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
आज़ादी का अमृत महोत्सव
G20 भारत 2023 INDIA

कार्यालय : बी-9, प्रथम एवं द्वितीय तल, कुतुब इंस्टीट्यूशनल एरिया, कटवारिया सराय, नई दिल्ली - 110016
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CIN : U40105DL2009GOI188682, Website : www.grid-india.in, E-mail : gridindiacc@grid-india.in, Tel.: 011- 40234672

**संदर्भ:** NLDC/SO/IEGC/Operating Procedure/ **दिनांक:** 18th Aug 2023

**सेवा में,**

All the Stakeholders

**विषय:** Stakeholder Workshop on Draft Procedure for **Carrying Out Periodic Testing for Power System Elements** – Reg.

**संदर्भ:** Central Electricity Regulatory Commission, Indian Electricity Grid Code, Regulations, 2023

**महोदय/महोदया,**

In compliance to the regulations 28 (3) of the Central Electricity Regulatory Commission (Indian Electricity Grid Code), Regulations 2023 published on 29th May 2023, NLDC in consultation with RLDCs has prepared a detailed Operating Procedure. **"Carrying Out Periodic Testing for Power System Elements"** pursuant to Clause 40 of the IEGC, is one of the important procedures to be included in the main Operating Procedure.

The above-mentioned procedure is necessary for ascertaining the correctness of mathematical models used for simulation studies as well as ensuring desired performance during an event in the system.

Accordingly, the draft procedure for **"Carrying Out Periodic Testing for Power System Elements"** has been published on Grid-India website on **18th August 2023** and is available at: https://posoco.in/notices/.

To familiarise the stakeholders about this procedure, an online workshop is being organized by Grid-India at **10:30 hrs** on **24th August 2023.**

All stakeholders are requested to join the workshop through the following link:

Stakeholder suggestions/feedback on this draft procedure are invited at "**operatingprocedure@grid-india.in** by **30th August 2023.**

**Microsoft Teams Meeting**

**Meeting ID: 451 561 554 429**

**Passcode: r2dXgN**

सधन्यवाद,

भवदीय,

सुरजीत

(सुरजीत बनर्जी)

मुख्य महाप्रबंधक (प्रणाली प्रचालन, रा.भा.प्रे.के.)

**Copy for kind information:**

1. All RLDC/NLDC Heads

# Grid Controller of India Limited

## (Formerly Power System Operation Corporation Limited)

## National Load Despatch Centre (NLDC)

# Procedure

# for

# Carrying Out Real Power Assessment of

# Synchronous generators



***Prepared in Compliance***

***to***

***Clause 40 (2)(c) & 40 (3)(4) of Central Electricity Regulatory Commission***
***Indian Electricity Grid Code***
***Regulations, 2023***
**August 2023**

# Contents

# <u>Procedure for carrying Out Real Power assessment Testing</u>

## 1. Background

1.1 This procedure is in accordance with clause *40 (2)(c) & 40 (3)(4)* of the Indian Electricity Grid Code, 2023 notified by the Central Electricity Regulatory Commission.

*"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"*

1.2 The procedure lays down the guidelines for performing Real Power assessment test and submission of.

## 2. Scope

The procedure 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 procedure 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 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 | **Metre** | |

| | | | |
|---|---|---|---|
| | (MDDL) | | |
| 11* | Water released at Design Head | $M^3$ / MW | |
| 12* | Unit-wise forbidden zones | MW | |

***For hydro generating stations**

### 5.2 Procedure

The following tests shall be performed:

I. Operation at a load of fifty five (55) percent or minimum turn down level declared by plant of MCR as per the CEA Technical Standards for Construction for a sustained period of four (4) hours.

   a. Result: Plot showing operation at 55% load for 4 hours

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).

| SI.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 | | | | | |

Success criteria: Average ramp over the period shall be more than 1% per minute.

IV. Operation at a MCR as per the CEA Technical Standards for Construction for a sustained period of four (4) hours. Plot showing operation at 100% load for 4 hours to be shown.

