Little Goose Dam Units 1-6

Model Validation Plan

Preliminary Draft

This test procedure was written for the model validation testing of the generators, exciters, and governors for Units 1-6 at the Little Goose Dam located on the Snake River. The testing at Little Goose Dam is to occur on the week of September 26th-30th of 2011.

Units 1-3 have a GE static excitation system with a power system stabilizer included. They also all have Pelton mechanical cabinet actuator governors. Units 4-6 also feature a static excitation system with a power system stabilizer. They have Woodward electro-hydraulic governors.

Ramping Rates

Ramping rates for transitioning between power levels throughout the entire testing process can be at a rate determined by the Corps. The only times that the active power levels and gate position will quickly change are in the governor tests where the timing of the gate responses are critical. These are in test procedures #22, 23, and 24. If the ramping rates specified by the Corps are much slower then what HDR is accustomed to, then time may need to be added to the estimated duration of each test.

Reference Documents

- General Electric PSS circuit drawings # 44C306563, 44C306565, 44C306567

Setup and Setting Documentation

1. **Connection Details:**
   With the unit shutdown, place the data acquisition (DAQ) system and laptop on a work table, route instrumentation cables to various transducers. Anticipated connection details include the following:

   a. Terminal Voltage
      i. The terminal voltage will be monitored via the secondary winding of the generator potential transformers. The connection to the secondary voltage will be made at the test switch.
   b. Terminal Current
      i. The terminal current will be monitored via the secondary winding on the current transformers. The connection to the current transformer's secondary circuit will be with test plugs inserted into the FT-1 test switches.
   c. Field Voltage
      i. The field voltage will be measured directly from the excitation cabinet field voltage meter.

d. Field Current
   i. The field current will be measured from the excitation cabinet field current meter. The field current meter is connected across a 1500A/100 mV shunt.

e. Gate Position
   i. The gate position will be measured with linear position transducers that will be installed in the governor cabinet on the restoring cable.

f. Servo Position
   i. The servo position will be measured with linear position transducers that will be installed in the governor cabinet on the pilot valve restoring linkage.

g. Rotor Angle
   i. The rotor angle position will be measured with a rotor angle transducer that is installed on the generator shaft.

Parameter	NI-Module	Channel	DAQ Conn	Measured Location	Comments
VT-Phase 1	9225	Ch-0	4-CC	Control Room	Connection via 120 VAC secondary of generator PTs
VT-Phase 2	9225	Ch-1	4-CC	Control Room	Connection via 120 VAC secondary of generator PTs
VT-Phase 3	9225	Ch-2	4-CC	Control Room	Connection via 120 VAC secondary of generator PTs
CT- Phase 1	9203	Ch-0	6-CC	Control Room	Connection via test plugs on ABB test switch
CT- Phase 2	9203	Ch-1	6-CC	Control Room	Connection via test plugs on ABB test switch
CT- Phase 3	9203	Ch-2	6-CC	Control Room	Connection via test plugs on ABB test switch
Gate Position	9203	Ch-3	3-CC	Governor Cabinet	Linear Position Transducer w/ 4-20 mA output
Field Current	9203	Ch-4	3-CC	Exciter	Phoenix Signal Conditioner w/ 4-20 mA output
Field Voltage	9203	Ch-5	3-CC	Exciter	Voltage Transducer w/ 4-20 mA output
Rotor Angle	9203	Ch-6	3-CC	Generator Shaft	Rotor Angle Transducer w/ 4-20 mA output
Pilot Servo Positon	9203	Ch-7	3-CC	Governor Cabinet	Linear Position Transducer w/ 4-20 mA output

2. Transducer Calibration (Estimated Time: 30 minutes)

a. Field Voltage
   i. To determine the linear scale for the field voltage transducer, carefully measure two separate readings for the field voltage.

mA	Vdc

   ii. From the above readings, calculate and record the slope and offset for the equation Y=mX+b, where Y is the field voltage in DC volts, m is the slope, X is the field voltage transducer measurement in mA, and b is the offset.

m:_______________

b:________________

b. Field Current
   i. To determine the linear scale for the field current transducer, carefully measure two separate readings for the field current.

mA	Amps

ii. From the above readings, calculate and record the slope and offset for the equation Y=mX+b, where Y is the field current in amps, m is the slope, X is the field current transducer measurement in mA, and b is the offset.

m:_______________

b:________________

3. Identify the over and under-excitation protection.

4. **Identify the Volts/Hz Limiter and Protection**

5. **Identify the Excitation Limits:**
    a. Under Excitation Limiter (UEL):____
    b. Over Excitation Limiter (OEL): ____

Generator Tests

6. **Steady State Impedance Measurements (not required for sister units) (Estimated time: 45-60 minutes)**
    a. With the unit online and at the output settings shown in the steady state measurement table on **Table 6-1**, record parameters indicated. Allow up to 2-3 minutes between each measurement to allow all parameters to reach steady state.
    b. For stable, reliable results turn off the GDAC system so the voltage is not being adjusted throughout the test.

