

# **Power Grid Infrastructure Security Through Small System Dependability**

**By Nancy Kroner, American Governor Company, Camas, Washington  
and Joel Preheim, Southern California Edison, Big Creek, California**

## **Abstract**

The grid in the United States and Canada tends to be a very stable, self-organized system. However, occasionally excursions do occur and may be very broad and threaten the integrity of the larger grid. As a large grid begins to become unstable, it would be optimal to break away from the grid and maintain essential operation of selected smaller systems. Because the fuel, which is water under pressure, is immediately available and minimal power is required, hydro-electric generators can be used to provide immediate and essential power for larger, more grid dependent generators to remain operational in the event of severe grid excursions. Southern California Edison (SCE) and American Governor Company performed successful small system isolation testing using five hydro-electric units in the Big Creek Project governed by Woodward Mechanical Cabinet Actuators. This paper presents the method by which these units were prepared and tested for small system operation.

## **Introduction**

The blackout on the east coast in August 2003 verified the theory that the grid is a self-organized critical system and underscores the importance of proper maintenance and calibration. A self-organized critical system exists without outside influence, or operator intervention. In the event that individual elements of the system were to become unstable, the rest of the elements in the system would react without being guided or managed by an outside source. This reaction may result in power outages. While large scale power outages remain a serious concern, steps can be taken to ensure the large grid can be brought back up as quickly as possible using a stabilized smaller system.

SCE, Northern Hydro is relied upon as a “Blackstart” backup source of power to support system restoration. Although the project includes nine powerhouses with a total potential power output of 1025 MW’s, only a portion of this total (i.e., about 370 MW’s) is relied upon as a “Blackstart” backup source of power.

Testing was performed by SCE at Big Creek to verify system stability by segregating the units to a local bus. Five units at the Big Creek project were selected for testing; three units at Big Creek #3 powerhouse and both units at Mammoth Pool powerhouse. The initial testing consisted of systematically disconnecting the small system from the large grid. Once the units were segregated from the large grid, the hydro units became unstable, causing significant frequency swings. American Governor Company was contracted to calibrate the units to eliminate the frequency swings and provide a stable small system.

Each Mechanical Cabinet Actuator was given a “mini” minor-overhaul and carefully tuned for small system operation. The units were intentionally left with settings that were appropriate for either small or large grid operation to ensure these units could remain remotely operated during excursions. Once the calibrations were completed, the units were again disconnected from the large grid and the frequency remained stable. Each unit was also used to connect the small system back to the larger grid through substations.

## **Definition of the Problem**

Most generators are connected to a large grid once the unit generator breaker is closed. With the exception of block loaded units, all of the units on the grid will contribute to speed or frequency control. The amount of contribution depends on the unit’s size and droop setting. This self-organized system has significant advantages because the frequency is self sustaining and does not require outside management. Once a unit is connected to a large, stable grid, any deficiencies in the individual unit may not be noticeable. In the event the grid becomes unstable, a well tuned and maintained unit can help to stabilize the grid, while an improperly tuned and/or maintained unit will add to the instability.

While the Mechanical Cabinet Actuators at Big Creek were adequately maintained and properly tuned for off-line synchronizing and on-line load control, they required additional tuning for on-line speed control. The units’ temporary compensation and permanent droop needed to be adjusted to properly respond to frequency excursions.

Temporary compensation controls how the unit reacts to excursions, while permanent droop controls how much the unit reacts. Two types of temporary compensation are used to control hydro-electric units: on-line and off-line. The off-line compensation is used to control the speed of the unit and allow it to be connected, or synchronized, to the grid. On-line compensation is primarily used to control unit loading and unloading but must also be adjusted, or tuned, for frequency deviations. Mechanical Cabinet Actuators utilize the off-line compensation and a modified dashpot reset time while on line. Permanent droop is often the most misunderstood feature of governors. The droop setting determines the amount the unit will respond to frequency deviations. The lower the droop setting, the more the unit will respond. Units with 0% droop will go to the minimum or maximum valve position in an attempt to pick up the entire speed change as long as the deviation exists. Most units on the large grid are set to 5% droop. All units set to 5% will contribute to system speed stability, but in a controlled manner. The amount of contribution is determined by the following equation:

$$\text{Change in Servo Valve Position (\%)} = \text{Change in Speed (\%)} / \text{Droop (\%)}$$

These variables need to be set and tested to ensure the unit response to excursions is controlled. In addition to tuning and setting the appropriate droop, units should have regular maintenance. Binding, worn linkage, worn bearings, or contaminated oil can contribute significantly to unit instability.

