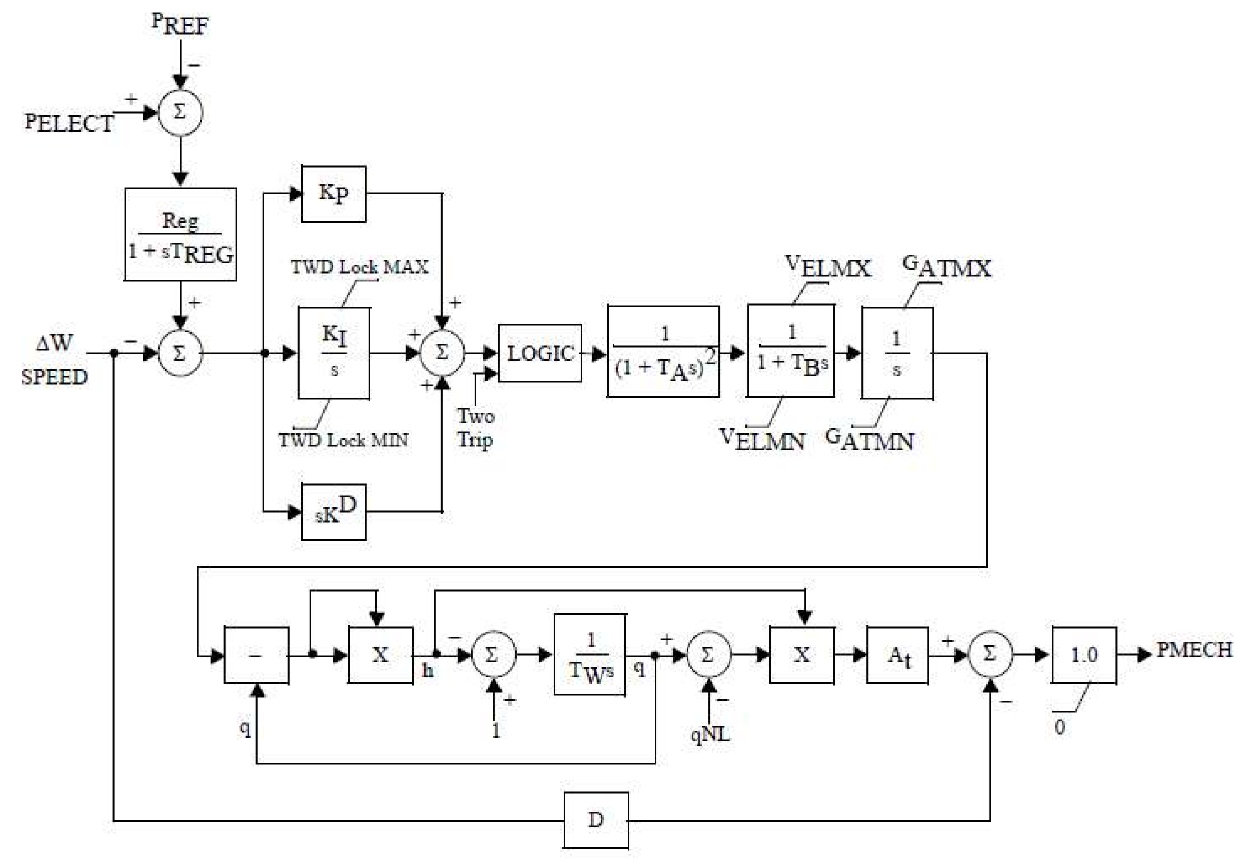


Tail Water Depression Model 1

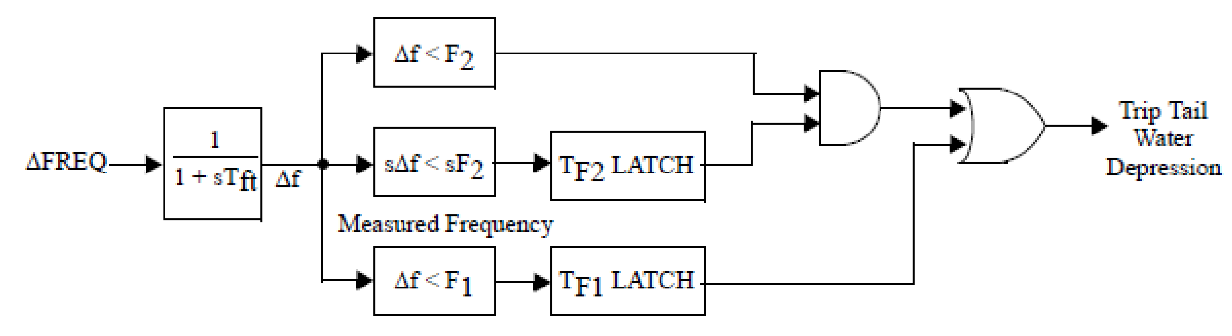


Tail Water Depression Trip Model

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

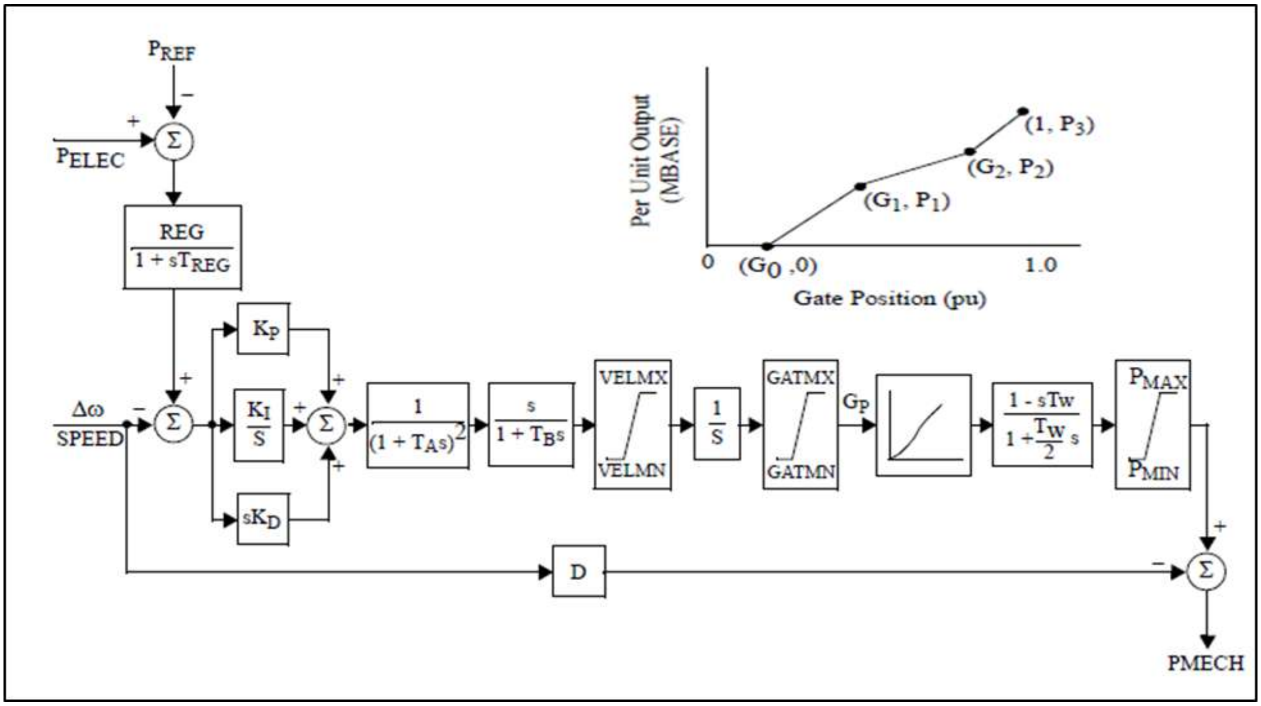


Tail Water Depression Model 2

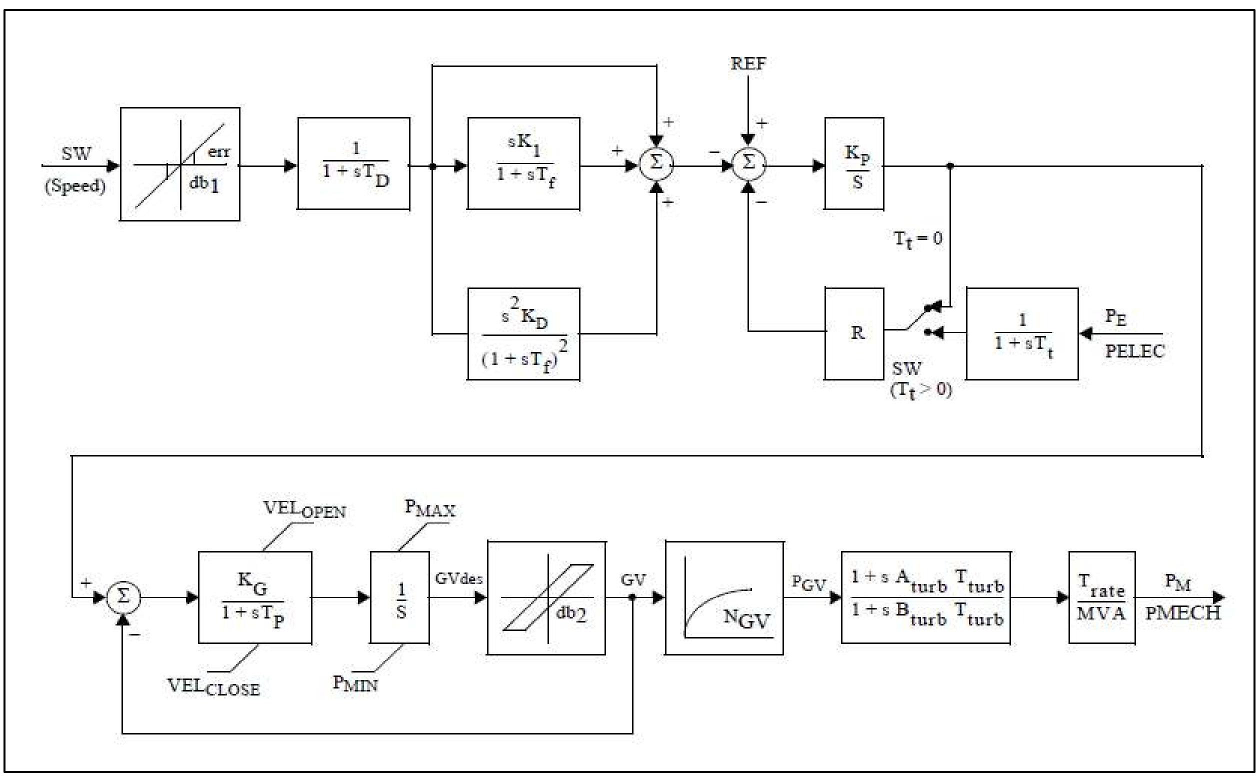


Tail Water Depression Trip Model

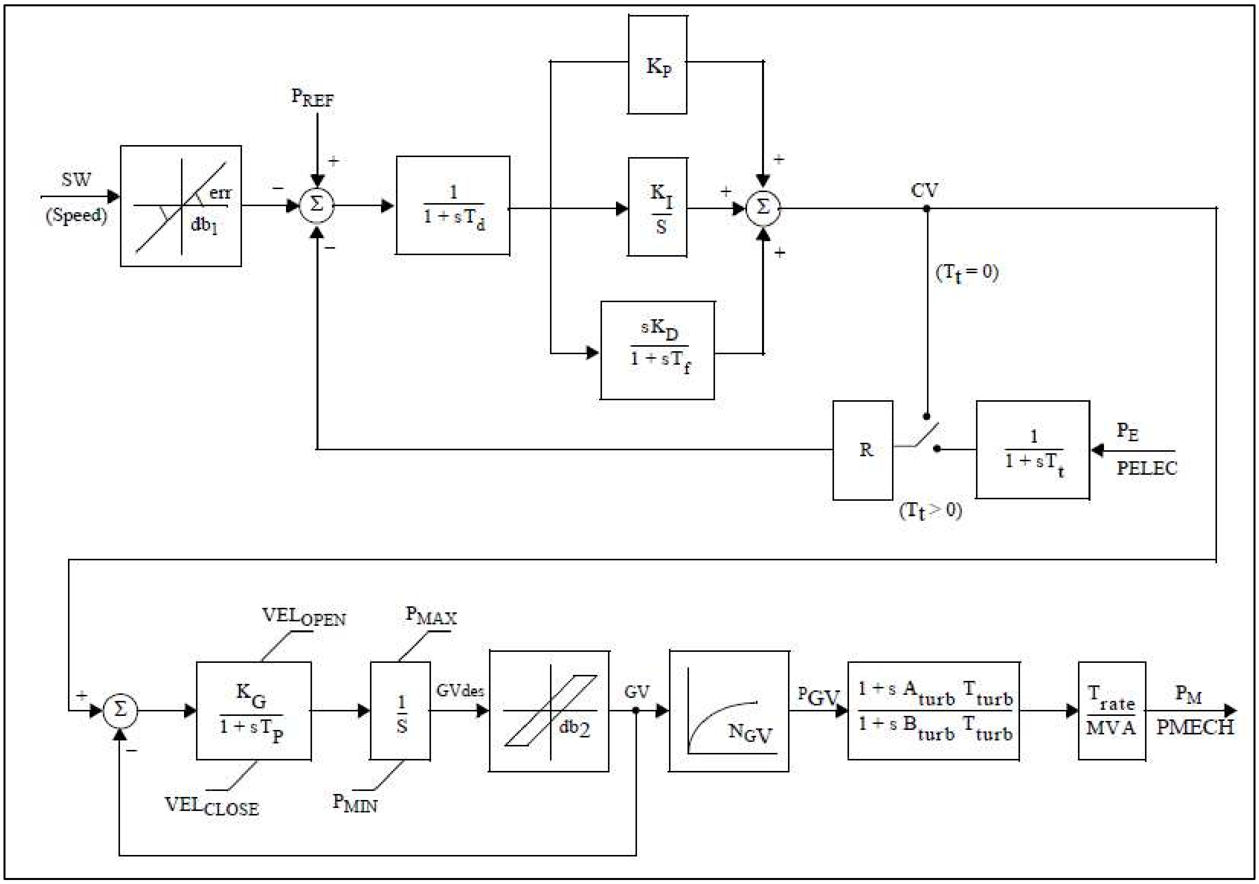
- **WPIDHY: Woodward PID Hydro Governor**



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



- **WSHYGP: WECC GP Hydro Governor Plus Turbine**



Source-PSSE Model Library

Calculation of saturation parameters:

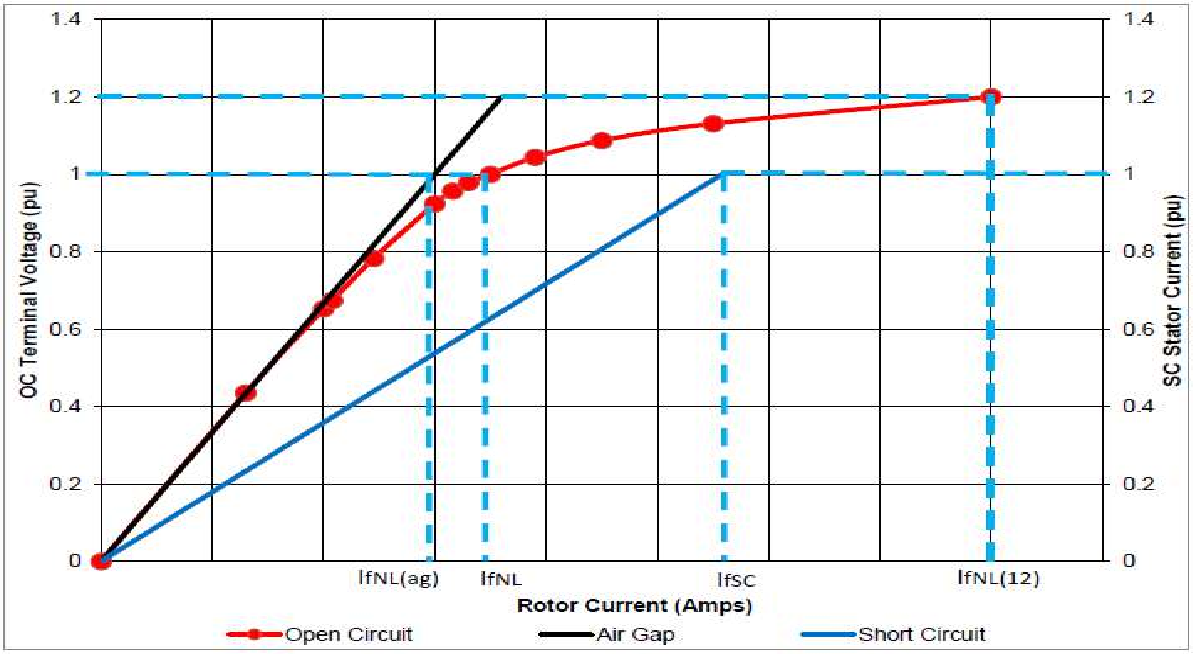


Figure 2: Open and short circuit characteristics

The saturation can be calculated using the following calculation:

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

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

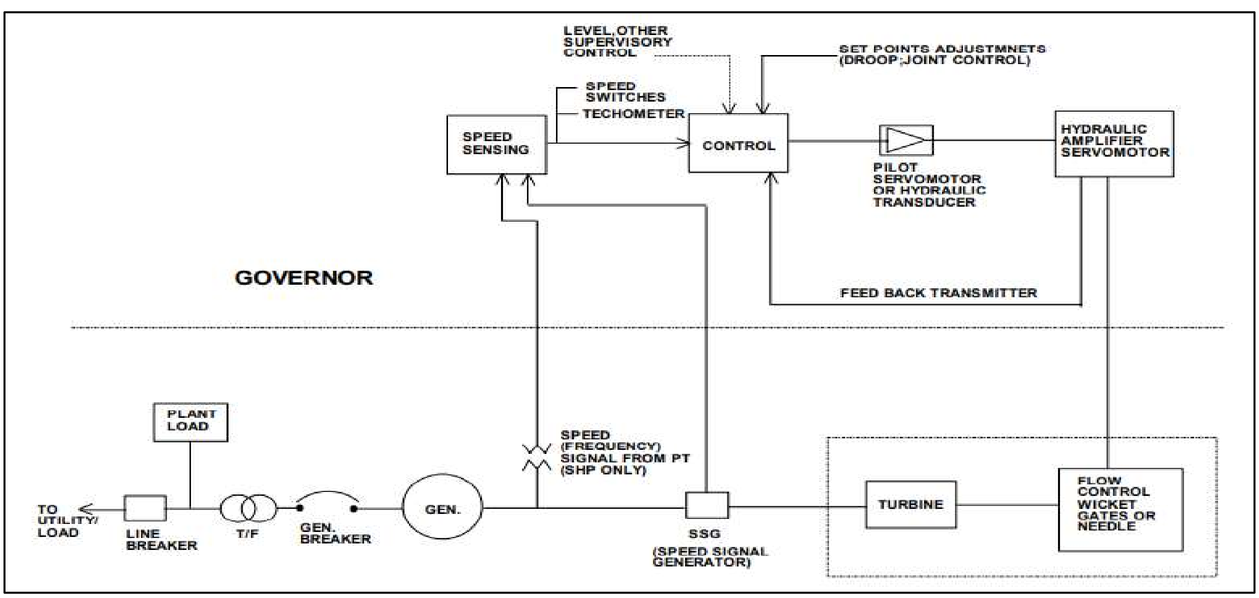


Figure 3: Governing system - Block Diagram (Typical) as per IEEE std. -75

Hydro Plant Details	
	Project/Plant details
1	Company/SLDC name:
2	Owner of the power station:
3	Project name and location:
4	Contact Number & Name of the Nodal person : Mr./ Ms.
5	Total Installed Capacity(MW): (e.g.2x100MW):
6	Turbine type: Francis /Kaplan / Pelton/Bulb/Any other
7	Intake River & Diversion dam:
8	Hydro station type - ROR/ ROR with poundage/Storage type:
	Reservoir details
1	Power station- Underground/Surface :
2	Energy content at FRL and Target energy for financial year :
3	Monthly design energy/10 daily energy:
4	Water usage (other than electricity production)- Irrigation/Flood control/ Bilateral treaty/ hydrology :
5	Which are the riparian States?
6	Is the Station part of the tandem hydro system? If yes then what are the constraints in operating the station?
7	Which is next hydro station (with pondage /reservoir) on the upstream and downstream side?
8	What is the accounting period for total water inflows and releases from the station?
9	Monthly pattern of release of water(over the day too)
10	What are the tools for forecasting the inflow silt etc. how much early (from the generation time) inflow forecasting is available?
	Beneficiaries of Plant
11	Who owns the Station and Who operates the Hydro Electric Station?
12	Which are the entities having entitlement on the power generated from the Station?
	Control/Direction
13	Which agency assesses the water inflows for the river basin on which the hydro station is built?
14	Which are the sectors/ entities that are entitled for water usage from the reservoir?
15	Who decides the allocation of water available for different usage such as drinking water, irrigation, industrial use, tourism, power generation?
16	Is the Station operation governed under some water sharing treaty?
17	In case the hydro station has multiple beneficiaries- Who coordinate the scheduling?
18	Who manages the water releases? Who decides the quantum of water available for power generation?
19	Where is the offtake for water for irrigation/drinking water- From the upstream from the reservoir or downstream of the tail race? What is the operating domain for the plant operator with respect to the water releases?
20	What is the philosophy for despatching the station - (managing peak demand / load following / ramping / deviation control / other)
21	How is the station compensated for the energy generated? Is the tariff multi-part or single part?

	Hydro Plant Details
	Pumped mode operation
22	Pumped Storage Capability available (Y/N), If yes operational since when?/Reason for Not utilized
23	In case of a pumped storage station, can the water be released when the lower reservoir is full?
	Scheduling aspects
24	Is the Station given a day-ahead schedule? If yes, can the schedule be revised in real-time?
25	What are the considerations/aspects to be taken care while revising day-ahead injection schedule?
	Operations
26	What is the operating range for operating the unit in the station?
27	Does the station have overload capacity (Yes/No)? If yes, how much?
28	Time required for synchronizing the unit and Time from synchronization to full load.
29	Is the station capable of operating in condenser mode? If yes, has it ever operated in this mode?
30	Is the station capable of black start(Yes/No) & AGC (Yes/No)
31	Who assesses the performance of the station? What are the indices for measuring the performance of the station?
32	What is the periodicity of assessing the performance and any incentive scheme?
33	Operational constraint
	Others
34	Comments if any

Check List of information to be submitted by New Regional Entity to RLDC

Sr. No.	Item	Available / Not Available / Value	Remark
	Name of the New Regional Entity:		
	Name of the Region / Concerned RLDC:		
I	**Metering Details**		
A	Main Meters **(feeder** wise, with nos.)		
B	**Standby Meter (feeder wise,** with nos.)		
C	**Check Meter (feeder** wise. with nos.)		
2	**Generation**		
A	**Total Installed Capacity (MW)**		
B	**No. of** Units		
C	Capacity of each unit (MW)		
D	FGM() / RGMO capability as per IEGC. Collected unit wise details		
I	[)ate of Commercial Operation (unit wise)		
3	**Transmission** Connectivity		
A	Voltage Level (kV)		
B	No. of Circuits		
C	Node of Connectivity to the Grid (in case of more than one node, add rows)		
I)	Date of the charging of lines / connection to the Grid (node wise)		
Ii	Map / Diagram showing connectivity to the Grid		
F	Details of Reactive Compensation		
(3	Details of Transformers – Number. MVA rating. Voltage Ratio, vector of each transformer bank		
4	**Protection**		
A	**Details of Protective Relays** obtained		
B	**Whether Protection Settings have been supplied to the** RLDC for Protection Coordination		
C	Any Special Protections Schemes used		
5	**Station Details**		
A	Single Line / Bus Diagram identi1iing all equipment		
6	Telemetry		
A	Type of Data Gateway (Remote Terminal Unit! Substation Automation System Gateway)		
B	Data Communication connectivity followed (As per interface requirement and other guideline made available by the respective RLDC)		
7	**Communication**		
A	Details of the communication media, interface and capacity being targeted for connection for Data Communication Main Channel		
B	[)etails of the communication media, interface and capacity being targeted for connection for Data Communication – Standby Channel		
C	Voice Communication – Main		
D	**Voice** Communication – Standby		

E	Integration of Station Data in the SCADA of the Concerned RLDC		
F	Integration of Station Data in the SCADA of NLDC		
G	L)etails of any dedicated communication (Voice / Data) that the Station has with another Control Area and the neighboring station		
S	Manning of the Control Room		
A	Contact details (Telephone, FAX)		
I)	Contact person		
C	Escalation Matrix starting from Control Room Shift In—charge to Senior Level		
I)	Details of the Shift Operation		
9	Modification of various applications to include the New Regional Entity at the Concerned **RLDC**		
A	Scheduling		
B	Metering		
C	Accounting (UI/RE)		
1)	Reporting Systems I las the new entity been informed about the information submission requirements to the RLDCs along with periodicity?		
10	Bank Account Details of the **new Regional Entity**		
A	Bank Account No.		
B	Bank Name & Branch		
C	Bank Address		
I)	RLDC bank account details been intimated to the new entity		
11	**Agreement Details**		
A	Quantum for which LTA has been sought (MW)		
B	Long Term Agreement (MW) fbr which PPA exists		
C	Medium Term Agreement (MW) for which PPA exists		
12	Simulation Studies		
A	Incorporation in the assessment of Transfer Capability		
13	Undertakings to be obtained		
A	Undertaking obtained from new entity that it is not going to breach any PPA to sell in short term		
14	Intimation to Concerned **RPC** about addition of a New Regional Entity		
A	Intimation sent		
B	Inclusion in the REA		

<u>Section 2</u>

Procedure for Integration of Solar, Wind or Hybrid Power Plant/Wind or Solar Power Parks, WPD/SPD/HPD those are regional entities

Table of Contents

	Contents	Page No.

