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ComEd Distribution Automation Strategy

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SUMMARY

Customer expectation for enhanced reliability has changed over the years -- uninterrupted power has become a necessity for everyday life. ComEd has invested 2.6 billion over the past 5 years to modernize its grid to improve reliability through programs focusing on underground cable, manholes, wood poles, storm hardening, training centers, and smart technology, including smart switches, substations, and smart meters. The distribution automation program focuses on installing smart switches on 12kV and 4 kV distribution feeders enabling power to be rerouted during outages. These smart switches or reclosers reconfigure feeders into smaller "sections", reducing the number of customers affected by an interruption. The automatic reclosers allow feeders to ultimately be divided into target sections of 500 to 750 customers to minimize the number of customers affected by a fault. Utilizing an analytical tool enables ComEd to incorporate historic feeder lockout data, overhead and underground feeder exposure, and a cost per avoided customer interruption when determining an optimal segmentation solution for each individual feeder.

KEYWORDS

Distribution Automation, Segment Strategy, Avoided Customer Interruptions, Cost per Avoided Customer Interruption

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Customer expectation for enhanced reliability has changed over the years and uninterrupted power has become a necessity for everyday life. ComEd is an energy delivery company providing safe and reliable electric service in northern Illinois to nearly 4 million customers. To meet customer expectations, ComEd has been making major investments to improve reliability through maintenance programs, replacing obsolete equipment, and implementing engineering solutions.

One of the key investments for improving reliability is ComEd's distribution automation program, which focuses on installing smart switches on 12kV distribution feeders. These switches enable power to be rerouted during outages. This is achieved by reconfiguring feeders into smaller "sections", which reduces the number of customers affected by an interruption. The automatic reclosers allow feeders to ultimately be divided into target sections to minimize the number of customers affected by a fault.

ComEd has more than 5,000 smart switches installed on its system, which includes approximately 4,000 switches installed on 12kV feeders. More than 2,600 of these devices have been installed from 2012 through 2016 as part of the smart grid program. By the end of 2016, ComEd's DA avoided approximately 7.3 million customer interruptions since 2012 through 2016, contributing to a 44% reduction in System Average Interruption Frequency (SAIFI). As the utility continues to install these devices, further analysis has been performed to determine the optimal segmentation strategy for making the greatest impact on reliability.

History of DA

ComEd has been installing reclosers on its 4/12kV distribution system since the early 2000's. The initial Distribution Automation (DA) strategy consisted of installing reclosers at feeder mid-points as standalone devices. These devices only operated to isolate a fault that occurs downstream of the device. Approximately 300 devices were installed prior to 2007. In 2007, ComEd increased the number of installed devices. This included implementing the next phase of DA device installation which incorporated a loop scheme. Loop schemes consist of either a half-loop or a full-loop scheme. A half-loop scheme allows for restoration of the back-half of a feeder by an alternate source such as an adjacent feeder with capacity should a fault occur upstream of the device. A full-loop scheme essentially has a tie between two adjacent feeders with the capability of restoring the back half of either feeder should a fault occur upstream of the devices. The DA devices do not communicate with each other; they operate automatically based on loss of voltage and time current curve coordination.

More complex DA schemes were utilized and implemented in 2012 when ComEd launched the smart grid program. With these complex schemes, multiple, normally closed DA devices were installed in series in conjunction with multiple tie reclosers, reducing customer exposure when a fault occurs. During this time, ComEd pursued a 500-750 customer segmentation strategy with the goal of not having feeders with segments serving more than 750 customers.

Until now, ComEd monitored the DA penetration on its system by tracking the number of feeders with DA devices. This method brought visibility to feeders with DA and also allowed for monitoring the status of high customer count feeders without DA. However, it did not provide visibility of segments with higher customer counts or feeders without tie reclosers. As the DA penetration on the system and the expectation for lower customer count outages have increased, the challenge for the utility has been to identify the optimal segmentation strategy with highest reliability impact. This has led the utility into looking at feeder segment data and the customer counts on each segment instead of simply tracking the number of feeders where DA devices have been installed.