V. Demonstrate overload capability with the valve wide open as per the CEA Technical Standards for Construction and sustained operation 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: % | | | |
| 1. | 00:01 (Time where active power generation reached to 105%/110% of MCR as applicable) | | |
| 2. | 00:02 | | |
| 3. | 00:03 | | |
| 4. | 00:04 | | |
| 5. | 00:05 | | |

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

VI. Ramp-down from MCR to seventy-five (75) 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 MCR to 55% 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% | $B_{15}$-$B_{14}$ | |

Success criteria: Average ramp over the period shall be more than 1% per minute.

VIII. 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.

IX. Detailed test report covering all the tests and relevant plots shall be submitted.

# Grid Controller of India Limited

## (Formerly Power System Operation Corporation Limited)

## National Load Despatch Centre (NLDC)

# Procedure

# for

# Carrying Out Reactive Power Capability Testing of

# Synchronous generators

***Prepared in Compliance***

***to***

***Clause 40 (2)(c) & 40 (3)(4) of Central Electricity Regulatory Commission***
***Indian Electricity Grid Code***
***Regulations, 2023***
**August 2023**

# Contents

# <u>Procedure for carrying Out Reactive Power Capability Testing</u>

## 1. Background

1. This procedure is in accordance with clause *40 (2)(c) & 40 (3)(4)* of the Indian Electricity Grid Code, 2023 notified by the Central Electricity Regulatory Commission.

2. The procedure lays down the guidelines for performing Reactive Power Capability test and submission of reports along with model validations.

## 2. Scope

The procedure 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.
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 procedure 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

### 5.1 Procedure

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

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

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

4. Both MVAR injection (lagging pf) and absorption (leading pf) sides testing to be performed at full load and at a load just above technical minimum of the generating unit.

5. Test timings for injection/absorption has to be finalized based on past voltage profile of connected substation.

6. 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.

7. a). Lagging Reactive Capability Test While operating in a steady state mode at near rated output, raise excitation in automatic voltage control mode until one of the following conditions occurs:

   i) The 100% MVA rating of the machine is reached (reach capability curve).

   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.

Hold unit at this level for a minimum of 15 minutes (30 minutes is a preferable duration) or till the temperature stabilizes then take the measurements as per format. Repeat the test at reduced loading (MW) level.

b). Leading Reactive Capability Test While operating in a steady state mode at almost rated load, lower excitation in automatic voltage control mode 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.

Take measurements as per format.

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 listed below for ready reference during the testing.

## 5.2. Basic 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) | |

## 5.3. 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:

| S.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 | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | |

From the test results the compliance to CEA technical standards for connectivity is verified by using the extreme power factors recorded. Reaching up to 0.85 lagging power factor depends on the real time grid conditions.

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. All the recording parameters ( such as active power, Generator terminal voltage, bus voltage and reactive power)data of 1 sec resolution for the testing period to be submitted in excel format. All the from table

Generator shall arrange for the schedule required for testing in coordination with beneficiaries through RPC. If the generating unit under test trips during the testing the treatment of scheduling and DSM shall be discussed in respective RPC and finalized.

# Grid Controller of India Limited

## (Formerly Power System Operation Corporation Limited)

## National Load Despatch Centre (NLDC)

# Procedure

# for

# Carrying Out Primary Response & AGC Testing of Synchronous Generators

***Prepared in Compliance***

***to***

***Clause 40 (2)(c) & 40 (3)(4) of Central Electricity Regulatory Commission***

***Indian Electricity Grid Code***

***Regulations, 2023***

**July 2023**

# Contents

# Procedure for carrying Out Primary Response Testing

## 1. Background

1.1 This procedure is in accordance with clause *40 (2)(c) & 40 (3)(4)* of the Indian Electricity Grid Code, 2023 notified by the Central Electricity Regulatory Commission.

1.2 The procedure lays down the guidelines for performing primary frequency response test and submission of reports along with model validations.

## 2. Scope

The procedure 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.

