TRANSMISSION SYSTEM STANDARD
SUPPORTING DOCUMENT

Bonneville
POWER ADMINISTRATION

Required Voltage and Frequency Control Performance Commissioning Tests
STD-N-000001 Number 01 REVISION 00

Standard/Technical Content Owner: TPP

DISTRIBUTION STATEMENT: Approved for public release

DESCRIPTION:

This document is a supporting document to the BPA STD-N-000001, Technical Requirements for Interconnection to the BPA Grid. It details the commission tests of electrical performance that are required for generators to be given clearance for commercial operation. This document is not a comprehensive list of technical requirements, nor a comprehensive list of required commissioning tests (See BPA STD-N-000001 and STD-N-000002). This document's content does not address contractual topics or requirements.

Questions should be directed to applicable BPA Customer Service Engineer or Transmission Account Executive.

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REVISION HISTORY

- Revision 00 (Current Revision), 2/18/2021

1. TEST MEASUREMENTS

The commissioning tests below require measurements to be taken in accordance with Figure 1, which assumes interconnection to transmission facilities at a 230 kV bus.

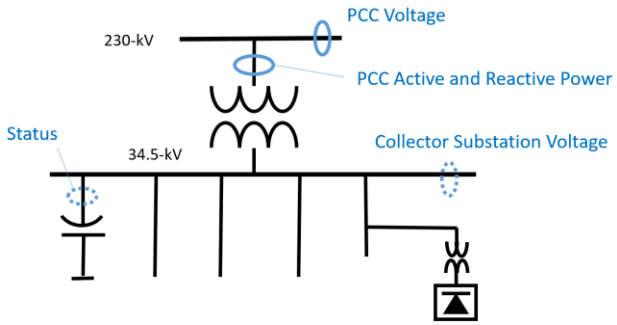


Figure 1.---Test measurement points

Output of solar and wind power plants may vary during the test period due to wind and cloud cover variability respectively. Therefore, BPA recommends the tests be performed several times to attain measurement consistency.

The generator operator shall provide the following test recordings (refer to Figure 1,

Figure 2, Figure 3, Figure 5, Figure 6**Error! Reference source not found.Error! Reference source not found.**) for each test:

- Time (sub-second resolution)
- High side Point of Common Coupling (PCC) voltage (per unit of nominal PCC voltage)
- PCC active and reactive power (MW and Mvar)
- (Optional) collector system voltage in per unit (e.g. of 34.5 kV voltage)
- (Optional) status of collector system capacitor and reactor banks

General Test Conditions:

- Unless otherwise specified, the plant output power must be above 20% active power. Headroom (between power production and prevailing maximum power) is required to observe response during some tests (e.g. under-frequency step test). These requirements must be met throughout the duration of the testing period.
- Before initiating a test, notify BPA Transmission Customer Service Engineer and/or Transmission Account Executive.

2. REQUIRED TESTS FOR POWER PLANT VOLTAGE CONTROLS

2.1 Requirement R1:

BPA requires:

- The power plant shall operate in continuous voltage control mode.
- The voltage control shall have no dead-band.
- The power plant shall demonstrate effective reactive power droop of 7 to 12% (effective droop could be different from the actual controller droop or slope settings, example of effective droop calculation is shown below).
- Required reactive power rise time is less than 5 seconds (see explanation below).
- The power plant voltage controller shall coordinate control of all plant level shunt capacitors and reactors where they are required by interconnection requirements.
- The requirement on reactive droop applies at the Point of Common Coupling (PCC).
- The generator operator shall report the bus selected as voltage reference for voltage control. The generator operator shall report the line compensation settings.

