ग्रिड-इंडिया
GRID-INDIA
ग्रिड कंट्रोलर ऑफ इंडिया लिमिटेड
(भारत सरकार का उद्यम)
GRID CONTROLLER OF INDIA LIMITED
(A Government of India Enterprise)
[formerly Power System Operation Corporation Limited (POSOCO)]
राष्ट्रीय भार प्रेषण केन्द्र / National Load Despatch Centre
कार्यालय : बी-9, प्रथम एवं द्वितीय तल, कुतुब इंस्टीट्यूशनल एरिया, कटवारिया सराय, नई दिल्ली - 110016
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संदर्भ: NLDC/SO/IEGC/Operating Procedure/ **दिनांक:** 25th Sep 2023

सेवा में,

सचिव,
केन्द्रीय विद्युत विनियामक आयोग
3rd एवं 4th फ्लोर, चंदरलोक बिल्डिंग
36, जनपथ, नयी दिल्ली, 110001

विषय: Guidelines for Periodic Testing of Power System Elements – Reg.

महोदय,

In Compliance to Clause 28(3) & 28 (4) in respect of Reg 40 of Central Electricity Regulatory Commission, Indian Electricity Grid Code Regulations, 2023, NLDC in consultation with RLDCs had prepared detailed Guidelines for Periodic Testing of Power System Elements. Details of stakeholder consultation carried out by NLDC/RLDCs are provided below:

S. No.	Procedure	Uploaded on Grid India website	Comments invited by	Stakeholder Consultation held on
1	Guidelines for Periodic Testing of Power System Elements	18th August 2023	30st Aug 2023	24st Aug 2023

The suggestions/feedback received from stakeholders have been considered and suitably incorporated in the final guidelines attached herewith for kind information of the Hon'ble Commission. The same has been uploaded on Grid India website at https://posoco.in/nldc-procedures/. The guidelines would be a part of the NLDC/RLDC Operating Procedures.

सधन्यवाद,

भवदीय,

(एस. सी. सक्सेना)
कार्यपालक-निदेशक-रा.भा.प्रे.कें.

Encl: As above

Copy for kind information:

1. CMD, Grid-India
2. Director (SO)/Director (MO), Grid-india
3. All RLDC Heads

Grid Controller of India Limited

(Formerly Power System Operation Corporation Limited)

National Load Despatch Centre (NLDC)

Guidelines for Periodic testing

Prepared in Compliance

to

Clause 28(3) & 28 (4) and Clause 40 of

Central Electricity Regulatory Commission Indian Electricity Grid Code Regulations, 2023

Contents

Guidelines for carrying Out Real Power Assessment Testing

1. Background

1.1 These guidelines are prepared in Compliance to Clause 28(3) & 28 (4) and in accordance with clause 40 of the Indian Electricity Grid Code, 2023 notified by the Central Electricity Regulatory Commission..

1.2 These guidelines shall be followed by synchronous generators for performing Real Power Capability assessment test.

2. Scope

The guideline shall apply to the users: "*Individual Unit of rating 100MW and above for Coal/lignite, 50MW and above gas turbine and 25 MW and above for Hydro*" under operational jurisdictions of State Load Despatch Centres (SLDCs), Regional Load Despatch Centres (RLDCs), National Load Despatch Centre (NLDC), Regional Power Committees (RPCs) to the extent applicable.

3. Definitions

Words and expressions used in this Guideline are defined in the Act or any other regulations specified by the Central Commission or Central Electricity Authority shall, unless the context otherwise requires, have the meanings assigned to them under the Act or other regulations specified by the Central Commission, as the case may be.

4. Responsibilities for Conducting Real Power assessment test

As per clause 40 (2) of IEGC 2023,

I. The owner of the power system element shall be responsible for carrying out tests as specified in these regulations and for submitting reports to NLDC, RLDCs, CEA and CTU for all elements and to STUs and SLDCs for intra-State elements.

II. All equipment owners shall submit a testing plan for the next year to the concerned RPC by 31st October to ensure proper coordination during testing as per the schedule. In case of any change in the schedule, the owners shall inform the concerned RPC in advance.

III. The tests shall be performed once every five (5) years or whenever major retrofitting is done. If any adverse performance is observed during any grid event, then the tests shall be carried out even earlier, if so advised by SLDC or RLDC or NLDC or RPC, as the case may be.

5. Test Data/Formats

5.1 Data to be Provided by Generator

1	**Generating station and Unit**	**Name and Number**	
2	**Installed Capacity**	**MW**	
3	**Maximum Continuous rating (MCR)**	**MW**	
4	**Over load capability as % of MCR**	**As % of MCR & in MW**	
5	**Minimum turndown level (Technical minimum)**	**As % of MCR & in MW**	
6	**Ramp up capability**	**(% of MCR/ Minute)**	
7	**Ramp down capability**	**(% of MCR/ Minute)**	
8*	**Full reservoir level (FRL)**	**Metre**	

9*	Design Head	**Metre**	
10*	Minimum draw down level (MDDL)	**Metre**	
11*	Water released at Design Head	M^3 / MW	
12*	Unit-wise forbidden zones	MW	

***For hydro generating stations**

5.2 Procedure

1) The following tests shall be performed for Thermal generators(Coal/lignite):

   I. Operation at a load of fifty five (55) percent of Maximum Continuous rating (MCR) or minimum turn down level declared by plant as per the CEA (Flexible operation of Coal based Thermal Generating units) for a sustained period of one time block (15 minutes).

      a. Result: Plot showing operation at 55% load for a period of one time block (15 minutes).

   II. Ramp-up from fifty five (55) percent of MCR to seventy (70) percent of MCR at a ramp rate of at least one (1) percent of MCR per minute (with stabilization period of 30 minutes).

Sl.No	Time	Active power generation in MW (A)	Active power as % of MCR (B)	Ramp per minute	Ramp rate (as % of MCR)
1.	00:01		55%	--	
2.	00:02			B_2-B_1	
3.	00:03			B_3-B_2	
..					

45.	00:15		70%	B_{15}-B_{14}	

III. Ramp-up from seventy (70) percent MCR to MCR at a ramp rate of at least one (1) percent of MCR per minute (with stabilization period of 30 minutes).

Sl.No	Time	Active power generation in MW (A)	Active power as % of MCR (B)	Ramp per minute	Ramp rate (as % of MCR)
1.	00:01		70%	--	
2.	00:02			B_2-B_1	
3.	00:03			B_3-B_2	
..					
25.	00:30		100%	B_{30}-B_{29}	
Average Ramp over the period					

Evaluating criteria: Average ramp over the period shall be at least 1% per minute.

IV. Operation at MCR for a sustained period of one time block (15 minutes). Plot showing operation at MCR for one time block (15 minutes) to be submitted.

V. Demonstrate overload capability with the valve wide open at that level for at least five (5) minutes.

Sl.No	Time	Active power generation in MW	Active power as % of MCR
Applicable over load capability: 105 %			
1.	00:01 (Time where active power generation reached to 105% of MCR)		
2.	00:02		
3.	00:03		
4.	00:04		
5.	00:05		

Note: LV side data of Generator transformer will be used to check the compliance.

VI. Ramp-down from MCR to seventy (70) percent of MCR at a ramp rate of at least one (1) percent of MCR per minute, (with stabilization period of 30 minutes).

Sl.No	Time	Active power generation in MW (A)	Active power as % of MCR (B)	Ramp per minute
1.	00:01		100%	--
2.	00:02			B_2-B_1
3.	00:03			B_3-B_2
..				
45.	00:29			B_{29}-B_{28}
46	00:30		70%	B_{30}-B_{29}

VII. Ramp-down from seventy (70) percent of MCR to 55% of MCR at a ramp rate of at least one (1) percent of MCR per minute (with stabilization period of 30 minutes).

Sl.No	Time	Active power generation in MW (A)	Active power as % of MCR (B)	Ramp per minute	Ramp rate (as % of MCR)
1.	00:01		70%	--	
2.	00:02			B_2-B_1	
3.	00:03			B_3-B_2	
..					
45.	00:15		55%	B_{15}-B_{14}	

Evaluating criteria: Average ramp over the period shall be at least 1% per minute.

2) The following tests shall be performed for hydro generators including pumped storage plants:

(a) The generating company shall submit OEM documents for the turbine characteristics curve indicating the operating zone(s) and forbidden zone(s).

(b) In order to demonstrate the operating flexibility of the generating unit, hydro unit shall be operated at two loading levels below forbidden zone and at two loading levels above the forbidden zone (loading level of 100% MCR shall be included) for one time block (15 minutes).

Unit operation below forbidden zone:

Sl. No	Loading level (As a % MCR)	Duration	Remarks
1.			
2.			

Unit operation above forbidden zone:

Sl. No	Loading level (As a % MCR)	Duration	Remarks
1.			
2.			

(c) Demonstrate overload capability for at least five (5) minutes as required for providing primary frequency response. Test needs to be carried out when sufficient water level is available in reservoir.

Sl.No	Time	Active power generation in MW	Active power as % of MCR
Applicable over load capability: 110 %			
1.	00:01 (Time where active power generation reached to 110% of MCR)		
2.	00:02		
3.	00:03		
4.	00:04		
5.	00:05		

Note: LV side data of Generator transformer will be used to check the compliance.