Unquote- "*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%*"- Central Electricity Authority (Technical Standards for Connectivity to the Grid) Amendment Regulations, 2013

*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 procedure 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 Primary Response Testing

As per clause 40 (2) of IEGC 2023,

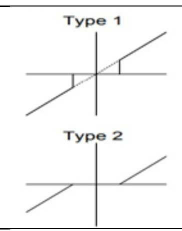
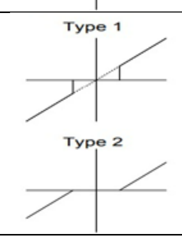
4.1. The owner of the power system element shall be responsible for carrying out tests as specified in these regulations and for submitting reports to NLDC, RLDCs, CEA and CTU for all elements and to STUs and SLDCs for intra-State elements.

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 | Capacity | MW | |
| 4 | DCS | Make | |
| 5 | Governor | Make | |
| 6 | Type | Model | |
| 7 | Pmax | MW | |
| 8 | Pmin | MW | |
| 9 | Droop | % of MCR | |
| 10 | Pressure correction-After Dead band slope implementation (Type-1 / Type-2) |  | |
| 11 | Ripple Filter-After Dead band slope implementation (Type-1 / Type-2) |  | |
| 12 | Governor Reference frequency set to 50.000 Hz | Yes/No | |

Note:- S.No 10 & 11, reference IEEE Technical report (PES-TR1)- Dynamic Models for Turbine Governors in Power System Studies.

### 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

**Below mentioned signals need to be recorded with resolution of 10Hz**

i) Simulated frequency

ii) Active power, Pgen, corresponding to turbine power

iii) FGMO Output

iv) EHTC O/P

v) Steam Pressure

vi) HPCV Opening

vii) Pressure correction

### 5.4. Calculated Droop :

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

where,

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

### 5.5. Tests to be performed:

| S.No | Load Level | Test Signal |
|---|---|---|
| 1 | Full Load & Technical Minimum (Ripple factor Test) | • -/+0.03HZ from 50 Hz |
| | | • +/-0.03HZ from 50 Hz |
| 2 | Technical Minimum | • -0.05 & +0.05 Hz from 50 Hz<br>• +0.05 & -0.05 Hz from 50 Hz |
| | | • -0.10 & +0.10 Hz from 50 Hz<br>• +0.10 & -0.10 Hz from 50 Hz |
| | | • -0.13 & +0.13 Hz from 50 Hz<br>• +0.13 & -0.13 Hz from 50 Hz |
| | | • -0.05 & +0.05 Hz from 50 Hz<br>• +0.05 & -0.05 Hz from 50 Hz |

| | | |
|---|---|---|
| **3** | **60% of MCR** | • **-0.10 & +0.10 Hz from 50 Hz**<br>• **+0.10 & -0.10 Hz from 50 Hz** |
| | | • **-0.13 & +0.13 Hz from 50 Hz**<br>• **+0.13 & -0.13 Hz from 50 Hz** |
| **4** | **75% of MCR** | • **-0.05 & +0.05 Hz from 50 Hz**<br>• **+0.05 & -0.05 Hz from 50 Hz** |
| | | • **-0.10 & +0.10 Hz from 50 Hz**<br>• **+0.10 & -0.10 Hz from 50 Hz** |
| | | • **-0.13 & +0.13 Hz from 50 Hz**<br>• **+0.13 & -0.13 Hz from 50 Hz** |
| **4** | **100% of MCR** | • **-0.05 & +0.05 Hz from 50 Hz**<br>• **+0.05 & -0.05 Hz from 50 Hz** |
| | | • **-0.10 & +0.10 Hz from 50 Hz**<br>• **+0.10 & -0.10 Hz from 50 Hz** |
| | | • **-0.13 & +0.13 Hz from 50 Hz**<br>• **+0.13 & -0.13 Hz from 50 Hz** |

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

### 5.6. Tests result Analysis:

Analysis for Ripple filter test, test below 50 Hz & test above 50 Hz 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 | Droop (%) Actual implemented droop | Droop (%) Calculated** at $t_0$+45 seconds | Droop (%) Calculated at $t_0$+100 seconds |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |

