

PLANNED ISLANDING AS A DISTRIBUTION SYSTEM OPERATION TOOL FOR RELIABILITY ENHANCEMENT

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ABSTRACT

Recently, planned islanding—operating the distribution system in isolation from the main grid—has been recognized as a distribution planning tool that can be used to improve the reliability of the system. This paper considers the process of planned islanding and the necessary steps that need to be taken in order to make it a successful project. We draw on experience from Canadian utilities in this area and detail the studies that were carried out in order to plan for the operation of a planned island by the country's largest utility, Hydro-Québec (HQ). This project needed close collaboration between the Distribution and Transmission engineers to attain the reliability improvement for the distribution customers when a planned outage is needed on the transmission line. The outcomes of the studies are analyzed and the current status of the project is discussed.

INTRODUCTION

The advent and subsequent growth of distributed generation has led to a situation in which the distribution network has evolved from a passive network to one that actively responds to the dynamics of the main grid. This poses a challenge to the distribution engineer as the network no longer behaves as it once did. Consequently, its planning and operation must be approached somewhat differently, and with a greater amount of care and diligence. However, this change can also be viewed as an opportunity: incorporating these sources into the distribution engineering process can yield a greater amount of flexibility and improved performance.

One of the potential avenues for distribution system innovation is planned islanding. Distributed generators, either utility-owned or private producers, can be used to sustain the local distribution system during unavailability of the transmission feeds, [1]. The reasons for disconnection of the distribution system from the transmission feed may vary—faulted system, maintenance, or even as part of an emergency response program. However, the undisputable fact is that if local generation is used during these periods, the direct benefit is a reliability improvement.

Reliability improvement is the motivation for planned islanding case studies in Canada. BC Hydro has been one of the leaders in this area having successfully operated a planned islanding project for over a decade [2], and have gone as far as developing an islanding guideline, which is published on their corporate website, [3]. Planned islanding has also been performed at Hydro-Québec for many years; one of the latest projects is discussed in this article.



With its 35 GW of installed power generation, Hydro-Québec (HQ) is one of the most important utilities in Canada.

Mostly hydraulic, HQ generation is almost entirely renewable energy. With the most extensive transmission system in North America [4], this utility provides electricity to more than 3.7 millions customers, accounting for almost 169 TWh in 2005. The company's activities are separated into four major divisions: the generator - HQ Production; the transmission provider - HQ TransÉnergie; the distributor - HQ Distribution; and a subsidiary division, HQ Équipement and SEBJ.

In 2005 the Distribution Automation (DA) program was initiated. Based on this program, HQ established a vision of its future network and a roadmap [6] towards an intelligent distribution system. The HQ DA roadmap proposes a step-by-step approach, starting with the present distribution system, and includes the integration of Distributed Energy Resources (DER) connected to the HQ distribution system. Within this vision, the HQ DA roadmap envisages using intelligent systems, together with DER to facilitate, whenever needed and possible, planned islanding and automatic reconfiguration, including micro-grids.

HYDRO-QUEBEC'S EXPERIENCE IN PLANNED ISLANDING

HQ's most recent planned islanding experience began when considering options for the maintenance of the transmission line feeding a substation named Senneterre, where a privately-owned thermal power plant (Boralex) was interconnected. The substation feeds three distribution lines, serving 3000 customers in the municipality of Senneterre and its surrounding area. This substation is supplied at 120 kV by a 40 km long transmission line. Standing on wooden structures, this line, more than 55 years old, required urgent

replacement of its angle and stop portals. This type of maintenance can only be performed on a de-energized line. Presently, HQ has no back-up feed, neither from Transmission nor Distribution. However, the Boralex thermal power plant, which has been feeding the HQ network since 2002, is connected through the Senneterre substation. To avoid service interruption for HQ customers during the restoration of the transmission line, it was decided to consider the option of using the Boralex power plant for islanding of HQ's Senneterre substation.