Procedure for Integration of Solar, Wind or Hybrid Power Plant/Wind or Solar Power Parks, WPD/SPD/HPD those are regional entities

This procedure shall be applicable for integration of Wind/Solar and hybrid (Wind/Solar and Battery Energy Storage System) generating stations those are regional entities:

1. Document Submission to RLDCs

The following documents shall be submitted to RLDC at-least three months ahead of the proposed date of commencement of first time charging activities

a) **Connectivity Details:** Connection Agreement & Format viz. RCON-IIA-Stage-II connectivity grant letter by CTU, CON-3,CON-4, CON-5, CON-6 and any other applicable formats to be submitted to RLDCs specifying the point of connection, bay numbers etc.
Ref : [Detailed Procedure made under Regulation 27 of the Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and related matters) Regulations, 2009 for grant of Connectivity to projects based on renewable energy sources to inter-State Transmission System (ISTS)]-

b) **Access Details:** LTA, MTOA details including but not limited to LTA grant letter, LTA /MTOA agreement letter etc.

c) **PPA/PSA details**- Copy of signed power purchase agreement (PPA), power sale agreement (PSA) etc. as applicable may be submitted to the respective RLDC.
Ref: [As per clause 6.4.14 of Indian Electricity Grid Code (IEGC)]

d) Copy of Coordination Agreement with the Qualified coordinating Agency(QCA)/Lead/Principal Generator, if any

e) Copy of agreement(s) between SPPD/WPPD/HPPD and SPD/WPD/HPD

f) Copy of Affidavit regarding PPA rates for the purpose of Deviation charge account [Ref: As per CERC approved Procedure dated 03.03.17]

g) Copy of registration with CEA in line with CEA "Framework for registration of generating Unit" dated 13.04.2018

h) **Technical Details-** Below mentioned technical details to be submitted as per CERC approved Procedure dated 03.03.17

i) **Static Details:** Details of Wind / Solar/Hybrid power plant, Static parameters for wind generating station and Static parameters for solar generating station has been provided as per format ***Annexure-I, Annexure-I(A)* and Annexure-I(B)**** respectively.[Ref: Formats are as per CERC approved Procedure dated 03.03.17]

ii) Additional Details: Following additional information are also required other than the details mentioned in CERC approved Procedure dated 03.03.17
   a) The latitude and longitude of the solar farm shall be one coordinate for every 50 MW. (The solar farms are spread in a wide area and for proper forecasting, we shall have more positional details of the plant)
   b) Number of PV panels & total area covered by PV panels

iii) **Dynamic Model**
   - Copy of dynamic model submitted to CTU during connectivity as per the CTU connectivity procedure which is enclosed at Annexure***-I(C)*** and ***Annexure-I (D)*** respectively
   - Updated dynamic model three months ahead of the proposed date of first-time charging
   - Following Reports also to be included along with the dynamic model:
     a. Parameters of WTG/Inverter in .dyr file to be validated with the test report results from the LVRT/HVRT certification and the validation report to be submitted.
     b. Simulation Report of plant model confirming CEA compliance for Dynamic reactive support/LVRT/HVRT/Frequency control.
     c. Simulation Report of Reactive Capability Curve of Plant measured at 220 kV bus (for Voltage 0.95/1/1.05 pu) and Short circuit study results.
   - Inclusion of EMTP model of plant (in PSCAD platform), benchmarking report of model along with the dynamic model data.
   - Final Updated dynamic model after COD of the entire station (within one month of COD declaration)

iv) Simulation Report
   a. Format for Simulation Report as per enclosed ***Annexure-I (E)***.

v) Single Generator equivalent model as per ***Annexure-I(F).***

vi) **Battery Energy Storage System**- Static, Dynamic and real time telemetry requirement of Battery Energy Storage System is as per ***Annexure-I(G).***

i) **Indemnity Bond-under** clause 5.1.2(j) of CERC approved procedure of 03.03.17 stated-

'Keep each of the RLDCs indemnified at all times and shall undertake to indemnify, defend and save the SLDCs/RLDCs harmless from any and all damages, losses including commercial losses due to forecasting error, claims and actions including those relating to injury to or death of any person or damage to property, demands, suits, recoveries, costs and expenses, court costs, attorney fees, and all other obligations by or to third parties, arising out of or resulting from the transactions undertaken by the Generators.'

Notarized Indemnify bond to be submitted by generator which is as per ***Annexure-II.***

j) **Notarized Undertaking on compliance of CEA**- As per Central Electricity Authority (Technical Standards for Connectivity to the Grid)(Amendment) Regulations, 2019, undertaking for harmonics, periodic measurement of other power quality parameters such as voltage sag, swell, flicker, disruptions, LVRT and HVRT compliance etc. to be submitted by RE generators.
   Ref: Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019

k) **Undertaking as per CERC approved procedure:** RE Generator or Lead Generator or Principal Generator shall submit undertaking as per CERC approved procedure of 03.03.17. Format for undertaking is as ***Annexure-III***

l) **Notarized undertaking towards exemption of transmission charge/loss (as applicable)**: As per Hon'ble CERC Notification (dated 14.12.2017) on 5th amendment to Sharing of Inter State Transmission Charges and Losses Regulation, 2017, certain wind/solar power generating stations are exempted from sharing the inter-state transmission charges and losses. Notarized undertaking to be submitted, if applicable. Format for undertaking is as per ***Annexure-IV***

m) **LVRT/HVRT Test report and Conformity certificate:** LVRT/HVRT Statement of Compliance/Conformity certificate and test report from an "accredited agency" as specified by MNRE, GoI. Accreditation certification from the agency can also be asked for verification if required. Undertaking for LVRT/HVRT compliance to be submitted. Format for undertaking is as per ***Annexure-V***

n) **Geotagging Information for each wind turbine:** NIWE, Chennai developed geo-tagged database /online registry of wind turbines installed across the country. As per office memorandum of MNRE, all wind turbines in a project should be geo-tagged before Commercial Operation Date (COD). Copy of same to be submitted to RLDCs.

o) **Compliance of aviation safety norms**: Undertaking to be given by WPD for all the WTGs for the compliance of aviation safety norms.

2. <u>User Registration with RLDC</u>

As per Clause 7.2 of CERC approved Procedure dtd 03.03.17 "The SPPD / WPPD shall be responsible for registering the Solar Power Park with the respective RLDC/SLDC as applicable as a User and shall submit Appendix-IV of CERC (Fees and Charges of Regional Load Despatch Centres and related matters) Regulations, 2019 before getting connected at the Connection point with the ISTS for the first time."
The SPPD/WPPD shall be registered under category "Generator" and therefore one-time registration fee shall be based on total installed capacity of SPPD/WPPD.

As per Clause 14..2 of CERC approved Procedure dtd 03.03.17:"RE Generators or lead generator or principal generator shall pay RLDC fees and charges as per Hon'ble CERC

Regulation “Fees and charges of Regional Load Despatch Centre and other related matters”, Regulation 2015 and further amendment thereof after getting registered with respective RLDCs as a User of RLDC.”

a) Submission of information in Appendix-IV of CERC “Fees and charges of Regional Load Despatch Centre and other related matters”, Regulation 2019 as ***Annexure-VI***
b) Bank Details for Payment of Registration fee to RLDC as ***Annexure-VI(A)***

Bank account details to be submitted along with PAN and GSTN details.

3. Pre-charging Activities

The following prerequisite must be ensured by the requester (WPD/SPD) prior to seeking code for first time charging of any new or modified power system elements:

a) Installation of Interface Meters (through CTU) –

As per CEA (Installation & Operation of Meters)-Regulation-2006 & amendments, Entity has to coordinate CTU for SEMs along with data collecting devices (DCD). Generating station is responsible for submission of weekly energy meter data and time drift correction to the respective RLDCs.

b) Statutory Approval-

In line with the CEA(Measures relating to safety & electric supply) Regulation-2015 (as amended), a copy of charging approval obtained from the Central Electricity Authority, Govt. of India is to be submitted to RLDCs before energisation of any electrical installation.

[Ref.: CEA - Measures relating to Safety & Electric supply Regulations-2010 (clause. 43)]

c) SCADA Integration for transfer of real time data to RLDCs

i) Entity has to provide real time data for wind and solar plants for all parameters mentioned in ***Annexure- VII(A) and VII(B)*** to the Respective RLDCs @ resolution of 10 sec (Ref: - Detailed parameters as per CERC Approved Procedure of 03.03.2017]

ii) Telemetered weather parameters like Ambient Temperature (^{0}C), Relative Humidity (%), Wind Speed, and Wind Direction etc. to be provided to respective RLDC. Segregation of telemetered points is as per ***Annexure-VII(C) and VII(D).***

iii) PMU Installation (Signal list as per ***Annexure-VII(E)***)

d) Details of approval of scheme/Minutes of Meeting such as standing committee etc.

e) Necessary protection coordination with all adjacent substation. Confirmation to be given regarding installation of DR/EL at Solar and Wind generating stations.

f) Redundant channel upto main control centre with automatic failover. Redundancy should work for all of the following failures:

- Single Communication link failure
- Single Gateway failure

- Single Master station polling server failure

g) Dedicated Voice communication from Solar/Wind Generating Plant to control centre (RLDC) using VOIP communication is mandatory before charging of station.

h) Following Details to be shared-

a) Details of PMU (make and version)

b) Details of gateway/RTU – Make and version

c) Details of the Multiplexor owned by RE station

4. **Submission of first time charging format for associated elements-**

First time charging of any power system element associated with Wind/Solar plants is carried out as per the Procedure for integration of a new or modified power system elements. First time charging of any element in generating station will be allowed only after submission of the information mentioned in Procedure for integration of a new or modified power system elements.

& after obtaining necessary approval from RLDC.

5. **Coordination with RLDC Control Room**: Any switching operation viz. charging of EHV line or first charging of WTGs/ solar inverters shall be done after availing permission (in the form of an instruction code) from the RLDC control room. Similarly, the charging date and time must be intimated to RLDC control room within 10 (ten) minutes of the first charging of the said element.

6. **Scheduling:** Scheduling of power from the generating station or unit thereof shall commence from 0000 hrs after declaration of COD subject to visibility of the WTGs/Solar inverters through telemetry at the RLDC SCADA system.

*Example: Suppose a Wind/Solar plant having installed capacity of 250 MW has declared COD for 250 MW. However, if on the proposed day of scheduling, status data & analog data for WTG/Solar inverters corresponding to only 50 MW capacity is visible at RLDC through SCADA system, RLDC shall consider only 50 MW for scheduling(**Annexure-VIII**);*

7. **Forecasting Scheduling & Deviation Settlement:** Power plants shall comply with the provision of CERC Regulations (IEGC-03rd amendment & DSM 2nd amendment regulation 2015) and CERC approved procedure dated 03.03.2017 for facilitation of forecasting, Scheduling & Deviation Settlement in respect of its power plants.

Note: Further amendment in the procedure can be done in line with IEGC/other CERC & CEA regulations/directive from time to time.

Enclosures.

Annexure-I: Details of Wind/Solar Generating Station

Annexure-I(A): Static data of Wind Generating Station

Annexure-I(B): Static data of Solar Generating Station

Annexure-I(C): Guidelines for Exchange of data for modelling wind farms

Annexure-I(D): Guidelines for Exchange of data for modelling Solar farms
Annexure-I(E): Template for Simulation Report Submission by RE Developer
Annexure-I(F): Single Generator Equivalent Model
Annexure-I(G): Battery Energy Storage System
Annexure-II: Indemnity Bond
Annexure-III: Undertaking by SPD / SPDD / WPD / WPPD
Annexure-IV: Undertaking by SPD /WPD
Annexure-V: Affidavit
Annexure-VI: Submission of information as per RLDC (Fees & Charges) Regulation 2019
Annexure-VI(A): Bank and Tax related details
Annexure-VII(A): Real time Telemetry Wind generating plants
Annexure-VII(B): Real time Telemetry Solar generating plants
Annexure-VII(C): Real-time Data Telemetry requirement Wind Turbine Generating plants
Annexure-VII(D): Real-time Data Telemetry requirement Solar Turbine Generating plants
Annexure-VII(E): PMU signal list
Annexure-VIII: Block diagram showing case wise scheduling procedure considering a sample case
Annexure-IX: Forecast and Schedule Data to be submitted by Wind/Solar plants/ Lead generator, Principal generator

Other than the documents mentioned above the formats for first time charging of transmission elements (Format A1-A6, B1-B5 and C1-C4) to be submitted to concerned RLDC.

Details of Wind/Solar Generating Station

Details to be submitted by the Wind/Solar generating stations which are regional entities/ lead generator, principal generator	
Type: Wind/Solar Generator	
Individual / on Behalf of Group of generators	
If on Behalf of Group of generators group of then details of agreement to be attached	
Total Installed Capacity of Generating Station	
Total Number of Units with details	
Physical Address of the RE Generating Station	
Whether any PPA has been signed: (Y/N)	If yes ,then attach details
Connectivity Details	Location/Voltage Level
Metering Details	Meter No. 1. Main 2. Check
Connectivity Diagram	(Please Enclose)
Static data	As per attached sheet
Contact Details of the Nodal Person	Name : Designation : Number: Landline Number, Mobile Number, Fax Number E - Mail Address :
Contact Details of the Alternate Nodal Person	Name : Designation : Number: Landline Number, Mobile Number, Fax Number E - Mail Address :

Static data of Wind Generating Station

S No	Particulars
1	**Type**
2	Manufacturer
3	Make
4	Model
5	Capacity
6	commissioned date
7	Hub height
8	total height
9	RPM range
10	Rated wind speed
11	**Performance Parameter**
12	Rated electrical power at Rated wind speed
13	Cut in speed
14	Cut out Speed
15	Survival speed (Max wind speed)
16	Ambient temperature for out of operation
17	Ambient temperature for in operation
18	survival temperature
19	**Low Voltage Ride Through (LVRT) setting**
20	**High Voltage Ride Through (HVRT) setting**
21	lightning strength (KA & in coulombs)
22	Noise power level (db)
23	**Rotor**

24	Hub type
25	Rotor diameter
26	Number of blades
27	Area swept by blades
28	Rated rotational speed
29	Rotational Direction
30	Coning angle
31	Tilting angle
32	Design tip speed ratio
33	**Blade**
34	Length
35	Diameter
36	Material
37	Twist angle
38	**Generator**
39	Generator Type
40	Generator no of poles
41	Generator speed
42	Winding type
43	Rated Gen. Voltage
44	Rated Gen. frequency
45	Generator current
46	Rated Temperature of generator
47	Generator cooling
48	Generator power factor
49	KW/MW @ Rated Wind speed
50	KW/MW @ peak continuous
51	Frequency Converter

52	Filter generator side
53	Filter grid side
54	**Transformer**
55	Transformer capacity
56	Transformer cooling type
57	Voltage
58	Winding configuration
59	**Weight**
60	Rotor weight
61	Nacelle weight
62	Tower weight
63	**Over speed Protection**
64	**Design Life**
65	**Design Standard**
66	Latitude
67	Longitude
68	COD Details
69	Past Generation History from the COD to the date on which DAS facility provided at RLDC, if applicable
70	Distance above mean sea level

Static data of Solar Generating Station

1. Latitude
2. Longitude
3. Turbine Power Curve
4. Elevation and orientation angles of arrays or concentrators
5. The generation capacity of the Generating Facility
6. Distance above mean sea level etc.
7. COD details
8. Rated voltage
9. Details of Type of Mounting: (Tracking Technology If used, single axis or dual axis, auto or manual)
10. Manufacturer and Model (of Important Components, Such as Turbine, Concentrators, Inverter, Cable, PV Module, Transformer, Cables)
11. DC installed Capacity
12. Module Cell Technology
13. I-V Characteristic of the Module
14. Inverter Rating at different temperature
15. Inverter Efficiency Curve
16. Transformer Capacity & Rating , evacuation voltage, distance form injection point

Guideline for exchange of data for modelling Wind farms

Annexure: Formats for submission of modelling data for wind turbine generators / wind farms

Version History:

Version no.	Release Date	Prepared by*	Checked/Issued by*	Changes

*Mention Designation and Contact Details

Details submitted:

Details pending:

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

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

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

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

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

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

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

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

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

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

Formats for submission of modelling data for PV inverters

Version History:

Version no.	Release Date	Prepared by*	Checked/Issued by*	Changes

*Mention Designation and Contact Details

Details submitted:

Details pending:

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

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

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

3.2 Generic Models for Utility Scale Solar-PV generation:

Category	Parameter Description	Data
GENERATOR model		
Solar PV (REGCA1)	Tg, Converter time constant (s)	
	Rrpwr, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)	
	Brkpt, LVPL characteristic voltage 2 (pu)	
	Zerox, LVPL characteristic voltage 1 (pu)	
	Lvpl1, LVPL gain (pu)	
	Volim, Voltage limit (pu) for high voltage reactive current manage-	
	Lvpnt1, High voltage point for low voltage active current management (pu)	
	Lvpnt0, Low voltage point for low voltage active current management (pu)	
	Iolim, Current limit (pu) for high voltage reactive current management (specified as a negative value)	
	Tfltr, Voltage filter time constant for low voltage active current management (s)-	
	Khv, Overvoltage compensation gain used in the high voltage reactive current management	
	Iqrmax, Upper limit on rate of change for reactive current (pu)	
	Iqrmin, Lower limit on rate of change for reactive current (pu)	
	Accel, acceleration factor (0 < Accel <= 1)	
Electrical Control model		
Large Solar PV : (REECB1) [Refer Block Diagrams]	Vdip (pu), low voltage threshold to activate reactive current injection logic	
	Vup (pu), Voltage above which reactive current injection logic is activated	
	Trv (s), Voltage filter time constant	
	dbd1 (pu), Voltage error dead band lower threshold (≤0)	
	dbd2 (pu), Voltage error dead band upper threshold (≥0)	
	Kqv (pu), Reactive current injection gain during over and undervoltage conditions	
	Iqh1 (pu), Upper limit on reactive current injection Iqinj	
	Iql1 (pu), Lower limit on reactive current injection Iqinj	
	Vref0 (pu), User defined reference (if 0, model initializes it to initial terminal voltage)	
	Tp (s), Filter time constant for electrical power	

Category	Parameter Description	Data
Electrical Control model		
Large Solar PV : (REECB1) [Refer Block Diagrams]	QMax (pu), limit for reactive power regulator	
	QMin (pu) limit for reactive power regulator	
	VMAX (pu), Max. limit for voltage control	
	VMIN (pu), Min. limit for voltage control	
	Kqp (pu), Reactive power regulator proportional gain	
	Kqi (pu), Reactive power regulator integral gain	
	Kvp (pu), Voltage regulator proportional gain	
	Kvi (pu), Voltage regulator integral gain	
	Tiq (s), Time constant on delay s4	
	dPmax (pu/s) (>0) Power reference max. ramp rate	
	dPmin (pu/s) (<0) Power reference min. ramp rate	
	PMAX (pu), Max. power limit	
	PMIN (pu), Min. power limit	
	Imax (pu), Maximum limit on total converter current	
	Tpord (s), Power filter time constant	

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

ANNEXURE-I(E)

Template for Simulation Report Submission by RE Developer

1) Technical Details: -

1) WTG/Inverter Details for each make: -

WTG/Inverter Details	
Model/Make	
No of WTG/Inverter	
Terminal Voltage	
Rated MVA	
Rated power	
Impedance	
Qmax	
Qmin	

2) Wind turbine Transformer / Inverter Transformer Details: -

WT/Inverter Transformer Details	
Rating	
Type	
Ratio	
Vector Group	
Tap changer	
Impedance	

3) Power Transformer Details:

Power Transformer Details	
Rating	
Type	
Ratio	
Vector Group	
Tap changer	
Impedance	

4) Conductor/Cable details :

Conductor Details	**Voltage in kV**	**Positive Sequence**			**Zero Sequence**			**Ampacity**	**MVA Rating**
		R in pu	**R in pu**	**X in pu**	**R in pu**	**X in pu**	**B in pu**		

2) Detailed Wind/Solar farm Simulation model

3) Equivalent Wind/Solar farm Simulation model

4) **Simulation results showing the comparison of detailed plant model and Equivalent model of the Wind/Solar farm**

5) **PQ Capability Curve plot of WTG/ Inverter for each make in the plant.**

6) **PQ Reactive Capability Curve plot of Wind/Solar Farm at PCC (i.e. at 220kV)**
   - Derived from detailed plant model steady state case for PCC voltages (0.95 pu, 1 pu, 1.05 pu).
   - Study report to be attached as Annexure

7) **Short circuit study results for 3 phase/ single phase fault at PCC.**
   - Derived from detailed plant model steady state case.
   - Voltage Factor – 1.1
   - Study report to be attached as Annexure.

8) **Simulation results of benchmarking report (if available)-**

   Benchmarking report includes validation of WTG/ Inverter Simulated model against actual measurement results from the test report of Statement of Compliance/Conformity Certificate for LVRT/HVRT.

   This validates the following parameters of Wind machine/ Inverter model submitted in the PSSE .dyr file
   - REGCA1 - Renewable Energy Generator/Converter Model
   - REECA1 - Generic Renewable Electrical Control Model
   - WTDTA1 - Generic Drive Train Model for Type 3 and Type 4 Wind Machines
   - WTPTA1 - Generic Pitch Control Model for Type 3 Wind Generator
   - WTARA1 - Generic Aerodynamic Model for Type 3 wind machine
   - WTTQA1 - Generic Torque controller for Type 3 wind machine

9) **Simulation results of the submitted PSSE model.**

   <u>LVRT Test</u>
   - Case-1: 3-ph impedance fault at 220 kV POC for 3 sec (220 kV grid voltage is <0.85 pu during fault)
   - Case-2: 3-ph impedance fault at 220 kV POC for 300 msec (220 kV grid voltage is 0.15 pu during fault)

   <u>HVRT Test (as applicable)</u>
   - Case-1: Rise in 220 kV grid voltage is up to 1.2 pu for 2 sec
   - Case-2: Rise in 220 kV grid voltage is up to 1.2 pu for 200 msecs

   <u>Operating Frequency Range [Frequency control flag(Fflag) set 0 in PPC model]</u>
   - Case -1: Rated Active Power Generation between 49.5 – 50.5 Hz.
   - Case -2: Stable power output between 47.5 – 52 Hz.

   <u>Voltage Response Test</u>
   - Case-1: Step increase in Voltage at POC from 1 pu to 1.05 pu
   - Case-2: Step decrease in Voltage at POC from 1 pu to 0.95 pu

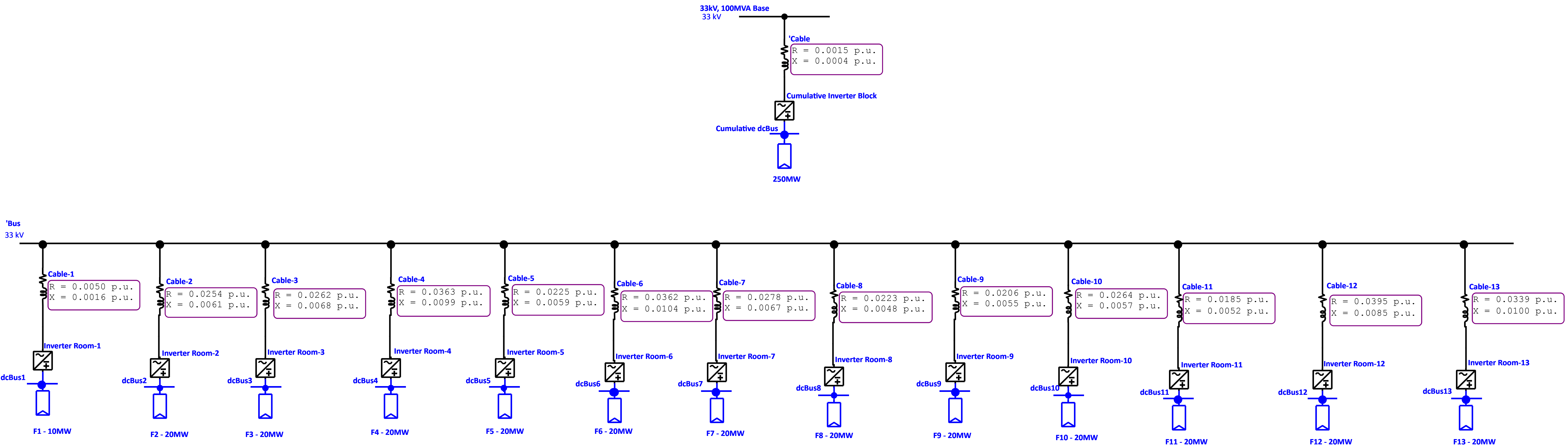
   <u>Frequency Response Test (as applicable)</u>
   - Case-1: Increase in grid frequency up to 50.5 Hz
   - Case-2: Decrease in grid frequency up to 49.5 Hz.