### 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 need to be validated with the test response of the machines.

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

**5.8. Conclusion & Recommendations:**

a. On site observations during the test.

b. Model validation need to be done for ripple filter test, below 50 Hz, above 50 Hz

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

**2.** Simulate communication failure and check if Plant DeltaP analog becomes zero
   - **a.** Power plant to create simulated communication failure (remove cable etc.)
   - **b.** Power plant to correct the logic if DeltaP analog does not become zero
   - **c.** NLDC to create simulated communication failure.
   - **d.** Power plant to 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 to create simulated AGC Suspend state
   - **b.** Power Plant to correct the logic if DeltaP analog does not become zero.

4. 4. Toggle AGC from Remote to Local status and check if Plant DeltaP analog becomes zero.
   - **a.** Power Plant to create simulated Local and Remote states
   - **b.** NLDC to concur change in Local and Remote states.
   - **c.** Power Plant to correct the logic if DeltaP analog does not become zero during Local state

**5.** Setup unit capability limits. For thermal plants, default limits shall be max = Units gross DC on bar. Min = 55% Max. Setup distribution factors. Default = (1/units on bar). For hydro plants P1 (min), P2 -P3 (forbidden zone) and P4 (max) may be checked.
   - **a.** Power plant to test using maximum limit less than unit set point.

        i. NLDC to check corresponding variation in DeltaP feedback signals
    b. Power plant to test using minimum limit more than unit set point.
        i. NLDC to check corresponding variation in DeltaP feedback signals
    c. Change distribution factors and check if same is reflecting in NLDC.
6. NLDC to 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.
9. Account data verification (1-week process)
   Understand the account data format circulated to plants from NLDC.
   5 min MWh, 15 min MWh data may be sent to NLDC over email on daily basis for one week
   NLDC to verify that the account data archived at NLDC and received through mail from power plant are matching. Revert to power plant for corrections if needed.
   Maintain max and min limits in unit DCS. Important before closed loop operation from plant safety perspective.

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. To familiarize the power plants with the real time operations, code exchange drill can also be conducted. Dummy AGC accounts may be generated by both power plant (as per LDC format) and LDC. In case of any discrepancy, suitable actions like precision adjustment at power plant may be taken up.

**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-NLDC & Power plant
2. Maximum allowed variation above or below RULSP shall be set at 50 MW per power plant-NLDC
3. Maintain units in 'Local' mode -Power plant
4. Inform RLDCs before the start of the test-NLDC

5. Alert ULDC / POWERGRID for ensuring uninterrupted communication ULDC, NLDC and Power plant.
6. Exchange od 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-NLDC & Power plant
8. In case of any abnormal behaviour by AGC, the power plant is free to take the into 'Local' without intimation. However, code may be exchanged subsequently with units 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.

**7. Revision of Procedure**

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

# Grid Controller of India Limited
## (formerly Power System Operation Corporation Limited)
## National Load Despatch Centre (NLDC)

# Procedure

# for

# Power System Stabilizer(PSS) Testing

*Prepared in Compliance*

*to*

*Clause 40(2)(c) & 40(3) of Central Electricity Regulatory Commission*
*Indian Electricity Grid Code*
*Regulations, 2023*

**July 2023**

# Contents

## 1. Background

This procedure lays down the guidelines for data submission and testing of the Power system stabilisers (PSS).

## 2. Scope

The procedure shall apply to all generating stations, State Load Despatch Centres (SLDCs), Regional Load Despatch Centres (RLDCs), National Load Despatch Centre (NLDC).