3) The following tests shall be performed for Gas generators:

a. Demonstration of MCR: The generating unit shall be run at MCR for at least one time block (15 minutes) and data to be recorded. Graph showing the operation of the generating unit at MCR for at least one time block(15 minutes) to be submitted.
b. Demonstrate overload capability for at least five (5) minutes as required for providing primary frequency response

Sl.No	Time	Active power generation in MW	Active power as % of MCR
Applicable over load capability: 105 %			
1.	00:01 (Time where active power generation reached to 105% of MCR)		
2.	00:02		
3.	00:03		
4.	00:04		
5.	00:05		

4) Active power and reactive power data at 1 sec or lowest available resolution to be shared in excel format and active power plots for each test showing compliance to relevant regulations shall be submitted.

5) Detailed test report covering all the tests and relevant plots shall be submitted

6) Generator/beneficiaries shall arrange/ensure the schedule required for testing in coordination with beneficiaries through RLDC as per Testing schedule finalized in Operation Coordination Committee meeting of Regional Power Committee.

Guidelines for carrying Out Reactive Power Capability Assessment

1. Background

i. These guidelines are in accordance with Clause 28(3) & 28 (4) and in accordance with clause 40 of Central Electricity Regulatory Commission, Indian Electricity Grid Code regulations 2023.

ii. These guidelines shall be followed by synchronous generators for performing Reactive Power Capability assessment and submission of reports along with model validations.

2. Scope

i. The guideline shall apply to the users: "*Individual Unit of rating 100MW and above for Coal/lignite, 50MW and above gas turbine and 25 MW and above for Hydro*" under operational jurisdictions of State Load Despatch Centres (SLDCs), Regional Load Despatch Centres (RLDCs), National Load Despatch Centre (NLDC), Regional Power Committees (RPCs) to the extent applicable.

ii. Unquote-*The objective of Reactive Power capability testing is to assess whether the generating unit is able to provide the reactive power support as per the capability curve provided by manufacturer.*

3. Definitions

Words and expressions used in this guideline are defined in the Act or any other regulations specified by the Central Commission or Central Electricity Authority shall, unless the context otherwise requires, have the meanings assigned to them under the Act or other regulations specified by the Central Commission, as the case may be.

4. Responsibilities for Conducting Reactive Power Capability Testing

As per clause 40 (2) of IEGC 2023,

i. The owner of the power system element shall be responsible for carrying out tests as specified in these regulations and for submitting reports to NLDC, RLDCs, CEA and CTU for all elements and to STUs and SLDCs for intra-State elements.

ii. All equipment owners shall submit a testing plan for the next year to the concerned RPC by 31st October to ensure proper coordination during testing as per the schedule. In case of any change in the schedule, the owners shall inform the concerned RPC in advance.

iii. The tests shall be performed once every five (5) years or whenever major retrofitting is done. If any adverse performance is observed during any grid event, then the tests shall be carried out even earlier, if so advised by SLDC or RLDC or NLDC or RPC, as the case may be.

5. Test Data/Formats

a. Procedure

i. Reactive Power testing needs to be carried out as per the testing plan approved by RPC.

ii. On site testing shall be carried out preferably in the presence of OEM.

iii. Over excitation limiter (OEL) and Under excitation limiters (UEL) settings needs to be vetted by OEM.

iv. Representatives from Benificiary/RPC/RLDC/SLDC/NLDC may witness the test.

v. Both MVAR injection (lagging pf) and absorption (leading pf) testing shall be performed at full load and at a load just above minimum turndown level of the generating unit. For Hydro and Gas generating stations, the MVAR capability testing in synchronous condenser mode (if available) also shall be carried out.

vi. Test timings for injection/absorption have to be finalized based on past voltage profile of connected substation. Injection test shall be carried out during low voltage period and absorption test shall be carried out during high voltage period.

vii. Bus/line reactors switching and MVAR capability of other units of the same generating station can be utilized to test MVAR capability as close as to the capability curve.

viii. Prerequisites for testing

i. AVR shall be in service and no maintenance activities shall be planned on any of station equipment during testing.

ii. Testing is to be paused in the event of appearance of alarm in the unit control panel. The test to be continued after taking appropriate correction by the OEM. If no corrective action can be taken by the OEM considering the stability of running unit, the test may be stopped at this point and to be repeated at different date.

iii. Generating station shall share the details of Generating unit and associated systems at least 10 days in advance as per Annexure-1 for ready reference during the testing.

ix. a). Lagging Reactive Capability Test: Prior to the testing, the generating unit shall be under stable operation and near to rated output. Excitation to be raised in small steps (automatic voltage control mode) for increasing the reactive power injection of the generating unit until one of the following conditions occurs:

i) The 100% MVA rating of the machine is reached.

ii) Rated field current or field voltage is reached.

iii) Terminal voltage limit is reached (105-110%, depending on unit).

iv) Generator temperature limits are reached (either stator winding or field winding).

v) The maximum/over excitation limiter is reached/alarms.

vi) Maximum auxiliary bus voltage is reached.

b. Hold the unit at this level for a period of 15 minutes or till the temperature stabilizes then take the measurements as per format.

c. Leading Reactive Capability Test: Prior to the testing, the generating unit shall be under stable operation and near to rated output. Excitation to be reduced in small steps (automatic voltage control mode) for increasing the reactive power absorption of the generating unit until one of the following conditions occurs:

i) Under excitation Limiter (UEL) is activated.

ii) 100% MVA rating is reached.

iii) Generator temperature limits are reached;(either stator or field).

iv) Minimum auxiliary bus voltage is reached.

v) Minimum terminal voltage is reached.

d. Hold unit at this level for a period of 15 minutes or till the temperature stabilizes then take the measurements as per format.

i. Repeat the above tests at reduced loading (MW) level near to minimum turndown level.

ii. Take measurements as per format enclosed at Annexure-2

iii. From the test results the compliance to regulation A5 of Part-II of CEA technical standards for connectivity shall be verified.

iv. Test report along with active power vs reactive power plot w.r.t the reactive power capability curve of the generator to be submitted to the SLDC, RLDC, RPC and NLDC. All the parameters being recorded in the test data sheet shall be submitted in excel format with 10 sec resolution for the testing period.

v. Generator/beneficiaries shall arrange/ensure the schedule required for testing in coordination with beneficiaries through RLDC as per Testing schedule finalised in Operation Coordination Committee meeting of Regional Power Committee.

12.Annexure-1

Generator data:

Sl No		Description	Data
1	Date		
2	Name of the Power Plant		
3	Code/Number of the unit under test		
4	Unit’s MCR (Pnom) (Motoring / Generator)		
5	Unit’s Minimum Continuous Operation Loading Level		
6	Generator Data		
	a	Make	
	b	Type	
	c	Generator’s Nominal MVA	
	d	Generator’s Nominal Terminal voltage and Voltage Range (Maximum and Minimum allowable range)	
	e	Generator Stator Current	
	f	Nominal voltage of the generator high voltage side bus	
	g	Type of generator cooling (direct air / water-air / water-hydrogen)	
	h	Manufacturer specified Overexcited MVARs (Qmax1 +) at Full load	
	i	Manufacturer specified Under excited MVARs (Q max1 -) at Full load	
	J	Manufacturer specified Over excited MVARs (Qmax2 +) at technical minimum	
	K	Manufacturer specified Under excited MVARs (Q max2 -) at technical minimum	
	L	Nominal Power Factor of the Generator	
	M	Generator Rated Field Current (Amps) / Voltage (Volts)	

8	Generators Excitation System		
	a	Type of excitation	
	b	Excitation System Rated Current (Amps) / Voltage (Volts)	
9	Generator Transformer (GT)		
	a	Nominal Primary LV Side Voltage and Current (ONAN/ONAF/OFAF)	
	b	Nominal Secondary HV Side Voltage and Current (ONAN/ONAF/OFAF)	
	c	GT impedance (%) at Present tap position	
	d	X/R Ratio	
	e	Nominal MVA (ONAN/ONAF/OFAF)	
	f	Tap Position of GT and corresponding Voltage Ratio during the test	
10	Unit Transformer (UT)		
	a	Nominal Primary HV Side Voltage and Current (ONAN/ONAF)	
	b	Nominal Secondary LV Side Voltage and Current (ONAN/ONAF)	
	c	UT impedance (%)	
	d	X/R Ratio	
	e	Nominal MVA (ONAN/ONAF)	
	f	Tap Position of UT and corresponding Voltage Ratio during the test	
	g	Maximum and minimum voltage range on LV side	
11	Station Transformer (ST)-6		
	a	Nominal Primary HV Side Voltage and Current (ONAN/ONAF)	
	b	Nominal Secondary LV Side Voltage and Current (ONAN/ONAF)	
	c	ST impedance (%)	

	d	X/R Ratio	
	e	Nominal MVA (ONAN/ONAF)	
	f	Tap Position of ST and corresponding Voltage Ratio during the test	
12	Protection and Limiter Settings		
	a.	V/f Limiter (Excitation System)	
	b.	Various stages of V/f Trip settings (Generator Over fluxing) [% and time delay]	
	c.	Over excitation Limiter (Field Current Limiter in %)	
	d.	Over excitation Limiter (Stator Current Inductive % of rated current)	
	e.	Over excitation Trip (% and time delay)	
	f.	Over Voltage Trip (% and time delay)	
	g.	Under excitation Limiter (Load angle limiter)	
	h.	Under excitation Limiter (Stator Current Capacitive % of rated current)	
	i.	Under excitation Trip/Loss of Excitation	
	j	Under voltage Trip	
13	Stator Winding Temp Limit (specified by manufacturer)		
	a	Alarm	
	b	Trip	
14	Field Winding Temp Limit (specified by manufacturer)		
	a	Alarm (only on H2 COLD GAS TEMP)	
	b	Trip (only on H2 COLD GAS TEMP)	