10) **List of protection and its settings for WTG/solar inverter**

Single Generator Equivalent Model

ANNEXURE-I(F)

324MWp/250MW REWA Solar power project



Procedure for First Time Charging of Battery Energy Storage System(BESS)

BESS shall consist of:

i) A power conversion system (PCS)

ii) An energy storage

iii) Battery Management System (BMS)

Basic components of BESS as follows:

i) Batteries as its underlying storage technology to be connected to an electrical network
ii) Bidirectional inverter is the main device that converts power between the AC line voltage and the DC battery terminals, and allows for power to flow both ways to charge and discharge the battery
iii) Other components of a BESS may include an isolation transformer, protection devices (e.g. circuit breakers), cooling systems, and a high-level control system to coordinate the operation of all components in the system

Documents and data to be submitted for integration of BESS:

1. The applicant shall furnish the undertaking to comply with CEA Technical Standards for connectivity to the Grid Regulations. The following information also need to be provided alongwith the application:

S.No.	Description	Details to be furnished
A	**Battery**	
1	Make/Manufacturer	
2	Type / Chemistry	
3	Design capacity of battery in terms of KWh	
4	Self-Discharge rate	
5	DoD	
6	Life cycle of battery	
7	Round trip efficiency	
8	Dimensions and weight of battery	
9	Test certificate available for battery cell/module (IEC Standards	
10	Number of series & parallel connected cells and modules	
11	Power/energy rating cells and modules	
12	BESS favorable operating temperature	

B	**Power Conditioning Unit**	
1	Make/manufacturer	
2	Type of charge controller(DC-DC converter)	
3	Inverter- power rating & efficiency	
4	Inverter minimum response time	
5	Test certificate available (IEC Standards)	
C	**Measurement and control Devices**	
1	Sensors	
2	Sensitivity Type/Make	
3	Accuracy/Precision	

Battery Static Parameters:

Details	**Technical requirement**
AC ratings	
Total rated output power to load @ nominal voltage (charge) MW to (discharge) MW	
Apparent power @ nominal voltage	
No of units	
Rate output power of each unit	
Real and reactive power control accuracy(%)	
Voltage range	
Type of output	
Frequency (Nominal Frequency and the tolerance band)	
VAR production (full MVAR production at rated Voltage)	
Harmonics (as per CEA standards)	
DC input ratings	
Voltage range	
Ripple voltage	
Ripple current (% of full current peak to Peak)	
Environmental ratings	
Operating temperature	
Humidity	
Functions/Features	
Power flow operation (, Support four - quadrant control)	Yes / NO

Real power control (Positive and negative)	Yes / NO
Reactive power control (capacitiveand inductive)	Yes / NO
Combination of real and reactive power control(priority real power)	Yes / NO
Load following (renewable smoothing)	Yes / NO
Low-voltage ride through	Yes / NO
Synchro-check function	Yes / NO
Operation modes	
Black start (external command)	Yes / NO
Commanded power (external command)	Yes / NO
Commanded VAR (external command)	Yes / NO
Frequency regulation	Yes / NO
Frequency response (Automatic)	Yes / NO
Islanding	Yes / NO
Renewable smoothing (if applicable , automatic)	Yes / NO
Scheduled power (preconfigured time/date of work power profiles	Yes / NO
Voltage regulation	Yes / NO
Response time of PCS to the command received (Milli seconds)	
Communications	
Communications with LDC (main /standby)	Yes / NO
Battery technologies	
Battery technologies supported(Ex Li-Ion etc ..)	
Battery Cycle life	> 4,000 at 20-80% SOC
Voltage Regulation (%)	
Reactive Power Regulation (Var flow level Range +/- example +/- 5%))	
Frequency Regulation (+/_ cycle /second)	
Capacity (Ah)	
Power factor	
Battery temperature (average/extreme)	
Overload capability (%) and Switching frequency(in kHz) State of Charge (SOC)	
Protection system	
Under/over voltage (DC and AC)	
Under/over frequency	
Over current protection	
Ground fault protection	
Over heat protection	

Surge protection (DC and AC)	
Automatic AC & DC open circuit when fault detection	

2. Following parameters need to be telemetered at RLDC/NLDC:

i. Operating Mode:
   a. Grid connected/ Standalone mode
   b. Automatic/ Manual mode
   c. Charge/discharge
ii. Measurements (Voltage, Current, P, Q, Status of Charging, charge/discharge rate freq., energy export/import)
iii. Events and alarms Breaker position/operation
iv. BESS Start Inhibit Status
v. Ambient Temperature
vi. Parameters of PCS such as active power, reactive power, power factor, operating DC voltage etc.
vii. Number of battery inverters in operation and Number of battery inverters available in BESS
viii. Full pack energy: Estimated maximum energy capacity of the batteries
ix. Energy remaining: Estimated energy remaining of the batteries
x. Available maximum capacity: State of energy available in batteries
xi. Possible charge and discharge power
xii. Local MW set point
xiii. Reference set points for voltage, power factor and reactive power control
xiv. Local limit for charge and discharge
xv. Charge and discharge ramp up and ramp down rates
xvi. MW reference (AGC)
xvii. AGC availability status
xviii. Control mode: AGC/Local
xix. Indication of frequency control status
xx. Indication of control modes; voltage, power factor, reactive power
xxi. State of Charge (SOC) (Mwh)
xxii. Maximum State of Charge (Mwh)

3. Test Certificates:

The applicant shall furnish the following test certificates prior to trial run:

i. Verification of sensors, metering and alarms
ii. Verification of all control functions including automatic, local and remote control
iii. Verification of the performance criteria
iv. Demonstration of all the intended applications
v. Demonstration of grid interface protection & control system
vi. Verification of power quality parameters

4. Grid-tied energy storage units are predominately DC in nature. To utilize the energy storage capability on the AC electric grid, the energy from batteries must be converted to a standard AC level and regulated through a converter, generally known as the Power Conversion System (PCS). The PCS serves as the interface between the DC battery system and the AC system, providing bi-directional conversion from DC to AC (for discharging batteries) and AC to DC (for charging batteries). The PCS may consist of one or more parallel units. The PCS shall be bi-directional converter that can be operated in inverting mode for battery discharging and rectifying mode for battery charging. Power Conversion System Operation conditions:

i. The AC power transformed efficiently from the DC power of the battery arrays shall be bi-directionally transferred to or from the distribution line without causing harmonics higher than the CEA regulation.

ii. The PCS shall contain a remote synchronization feature, as well as the standard synchronization used when starting the PCS online. The remote synchronization feature allows the PCS to synchronize its voltage and frequency to any other remote AC bus or generator.

iii. Black start capability

iv. The PCS shall have the ability to perform four-quadrant control.

v. The PCS shall be able to perform load following (for PV smoothing) Voltage shall be maintained at +/- 5% nominal under normal operating conditions and +/- 10% under emergency conditions.

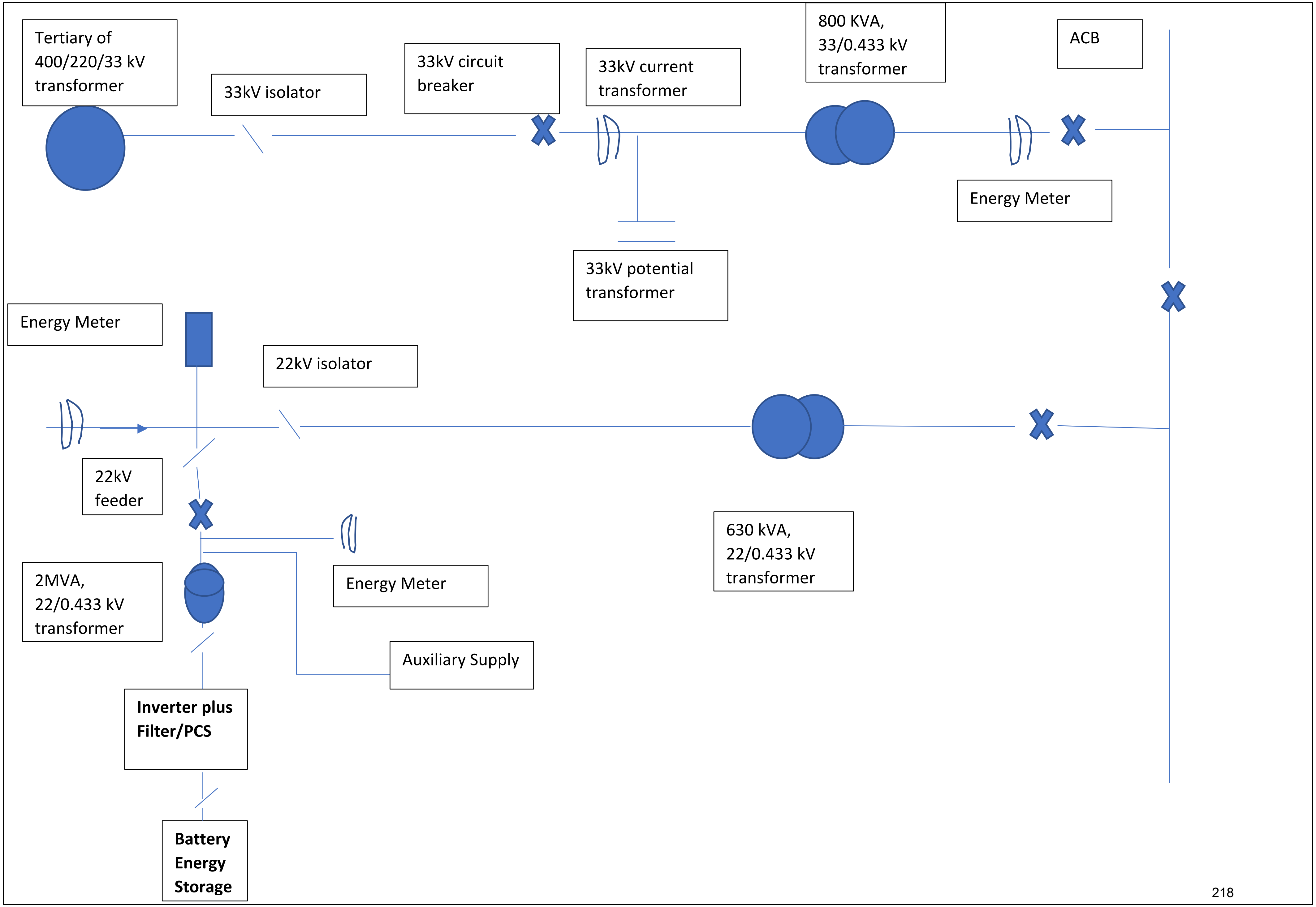
vi. The PCS shall have the synchro-check function to allow parallel operation with the grid, diesel and PV generators.

vii. PCS shall be able to operate in the following four modes of operation:

a. Active and reactive power control: In this mode of operation, PCS controls the output active and reactive powers supplied to the grid following their reference values which may be set locally or remotely.

b. Voltage and frequency control: In this mode of operation, PCS controls its own voltage and frequency, enabling it to create an islanded grid. Voltage and frequency control is possible when the PCS is in the voltage source operating mode.
c. Virtual synchronous generator: This mode of operation makes the PCS work as a voltage source converter. Under this mode, the BESS shall be able to provide its own voltage and frequency to an islanded grid, or to work in parallel with the utility grid in the grid-connected mode.
d. Voltage and frequency droop for parallel operation: The voltage droop allows reactive power sharing when the BESS is in an islanded mode or paralleled with other voltage sources. The frequency droop allows active power sharing when the BESS is in an islanded mode or paralleled with other voltage sources.

5. A sample connectivity of the BESS connected with the system is given below. BESS system is shown to be inter-connected with grid at secondary terminal of distribution transformer i.e. three-phase four-wire, 433 Volts (L-L) at point of common coupling (PCC).


Tertiary of 400/220/33 kV transformer
33kV isolator
33kV circuit breaker
33kV current transformer
800 KVA, 33/0.433 kV transformer
ACB
Energy Meter
33kV potential transformer
Energy Meter
22kV isolator
22kV feeder
2MVA, 22/0.433 kV transformer
Energy Meter
630 kVA, 22/0.433 kV transformer
Auxiliary Supply
Inverter plus Filter/PCS
Battery Energy Storage

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

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

(Stamp paper of Rs. 100)

Indemnity Bond

This bond of indemnity is executed at ……..(time) on this … day of ….(month) in the year 2018 by Sh./Smt. ….**[Name of authorized personal]** on behalf of M/s …**[Name of company]** (herein after referred to as the 'declarant') registered under ……….act, having its registered address at …**[registered address of company]** in favour of **XXXXX** Regional Load Dispatch Centre (XRLDC), **Place**, having its registered address at B-9, first floor Qutab Institutional Area, New Delhi 110016.

I, …..**[Name of authorized personal]** working as …**[designation of authorized personal]** at M/s ….**[Name of company]**, which has an ultimate installed capacity of …**[Installed Capacity]** MW and which has connectivity to ISTS at …**[Name of Station Name, voltage level and Transmission licensee]**, do here by solemnly state and confirm as under:

1. I am authorized representative of M/s ….[name of Company] and is legally entitled to sign this indemnity bond.
2. That this indemnity bond is being signed on behalf of M/S ….**[Name of company]** in compliance to the clause 5.1.2.j. of the CERC Approved Procedure dated 03.03.2017 for Implementation of Framework on Forecasting, Scheduling and Imbalance handling for Renewable energy generation stations including power parks based on **Wind/Solar** at Interstate level
3. Pursuant to the above, **…..[Name of company]** including its successor shall keep each of RLDCs (including **XRLDC** New Delhi) and NLDC, indemnified at all times and undertake to indemnify, defend and save the concerned SLDCs /RLDC/NLDC harmless from any and all damages, losses including commercial losses due to forecasting error, claims and actions including those relating to injury to or death of any person or damage to property, demands, suits, recoveries, costs and expenses, court costs, attorney fees, and all other obligations by or to third parties, arising out of or resulting from the transactions undertaken by our generators.

(Signature of the Declarant with seal)

Witness1:	**Witness2:**
Signature:	Signature:
Name:	Name:
Address:	Address:
Email ID:	Email ID:
Telephone no.:	Telephone no.:

Undertaking by SPD / SPDD / WPD / WPPD

This Undertaking is executed by MR. ………**[Name of authorized personal]** on behalf of M/s ……………**[Name of company]** having its registered address at………**[registered address of company]**, in favour of **XXXXX Regional Load Dispatch Centre (XRLDC), Place**, having its registered address at **RLDC Address**.

I, ……….**..[Name of authorized personal]** working as ……………**..[designation of authorized personal]** at M/s ……………**[Name of company]** with an ultimate installed capacity of ..**[Installed Capacity]** MW and having connectivity to ISTS at ..**[Name of Station Name, voltage level and Transmission licensee],** do here by solemnly state and confirm as under:

1. Shall be responsible for ensuring metering (ABT compliant meter), data collection and weekly transmission of data (in **XRLDC** data format) to **XRLDC** as per IEGC and extant CERC Regulations.
2. Shall under take commercial settlement of all deviation settlement charges to the Regional Pool Account on Weekly basis, as per applicable CERC Regulations.
3. Shall be responsible for commercial settlement on scheduled generation with it beneficiaries as per the monthly Regional Energy Account (REA) issued by **XRPC**.
4. Shall abide by the Indian Electricity Grid Code and Central Electricity Authority Regulations.
5. Shall follow the new element / generator procedure of **XRLDC** while connecting to the grid.
6. Shall undertake to indemnify , defend and save **XRLDC** harmless from any and all damages, losses including commercial losses due to forecasting error, claims and actions including commercial losses due to forecasting error, claims and actions including those relating to injury to or death of any person or damage to property, demands, suits, recoveries, costs and expenses, court costs, attorney fees, and all other obligations by or to third parties, arising out of or resulting from the transactions undertaken by the generators.
7. Shall be responsible for sending the SCADA data to the RLDC and to the Renewable Energy management Center, as and when required.
8. Shall inform **XRLDC** regarding the new additions / deletion of Power system elements within the solar park, as and when there is a change.
9. Shall provide the information sought by **XRLDC** & **XRPC** regarding the solar park activities from time by coordinating with the SPDs.
10. Shall submit to **XRLDC** the grant of connectivity agreement with CTU / STU and the agreements entered with SPDs.

Place: Signature:

Date: Name of the authorized personal:
Designation of the authorized person:

(Stamp paper of Rs. 100)

Undertaking by SPD/WPD

This undertaking is executed by ……………………………on behalf of M/s………………, having its registered address at …………………………, in favour of ……………….. Regional Load Despatch Centre having its registered address at …………………… …………………………………………………………………………………….

I ………………………… authorized signatory of M/s…………………… with an ultimate installed capacity of …….. MW and having connectivity to ISTS at………………………………, do here by solemnly state and confirm as under:

Our solar project falls under Central Electricity Regulatory Commission (Sharing of Inter-State Transmission Charges and Losses) (Sixth Amendment), Regulations, 2019 which states that "No transmission charges and losses for the use of ISTS network will be payable for the generation based on solar and wind power resources for a period of 25 years from the date of commercial operation" under following conditions:

1. Such generation capacity has been awarded through competitive bidding process in accordance with the guidelines issued by the Central Government. [Supporting document attached as annex-1]

2. Such generation capacity has been declared under commercial operation between 13.02.2018 till 31.03.2022. [Supporting document attached as annex-2]

3. Power Purchase Agreement(s) have been executed for sale of such generation capacity to all entities including Distribution Companies for compliance of their renewable purchase obligations. [Supporting document attached as annex-3]

Place : Signature
Date :

Name:
Designation:

(To be notarized on a Rs 100 non-judicial stamp paper)

Affidavit

I ________, Son/Daughter/Wife of _____________, aged about _______ years, residing at __________ do hereby solemnly affirm and sincerely state as follows:

1. That I am the ________(Designation) of the _______ (Company Name). I have been authorized by the ___________(*company name)* vide Board Resolution / Power of Attorney / Authorization Letter dated ……………..to sign this affidavit on behalf of the company.

2. The ___ MW Wind power plant _________(*Plant Name*) situated at Village: ______, Taluka: ______, District _____ has been awarded via competitive bidding conducted by ________ vide Letter of Intent _________ dated _______.

3. The above Wind Power Plant is scheduled to be commissioned by ……………………(dd.mm.yyyy) *(ref. PPA dated ……………).*

4. The date of Commercial operation (COD) will be intimated by ___________________(*Name of WPD/SPD*) to WRLDC, Mumbai prior to commencement of scheduling of power.

5. I state that ___________*(WPD/SPD Name)* undertakes to ensure compliance to following regulations and guidelines as amended from time to time:

   a. Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and any subsequent amendments thereof including but not limited to the norms for Low Voltage Ride Through (LVRT) and High Voltage Ride Through Capabilities (HVRT) as specified under standard B2 of the CEA (Technical Standards for Connectivity (Amendment) Regulations 2019.

b. Central Electricity Regulatory Commission (CERC) (Grant of Connectivity, Long-Term Access in Inter-State Transmission and related matters) regulation, 2009 and subsequent amendments thereof.

6. I undertake to submit the test report and Statement of Compliance (SoC)/ Conformity Statement (CS) as stipulated in MNRE guidelines demonstrating the compliance of applicable CEA Technical standards for Connectivity to the Grid (as amended from time to time) including LVRT/HVRT.

DEPONENT

Verification: -

Verified at _______________, this the ______ day of __________ 20__, that the contents in the above affidavit is true and correct to the best of knowledge and belief. No part of this affidavit is wrong and nothing material has been concealed therefrom.

DEPONENT

Solemnly Affirmed at ……………….

On this…………day of…… ..20___

And signed his/her name in my presence Deponent signed before me.

Submission of information as per RLDC (Fees & Charges) Regulation 2019

(In Compliance of Regulation 4)

1. **Name of the entity** (in bold letters):

2. **Registered office address**:

3. **Region in which registration is sought**:
   - i. North-eastern
   - ii. North
   - iii. East
   - iv. West
   - v. South

4. **User category**:
   - i. Generating Station
   - ii. Seller
   - iii. Buyer
   - iv. Transmission Licensee
   - v. Distribution Licensee
   - vi. Trading Licensee
   - vii. Power Exchange
   - viii. Battery Energy Storage system
   - ix. QCA / Aggregators
   - x. Others

5. **User details** (as on 31st March of last financial year):

   i. Category – generating Station
   - i. Total Installed Capacity
   - ii. Maximum Contracted Capacity (MW) using ISTS
   - iii. Points of connection to the ISTS:

Sl. No.	Point of connection	Voltage level (kV)	Number of Special Energy Meters (Main) installed at this location

   ii. Category - Seller/Buyer/Distribution Licensee
   - i. Maximum Contracted Capacity (MW) using ISTS
   - ii. Points of connection to the ISTS:

Sl. No.	Point of connection	Voltage level (kV)	Number of Special Energy Meters (Main) installed at this location

iii. Category – Transmission Licensee (inter-State)

i. Sub-stations:

Sl. No.	Sub-station Name	Number of transformer	Total Transformation Capacity or Design MVA handling capacity if switching Station

ii. Transmission lines: (line wise details to be given)

Sl. No.	Voltage level (kV)	Number of transmission lines	Total Circuit-Kilometers

iv. Category (Others): Please specify details.

6. Contact person(s) details for billing related to […] LDC:

i. Name:

ii. Designation:

iii. Telephone No.:

iv. E-mail address:

v. Postal address:

7. Other Details:

i. PAN No.:
ii. GST No.:
iii. Bank Account No.:
iv. Bank Name and Address:
v. MICR No:

The above information is true to the best of my knowledge and belief.

Signature of Authorized Representative

Place: Name:

Date: Designation:

Contact number:

Bank and Tax related details

Please furnish the details of the Entity User, Bank details for DSM, RRAS, Congestion, Reactive, RLDC Fees & Charges payments with cancelled cheque:

Name of the Entity:

1. Account Name:
2. Account Number:
3. Name of the Bank:
4. Branch:
5. IFSC Code:
6. PAN:
7. GSTIN :
8. TAN:
9. RTGS Details:
   (No./Date/Amount)
10. DD/Cheque Details:
    (No./Date/Amount)

Place: Signature :

Date: Name of the authorized personnel

Seal of the authorized person

Wind generating Plants

1. Turbine Generation (MW and MVAR)
2. Wind Speed(meter/second)
3. Generator Status (on/off line)- this is required for calculation of availability of the WTG
4. Wind Direction (degrees from true north)
5. Voltage (Volt)
6. Ambient air temperature (^{o} C)
7. Barometric Pressure (Pascal)
8. Relative humidity (%)
9. Air Density (kg/m^3)
10. Power plant controller signals

Solar Generating Plants

1. Solar Generation unit/Inverter-wise (MW and MVAR)
2. Voltage at interconnection point (Volt)
3. Generator/Inverter status (on/off line)
4. Global horizontal irradiance (GHI) –Watt per meter square
5. Ambient temperature (^{o} C)
6. Diffuse Irradiance –Watt per meter square
7. Direct Irradiance –Watt per meter square
8. Sun rise and sunset timings
9. Cloud cover (Okta)
10. Rainfall (mm)
11. Relative humidity (%)
12. Performance ratio
13. Power plant controller signals

Real-time Data Telemetry requirement

Wind Turbine Generating plants

Name	Unit	Data type	Remarks
Telemetry from WTG			
Power	kW	Analog	
Reactive Power	kvar	Analog	
Wind Speed	m/s	Analog	
WTG CB status	Boolean	Status	
LVRT trigger	Boolean	Status/SOE	
HVRT trigger	Boolean	Status/SOE	
Plant level Telemetry			
LVRT Status	Boolean	Status	
Voltage Control Mode	Boolean	Status	
Voltage control Setting	p.u.	Analog	
Reactive Power control Mode	Boolean	Status	
Power Factor setting	-	Analog	
No. of WTG online	No.	Analog	
Available Active Power	MW	Analog	
Active Power Control mode	Boolean	Status	
Active Power set point	MW	Analog	
Available Reactive Power	MVAR	Analog	
Constant Reactive Power mode	Boolean	Status	
Constant Reactive Power setpoint	MVAR	Analog	
Power factor control mode	Boolean	Status	
Power factor control setpoint	-	Analog	
Power factor actual	-	Analog	
Frequency control mode	Boolean	Status	
Frequency control droop	%	Analog	
Any overriding command received to stall the complete wind farm must be shared with RLDC in SCADA	Boolean	Status	
Slope/Deadband setting of Voltage Control mode	-	Analog	
Active power ramp rate UP and down setting	MW	Analog	

Telemetry from Developer Pooling Station			
Active Power	MW	Analog	
Reactive Power	MVAR	Analog	
CB Status	Boolean	Status	
Isolator Status	Boolean	Status	Below 220kV level, Isolator status not to be taken
Bus Voltage	KV	Analog	
Bus Frequency	Hz	Analog	Below 220kV level, Isolator status not to be taken
Wind Speed	Meter/Second	Analog	From Weather Station
Ambient Air Temperature	^{O} C	Analog	
Barometric Pressure	Pascal	Analog	
Relative Humidity	%	Analog	
Air Density	Kg/m^3	Analog	
Wind Direction	Degrees from	Analog	

Note:

Developer pooling station shall preferably provide telemetry to the respective RLDCs from the Gateway of the Developer Pooling station. In case direct integration of the Gateway is not feasible, telemetry could be provided from Central Control Centre of the developer. However, in case the telemetry is provided from a Central Control Centre of the Developer, efforts should be made to integrate communication to the nearest wideband node of ISTS for transmitting the data to the respective RLDCs over IEC-104.

Solar Turbine Generating plants

Name	Unit	Data type	Remarks
Telemetry from Inverter/IDT			
Inverter(500V)/IDT(33kV)*	kW	Analog	
Inverter(500V)/IDT(33kV)* Reactive Power	kvar	Analog	
Inverter(500V)/IDT(33kV)*	Boolean	Status	
Plant level Telemetry			
Active Power Control Mode	Boolean	Status	
Active Power Setting	p.u.	Analog	
Reactive Power Control	Boolean	Status	
Reactive Power Setting	p.u.	Analog	
Power Factor control Mode	Boolean	Status	
Power Factor setting	p.u.	Analog	
Total numbers of Inverters	-	Analog	
No. of Inverters in Service	-	Analog	
Performance Ratio	-	Analog	
Telemetry from Developer Pooling Station			
Active Power	MW	Analog	
Reactive Power	MVAR	Analog	
CB Status	Boolean	Status	
Isolator Status	Boolean	Status	Below 220kV level, Isolator status not to be taken
Bus Voltage	KV	Analog	
Bus Frequency	Hz	Analog	Below 220kV level, Isolator status not to be taken
Sun-rise and Sunset timings		Analog	
Ambient Air Temperature	^{O} C	Analog	From Weather Station
Relative Humidity	%	Analog	
Air Density	Kg/m^3	Analog	
Rainfall	Mm	Analog	
GHI	W/m2	Analog	
GI	W/m2	Analog	
Cloud Cover	Okta	Analog	

*In case of string inverter, Inverter Duty Transformer Status and Analog to be taken as the number of inverters is large

**If Cloud Cover measuring instrument is available otherwise cloud cover data can be taken from Weather Service Provider

NOTE:

Developer pooling station shall preferably provide telemetry to the respective RLDCs from the Gateway of the Developer Pooling Station. In case direct integration of Gateway is not feasible, telemetry could be provided from Central Control Centre of the Developer. However, in case the telemetry is provided from a Central Control Centre of the Developer, efforts should be made to integrate communication to the nearest wideband node of ISTS for transmitting the data to the respective RLDCs over IEC-104.