Table 6-1

Hydro Generator Steady State Impedance Estimation Test

Rated MVA		**1.0 pu Field VDC**	
Rated Volts		**1.0 pu Field ADC**	
Rated Amperes/Phase		**Angle Xdcr base mA (0 deg)**	
Plant Name		**Unit Number**	

Setpoint Requested		Actual							Bus or Transformer		
MW (pu)	MVAR (pu)	MW	MVAR	If (A)	Vf (V)	Vt (V)	It (A)	Rotor Angle	Unit ____ MVAR	Unit ____ MVAR	Unit ____ MVAR
0	-0.55										
0	-0.3										
0	-0.1										
0	0.1										
0	0.3										
0	0.55										
0.3	0.4										
0.3	0.2										
0.3	0.1										
0.3	-0.1										
0.3	-0.2										
0.3	-0.4										
0.6	-0.4										
0.6	-0.2										
0.6	-0.1										
0.6	0										
0.6	0.1										
0.6	0.2										
0.6	0.3										
0.6	0.4										
0.9	0.3										
0.9	0										
0.9	-0.3										

7. **Generator Open Circuit Saturation Test and Field Discharge Test (not required for sister units) (Estimated time: 30 minutes)**
    a. Using HDR's data acquisition equipment, record the terminal voltage, terminal current, field voltage, and field current. Start recording with the DAQ before the operator begins increasing the voltage. Do not stop recording until the field breaker has been tripped in the last step of this test.
    b. Start unit in offline, SNL condition and set AVR in Auto mode and lower voltage as low as possible. Beginning test at 0.5 per-unit is recommended. It may be necessary to defeat the minimum and maximum voltage reference set points.
    c. Operator increases voltage in steps of 0.1 per-unit. When 0.8 per unit is reached, decrease step size to about 0.05 per-unit. At each step, the field voltage, current and terminal voltages are manually recorded in **Table 7-1**.
    d. Continue recording each step until field breaker trips on overvoltage or 1.1 per-unit terminal voltage is reached.
    e. If 1.1 per-unit terminal voltage is reached, then manually trip the exciter supply breaker to initiate the field discharge test. Stop the DAQ recording when the terminal voltage has finished its decay.

Table 7-1

Terminal Voltage	Field Current	Field Voltage

8. **Zero Power Factor Load Rejection (not required for sister units) (Estimated time: 10 minutes)**
    a. The AVR should be in manual mode and, if possible, regulating on field voltage.

b. Load the unit to 0 MW and -0.6 per-unit reactive power; manually record steady-state field current and terminal voltage below.
    i. Field Current:________________
    ii. Terminal Voltage:_____________
c. Adjust the load to 0 MW and -0.4 per-unit reactive power; manually record steady-state field current and terminal voltage below.
    i. Field Current:________________
    ii. Terminal Voltage:_____________
d. Adjust the load to 0 MW and about -0.5 per-unit reactive power. NOTE: If a different initial Q0 is required, then alter steps c and d above to be 0.1 per-unit below and 0.1 per-unit above Q0, respectively.
e. Record the amount of reactive power the unit was loaded at before the unit trip:__________MVAR
f. Using HDR's data acquisition equipment, record terminal voltage, terminal current, field voltage, and field current.
g. Trip the unit circuit breaker. Continue recording until the terminal voltage reaches steady state.

9. Quadrature Axis Load Rejection (not required for sister units) (Estimated time: 10 minutes)

a. Determine the loading condition for this load rejection by using the rotor angle transducer. Vary the load until the estimated direct axis current = 0 (all current is quadrature axis). You may also review the calculations from the steady state measurements and determine the loading condition where the direct axis current is close to zero.
b. Using HDR's DAQ equipment, begin recording terminal voltage, terminal current, field voltage, and field current.
c. Record the amount of power the unit was loaded to before tripping the unit offline:
    i. Real Power: ____________ MW
    ii. Reactive Power:_______________MVAR
d. Trip the unit circuit breaker and record until the terminal voltage reaches steady state.