Recording sheet:

The parameters during the testing shall be tabulated as per the recording sheet given below

MVAR Capability Testing - Recording Sheet

MVAR testing at (Station): Unit Number: Date:
GT Tap no and corresponding voltage:

Sl.No.	Time (HH:MM)	Gross Generator Output		Generator Terminal		Field		Frequency (Hz)	System Voltage (HV Side) kV	HV side (After GT)		Auxiliary Bus voltage (kV)	Stator Temp Min / Max	H2 Pressure	Load angle	pf	MVAR Capability as per the Generator capability curve (MVAR)	Remarks
		Gross Real Power (MW)	Gross Reactive Power (MVAr)	Voltage (kV)	Current (kA)	Voltage (V)	Current (A)			Net Ex Bus Real Power (MW)	Net Ex Bus Reactive Power (MVAr)							
Initital conditions																		
1																		
2																		
LAGGING TEST																		

1																		
2																		
3																		
4																		
LEADING TEST																		
1																		
2																		
3																		

Guidelines for carrying Out Primary Response Testing and AGC testing

1. Background

i. These guidelines are prepared in compliance to Clause 28(3) & 28 (4) and in accordance with clause 40 of Central Electricity Regulatory Commission (Indian Electricity Grid Code Regulations), 2023.

ii. These guidelines shall be followed by synchronous generators for performing primary frequency response test, Automatic Generation Control (AGC) test and submission of reports along with model validations.

2. Scope

The guideline shall apply to the users: "*Individual Unit of rating 100MW and above for Coal/lignite, 50MW and above gas turbine and 25 MW and above for Hydro*" under operational jurisdictions of State Load Despatch Centres (SLDCs), Regional Load Despatch Centres (RLDCs), National Load Despatch Centre (NLDC), Regional Power Committees (RPCs) to the extent applicable.

As per clause 30 (10) (d) & 30 (10) (g) of Central Electricity Regulatory Commission (Indian Electricity Grid Code Regulations), 2023

"The generating stations and units thereof shall have electronically controlled governing systems or frequency controllers in accordance with the CEA Technical Standards for Connectivity and are mandated to provide PRAS. The generating stations and units thereof with governors shall be under Free Governor Mode of Operation

All generating machines irrespective of capacity shall have electronically controlled governing system with appropriate speed/load characteristics to regulate frequency. All the generating units shall have their governors or frequency controllers in operation all the time with droop settings of 3 to 6 % (for thermal generating units and WS Seller) or 0-10% (for hydro generating units) as specified in the CEA Technical Standards for Connectivity"

IEGC 2023 Clause 30 (10) Table-4 "Gas Turbine above 50 MW shall have a droop ±5% of MCR (corrected for ambience temperature)"

3. Definitions

Words and expressions used in this guideline are defined in the Act or any other regulations specified by the Central Commission or Central Electricity Authority shall, unless the context otherwise requires, have the meanings assigned to them under the Act or other regulations specified by the Central Commission, as the case may be.

4. Responsibility of Conducting Primary Response Testing

As per clause 40 (2) of IEGC 2023,

4.1. The owner of the power system element shall be responsible for carrying out tests as specified in these regulations and for submitting reports to NLDC, RLDCs, CEA and CTU for all elements and to STUs and SLDCs for intra-State elements.

4.2. All equipment owners shall submit a testing plan for the next year to the concerned RPC by 31st October to ensure proper coordination during testing as per the schedule. In case of any change in the schedule, the owners shall inform the concerned RPC in advance.

4.3. The tests shall be performed once every five (5) years or whenever major retrofitting is done. If any adverse performance is observed during any grid event, then the tests shall be carried out even earlier, if so advised by SLDC or RLDC or NLDC or RPC, as the case may be.

5. Test Data/Formats:

5.1. Basic Data:

1	Turbine	Speed (in RPM)	
2	Generator	Make	
3	Generator Capacity	MW	
4	DCS	Make	
5	Governor	Make	

6	Governor Type	Model	
7	Pmax	MW	
8	Pmin	MW	
9	Droop	% of MCR	
12	Governor Reference frequency set to 50.000 Hz	Yes/No	

5.2. Turbine-Governor information

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, details of control mode (boiler-follow, turbine-follow, or coordinated control), commissioning report of turbine-governor system or recent governor testing report to be furnished.

5.3. Signals to be Recorded

The following signals shall be recorded during the tests for analysis of power plant performance

S.No	Signal	Description
1	Simulated frequency	The frequency signal injected into the governor from the test equipment
2	EHTC O/P	The signal from the Electro-hydraulic turbine controller that is sent to the valve position controller for the inlet valves
3	HP control valve positions (HPCV1)	Positions of HP turbine steam inlet valves, which are the main valves for controlling the steam flow to the turbine

S.No	Signal	Description
4	Pressure Correction (P.C.)	Signal for pressure correction in terms of MW
5	Steam pressure	Signal for main steam pressure before control valves.
6	FGMO O/P	Signal for total MW correction.
7	Active Power	Signal for net power generation.
8	Load Setpoint (LSP)	Signal for actual load setpoint

Note: Above mentioned signals shall be recorded with resolution of 10 Hz

5.4. Calculated Droop:

The primary frequency response test is performed to observe, how well the unit supports the power system during frequency changes in the grid. The droop constant is the parameter which decides the magnitude of response

The Droop from the test results shall be calculated based on below formula

$$Droop = \Delta f * \frac{P_0}{\Delta P * f_0} | * 100$$

where,

- P_0 is the MCR (maximum continuous rating) in MW for unit operation
- Δf is the change in frequency in Hz
- f_0 is the rated frequency as 50 Hz
- ΔP is the total change in power observed on frequency step injection.

5.5. Tests to be performed:

As per the CEA (Technical Standard for Connectivity to the Grid) Regulations - All generating machines irrespective of capacity shall have electronically controlled governing system with appropriate speed/load characteristics to regulate frequency. The governors of thermal generating units shall have a droop of 3 to 6% and those of hydro generating units 0 to 10%. Accordingly, the Primary frequency response testing shall be carried out at implemented droop settings.

(a) Thermal generating units: Implemented Droop (In the range of 3- 6%)
(b) Hydro generating units: Implemented Droop (In the range of 0-10%)
(c) Gas Generating units: 5% droop.

i) Dead Band Test

S.No	Load Level	Test Signal
1	Full Load & Technical Minimum (i) (Dead Band Test)	-/+0.01HZ from 50 Hz
		-/+0.02HZ from 50 Hz
		-/+0.03HZ from 50 Hz
		+/-0.03HZ from 50 Hz

ii) The Details of Tests i.e, frequency steps, loading level to be done for a given droop setting shall be as detailed in Annexure – 1.

Note: For Hydro & Gas units above tests shall be done at various loadings within the operating zone.

iii) **Governor response with respect to fixed reference frequency of 50 Hz**:- Free governing mode of operation for below and above 50 Hz, a test including transition of frequency from a value less than 50 Hz to above 50 Hz and vice versa is to be done as with period of 300 seconds as suggested below.

S.No	**Load Level**	**Test Signal**
1	**Technical Minimum**	Step Signal from 49.92 Hz to 50.08 Hz
		Step Signal from 50.08 Hz to 49.92 Hz

2	**100 % of MCR**	Step Signal from 49.92 Hz to 50.08 Hz
		Step Signal from 50.08 Hz to 49.92 Hz

5.6. Tests result Analysis:

The Primary response shall start immediately when the frequency deviates beyond the dead band (not greater +/- 0.03 Hz.) and shall be capable of providing its full primary capacity obligation within 45 seconds and sustaining at least for the next five (5) minutes. Accordingly, the measurement has to be taken up to 5 minutes

Analysis for tests as mentioned in section 5.5 to be done as per below given format.

Simulated frequency (Hz)	MW at test start t_0	MW change at t_0+45 seconds	MW change at t_0+100 seconds	MW change at t_0+300 seconds	Actual implemented Droop (%)	Droop (%) Calculated** at t_0+45 seconds	Droop (%) Calculated at t_0+100 seconds	Droop (%) Calculated at t_0+300 seconds

Note: The Test Results along-with the measurement data shall be submitted in excel file with a minimum resolution of 10 Hz

5.7. Turbine -Governor Model Validation:

a. Turbine – governor model development- IEEE equivalent Model need to be submitted.

b. Simulation scenarios

1. Governor validation – Developed IEEE model shall be validated with the test response of the machines.

2. Past event simulation- Developed IEEE model shall be validated with the past event data/response of the machines.

Note:

i) Developed Model should contain the Generator, Excitation system, Power System Stabilizer & Governor models in standard IEEE Format.

ii) The Simulation studies to be done in RMS Simulation software (Preferably PSS/E Simulation software)

5.8. Conclusion & Recommendations:

a. On site observations during the test.
b. Model validation need to be done for tests as mentioned in section 5.5
c. Recommendations

6. AGC Test procedure:

Open Loop Testing Procedure

Efficacy of the power plant model in the AGC software and the power plants response to AGC commands is first checked through Open Loop Testing (OLT). In the OLT, AGC software generates setpoint obeying all the limits and setpoint is also sent to the power plant. But, this AGC signal "DeltaP" is not fed to power plant DCS. Before start of the test, procedure for OLT is also circulated to the power plants which is given below:

1. Every signal in predefined signal list shall be validated through verbal confirmation.
   a. Signal list shall be kept ready by NLDC and Power plant before starting the process.
   b. Power plant executive shall be present in control room with access to unit Digital Control System (DCS) and AGC Remote Terminal Unit (RTU) HMI.
   c. NLDC executive shall be monitoring AGC application.