2.1.1 *Required Inspection of Voltage Controller Settings:*

The generator operator shall:

- Prioritize safety of personnel and equipment.
- Confirm that the plant-level voltage control mode is enabled.
- Confirm that the plant-level voltage controller has no dead-band.
- Confirm that the plant level voltage controller has module enabled that coordinates switching of plant-level shunt capacitors and reactors were applicable.
- Record reactive droop or slope setting in the voltage controller.
    - Note that the droop / slope software setting my not be the same as the effective reactive droop described above. Some manufacturers define droop on plant reactive capability, while BPA is asking for effective droop
- Notify BPA Transmission Customer Service Engineer and/or Account Executive prior to initiating the test.
- Check that system voltages are normal and determine the direction of the voltage step. Typically, BPA has high voltages meaning the 3% voltage step needs to be in the downward direction.
- Check the plant reactive capability in the control software. Ensure that the plant response is not limited by the stated reactive capability.

2.2 Required Test T1:

The generator operator shall perform a 3% voltage reference step for at least 60 seconds to demonstrate that the plant meets the voltage control requirement. A 2% voltage step may be used in weaker transmission networks. Ensure that the plant does not reach its full reactive capabilities during the step test.

Reactive Droop Calculation and Rise Time Confirmation:

1. Confirm reactive power droop value by tabulating your test data similar to Table 1.

Table 1.— Reactive Power Droop Calculation Example

Description / Variable Name	Initial	@ 5[s]	@ 30[s]	Delta (Δ)
Input Voltage Step (PU) / $V_{step,\ pu}$	N/A	N/A	N/A	-0.03
PCC Voltage V (PU of 230 kV) / V_{pu}	1.045		1.033	-0.012
Plant PCC Reactive Power Q (Mvar) / Q_{MVAR}	-5	-28	-30	-25
MW Base / MW_{base}	125	125	125	125
Droop				**0.09**
Change in Q within Rise Time as a % of total change	0	-23	-25	**92%**

$$Reactive\ Droop\ =\ -(V_{step,\ pu} - \Delta V_{pu})\ /\ (\Delta Q_{MVAR}\ /\ MW_{base})$$

Example: 125 MW wind power plant

A 3% voltage step down test resulted in a 1.2% voltage decrease and -25 Mvar reactive power change (export decreased) at the PCC.

Reactive Droop = $(-(0.03 - 0.012)) / (-25 / 125) = 0.09, or\ 9\%$

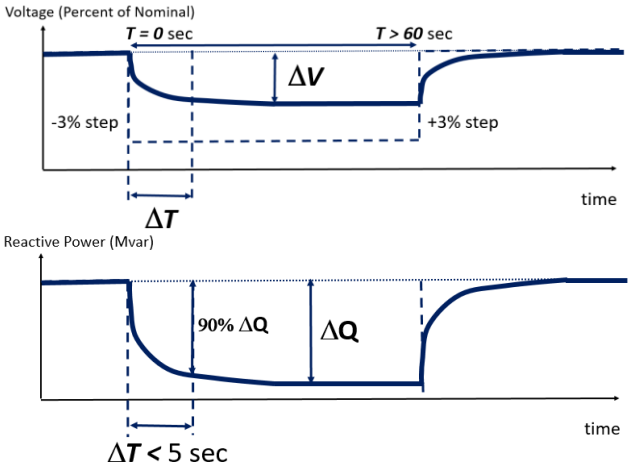
2. Confirm Sufficient Response During Rise Time

The power plant reactive power decreases by 23 Mvar within 5[s] after the voltage step and 25 Mvar within 30[s].

Percent change $= 23/25 * 100\% = 92\%$ *exceeds the 90% definitional to rise time. Thus the plant passes the test.*

2.2.1 *Test recordings:*

Provide comma-separated values (.csv) file with the test recordings: time (seconds), PCC voltage (kV or per unit), active power (MW), reactive power (Mvar), 34.5 kV voltage (kV or per unit), shunt capacitor and reactor Mvars to BPA Transmission Customer Service Engineer and/or Account Executive. Please also specify the PCC by bus name in the communications that contain the .csv file.