10. Automatic Voltage Regulator Settings (Estimated time: 15 minutes)

a. With the unit offline and operated at rated speed and rated voltage, using a DMM, record the following test points on the front of the voltage regulator card.

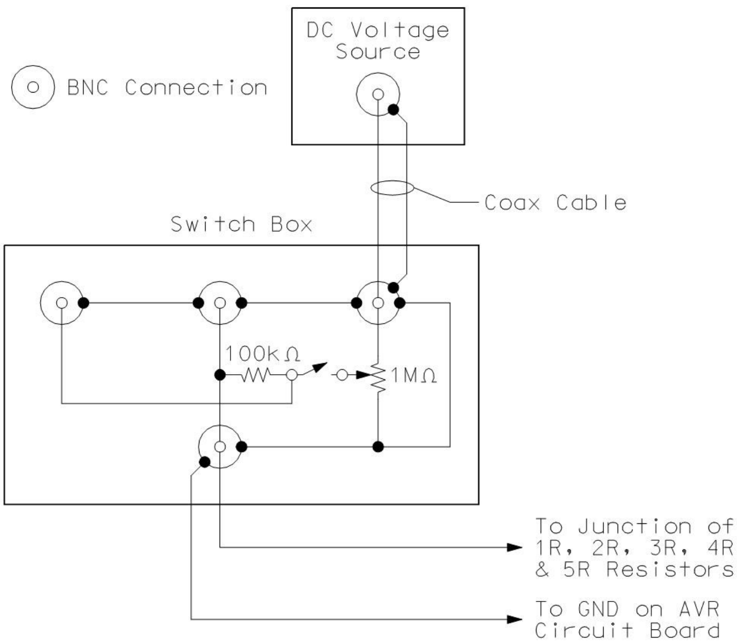
Table 10-1

Setting	Value
Test Point 3	
Test Point 4	
Test Point 5	
Test Point 6	
Test Point 7	
Test Point 8	
Test Point 9	

11. **Make AVR Connections**

a. With the unit offline and shutdown, connect a dc voltage source to a resistor switch box and the resistor switch box to the junction of resistors 1R, 2R, 3R, 4R, and 5R as seen in Figure 11-1. The ground point from the signal generator via the resistor box should be connected to the ground on the AVR circuit board.
b. The switch should be in the open configuration.
c. Set the dc voltage source to about 2 Vdc. Adjust the 1MΩ potentiometer to 100k Ω for a total resistance of 200kΩ between the dc voltage source and the AVR.
d. Verify that the DC test input produces a terminal voltage change of -1%/V.

Figure 11-1 AVR Connection Diagram



12. Closed-Loop Offline Exciter Step Response (Estimated Time: 10 minutes)

a. The unit shall be offline at speed-no-load.
b. Set the DC voltage at 2V to achieve a 2% step in terminal voltage.
c. Using HDR's DAQ equipment, begin recording terminal voltage, terminal current, field voltage, and field current.
d. Close the switch on the resistor switch box. The terminal voltage should step up about 2%.
e. As the field voltage, field current, terminal voltage, and terminal current reach a steady state value, step the terminal voltage back down to its initial value by opening the switch. Continue recording until all recorded signals have reached a steady state.

13. Closed-Loop Online Exciter Step Response (PSS Off) (Estimated Time: 10 minutes)

a. The unit shall be online at 0 MW and 0 MVAR.
b. The PSS should be off.
c. The neighboring unit's PSS should be off.
d. Using HDR's DAQ equipment, begin recording terminal voltage, terminal current, field voltage, and field current.
e. Record the amount of reactive power before and after the step response:
   i. Before Step Response: ____________ MVAR
   ii. After Step Response:______________MVAR

f. Using the same step used for offline voltage step response, close the switch to initiate a step up in the terminal voltage and continue recording.
g. As the field voltage, field current, terminal voltage, and terminal current reach a steady state value, step the terminal voltage back down to its initial value by opening the switch. Continue recording until all recorded signals have reached a steady state.