2. Simulate communication failure and check if Plant DeltaP analog becomes zero

  a. Power plant shall create simulated communication failure (remove cable etc.)
  b. Power plant shall correct the logic if DeltaP analog does not become zero
  c. NLDC shall create simulated communication failure.
  d. Power plant shall correct the logic if DeltaP analog does not become zero.
3. Simulate AGC Suspend status and check if Plant DeltaP analog becomes zero
  a. NLDC shall create simulated AGC Suspend state
  b. Power Plant shall correct the logic if DeltaP analog does not become zero.
4. Toggle AGC from Remote to Local status and check if Plant DeltaP analog becomes zero.
  a. Power Plant shall create simulated Local and Remote states
  b. NLDC shall concur change in Local and Remote states.
  c. Power Plant shall correct the logic if DeltaP analog does not become zero during Local state
5. Setup unit capability limits.
  a. For thermal plants, default limits shall be max = Units gross DC on bar, Min = 55% of Units gross DC on bar. Setup distribution factors for the units (**Note:** Default = (1/units on bar)). For hydro plants P1 (min), P2 -P3 (forbidden zone) and P4 (max) may be checked.
    i. Power plant shall test using maximum limit less than unit set point.
    ii. NLDC shall check corresponding variation in DeltaP feedback signals
  b. Power plant shall test using minimum limit more than unit set point.
    i. NLDC shall check corresponding variation in DeltaP feedback signals
  c. Change distribution factors and check if same is reflecting in NLDC.
6. NLDC shall explain the process for changing setting from 'Local' to 'Remote'. Note that before closed loop control, either keep the machine in 'dummy Remote' or in 'Local'.
7. Local to Remote toggle is a manual process to be adopted by the power plant, only after code exchange with NLDC.
8. Remote to Local can be done by the power plant without prior code exchange in case of emergency. But post-facto code exchange has to be done. For planned remote to local, code exchange is a must.

In addition to the plant max, min, ramp and other limits, response of the power plant to the AGC Suspend Status and communication failure signals are also checked in the OLT.

Closed Loop Testing Procedure

Once the problems observed in open loop testing are addressed, Closed Loop Testing (CLT) is conducted with the power plant. In the CLT, AGC signal "DeltaP" is fed to power plant DCS and as a result the power plant is required to track 'AGC set point' instead of the power plant operator fed 'unit load set point'. Before the CLT, test procedure is circulated to the power plants which is given below,

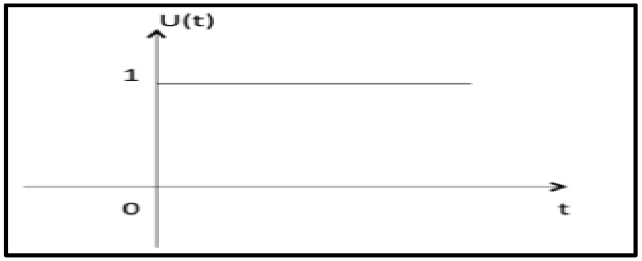
1. Check all the Analog and Digital signals are updating correctly before the starting of the test – action by NLDC & Power plant
2. Maximum allowed variation above or below RULSP shall be set at 50 MW per power plant - action by NLDC
3. Maintain units in 'Local' mode - action by Power plant
4. Inform RLDCs before the start of the test - action by NLDC
5. Alert ULDC / POWERGRID for ensuring uninterrupted communication - action by ULDC, NLDC and Power plant.
6. Exchange of code between NLDC and Power plant for bringing units into 'Remote' - code by NLDC, code & action by Power plant
7. Allow the units to remain in 'Remote' un-interrupted for 45 minutes. Observe closely the variations of power plant. Power plants shall bear the deviations under DSM - action by NLDC & Power plant
8. In case of any abnormal behaviour by AGC, the power plant is free to take the AGC into 'Local' without intimation. However, code may be exchanged subsequently - action by NLDC & Power plant.
9. Simulate AGC Suspend status and check if individual unit DeltaP analog becomes zero- action by NLDC.
10. Simulate communication failure and check if unit DeltaP analog becomes zero -action by NLDC.
11. Toggle AGC from Remote to Local status and check if unit DeltaP analog becomes zero - action by Power plant.

Annexure -1

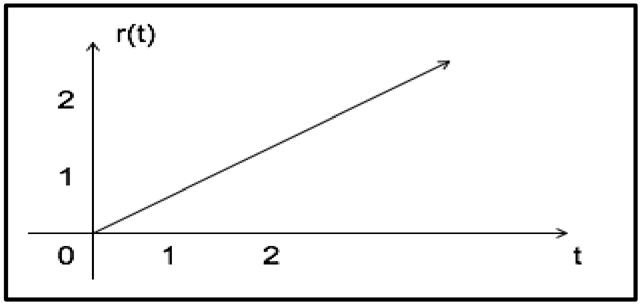
Suggested Tests to be done for different frequency steps, loading level for a given Droop Setting

The tests shall be carried out by injecting various simulated frequency inputs to the generating unit. The injections of simulated frequency signals shall be finalized to assess the primary frequency response under different operating conditions. The following types of signals shall be considered for injecting simulated frequency:

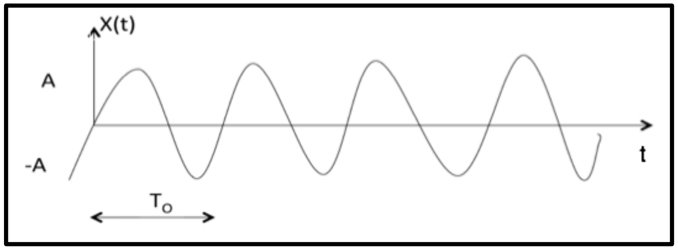
i. **Unit Step Function**: Unit step function is denoted by u(t). It is defined as u(t) which is denoted below:



ii. **Ramp Signal**: Ramp signal is denoted by r(t), and it is denoted by r(t) which is given below:



iii. **Sinusoidal Signal :** Sinusoidal signal is in the form of x(t) = A cos(wt) or A sin(wt) as given below:



The quantum of maximum frequency injection input shall be limited and would be dependent upon the droop being implemented in the generating unit.

a. Test Signal for 2% Droop (for hydro units only)

S.No	Test Signal for 2% Droop	Generation Level
1	-0.04 Hz from 50 Hz	Technical Minimum
2	-0.05 Hz from 50 Hz	
3	-0.04 Hz and + 0.04 Hz from 50 Hz	1. 60 - 80% of MCR Generation Level and 2. At 100% MCR Generation Level
4	-0.05 Hz and +0.05 Hz from 50 Hz	
5	+ 0.04 Hz and -0.04 Hz from 50 Hz	
6	+ 0.05 Hz and -0.05 Hz from 50 Hz	

b. Test Signal for 3% Droop

S.No	Test Signal for 3% Droop	Generation Level
1	-0.04 Hz from 50 Hz	Technical Minimum
2	-0.05 Hz from 50 Hz	
3	-0.075 Hz from 50 Hz	
4	-0.04 Hz and + 0.04 Hz from 50 Hz	1. 60 - 80% of MCR

5	-0.05 Hz and +0.05 Hz from 50 Hz	Generation Level and 2. At 100% MCR Generation Level
6	-0.075 Hz and +0.075 Hz from 50 Hz	
7	+ 0.04 Hz and -0.04 Hz from 50 Hz	
8	+ 0.05 Hz and -0.05 Hz from 50 Hz	
9	+ 0.075 Hz and -0.075 Hz from 50 Hz	

c. Test Signal for 4% Droop

S.No	Test Signal for 4% Droop	Generation Level
1	-0.05 Hz from 50 Hz	Technical Minimum
2	-0.075 Hz from 50 hz	
3	-0.1 Hz from 50 Hz	
4	+ 0.05 Hz and -0.05 Hz from 50 Hz	1. 60 - 80% of MCR Generation Level and 2. At 100% MCR Generation Level
5	+ 0.075 Hz and -0.075 Hz from 50 Hz	
6	-0.1 Hz and + 0.1 Hz from 50 Hz	
7	-0.05 Hz and +0.05 Hz from 50 Hz	
8	-0.075 Hz and + 0.075 Hz from 50 hz	
9	-0.1 Hz and +0.1 Hz from 50 Hz	

d. Test Signal for 5% Droop

S.No	Test Signal for 5% Droop	Generation Level
1	-0.05 Hz from 50 Hz	Technical Minimum
2	-0.01 Hz from 50 hz	
3	-0.125 Hz from 50 Hz	
4	+ 0.05 Hz and -0.05 Hz from 50 Hz	1. 60 - 80% of MCR Generation Level