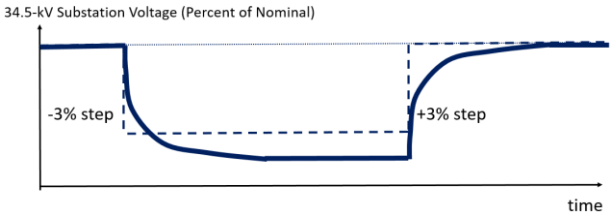


Figure 2.--- Generic Test Recordings for the Voltage Step Test

3. REQUIRED TESTS FOR POWER PLANT VOLTAGE CONTROL AT LOW ACTIVE POWER

3.1 Requirement R2:

BPA requires:

- The plant must be able to absorb (at the PCC) Mvars greater than or equal to 33% of the maximum active power rating of the plant or other amount as required by BPA interconnection studies.

3.1.1 *Required inspection of voltage controller settings:*

- See requirement R1 of this document.

3.2 Required Test T2a:

The generator operator shall:

- Prioritize safety of personnel and equipment.
- Curtail the active power output of the power plant to 0% of the MW rating of the plant. The plant should enter NightVAR Mode or WindFree mode if applicable.
- The generator operator shall perform steps in the voltage reference in the downward direction. The steps shall be performed 0.5% at a time with at least 20 seconds between each step. The first step may be similar to that of Required Test T1.
- The steps shall stop when any plant equipment applicable rating exceedance is imminent or the reactive capability of the plant does not change with an additional step for at least 20 seconds, whichever comes first.
- Notify BPA Transmission Customer Service Engineer and/or Account Executive prior to initiating the test.

Reactive Capability Calculation:

1. Calculate reactive capability at low active power output by tabulating test data similar to Table 2.

Table 2.— Reactive Capability Calculation Example

Description / Variable Name	Final
Cumulative Input Voltage Reference Step (PU) / $V_{step,\ pu}$	4%
MW Base / MW_{base}	125
Reactive Power Absorbed at PCC (Mvar) / Q_{min}	47
PCC Voltage at the time of recording Q_{min} / V_{pu}	1.034

Plant PCC Reactive Power Q (%) / Q_pu	**37.6%**

Reactive Capability at Low Power Output $= Q_{min}/MW_{base} * 100$

Example: 125 MW wind power plant

The plant is producing 0 MW and 0 Mvar. Then a 2% voltage step down, and 4 additional 0.5% steps test resulted in the plant absorbing (bucking) 47 Mvar at the PCC.

Reactive Capability at Low Power Output$= 47/125 * 100 =$ 37.6%. *This passes the test.*

3.2.1 *Test recordings T2a:*

Provide CSV file with the test recordings: time (seconds), PCC voltage (kV or per unit), active power (MW), reactive power (Mvar), 34.5 kV voltage (kV or per unit), shunt capacitor and reactor Mvars to BPA Transmission Customer Service Engineer and/or Account Executive. Please also specify the PCC by bus name in the communications that contain the .csv file.

