FROM OLD GRID TO SMART GRID: MAKING THE BUSINESS CASE FOR A SELF-HEALING GRID

ABSTRACT

Since electric utilities began deploying self-healing grids, there's been a concern that there isn't a solid business case to support the investment. The business case that's typically made for self-healing grids revolves around the return on investment the utility itself will realize from the savings the automation will produce. But these approaches to the business case ignore one very important aspect: the savings that electricity customers realize from improved reliability. Self-healing grids can restore power very quickly to most electricity users, dramatically cutting customer minutes of interruption (CMI), SAIDI and, most importantly, electricity user costs. When these costs are considered, the business case is strong.

In this paper, S&C Electric Company will present a framework for evaluating the business case for self-healing smart grids. The presentation will compare the actions taken in response to system disturbances in the "old grid" as compared to a "smart grid," and will explore the costs associated with the two approaches.

Background

The traditional approach that is taken today with most utilities in assessing the business case for Smart Grid applications such as Distribution Automation is usually presented and calculated based upon internal financial drivers. These are usually factors such as increased revenue and reduced operating costs to resolve problems. Also, depending upon the regulatory framework in which the utility is operating, the reduction of penalties may also be considered.

Though this approach may seem reasonable, it does not take into account all of the financial impacts to the greater community and economy. During outages, manufacturing facilities are no longer able to produce, retail outlets loose income with registers not working, foodstuffs may be ruined with the loss of refrigeration, or cargoes may not be loaded. These are just a few examples which present a loss of productivity which impacts upon the general community and reduces the output of the economy.

Potentially these cost impacts have not been factored into utility business cases, as they were viewed as potentially irrelevant, too difficult to calculate via a standard means, or simply overlooked.

The aim of this paper is not to examine the internal costs savings and revenue increases, which most utilities already understand; rather it will examine the cost to the greater community, and method of calculating this. With this method, these costs could be presented in a standard format to regulators or legislators when presenting a business case around rates or project funding.

Definitions and Terms

This paper is aimed at people both within the electrical industry, as well as those who are not. As such, we would like provide some descriptors around some of the terms used to assist in the understanding of this paper.

Feeder – the medium or high Voltage line which delivers powers to the customers

Fault – an event such as tree branch falling onto the feeder, or the feeder dropping to the ground.

Interruption – loss of power by the customer

SAIDI – System Average Interruption Duration Index, is a calculated number which shows the number of minutes per year on average that a customer is without power.

SAIFI – System Average Interruption Frequency Index, is a calculated number which shows the number of times on average a customer loses power over a year.

Case Analysis and Assumptions

Firstly, in order to utilise standard data around the impact of supply interruptions, this paper will source data published by the US Department of Energy. This department publishes it's ICE Calculator (Interruption Cost Estimate Calculator). Based upon data it has collected in the USA, it has calculated average impact to residential, commercial and industrial consumers, to calculate in a standard manner which could be applied elsewhere in the world with some analysis around local financial impacts.

This calculator has been based upon a paper “Estimated Value of Service Reliability for Electric Utility Customers in the United States” which was prepared for the US Department of Energy by the Ernest Orlando Lawrence Berkley National Laboratory.

For the sake of this paper, we will examine a theoretical scenario; where a permanent fault requiring repair occurs. The distribution network will be laid out as per Figure 1 below.

This diagram contains 5 separate substations which are represented by the numbered squares. For the sake of simplicity, each substation has a single feeder coming from it to deliver power to the utility customers. As is customary with most networks, there are a number of points where there are switches which would normally be open and as such isolate the different feeders, however, they can be used to re-energise sections of line from alternate substations in the event of an event such as our proposed fault scenario.

In particular, we will focus on Feeder 2, which is represented by the light blue lines. We will introduce a fault onto this feeder, and then examine what happens in both the scenario of the “Old Grid” which is mostly happening today, and the “Smart Grid”, and examine the different impact of the two scenarios.

For the sake of metrics (and ease of calculation) we shall assume that the feeder has a total of 2000 customers, and they are evenly spaced between the different switches located along that feeder.

We will also assume the following mix of residential, commercial and industrial customers along that feeder.