Analytical Tool

As ComEd continues to pursue a segmentation strategy of 500-750 customers per segment, an analytical tool using QlikView has been developed to assess and validate the customer segmentation strategy. The tool incorporates feeder overhead and underground mileage exposure, historic feeder outage data, and a cost per Avoided Customer Interruption (ACI) to determine an optimal segmentation solution for each individual feeder.
In order to asses if the existing segmentation strategy is appropriate and beneficial for the system, various factors were considered when developing the tool. Such factors include:

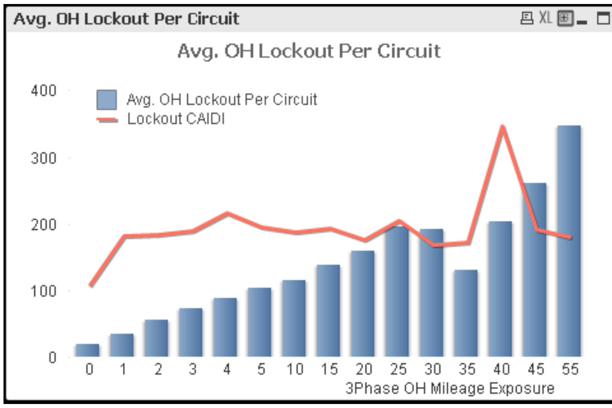
- Number of customers per segment
- Overhead/underground three-phase mileage exposure of each feeder
- Probability of an outage based on ten-year historic data
- Cost per device including additional tie reclosers needed

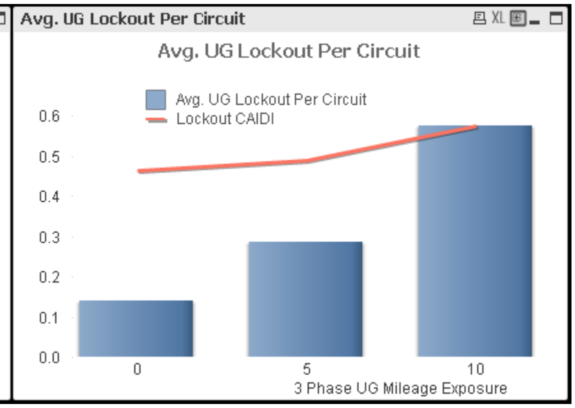
As DA penetration increased, high customer count outages required further investigation. Installation of DA devices at the midpoint of the feeder regardless of the number of customers per segment can be attributed to some higher customer count outages. It was critical to look at the customers per segment data instead of customers per feeder. For example, feeder XYZ is a feeder on the system that serves nearly 2,400 customers. A line recloser was installed on the feeder as a standalone device that does not have a loop scheme or tie recloser capability. When this feeder experiences an outage downstream of the device, there are more than 1,000 customers affected since each segment consists of more than 1,000 customers as shown below.

FEEDER	SEGMENT	SEGMENT CUSTOMERS	NO. LINE RECLOSERS	NO. TIE RECLOSERS	TOTAL DA DEVICES	LOOP_SCHEME
XYZ	Segment 1	1115	1	0	1	NO
XYZ	Segment 2	1275	1	0	1	NO

ComEd used the tool to develop a list of feeders based on the number of customers per segment. This makes it easy to identify and target the feeder segments that are above the segment strategy maximum of 750 customers per segment.

Overhead and underground three-phase mileage exposure was factored into the tool as data show that feeders with larger sections of overhead exposure have a higher probability of experiencing an outage when compared to feeders with less overhead exposure. To prove this, 10- year historic lockout data was obtained for all feeders on the system. The feeders were then separated into different categories/bins depending on the number of overhead or underground three-phase miles. As the historic outage data are correlated to the different feeder mileage bins/categories, it can be observed that as the overhead mileage exposure increased, the probability of the feeder locking out within a year increased. For example, the tool identified that for a feeder serving more than 500 customers per segment, the probability of an outage doubled going from one mile of overhead exposure to three miles of overhead exposure.





Along with setting the tool to look into existing feeder conditions and historic lock out data, multiple variables were created to be used and changed within the tool for quick analysis. Such variables include a cost per device to determine a total cost per segment strategy and cost per ACI, customers served; as well as a tie recloser ratio to determine the number of tie reclosers needed for each DA device required to meet the segment strategy. All of these variables can be modified to generate and compare charts and graphs dynamically. Whenever any of these variables are changed within the tool all applicable charts and graphs are updated instantaneously for quick analysis.