5	+ 0.1 Hz and -0.1 Hz from 50 Hz	and 2. At 100% MCR Generation Level
6	-0.125 Hz and + 0.125 Hz from 50 Hz	
7	-0.05 Hz and +0.05 Hz from 50 Hz	
8	-0.1 Hz and + 0.1 Hz from 50 hz	
9	-0.125 Hz and +0.125 Hz from 50 Hz	

e. Test Signal for 6% Droop

S.No	Test Signal for 6% Droop	Generation Level
1	-0.05 Hz from 50 Hz	Technical Minimum
2	-0.1 Hz from 50 Hz	
3	-0.15 Hz from 50 Hz	
4	+ 0.05 Hz and -0.05 Hz from 50 Hz	1. 60 - 80% of MCR Generation Level and 2. At 100% MCR Generation Level
5	+ 0.1 Hz and -0.1 Hz from 50 Hz	
6	-0.15 Hz and + 0.15 Hz from 50 Hz	
7	-0.05 Hz and +0.05 Hz from 50 Hz	
8	-0.1 Hz and + 0.1 Hz from 50 hz	
9	-0.15 Hz and +0.15 Hz from 50 Hz	

f. Test Signals for 7% Droop

S.No	Test Signal for 7% Droop	Generation Level
1	-0.05 Hz from 50 Hz	Technical Minimum
2	-0.1 Hz from 50 Hz	

3	-0.175 Hz from 50 Hz	
4	-0.05 Hz and + 0.05 Hz from 50 Hz	1. 60 - 80% of MCR Generation Level and 2. At 100% of MCR Generation Level
5	-0.1 Hz and +0.1 Hz from 50 Hz	
6	-0.175 Hz and +0.175 Hz from 50 Hz	
7	+ 0.05 Hz and -0.05 Hz from 50 Hz	
8	+ 0.1 Hz and -0.1 Hz from 50 Hz	
9	+ 0.175 Hz and -0.175 Hz from 50 Hz	

g. Test Signals for 8% Droop

S.No	Test Signal for 8% Droop	Generation Level
1	-0.05 Hz from 50 Hz	Technical Minimum
2	-0.1 Hz from 50 Hz	
3	-0.2 Hz from 50 Hz	
4	-0.05 Hz and + 0.05 Hz from 50 Hz	1. 60 - 80% of MCR Generation Level and 2. At 100% of MCR Generation Level
5	-0.1 Hz and +0.1 Hz from 50 Hz	
6	-0.2 Hz and +0.2 Hz from 50 Hz	
7	+ 0.05 Hz and -0.05 Hz from 50 Hz	
8	+ 0.1 Hz and -0.1 Hz from 50 Hz	
9	+ 0.2 Hz and -0.2 Hz from 50 Hz	

h. Test Signals for 9 % Droop

S.No	Test Signal for 9 % Droop	Generation Level
1	-0.1 Hz from 50 Hz	Technical Minimum
2	-0.15 Hz from 50 Hz	
3	-0.225 Hz from 50 Hz	
4	-0.1 Hz and + 0.1 Hz from 50 Hz	1. 60 - 80% of MCR Generation

5	-0.15 Hz and +0.15 Hz from 50 Hz	Level and 2. At 100% MCR Generation Level
6	-0.225 Hz and +0.225 Hz from 50 Hz	
7	+ 0.1 Hz and -0.1 Hz from 50 Hz	
8	+ 0.15 Hz and -0.15 Hz from 50 Hz	
9	+ 0.225 Hz and -0.225 Hz from 50 Hz	

i. Test Signals for 10 % Droop

S.No	Test Signal for 10 % Droop	Generation Level
1	-0.1 Hz from 50 Hz	Technical Minimum
2	-0.15 Hz from 50 Hz	
3	-0.25 Hz from 50 Hz	
4	-0.1 Hz and + 0.1 Hz from 50 Hz	1. 60 - 80% of MCR Generation Level and 2. At 100% MCR Generation Level
5	-0.15 Hz and +0.15 Hz from 50 Hz	
6	-0.25 Hz and +0.25 Hz from 50 Hz	
7	+ 0.1 Hz and -0.1 Hz from 50 Hz	
8	+ 0.15 Hz and -0.15 Hz from 50 Hz	
9	+ 0.25 Hz and -0.25 Hz from 50 Hz	

Guidelines for Model Validation and Verification test for the complete Generator and Excitation system model including PSS

1. Background

Accurate models of generators are required for simulations of power system. Hence testing and periodic validation of the model data is necessary, thus enabling usage of models in the simulations. These guidelines shall be followed for model parameter determination, model validation and verification test for the Generator, excitation system model including PSS.

These guidelines suggest typical test methods for dynamic data validation. However, the appropriate tests shall be conducted with plan and procedure finalized by respective RPC.

2. Scope

These guidelines shall apply to all generating units (Individual Unit of rating 100 MW and above for Coal/Lignite, 50 MW and above for gas turbine and 25 MW and above for Hydro), State Load Despatch Centres (SLDCs), Regional Load Despatch Centres (RLDCs), National Load Despatch Centre (NLDC).

3. Definitions

Words and expressions used in this guideline are defined in the Act or any other regulations specified by the Central Commission or Central Electricity Authority shall, unless the context otherwise requires, have the meanings assigned to them under the Act or other regulations specified by the Central Commission, as the case may be.

4. Regulatory provisions as per IEGC 2023

a. ***As per Regulation 29(6) & 29(8) of Central Electricity Regulatory Commission (Indian Electricity Grid Code Regulations) 2023***

"All generating units shall have their automatic voltage regulators (AVRs), Power System Stabilizers (PSSs), voltage (reactive power) controllers (Power Plant Controller) and any other requirements in operation, as per the CEA Technical Standards for Connectivity. If a generating unit with a capacity higher than 100 (hundred) MW is required to be operated without its AVR or voltage controller in service, the generating station shall immediately inform the concerned RLDC of the reasons thereof and the likely duration of such operation and obtain its permission.

Power System Stabilizers (PSSs), AVRs of generating units and reactive power controllers shall be properly tuned by the generating station *as per the plan and the procedure prepared by the concerned RPC. In case the tuning is not complied with as per the plan and procedure, the concerned RLDC shall issue notice to the defaulting generating station to complete the tuning within a specified time, failing which the concerned RLDC may approach the Commission under Section 29 of the Act."*

b. As per clause 40 of IEGC 2023,

i. The owner of the power system element shall be responsible for carrying out tests as specified in these regulations and for submitting reports to NLDC, RLDCs, CEA and CTU for all elements and to STUs and SLDCs for intra-State elements.

ii. All equipment owners shall submit a testing plan for the next year to the concerned RPC by 31st October to ensure proper coordination during testing as per the schedule. In case of any change in the schedule, the owners shall inform the concerned RPC in advance.

iii. The tests shall be performed once every five (5) years or whenever major retrofitting is done. If any adverse performance is observed during any grid event, then the tests shall be carried out even earlier, if so advised by SLDC or RLDC or NLDC or RPC, as the case may be.

5. Modelling of Generating unit

i. The Single machine Infinite Bus (SMIB) approach may be used for modelling and conducting the Model validation studies of Generator, Excitation system along-with PSS, Turbine Governor Model in a RMS Simulation software.

ii. The Developed Generator, Excitation system, PSS Model and Turbine –Governor Model needs to be validated with the suggested tests for accurate representation of the machine in the simulation software (Preferably PSS/E).

iii. The SMIB is to be developed using IEEE Models

iv. If User Defined Models (UDM) are considered for model Validation, the source code of UDM (Specific to PSS/E) and compilation procedure shall be shared

v. The dynamic models are generally used for transient simulations typically studying conditions up to 60 seconds.

vi. The model should initialize properly for the dynamic simulation. The model should be dispatched within active power, reactive power, and terminal voltage limits prior to initialization.

Note: There shall not be any errors during Initialization.

vii. An initialized dynamics case shall remain in equilibrium during a dynamic simulation flat run (without applying any contingency). The simulation should typically run for at least 20 seconds to check for potential small signal or control interaction instabilities. Additionally, it is suggested that the model may be checked for fault simulation, reactor/capacitor switching, line switching.