## 3. Definitions

Words and expressions used in this procedure 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

***Quote*** ‘‘

***Regulation 29(6)***

*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.*

***Regulation 29(8)***

*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.*

*’’ Unquote*

## 5. Responsibilities for Conducting Primary Response Testing:-

As per clause 40 (2) of IEGC 2023,

- 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.
- 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.
- 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

## 6. Modelling of power plant before performing PSS Testing

- The SMIB approach may be used for modelling and conducting the studies of PSS along-with the Excitation system in a RMS Simulation software.
- To account for varying network conditions at the generator bus, the equivalent reactance of the transmission line to the infinite bus to be varied and checked.
- The Developed Generator+ Excitation system + PSS Model needs to be validated, before using the tuning results from the model
- Inputs from plant to be taken as per the data format at Annexure-1 and Single Machine Infinite Bus Model( The SMIB is to be developed using IEEE Models, if User Defined Model(UDM) are considered, source code of UDM to be shared) is to be prepared and suitable tests shall be carried out on this model
- Model Validation may be done by validation of the local mode of frequency during the step test.

## 7. Tests to be performed in the site

Before performing the actual PSS testing on the generator at any given loading, the already existing PSS set parameters of the generator shall be verified with the simulated parameters as mentioned in previous section. If there is huge variation of the parameters, then it is suggested to tune the parameters accordingly with the simulated parameters. Once the initial set of tuned parameters are incorporated in to the actual PSS settings, a preliminary ± 2% AVR step test may be performed on the generator. After conforming the non-existence of the abnormal behavior of the generator, the parameters shall be finalized in to the PSS for performing the suggested tests as mentioned in the procedure

During the PSS Testing, it is recommended to record the following signals

a. Real Power
b. Field Current
c. PSS Output
d. Field Voltage
e. Reactive current
f. Generator Voltage

In case of non-availability of the 6 channel recorder the following 4 signals (can be recorder if a 4 channel recorder is used) have been prioritized and the same to be presented for test results

a. Real Power
b. Field Current
c. PSS Output
d. Field Voltage

A graphical comparison of the $P_{Out}$ with the PSS OUT and PSS IN shall be attached as per the Annexure-2 for both the channels.

### A. PSS Gain Margin Test

After setting the tuned parameters in the PSS, the gain margin test should be performed by increasing the gain step-by- step gradually, without applying step signal until one of the output signals(Real becomes osciallatory hunted. (e.g., for a typical system suppose at approximately 20 p.u. of the gain, the MW and field voltage is found to be hunting then, the maximum gain should tentatively be considered as 7 p.u.). The final value of gain should be selected after checking the response in the next test.

B. **AVR Step response test with Partial and Full Load (After Tuning):** The step change is given to Vref of AVR and the machines performance ( Real Power Oscillation time duration & Magnitude) with PSS in-service against PSS out-service is to be checked.

| | | | | |
|---|---|---|---|---|
| Step Response Test | Channel 1 &2 | ± 2-3% Step | PSS-ON | Around Technical Minimum Load |
| | | | PSS-OFF | |
| | | | PSS-ON | 80 % - MCR Loading |
| | | | PSS-OFF | |
| | Channel 1 &2 | ± 5% Step | PSS-ON | Around Technical Minimum Load |
| | | | PSS-OFF | |
| | | | PSS-ON | 80 % - MCR Loading |
| | | | PSS-OFF | |

**C. Actual Disturbance test**

This 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.

**Brushless Excitation System:** PSS performance of brushless exciters is not evident when compared to the PSS performance of static excitation system and there was no discernible improvement observed with PSS On against PSS Off. Thus in general the following test may be done for all Machines

i. The Tripping of any transmission line connected to the generating station may be done to simulate the effect of change in Vref.
ii. The above test would provide the disturbance in the stator side and the PSS response would be checked rather than the change in Vref by imbibing the step change in Field voltage.
iii. During this test, if possible the PSS at other machines (if any) also may be kept off.

D. **Impulse Test**

Complimentary to the Disturbance Test, the impulse test is to be done this test is analogous to the various disturbances the machine experiences. A low magnitude impulse signal super-imposed over the AVR reference set-point needs to be given for the generator and machine behavior to be checked with and without PSS

E. **Validation of PSS Performance during Under-Excitation/Over-Excitation**: The Step Response Test needs to be done at MCR with maximum leading/lagging reactive power output as per the capability curve and machine is excited until the Over Excitation Limiter/ Under Excitation Limiter becomes active. This is to be checked for the inter-action of the PSS with OEL/UEL.