Determining the Optimal Strategy

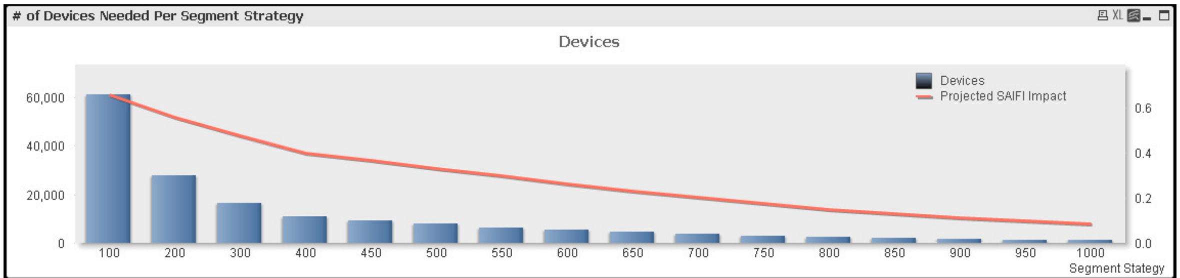
To analyze the different segment strategies, the tool was set up to calculate a projected number of avoided customer interruptions based on the number of customers per segment, overhead and underground mileage exposure, and the 10- year historic feeder lockout data. To calculate the projected avoided interruptions, all feeders were separated into different categories/bins depending on the mileage exposure. The 10-year historic feeder lockout data was then grouped by feeder overhead and underground mileage exposure. The lockout data is being used as a feeder lockout probability, enabling the utility to determine a yearly projected number of customer interruptions per section.

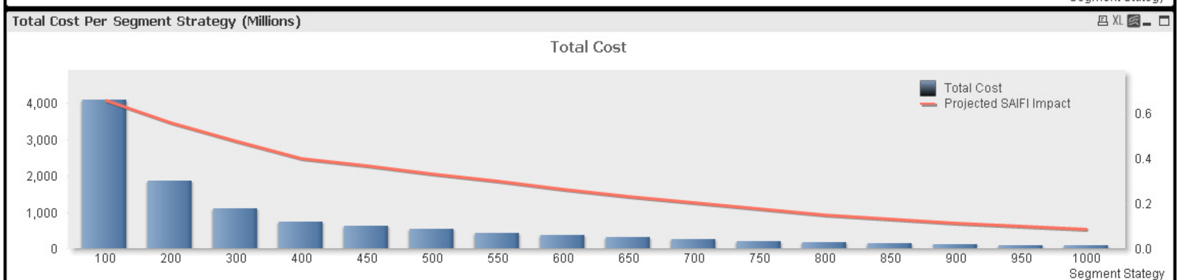
Each individual feeder is then analyzed to determine the number of additional devices needed to meet the different segment strategies ranging from 400-750 customers per segment. Using the tie recloser variable, the number of tie recloser devices needed is determined by multiplying the tie recloser variable to the total number of recloser devices needed to meet the segment strategy. The number of additional tie reclosers needed is added to the number of DA devices needed for a total number of devices needed per feeder. Based on previous tie recloser installations, the tie recloser variable was set so that for every two DA devices required to meet the segment strategy one additional tie recloser is required. Once the number of additional devices required is determined, the tool is able to project the number of customer interruptions per segment based on the new configuration of the feeder with the additional devices needed. Assuming proper DA device function, a fault on a feeder will be isolated to only affect one section. Therefore, the remaining customers on the other sections are avoided customer interruptions.