Residential: 1800 customers
Small Commercial or Industrial: 191 Customers
Large Commercial or Industrial: 9 Customers

Each of these customers will have a different financial impact burdened on them because of an outage. It could be the loss of food, or motor windings burning out, it could be that cash registers cannot operate, or there is loss to production.

The data contained in the ICE Calculator, is based upon the 2011 average data for USA.

Sector	Cost per Event (2011$)	Cost per Average kW (2011$)	Cost per Unserved kWh (2011$)
Medium and Large C&I	$10,069.60	$43.30	$23.90
Small C&I	$1,115.50	$136.10	$75.30
Residential	$5.10	$2.80	$1.60

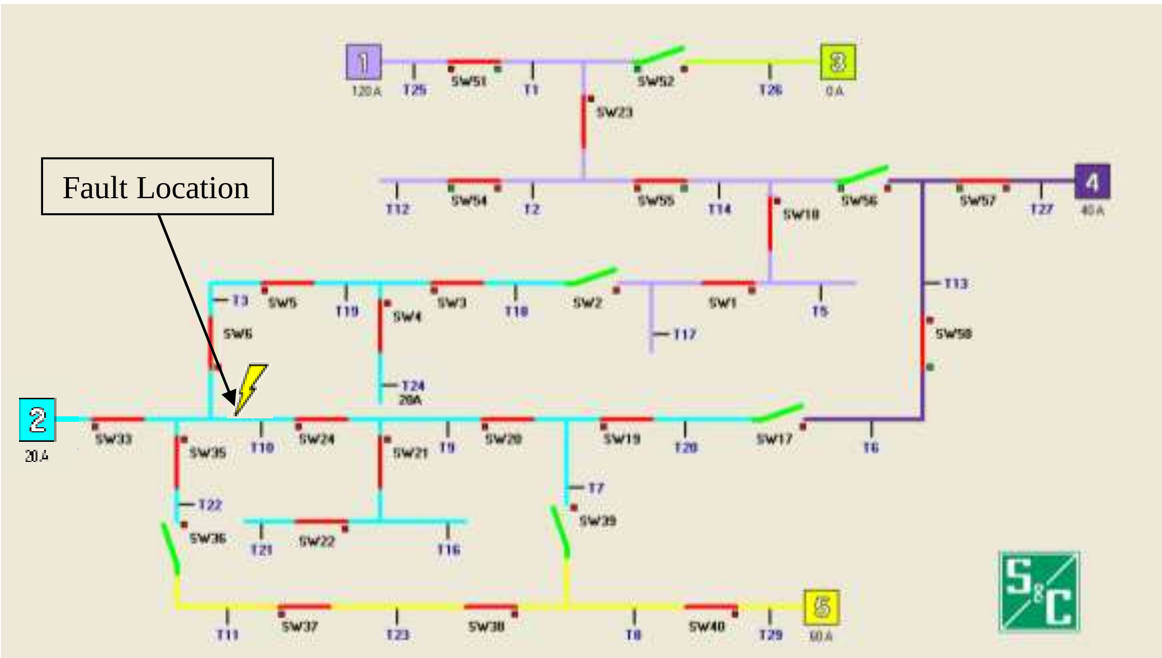

Figure 1. Network Layout for cost impact analysis

Old Grid

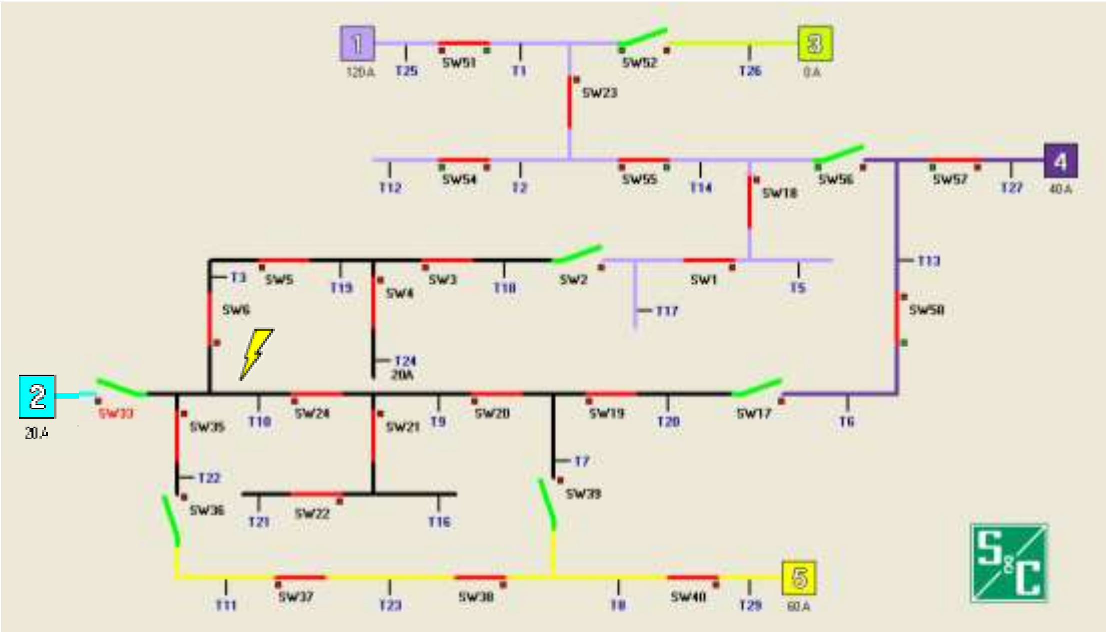

Figure 2. Status of Network immediately after fault (Black indicates sections of line without power

In the event of the nominated fault occurring, the circuit breaker at the substation trips in response. It may reclose the faulted section of line 10-20 seconds later in the hope that it was a tree branch that may have fallen off the lines. For this scenario, this is not the case, and the circuit breaker will open and de-energise the fault. This is like to be the scenario should a "Smart Grid" be deployed.

Here is a scenario as to how long it would take for repair work to start on the faulted section of the feeder.

Time since Outage	Event Occuring	No. of customers without Power
5-10 mins	Telephone calls from customers alert Utility of problem	2000
30 mins	Line Crew has found location of fault after patrolling the line, and radios back to the Control Room	2000
44 mins	Crew drive to Switch 20 and open it after authorisation	2000
53 mins	Crew drive to Switch 6 and open it	2000
72 mins	Crew instructed by control room they can close Switch 17, so they drive there, and restore 666 customers as they close that switch.	1334
81 mins	Crew drive to Switch 35 and open it	1334
94 mins	Crew instructed by control room they can close Switch 2, so they drive there, and restore 666 customers as they close that switch.	668
103 mins	Crew instructed by control room they can close Switch 36, so they drive there, and restore 334 customers as they close that switch.	334
110 mins	Crew drive to fault location and start work repairing the fault	334

For the sake of this scenario, we stop the clock at this point, as the time to repair the faulted feeder will take the same amount of time as it will in the Smart Grid Scenario.