## Explanation of the Solution

Regular maintenance contributes significantly to unit stability. Rarely can just tuning the unit compensate for mechanical deficiencies. Regular maintenance should include changing oil filters and oiling pivot points. Clean oil and free moving linkage can not only assist in unit stability, it can significantly extend the life and reliability of components. In addition to the normal maintenance, each unit should be tested yearly. This testing may be used to indicate the need for an overhaul.

The three units at Big Creek #3 and the units at Mammoth were given “mini” minor-overhauls. Included in the overhaul was inspecting the ball head for free motion, removing and checking the dashpot for air and any binding, removing and inspecting the pilot valve bushing and plunger, and checking for lost motion in the Permanent Magnet Generator (PMG). Minor issues were found and corrected.

A full governor calibration procedure was performed on all five units. The procedure consists of seven steps. The first five steps were performed in the dry (no water on the runners) to allow full gate movement to verify proper operation of the mechanics without speed influence. The last two steps were performed with water on the runner and the unit operating normally both off-line and on-line, testing their ability to control speed excursions. The test procedure consisted of the following steps:

1. Hand Alignment - Hand alignment consists of checking pointer position, gate position, and the operation of both the auxiliary and main valves. While the procedure will ensure proper indication and positioning, the unit should be observed for lost or binding motion.
2. Droop - The ballhead is blocked to simulate the proper speed and the speed adjust is given a 1% change in speed request. The gates should move proportional to the droop setting. (Example: 5% droop should result in 20% gate movement with a 1% change in speed/speed adjustment).
3. Dither - Dither, or vibration, is used to keep the pilot valve and distributing valve moving freely. This may only be performed on strap suspended type ballheads. The amount of vibration is important to ensure maximum movement on the distributing valve without actually transferring oil to the gates.
4. Dashpot – The dashpot is crucial to unit operation. It must be operating properly to allow the unit to remain stable.
5. Preparation for Starting – Steps must be taken prior to starting the unit for the safety of the unit. All test devices must be removed and initial values set.
6. Speed-No-Load (SNL) – This is the starting point for the unit. The SNL is determined by the amount of energy the unit requires to overcome frictional and other forces and is often around 10% gate. During start-up, the partial shutdown solenoid should be set to approximately 5% over the SNL gate position. This ensures that the unit can obtain the rated speed in a controlled manner.

7. Stability – Stability is checked with 5% speed upsets both off-line and on-line. Adjustments are made to ensure the unit returns to the rated speed in a controlled manner.

All five units were optimized for both off-line and on-line speed control. The settings found on the units initially allowed the units to be loaded and unloaded quickly. However, the settings also made the units too “hot” for on-line speed control. With the exception of Unit #5 at Big Creek #3, the units did not sense the correct speed changes and did not have adequate compensation. The floating lever connecting rod was moved to the inner hole to increase the units’ sensitivity to speed deviations translated through the ballhead. (Note: This adjustment was appropriate for these units and may not be universally appropriate for all governors.) Relay restoring was adjusted to ensure full distributing valve participation during large changes. Both the main and bypass dashpot needles were adjusted for stability. Because these units are operated remotely, it was optimal to allow all of the units to participate in speed control for small system operation with normal on-line settings, including the normal droop. The loading and unloading characteristics of the units were unchanged with the new settings. Droop for all five units was left at 5%.

## **Testing and Results**

Testing of the small system operation was conducted using the additional two units at Big Creek #3 and two units at Big Creek #4 to provide a local load. All five of the units at Big Creek #3, both units at Big Creek #4 and both units at Mammoth were put on-line normally. All five of the test units were set at a minimum load, while the gates on the other four units were closed to motor and provide load.

The small system grid was systematically disconnected from the larger grid. Once the last circuit breaker was open and the five test units were isolated, there was a minor change in frequency as the units balanced the load. Within seconds, the load was balanced and the frequency stable at 60 Hz.

Each unit was then individually tested for its ability to control the load. All but one of the units was brought to 0% gate and the lone unit was allowed to carry the entire load. Each unit controlled well. Operators at the substations were allowed to use each of the units to connect the small system grid to the larger grid. Once again, each unit performed very well.

Example of frequency excursion experienced during synchronizing the isolated system of five generators to the grid after tuning.



## Conclusion

Mechanical Cabinet Actuators are fully capable of controlling a self-organized system when properly maintained and tuned. Droop need not be modified on an individual unit to control frequency. By using this method of tuning and testing, the length and severity of blackouts may be minimized, if not altogether eliminated.

## Authors

Nancy Kroner is a Project Manager / Engineer for American Governor Company. She was also a Field / Application / Commissioning Engineer for Woodward Governor Company and a Mechanical Engineer for the Bureau of Reclamation.

Joel Preheim is a Supervisor for Southern California Edison in Northern Hydro, with 23 years of Hydro experience.