Technical Constraints

To perform this islanding project the power plant has to be sufficiently equipped, in order to: respond to load demand, meet voltage and frequency requirements and sustain power plant stability. Those requirements are certainly atypical for private producers connected to HQ network who are normally required to disconnect when the substation supply is lost. Consequently, Boralex had to modify its installation at the request of HQ. In addition, the following technical limitations had to be taken into consideration, which added to the complexity of the project:

Limited synchronous reserve - The Boralex power plant produces steam from combustion of wooden shavings and can maintain a synchronous reserve of up to 4 MW. However, the operating costs are much higher than for normal operation. Therefore, during islanding operation the synchronous reserve is kept between 1 and 2 MW. This reserve is equivalent to normal load variations but is certainly not enough to accommodate more severe load variations, such as load pick-up. Consequently, during islanding, all automatic reclosures (substation and feeder reclosers) are required to be deactivated. Authorization must then be obtained from the power plant operator before initiating any reclosure of protection devices that happen to have operated during islanding.

Lack of black start capability – Boralex power plant needs the presence of HQ network to start production. As a result, a power plant shut down during islanding will require return of HQ power before restarting. To reduce the risk of a power plant shutdown, each islanding event is planned during normal weather and limited to the replacement of one structure, equivalent to approximately 12 hours.

Analyses

The principal effect of the absence of HQ power can be summarized by a significant reduction in short-circuit power. Therefore, protection settings may no longer be adequate. Moreover, this method of exploitation could cause non-desired dynamic behaviour of the generator, perturbation on the network and could eventually lead to equipment failure and risk for human security. For these reasons, analyses have been realized by the Distributor and

the Transmission Provider prior to approval of this islanding project. Note that this project was initiated and coordinated by HQ TransÉnergie, the transmission provider, who helped lead the project to a successful outcome. The distribution and transmission engineers mandate consisted of the following four analyses:

Protection study

A protection study has been realised to verify, from the distribution side: the HQ protection coordination for minimum short circuit; from transmission side: coordination between HQ and Boralex power plant's protections, and to study the performance of the power plant's protections for a fault occurring near the substation (i.e. important under voltage). The transmission study was conducted as well to verify the protection settings within the substation (busbar, transformer protections, etc.)

Stability study

The stability study executed by the distributor was to evaluate the power plant's stability for: load pick-up of one feeder, the starting of a 500 hp motor, and for a high current fault in the distribution network. The transmission provider completed the stability study by verifying the performance of the power plant for an important loss of load.

Flicker study

Two important sawmills are connected to one of the distribution feeders and could potentially cause voltage flicker during islanding. Therefore, a flicker analysis was performed considering these disturbing sources.

Disconnection from HQ network

At the exact time of the disconnection from the HQ network, the power factor of the generator has to go from inductive to capacitive. Simulations have been done to confirm that the overvoltages caused by this transition would not pose unacceptable risks to the power station equipments.

Simulation models

To perform the aforementioned analyses, a model representing the HQ network and the Boralex power plant has been created in Matlab-Simulink by the Distributor, Fig. 1.

Boralex Power Plant Characteristics

The Boralex power plant consists of a 35 MW steam turbine that drives a 34 MW synchronous generator. The power station is fully equipped with a governor and excitation system that regulates respectively the frequency and voltage at generator's exit.