## 8. Precautions to be taken while performing the PSS tuning

- The test should be stopped when the large deviation is observed in simulated and actual response.
- Any Test should be immediately stopped when growing/sustained oscillation is observed in the parameters of the generator.
- Both Step Up and Step Down tests needs to be carried out.
- Step up to be followed by Step down with a time gap of 20 sec, if taken up, simultaneously.

## 9. Periodicity of the PSS Tuning

A. At least once every five (5) years
B. Based on operational feedback provided by the RLDC after analysis of a grid event or disturbance
C. In case of major network changes or fault level changes near the generating station as reported by NLDC or RLDC(s), as the case may be
D. In case of a major change in the excitation system of the generating station

## 10. Contents of the PSS Tuning Report

The PSS Tuning Report should be able to demonstrate the following and should include:

- Improved damping for
    a. Step change in voltage from 2% -5%.
    b. Tuned for Frequency band 0.02 Hz – 4 Hz.
    c. Reduction in No. of Cycles of Oscillation
- No appreciable instability at 3 times proposed gain.
- Improved Damping under variable system operating condition (Real and Reactive Power and Terminal voltage) and network.
- Procedure adopted for simulation model validation after PSS Tuning.
- Changes made on filed during the PSS tuning Activity.
- Proposed changes / suggestions for the PSS
- Static details of the generator like OCC, SCC characteristics, P-Q capability curves, datasheets of the turbine and governor.
- Damping torque calculation shall be submitted as per the procedure shown in the Annexure-3.
- Make, Model, transfer function - IEEE equivalent models along-with the final Implemented settings of
    i. Generator
    ii. Excitation system
    iii. PSS
    iv. Governor

# Grid Controller of India Limited

## (Formerly Power System Operation Corporation Limited)

## National Load Despatch Centre (NLDC)

# Procedure

# for

# Carrying Out Power Plant Controller Functionality Testing

***Prepared in Compliance***

***to***

***Clause 40 (2)(c) & 40 (3)(4) of Central Electricity Regulatory Commission***
***Indian Electricity Grid Code***
***Regulations, 2023***

**August 2023**

# Contents

# Procedure for carrying Power Plant Controller Function Testing

## 1. Background

1.1 This procedure is in accordance with clause *40 (2)(c) & 40 (3)(4)* of the Indian Electricity Grid Code, 2023 notified by the Central Electricity Regulatory Commission.

1.2 The procedure lays down the guidelines for performing Power Plant Controller Function Test including active, reactive set point change, frequency response testing and submission of reports along with model validations.

## 2. Scope

The procedure 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 procedure 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,

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.

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.

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 PV Inverter/ WTG details

| | | | |
|---|---|---|---|
| 1 | Power plant name | Name | |
| 2 | WTG/ PV Inverter | Make & Model | |
| 3 | Plant Installed Capacity | MW | |
| 4 | Plant Peak Capacity | MW | |
| 5 | Master PPC | Make | |
| 6 | 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 a generation level as mentioned in the test procedure. However if the weather conditions are conducive for conducting the tests at the maximum generation level as specified for each test during commissioning phase, tests may be carried at available generation level. Subsequently the developer has to carryout the tests at more than 70% generation level and submit the reports within one year after plant commissioning.

For each test 1sec data of all the recording parameters shall be shared in excel/csv format along with relevant graphs showing the compliance. Passing criteria for each test shall be the compliance to CEA connectivity standards and reaching the set points provided.

#### 5.3.1 Inverter communication test

This test will be carried out through IP ping test for all the inverters. The inverters IP addresses will be pinged from the PPC server. The ping response time will be recorded and it shall be less than the expected time. The status of commands writing and reading also to be checked.

| Inverter Number | Inverter 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 complying to 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 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 disable.
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 disable.
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) | Frequenct at the time of set pont 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

| 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 be performed during no generation period.