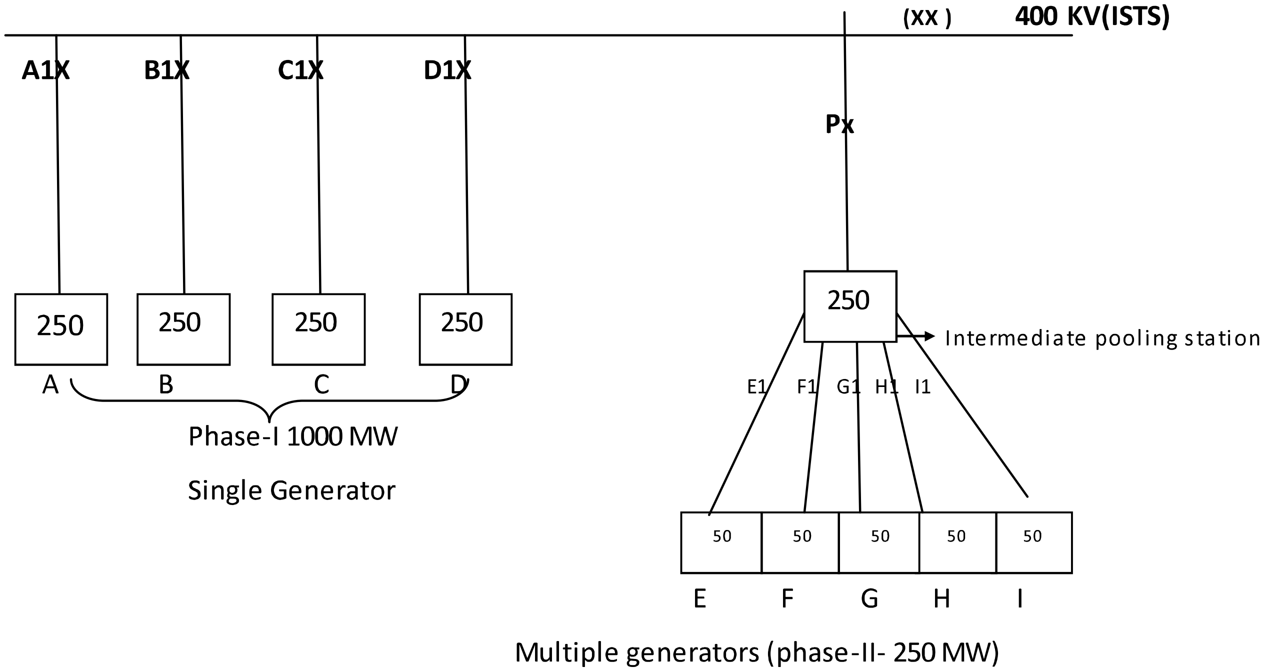
PMU signal list

S.No	Description	Analog Points	Digital Points	Protection Signal
1	Line	VOLTAGE {VRM, VYM, VBM, VPM, VRA, VYA, VBA, VPA} CURRENT {IRM, IYM, IBM, IPM, IRA, IYA, IBA, IPA} MW, MVAR, F , DF/DT	-Main Breaker status -Tie Breaker status -Isolators	Main1/Main2 protection
2	Bays		- Breaker -Isolators	
3	Main Buses	- VOLTAGE {VRM, VYM, VBM, VPM, VRA, VYA, VBA, VPA} F , DF/DT	Bus sectionalizer Breaker	
4	Transformer/Coupling Transformer/Converter Transformer	- VOLTAGE {VRM, VYM, VBM, VPM, VRA, VYA, VBA, VPA} CURRENT {IRM, IYM, IBM, IPM, IRA, IYA, IBA, IPA} MW/MVAR	-Breaker -Isolators	Main1/Main2 protection
5	Reactor/Capacitor (if applicable)	VOLTAGE {VRM, VYM, VBM, VPM, VRA, VYA, VBA, VPA} CURRENT {IRM, IYM, IBM, IPM, IRA, IYA, IBA, IPA} MVAR	-Breaker -Isolators	

Sample for understanding the scheduling /forecasting procedure.

Block Diagram showing the case wise Scheduling and Forecasting considering a sample case

Case-I: 50 MW and above (Phase-I &II)



Phase-I – 1000 MW,

A single generator of 1000 MW capacity is developing the generating station in phase-1 in four blocks namely A,B,C & D of 250 MW capacity each and is directly connected to point A1,B1,C1& D1 respectively at ISTS. At the interface point scheduling and forecasting will be done by RLDC / SLDC (in case full share is allocated to host state as per IEGC).

Phase-II- 500 MW (Separate Generator/Entities)

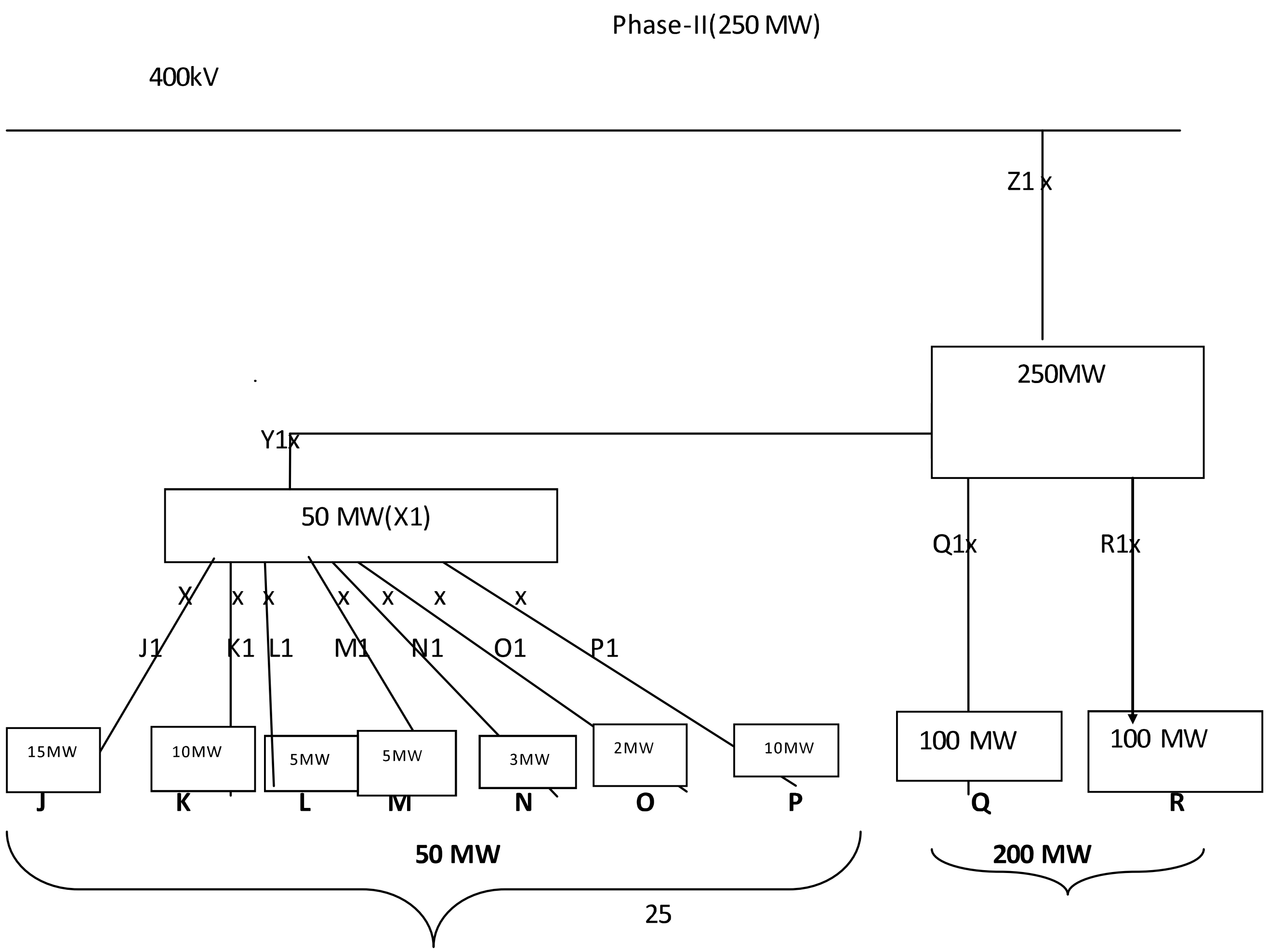
Let multiple generators of 50 MW each aggregating to 250 MW (5 Nos. Multiple Generator of 50 Mw each (as separate entities), be connected to inter mediate pooling stations.

In this case Solar generating station may be developed by single or Multiple generators. Here we have considered as multiple generators namely E, F, G, H & I each having the capacity of 50 MW each ,the RE generators are connected to interface point E1, F1, G1, H1& I1 and thereby connected to ISTS at XX point.

In such a case scheduling, accounting, forecasting for these generators needs to be segregated at point E1, F1,G1, H1, I1. Scheduling shall be done at point P and shall be segregated at E1,F1,G1,H1,I1 by RLDC.

Further there may be case where multiple generators less than 50MW (<50MW) capacity are connected to the intermediate pooling station are stated as under:-

Case-II Below 50 MW



For remaining 250 MW of Phase-II, let us consider, multiple generators of 7 Nos (J,K,L,M,N,O&P) each having capacity less than 50 MW but collectively having an aggregate installed capacity of 50 MW or more. Further Generators Q & R each of 100 MW are connected at Q1 & R1. All these generators are connected to ISTS at point Z1.

Scheduling and forecasting for the generators J,K,L,M,N,O& P shall be done at Point Z1, but need to segregated at Point J1, K1,L1, M1, N1,O1& P1 and for generators Q & R needs to be segregated at Q1 and R1. In this case, RLDC shall schedule at point Z1 and segregate at Y1,Q1& R1 . The lead generator shall provide aggregated schedule to RLDC at Y1. Further the lead generator shall do segregation of schedules and other operational & commercial activities for generators J,K,L,M,N,O,P at points J1, K1,L1, M1, N1,O1& P1.

Forecast and Schedule Data to be submitted by Wind/Solar plants/ Lead generator, Principal generator

FORMAT: A (to be submitted a day in advance)

15 Min time block (96 Block in a day)	TIME	Available Capacity (MW) - Day Ahead	Day Ahead Forecast (MW)	Day Ahead Schedule (MW)
1	00:00-00:15			
2	00:15-00:30			
3	00:30-00:45			
4	00:45-01:00			
.				
94				
95				
96				

Note: The forecast should ideally factor forecasting errors. As such schedule should ordinarily be same as forecast.

FORMAT: B (to be submitted on the day of actual generation, revision of availability and schedule, if any, shall be done as per CERC(IEGC) Regulations.

15 Min time block (96 Block in a day)	TIME	Day ahead schedule (MW)	Current Available Capacity (MW)	Revised Schedule (MW)
1	00:00-00:15			
2	00:15-00:30			
3	00:30-00:45			
4	00:45-01:00			
.				
94				
95				
96				

Section 3:

Procedure for integration of a new or modified HVDC transmission elements and issue of certificate of successful trial operation by National Load Despatch Centre (NLDC) / Regional Load Despatch Centres (RLDCs)

Table of Contents

Procedure for integration of a new or modified HVDC transmission elements and issue of certificate of successful trial operation by National Load Despatch Centre (NLDC)/ Regional Load Despatch Centres (RLDCs)

1. Pre Charging Activities

The procedure is applicable for the first time charging of HVDC transmission elements along with all filters and sub-filter banks. All the timelines & formats mentioned in this procedure shall be provided by transmission licensee/owner to concerned RLDC. Approval of first time charging of HVDC transmission elements shall be provided by NLDC/RLDC in line with these guidelines and the procedure for facilitating first time charging of new or modified power system elements.

Following modelling and operational information shall be provided by the owners of HVDC station before commencement of any testing of HVDC transmission elements:

a) Name plate details
b) Main Circuit Parameter Design report(Forward and Reverse Direction)
c) Minimum power in different Configuration
d) Active and reactive power control
e) Frequency Controller study report
f) Emergency Power control study report
g) Power Order Compensation study report
h) Network Data Summary
i) HVDC Operation & Control Strategy
j) Protection Philosophy
k) Modes of operation
l) Filter Arrangement with rating and minimum filter requirement
m) AC filter Protection
n) Protection Setting
o) Power Oscillation Damping (POD) Status along with the document on tuning.
p) Auxiliary model (Frequency Controller Model, POD controller Model, Voltage controller model)
q) Dynamic parameters file *.dyr
r) PSCAD model
s) Steady state and dynamic modelling details as per the guidelines for exchange of data from modelling HVDC as per Annexure-I(A)
t) Load flow and stability report
u) Dynamic Performance Study report
v) Sub synchronous resonance study report
w) Fundamental Frequency Temporary over voltages (FFTOV) study report
x) Dynamic Multi HVDC interaction report
y) Any other information as required by RLDC

Owners of the HVDC station shall submit a detailed proposal for testing at least 10 days in advance along with intimation of first time charging (Format A). Proposed testing schedule of HVDC transmission elements shall be duly approved by concerned Regional Power committees(RPCs)

The auxiliary consumption of HVDC station is generally drawn from the tertiary of the 400/220/33 kV transformer at the substation. The meter reading of this transformer would include the auxiliary consumption of HVDC station as well. Therefore, a No Objection Certificate (NOC) from the local DISCOM and SLDC would also be provided by the owner of the HVDC station.

2. Data Telemetry Requirements

a. Following SCADA points shall be made available to the NLDC/RLDC control room:

Analog Signal

I. AC Power Flow for converter transformer
II. Tap position of converter transformer
III. DC Voltage
IV. DC Power Flow
V. DC Current
VI. Individual and cumulative Filter MVAR
VII. Firing Angle-Alpha
VIII. Extinction angle- Gamma, etc.
IX. Power order, set point
X. Compensation settings if applicable

Digital Signal

I. Individual Filter Status
II. HVDC Mode (Metallic return / Ground return)
III. Isolator/CB Status of DC Switchyard
IV. RPC Status
V. Run back Status
VI. POD Status
VII. SSDC Status
VIII. SOE with Time Stamping
IX. DMR 1 status
X. DMR2 status
XI. MRTB status
XII. GRTB status
XIII. SoE for HVDC autorestart

Protection Signal

I. DC line Fault Protection
II. ESOF (emergency Switch Off) and HVDC Pole Block protection
III. POD Status (operated or not

Other than the SCADA data, PMU data shall also be provided.

3. Trial Operation of HVDC link/Pole

a) The trial operation of HVDC link/Pole shall start only after getting all the documents and modelling data and telemetry of the points as defined above are available at NLDC/RLDC.
b) Date and time of commencement of trial run operation shall be intimated in advance but not less than twenty four hours to NLDC and concerned RLDCs.
c) The trial operation for the purpose of HVDC link/Pole shall be continuous operation for 24 hrs.
d) During the trial operation minimum load operation, ramp rate, Overload capability and Black start capability in case of Voltage source convertor (VSC) HVDC station, reversal of power shall be demonstrated as desired by NLDC/RLDCs.

4. Post Charging Activities

a. Successful Trial Operation completion certificate for inter-regional HVDC link/Pole shall be issued by NLDC in accordance with procedure for first time charging of power system elements.

b. Successful Trial Operation completion certificate for Intra-Regional HVDC link/pole connected as designated ISTS network shall be issued by concerned RLDC in accordance with procedure for first time charging of power system elements.

c. Following data shall be provided by the owner of HVDC station after successful trial operation for issuance of trial operation completion certificate:

i. Converter transformer meter reading for the period of trial operation from both end

ii. SCADA readings/plot of active and reactive power flow from both the end during the trial operation

iii. Event log indicating Opening/closing of breakers

vi. Output of Disturbance Recorder for the period of trial operation

vii. Any other data as required by RLDC to ascertain effective operation of HVDC link/Pole

Enclosures.

Annexure-I: Guideline for exchange of data for modelling HVDC link/Pole

Other than the documents mentioned above the formats for first time charging of transmission elements (Format A1-A6, B1-B5 and C1-C4) to be submitted to concerned RLDC.

Guideline for furnishing information for Modelling HVDC links in Indian Grid

1.0 Introduction:

The purpose of this document is to act as a guideline for exchange of information for accurate modelling of high voltage direct current (HVDC) links in India. HVDCs have played a pivotal role in integration and formation of the Indian national grid, and still continue to enable bulk power transfer across regions. HVDCs enable additional flexibility in power system operations, aiding in control of active power flows and voltages. Availability of fit-for-purpose steady state and dynamics models of HVDC installations are necessary to undertake simulation studies for secure operation of Indian power grid.

1.1 Applicability:

The guideline shall be applicable to all HVDC installations in India, irrespective of the technologies used.

This document presents the desired information for collection of data for modelling of HVDC installations in PSS/E software, a software suite being used pan-India at CEA, CTU, SLDCs, RLDCs, and NLDC for modelling of India's power grid. A systematic set of data and basic criteria for furnishing data are presented.

1.2 Need for a fit-for-purpose model:

There is a cost involved in developing and validating dynamic models of power system equipment. But there are much higher benefits for the power system if this leads to a functional, fit-for-purpose model, and arrangements that allow that model to be maintained over time.

A functional fit-for-purpose dynamic model will:

- Facilitate significant power system efficiencies by allowing power system operations to confidently identify the secure operating envelope and thereby manage security effectively
- Allow assessment of impact on grid elements due to connection of new elements (network elements, generators, or loads) for necessary corrective actions
- Permit power system assets to be run with margins determined on the basis of security assessments
- Facilitate the tuning of control systems, such as power oscillation dampers, frequency controllers, etc.
- Improve accuracy of online security tools, particularly for unusual operating conditions, which in turn is likely to result in higher reliability of supply to power system users.

The power system model would enable steady state and electromechanical transient simulation studies that deliver reasonably accurate outcomes.

1.3 Regulation:

- **CEA Connectivity Standard 6.4.d :**

The requester and user shall cooperate with RPC and Appropriate Load Despatch Centre in respect of the matters listed below, but not limited to

furnish data as required by Appropriate Transmission Utility or Transmission Licensee, Appropriate Load Despatch Centre, Appropriate Regional Power Committee and any committee constituted by the Authority or appropriate Government for system studies or for facilitating analysis of tripping or disturbance in power system;

Here Requester and User Includes a generating company, captive generating plant, energy storage system, transmission licensee (other than Central Transmission Utility and State Transmission Utility), distribution licensee, solar park developer, wind park developer, wind-solar photovoltaic hybrid system, or bulk consumer *(2019 Amendment)*

- **IEGC 4.1 :**

CTU, STU and Users connected to, or seeking connection to ISTS shall comply with Central Electricity Authority (Technical Standards for connectivity to the Grid) Regulations, 2007 which specifies the minimum technical and design criteria and Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations,2009.

2.0 HVDC technologies

HVDC systems is widely recognized as having the ability to transfer more power over longer distances than comparable HVAC (high voltage alternating current) systems, along with several other benefits such as lower transmission losses, higher stability, and more controllability. HVDCs can also be utilized to connect parts of the grid at different frequencies (such as connections between India and Bangladesh in Eastern Region) as well as facilitate long distance undersea cable transmission (such as proposed transmission between India and Sri Lanka). HVDC schemes can be classified in two types:

- Back-to-Back schemes
- Long distance transmission schemes

Back-to-back schemes are usually used to interconnect two AC networks with different frequencies. Both the converters in this scheme are located in the same location and no transmission line is used between them. Because no DC conductor is used back-to-back schemes are operated with high currents (3-4 KA) in order to minimize the cost and losses of the converter equipment.

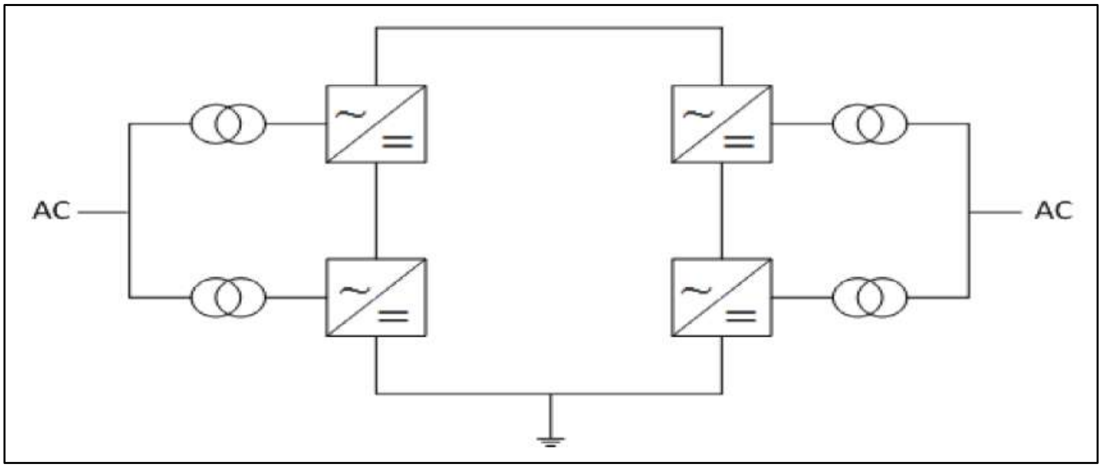


Figure 1: Back to Back Scheme

On the other hand transmission schemes are used for bulk energy transmission over long distances. The two converter stations are connected through a DC conductor, either a transmission line or an underground/submarine cable. Two configurations are usually used for this scheme:

- Monopolar configuration
- Bipolar configuration

In monopolar configuration, the return is accomplished either by ground or sea (depending on the application) or by a metallic conductor.

The bipolar configuration has two independent poles, each consisting of an independent converter. This configuration uses two conductors; one has positive polarity while the other negative. Power flow can be in one or both directions. The bipolar configuration is arranged in such a way that the return currents cancel each other out. Each pole can operate separately or in a master slave configuration.

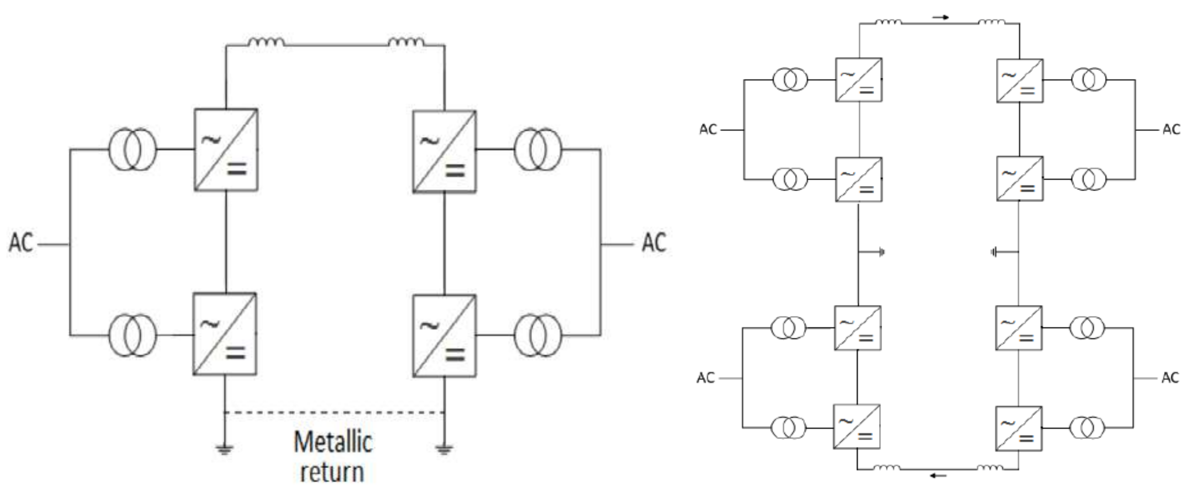


Figure 2: Monopolar and Bipolar HVDC links

The power electronic based converters (rectifiers at sending end, and inverters at receiving end) are the core component of HVDC systems. Depending on the type of technologies used in converters, 2 broad categories of HVDC systems are in place:

1. Line Commutated Converter (LCC) based HVDCs
2. Voltage Source Converter (VSC) based HVDCs

With integration of inherently variable renewable energy generation in Indian grid, the operation of HVDCs assumes greater importance.

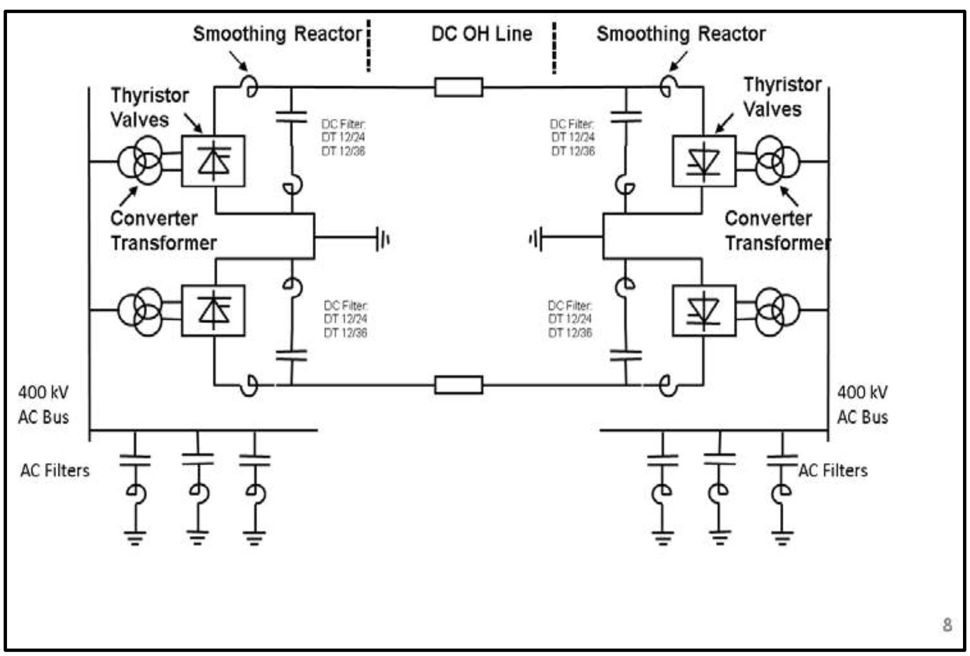
3.0 Models for HVDC links:

- **Line Commutated Converter (LCC) based HVDCs**

LCCs are also known as line commutated converters. As the name indicates, conversion depends on the line voltage of the AC system. This happens because the switching device used in this type of converters is a thyristor. In order to achieve high voltage levels needed for HVDC transmission applications, each thyristor valve of the converter bridge consists of a series connection of a number of thyristors. For typical applications 24 to 30 thyristors are connected in series to create a valve. Regarding the mode of operation LCCs operate in the two lower quadrants of the PQ plane. This means that they can provide or absorb active power but only absorb reactive power.

The reactive power consumption of CSC converters is usually about 50% to 60% of the active power transferred. Due to this reactive power consumption reactive power sources such as shunt capacitors, must be connected at the terminals of the converters.

Components of a typical LCC HVDC system are depicted in figure below:



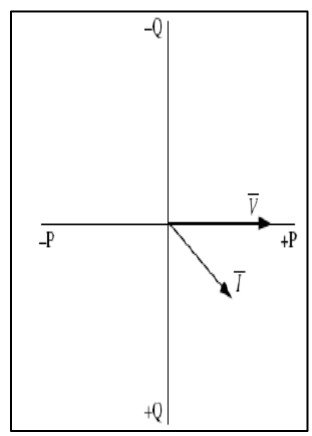


Figure 3: Typical components of LCC HVDC installation

- **Voltage Source Converter Based VSC:**

VSC-HVDC links consist of the converter station and the DC conductor. VSCs use solid state devices such as IGBTs (for high switching frequency) or thyristor-type devices such as GTOs or IGCTs (for low switching frequencies) so that their switching-on and switching-off are fully controlled. This allows VSCs to operate on the four quadrants of the P-Q plane and therefore can generate or absorb reactive power in contrast to LCCs which only absorb. In VSC-HVDC transmission the voltage polarity is constant and power flow reversal is accomplished through current reversal.

