Full Load Rejection Procedure For Point Lepreau GS

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Abstract

In 1999 WANO issued Significant Operating Event Report 99-01 recommending that the industry verify whether or not currently approved procedures were adequate for a loss or degradation of the electrical grid. A detailed review identified that the procedures available at the time were not adequate to respond effectively to such a disturbance. Operations personnel reviewed operating expectations and the expected plant response to a Loss of Grid and updated the Operating Manual to cover "Full Load Rejection". Operations used the simulators to validate the procedure and train crews and Licensed staff. The revised documentation was approved and implemented.

1. Introduction

In 1999 WANO (World Association of Nuclear Operators) issued a Significant Operating Event Report (SOER) 99-01 with a recommendation for the industry to verify whether or not the currently procedures were adequate for a loss and/or degradation of the electrical grid. In June of 2001, Point Lepreau Generating Station (PLGS) initiated actions to assess and resolve any problems related to present procedures and implement WANO recommendation. The primary driver for modifications or improvements to existing procedures was to continue to improve on reliability and thus Nuclear Safety.

2. PLGS Classes of Power

PLGS power supplies are divided into various categories, depending on their source and/or backup supplies as follows:

- Class I power is 250 V**DC** and 48 V**DC**. It is used for plant control and protection circuits and is fed via battery chargers from Class III power or batteries themselves if CLASS III fails. Class I power has the highest reliability.

- Class II power is 600VAC and 120VAC. It is used in monitoring plant equipment and operation. Class II is fed from the Class I batteries via inverters and is also considered to have high reliability.

- Class III power is 4.16 KVAC. It is supplied by either the normal Class IV supply or, in an emergency, by the two Class III Diesel Generators (SG). It provides reliable power for heat sink loads required for fuel cooling and is the supply to Class I power.

- Class IV power is 13.8 KVAC. It is supplied from either the Grid at 345 KV via the SST (System Service Transformer) or from the Turbine / Generator set via the UST (Unit Service Transformer) which is also connected to the grid. Note that these various connections of transformers and the grid form what is known as a ring bus which ensures connection to the grid as well as redundancy.

The final category of power is EPS (Emergency Power System). It is the backup power supply independent of and separately located from the previously mentioned power supplies. On a total loss of power to the Main Control Room, one of the two EPS Diesel Generators can be started manually to provide the power required to maintain the ability to Control, Cool and Contain the fuel in the Reactor. This was primarily designed for use following a seismic event.

3. Full Load Rejection

A Full Load Rejection occurs when the Point Lepreau Generating Station turbine / generator set becomes disconnected from the grid by either opening of 2 specific breakers in the local switchyard or by the opening of certain specific breakers remotely. In short there is no load to accept the power that PLGS is capable of producing.

One of two conditions now exists.

1) If this upset does not cause the turbine / generator set to trip, the generator will still supply the power required for the station to operate.

Or

2) If this upset is the result of a total loss of grid completed with a turbine trip, this will cause a total loss of power to the station.

4. External OPEX

Grid upsets can result from a wide range of disturbances. This can range from natural causes to ineffective operation by corporations. Some recent examples of major grid disturbances are:

March 1989 - A magnetic storm in space is believed to be the cause of a transformer failure on one of the main power transmission lines of Hydro Quebec, precipitating a grid collapse that left 6 million people without power for a day.

January 1998 – As we all remember, a series of ice storms caused significant power outages in Quebec, Ontario, and Atlantic Canada. Many kilometers of transmission lines fell under the accumulated weight of the ice. Many Canadians were without power for several weeks in the mid of winter. Locally, approximately 5 kilometers of line from the Coleson Cove Generating Station fell across a main highway.

2000 and 2001 - The rolling blackouts of California were implemented by the Utility as a result of insufficient generation capacity.

August 2003 - Insufficient capacity with overloaded and sagging transmission lines, in combination with a failure to trim the trees underneath, started a series of grid interruptions beginning in Ohio. When the transient was complete, over 10 million customers in Central Canada and 40 million in North Eastern USA were without power.

5. PLGS OPEX

The previous examples of global transients on the Grid clearly demonstrate that the potential risk of a loss of grid is real. It is easier to demonstrate the risk by looking at the local instabilities within our own New Brunswick connection to the grid. Here are several recent examples:

January 1986 - A loss of Class IV power resulted when the Unit Transformers tripped on electrical protection with reactor setback to 60%. A few minutes later the System Service Transformer (SST) was lost because of electrical protection. In this case the generator came off line and there was safety system operation. A total loss of Class IV power resulted.