#### 5.3.5.a Fixed Q-control mode

i) When 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) 20%,50%,100% of maximum Reactive power at the point of interconnection at full generation and 50% of full generation.

b) -25%, -50%, -100% of maximum Reactive power at the point of interconnection at full generation and 50% of full generation.

This test is to be carried out at maximum available generation at the time of testing (shall not be less than 70% of rated capacity) and 50% of rated capacity. Q Set point test of 100% shall be carried out based on the grid voltage with prior permission of RLDC/SLDC as the case may be.

| 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 active power generation 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 set-point during no generation period (For PV inverters during night time and for WTGs no wind period). The following set-point changes 0%, 50%, 100%, -50% & -100% of maximum Reactive power at the point of connection. The testing steps may vary 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 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 droop and dead band of voltage control mode to be submitted. 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 and tabulate the results 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)** | **Start Time** | **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 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 reactive powers needs to be recorded. *"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 RLDC/SLDC | Same Set point received at Site (Yes/No) | Starting generation (MW) | End Generation (MW) | Time taken (Sec) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

| Sl.No | Reactive power Set Point sent from RLDC/SLDC | Same Set point received at Site (Yes/No) | Starting MVAR | End MVAR | Time taken (Sec) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

### 5.3.7 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. In order to check whether the secondary PPC is able to control the plant. This can be validated by changing the setpoints from UI.

3.Remove the communication cable to PPC and check the plant active power and reactive power at POI. 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 (MW) | Active power (MW) | Reactive power (MW) | Reactive power | Remarks |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| | before PPC failure | after PPC failure | before PPC failure | (MW) after PPC failure | |
| | | | | | |
| | | | | | |
| | | | | | |

## 5.4 Model Validation

a. The plant model submitted by the developer shall be validated with the test results and validation report with appropriate plot showing the validation to be submitted.

## 5.5 Data submission

5.5.1 All the recording parameters for each test shall be submitted in csv/excel format with 1 sec resolution (or lesser) for testing period and 5 minutes before & after the testing.

5.5.2 Test report covering all the tests performed, recording tables, relevant plots and conclusion on the compliance to CEA technical standards to Connectivity as applicable.

## 5.5 Conclusion & Recommendations

a. Observations on the field testing of PPC

b. Observations model validation with respect to the field testing

c. Recommendations

# Grid Controller of India Limited

## (Formerly Power System Operation Corporation Limited)

## National Load Despatch Centre (NLDC)

# Procedure

# for

# Carrying Out HVDC/FACTS devices Testing

***Prepared in Compliance***

***to***

***Clause 40 (2)(c) & 40 (3)(4) of Central Electricity Regulatory Commission***
***Indian Electricity Grid Code***
***Regulations, 2023***

**July 2023**

# Contents

# Procedure for carrying HVDC/FACTS devices Testing

## 1. Background

1.1 This procedure is in accordance with clause *40 (2)(c) & 40 (3)(4)* of the Indian Electricity Grid Code, 2023 notified by the Central Electricity Regulatory Commission.

1.2 The procedure lays down the guidelines for performing HVDC/FACTS devices testing including Reactive Power Controller (RPC) Capability for HVDC/FACTS, Filter bank adequacy assessment, Validation of response by FACTS devices as per settings and submission of reports along with model validations.

## 2. Scope

The procedure 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 procedure 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,

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 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 AC bus voltage control by RPC ( U control)

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:**

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

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

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

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's 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 (manual as well as auto):**

| Set Point MW | Active power (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 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

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 | Active power (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 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

### 5.2 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.

### 5.3 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 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 specified limits in the continuous operating mode, 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.

ii) If the FACTS device installation is intended to control the system voltage, the slope characteristic 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 Vref, 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.

### 5.4 Model Validation

The plant model submitted by the developer shall be validated with the test results and validation report with appropriate plot showing the validation to be submitted.

### 5.5 Conclusion & Recommendations

i) Observations on the testing of HVDC/FACTS

ii) Observations model validation with respect to the field testing

iii) Recommendations

## 6. Revision of Procedure

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