Just as in the LCC case, filters are needed in order to block harmonics in the converter's output reach the AC grid. Filters in VSC-HVDC schemes are much smaller than in LCC-HVDC schemes due to the smaller harmonic content of the VSC converter output. Components of typical VSC HVDC are depicted in figure below:

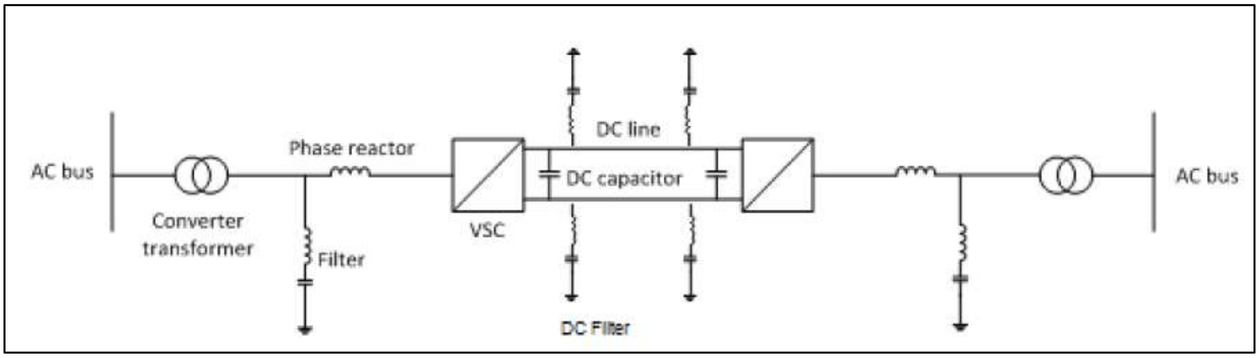


Figure 4: Typical VSC link

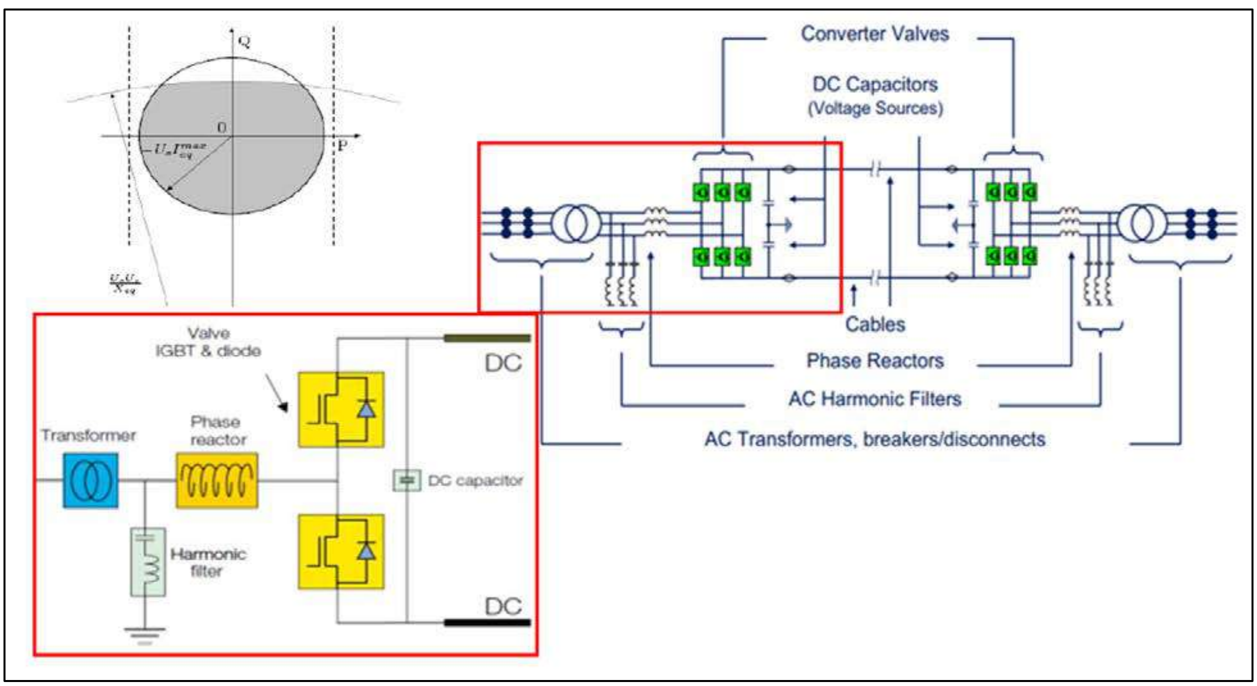


Figure 5: VSC Components and capability chart

Within PSSE the transformer impedance data is only required to be separated if a three winding converter transformer is used and there is reactive power equipment connected to its tertiary winding. In this case, the star-point to secondary data must be entered into the HVDC model however the primary to star-point and star-point to tertiary impedances must be represented explicitly as AC branches within the load-flow case (with appropriate equivalencing if there are multiple transformers in parallel). Otherwise, the primary to secondary converter transformer impedances should be calculated and directly entered into the DC line data with no additional AC components. Please refer to the PSSE manual (PAG Volume 1, Section 6.4.7.5).

Formats for submission of modelling data for HVDC Links

Version History:

Version no.	Release Date	Prepared by*	Checked/Issued by*	Changes

***Mention Designation and Contact Details**

Details submitted:

Details pending:

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

For POSOCO to get access to steady state and transient simulation models of HVDC links in India grid, the following information is required.

1. Load-flow data for the HVDC station: rated DC voltage, rated DC current, rated power, line length, converter type (LCC or VSC)
2. Electrical Single Line Diagram (SLD) of as built HVDC station depicting:
    - AC infeed with filter banks
    - Converter transformers
    - DC system with filters and other equipment
3. Generic models of HVDC link and auxiliaries. Refer **Table-2** for details.
4. Encrypted user defined model (UDM) in a format suitable for latest release PSS/E (*.dll files) for electromechanical transient simulation for HVDC station (in case non-availability of validated generic model)
    - User guide for Encrypted models to be provided including instructions on how the model should be set-up. It should contain all relevant technical information, including block diagrams, list of state variables and values / descriptions of all model parameters.
    - Corresponding transfer function block diagrams to be provided
    - Simulation results depicting validation of User-Defined models against actual measurement (for P, Q, V, I) to be provided
    - The use of black-box type representation is not preferred.
    - Models should be suitable for an integration time step between 1ms and 10ms, and suitable for operation up-to and in excess of 100s.

Apart from this, salient aspects of the physical operation may also be provided, like details of inter-pole compensation, inter-station compensation, metallic return operation, other special cases etc.

4.0 PSS/E representation for HVDC links:

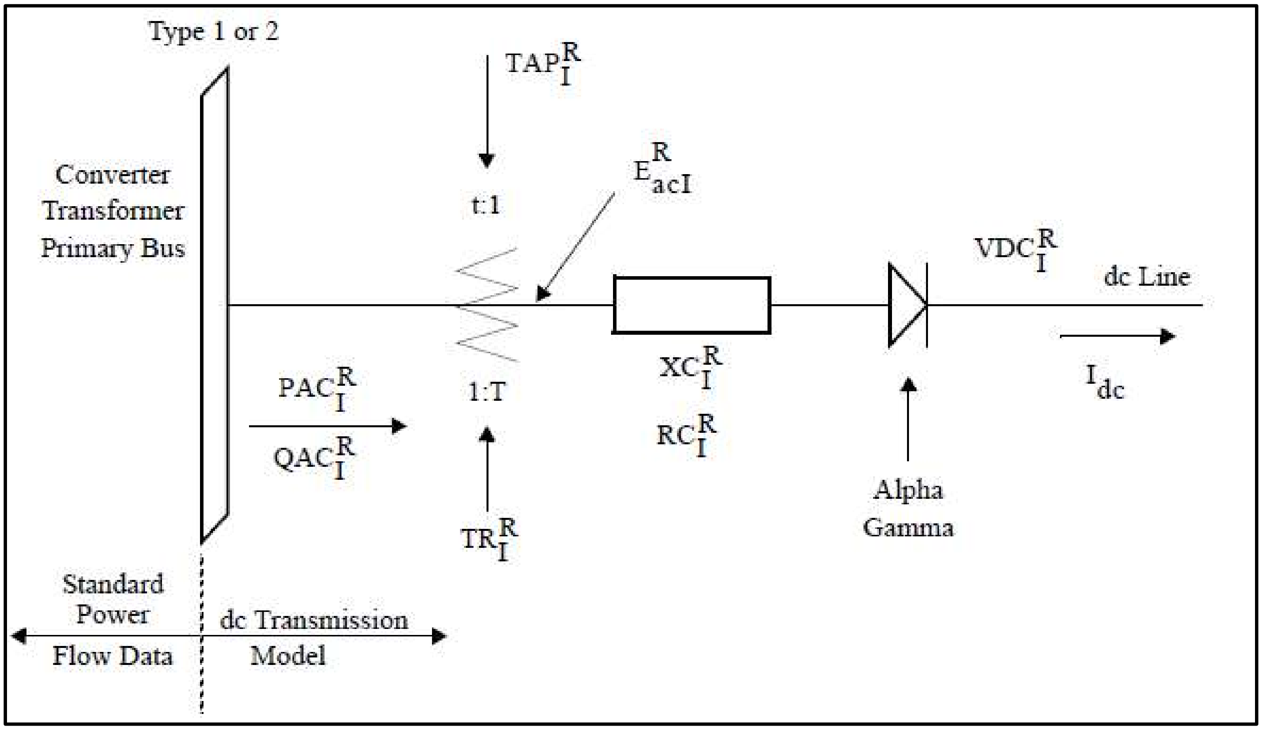


Figure 6: PSS/E rectifier/inverter representation of HVDC link

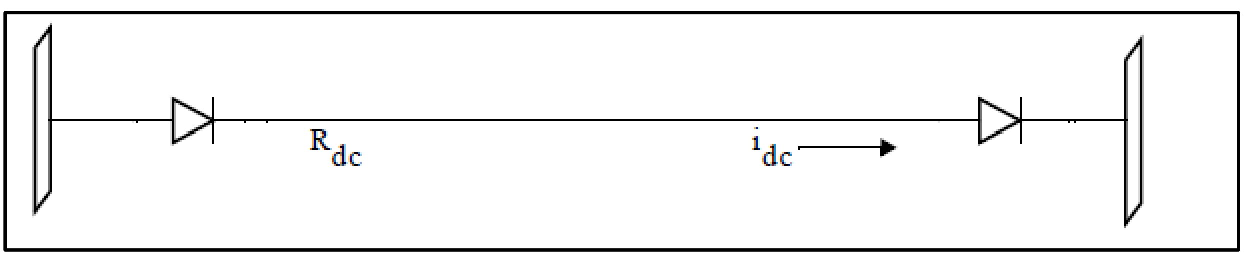


Figure 7: PSS/E power flow representation of HVDC model

The power flow representation of HVDC links in PSS/E is depicted in Figure-2 and Figure-3 above.

Details of models in PSS/E for modelling HVDC Links:

A. Steady State model (Power Flow)

Table 1: Information for Steady State model of HVDC links

Category	Parameter Description	Data
Link OEM and rating	Manufacturer and product details (for example Siemens, Areva, ABB, etc)	
	Year of commissioning	
	Rated DC voltage	
	Length of the link	
	Conductor Type (of DC lines)	
	Number of Poles	
	Rating of Each Pole (Power-MW, and Current-Amperes)	
	Minimum Power flow on DC link (per pole) in MW	
	Overload capability of DC link (per pole) in MW and no. of hours	
	LCC, Rectifier controls maintain - constant DC power or DC current?	
	LCC, Inverter controls maintain - constant DC voltage or extinction angle?	
	LCC, For DC voltage control, whether any compensation is utilized?	
	LCC, Inverter current margin	
	VSC, converter controls DC voltage or DC power?	
	VSC, converter controls AC voltage or power factor ?	
Technology	Converters: - LCC (conventional) - Voltage Source Converter (VSC) - Multi-terminal	
DC Components	Smoothing Reactors	
	DC Line resistance (Rdc) in Ohms	
	Minimum inverter dc voltage for power control mode (in kV)	
Converter transformer	Make	
	MVA rating	
	Two winding transformer or three winding transformer?	
	If three winding, any auxiliary equipment connected to tertiary winding?	
	AC side base voltage	
	DC side base voltage	
	Impedance (in Ohms, in % on 100 MVA base and mention Voltage reference side)	
	Converter transformer secondary commutating reactance in ohms per bridge[Star point to Secondary]	
	Converter transformer secondary commutating resistance in ohms per bridge [Star point to Secondary]	
	Primary to Star-point impedance of Converter transformer (R+jX)	
	Tertiary to Star-point impedance of Converter transformer (R+jX)	

Category	Parameter Description	Data
	Maximum value of converter transformer tap ratio (in p.u. of Voltage)	
	Minimum value of converter transformer tap ratio (in p.u. of Voltage)	
	Converter transformer tap-step (in pu of voltage)	
Converter Details	Minimum firing (delay) angle of rectifier in degrees (Alpha-min)	
	Maximum firing (delay) angle objective for rectifier in degrees (Alpha-max)	
	Minimum margin angle of inverter in degrees (Gamma-min)	
	Maximum margin angle objective for inverter in degrees (Gamma-max)	
	Number of Pulses (Ex. 12 pulse bridge, with 2 nos. 6 pulse bridge in series)	
	Alpha-min, actual absolute minimum firing angle during transients	
	Gamma-min, actual absolute minimum extinction angle during transients	
Additional information for VSC HVDC	AC side MVA rating	
	Q limits	
	Converter Losses	
	Voltage Control Settings	
AC Filters	Details of AC filters (Switching sequence w.r.t. Power order, MVAR values at nominal voltage and fundamental frequency	

B. Transient simulation model (Dynamics):

For representation of the electromechanical transient behavior of HVDC links, standard models are available in PSS/E library. A list of standard models are listed below:

Table 2: Generic Models for HVDC links

Category	Type	Model Description
CDC1T	LCC	Two-terminal dc line model
CDC4T	LCC	Two-terminal dc line model
CDC6T	LCC	Two-terminal dc line model
CDC6TA	LCC	Two-terminal dc line model
CDC7T	LCC	DC line model
CDCABT	LCC	ABB dc line model for Kontek line
CEELRIT	LCC	New Eel River dc line and auxiliaries model
CEELT	LCC	New Eel River dc line and auxiliaries model
CHIGATT	LCC	Highgate dc line model.
CHVDC2U1	LCC	WECC Generic 2-Terminal HVDC Model
CMDWAST	LCC	Madawaska dc line model
CMDWS2T	LCC	New Madawaska dc line model

CMFORDT	LCC	Comerford dc line model
HVDCPL1	VSC	Siemens HVDC plus model
VSCDCT	VSC	Two-terminal VSC dc line model
MTDC1T	MTDC	Multiterminal (five converter) dc line model
MTDC2T	MTDC	Multiterminal (five converter) dc line model
MTDC3T	MTDC	Multiterminal (eight converter) dc line model

Source: PSSE Model Library, for models other than the above list refer to

https://w3.usa.siemens.com/smartgrid/us/en/transmission-grid/products/grid-analysis-tools/transmission-system-planning/transmission-system-planning-tab/pages/user-support.aspx

At present, it is preferred to use one of the three models viz., CDC4T, CDC7T, and CHVDC2U1 for LCC type HVDCs.

In addition to the above, any modulation control of relevance to system performance for RMS simulations should be modelled utilizing generic HVDC auxiliary models as listed below:

Table 3: Generic HVDC auxiliary signal models

Model	Model Description
CHAAUT	Chateauguay auxiliary signal model
CPAAUT	Frequency sensitive auxiliary signal model
DCCAUT	Comerford auxiliary signal model
DCVRFT	HVDC ac voltage controller model
FCTAXBU1	FACTS device Auxiliary Control Model
HVDCAT	General purpose auxiliary signal model
PAUX1T	Frequency sensitive auxiliary signal model
PAUX2T	Bus voltage angle sensitive auxiliary signal model
RBKELT	Runback model
RUNBKT	Runback model
SQBAUT	dc line auxiliary signal model

Commonly Used LCC based HVDCs:

- **CDC4T: Two-terminal dc line model**

CDC4T is a pseudo steady-state model and omit some of the dynamics of HVDC converters such as L/R dynamics of DC line, smoothing reactors, and high frequency controller dynamics. A more detailed representation (CDC7T / CHVDC2U1) would be preferred if information pertaining to the same are verifiable against actual measurements.

- **CDC7T: DC line model**

There are significant differences between this model and generic HVDC models, such as CDC4T or CDC6T, available in the PSS®E library. The CDC4T and CDC6T models assume an instantaneous response of the dc system to disturbances coming from adjacent grids. The dc circuit arrangement that can be simulated by the CDC7T model is shown in Figure 1. A dc line may comprise overhead lines from both rectifier and inverter sides and a cable.

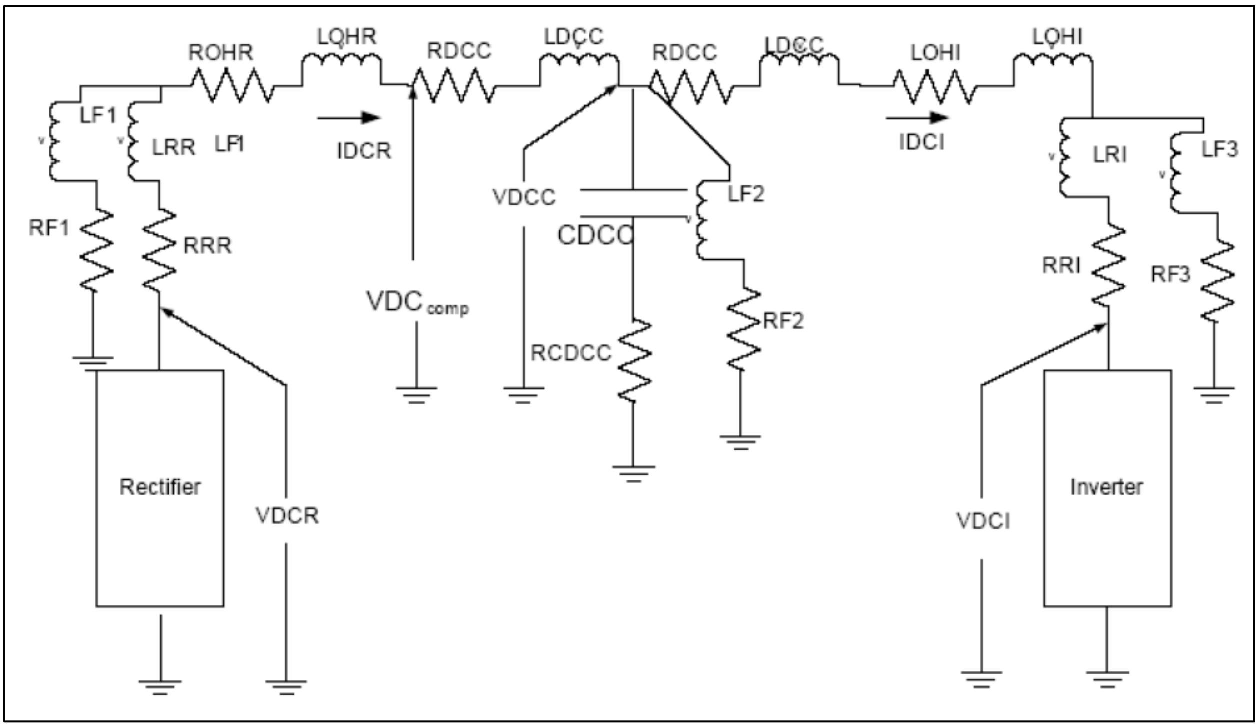


Figure 8: A DC Circuit Arrangement Simulated by the CDC7T Model

Although the dc line can be represented by a T-circuit with lumped Rdc and Ldc parameters, for the sake of flexibility the model uses resistances and inductances of overhead lines on rectifier (ROHR, LOHR) and inverter (ROHI, LOHI) sides, resistance, inductance, and capacitance of the dc cable (RDCC, LDCC, CDCC), and resistance and inductance of smoothing reactors on both sides (RRR, LRR and RRI, LRI). CDC7T model has a provision for choosing the control configuration. The CDC7T model uses 79 parameters of the dc circuit and controls.

Category	Parameters	Data
LCC based HVDC		
CDC4T	ALFDY, minimum alpha for dynamics (degrees)	
	GAMDYa, minimum gamma for dynamics (degrees)	
	TVDC, dc voltage transducer time constant (sec)	
	TIDC, dc current transducer time constant (sec)	
	VBLOCK, rectifier ac blocking voltage (pu)	
	VUNBL, rectifier ac unblocking voltage (pu)	
	TBLOCK, minimum blocking time (sec)	
	VBYPAS, inverter dc bypassing voltage (kV)	
	VUNBY, inverter ac unbypassing voltage (pu)	
	TBYPAS, minimum bypassing time (sec)	
	RSVOLT, minimum dc voltage following block (kV)	
	RSCUR, minimum dc current following block (amps	
	VRAMP, voltage recovery rate (pu/sec)	
	CRAMP, current recovery rate (pu/sec)	
	C0, minimum current demand (amps)	
	V1, voltage limit point 1 (kV)	
	C1, Current limit point 1 (amps); >C0	
	V2, voltage limit point 2 (kV)	
	C2, current limit point 2 (amps)	
	V3, voltage limit point 3 (kV)	
	C3, current limit point 3 (amps)	
	TCMODE, minimum time stays in switched mode (sec)	
CDC7T	dc voltage sensor time constant, sec.	
	dc current sensor time constant, sec.	
	Rectifier smoothing reactor inductance, mH	
	Rectifier smoothing reactor resistance, ohm	
	Inverter smoothing reactor inductance, mH	
	Inverter smoothing reactor resistance, ohm	
	Inductance of O/H dc line from rectifier side, mH	
	Resistance of O/H dc line from rectifier side, ohm	
	Inductance of O/H dc line from inverter side, mH	
	Resistance of O/H dc line from inverter side, ohm	
	Inductance of dc cable line, mH	
	Damping resistance of dc cable line, ohm	
	dc line capacitance, µF	
	dc fault shunt inductance, rectifier side, mH	
	dc fault shunt resistance, rectifier side, ohm	

Category	Parameters	Data
LCC based HVDC		
CDC7T	dc fault shunt inductance, mid-line, mH	
	dc fault shunt resistance, mid-line, ohm	
	dc fault shunt inductance, inverter side, mH	
	dc fault shunt resistance, inverter side, ohm	
	dc cable damping resistor	
	Rated dc current, A	
	Rated dc voltage, kV	
	VDComp down time constant for VDCL, rectifier, sec	
	VDComp up time constant for VDCL, rectifier, sec	
	VDComp down time constant for VDCL, inverter, sec	
	VDComp up time constant for VDCL, inverter, sec	
	Current margin, rectifier, pu	
	Current margin, inverter, pu	
	Voltage margin, rectifier, pu	
	Voltage margin, inverter, pu	
	Gamma margin, rectifier, pu	
	Gamma margin, inverter, pu	
	IDC error to V-control gain, rectifier	
	IDC error to V-control gain, inverter	
	IDC error to Gamma-control gain, inverter	
	VDComp filter gain, rectifier, pu	
	VDComp filter gain, inverter, pu	
	VDComp filter time constant, rectifier, sec.	
	VDComp filter time constant, inverter, sec.	
	Selected controller output gain, rectifier	
	Selected controller output gain, inverter	
	PI-controller proportional gain, rectifier	
	PI-controller integrator time constant, rectifier, sec.	
	PI-controller proportional gain, inverter	
	PI-controller integrator time constant, inverter, sec.	
	Max Alfa limit, rectifier	
	Min Alfa limit, rectifier	
	Max Alfa limit, inverter	
	Min Alfa limit, inverter	
	Control configuration 1	
	Control configuration 3	
	Min GAMA in dynamics	
	Rate of current order change when blocking, A/sec	
	Rate of current order change when unblocking, A/sec	
	VDC filter time constant for Pordr calculation, sec.	
	5 pairs of rectifier VDCL coordinates (Vd1, Id1) … (Vd5, Id5)1	
	5 pairs of inverter VDCL coordinates (Vd1, Id1) … (Vd5, Id5)1	

Category	Parameters	Data
VSC based HVDC		
HVDCPL1	Rated AC voltage on DC side of converter Xfmr [kV]	
	Rectifier transformer impedance [pu of SBASE]	
	Inverter transformer impedance [pu of SBASE]	
	DC line total inductance [H]	
	DC line total capacitance [F]	
	Gain GQr of the rectifier reactive power controller	
	Lead time constant TLeadQr of the rectifier reactive power controller [s]	
	Lag time constant TLagQr of the rectifier reactive power controller [s]	
	Gain GQi of the inverter reactive power controller	
	Lead time constant TLeadQi of the inverter reactive power controller [s]	
	Lag time constant TLagQi of the inverter reactive power controller [s]	
	Gain G1Ud of the DC voltage controller	
	Lead time constant TLead1Ud of the DC voltage controller [s]	
	Lag time constant TLag1Ud of the DC voltage controller [s]	
	Gain G2Ud of the DC voltage controller	
	Lead time constant TLead2Ud of the DC voltage controller [s]	
	Lag time constant TLag2Ud of the DC voltage controller [s]	
	Ramp rate of the inverter active power setting value [p.u./s] (used for interconnected application)	
	Gain G1P of the inverter active power controller (interconnected application)	
	Lead time constant TLead1P of the inverter active power controller [s] (interconnected application)	
	Lag time constant TLag1P of the inverter active power controller [s] (interconnected application)	
	Gain G2P of the inverter active power controller (interconnected application)	
	Lead time constant TLead2P of the inverter active power controller [s] (interconnected application)	
	Lag time constant TLag2P of the inverter active power controller [s] (interconnected application)	
	TIntQr (s); Rectifier Q controller integrator time constant	
	LMXQr (pu); Rectifier Q controller integrator upper limit	
	LMNQr (pu); Rectifier Q controller integrator lower limit	
	TIntQi (s); Inverter Q controller integrator time constant	
	LMXQi (pu); Inverter Q controller integrator upper limit	
	LMNQi (pu); Inverter Q controller integrator lower limit	
	TIntUd (s); Inverter dc voltage controller integrator time constant	
	LMXIUd (pu); Inverter dc voltage controller integrator upper limit	
	LMNIUd(pu); Inverter dc voltage controller integrator lower limit	
	TIntP (s); Inverter P controller integrator integrator time constant	
	LMXP (pu); Inverter P controller integrator upper limit	
	LMNP (pu); Inverter P controller integrator lower limit	
	Tsync (s); Inverter POI Angle measurement delay	
	LMX1Ud (deg.); Rectifier dc voltage controller first lead-lag upper limit	