July 2004 - A lightning storm in July had a strong impact on the New Brunswick grid. During the storm, L3009 tripped at 21:47 and was re-closed with System Operator approval before L3003 tripped at 22:06. L3003 and L3009 are the only two lines connecting PLGS with the NB Power grid. Also, that night a total of 14 major lines tripped along with transformer trips and significant damage to grid equipment ranging from insulators to entire electrical terminals. Severe weather is always a major threat to the operation of any power station and has resulted in PLSG coming off line in the past.

May 2005 – On return to service of a Nova Scotia plant following an outage, a automatic voltage regulator failure resulted in large voltage swings on the grid. The power transient only occurred after midnight when that plant was running at low load. The effect could be felt at PLGS where 40 – 50 MW power swings were experienced for up to one hour on several consecutive nights before the source of the disturbance was identified and corrected.

June 2005 - A lightning strike caused a trip on Coleson Cove Unit #1 resulting in L3009 being de-energized. The line was open for 13 minutes before being re-energized. L3009 had to be de-energized Approx. 1 hour to support Coleson Cove Unit #1 return to service. During the time that any one of the two lines to Point Lepreau GS is open, a single fault on the other line will result in a full load rejection from a loss of connection to the Grid. Currently, a third line from PLGS is being run that will help improve both stability and reliability of the Grid connection.

6. RISK REDUCTION

The risk of a Full Load Rejection event can be reduced by maintenance of Grid lines, safety devices, and ensuring that sufficient power supplies are available in the case of a loss of a single power station. NB Power routinely upgrades its components to increase the reliability of its power supply. In recent years, grounding work has been completed on power support structures of lines near highly rocky ground so as to reduce the risk of interruption of power from a lightning strike.

Power interruptions cannot be prevented as long as severe weather patterns exist and mechanical component have the potential to fail. In these cases, being prepared is still the best defense which includes:

- Maintaining good communication with the grid operators.
- Co-ordination of all activities that impact the electrical grid and its reliability.
- Developing appropriate procedures and training plant personnel to a high standard. At Lepreau this includes practicing and be evaluated for performance using a full scale simulator.
- Finally, lessons learned from within the industry must then be used to further improve performance and reliability of the Grid.

Based on Operating Experience, SOER 99-01 recommended that each of the WANO members address the following:

1. Establish appropriate interfaces between nuclear power plants and grid operators.

2. Review the adequacy of procedures for loss or degradation of the electrical grid.

3. Verify that plant and switchyard high voltage grid distribution equipment for which the plant is responsible is fully incorporated into the plant preventive maintenance programme.

4. Review trip set-points for safety-related components to determine if degraded grid voltage may result in unanticipated component trips prior to emergency power source automatic actuation. Identify and implement corrective measures for vulnerabilities discovered by this review.

5. Incorporate degraded grid voltage conditions into operator training (in addition to complete loss-of-grid training). Provide operator training on post-loss-of-grid recovery actions, including additional grid losses during recovery phases, and on manual electrical bus alignments that may be necessary during complicated loss-of-grid events. Conduct periodic drills or simulations to verify adequacy of loss-of-grid procedures and training.

7. PROCEDURES

As was previously mentioned, when there is a complete Loss of Grid, there are two possible outcomes. When the grid is lost combined with a turbine / generator set trip, the result is a complete loss of power to the station. If the grid is lost and the turbine / generator does not trip, then the power to the station remains.

Detailed procedures were already in place to cover a complete loss of Class IV power.

Procedures at the time were not contained in a consolidated document that covered a Loss of Grid where Station services are still provided by the turbine / generator set through the UST (Unit Service Transformer). The information to handle the issues that could arise was covered in various Operating Manuals for each of the systems that would be affected. Prior to the current procedure, operator experience, diagnosis, and decision making would have to be used to prioritize and respond to such an event. This approach was found to be lacking.

8. Loss of Grid (Full load Rejection) Procedure

The Full Load Rejection procedure will only be implemented when there is a complete loss of Grid to PLGS and the Turbine / Generator set alone is providing power to the station. If the plant was operating at high power there would be an automatic reduction in reactor power to 60% initiated by the Reactor Regulating System program.

