5.0 Reliability Test Cases

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One objective of a smart grid is to improve the reliability of electric power for its end users. Toward this end, Pacific Northwest Smart Grid Demonstration (PNWSGD) utilities automated their distribution systems, including the application of fault detection, isolation, and restoration (FDIR) to more rapidly get customers' power restored after outages. Several of the project's utilities took advantage of automated power-quality alerts that have become available from advanced metering infrastructure (AMI) and new distribution equipment to help them more quickly pinpoint and respond to outages, abnormal supply voltages, and other conditions. Still others installed batteries and automated distribution switching to define high-reliability zones that may separate from the rest of the grid and operate as microgrids when they become threatened by power outages.

Reliability is one of the PNWSGD's three major technology performance report categories. The reliability test case summary provided here is structured as follows. The standard reliability indices definitions are summarized first. Then the effectiveness of smart grid assets such as AMI and FDIR on reliability indices is discussed next. The important lessons learned and utility recommendations conclude this summary.

This next section briefly discusses the reliability indices used by project participants to evaluate the performance of their distribution systems.

5.1 Reliability Indices

Distribution utilities measure the performance of their feeders using standardized reliability indices. These indices measure the utilities' performance while responding to power outages. They provide information regarding the number of customers affected by the power outage, outage duration, etc. These indices enable fair comparison of the performance of different utilities' feeder circuits. A utility can also compare performance among its own feeders. And the PNWSGD further used the indices to validate the benefits that had been anticipated from certain novel smart grid systems and tools, and looked for improvements in theses indices after the new technologies were installed.

Several reliability indices are listed and described in Table 5.1. These indices are defined in accordance with the IEEE guide for electric power distribution reliability indices (IEEE 2004). Typically these indices monitor *sustained* outages, which are interruptions that last more than 5 minutes. Typical annual median values for sustained indices for the U.S. utilities are also listed.

Table 5.1. Distribution System Reliability Indices

Index	Index Definition	Mathematical Calculation	Typical Values (IEEE 2004)
CAIDI	Average duration of sustained customer interruptions	Total customer outage duration/total number of customer interruptions	1.26 hours per interruption
SAIDI	Average total duration that a customer was interrupted by sustained interruptions	Total customer interruption duration/total number of customers served	1.5 hours per customer
SAIFI	Average number of times that a customer was interrupted by sustained interruptions	Total number of customer interruptions/total number of customers served	1.1 interruptions per customer

CAIDI = Customer Average Interruption Duration Index
SAIDI = System Average Interruption Duration Index
SAIFI = System Average Interruption Frequency Index

5.2 Effect of Smart Grid Assets on Reliability

Each of the smart grid asset systems reported in this category has been implemented by participating utilities to improve distribution system reliability or power quality. The analyses relied heavily upon standard reliability indices that were reported to the project by the owners of the asset systems. While the analysis of reliability was found to be consistent throughout this report, the report discusses asset systems into two categories. These subcategories are based upon the minor differences in the types of data collected for reliability analysis. The categories are as follows:

- Effect of AMI on reliability: AMI provides information concerning outages and other performance indicators.
- Effect of distribution automation and distributed generation on reliability: Asset systems facilitate automation that should improve distribution system reliability.

5.2.1 Effect of AMI on Reliability

Two utilities—Flathead Electric Cooperative (Section 10.1), and Lower Valley Energy (Section 12.4)—upgraded their metering infrastructures during the PNWSGD and supplied the project reliability indices to evaluate the impacts of the new metering infrastructure on system reliability. Also, Benton Public Utility District (PUD) (Section 8.1) had installed smart meters at most of its customer locations by the beginning of the PNWSGD project and completed the installations by 2012. Benton PUD's AMI system featured an interesting set of outage and power-quality alerts. Benton PUD provided the historical reliability data from before the AMI was implemented for 2010-2011 period, and its 2014 values were its best system reliability values in recent years. For all years reported by Benton PUD, reliability values were better than the typical System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) values reported in Table 5.1. But the project cannot conclude from this limited data that system reliability improved for Benton PUD due to features of its AMI system.

Similarly for Flathead Electric Cooperative, the historical data prior to and after implementation of AMI infrastructure was not available. The reported SAIFI and SAIDI indices however were mostly worse than the typical values listed in Table 5.1. Lower Valley Energy provided the historic data prior to implementation of AMI, but there was a steady increase in SAIFI values. The project could find no clear trend in the SAIDI value decrement. Thus, for Lower Valley Energy, AMI infrastructure did not necessarily result in measurably better reliability indices. Hence, improved reliability was not clearly evident for any of the three studied utilities and could not be concluded from available reliability data.