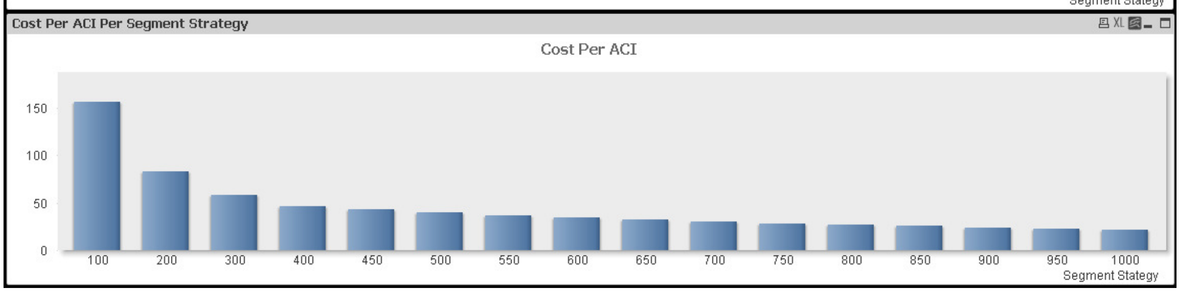
Various charts and graphs were created in the tool to aid in analyzing the different segment strategies. These charts and graphs provide a visual to compare the total number of devices needed, total cost, projected number of avoided customer interruptions, cost per avoided customer interruptions, and reliability impact for each segment strategy.

Results/Proposed Strategy

As the segment strategy decreases with lower customers per segment, the total number of devices required, total cost, cost per ACI, and reliability impact increases as expected.

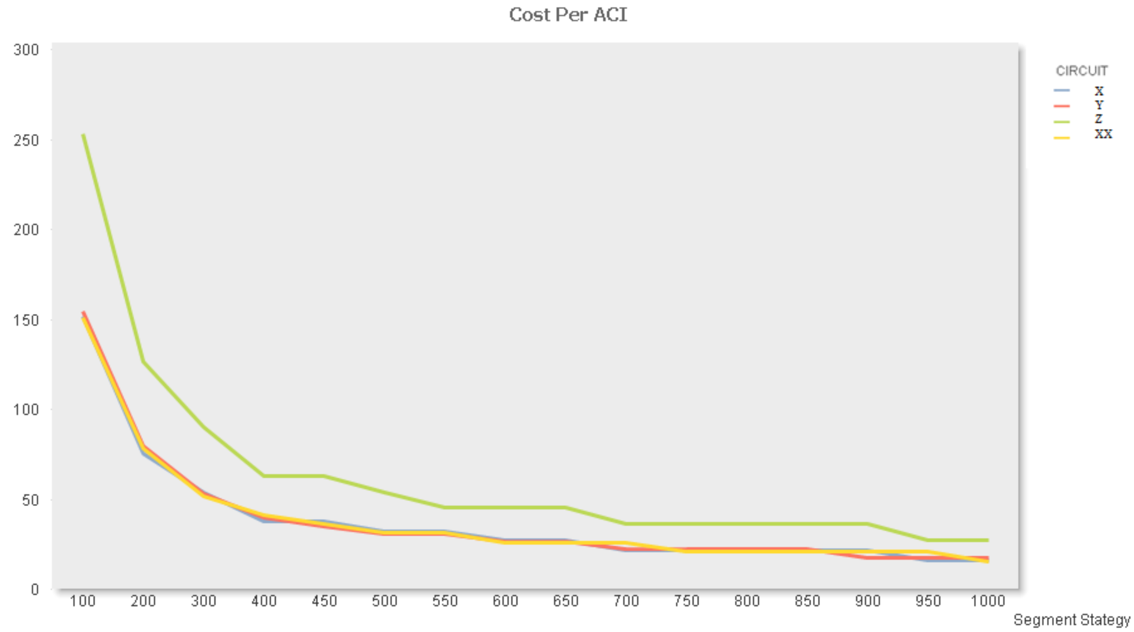






The utility was looking for a clear indication of the most effective segment strategy. The graphs produced by the tool were able to identify that there was a diminishing return on investment when segmenting below 400 customers per segment in terms of cost per ACI. Therefore, based on the graphs, the ideal segment strategy is between 400 to 750 customers per segment.

A more granular look into the data provided by the tool also allowed for a cost per ACI analysis to be completed when comparing segment strategies. Each feeder has an optimal segment strategy solution based on a cost per ACI. There are feeders on the system that can be segmented into as small as 400 customers per segment and still be within a reasonable cost per ACI as shown below.



As a result, the utility will strive for a segment strategy of 400 to 750 customers per segment with the optimal segmentation strategy based on a cost per ACI for each individual feeder. The tool will provide the list of feeders by ranking the feeders based on highest reliability impact. As ComEd continues to install more DA devices, prioritization of feeders for DA installation will be based on system average interruption duration index (SAIDI), addressing feeders with larger customer count segments and worst performing circuits.