If the plant was previously operating at less than 60% FP, the reactor power would not change, however, the generator will now only be providing approximately 40MW to match station service demands.

If station service requirements can not be provided by the Generator during the a loss of Grid, a total loss of class IV power will result and other higher order procedures would be used to manage the event.

For a loss of grid event, the generic response would be applied by the licensed operations team at PLGS. The response is used to monitor the power rundown and the assess the plant state to ensure that all of the required plant equipment is still in operation to maintain control of Reactor Power, provide a heat sink for maintaining the fuel cool, and ensuring there is no risk of releases to the public.

If the plant is still operating within the designed safe limits, then reactivity control is addressed first. Monitoring of devices that are part of reactor control and confirming that all power limits are adhered to at all power levels is of the highest priority.

The nature of the CANDU design with natural Uranium fuel will result in the buildup of Neutron absorbers known as poison any time there is a significant reduction in reactor power. Maximizing Moderator Purification flow will increase the time before the reactor will enter into a Poison Out condition (shuts itself down).

Following confirmation of reactivity control and all expected automatic actions, checks of the 345KV switchyard and contact with the System Operator will be performed to identify the cause of the loss of Grid and todetermine if it is possible to re-establish a connection to the grid. The procedure will then have the Turbine / Generator speed checked since following a disconnect from the grid, the generator will be running at a reduced speed but providing the required power to station services. Running at a reduced speed will cause turbine blade vibration. The speed will then be adjusted manually to 1800 rpm (60Hz) to alleviate this concern. With the low flow rate of steam through the turbine, and a high flow rate of steam bypassing the turbine, various automatic systems will operate to prevent overheating of the turbine blades and ensure stability in this mode of operation was according to the original design intent.

Restoration of Class IV power is addressed next. If the Grid is proven to be healthy, then power can be restored from the Grid into Point Lepreau or from Point Lepreau out to the grid. The preferred method is to restore the grid into PLGS via the SST.

Once the SST is energized from the grid then the priority is to transfer over the station power supply from the turbine / generator set to the grid powered supply via the SST.
If there is more than 30 minutes of time available, then normal practice of synchronizing the turbine generator to the grid would be performed. If not, a manual residual voltage power transfer would be done. To perform a residual voltage transfer, the breaker feeding half of the Class IV power is momentarily opened to interrupt the power supply from the turbine generator set and a different breaker is closed in order to allow the power to be supplied by the SST. This transfer is required to prevent a transient that would be caused by joining a power supply to a load that is electrically out of phase (not synchronized).

If a 345kV line to Point Lepreau is not energized and the cause of the original failure is now understood and no longer an issue, then Point Lepreau would attempt to energize the lines to the grid. If successful, the SST would be energized as described previously. With Class IV power from the grid restored, station transfer would be re-poised and the plant would be shut down using normal procedures.

If at any point in the execution of the procedure any parameter indicates a risk to fuel cooling by not being within specific safety limits or Turbine / Generator set parameters deteriorate as a result of the low load operation, the course of action would be to confirm standby diesel generators are available, reduce reactor power to 15%, manually trip the Shutdown System to rapidly shutdown the reactor and reduce fuel heat production, and then trip the Turbine / Generator. If Class IV power was not restored using the SST before the Turbine was tripped, then other high order procedures will have to be applied as the station is now without a Class IV power supply.

The activities within the procedure cannot be completed solely by PLGS activities. The procedure is structured so that the required communication is identified within the text. It identifies the information required to be communicated to the System Operator and the approval needed to place the plant in a safer state. The procedure not only considers the needs of PLGS but gives options to support the stability of the Grid and thus improve the reliability of the power supply to Point Lepreau GS.

10. Issues in developing the procedure

Operating Policies and Principles (OP&P) is a set of governing conditions to which the station is to be operated. It can be expected that failures will occur from time to time that represent breaches to OP&P. A loss of Grid is one such circumstance. OP&P identifies that if the "Unit is on line, the normal status of the 13.8kV Class IV distribution buses is when the "even" bus is supplied by the UST and the "odd" bus is supplied by the SST." This configuration is too maintained so that a single electrical fault cannot result in a complete interruption of Class IV power supplies. In the event of the grid connection being lost, the redundancy is lost and the station becomes vulnerable to a complete loss of Class IV power.