14. Closed-Loop Online Exciter Step Response (PSS On) (Estimated Time: 10 minutes)

a. The unit shall be online at 0 MW and 0 MVAR.
b. The PSS should be on.
c. The neighboring unit's PSS should be off.
d. Using HDR's DAQ equipment, begin recording terminal voltage, terminal current, field voltage, and field current.
e. Record the amount of reactive power before and after the step response:
   i. Before Step Response: ___________ MVAR
   ii. After Step Response:_____________MVAR
f. Using the same step used for offline voltage step response, close the switch to initiate a step up in the terminal voltage and continue recording.
g. As the field voltage, field current, terminal voltage, and terminal current reach a steady state value, step the terminal voltage back down to its initial value by opening the switch. Continue recording until all recorded signals have reached a steady state.

Power System Stabilizer Tests

The following tests on the power system stabilizer (PSS) should be done with the AVR in manual. The unit may be running, offline, or shutdown provided that the PSS is powered on and the AVR is in manual. **Caution:** Run the test described below in the **manual regulating mode**, so that the generator field does not respond to the test signals.

15. PSS Settings

a. Record the PSS dial settings shown in the table below.
b. See General Electric drawings # 44C306563 for Signal Conditioning Card circuit, 44C306565 for Washout and Output Card circuit, and 44C306567 for Ceiling Sensing Card circuit.

Table 15-1

	PSS Setting	As Found
Signal Condition Card	TC T2 V	
	TC T2 F	
	TC3	
	TC4	
	TC5	
Washout and Output Card	Neg. Limit	
	Pos. Limit	
	Gain K	
	TC T1	
	C1S (jumper)	
	C2S (jumper)	
	C3S (jumper)	
	C4S (jumper)	
	C5S (jumper)	
Ceiling Sensing Card	Delay	
	Pos. Limit	
	Neg. Limit	
	E1S (jumper)	

16. Frequency Transducer Card (Estimated Time: 15 minutes)

a. Connect a signal generator to the frequency transducer input and a digital multimeter to the frequency transducer output. Apply 57 Hz sine wave to the input and record the output voltage in the table below. Continue Increasing the frequency by 1 Hz and recording the output in the table below up to 63 Hz.

Table 16-1

Frequency (Hz)	Volts (DC)
57	
58	
59	
60	
61	
62	
63	

17. PSS Step Response (Estimated Time: 15 minutes)

a. See General Electric drawing # 44C306563 for Signal Conditioning Card circuit.

b. Remove Frequency Transducer card.

c. Connect a signal generator in series with a switch (in the open postion) to IN1 BNC connection on the Signal Conditioner Card also connect IN1 to the oscilloscope. Connect an oscilloscope to the OUT BNC connection on the Washout and Output Card.
d. Apply a .05 Vdc signal with the signal generator.
e. Record the input and output signals as you step up the voltage signal by closing the switch. Save the file.
f. Record the input and output signals as you step down the voltage signal by opening the switch. Save the file.

18. PSS Frequency Response (Estimated Time: 20 minutes)

a. Remove Frequency Transducer card.
b. Connect a signal generator to IN1 BNC connection on the Signal Conditioner Card also connect IN1 to the oscilloscope. Connect the OUT 1 BNC connection on the Washout and Output Card to the other channel on the oscilloscope.
c. Apply a sine-wave input from the function generator. The input amplitude, based on calculations, should be low enough so that the output does not saturate. This is very important. Start with an amplitude of 0.01 V, increasing until a good, but non-saturating signal is obtained with good signal to noise ratio. It may be necessary to use a voltage divider on the output of the signal generator. Note that you are measuring the output prior to the PSS limiter stage, so it is possible that limiter indications will occur on the PSS panel. These should not affect your measurement.
d. Perform this test at the following frequencies 0.2, 0.4, 0.8, 1.5, 3, 6, and 10 Hz. For each frequency, record the input and output and save the file.
e. Note that the gains can be quite high at certain frequencies. For example, a gain of 40 dB means the output is 10^(40/20) or 100 times the input amplitude. So, if your input is 0.01 Vpp then the output will be 1.0 Vpp. You can use a higher input signal, in the event the signal is not of high enough signal to noise ratio. Obviously, low noise measurement is essential.

Governor Tests

19. **Governor Settings**

a. Record the settings on the governor controller in the table below (only for Units 4-6 Woodard electro-hydraulic governors.)