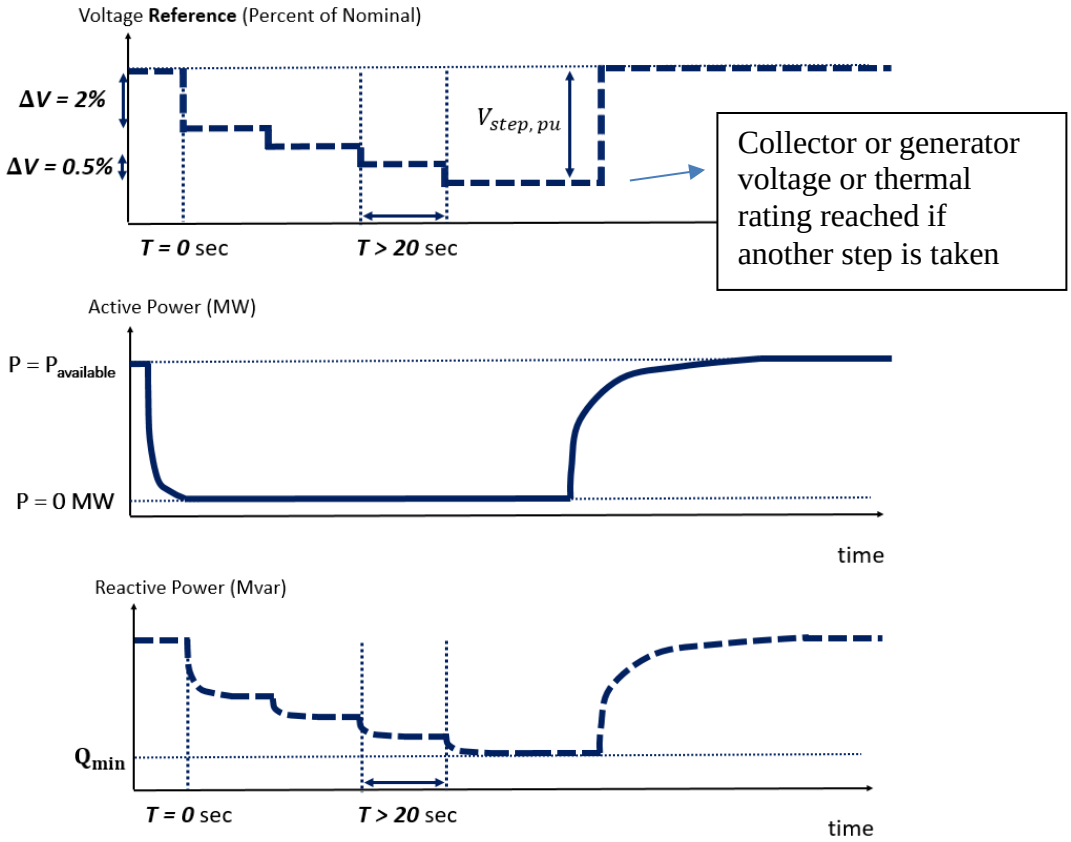


Figure 3.--- Generic Test Recordings for the Lower Active Power Reactive Capability Test

3.3 Required Test T2b:

The generator operator shall:

- Prioritize safety of personnel and equipment.
- Curtail the active power output of the power plant to 5% of the MW rating of the plant. The plant should not enter NightVAR Mode or WindFree mode.

- Follow remaining procedures from Required Test T2a.

3.3.1 *Test recordings T2b:*

Provide CSV file with the test recordings: time (seconds), PCC voltage (kV or per unit), active power (MW), reactive power (Mvar), 34.5 kV voltage (kV or per unit), shunt capacitor and reactor Mvars to BPA Transmission Customer Service Engineer and/or Account Executive. Please also specify the PCC by bus name in the communications that contain the .csv file.