OP&P then continues to identify that if "Both 13.8 KV buses are supplied from the UST for more that 2 hours with the unit on line then a Standby Diesel generator shall be started and loaded, and an assessment of the repair time shall be given to the Station Manager as soon as possible. Reactor power shall not be increased." PLGS is then required to have repairs completed within 48 hours and notification to the CNSC within 24 hours. The intent of the clause had assumed that the Turbine Generator set still acts as a single remaining grid supply. In such a case, motoring the Generator would still maintain a connection if the reactor was shut down. With a loss of Grid this may not be the case. In many circumstances, the reactor over time may be forced into a shutdown as a result of Reactor Physics constraints (such as a forced poison outage). If the plant was in a unit start-up during a lost of grid, prolonged operation with the UST providing all station services could be possible. In such a case, "an alternative proposal shall be submitted to the CNSC, seeking approval to operate for a further specified period of time", as per OP&P.

The manual start and loading of the Standby diesel Generator within 2 hours posed some concerns on availability and reliability of the Class III power supply. Even with the most recent procedure updates and stream lining of the Operating Manual Test procedure for Starting an SG within 30 minute, the SG can be made unavailable for AUTO start and loading for up to 20 minutes. This procedure, when developed, identified this as a major concern and now directs the SG for Auto start only with no operator intervention. This reduces the unavailability time and reduces the operator requirements that would become an issue during any plant transient. OP&P is not such a robust documents that it considers and gives direction for all potential failures, but it gives leeway such that an alternate proposal can be submitted to the CNSC that can increase nuclear safety for a given situation.

Prioritization of actions within the procedure that has such station wide implications became a challenge. With engineering input from the various system specialists came a list of issues that all should be address with first priority. For instance, the Turbine / Generator set following a loss of grid where the generator is providing station services via the UST will operate at a significantly reduced speed. When the speed of the turbine generator is reduced as a result of the Electro Hydraulic Governor (EHG) controlling the turbine speed, the turbine blades will enter a resonance frequency. This will increase the risk of damage to the turbine from blade vibration.

It was felt that priority should be given to make speed adjustments early to restore the speed of the unit of 1800 rpm (representing 60Hz).

All inputs from various specialists were taken into consideration in the organization of the final procedure. The hierarchy of the final document was based on Operation Expectations. These expectations require the execution of high order procedures and documentation based on nuclear risk and safety. The highest order procedure to be applied in every plant upset is the OURS (Operator Upset Response Strategy) for the Control Room Operator and the SSURS (Shift Supervisor Upset Response Strategy). These procedures are in place to ensure that the correct procedure is applied in a timely manner. The general organization of the response is to address Special Safety Systems, then ensure that an appropriate heat sink is available, and then applied Operating Manual Procedures based on the specific upset. A loss of Grid falls in the Operating Manual Procedure category of the hierarchy.

When a plant experiences a loss of Grid from high power, reactor power will Setback to a maximum of 60% FP. Since station services only require around 40 MW of electrical power (6-7% FP) the rest of the energy difference will be discharged to the condensers via CSDV (Condenser Steam Discharge Valves). The CSDV are designed for the purpose of transferring excess energy to the condensers during a transient condition.

10. Implementation of a new procedure

The new procedure was then tested on the PLSG Simulator for validation of its effectiveness. When the final modifications were completed, the Full Load Rejection procedure then went through a Training Needs Assessment to identify if formal training was required for the operations staff. The assessment indicated that training was required. Event based training on the Simulator was developed for all operation crews. The exercises simulated the various issues and failures that may develop during a Loss of Grid. A record of the training is maintained that is auditable by the CNSC (Canadian Nuclear Safety Commission). Implementation of SOER recommendations is one of the criteria used On WANO peer reviews for evaluating PLGS progress towards World Class Performance.

11. Conclusion

Point Lepreau Generating Station Operations carried out the WANO Significant Operating Event recommendations of SOER 99-01 and put in-place upgraded and approved procedures that enable the Operator to respond effectively to a loss or degradation of the electrical grid. Operating Expectations and expected plant response were reviewed and the new procedures were tested on the desktop and plant simulators. Licensed staff and crews were trained to respond to this operating event.