Table 19-1

Gains	Dial Setting
Integrator Offline	
Integrator Online	
Propotional Offline	
Propotional Online	
Derivative	
Speed Sensor	

b. Record the droop setting on the front panel:________%

c. Record the relaying restoring ratio:_______ /60

20. Offline Governor Speed Dial Measurements (Estimated Time: 30 minutes)

a. The unit should be offline. The over-frequency setting may need to be disabled to allow operation at higher frequencies.

b. Starting at 60 Hz, record the speed dial position and the frequency in the first row of the table shown below. Using increments of about 0.5 Hz, continue recording in Table 18-1, the speed dial position and frequency until you reach 63.0 Hz. The columns for online gate position and online MW will be used in test described later in the procedures.

Table 20-1

Speed Dial	Offline Hz	Online Gate Pos. (%)	Online Gate Pos. (mA)	Online MW

21. Online Governor Speed Dial Measurements (Estimated Time: 30 minutes)

a. The unit shall be online and at a unity power factor.
b. Completing **Table 20-1** from the offline governor speed dial measurement section, record the gate position and MW for each speed dial position. Stop recording when you have reached full rated power. This is typically between 62.0 and 63.0 Hz for the offline speed dial positions.
c. Record the gate position at full load and no load.
    a. Full Load Gate Position:_____________% ___________mA
    b. No Load Gate Position:_____________% ___________mA
d. After the final measurement at full load is taken, the unit shall remain online with the load reduced to 0 MW for the next test.

22. Online Governor Step Response (Estimated Time: 10 minutes)

a. The unit shall be online and at a unity power factor.
b. Record initial speed dial position:____________.
c. Beginning with the governor operating the unit at a steady speed on-line and the dashpot in the normal on-line mode, using HDR's data acquisition equipment, record the gate position, pilot servo position, and output power as the speed dial is quickly increased to a position that will yield an approximate 1%, offline-equivalent speed increase.
d. Record the final speed dial position:____________.
e. Keep the unit online and return the load to 0 MW for the next test.

23. Opening and Closing Gate Rates Using the Gate Limiter (Estimated Time: 10 minutes)

a. The unit shall be online and at a unity power factor.

b. Using HDR's data acquisition equipment, record gate position and pilot servo position.

c. Starting with gate limiter positioned at speed no load and the speed reference set point set at maximum, quickly adjust the gate limiter to increase the gate position by about 20%. Repeat this with 20% steps until the gate position is at full load. Observe stop nut engagement to verify servo reached maximum position.

d. Starting with gate limiter positioned at full load gate and the speed reference set point set at maximum gate position, quickly adjust the gate limiter to decrease the gate position by about 20%. Repeat this with 20% steps until the unit is at speed no-load. Observe stop nut engagement to verify servo reached maximum position.

e. Return the speed dial to the speed-no-load position and move the gate limiter back to its normal operating position.

24. Partial Load Rejection Test (Estimated Time: 5 minutes)

a. The unit shall be online and at a unity power factor with a load of about 10%-20% of full load MW and 0 MVARs.

b. Using HDR's data acquisition equipment, record terminal voltage, terminal current, gate position, pilot servo position, and unit speed.

c. Record the load before tripping the unit offline: __________MW

d. Trip the unit breaker and record for several minutes. Verify a clear transient gate response has been recorded and the unit has reached a steady state speed.

Estimated Time Breakdown for Each Test Unit (Minutes)

Test Procedure	Offline at SNL	Online at No-Load	Online Below 1% Criteria	Online Inside 1% Criteria	Online Above 1% Criteria	Total
1	-	-	-	-	-	0
2	15	0	15	0	0	30
3	-	-	-	-	-	0
4	-	-	-	-	-	0
5	-	-	-	-	-	0
6	0	15	15	15	0	45
7	30	0	0	0	0	30
8	0	10	0	0	0	10
9	0	0	10	0	0	10
10	15	0	0	0	0	15
11	-	-	-	-	-	0
12	10	0	0	0	0	10
13	0	10	0	0	0	10
14	0	10	0	0	0	10
15	-	-	-	-	-	0
16	15	0	0	0	0	15
17	15	0	0	0	0	15
18	20	0	0	0	0	20
19	-	-	-	-	-	0
20	30	0	0	0	0	30
21	0	10	10	5	5	30
22	0	5	5	0	0	10
23	0	5	5	0	0	10
24	0	0	5	0	0	5
Total	150	65	65	20	5	305

Note:

1. The 1% criteria is for Units 1-3 is defined as the active power ranger of 79 MW – 124 MW. For Units 4-6, it is defined as the active power range of 93 MW – 135.8 MW.
2. Test procedures 6, 7, 8, and 9 are not required for sister units.