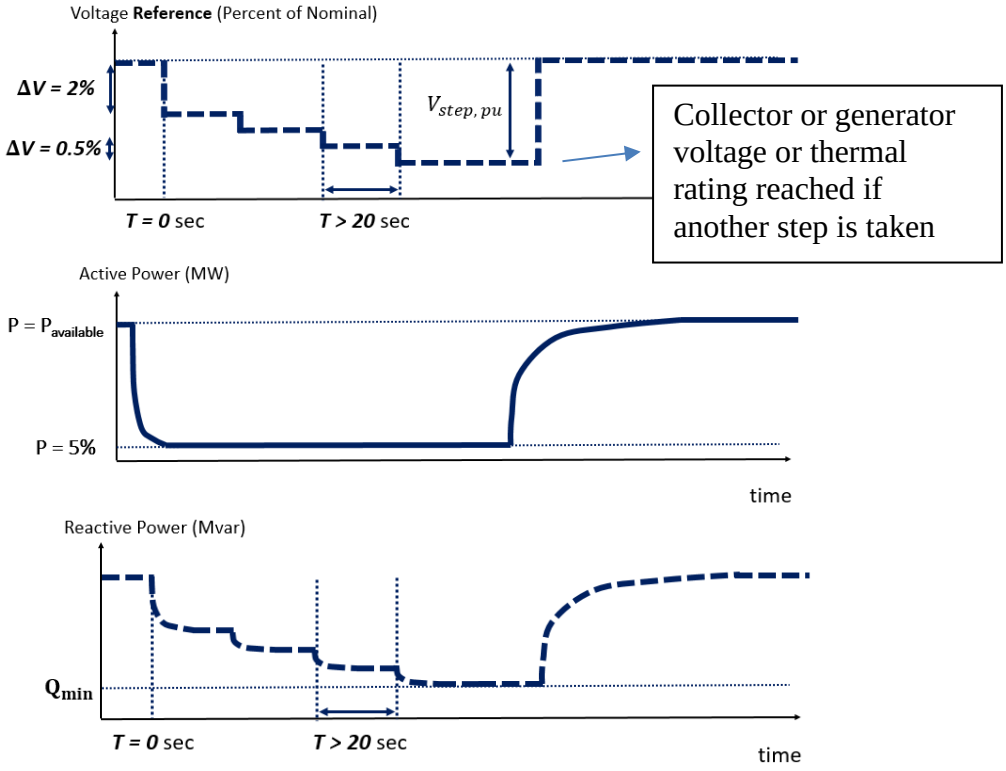


Figure 4.--- Generic Test Recordings for the Lower Active Power Reactive Capability Test

4. REQUIRED TESTS FOR POWER PLANT FREQUENCY CONTROLS

4.1 Requirement R3:

BPA requires:

- The plant shall be capable of providing autonomous primary frequency response.
- The plant shall have plant-level frequency controller module installed and enabled.
- The frequency controller shall provide frequency response in accordance with droop between 3% and 5% (inclusive).
- The requirements on active droop apply at the PCC.
- The frequency controller may have a frequency dead-band. The frequency dead-band shall be less than or equal to +/- 0.06% (of 60 Hz, i.e. 36 mHz).

- The frequency controller shall provide 90% of active power response to step change in frequency measurement in less than 5 seconds. If you believe this is not possible for your preferred technology, consult your BPA Transmission Customer Service Engineer and/or Account Executive.
- The plant response shall be sustained for the duration of frequency events.

4.1.1 *Required Inspection of Frequency Control Settings:*

The generator operator shall:

- Prioritize safety of personnel and equipment.
- Confirm that within the frequency controller software the droop setting does not exceed the maximum allowable droop setting.
- Confirm that the frequency dead-band is less or equal to +/-0.06% (+/-36 mHz) in the frequency controller software.
- Provide droop and dead-band settings in the frequency controller software to BPA Transmission Customer Service Engineer and/or Account Executive. BPA recommends submission of a screenshot or photo if possible.
- Notify BPA Transmission Customer Service Engineer and/or Account Executive prior to initiating the test.

4.2 Required Test T3a:

The generator operator shall:

- Conduct a 1% (600 mHz) step to the measured frequency in upward direction for at least 60 seconds simulating an over-frequency event (see Figure 5**Error! Reference source not found.**).

Active Power Droop Calculation and Rise Time Calculation:

1. Confirm active power droop value by populating a similar table with your test data.

Table 3.— Active Power Droop Calculation Example

Description / Variable Name	Initial t=t_0=0[s]	t = 5[s]	t = 30[s]	Delta
Frequency Step (MW) / $-F_{step,pu}$	N/A	N/A	N/A	0.01
Plant PCC Active Power (MW) / P_{MW}	90	70	68	-22
MW Base / MW_{base}	125	125	125	125
Droop				**0.0568**
MW Change within Rise Time as a % of total change	0	20	22	**90.9%**

$$Active\ Droop\ = \left(-F_{step,pu}\right) / \left(\frac{\left[P_{t=30[s],MW}\right]-\left[P_{t=0[s],MW}\right]}{MW_{base}}\right)$$

Example: 125 MW wind power plant

A 125 MW wind power plant was operating at 90 MW on average prior to the step in frequency setpoint. Following the 1% step in frequency setpoint, the plant MW output reduced to 68 MW on average (at $t_0 + 30[s]$*).*
$Active\ Droop = -0.01 / \left(\frac{68-90}{125}\right) = 5.68\%$*, which is within the test accuracy accounting for generation variability*