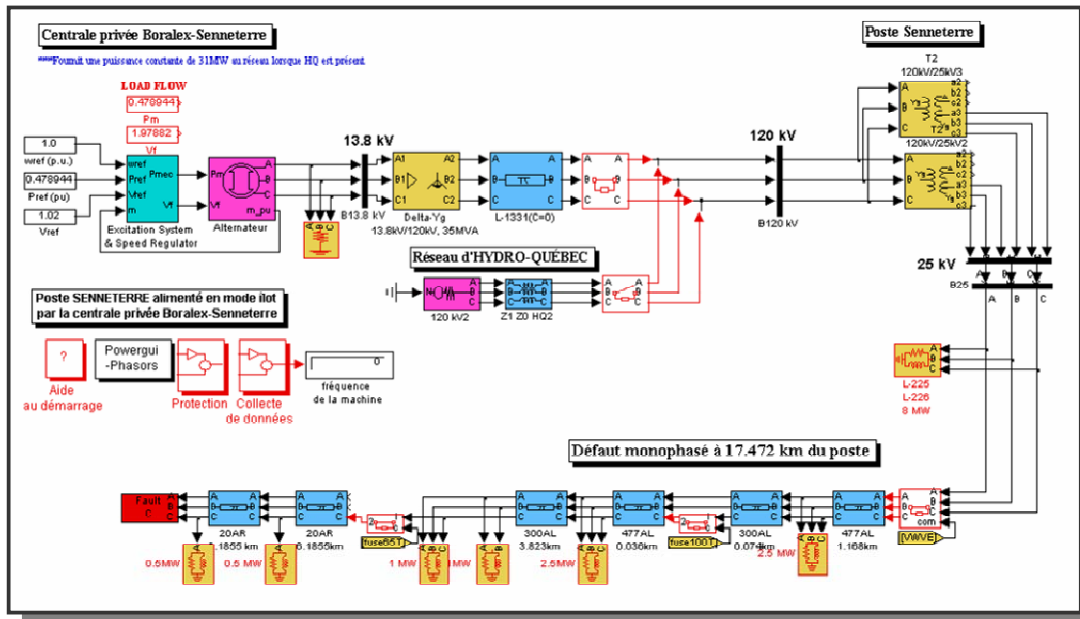


Fig. 1. MATLAB-SimPowerSystems model of the Senneterre system used for planned islanding studies

The power station, considered as a private producer of 31 MW in steady-state, is connected to the Senneterre substation through a 13.8/120kV transformer and a 3 km transmission line.

Senneterre Substation Characteristics

The distribution feeders and their protections have been included in the model. For the simulations, an average load of 15 MVA, which represent the load for normal weather during spring or fall, has been considered. Aside from the sawmills, the majority of the load is residential.

Results and conclusions

As said previously, during islanding there is a significant reduction of the short-circuit power. This fact is primarily responsible for differences in performance between the islanded and grid connected systems. The specific results of the studies are discussed below.

Conclusions of the Distributor

To assess the impact of the island on the performance of the network, all study cases have been simulated with and without presence of HQ system and are presented in [5].

The evaluation of the minimum fault current on the Distribution's line shows that the reduction of the short-circuit power does not slow down ground protections but causes a much more significant delay on phase delay protections.

For a direct fault near the 25 kV busbar of the Senneterre substation, an increase of the amplitude and duration of undervoltage has been observed, Fig. 2. In the simulation,

the Boralex protections have not been considered but this type of fault could cause an unwanted activation of the power plant's undervoltage protections.

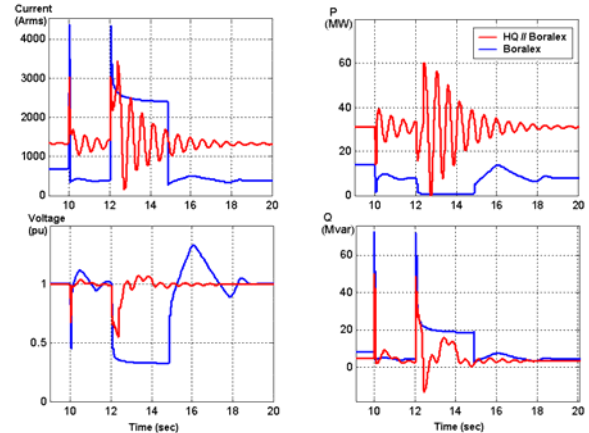


Fig. 2. Simulation results at Boralex busbar for maximal short circuit on distribution system with and without HQ power

Starting of a 500 hp motor or reclosing on a load pick-up do not cause any significant variations of frequency and voltage.

Then, considering the low probability, two- or three-phase faults near the substation, the distributor conclusions were positive. The distributor protection settings require no modifications, other than the inhibition of automatic reclosures.

During islanding, the two sawmills connected to one of Senneterre substation's feeder could potentially cause flicker. Pessimistic assumptions of motors directly connected to the line and starting currents equal to six times nominal current have been considered. The results showed that the visibility limit could be exceeded under those conditions. Nevertheless, considering these pessimistic assumptions and knowing that maintenance will be of short duration, this violation was deemed acceptable.