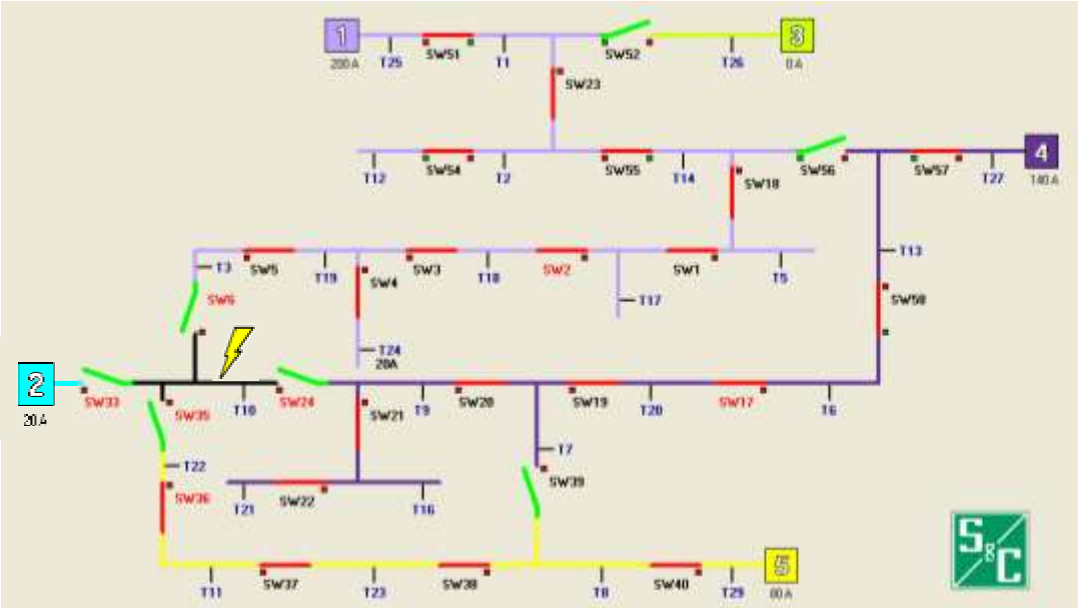

Figure 3. Status of Network after restoratation (either manual or automatic) (Black indicates sections of line without power

Smart Grid

We will know examine the customer impact under a Smart Grid Scenario

Time since Outage	Event Occurring	No. of customers without Power
10 secs	Switches 6, 24, 33 and 35 automatically open, isolating the faulted section of line	2000
18 secs	Switches 2, 17 and 36 all close to restore as many customers as possible	334
19 mins	Crew drive and find fault, and radio back to control room	334
58 mins	Crew drive to Switches 6, 24, 33 and 35, and open visible break disconnects to enable them to start work on repairing the fault.	334

So the comparison is quite compelling. Not only is the crew working to fix the fault much quicker, 1666 customers only see 20 seconds without power, than the extended duration in the Old Grid scenario.

Comparison

Assuming the breakdown of customers as previously noted, we will apply an average values through this calculation to examine just what was the cost impact of the outage to the community's economy, and how that is reduced using Smart Grid technology.

	Old Grid	New Grid
Elapsed Time (mins)	110	58
No. of Customers remaining without power	334	334
Customer Minutes of Interruption	181,307	19,229
SAIDI (CMI/2000)	90.7	9.61
Customer Cost for Interruption	$276,573	$111,999
SAIFI	1.29	1.29
Annualised Average Customer Cost	$356,778	$144,478

The difference in the average annualised cost for all customers is $212,300 per customer per annum, which represents the annual savings along this feeder.

On the other side of this equation is the cost required to implement such a scheme. For the sake of this discussion, we will assume that all field devices will be replaced. For the sake of this feeder we are looking at 5 devices, and 4 devices which are the interconnects. The cost of these devices could be $200,000-$500,000, for the sake of this calculation we will use $500,000 (worst case), and that would also include an appropriate communication device. The actual installation of these devices is usually significant higher than the cost of the device itself, often more than double. Let us allow $700,000. In the case of deploying the automation software, that is usually included within the device and does not represent an additional cost, however, in deploying such a scheme, you will need to look at training, updating operating procedures, as well as some testing. Let us allow $400,000 in this case. As such we come up with an estimated cost of $1,600,000. If we were to look at this as having a 30 year life, than the average annualised cost based on an interest rate of 11%, and an operation/maintenance spend of 3%, then with some round we arrived at an average annual cost of $62,500. Please remember that this represents a worst case scenario for cost, and the reality would be that the actual cost of deployment could be significantly lower if smart switches are already installed, and there may be no additional spend required for maintenance over the existing equipment which may be replaced.

Based upon these budgetary calculations, there is a saving of approximately $210,000, for a cost of $65,000.

This has only taken into account the cost savings to the customers, and not the operational savings which could be realised as well through line crews taking less time to fix problems and fewer crews being required. And under some regulatory frameworks there are penalties delivered around customer outages. This paper has not looked at these costs, as they are well understood by the distribution utilities. These costs should obviously be added within the business case proposal.

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Reference:

"Estimated Value of Service Reliability for Electric Utility Customers in the United States" which was prepared for the US Department of Energy by the Ernest Orlando Lawrence Berkley National Laboratory.