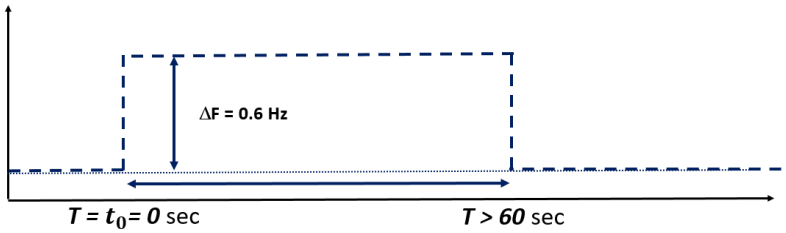
2. Confirm sufficient response during rise time

The plant had achieved 20 MW change within the first 5[s] of the frequency step and 22MW in 30[s].
Change during allowable Rise Time window: 20/22 = 90.9%, which exceeds the 90% definitional to rise time, and thus the plant passes the test.

Test Recordings T3a:

Provide CSV file with the test recordings: time (seconds), PCC voltage (kV or per unit), active power (MW), reactive power (Mvar), 34.5 kV voltage (kV or per unit), shunt capacitor and reactor Mvars to BPA Transmission Customer Service Engineer and/or Account Executive. Please also specify the PCC by bus name in the communications that contain the .csv file.

Frequency Setpoint (Hz):



Active Power (MW):

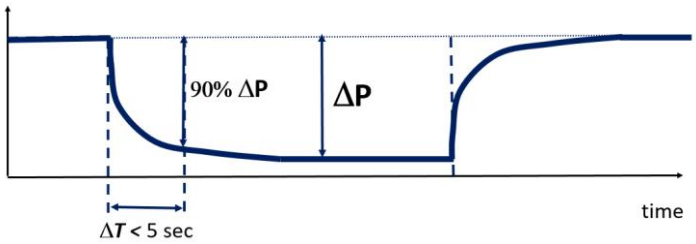


Figure 5. Generic Test Recordings for the Over-frequency Step Test

4.3 Required Test T3b:

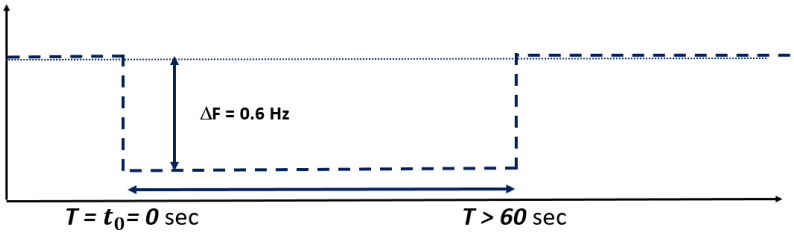
The generator operator shall conduct a 1% (600 mHz) step to the measured frequency in the downward direction for at least 60 seconds simulating an under-frequency event (see Figure 6**Error! Reference source not found.**).

Example: 125 MW wind power plant (see Required Test T3a:)

4.3.1 *Test Recordings T3b:*

Provide CSV file with the test recordings: time (seconds), PCC voltage (kV or per unit), active power (MW), reactive power (Mvar), 34.5 kV voltage (kV or per unit), shunt capacitor and reactor Mvars to BPA Transmission Customer Service Engineer and/or Account Executive.

Frequency Setpoint (Hz):



Active Power (MW):

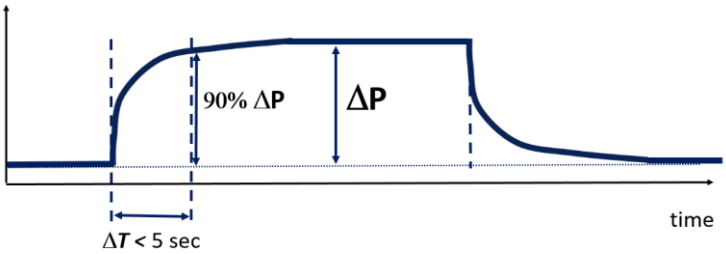


Figure 6. Generic Test Recordings for the Under-Frequency Step Test

5. REFERENCES

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