6. Tests to be performed

a. Synchronous Generators

The following tests shall be done to determine the model parameters of a synchronous generator

a. **Generator Open Circuit Magnetization (Saturation) Test**: The Generating unit is operated at rated speed with no load and generator circuit breaker open. During these tests generally, the excitation is in manual control mode and measurements are taken monotonically by changing the field current and terminal voltage to avoid hysteresis effects in measurements. OCC curve tests is used to estimate the air gap line field current at 1.0 pu terminal voltage and magnetization saturation factors at 1.0 pu ($S_{1.0}$) and 1.2 pu $S_{1.2}$ terminal voltage.

b. **V Curve**: The V curve test is intended to validate the d- and q- axis reactance's (X_d and X_q), leakage reactance (X_l). During this test, field current, field voltage, active power, reactive power and stator terminal voltage are to be recorded. In this test the generating unit is operated at unity power factor (0 MVAR output, then gradually reactive power absorption is increased to its limit, after reaching its limit the reactive power generation is gradually incremented towards the injection limit. The test is repeated at several generating levels i.e. 0 %(no-load), 50 – 70 % and > 90% loading. The V- Curve tests also needs to be done monotonically to avoid magnetic hysteresis. The determination of the parameters is an iterative process. The V-curve data between the steady-state model parameters and the actual test results should match.

c. **Load Rejection Test:** Inertia of the Machine (Generator, Excitation System (rotating) and Turbine) is taken from the technical data sheets provided by the manufacturer for the generator and turbine. In case the data from manufacturer is not available a load rejection tests may be done to derive H. Load Rejection tests is carried out when generating unit is operating at low level, during this test the frequency, active power is used to derive Inertia using the following equation

$$H = \frac{\Delta P_{pu}}{2 * \left(\frac{\Delta f_{pu}}{\Delta t}\right)}$$

Note: Load Rejection test is not required when Inertia data is available from OEM datasheets

b. Excitation System:

The following tests may be done for validating the Excitation model of a synchronous generator including Power System Stabilizer. During the Testing, it is recommended to record Real Power, Field Current, PSS Output, Field Voltage, Reactive current, Generator Voltage

a. **Voltage reference Step tests at No Load:** The results from this test i.e. step change of voltage regulator reference with the generator circuit breaker open to be used for validating the excitation system model.

b. **Voltage reference Step test:** The results from step change in Voltage Regulator of AVR and the machines performance (Real Power Oscillation time duration & Magnitude) with PSS in-service, PSS out-service to be used for validation the excitation system along-with Power System Stabilizer model. The following suggested tests may be used for validation

Step Response Test	± 2-3% Step	PSS-ON	Around Technical Minimum Load
		PSS-OFF	
		PSS-ON	80 % - MCR Loading
		PSS-OFF	
	± 3-5% Step	PSS-ON	Around Technical Minimum Load
		PSS-OFF	
		PSS-ON	80 % - MCR Loading
		PSS-OFF	

c. **Impulse Step Test:** The exciter impulse tests are typically larger in magnitude (five percent to 10 percent) but for much shorter durations (0.1–0.5 seconds). Exciter impulse tests are often used in analysis of PSS commissioning to determine its effectiveness in damping oscillations. The Impulse Step test results with PSS On and PSS OFF to be used for model validation

d. **Actual Disturbance test :** This test is the most effective way to check PSS performance by creating an actual disturbance like the opening of transmission lines/switching of reactors after consultation with the system operator. This ensures the conformance of the PSS tuning impact in real-time. During this test, the PSS of all other units shall be made OFF by keeping the PSS ON for the actual unit which is being tested.

7. Periodicity of the Testing

1. At least once every five (5) years
2. In case of R&M of the Generating unit
3. In case of a major change in the excitation system(or the PSS) of the generating unit

8. Model Validation

The derived dynamic model data of the generating unit, Excitation system (PSS) and Turbine Governor from the testing data, should replicate the response in the simulation software as similar to the results obtained from the suggested tests, within normally acceptable levels of accuracy. The following parameters to be used for benchmarking the model accuracy

a. Magnitude of response, Rate of the response
b. Rise-time, settling time, overshoot
c. Initial & Settling value

9. Data to be furnished after model validation.

- Single Line Diagram of Generating Facility
- Generating Unit Data
    a. Nameplate , Manufacturer, Make & Model Number
    b. Impedance data in per unit on machine rated MVA & Kv
    c. Time Constants

d. Inertia Constant
e. Completely filled Modelling Data parameters (GENROU, GENSAL etc.)

- Excitation system data
  a. Excitation system type (Static/AC Rotating/Brushless/DC Generator etc)
  b. Manufacturer, Make & Model Number
  c. Complete filled data sheet for the IEEE equivalent models
  d. Transfer Function/Block-Diagram of the Excitation system
- Power System Stabilizer (PSS)
  a. PSS IEEE Model, Make & Manufacturer
  b. Complete filled data sheet for the corresponding IEEE equivalent model
  c. Transfer Function/Block-Diagram of the PSS
- Procedure adopted for simulation model validation.
- Changes made on field during the Testing activity (if any).
- The Tests Result data to be provided in csv or excel with a minimum of 10Hz resolution data.
- Static details of the generator like GT Transformer Data, OCC Test Result, SCC characteristics, V Curves, P-Q capability curves, datasheets of the turbine and governor.

Guidelines for Power Plant Controller Function Testing of Renewable Energy Based Generating Station

1. Background

i. These guidelines are prepared in accordance with Clause 28(3) & 28 (4) and in accordance with clause 40 of Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2023

ii. These guidelines shall be followed for performing Power Plant Controller Function Test including active, reactive set point change, frequency response testing and submission of reports.

2. Scope

The guideline shall apply to all the Renewable Energy based generating stations under operational jurisdictions of State Load Despatch Centres (SLDCs), Regional Load Despatch Centres (RLDCs), National Load Despatch Centre (NLDC). The respective tests shall be carried out as per the applicability of CEA Technical Standards for Connectivity.

3. Definitions

Words and expressions used in this guideline are defined in the Act or any other regulations specified by the Central Commission or Central Electricity Authority shall, unless the context otherwise requires, have the meanings assigned to them under the Act or other regulations specified by the Central Commission, as the case may be.

4. Responsibilities for Conducting Power Plant Controller Function Testing

As per clause 40 (2) of IEGC 2023,

i. The owner of the power system element shall be responsible for carrying out tests as specified in these regulations and for submitting reports to NLDC, RLDCs, CEA and CTU for all elements and to STUs and SLDCs for intra-State elements.

ii. All equipment owners shall submit a testing plan for the next year to the concerned RPC by 31st October to ensure proper coordination during testing as per the schedule. In case of any change in the schedule, the owners shall inform the concerned RPC in advance.

iii. The tests shall be performed once every five (5) years or whenever major retrofitting is done. If any adverse performance is observed during any grid event, then the tests shall be carried out even earlier, if so advised by SLDC or RLDC or NLDC or RPC, as the case may be.

5. Test data formats

5.1 PV Inverter/ WTG details

1	Power plant name	Name	
2	WTG/ PV Inverter	Make & Model	
3	Plant Installed Capacity	MW	
5	Plant Peak Capacity	MW	
6	WTG/Inverter rating in MVA	MVA	
7	WTG/Inverter active power rating in MW	MW	
8	Number WTGs/Inverters	Numbers	
9	Master PPC	Make	

10	Auxiliary PPCs	Number and Make	

5.2 Power Plant Controller (PPC) details

The power plant controller user manual covering details of various control functions of PPC shall be submitted.

5.3 Test procedures

The active power and reactive power control tests shall be carried out at generation levels as mentioned in the test procedure.

Evaluating criteria for each test shall be the compliance to CEA connectivity standards.

5.3.1 Inverter/WTG communication test

This test will be carried out through IP ping test for all the inverters/WTGs. The inverters/WTGs IP addresses will be pinged from the PPC server. The ping response time shall be recorded by testing team and it shall be less than the expected time. Commands writing and reading status also shall be checked and recorded.

Inverter/WTG Number	Inverter/WTG Name	Ping response Expected (ms)	Ping response Actual (ms)	Commands Writing (Ok)	Commands Reading (Ok)

5.3.2 PQ Meter communication test

This test verifies whether communication and reading from PQ meter is proper or not. Various parameter values shown on the PQ meter display and the parameters received at PPC from PQ meter will be compared and checked for correctness

Type of Test	Test Result	Date
Ping Expected (ms)		
Ping Actual (ms)		

Parameters	Value shown at PPC monitoring station	PQ meter display
Active power (MW)		
Reactive Power (MW)		
Power factor		
Voltage (Kv)		
Frequency (Hz)		

5.3.3 Active Power Set Point change test

This test is performed to check whether active power is generated as per the set point given to PPC. As per CEA (Technical Standards for Connectivity to the Grid) Regulations (amendment, 2019) clause B2(4):

"i) Shall be equipped with the facility to control active power injection in accordance with a set point, capable of being revised based on directions of the State Load Dispatch Centre or Regional Load Dispatch Centre, as the case may be;

iv) shall be equipped with the facility for controlling the rate of change of power output at a rate not more than ± 10% per minute"

This test shall be carried out at a power not less than 70% of rated capacity.

[Note: It is preferable to carry out the test during peak solar hours (11:00 Hrs to 13:00Hrs) under clear sky conditions for solar plants and during maximum wind generation period for wind plant.]

5.3.3.a Test procedure:

i) Change the active power set point from 100% (maximum available active power) to 10% in steps of 20% with hold time of 5minutes for each step with frequency control in disabled condition.

ii) Subsequently increase the active power set point from 10% to 100% of maximum available active power in steps of 20% with hold time of 5minutes for each step with frequency control in disabled condition.

iii) Record the parameters as per the following format. The active power set point vs actual generation to be plotted.