Conclusions of the Transmission Provider

After receiving the Distributor's results, the Transmission Provider has some complementary analyses to perform whose results are presented in [4]. The Transmission Provider's stability analysis showed that for an important load loss, the power plant equipment allows almost instantaneous shedding of a quantity of steam necessary to retain stability.

Then, the protection evaluation validated that the transformers and busbar protections of Senneterre substation are adequate. Any fault on the transmission line (120 kV) is covered by Boralex's protections. However, a fault on the transmission line would cause the shut down of the power plant, as in the case of a high current fault on the distribution network, due to the activation of the undervoltage relay. However, under the notion that islanding would be performed during favourable weather condition, the probability of these contingencies occurring was assumed to be negligible and the decision was made to proceed with the islanding project.

Operating procedure

Once the project was approved, Boralex and HQ worked together to establish an operation protocol before performing tests. This protocol specifies procedures for formation of the island and return to grid parallel mode. They can be summarized by the following:

Island formation protocol -

To allow island exploitation, all automatic reclosures on distribution lines and those identified in Senneterre substation are deactivated. Then, active and reactive power from Boralex power station are adjusted to meet a power flow of near zero at the disconnection point. Once the island is formed, the Boralex regulator is transferred from power factor regulation to voltage regulation.

Island operation constraints

The network is operated according to the protocol developed by the producer and HQ, considering the constraints identified.

Connection protocol

The reconnection of the island to HQ transmission system cannot be done in closed transition. To avoid sudden

perturbation to the generator equipments, the 3 distributions feeders are first sequentially disconnected before interruption of Boralex power plant generation. After the power plant shut down, all protections and automatic reclosures earlier deactivated are put back in service before the reconnection of Senneterre substation to the live HQ transmission line. Finally, the Boralex plant is re-started, synchronized with the system, and reconnected.

SUMMARY AND STATUS

In October 2005, the first attempt of islanding of the HQ Senneterre system by the Boralex power plant was performed and persisted for eight hours. The peak load during the event was measured near 7 MW. During this experience, the stability of the system was validated for important variation of load, such as, the disconnection and reconnection of one distribution feeder, the disconnection of all three distribution feeders (the only loading on the power plant was the substation and power plant's auxiliary loads). Results showed that voltage and frequency remained stable for both important load reduction and controlled load augmentation. The first maintenance work of the transmission line began last fall. Due to great weather conditions, it was decided to maintain the island for three days, allowing the replacement of five structures.

This project is a good example of the application of planned islanding for reliability improvements. The study approach revealed that planned islanding is a feasible option and can be assessed using readily available planning tools. This option could also be reproduced on a much smaller scale to improve reliability of HQ customers during outages, for planned interruptions.

REFERENCES

- [1] Barsali, S., Ceraolo, M., Pelacchi, P., and Poli, D., 2002, "Control techniques of dispersed generators to improve the continuity of electricity supply", Proc. of IEEE Power Engineering Society Winter Meeting, vol. 2, pp. 789-794
- [2] R. Fulton and C. Abbey, 2004, "Planned islanding of 8.6 MVA IPP for BC Hydro system reliability" in First International Conference on the integration of RE and DER, pp. 9.
- [3] BC Hydro, 2006, "Distribution Power Generator Islanding Guidelines". Available [Online]: <http://www.bchydro.com/info/ipp/ipp992.html>
- [4] J-L Pépin, 2003, "Projet d'alimentation du poste Senneterre à partir de la centrale Senneterre en mode îlot", Hydro-Québec TransÉnergie document.
- [5] M. Gauthier, M. Plamondon, 2003, "Relève du poste Senneterre par la centrale thermique Boralex lors du retrait de la ligne 1317 d'Hydro-Québec", Hydro-Québec Distribution document N° 30012-03-12R.
- [6] G. Simard, D. Chartrand, September 2006, "Hydro-Québec's Distribution Technology Roadmap", *Utility Automation & EngineeringTMT&D*, pp.38-42
- [7] <http://www.hydroquebec.com/en/index.htm>