Category	Parameters	Data
VSC based HVDC		
HVDCPL1	LMN1Ud (deg.); Rectifier dc voltage controller first lead-lag lower limit	
	LMX2Ud (deg.); Rectifier dc voltage controller second lead-lag upper limit	
	LMN2Ud (deg.); Rectifier dc voltage controller second lead-lag lower limit	
	LMX1P (deg.); Inverter P controller first lead-lag upper limit	
	LMN1P (deg.); Inverter P controller first lead-lag lower limit	
	LMX2P (deg.); Inverter P controller second lead-lag upper limit	
	LMN2P (deg.); Inverter P controller second lead-lag lower limit	
	C_Module (F),Converter module capacitor	
	V_Module (kV), Converter module rated capacitor voltage	
	Protection threshold peak current of the IGBTs, kA	
	Model Acceleration factor(>0 and <=1)	
	Undervoltage characteristics, X1 (measured AC-voltage in pu)	
	Undervoltage characteristics, Y1 (AC-voltage reference in pu)	
	Undervoltage characteristics, X2	
	Undervoltage characteristics, Y2	
	Undervoltage characteristics, X3	
	Undervoltage characteristics, Y3	
	Undervoltage characteristics, X4	
	Undervoltage characteristics, Y4	
	Undervoltage characteristics, X5	
	Undervoltage characteristics, Y5	
	Undervoltage characteristics, X6	
	Undervoltage characteristics, Y6	
	Undervoltage characteristics, X7	
	Undervoltage characteristics, Y7	
	Undervoltage characteristics, X8	
	Undervoltage characteristics, Y8	
	Undervoltage characteristics, X9	
	Undervoltage characteristics, Y9	
	Undervoltage characteristics, X10	
	Undervoltage characteristics, Y10	
	Power-Voltage characteristics, X1 (measured AC-voltage in pu)	
	Power-Voltage characteristics, Y1 (maximum active power in pu of MVA rating of second converter)	
	Power-Voltage characteristics, X2	
	Power-Voltage characteristics, Y2	
	Power-Voltage characteristics, X3	
	Power-Voltage characteristics, Y3	
	Power-Voltage characteristics, X4	
	Power-Voltage characteristics, Y4	
	Power-Voltage characteristics, X5	
	Power-Voltage characteristics, Y5	

Category	Parameters	Data
VSC based HVDC		
HVDCPL1	Power-Voltage characteristics, X6	
	Power-Voltage characteristics, Y6	
	DC Chopper characteristics, X1 (Direct voltage in pu)	
	DC Chopper V-I characteristics, Y1 (chopper current in kA)	
	DC Chopper characteristics, X2	
	DC Chopper characteristics, Y2	
	DC Chopper characteristics, X3	
	DC Chopper characteristics, Y3	
	DC Chopper characteristics, X4	
	DC Chopper characteristics, Y4	
	DC Chopper characteristics, X5	
	DC Chopper characteristics, Y5	
	DC Chopper characteristics, X6	
	DC Chopper characteristics, Y6	
	DC Chopper characteristics, X7	
	DC Chopper characteristics, X7	
	DC Chopper characteristics, X8	
	DC Chopper characteristics, X8	
	DC Chopper characteristics, X9	
	DC Chopper characteristics, X9	
	DC Chopper characteristics, X10	
	DC Chopper characteristics, X10	
VSCDCT	Tpo_1, Time constant of active power order controller, sec (For VSC # 1).	
	AC_VC_Limits_1, Reactive power limit for ac voltage control, pu on converter MVA rating. When 0, it is not used and Qmax/Qmin pair is used instead (For VSC # 1).	
	AC_Vctrl_kp_1, AC Voltage control proportional gain, converter MVA rating/BASEKV (For VSC # 1).	
	Tac_1 > 0.0, Time constant for AC voltage PI integral, sec (For VSC # 1). When 0, VSC#1 is ignored.	
	Tacm_1, Time constant of the ac voltage transducer, sec (For VSC # 1).	
	Iacmax_1, Current Limit, pu on converter MVA rating (For VSC # 1).	
	Droop_1, AC Voltage control droop, converter MVA rating/BASEKV (For VSC # 1).	
	VCMX_1, Maximum VSC Bridge Internal Voltage (For VSC # 1).	
	XREACT_1 > 0.0, Pu reactance of the ac series reactor on converter MVA rating (For VSC # 1). When 0.0, default value 0.17 is used.	
	QMAX_1, Maximum system reactive limits in Mvars (For VSC # 1). When AC-VC_Limits_1 >0, QMAX_1 is not used.	
	QMIN_1, Minimum system reactive limits in MVARs (For VSC # 1). When AC-VC_Limits_1 >0, QMIN_1 is not used.	
	AC_VC_KT_1, Adjustment Parameter for the feedback from reactive power limiter to ac voltage controller (For VSC #1).	
	AC_VC_KTP_1, Adjustment Parameter for the feedback from current order limiter to ac voltage controller (For VSC #1).	
	Tpo_2, Time constant of active power order controller, sec (For VSC # 2).	

Category	Parameters	Data
	VSC based HVDC	
VSCDCT	AC_VC_Limits_2, Reactive power limit for ac voltage control, pu on converter MVA rating. When 0, it is not used and Qmax/Qmin pair is used instead (For VSC # 2).	
	AC_Vctrl_kp_2, AC Voltage control proportional gain, converter MVA rating/BASEKV (For VSC # 2).	
	Tac_2 > 0.0, Time constant for AC voltage PI integral, sec (For VSC # 2). When 0, VSC#2 is ignored.	
	Tacm_2, Time constant of the ac voltage transducer, sec (For VSC # 2).	
	Iacmax_2, Current Limit, pu on converter MVA rating (For VSC # 2).	
	Droop_2, AC Voltage control droop, converter MVA rating/BASEKV (For VSC # 2).	
	VCMX_2, Maximum VSC Bridge Internal Voltage (For VSC # 2).	
	XREACT_2 > 0.0, Pu reactance of the ac series reactor on converter MVA rating (For VSC # 2). When 0.0, default value 0.17 is used.	
	QMAX_2, Maximum system reactive limits in MVARs (For VSC # 2). When AC-VC_Limits_2 >0, QMAX_2 is not used.	
	QMIN_2, Minimum system reactive limits in MVARs (For VSC # 2). When AC-VC_Limits_2 >0, QMIN_2 is not used.	
	AC_VC_KT_2, Adjustment Parameter for the feedback from reactive power limiter to ac voltage controller (For VSC #2).	
	AC_VC_KTP_2, Adjustment Parameter for the feedback from current order limiter to ac voltage controller (For VSC #2).	
	Tpo_DCL, Time constant of the power order controller, sec (For DC Line).	
	Tpo_lim, Time constant of the power order limit controller, sec (For DC Line).	
	MTDC	
MTDC1T	DY1, minimum angle converter 1 (degrees)	
	TVAC1, ac voltage transducer converter 1 (sec)	
	TVDC1, dc voltage transducer converter 1 (sec)	
	TIDC1, current transducer converter 1 (sec)	
	RSVLT1, minimum dc voltage following block, converter 1 (kV)1	
	RSCUR1, minimum dc current following block, converter 1 (amps)2	
	VRMP1, voltage recovery rate, converter 1 (pu/sec)1	
	CRMP1, current recovery rate, converter 1 (pu/sec)2	
	C0-1, minimum current demand converter 1 (amps)3	
	V1-1, voltage limit point 1, converter 1 (kV)2	
	C1-1, current limit point 1, converter 1 (amps)2	
	V2-1, voltage limit point 2, converter 1 (kV)2	
	C2-1, current limit point 2, converter 1 (amps)2	
	V3-1, voltage limit point 3, converter 1 (kV)2	
	C3-1, current limit point 3, converter 1 (amps)2	
	DY2, minimum angle converter 2 (degrees)	
	TVAC2, ac voltage transducer converter 2 (sec)	
	TVDC2, dc voltage transducer converter 2 (sec)	
	TIDC2, current transducer converter 2 (sec)	
	RSVLT2, minimum dc voltage following block, converter 2 (kV)1	
	RSCUR2, minimum dc current following block, converter 2 (amps)2	

Category	Parameters	Data
MTDC		
MTDC1T	VRMP2, voltage recovery rate, converter 2 (pu/sec)1	
	CRMP2, current recovery rate, converter 2 (pu/sec)2	
	C0-2, minimum current demand converter 2 (amps)3	
	V1-2, voltage limit point 1, converter 2 (kV)2	
	C1-2, current limit point 1, converter 2 (amps)2	
	V2-2, voltage limit point 2, converter 2 (kV)2	
	C2-2, current limit point 2, converter 2 (amps)2	
	V3-2, voltage limit point 3, converter 2 (kV)2	
	C3-2, current limit point 3, converter 2 (amps)2	
	DY3, minimum angle converter 3 (degrees)	
	TVAC3, ac voltage transducer converter 3 (sec)	
	TVDC3, dc voltage transducer converter 3 (sec)	
	TIDC3, current transducer converter 3 (sec)	
	RSVLT3, minimum dc voltage following block, converter 3 (kV)1	
	RSCUR3, minimum dc current following block, converter 3 (amps)2	
	VRMP3, voltage recovery rate, converter 3 (pu/sec)1	
	CRMP3, current recovery rate, converter 3 (pu/sec)2	
	C0-3, minimum current demand converter 3 (amps)3	
	V1-3, current limit point 1, converter 3 (kV)2	
	C1-3, current limit point 1, converter 3 (amps)2	
	V2-3, voltage limit point 2, converter 3 (kV)2	
	C2-3, current limit point 2, converter 3 (amps)2	
	V3-3, voltage limit point 3, converter 3 (kV)2	
	C3-3, current limit point 3, converter 3 (amps)2	
	DY4, minimum angle converter 4 (degrees)	
	TVAC4, ac voltage transducer converter 4 (sec)	
	TVDC4, dc voltage transducer converter 4 (sec)	
	TIDC4, current transducer converter 4 (sec)	
	RSVLT4, minimum dc voltage following block, converter 4 (kV)1	
	RSCUR4, minimum dc current following block, converter 4 (amps)2	
	VRMP4, voltage recovery rate, converter 4 (pu/sec)1	
	CRMP4, current recovery rate, converter 4 (pu/sec)2	
	C0-4, minimum current demand converter 4 (amps)3	
	V1-4, voltage limit point 1, converter 4 (kV)2	
	C1-4, current limit point 1, converter 4 (amps)2	
	V2-4, voltage limit point 2, converter 4 (kV)2	
	C2-4, current limit point 2, converter 4 (amps)2	
	V3-4, voltage limit point 3, converter 4 (kV)2	
	C3-4, current limit point 3, converter 4 (amps)2	
	DY5, minimum angle converter 5 (degrees)	
	TVAC5, ac voltage transducer converter 5 (sec)	
	TVDC5, dc voltage transducer converter 5 (sec)	

Category	Parameters	Data
MTDC		
MTDC1T	TIDC5, current transducer converter 5 (sec)	
	RSVLT5, minimum dc voltage following block, converter 5 (kV)1	
	RSCUR5, minimum dc current following block, converter 5 (amps)2	
	VRMP5, Voltage recovery rate, converter 5 (pu/sec)1	
	CRMP5, current recovery rate, converter 5 (pu/sec)2	
	C0-5, minimum current demand converter 5 (amps)3	
	V1-5, voltage limit point 1, converter 5 (kV)2	
	C1-5, current limit point 1, converter 5 (amps)2	
	V2-5, voltage limit point 2, converter 5 (kV)2	
	C2-5, current limit point 2, converter 5 (amps)2	
	V3-5, voltage limit point 3, converter 5 (kV)2	
	C3-5, current limit point 3, converter 5 (amps)2	
	TCMODE (sec)	
MTDC2T	DY1, minimum angle converter 1 (degrees)	
	TVAC1, ac voltage transducer converter 1 (sec)	
	TVDC1, dc voltage transducer converter 1 (sec)	
	TIDC1, current transducer converter 1 (sec)	
	RSVLT1, minimum dc voltage following block, converter 1 (kV)1	
	RSCUR1, minimum dc current following block, converter 1 (amps)	
	VRMP1, voltage recovery rate, converter 1 (pu/sec)1	
	CRMP1, current recover rate, converter 1 (pu/sec)	
	C0-1, minimum current demand converter 1 (amps)	
	V1-1, minimum current demand converter 1	
	C1-1, minimum current demand converter 1 (amps)	
	V2-1, minimum current demand converter 1	
	C2-1, minimum current demand converter 1 (amps)	
	V3-1, minimum current demand converter 1	
	C3-1, minimum current demand converter 1 (amps)	
	DY2, minimum angle converter 2 (degrees)	
	TVAC2, ac voltage transducer converter 2 (sec)	
	TVDC2, dc voltage transducer converter 2 (sec)	
	TIDC2, current transducer converter 2 (sec)	
	RSVLT2, minimum dc voltage following block, converter 2 (kV)1	
	RSCUR2, minimum dc current following block, converter 2 (amps)	
	VRMP2, voltage recovery rate, converter 2 (pu/sec)1	
	CRMP2, current recover rate, converter 2 (pu/sec)	
	C0-2, minimum current demand converter 2 (amps)	
	V1-2, minimum current demand converter 2	
	C1-2, minimum current demand converter 2 (amps)	
	V2-2, minimum current demand converter 2	
	C2-2, minimum current demand converter 2 (amps)	
	V3-2, minimum current demand converter 2	

Category	Parameters	Data
MTDC		
MTDC2T	C3-2, minimum current demand converter 2 (amps)	
	DY3, minimum angle converter 3 (degrees)	
	TVAC3, ac voltage transducer converter 3 (sec)	
	TVDC3, dc voltage transducer converter 3 (sec)	
	TIDC3, current transducer converter 3 (sec)	
	RSVLT3, minimum dc voltage following block, converter 3 (kV)1	
	RSCUR3, minimum dc current following block, converter 3 (amps)	
	VRMP3, voltage recovery rate, converter 3 (pu/sec)1	
	CRMP3, current recover rate, converter 3 (pu/sec)	
	C0-3, minimum current demand converter 3 (amps)	
	V1-3, minimum current demand converter 3	
	C1-3, minimum current demand converter 3 (amps)	
	V2-3, minimum current demand converter 3	
	C2-3, minimum current demand converter 3 (amps)	
	V3-3, minimum current demand converter 3	
	C3-3, minimum current demand converter 3 (amps)	
	DY4, minimum angle converter 4 (degrees)	
	TVAC4, ac voltage transducer converter 4 (sec)	
	TVDC4, dc voltage transducer converter 4 (sec)	
	TIDC4, current transducer converter 4 (sec)	
	RSVLT4, minimum dc voltage following block, converter 4 (kV)1	
	RSCUR4, minimum dc current following block, converter 4 (amps)	
	VRMP4, voltage recovery rate, converter 4 (pu/sec)1	
	CRMP4, current recovery rate, converter 4 (pu/sec)	
	C0-4, minimum current demand converter 4 (amps)	
	V1-4, minimum current demand converter 4	
	C1-4, minimum current demand converter 4 (amps)	
	V2-4, minimum current demand converter 4	
	C2-4, minimum current demand converter 4 (amps)	
	V3-4, minimum current demand converter 4	
	C3-4, minimum current demand converter 4 (amps)	
	DY5, minimum angle converter 5 (degrees)	
	TVAC5, ac voltage transducer converter 5 (seconds)	
	TVDC5, dc voltage transducer converter 5 (seconds)	
	TIDC5, current transducer converter 5 (seconds)	
	RSVLT5, minimum dc voltage following block, converter 5 (kV)1	
	RSCUR5, minimum dc current following block, converter 5 (amps)	
	VRMP5, voltage recovery rate, converter 5 (pu/sec)1	
	CRMP5, current recovery rate, converter 5 (pu/sec)	
	C0-5, minimum current demand converter 5 (amps)	
	V1-5, minimum current demand converter 5	
	C1-5, minimum current demand converter 5 (amps)	

Category	Parameters	Data
MTDC		
MTDC2T	V2-5, minimum current demand converter 5	
	C2-5, minimum current demand converter 5 (amps)	
	V3-5, minimum current demand converter 5	
	C3-5, minimum current demand converter 5 (amps)	
	TVF, power control VDC transducer time constant (sec)	
	VDCOLUP, voltage transducer time constants (sec)	
	VDCOLON, voltage transducer time constants (sec)	
	Current margin (amps)	
	Converter 1 DV/DI multiplier (pu)2	
	Converter 2 DV/DI multiplier (pu)2	
	Converter 3 DV/DI multiplier (pu)2	
	Converter 4 DV/DI multiplier (pu)2	
	Converter 5 DV/DI multiplier (pu)2	

CDC4T: Two-terminal dc line model

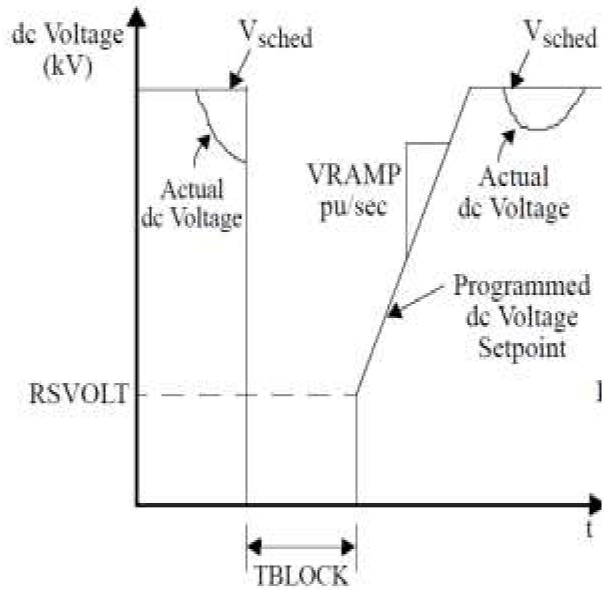


Figure 9: Illustration of RSVOLT, VRAMP

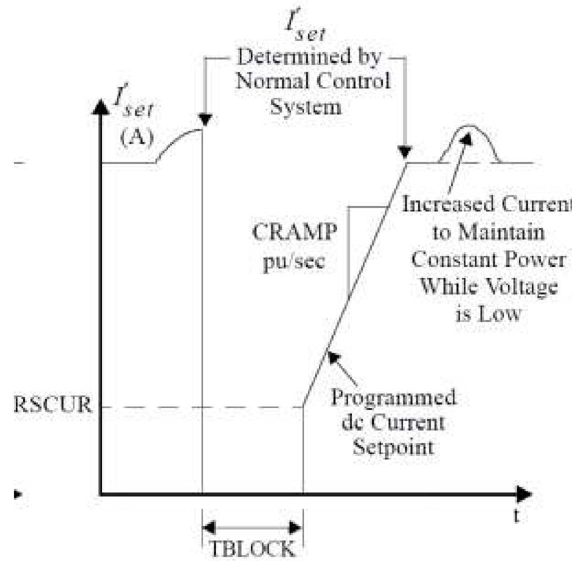


Figure 10: Illustration of RSCUR, CRAMP

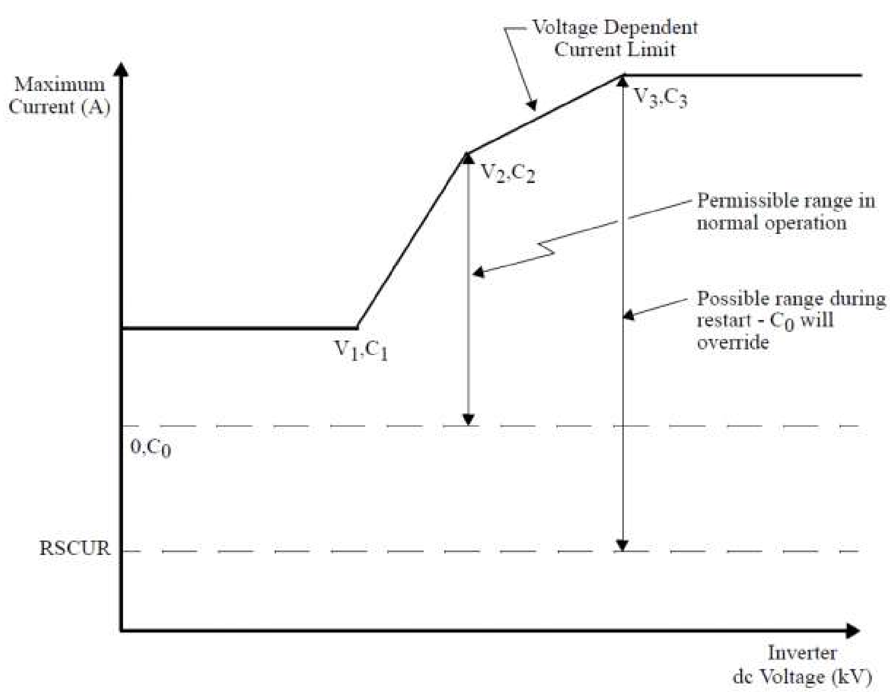
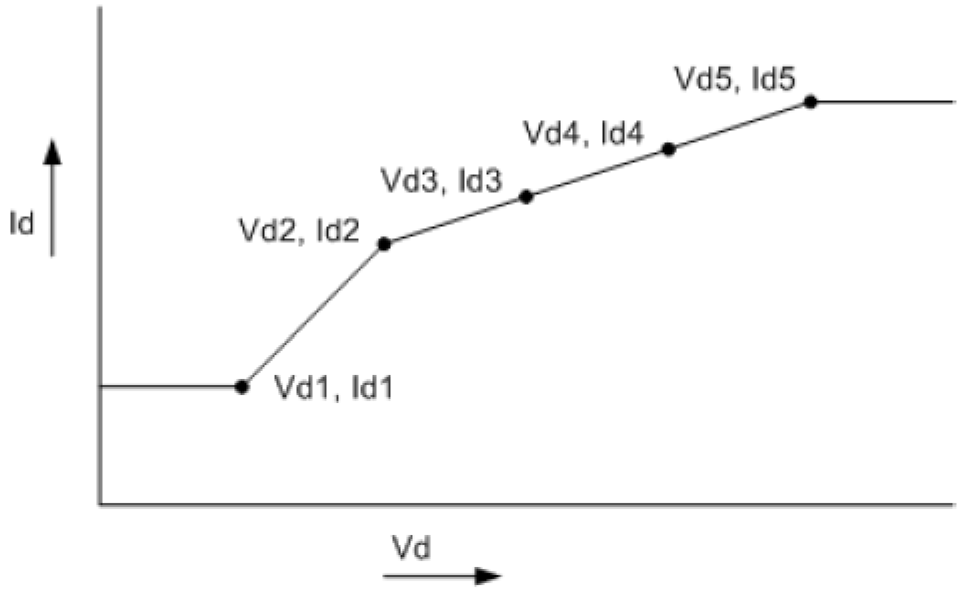


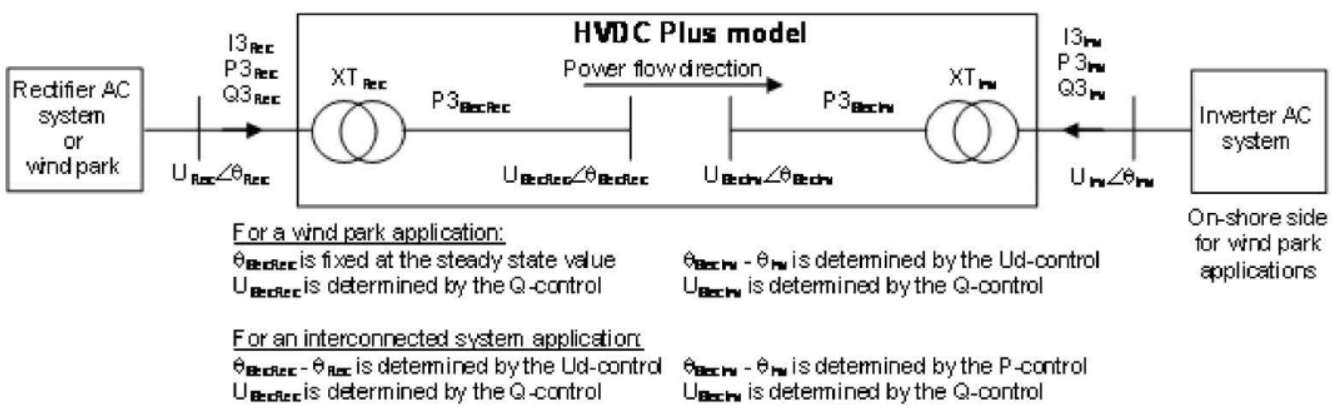
Figure 11: Illustration of VDCOL characteristic

- **CDC7T: dc Line VDCOL**



VDCL Characteristics

- **HVDCPL1: dc Line Model**



Section 4:

Procedure for interconnection of a STATCOM/SVC and issue of certificate of successful trial operation by Regional Load Despatch Centres (RLDCs)

Table of Contents

Procedure for interconnection of a STATCOM/SVC and issue of certificate of successful trial operation by Regional Load Despatch Centres (RLDCs)

1. **Pre Charging Activities**
   a. The procedure in place for first time charging of transmission elements shall be followed for STATCOM as well and all the timelines & formats mentioned in that procedure shall be applicable to STATCOM as well.
   b. Approval of first time charging of STATCOM shall be provided by respective RLDC in line with these guidelines and the procedure for facilitating first time charging of new transmission elements already in place.
   c. Following information shall be provided by the owners of STATCOM before first time charging of STATCOM
      i. Modelling data from STATCOM stations(Annexure-II(B))
      ii. Number of Blocks and rating of each block
      iii. Detailed Single Line Diagram of STATCOM
      iv. V/I Characteristics
      v. Coupling Transfer HV /LV rating
      vi. Coupling Transformer Rating / Impedance
      vii. MSR and MSC design parameters
      viii. Different Operating Modes
      ix. IEEE Standard Dynamic Model
      x. Whether POD is enabled and tuned. If No, then reasons for the same.
      xi. Any other information as required by RLDC
   d. Owners of the STATCOM shall submit a detailed proposal for testing at least 10 days in advance along with intimation of first time charging (Format A).
   e. The auxiliary consumption of STATCOM is generally drawn from the tertiary of the 400/220/33 kV transformer at the substation. The meter reading of this transformer would include the auxiliary consumption of STATCOM as well. Therefore, a No Objection Certificate (NOC) from the local DISCOM and SLDC would also be provided by the owner of the STATCOM.
   f. Special Energy Meter shall be installed by CTU at the coupling transformer as well in consultation with concerned RLDC. The dummy meter readings shall be sent to respective RLDC along with B type formats.