Test format for WTG/ PV Inverter plant:

Set point given time (hh:mm:ss)	Given Set Point in MW at PPC	Solar Irradiance /Wind speed @ time of set point given	Active power (MW) at the time of set point given (At POI)	Active power (MW) at the time of set point reached (At POI)	Set Point Reached time (hh:mm:ss)	Time taken to reach set point (in Seconds)	Frequency at the time of set point given (Hz)	Implemented Ramp rate (% per minute) at the PPC	Achieved Ramp rate (% per minute)	Remarks

5.3.4 Frequency response test

This test is performed to check whether the RE plant is providing frequency response as specified in CEA (Technical Standards for Connectivity to the Grid) Regulations (amendment, 2019) clause B2(4):

"(ii) shall have governors or frequency controllers of the units at a droop of 3 to 6% and a dead band not exceeding ±0.03 Hz:

Provided that for frequency deviations in excess of 0.3 Hz, the Generating Station shall have the facility to provide an immediate (within 1 second) real power primary frequency response of at least 10% of the maximum Alternating Current active power capacity;

(iii) shall have the operating range of the frequency response and regulation system from 10% to 100% of the maximum Alternating Current active power capacity, corresponding to solar insolation or wind speed, as the case may be;"

This test shall be carried out at different power generation level as given below, At the time of testing the maximum available active power generation as per the prevailing weather conditions shall not be less than 70% of rated capacity.

[Note: It is preferable to carry out this test during peak solar hours (11:00 Hrs to 13:00Hrs) under clear sky conditions for solar plants and maximum wind generation period for wind plant.]

5.3.4.a Test procedure

Frequency response test to be carried at the implemented droop settings (in the range of 3% - 6%). Testing for different frequency changes as given in below table needs to be carried out.

Sl.No	Load Level	Test Signal
1	At 90% (or maximum of active power capacity	-0.03 & +0.03 Hz from 50 Hz
		-0.10 & +0.10 Hz from 50 Hz
		-0.15 & +0.15 Hz from 50 Hz
		- 0.3Hz & +0.3Hz from 50Hz

		- 0.5Hz & +0.5Hz from 50Hz
2	At 50% of active power capacity	-0.03 & +0.03 Hz from 50 Hz
		-0.10 & +0.10 Hz from 50 Hz
		-0.15 & +0.15 Hz from 50 Hz
		- 0.3Hz & +0.3Hz from 50Hz
		- 0.5Hz & +0.5Hz from 50Hz
3	At 25% of active power capacity	-0.03 & +0.03 Hz from 50 Hz
		-0.10 & +0.10 Hz from 50 Hz
		-0.15 & +0.15 Hz from 50 Hz
		- 0.3Hz & +0.3Hz from 50Hz
		- 0.5Hz & +0.5Hz from 50Hz

Following shall be recorded for each testing step

Simulated frequency signal (Hz)	Initial Active power generation (MW)	Initial Irradiance /Wind speed	Implemented Droop setting (%)	Expected frequency response (MW)	Expected final active power generation (MW)	Final Settled Active power (MW)	Time taken for providing response (Sec)	Droop calculated based on frequency Response (%)	Remarks
50-->50.03									

5.3.5 Reactive Power control test

Three types of reactive power control i.e, Fixed reactive power control (Q control), Power factor (PF) control and voltage control tests shall be performed when the plant is generating active power. Fixed Q and Voltage control tests shall also be performed during no generation period (Where the feature is available).

5.3.5.a Fixed Q-control mode

i) When the Plant is generating active power:

This test is required to check whether the plant generates reactive power as per the given set-point. The following set point changes shall be performed

a) Reactive power set point of 20%, 50% & 100% of maximum Reactive power at the point of interconnection at full generation (or maximum available generation above 70%) and 50% of full generation.

b) Reactive power set point of -25%, -50% & -100% of maximum Reactive power at the point of interconnection at full generation (or maximum available generation above 70%) and 50% of full generation.

The testing needs to be carried out in coordination with RLDC/SLDC in real time based on POI voltage.

Start Time	End Time	MVAR Set point given	MVAR at start time	MVAR at End time	POI Voltage at start time	POI Voltage at end time	PF at end time	Response Time (Sec)

*Maximum reactive power is 33% of the rated active power capacity at POI.

Reactive power set point vs actual reactive power shall be plotted.

ii) Test during no generation period:

This test is to check whether the plant generates a Reactive power as per the given reactive power set-point during no generation period (For PV inverters during night time and for WTGs during no wind period).The testing needs to be carried out in coordination with RLDC/SLDC in real time based on POI voltage The following set-point changes 0%, 50%, 100%, -50% & -100% of maximum Reactive power at the point of connection shall be given. The testing steps shall be selected based on real time grid conditions.

Start Time	End Time	MVAR Set point given	MVAR at start time	MVAR at End time	POI Voltage at start time	POI Voltage at end time	Response Time (Sec)

* Maximum reactive power is 33% of the rated active power capacity at POI

5.3.5.b Voltage control mode

This test is required for checking whether the plant generates an amount of reactive power, proportionally to the error between the voltage set-point and the actual voltage value. Details of implemented droop and dead band settings of voltage control mode to be submitted. The testing needs to be carried out in coordination with RLDC/SLDC in real time based on POI voltage This test shall be carried out at maximum available active power generation (not less than 70% of rated capacity) and during no generation period.

Simulated Voltage %	Simulated Voltage (kV)	Active Power (MW)	Initial Reactive Power (MVAr)	Expected MVAR as of V-control settings	Final MVAR	Start Time	End Time	Duration (Sec)	Remarks

5.3.5.c Power Factor Control mode

This test is to check that the plant is operating with a power factor equal to the set-point value.

i) The testing needs to be carried out in coordination with RLDC/SLDC in real time based on POI voltage.

ii) Change the power factor set points from 0.95 pf lead to 0.95lag in steps of 0.02 shall be done and the results shall be tabulated as below.

This test needs to be carried out at 100% power generation (or maximum possible generation not less than 70% of rated capacity) and 50% generation level.

Power Factor Set-point Change	Active Power at POI (MW)	Reactive Power at POI (MVAR)	Power Factor at POI	POI Voltage (kV)	StartTime	End Time	Duration	Remarks
--								Initial conditions
Lagging power factor test								
1.00→0.98								
0.98→0.96								
0.96→0.95								
0.95→1.00								
Leading power factor test								
1.00→0.98								

0.98→0.96								
0.96→0.95								
0.95→1.00								

5.3.6 Operating frequency range test

a. This test is performed to check whether the generating unit has the capability to remain connected to grid when grid frequency is in the range of 47.5 to 52 Hz in line with CEA technical standards for connectivity to the Grid regulations 2007 and subsequent amendments. This test will be performed on the sample WTGs/Inverters (WTG/Inverter of different makes shall be part of the sample). The frequency signals of 49Hz, 48Hz and 47.5 Hz and 51Hz, 52 Hz will be injected in the WTG controller. The following shall be recorded

Sl. No	WTG/Inverter number	Frequency signal injected in HZ	WTG/Inverter status (In service/Trip)

5.3.7 Test to check the ability to receive signals from control center

Active and reactive power set points sent from SLDC/RLDC needs to be validated for correctness and corresponding change in active and reactive powers needs to be recorded. As per CEA technical standards for connectivity to the Grid regulations 2007 and subsequent amendments

"The generating stations of aggregate capacity of 500 MW and above shall have the provision to receive the signal from the State Load Dispatch Centre or Regional Load Dispatch Centre, as the case may be, for varying active and reactive power output."

Sl.No	Active power Set Point sent from	Set point received at Site (Yes/No)	Initial generation	Final Generation	Time taken

	RLDC/SLDC		(MW)	(MW)	(Sec)

Sl.No	Reactive power Set Point sent from RLDC/SLDC	Set point received at Site (Yes/No)	Initial MVAR	Final MVAR	Time taken (Sec)

5.3.8 PPC redundancy test

PPC system provides automatic switch over from primary to back-up processor when a fault occurs in the primary. Normally, the primary PLC processor controls the logic execution while the other performs standby operation. It is important to ensure normal operation of the plant in the event of communication failure/ PPC failure.

Testing method:

1: Stop the primary processor (power off / stop mode)

2. Check the PPC Status whether the data is synchronizing. Check whether the secondary PPC is able to take control of the plant by changing the setpoints from User Interface.

3.Remove the communication cable to PPC and check the plant active power and reactive power at POI.

4.If master and slave PPCs are available the testing needs to be carried out for failure of master PPC and slave PPCs.

Sl. No	Active power	Active power	Reactive power	Reactive power	Remarks

	(MW) before PPC failure	(MW) after PPC failure	(MW) before PPC failure	(MW) after PPC failure	

5.4 Data submission

5.4.1 All the recording parameters for each test shall be submitted in csv/excel format with 100 milli sec resolution wherever available (if 100 ms resolution is not available next higher available resolution data not more than 1 second resolution shall be considered) for testing period and 5 minutes before & after the testing.
5.4.2 Test report covering all the tests performed, recording tables, relevant plots and conclusion on the compliance to CEA technical standards to Connectivity as applicable.

Guidelines for Carrying Out HVDC/FACTS devices Testing

1. Background

i. These guidelines are in Compliance to Clause 28(3) & 28 (4) and in accordance with clause 40 of the Indian Electricity Grid Code, 2023 notified by the Central Electricity Regulatory Commission.

ii. These guidelines to be followed for performing Reactive Power Controller (RPC) Capability for HVDC/FACTS, Filter bank adequacy assessment based on present grid condition, in consultation with NLDC, Validation of response by FACTS devices as per settings and submission of reports along with model validations**.**

2. Scope

The guideline shall apply to all ISTS HVDC as well as Intra-State HVDC/FACTS, as applicable under operational jurisdictions of State Load Despatch Centres (SLDCs), Regional Load Despatch Centres (RLDCs), National Load Despatch Centre (NLDC).

