

## **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  $\pm 10\%$  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  $\pm 0.03$  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<br>Set Point sent<br>from RLDC/SLDC | Set point received<br>at Site (Yes/No) | Initial<br>MVAR | Final<br>MVAR | Time<br>taken<br>(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<br>power | Active<br>power | Reactive<br>power | Reactive<br>power | Remarks |
|--------|-----------------|-----------------|-------------------|-------------------|---------|
|--------|-----------------|-----------------|-------------------|-------------------|---------|

|  | (MW)<br>before<br>PPC<br>failure | (MW)<br>after PPC<br>failure | (MW)<br>before PPC<br>failure | (MW) after<br>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.