2. **Data Telemetry Requirements**
   a. Following SCADA points shall be made available to the NLDC/RLDC control room
      i. Q_{stat} : Reactive power exchange with STATCOM
      ii. Q_{MSR} & Q_{MSC} : Reactive power exchange with Mechanically switched Reactor and Mechanically Switched capacitor
      iii. V_{HV} & V_{MV} : Voltage of high voltage bus and Medium Voltage bus where STATCOM is connected
      iv. Q_{Tra} : Reactive power through the coupling transformer

v. P_{aux} & Q_{aux} : Active and reactive power through the auxiliary supply
vi. Circuit Breaker and Isolator Status
vii. Tap position of coupling transformer
viii. Power Oscillation damping setting
ix. STATCOM modes

An indicative SLD specifying these parameters are enclosed as Annexure I.

3. Trial Operation of STATCOM

a. The trial operation of STATCOM shall start only after all the units/blocks are in operation and telemetry of the points as defined above are available at RLDC/NLDC.
b. The trial operation for the purpose of STATCOM shall be continuous operation for 72 hrs.
c. During the trial operation, performance of MSR, MSC and STATCOM shall be verified. Hence, MSR and MSC shall be operated continuously for 24 hours one by one
d. The continuous of operation of MSR, MSC and the operating range test of STATCOM shall be demonstrated during the trial operation.
e. RLDCs in coordination with NLDC shall ensure that the STATCOM is operated at least once in Voltage Control Mode (by changing Vref) and once in Constant Reactive Power Control Mode. If required, bus reactors at that substation may be switched for this purpose.

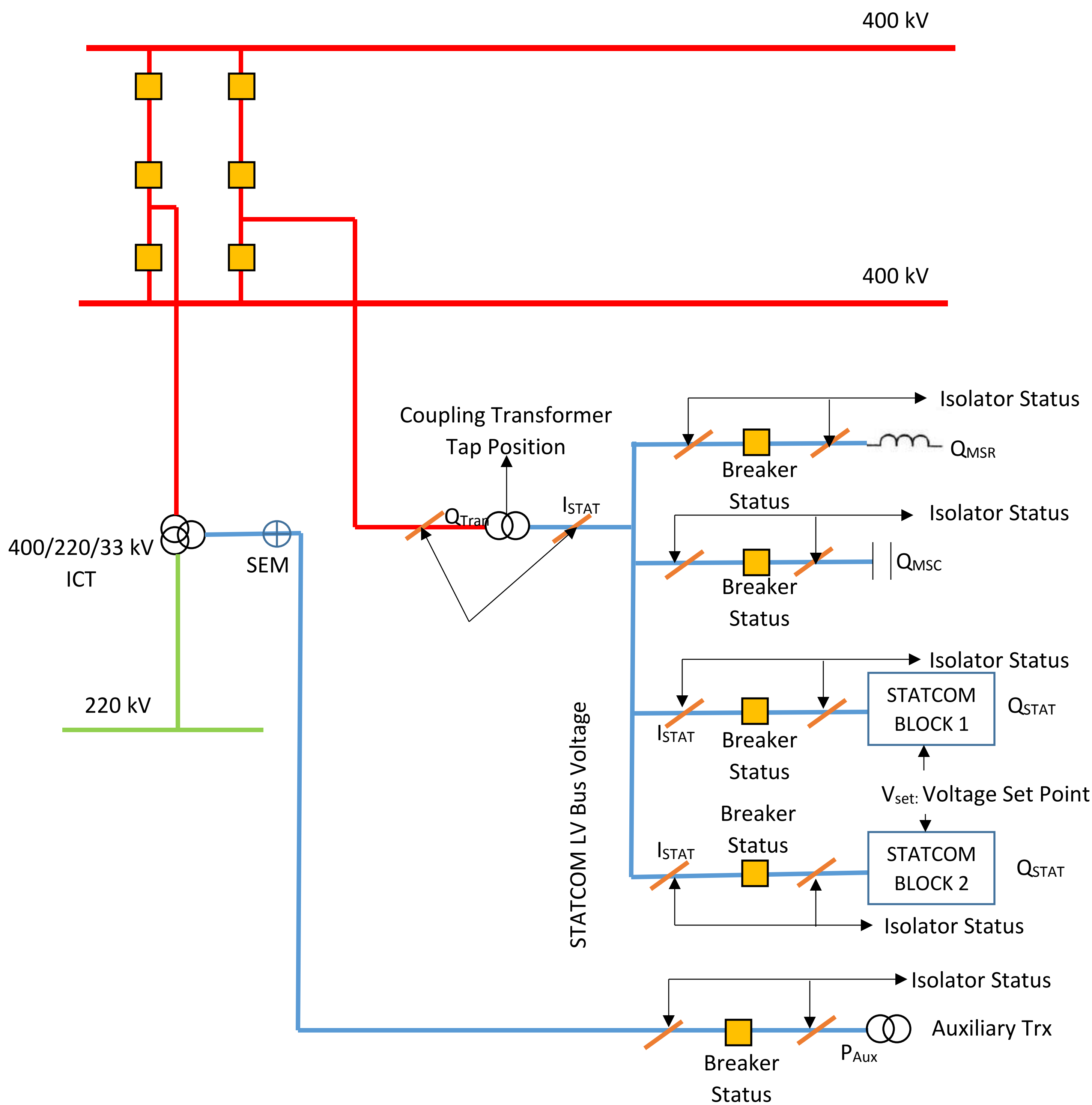
4. Post Charging Activities

a. Successful Trial Operation completion certificate for STATCOM shall be issued by RLDC in accordance with procedure in place for first time charging of transmission elements.
b. Following data shall be provided by the owner of STATCOM post successful trial operation for issuance of successful trial operation completion certificate:
    i. Coupling transformer meter reading for the period of trial operation
    ii. SCADA readings/plot of reactive power injected or absorbed during the trial operation
    iii. SCADA readings/plot of current drawn by STATCOM
    iv. SCADA readings/plot of STATCOM HV bus
    v. Event log indicating closing of STATCOM breaker
    vi. Output of Disturbance Recorder for the period of trial operation
    vii. Any other data as required by RLDC to ascertain effective operation of STATCOM

Enclosures.
Annexure-I: Indicative SLD
Annexure-II: Guideline for exchange of data for modelling STATCOM

Other than the documents mentioned above the formats for first time charging of transmission elements (Format A1-A6, B1-B5 and C1-C4) to be submitted.

Annexure I



400 kV
400 kV
Coupling Transformer
Tap Position
QTran
ISTAT
400/220/33 kV
ICT
SEM
220 kV
Isolator Status
QMSR
Breaker
Status
Isolator Status
QMSC
Breaker
Status
Isolator Status
STATCOM
BLOCK 1
QSTAT
ISTAT
Breaker
Status
Vset: Voltage Set Point
Breaker
Status
ISTAT
STATCOM
BLOCK 2
QSTAT
Isolator Status
STATCOM LV Bus Voltage
Isolator Status
Auxiliary Trx
PAux
Breaker
Status

Guideline for furnishing information for Modelling Static Synchronous Compensator (STATCOM) in Indian Grid

1.0 Introduction:

The purpose of this document is to act as a guideline for exchange of information for accurate modelling of Static Synchronous Compensator (STATCOM) in India. STATCOMs are relatively recent technological additions into the Indian grid and their number is expected to increase further in the future. STATCOMs deliver reactive power to counter voltage deviations from the nominal, supporting the stability of the grid. STATCOMs are typically voltage source converter (VSC) devices. Availability of fit-for-purpose steady state and dynamics models of STATCOM installations are necessary to undertake simulation studies for secure operation of the Indian power grid.

1.1 Applicability:

The guideline shall be applicable to all STATCOM installations in India, irrespective of the technologies used.

This document presents the desired information for collection of data for modelling of STATCOM installations in PSS/E software, a software suite being used pan-India at CEA, CTU, SLDCs, RLDCs, and NLDC for modelling of India’s power grid. A systematic set of data and basic criteria for furnishing data are presented.

1.2 Need for a fit-for-purpose model:

There is a cost involved in developing and validating dynamic models of power system equipment. But there are much higher benefits for the power system if this leads to a functional, fit-for-purpose model, and arrangements that allow that model to be maintained over time.

A functional fit-for-purpose dynamic model will:

- Facilitate significant power system efficiencies by allowing power system operations to confidently identify the secure operating envelope and thereby manage security effectively
- Allow assessment of impact on grid elements due to connection of new elements (network elements, generators, or loads) for necessary corrective actions
- Permit power system assets to be run with margins determined on the basis of security assessments
- Facilitate the tuning of control systems, such as power oscillation dampers, frequency controllers, etc.
- Improve accuracy of online security tools, particularly for unusual operating conditions, which in turn is likely to result in higher reliability of supply to power system users.

The power system model would enable steady state and electromechanical transient simulation studies that deliver reasonably accurate outcomes.

1.3 Regulation:

- **<u>CEA Connectivity Standard 6.4.d :</u>**

The requester and user shall cooperate with RPC and Appropriate Load Despatch Centre in respect of the matters listed below, but not limited to

furnish data as required by Appropriate Transmission Utility or Transmission Licensee, Appropriate Load Despatch Centre, Appropriate Regional Power Committee and any committee constituted by the Authority or appropriate Government for system studies or for facilitating analysis of tripping or disturbance in power system;

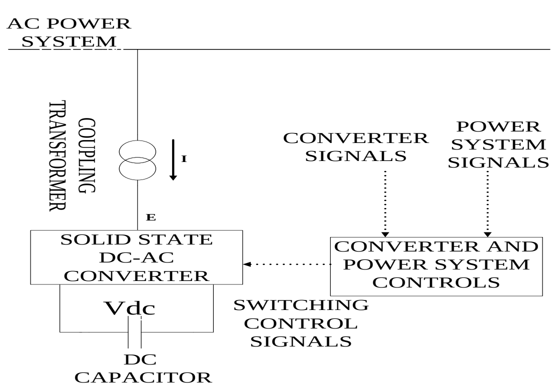
Here Requester and User Includes a generating company, captive generating plant, energy storage system, transmission licensee (other than Central Transmission Utility and State Transmission Utility), distribution licensee, solar park developer, wind park developer, wind-solar photovoltaic hybrid system, or bulk consumer *(2019 Amendment)*

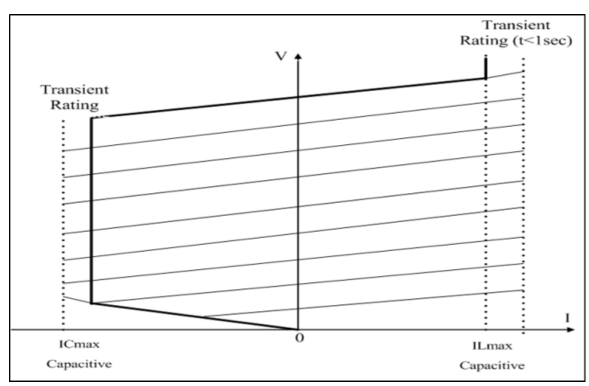
- **<u>IEGC 4.1 :</u>**

CTU, STU and Users connected to, or seeking connection to ISTS shall comply with Central Electricity Authority (Technical Standards for connectivity to the Grid) Regulations, 2007 which specifies the minimum technical and design criteria and Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations,2009.

2.0 STATCOM:

Static Synchronous Compensator (STATCOM) is a reactive power regulating device based on the voltage source converter (VSC) used to maintain AC system voltage and enhance stability of the AC system. STATCOM provides operating characteristic similar to rotating synchronous compensator (condenser) but without mechanical inertia since it has no rotating component. By generating and absorbing reactive power within its working output range the STATCOM is able to maintain virtually constant voltage at its point of connection to the power system.STATCOM may be combined with mechanically switched Reactors & Capacitors controlled by STATCOM controller. The STATCOM would be primarily for dynamic compensation while the mechanically switched reactors/capacitors would be for reactive compensation under steady state.





Version History:

Version no.	Release Date	Prepared by*	Checked/Issued by*	Changes

***Mention Designation and Contact Details**

Details submitted:

Details pending:

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

For POSOCO to get access to steady state and transient simulation models of STATCOMs in the Indian grid, the following information is required.

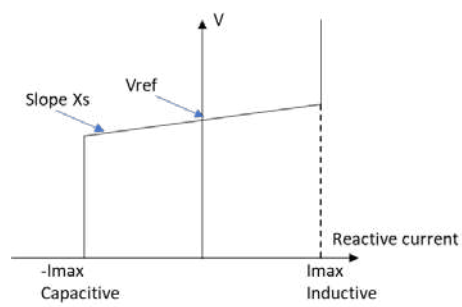
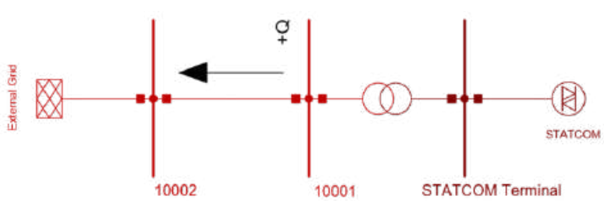
1. Load-flow data for the STATCOM **(Section-3.0)**
2. Electrical Single Line Diagram (SLD) of as built STATCOM station depicting:
    - VSC
    - Coupling Transformer
    - DC capacitor
    - Thyristor Switched Capacitor (TSC) / Mechanically Switched Capacitor
    - Thyristor Switched Reactor (TSR) / Mechanically Switched Reactor
3. Generic models of STATCOM **(Section-3.0)**
4. Encrypted user defined model (UDM) in a format suitable for latest release PSS/E (*.dll files) for RMS simulation for STATCOM (in case non-availability of validated generic model)
    - User guide for Encrypted models to be provided including instructions on how the model should be set-up. It should contain all relevant technical information, including block diagrams, list of state variables and values / descriptions of all model parameters.
    - Corresponding transfer function block diagrams to be provided
    - Simulation results depicting validation of User-Defined models against actual measurement (for P, Q, V, I) to be provided
    - The use of black-box type representation is not preferred.
    - Models should be suitable for an integration time step between 1ms and 10ms, and suitable for operation up-to and in excess of 100s.

3.0 Data for STATCOM:

A. Steady State model (Power Flow):

Table 1 can be used as a guideline for gathering the relevant modelling parameters of STATCOM for steady state power flow calculations.

Table 1: Steady State STATCOM model parameters with example value for voltage droop control

<table>
<tr><th>Parameter</th><th>Example value</th></tr>
<tr><td>STATCOM rating (MVA)
This is the MVA base for all control parameters.</td><td>10 MVA</td></tr>
<tr><td>Continuous current limit (kA)</td><td>0.175 kA</td></tr>
<tr><td>Nominal voltage at the controlled remote bus (kV)</td><td>33 kV</td></tr>
<tr><td>Nominal voltage at the converter terminal (kV)</td><td>0.5 kV</td></tr>
<tr><td>Temperature and voltage dependence of STATCOM rating (e.g. 90% of MVA base when voltage is at 90%)</td><td>9 MVAr when terminal voltage is at 90% of nominal voltage.</td></tr>
<tr><td>Overload capacity</td><td>+25% of nominal current for 1second</td></tr>
<tr><td>Modulation limit</td><td>1.0</td></tr>
<tr><td>No-load loss (kW)</td><td>100 kW</td></tr>
<tr><td>Switching loss factor (kW/A)</td><td>5 kW/A</td></tr>
<tr><td>Resistive loss factor (ohm)</td><td>0 ohm</td></tr>
<tr><td>Negative sequence impedance r2, x2</td><td>998 + j1503 pu</td></tr>
<tr><td>Typical control mode (Voltage control, voltage droop, reactive power, or power factor)</td><td>Voltage droop</td></tr>
<tr><td>Typical setpoint (Voltage, reactive power, or power factor)</td><td>1.0 pu</td></tr>
<tr><td>Voltage droop (% of MVA base) or relevant V-I curve</td><td>4%
Or V-I curve as shown below

</td></tr>
<tr><td>Voltage deviation deadband for reducing controller sensitivity (pu)</td><td>0.0 pu</td></tr>
<tr><td>Load flow single line diagram of the STATCOM

</td><td>As shown</td></tr>
</table>

Parameter	Example value
Remote bus for voltage measurement	10001/Bus Name & Voltage Level
Remote bus for branch / line for reactive power measurement – sending end (where reactive current injection convention to this bus is positive)	10001/Bus Name & Voltage Level
Remote bus for branch / line for reactive power measurement – receiving end (where reactive current injection convention to this bus is negative)	10002/Bus Name & Voltage Level

B. Transient simulation model (Dynamics):

For representation of the RMS behavior of STATCOMs, two standard models are available in the PSS/E library, namely SVSMO3T2 and CSTCNT. Details for SVSMO3T2 are given in Table 2 and Table 3 and the CSTCNT model are given in Table 4 and Table 5. The SVSMO3T2 has been described as STATCOM based SVC with logic to trip mechanically switched shunts (MSS). In comparison, the CSTCNT is a simpler representation of STATCOM with no dependence on shunt devices.

Note that for a user-defined model, similar level of details presented in the steady state (Table 1) and transient may be required.

Table 2: Parameters of SVSMO3T2 generic STATCOM model

Parameter (Controller parameters or PSS/E CON)	**Value**
Xc0, linear droop	
Tc1, voltage measurement lead time constant (sec)	
Tb1, voltage measurement lag time constant (sec)	
Kp, proportional gain	
Ki, integral gain	
Vemax, voltage error max. (pu)	
Vemin, voltage error min. (pu)	
T0, firing sequence control delay (sec)	
Imax1, max. continuous current rating (pu on STBASE)	
dbd, deadband range for voltage control (pu)	
Kdbd, ratio of outer to inner deadband	
Tdbd, deadband time (sec)	
Kpr, proportional gain for slow-reset control	
Kir, integral gain for slow-reset control	
Idbd, deadband range for slow-reset control (pu on STBASE)	
Vrmax, max. limit on slow-reset control output (pu)	
Vrmin, min. limit on slow-reset control output (pu)	
Ishrt, max. short-term current rating as a multiplier of max. cont. current rating (pu)	

Parameter (Controller parameters or PSS/E CON)	Value
UV1, voltage at which STATCOM limit starts to be reduced linearly (pu)	
UV2, voltage below which STATCOM is blocked (pu)	
OV1, voltage above which STATCOM limit linearly drops (pu)	
OV2, voltage above which STATCOM blocks (pu)	
Vtrip, voltage above which STATCOM trips after time delay Tdelay2 (pu)	
Tdelay1, short-term rating time(sec)	
Tdelay2, trip time for V .GT. Vtrip(sec)	
Vrefmax, max. limit on voltage reference (pu)	
Vrefmin, min. limit on voltage reference (pu)	
Tc2, lead time constant(sec)	
Tb2, lag time constant(sec)	
I2t, short-term limit	
Reset, reset rate for I2t limit	
hyst, width of hysteresis loop for I2t limit	
Xc1, non-linear droop slope 1	
Xc2, non-linear droop slope 2	
Xc3, non-linear droop slope 3	
V1, non-linear droop upper voltage (pu)	
V2, non-linear droop lower voltage (pu)	
Tmssbrk, time for MSS breaker to operate (sec)	
Tout, time MSC should be out before switching back in (sec)	
TdelLC, Time delay for switching in a MSS(sec)	
Iupr, Upper threshold for switching MSSs(pu on STBASE)	
Ilwr, Lower threshold for switching MSSs(pu on STBASE)	
Sdelay, time STATCOM should remain blocked before being unblocked	
STBASE (>0), STATCOM BASE MVA	

Table 3: Parameters of SVSMO3T2 generic STATCOM model – additional information

Parameter (Other relevant information or PSS/E ICON)	Value
Remote bus number for voltage regulation	Bus Name & Voltage Level
Disable or enable coordinated MSS switching, 0 - no MSS switching, 1 - MSS switching based on STATCOM current	
flag1, slow-reset off/on, flag1 (0/1)	
flag2, non-linear droop off/on, flag2 (0/1)	
1st MSS bus #	
1st MSS Id (to be entered within single quotes)	
2nd MSS bus #	
2nd MSS Id (to be entered within single quotes)	

3rd MSS bus #	
3rd MSS Id (to be entered within single quotes)	
4th MSS bus #	
4th MSS Id (to be entered within single quotes)	
5th MSS bus #	
5th MSS Id (to be entered within single quotes)	
6th MSS bus #	
6th MSS Id (to be entered within single quotes)	
7th MSS bus #	
7th MSS Id (to be entered within single quotes)	
8th MSS bus #	
8th MSS Id (to be entered within single quotes)	

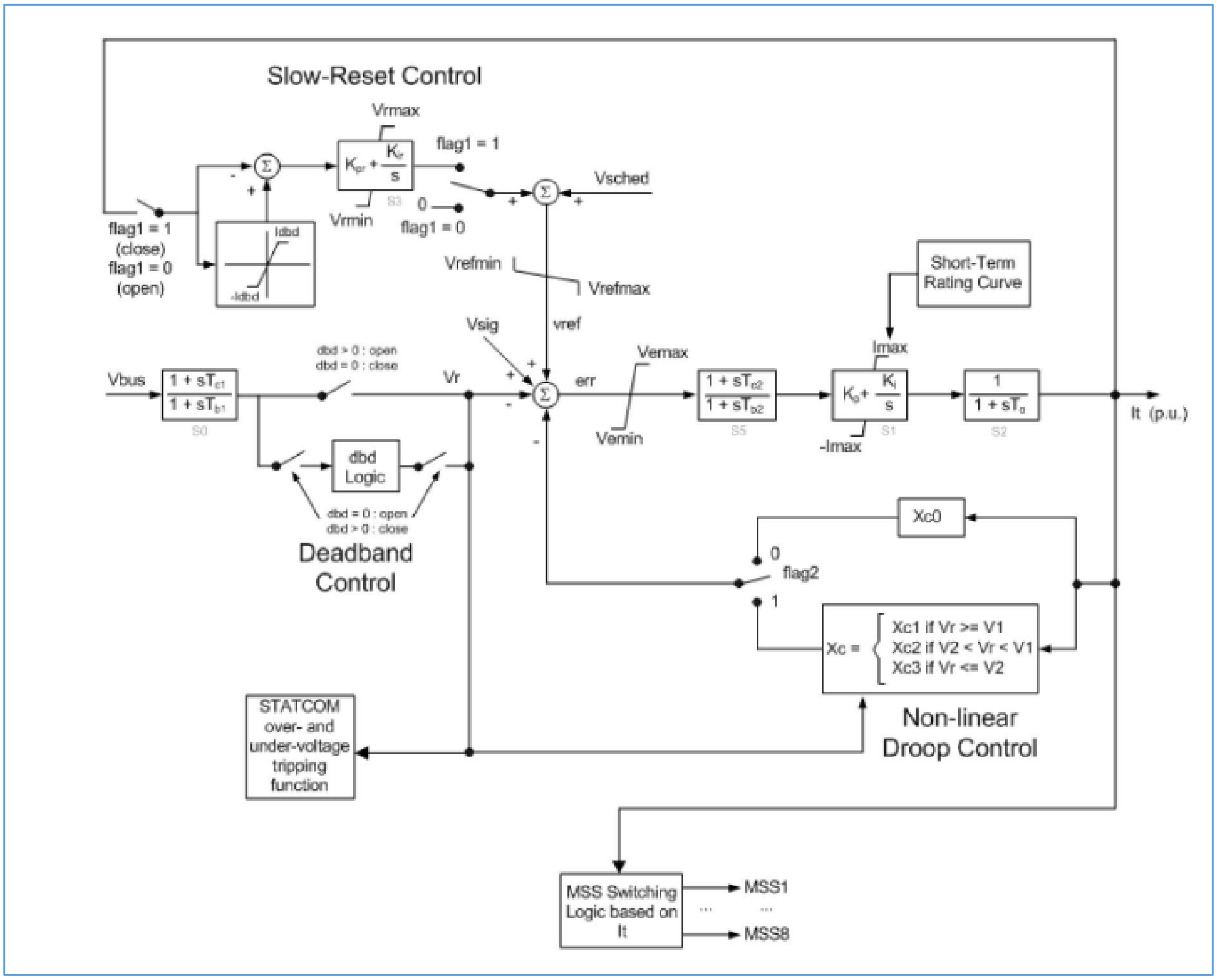


Figure 1: Illustration of STATCOM characteristic for model SVSMO3T2

Table 4: Parameters of CSTCNT generic STATCON model

Parameter (Controller parameters or PSS/E CON)	**Value**
T1 (>0)	
T2 (>0)	
T3 (>0)	
T4 (>0)	
K(Typical = 25/(dv/dei))	
Droop (typical = 0.03)	
VMAX (typical = 999)	
VMIN (typical = -999)	
ICMAX (typical = 1.25) Max capacitive current	
ILMAX (typical = 1.25) Max inductive current	
Vcutout (typical = 0.2)	
Elimit (typical = 1.2)	
Xt (>0) (transformer reactance, typical = 0.1)	
Acc (acceleration factor, typical = 0.5)	
STBASE (>0) STATCON base MVA	

Table 5: Parameters of CSTCNT generic STATCOM model – additional information

Parameter (Other relevant information or PSS/E ICON)	**Value**
IB, remotely regulated bus	Bus Name & Voltage Level

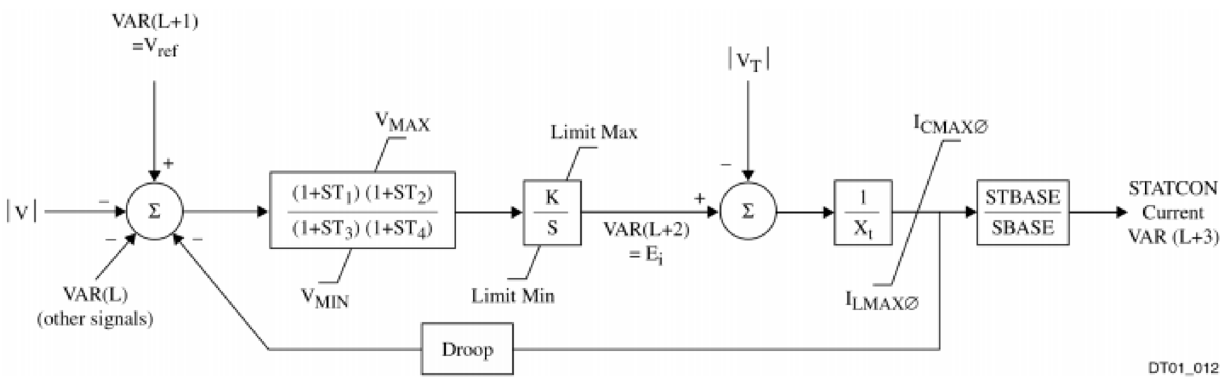


Figure 2: Illustration of STATCOM characteristic for model CSTCNT

Section5:

Procedure
for integration of a new or modified power system elements and issue of certificate of successful trial operation by National Load Despatch Centre (NLDC)/ Regional Load Despatch Centres (RLDCs)

Table of Contents

`Procedure for integration of a new power system elements and issue of certificate of successful trial operation by National Load Despatch Centre (NLDC)/ Regional Load Despatch Centres (RLDCs)

This procedure is applicable for following power system elements:

- Inter-Regional/Inter-State transmission lines irrespective of voltage level/ownership
- HVDC transmission elements irrespective of ownership
- Transnational lines/elements
- 400kV level and above transmission lines/ICT/Bus Reactor/Line Reactor/FACTS devices (TCSC /FSC /STATCOM /SVC)/Bus/Bay/Series Capacitor/Series Reactor/Generating Transformer/any other elements irrespective of ownership
- 220 kV level transmission lines/ICT/Bus Reactor/Line Reactor/FACTS devices (TCSC /FSC / STATCOM /SVC)/ Bus/ Bay/ Series Capacitor/ Series Reactor/ Generating Transformer/any other elements emanating from ISGS / ISTS substations
- Station Transformers (STs) at generating station those are regional entities.
- Generating station those are regional entities.
- Bulk Consumers or Load Serving Entities those are regional entities.
- Combined (Load & Captive) generation complex those are regional entities.
- Short Circuit Testing of power transformers at National High Power Test Laboratory Pvt. Ltd.(NHPTL)

Indian Electricity Grid Code provides for formulation of operating procedure by NLDC/RLDCs. The same is quoted below:

"A set of detailed operating procedures for the National grid shall be developed and maintained by the NLDC in consultation with the RLDCs, for guidance of the staff of the NLDC and it shall be consistent with IEGC to enable compliance with the requirement of this IEGC.

