WHITE PAPER

Building Resilient, Self-Healing Grids Starts With Careful Analysis of Feeder Layouts and Load Distribution

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Electric utilities are facing a grim horizon of rapidly aging distribution system assets at a time when extreme weather events and natural disasters are increasing in frequency. Though smart protection devices and other advanced technologies can give utilities the means to upgrade and better protect their systems, cost can be a significant obstacle. An analytical approach utilizing system data can supplement a utility's grid modernization plans, prioritizing the most critical needs so they are addressed first in a cost-effective implementation.

Distribution grids for utilities throughout North America are the critical "last mile" of a complex power delivery network. The system depends on a series of power lines, originating at distribution substations, that deliver electricity to homes, businesses, schools, hospitals and other institutions.

Currently, many feeder lines are configured in a radial pattern with power fed through a single breaker at the distribution substation. Feeder tie switches and occasionally tie reclosers are installed to provide power transfer capabilities that prevent widespread service outages following a fault or during a planned outage for repairs. However, these devices are often not enough to prevent long-duration service disruptions to large numbers of customers.

Building Smart Protections

Fault location, isolation and service restoration (FLISR) systems are increasingly becoming a means to add levels of reliability and resiliency to distribution grids. The basic goal of a FLISR system is to complement existing protection schemes by isolating a fault to a smaller section of a distribution circuit and then restoring power to other portions of the circuit.

Without FLISR protection, faults on distribution circuits can only be isolated with switches and reclosers that are typically limited by the operation of a field crew or supervisory control and data acquisition (SCADA) operation of reclosers when available. These faults, often caused by downed power poles or even tree limbs contacting power lines, normally result in a loss of service for the whole distribution feeder until there is a manual intervention. With a FLISR scheme implemented, portions of a circuit experiencing a fault can be restored within seconds of an unplanned outage.

Under a FLISR protection scheme, a number of automated recloser devices are installed in a network controlled by the utility's SCADA system to provide the data needed to manage all equipment and devices installed on the grid.

FLISR systems are configured with reclosers installed at multiple strategic locations within a feeder line, creating smaller customer zones. If a fault occurs within any of these zones, the reclosers instantly open and isolate it, leaving only a fraction of the feeder without power. For the rest of the circuit served by this feeder, the load is picked up by one or more feeder tie reclosers as well as the original recloser. The result is an operation of the grid in which many customers only experience a short interruption of power.

Understanding the Utility's Criteria

The goal of every power utility is to provide affordable and reliable electricity to customers. FLISR systems can help achieve that objective through careful placement of reclosers in a well-designed pattern that maximizes benefits with consistent levels of protection.

The costs and benefits of FLISR will vary depending on the feeder configuration and the selected position of each sectionalizing device. With many utilities managing hundreds to thousands of feeders, identifying the most optimal placement of these smart devices can be a significant challenge.

To optimize benefits, placement of reclosers and other SCADA-controlled devices should consider distance between devices, distance to the feeder, total customers, total load and the systems' topology. Device placement generally depends on the utility's criteria, budget and service areas. Criteria for planning a FLISR network should be tailored to the utility's individual operating profile and overall goals. With many utilities struggling with a variety of issues related to operations and reliability, FLISR systems often prove to be the right solution to mitigate these risks.

For heavily populated service areas, the utility may prefer to focus on maintaining a consistent number of customers within a FLISR zone. This sets a predetermined value for the dropped load in the event of a fault. In rural areas where feeders typically span longer distances, the emphasis may be on isolating sections that are considerable distances from service centers and that otherwise would impose challenges in achieving reasonable restoration times. For a utility with an abundance of outage management system (OMS) data, the preference may be to create criteria focused on circuits that have historically had many unplanned outages.

Understanding local customer profiles is essential to develop rationale that determines the practicality of implementing a FLISR system on a feeder. While a residential consumer may prefer a three-second outage over a three-hour outage, the benefit an industrial customer may receive from this short outage may not matter. A quick restoration time may be immaterial to an industrial customer that operates equipment that has a long start/restart time.

Baseload Analysis Is First Item in Feeder Study

A critical function of a FLISR system is the ability of one or more adjacent tie feeders to pick up the load of a main feeder that is experiencing a fault. With the growth utilities have experienced in recent decades, the system analysis must first look at whether the feeder is operating under conditions that exceed thermal thresholds. Equipment upgrades should be modeled and evaluated prior to installation to understand all attributable causes that may potentially overload a feeder.

Capable Feeder Evaluation

Following the baseload analysis, capable feeders are identified alongside adjacent feeders that either are currently tied or could be tied to the main feeder. Feeders that would be a good fit for further evaluation can be selected based on requirements for customer count, loading, distance per zone and other factors. Evaluating a whole system/area for its ability to sustain FLISR is not necessary; however, engineers are often challenged to be cognizant of the costs and benefits that are associated with installing distribution automation equipment on each feeder.

Feeder configuration may determine the number of FLISR zones necessary, and the number of zones implemented will have a direct correlation with cost of implementation. A radially configured feeder that is tied at the end of the mainline would require the fewest number of feeder tie-points, thus making it the most cost-effective. Multiple feeders may be utilized to support a single faulted feeder, though this could increase scheme complexity and cost. Therefore, analysis of the feeder's configuration is imperative to arrive at the optimal reliability improvement plan at the lowest cost.

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These devices should be accounted for in the study:

- Substation breakers
- Sectionalizing reclosers
- Tie reclosers

Substation breakers — which must be intelligent electronic devices — can detect faults directly outside the station and communicate with the other sectionalizing recloser devices. Tie reclosers will enable the transfer of power from the faulted feeder. The number of sectionalizing reclosers needed will depend on the size and configuration of the feeder; however, the operations and control team will gain flexibility in dealing with faults as more reclosers are added.

Under a rudimentary FLISR application, two feeders would be tied together. However, the size and loading of the feeders and topology may make it necessary to tie multiple feeders together so that the load from a faulted main feeder can be picked up. These scenarios will normally increase cost in application, while adding complexity in placement algorithms and planning efforts.

Identify Required System Upgrades

A worst-case fault is one located directly outside of the main feeder, between the breaker and first recloser. This scenario results in the largest load that would need to be picked up and served by one or more feeders via normally open ties. In scenarios in which only one feeder is tied to the faulted feeder, the load on this feeder would nearly double following the fault.

The distribution model is configured to simulate each fault individually as a method to observe the expected level of new thermal overloads following installation of sectionalizers. The breakers, conductors and transformers are among the equipment that may be most affected, and the model will pinpoint whether any of this or other equipment should be upgraded to perform under increased loading conditions. This is similar to an N-1 contingency planning exercise that utilities already may be regularly implementing to analyze system conditions. Analyzing system upgrades during peak loading conditions would mean that the FLISR scheme will protect the area during all times of the year, even in the most severe loading conditions.

Conclusion

Installing automated devices will improve restoration time and reduce costs on the distribution system. However, inconsistency in feeder layouts and load distribution presents some challenges in developing the most optimal placement of devices.

Adopting a rigorous modeling methodology to identify, analyze and evaluate the most capable and beneficial feeders can provide benefits in the planning and decision-making process.

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