3. Definitions

Words and expressions used in this guideline are defined in the Act or any other regulations specified by the Central Commission or Central Electricity Authority shall, unless the context otherwise requires, have the meanings assigned to them under the Act or other regulations specified by the Central Commission, as the case may be.

4. Responsibilities for Conducting HVDC/FACTS Testing

As per clause 40 (2) of IEGC 2023,

i. The owner of the power system element shall be responsible for carrying out tests as specified in these regulations and for submitting reports to NLDC, RLDCs, CEA and CTU for all elements and to STUs and SLDCs for intra-State elements.

ii. All equipment owners shall submit a testing plan for the next year to the concerned RPC by 31st October to ensure proper coordination during testing as per the schedule. In case of any change in the schedule, the owners shall inform the concerned RPC in advance.

iii. The tests shall be performed once every five (5) years or whenever major retrofitting is done. If any adverse performance is observed during any grid event, then the tests shall be carried out even earlier, if so advised by SLDC or RLDC or NLDC or RPC, as the case may be.

5. Test data formats

b. Reactive Power Control (RPC) in HVDC

In a high voltage direct current (HVDC) transmission converter station, the purpose of the Reactive Power Control (RPC) is to facilitate the switching of alternating current (ac) filters to meet the reactive power demand with the ongoing dc power flow. In addition to it, the RPC will also ensure that the required ac filters are connected to prevent harmonics from entering into the AC system.

In an LCC based HVDC system, the RPC consists of the ac filters. The ac filters connected to the 400-kV bus consists of filter sub banks of various ratings and tuned to different harmonics which are connected and disconnected by RPC based on the dc power level. The reactive power absorption of a converter station increases with the increase in transmitted dc power and the need for filtering of ac side harmonics also increases. The RPC scheme considers the reactive power requirement as per the dc power flow and switches on the filter sub banks accordingly or it can consider the ac grid voltage and switch on the filter sub banks accordingly.

The RPC is an integral function provided in the control system. The RPC switches in or switches out the ac filter/shunt-capacitor banks in order to control the reactive power exchange with the a.c. system (Q_Control), the a.c. bus voltage (U_Control) and the filtering of a.c. harmonics. The RPC function can be kept in auto mode or in manual mode. When the RPC is in auto mode, it will try to fulfil minimum filter conditions and when it is in manual mode, it will try to fulfil the absolute minimum filter conditions. In absolute minimum condition, RPC aims to provide filters only to suffice the reactive power requirements. However, in minimum filter condition, RPC aims to provide filters to provide the reactive power requirements as well as cater to the need of eliminating harmonics.

Test procedures

5.1.1 <u>AC bus voltage control by RPC (U control)</u>

U control is used to control the a.c. bus voltage at steady state operation. A suitable dead band is chosen to avoid the hunting.

5.1.1.1 In auto mode

In RPC Auto mode, the Minimum Filter condition is satisfied and the filter sub banks gets connected and disconnected automatically based on the dc power level.

Test procedure:

iv) Note the no. of filter bank, voltage on AC bus, active power, and reactive power exchange in the antecedent conditions.

v) Change the HVDC active power set point by 20% in steps of 10% (in both increasing and decreasing directions) with a hold time of 5 minutes for each step.

vi) Record the filter switching per the following format. The reactive power vs actual voltage to be plotted.

vii) The procedure has to be carried out with monopole as well as bipole mode of operation for HVDC.

5.1.1.2 **In manual mode:**

In manual mode, RPC aims to fulfil the minimum Filter condition. In this mode, with the increase of power level the only the absolute minimum filters as per settings get connected automatically but the disconnection of the filter sub banks has to be done manually at all conditions in RPC Manual mode.

i) Note the no. of filter bank, voltage on AC bus, active power, and reactive power exchange in the antecedent conditions. Check whether the minimum filter condition is being satisfied or not.

ii) Change the HVDC active power set point by 20% in steps of 10% in increasing directions withhold time of 5 minutes for each step.

iii) Record the filter switching per the following format. The reactive power vs actual voltage to be plotted.

iv) Change the HVDC active power set point by 20% in steps of 10% in decreasing directions withhold time of 5 minutes for each step.

v) Record the filter switching’s per the following format. The reactive power vs actual voltage to be plotted.

Test format for HVDC RPC in U control for monopole/bipole mode of operation (manual as well as auto):

Set Point MW	Activepower(MW) at time of set point given	Active power (MW) at time of set point reached	REACTIVE POWER (MVAR) AT TIME OF SET POINT GIVEN	REACTIVE POWER (MVAR) AT TIME OF SET POINT Reached	Voltage (kV)	Filter injection prior to power order change (MVAR)	Filter injection after power order change (MVAR)

5.1.2 **Reactive power control by RPC (Q control)**

The reactive power control system will not require any reactive element switching, in either direction since the last switching operation had taken place, considering that a.c. network has not changed. However, switching necessary to maintain the AC bus voltage within the ranges will be performed for smaller than 5% change in transmitted power.

Test Procedure

i) Note the no. of filter bank, voltage on AC bus, active power and reactive power exchange in the antecedent condition**.** Check whether the minimum filter condition is being satisfied or not.

ii) Change the HVDC active power set point by 20% in steps of 10% in increasing directions withhold time of 5 minutes for each step.

iii) Record the filter switching per the following format. The reactive power vs actual voltage to be plotted.

Set Point MW	Activepower(MW) at time of set point given	Active power (MW) at time of set point reached	REACTIVE POWER (MVAR) AT TIME OF SET POINT GIVEN	REACTIVE POWER (MVAR) AT TIME OF SET POINT Reached	Voltage(kV)	Filter injection prior to power order change	Filter injection after power order change

c. Filter bank adequacy assessment based on present grid condition

The intention of this test is to analyse the impact of filter bank switching on the system voltages. The filter bank switching shall not cause any unwanted or a major rise or fall in the voltages. The filter bank sizing shall factor the granularity aspect so that HVDC can be used as a flexible resource and change in power order not causing any sharp change in voltages.

Test Procedure:

i) Review the filter switching sequence table and note the various power orders where filter switching may take place.
ii) Set HVDC at minimum power order.
iii) Increase HVDC power order in steps in line with Table mentioned at Sl. No. 1 above.
iv) Record the change in voltage with each step rise in power order.
v) Plot the voltage vs Power order characteristics with the recorded values.

d. Validation of response by FACTS devices as per settings:

The purpose of this test is to validate the response of FACTS devices as per the design capability declared during first time charging of equipment. The response quantum alongwith time to achieve the response is required for assessing the response. The following tests are recommended for validation of response:

i) The test of continuous operating range should verify that the FACTS device is capable of operating up to its declared rating while in operation, from maximum Mvar capacitive to maximum Mvar inductive. The reactive power shall be computed on the basis of voltage and compared with actual reactive power injection/absorption.

ii) If the FACTS device installation is intended to control the system voltage, the slope settings of the FACTS device should be verified by measurements and calculations. In the voltage control operating mode, the reactive power output of the FACTS device should be adjusted by means of altering reference voltage i.e. V_{ref}, such that the FACTS device just obtains maximum inductive output. To compute the error between the specified slope and the actual slope, the specified slope should be superimposed on the measured characteristic.

iii) In addition to the above, following tests need to be carried out in sequence suggested:

- Control mode selection
  a) Constant Mvar output
  b) Constant system voltage
  c) Float (zero Mvar output)

- Transfer of operation
  a) Local/remote
  b) Manual/automatic

- Control range capability sequences. In each control mode, demonstrate possible control over the entire operating range by testing the following:
  a) Mvar capability (local/remote)
  b) Voltage reference adjustment capability (local/remote)
  c) Slope adjustment capability (local/remote)
  d) Slope linearity

- Demonstration of control modes:
  a) Set reference Q and verify constant Mvar output
  b) Set reference voltage and verify constant system voltage
  c) Maintain zero Mvar output

To verify the behavior of the FACTS, simulated system disturbances should be applied. These disturbances will try to displace the operating point within the normal control range of regulation without excursions outside the limits. Response time of the devices should be monitored.

The following actual operating conditions can provide valuable test data for system performance:

i) Transmission line(s) switched into and out of service, energization of nearby capacitor banks, or loading of transformer bank.

ii) Placing FACTS into service, taking FACTS out of service

iii) System response when FACTS is operated across the whole range by step change of reference point (Vref, Qref) subject to system limitation

iv) In order to assess transient and possible resonance phenomena, current waveforms in each filter branch and voltage waveforms across each filter branch element should be recorded during the dynamic conditions

It is recommended that measurements of the above switching events to be made with high-resolution (kHz range) recorders that can trace the actual transients. These records can be used to determine the magnitude of dynamic voltages and currents that are seen by the filter elements. The records should be kept as reference for future measurements to verify that filter effectiveness and system operating conditions have not changed.

e. Model Validation

The HVDC/FACTS simulation model submitted by the HVDC/FACTS OEM shall be validated with the test results and validation report with appropriate plot showing the validation to be submitted.

f. Conclusion & Recommendations

i) Observations on the testing of HVDC/FACTS

ii) Observations model validation with respect to the field testing

iii) Recommendations

10. Revision of guideline

The guideline shall be reviewed and updated as and when required with intimation to the Commission.

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