Other utilities involved in this project opted for FDIR implementation rather than AMI. Their results are discussed next.

5.2.2 Effect of Advanced Distributed Automation Investment on Reliability

NorthWestern Energy (Section 14.2), Avista Utilities (Section 7.7), Idaho Falls Power (Section 11.3), and Peninsula Light Company (Section 15.3) upgraded their infrastructures using FDIR systems.

NorthWestern Energy installed FDIR on four circuits at one of their sites to automatically reconfigure circuits after an outage and restore service to as many customers as possible. They reported data on distribution restoration costs, CAIDI and SAIDI values from the beginning of 2010 till August 2014. The reported distribution restoration costs from 2010 to 2013 were not significantly different. There was no clear trend for the yearly CAIDI values. SAIDI values reported from 2011 to 2013 were better than 2010. SAIDI values for 2014 were very low, however no clear conclusion could be drawn as data collection only lasted until August. NorthWestern, however, reported anecdotally that the effectiveness of FDIR could not be conclusively established based on the reported data from several events that had occurred since they implemented FDIR.

Avista incorporated FDIR capability and fault circuit indicators within its distribution management system. Avista provided the project with detailed outage information and calculations of several reliability indices; however, the utility later said that its calculations had not excluded certain long outages that should have been omitted from the analysis. The project's comparison concluded that SAIFI values were trending slightly toward worse until the end of the project in 2014. SAIDI values for Avista in years 2013 and 2014 were perhaps slightly trending toward worse as well. The project's findings from the reliability indices were inconsistent with Avista's projections of their avoided outage durations. Avista reported that few outage had occurred during the PNWSGD of the type that would lock out their site's reclosers and engage the capabilities of FDIR.

Idaho Falls Power implemented remotely controlled switches, an AMI system, and fault indicators to quickly detect faults on the feeder. The system was expected to reduce outage durations due to quick identification of a fault's location. Due to limited availability of historical data, the project cannot report any strong conclusions regarding reliability at Idaho Falls. But, Idaho Falls Power reported no outages during the last nine months of the project, which is very promising, providing this trend endures. This promising performance in the last nine months, however, cannot be directly attributed to the utility's investment in smart grid infrastructure.

Peninsula Light Company used supervisory-control-and-data-acquisition connected distribution switches to monitor fault currents. The supervisory-control-and-data-acquisition maintained the real-time status of the connected network and calculated an optimal network configuration. Reliability indices were made available for the months from June 2012 through August 2014. The average SAIDI for all project months at this site was approximately 1 hour. Peninsula Light Company also recorded outage response times. The average of all of its monthly outage response times collected by the project was 2 hours 25 minutes per outage. From the available data, no clear trends in SAIDI values and outage response times were evident. The installation of the FDIR system occurred in September 2012; however, SAIDI values improved only since March 2014. Hence, correlation between the newly implemented FDIR system and improvement in reliability values cannot be fully established.

5.3 Observations and Lessons Learned

- In many cases utilities reported insufficient data to derive requisite conclusions concerning changes in reliability. Where sufficient data was available, smart grid infrastructure did not always yield desired results. In some cases reliability indices became worse.
- Utilities should consistently apply data collection and reliability analysis procedures to study and validate benefits from smart grid technologies. The data collection methods prescribed in the latest IEEE Guide for Collecting, Categorizing, and Utilizing Information Related to Electric Power Distribution Interruption Events (IEEE 2014) can help achieve this.
- This study contributed a novel analysis method to examine the impact of smart grid technologies. The populations of indices before and after the implementation of smart grid technologies are treated as independent sets. Then, Student’s t-test was applied to objectively compare the two populations. The process marches through the successive months and reports whether the indices in the following months have significantly reduced values when compared with those in the preceding months. The utilities should consider this as a practice to continuously observe whether changing distribution utility practices are improving or harming service reliability. Even after using this method, strong conclusions about changes in reliability were difficult to assess among the natural randomness of the infrequent outages.
- Economic impacts from changes in reliability index values before and after implementation of FDIR or AMI systems could not be assessed with project data. No improvement in reliability could be clearly verified in this particular study. Utilities should consistently use accepted data collection practices and calculation procedures. Indices and methods should be revised to better identify best and worst performing feeders, and best and worst performing technologies. Results must ultimately be verifiable.