A set of detailed operating procedures for each regional grid shall be developed and maintained by the respective RLDC in consultation with the regional entities for guidance of the staff of RLDC. and shall be consistent with IEGC to enable compliance with the requirement of this IEGC."

In accordance with the above provisions and as a part of NLDC/RLDC operating procedure, procedure for energization of a new or modified power system elements belonging to any transmission licensee has been formulated to enable NLDC/RLDC for secure and reliable integration of new elements. This procedure specifies requirements for integration with the grid such as protection, telemetry and communication systems, metering, statutory clearances and modelling data requirements for system studies.

The details of the same are as follows:

1. **Compliance to the regulations**: All the transmission licensee shall be complied to the regulation & their amendments mentioned below-

   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 Inter-State Transmission of Electricity) Regulations,2017
   v) Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006
   vi) Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in Inter-State Transmission and related matters) Regulations,2009
   vii) Central Electricity Regulatory Commission (Fees and Charges for Regional Load Despatch Centres) Regulations, 2019
   viii) Any other regulations and standards specified from time to time

2. **Intimation for energization to RLDCs**-All the Transmission Licensees including deemed transmission licensees or cross-border entity(Indian side) intending to energize a new or modified any power system elements, which is part of inter-state transmission system, shall intimate the concerned RLDC the details as per the formats given below, at least **(10) days** prior to the anticipated date of first test charging.

   a. **Annexure A1:** Intimation regarding anticipated charging of the power system elements along with the list of the desired documents being submitted**.**

   b. **Annexure A2** : List of elements to be charged with their Rating

   c. **Annexure A3** : Single line diagram of the concerned sub stations, along with status of completion of each dia/bus/breakers clearly indicating which elements are proposed to be charged.

   d. **Annexure A4** : List of SCADA points to be made available (as per standard requirement, RLDC would need all MW and MVAr data, voltage and frequency of all the buses, all the breaker and isolator positions, OLTC tap positions, Main-1/Main-2 protection operated signals, DC side SCADA data in case of HVDC station, data for SVC/STATCOM as per RLDCS/NLDC requirement)

   e. **Annexure A5** : Location of Energy meters as per relevant CEA regulations

f. **Annexure A6**: Connection Agreement, wherever applicable along with all annexures.

Other than the documents mentioned above following documents needs to be submitted to RLDCs-

- CTU charging instructions to be provided which shall clearly mentioned about the assumption made in the studies for ex. Whether it is anti-theft charging or complete line is going to be charged, status of parallel line etc.
- Details of approval of the transmission scheme from the Standing Committee / CTU and approval for changes in the approved scheme, if any.
- Availability of line reactors with the switchable or non-switchable status as per approved scheme.
- CEA approval for energization as per Central Electricity Authority (Measures Relating to Safety & Electric Supply) Regulations,2010
- PTCC clearance certificate
- Technical parameters of the power system element required for network modeling shall be made available by CTU/STU
- In case of HVDC transmission elements all desired modelling data, operational documents and telemetered data to be provided as per the procedure of integration of HVDC transmission elements.
- In case of STATCOM/SVC all technical details to be provided as per procedure of STATCOM/SVC.
- Short Circuit Testing of power transformers at National High Power Test Laboratory Pvt. Ltd.(NHPTL) is allowed as per the CERC approved procedure of testing enclosed as ***Annexure-I***
- Status of PMU installation

3. Within 3 days of submission of above information by the Transmission Licensee, concerned RLDC shall acknowledge the receipt of the same, as per Format II, and seek clarifications, if any. The transmission licensee shall submit the desired information/documents to the concerned RLDC within next three days.

4. **Request for trial operation**-The request for charging of new or modified power system element and towards start of the trial operation as per Format III shall be submitted by the Transmission Licensee to the concerned RLDC, **at least three (3) days** prior to the date of first-time charging. There could be a separate schedule for test charging and the final schedule for trial operation, which may be mentioned in the Format-I itself. The Transmission Licensee shall also submit the following documents in this regard:

   a. **Annexure B1:** Request for charging of the new or modified power system elements along with the summary of the undertakings being submitted as per **Format III**

   b. **Annexure B2:** Undertaking in respect of Protective systems as per **Format III A**

c. **Annexure B3:** Undertaking in respect of Telemetry and communication as per Format **III B**

d. **Annexure B4:** Undertaking in respect of Energy metering as per **Format III C**

e. **Annexure B5:** Undertaking in respect of Statutory clearances as per **Format III D**

5. On satisfying itself with the submitted information as stated above under Para 3, the RLDC would issue a provisional approval for charging to the Transmission Licensee as per **Format IV** within two days of receipt of above documents. On the designated day, the transmission licensee shall charge the transmission line and do trial operation as per the timeline mentioned in Format III, after obtaining the real time code from RLDC. All attempts would be made by the real time operating personnel at the concerned RLDC to facilitate charging and commissioning of the new or modified power system elements at the earliest, subject to availability of real time data and favorable system conditions. Charging of any new elements will not be allowed after 18:00 hrs.

6. **<u>Issuance of Trial Certificate</u>**- Clause (5) of Regulation 6.3A of Indian Electricity Grid Code provides for certification of successful trial operation of new transmission assets by RLDC. The same is quoted below:

   "Trial run and Trial operation in relation to a transmission system or an element thereof shall mean successful charging of the transmission system or an element thereof for 24 hours at continuous flow of power, and communication signal from the sending end to the receiving end and with requisite metering system, telemetry and protection system in service enclosing certificate to that effect from concerned Regional Load Despatch Centre."

   After successful trial operation, following documents shall be submitted by the Transmission Licensee to concerned RLDC :

   a. **Annexure C1:** Request for issuance of successful trial operation certificate as per **Format V**
   b. **Annexure C2**: Values of the concerned line flows and related voltages as per local SCADA just before and after charging of the element.
   c. **Annexure C3:** Special Energy meter (SEM) Reading corresponding to the trial run
   d. **Annexure C4:** Output of Disturbance Recorders / Event Loggers including the graph and event list.

7. Within three (3) working days of submission of the information mentioned above,

N L D C / RLDC concerned shall issue the certificate for successful completion of trial run of the transmission lines as per **Format VI** subject to the correctness of information provided by the transmission licensee. If any clarification is required from transmission licensee then trial certificate will be issued after resolving all the issues.

8. Jurisdiction of Issuance of trial Certificate is as follows:
   NLDC- Inter Regional transmission lines designated as ISTS irrespective of voltage level, inter regional HVDC link/Pole irrespective of ownership and all transnational lines.
   RLDC- Transmission lines designated as ISTS irrespective of voltage level/ownership, Intra Regional HVDC link/pole connected as designated ISTS network, FACTS devices (TCSC/FSC/STATCOM/SVC) associated with designated ISTS;

x-----x-----x

Annexure-I

Procedure for approval of testing at NHPTL, Bina

1. NHPTL shall register with WRLDC as its user before commencement of short circuit tests by filing an application in the Format I enclosed and payment of one time registration fee of INR ten lakh only in line with the provisions of the CERC (RLDC Fees and Charges) Regulations, 2015.

2. NHPTL shall apply to WRLDC at least seven (7) days in advance for approval of testing of any High Voltage Transformer (HVTR) test equipment in Format II enclosed. Only one application for the specified rating of the transformer for the desired period of testing time of maximum one day shall be submitted by NHPTL. Non-refundable Application Fees of Rs 5000/- only per application/testing would be payable by NHPTL to WRLDC. In case there is requirement of short circuit current for multiple times on the same equipment, then the same shall be clearly mentioned in the application format including any shots for calibration which shall be indicated separately.

3. WRLDC shall give its approval within three (3) days of receipt of the application in Format III enclosed considering the grid conditions, anticipated fault levels and/or any other event in the vicinity of the test laboratory with a copy to NLDC and MP SLDC. In case of any anticipated grid condition which requires deferment of the proposed testing, WRLDC shall intimate the revised date and time for testing for which no additional fee is required to be paid.

4. NHPTL shall give at least one day notice to revise the date of testing. In such case no additional application fee would be applicable. In case NHPTL is not able to conduct the test on the approved day and time window due to reasons not attributable to POSOCO, a fresh application shall be submitted by NHPTL at least 3 days in advance. Application fee as mentioned in S no 2 above would be applicable.

5. On the day of testing, POWERGRID (on the request from NHPTL) shall seek real time code from WRLDC for switching ON the 400/765 kV NHPTL feeder from Bina (PG) substation depending upon the feeder requirements for conducting test on a particular rating of transformer. NHPTL would then seek code from WRLDC just before applying short circuit to the test equipment only once for a maximum duration of 250 milliseconds with tolerance of + 10% as per IEC 60076-5. The real time code shall be issued by WRLDC, in consultation with NLDC and MP SLDC, considering the real time grid conditions and availability of real time data and PMU data which shall be valid for a maximum of 4 hours. NHPTL shall attempt to complete all shots of short circuit testing during this 4 hour window only. In case NHPTL is not able to complete the same with 4 hours, a fresh code shall be taken after indicating the reason for delay.

6. In case real time conditions do not permit testing or real time data / PMU data is not available due to any reason, WRLDC may defer the testing to some other time or date. In such scenario, no new application or application fees are required.

7. After the test is over, POWERGRID (on the request from NHPTL) shall seek real time code from WRLDC for switching OFF the 400 /765kV NHPTL feeder from Bina (PG). POWERGRID Bina would also forward the energy meter data for the NHPTL feeders every week by 1200 hours on Monday.

8. Within 24 hrs of testing of any HVTR test equipment, NHPTL shall submit output of Disturbance Recorder and Event Logger (EL) to WRLDC.

9. Based upon the operational experience, any modification may be incorporated in the procedure for better operation and coordination in the testing, after mutual consultation.

X—x—x

Format I

Application for registration of entity with RLDC

1. Name of the entity (in bold letters):

2. Registered office address:

3. Region in which registration is sought:

   a. North-eastern
   b. North
   c. East
   d. West
   e. South

4. User category: Short Circuit Testing Laboratory
5. User details:

Sl No	Point of Connection with ISTS	Voltage Level	Number of Special Energy Meters (Main) installed at this location	Max Short Circuit current likely to be drawn from the system	Time duration of short circuit current

6. Contact person(s) details for matters related to RLDC/NLDC:
   a. Name:
   b. Designation:
   c. Landline Telephone No.:
   d. Mobile No.:
   e. E-mail address:
   f. Postal address:

The above information is true to the best of my knowledge and belief.

Place:
Date:

Signature of Authorized Representative

Name;
Designation:
Contact number:

Format II

APPLICATION FOR TESTING

To: WRLDC

1	Application No:		Date	
	Applicant Name		Registration Code	

3	Test Equipment Description	Expected Short Circuit Current to be drawn from the system	Expected fault current (In case of failure of transformer during testing)	Time duration of Short Circuit Current	Number of shots of short circuit current (excluding calibration shots)	Testing Window		
						Date	From Time	To Time

No of calibration shots and sequence

4 Declaration: The applicant undertakes to abide by the provisions of the various CERC and CEA Regulations/orders.

Signature (With Stamp)

Date:

Place:

Name:

Designation:

Format III

ACCEPTANCE OF TESTING REQUEST

1	**Application No:**		**Date**	
	Applicant Name		**Registration Code**	

Testing Requested

3	Testing Equipment	Expected Short Circuit Current to be drawn	Time duration of Short Circuit Current	Testing Window		
				Date	From Time	To Time

Testing Approved

4	Testing Equipme nt	Anticipated fault level at 400 kV Bina (PG)	Time duration of Short Circuit Current	Testing Window		
				Date	From Time	To Time

Payment Schedule

5	**Total Application Fee**	
	Total Operating Charges	
	Grand Total	

This approval is subject to the applicant adhering to provisions of the relevant CEA and CERC Regulations/orders as amended from time to time.

This approval is further subject to real time conditions and availability of real time data including PMU data from Bina (PG).

In case any of the above condition is violated, this approval stands cancelled.

Signature

Place:
Date:

Name:
Designation:

Documents to be submitted by Transmission Licensee/Generating Stations to RLDCs

Annexure	Subject	Remarks
Annexure A1	Intimation regarding anticipated charging of the line along with other documents	As per Format I
Annexure A2	List of elements to be charged and Element Rating details	As per Format I A
Annexure A3	Single line diagram of the concerned sub stations, along with status of completion of each dia/bus/breakers	
Annexure A4	List of SCADA points to be made available (as per standard requirement, RLDC would need all MW and MVAr data, voltage and frequency of all the buses, all the breaker and isolator positions, OLTC tap positions, Main-1/Main-2 protection operated signals)	
Annexure A5	Type and Location of Energy meters as per relevant CEA regulations	
Annexure A6	Connection Agreement, wherever applicable along with all annexures	
Annexure B1	Request for charging of the new transmission element along with the summary of the undertakings being submitted	As per Format III
Annexure B2	Undertaking in respect of Protective systems	As per Format III A
Annexure B3	Undertaking in respect of Telemetry and communication	As per Format III B
Annexure B4	Undertaking in respect of Energy metering	As per Format III C
Annexure B5	Undertaking in respect of Statutory clearances	As per Format III D
Annexure C1	Request for issuance of successful trial operation certificate	As per Format V
Annexure C2	Values of the concerned line flows and related voltages just before and after charging of the element	
Annexure C3	Special Energy meter (SEM) Reading for the trial	
Annexure C4	Output of Disturbance Recorders / Event Loggers	

Annexure A1

Format I

Intimation by Transmission Licensee/Generating Station regarding anticipated charging of new elements

<Name of Transmission Licensee /Generating Stations>

Name of the transmission element :

Type of Transmission Element : Transmission Line / ICT / Bus Reactor / Line Reactor / Bus / Bay / Series Capacitor/ Series Reactor/Station transformer/ Generator transformer/STATCOM/ HVDC Terminal /Converter Transformer/ HVDC Line / MSR / MSC / TCSC / FSC

Voltage Level : AC/DC kV

Owner of the Transmission Asset :

Likely Date and time of Charging :

Likely Date and time of start of Trial Operation :

Schedule Date of Commercial Operation:
(As per original scheme)

Project Scheme : TBCB / Other than TBCB

Associated elements of this project :
(In case co-ordinated Transmission /Generation evacuation project)

Details of Standing Committee / Scheme Approval -

Date of Meeting	Standing Committee meeting Number	MOM Item no. / Point No. /Serial No	Page No

Copy to be essentially enclosed

Place:

Date:

(Name and Designation of the authorized person with official seal)

Encl: Please provide full details.

☐ **Annexure A2 :** Format IA: List of elements to be charged and Element Rating details

☐ **Annexure A3 :** Single line diagram of the concerned sub stations, alongwith status of completion of each dia /bus/breakers

☐ **Annexure A4:** List of SCADA points to be made available

☐ **Annexure A5:** Location of installation of Energy meters as per relevant CEA regulations

☐ **Annexure A6:** Connection Agreement, if applicable along with all annexures

Standing Committee / Scheme Approval – Relevant pages

Annexure A2

Format I A

List of elements to be charged and Element Rating details

I. List of Elements to be charged:

II. Element Ratings

a. Transmission Line

1	From Substation	
2	To Substation	
3	Voltage Level (kV)	
4	Line Length (km)	
5	Conductor Type	
6	No of sub Conductors	
7	Thermal Capacity	

b. ICT / Station Transformer/Startup Transformer

1	Voltage (HV kV / LV kV)	
2	Capacity (MVA)	
3	Transformer Vector group	
4	Total no of taps	
5	Nominal Tap Position	
6	Present Tap Position	
9	Tertiary Winding Rating and Ratio	
10	% Impedance	

c. Shunt / Series Reactor

1	Substation Name / Line Name	
2	Voltage	
3	MVAR Rating	
4	Switchable / Non Switchable	
5	In case of Line Reactor, whether it can be taken as bus reactor	

d) Generator Transformer (GT)

(Name and Designation of the authorized person with official seal)

Annexure A4

List of SCADA points to be made available (as per standard requirement, RLDC would need all MW and MVAr data, voltage and frequency of all the buses, all the breaker and isolator positions, OLTC tap positions, Main-1/Main-2 protection operated signals)

<Name of Transmission Licensee/Generating Station>

Name of the transmission element :

SNo	List of SCADA Points to be made available	IEC Address
1	Analog Point	
2	Digital Point	
3	SOE	

(Name and Designation of the authorized person with official seal)

Annexure A5

Type and Location of Energy meters as per relevant CEA regulations

<Name of Transmission Licensee/Generating Station>

Name of transmission element:

S no	Name of substation	Feeder name	Make of meter	Meter no	CT Ratio	PT/CVT Ratio

(Name and Designation of the authorized person with official seal)

Format II

<Name of RLDC>

Acknowledgement of Receipt by RLDC

This is to acknowledge that the intimation of likely charging of (Name of the transmission element) has been received from (Name of the owner of the transmission asset) on (Date).

Kindly complete the technical formalities in connection with energy metering, protection and real time data and communication facilities and inform us of the same three (3) days before charging of the above transmission element as per Formats III, IIIA, IIIB, IIIC and IIID.

Or

The intimation is incomplete and the following information may be submitted within three (3) days of issue of this acknowledgment receipt.

1. _
2.
3.

&&&&&&&&&&&..

Date

Signature

Name:

Designation:

RLDC

<u>Annexure B1</u>

Format III

<Name of Transmission Licensee/Generating Station>

<u>Request by Transmission Licensee/Generating Station for first time charging and start of Trial Operation</u>

Past references: :

Name of the transmission element :

Type of Transmission Element : Transmission Line / ICT / Bus Reactor / Line Reactor / Bus / Bay

Voltage Level :

Owner of the Transmission Asset :

Proposed Date and time of first time Charging :

Proposed Date and time of Trial Operation :

Details of Standing Committee / Scheme Approval -

Date of Meeting	Standing Committee meeting Number	MOM Item no. / Point No. /Serial No	Page No

Place:

Date:

(Name and Designation of the authorized person with official seal)

Encl:

Annexure B2 : Undertaking in respect of Protective systems as per Format IIIA

Annexure B3 : Undertaking in respect of Telemetry and communication as per Format IIIB

Annexure B4: Undertaking in respect of Energy metering as per Format IIIC

Annexure B5: Undertaking in respect of Statutory clearances as per Format IIID

Annexure B2

Format IIIA

< Name and Address of Transmission Licensee/Generating Station>

Undertaking by Transmission Licensee/Generating Station in respect of Protective systems

The following transmission element is proposed to be charged on ___________<date> tentatively around ____ hours.

S no and Name of transmission element:

1.0 It is certified that all the systems as stipulated in Part-III of the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 (as amended from time to time) have been tested and commissioned and would be in position when the element is taken into service.

2.0 The protective relay settings have been done as per the guidelines of the Regional Power Committee (RPC) as per section 5.2 l of the Indian Electricity Grid Code (IEGC). The necessary changes have also been made/would be made appropriately for the following lines at the following substations:

Sl No:	Name of the substation	Name of Transmission Element

Place:
Date:

(Name and Designation of the authorized person with official seal)

Annexure B3

Format IIIB

< Name and Address of Transmission Licensee/Generating Station>

Undertaking by Transmission Licensee/Generating station in respect of Telemetry and communication

The following transmission element is proposed to be charged on ___________<date> tentatively

around ____ hours.

S no and Name of transmission element:………………………………………

The list of data points that would be made available to RLDC in real time had been indicated vide communication dated ___________. It is certified that the following data points have been mapped and real time data would flow to RLDC immediately as the element is charged and commissioned.

S no	Name of substation	Data point (analog as well as digital) identified in earlier Communication dated	Point to point checking done jointly	Data would be available at RLDC (Y/N)	Remarks (path may be specified)
1	Sending end	Analog			
		Digital			
		SoE			
		Main Channel			
		Standby Channel			
		Voice Communication (Specify:(Mobile No /Landline No)			
2	Receiving end	Analog			
		Digital			
		SoE			
		Main Channel			
		Standby Channel			
		Voice Communication (Specify: Mobile No/Landline No)			

It is also certified that the data through main channel is made available to RLDC as well as alternate communication channel is available for data transfer to RLDC to ensure reliable and redundant data as per IEGC (as amended from time to time). Also, Voice communication is established as per IEGC. The arrangements are of permanent nature. In case of any interruption in data in real time, the undersigned undertakes to get the same restored at the earliest.

Place:

Date:

(Name and Designation of the authorized person with official seal)

Annexure B4

Format IIIC

< Name and Address of Transmission Licensee>

Undertaking by Transmission Licensee in respect of Energy metering

The following transmission element is proposed to be charged on ___________<date> tentatively around ____ hours.

S no and Name of transmission element:

Special Energy Meters (SEMs) conforming to CEA (Installation and Operation of Meters) Regulations, 2006 have been installed and commissioned. The SEMs are calibrated in compliance of regulation 9 of Part-I of CEA (Technical Standard for Grid Connectivity) Regulations 2007 as per the following details:

S no	Name of substation	Feeder name	Make of meter	Meter no	CT Ratio	PT/CVT Ratio
1	Sending end					
2	Receiving end					

Data Format Conformity: Yes / No

S no	Meter no	Meter Time (T1)	GPS Time (T2)	Time Drift (T2-T1) shall be less than 1 minute	CT shorting removed (Y/N)	CT polarity as per convention checked (Y/N)	CVT/PT supply to the SEM checked Y/N)
1	Sending end						
2	Receiving end						

Time Drift Correction carried out: Yes/No

The data from the above meters would be forwarded on weekly basis to the RLDC as per section 6.4.21 of the Indian Electricity Grid Code (IEGC) (as amended from time to time) and also as and when requested by the RLDC.

(RLDC to indicate the email ids where the data has to be forwarded).

Place:

Date:

(Name and Designation of the authorized person with official seal)

Annexure B5

Format III D

< Name and Address of Transmission Licensee/Generating Station>

Undertaking by transmission licensee/Generating Station in respect of statutory clearances

It is hereby certified that all statutory clearances in accordance with relevant CERC Regulations / CEA standards / CEA regulations and PTCC route approval for charging of ____ have been obtained from the concerned authorities.

Place:

Date:

(Name and Designation of the authorized person with official seal)

Format IV

Provisional Approval for charging and trial run

<Name of RLDC>

Approval no:

To,

The Transmission Licensee,

Sub: Charging and trial run of <Name of Transmission element>____Provisional approval

Ref: 1) Your application dated in Format_I
2) RLDC response dated in Format_II
3) Your request and details forwarded on dated in Format III, IIIA, IIIB IIIC and IIID

Madam/Sir,

1) The above documents have been examined by RLDC and permission for charging of <Name of Transmission element> on or after _ is hereby accorded. This approval is provisional and in the intervening period, if any of the conditions given in the undertakings submitted by you are found to be violated, the approval stands cancelled. Kindly obtain a real time code from the appropriate RLDC for each element switching as well as commencement of trial operation.

2) The following shortcomings have been observed in the documents at S no 3) above.

   a.
   b.
   c.

Please rectify the above shortcomings at the earliest to enable RLDC to issue the provisional approval for test charging, commissioning and trial operation of <Name of transmission element>.

Thanking you,

Yours faithfully,

(Name and designation of authorized personnel with seal)

Annexure C1

Format_V

(Transmission Licensee request for issuance of successful trial operation certificate)

To,

<Name of RLDC>

Sub: Successful trial operation of <Name of Transmission element>___request for issue of certificate.

Ref:i) Our application dated in Format_I
ii) Your acknowledgement dated in Format_II
iii) Our application dated ____ in Format_III along with Format IIIA, IIIB IIIC and IIID
iv) Provisional approval dated ____ issued by your office.
v) Real time codes from RLDC on ……

Madam/Sir,

Referring to the above correspondence, this is to inform you the successful charging and trial operation of <Name of Transmission element> from _____ to _____ (time & date). Please find enclosed the following:

1. A plot of the MW/MVAr power flow during the 24 hour trial operation based on the substation SCADA is enclosed at Annexure 1.
2. The Energy Meter readings have already been mailed to your office on ________. The 15-minute time block wise readings for the trial operation period is enclosed at Annexure-2
3. Event Logger and Numerical Relay or Disturbance Recorder outputs at Annexure_3 indicating all the switching operations related to the element. It is further to certify that the time synchronization of numerical relay, event logger and Disturbance recorder has been established.

It is requested that a certificate of successful trial operation may kindly be issued at the earliest.

Thanking you,

Yours faithfully,

( )
<Name and Designation of authorized person with official seal>

Encl: Annexure C2: Plot of MW/MVAr flow during 24 hour trial operation.
Annexure C3: Energy Meter
Annexure_C4: Reading Numerical relay or Disturbance Recorder (DR) output and Event Logger output.