The *Evolution* of the Modern Grid

By: Milhouse's Telecom Experts

MILHOUSE

‘HISTORICALLY, THE POWER INDUSTRY HAS BEEN CAUTIOUS ABOUT ADOPTING **NEW** TECHNOLOGIES...’

INTELLIGENT SUBSTATIONS

Since the inception of the power grid in the early 20th century—during the development of the alternating current system—the need for substations as the hub for protection and control became paramount to the delivery of safe and reliable electricity to consumers. Early systems were initially protected by fuses which later evolved into oil-filled circuit breakers in conjunction with analog electromechanical relays that became the standard for protecting and controlling the grid. These protection systems were designed to de-energize the smallest possible section as quickly as possible. One of the biggest benefits of electromechanical relays has always been their durability and long life span. However, in today's modern world, the drawbacks are that they are slower than the new microprocessors and their accuracy fades over time, requiring regular calibration.

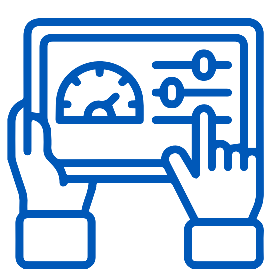
Historically, the power industry has been cautious about adopting new technologies. The reliability of analog relays and the criticality of the bulk electric system only welcomed small, gradual changes to protection schemes. In the 1960s, advancements in technology made way for discrete components to be used in electric system protection. This enabled the introduction of the solid state relay. These relays had quicker operating and reset times and no moving parts, giving them an edge over electromechanical relays. As computer-based technologies advanced further in the 1970s, a microprocessor relay was introduced in 1979. Through the 1980s, microprocessor relays were basically restricted to the theory of electromechanical relays. It wasn't until later that they were actually able to replace a full relay package.

It took some time, but utilities eventually realized the pros outweighed the cons when it came to microprocessor relays. The benefits include “multiple setting groups, programmable logic, adaptive logic, self-monitoring, self-testing, sequence-of-events recording, oscillography, and ability to communicate with other relays and control computers”. Since a single microprocessor relay can replace multiple electromechanical relays, less panel space is needed which makes microprocessor relays a less expensive option. The drawback is that their lifespan is dependent on that of the individual electrical components, which is typically shorter than electromechanical relays.

As we have seen in the past, it sometimes takes a catastrophic event to force a change. On August 14, 2003, a massive blackout impacting as many as 50 million people prompted governing agencies to enact measures to improve the electric infrastructure in an effort to reduce outages and prevent widespread blackouts of this severity. These mandatory measures have driven utilities to invest in grid technologies to improve system reliability at a faster rate than before the blackout.

With the advancement of communication technologies, digital data is collected more quickly and more accurately than before, allowing Supervisory Control and Data Acquisition (SCADA) systems the ability to monitor and control more points with less wiring. The relays that protect the equipment are able to monitor the health of the equipment, including transformer gases and breaker wear. This allows for more efficient maintenance programs that can extend the life of the equipment. This monitoring minimizes the chances of a catastrophic failure, thus preventing outages. Asset replacement programs can be more predictable and efficient with accurate, real-time equipment monitoring.

The synchrophasor is another notable advancement in power technology. Synchrophasors are devices that monitor voltage, current, power, etc. at a high sample rate. They use the time stamping of a satellite clock and send the data, via SCADA, to a central location like an Independent System Operator (ISO) for monitoring. This is primarily used at utility interties and high voltage/high profile circuits. Utilizing multiple synchrophasors, ISOs can monitor power flow from multiple sources and make decisions regarding system stability in the event of unintended outages. This allows dispatching systems the ability to react to negative system conditions in real-time and prevent blackouts from cascading.



SYNCHROPHASORS are devices that monitor voltage, current, power, etc. at a high sample rate.

Substation and Grid technologies continue to advance to increase capabilities, reliability, and reduce capital and maintenance costs. Automation is another driver in technology. An emerging substation automation standard being adopted globally is IEC 61850. This standard outlines a method of data collection inside the substation. Similar to Programmable Logic Controller's (PLC) Modbus design, IEC 61850 defines a "Process Bus" where all data is collected and merged from current and voltage monitoring devices where it can be used by any relay. The relays are then able to make control decisions and forward information to the "Substation Bus" where it can be sent via SCADA or accessed remotely on a network. This method of data collection and data buses eliminates a majority of the analog wiring that is typically a significant cost in substation design.

The analog wiring used to connect current transformers/potential transformers to the relays is susceptible to failure and lacks the accuracy of digital signals. Running a network signal from a current transformer (CT) also eliminates the possibility of opening that CT which can result in major damage to that equipment or, more importantly, unsafe conditions for personnel. A purely networked communication system comes with several drawbacks, including the increase in complex logic that has to be rigorously maintained and stored. Likewise, methods of testing and commissioning must drastically change, as manually sending discrete direct current (DC) signals to the equipment becomes obsolete. Rather, all logic needs to be tested and verified for proper operation. Additionally, the new substation automation standard IEC 61850 will require increased security measures. Security gateways will need to be installed before access to the Process Bus, amongst other cyber-security measures.

The United States has been slow to adopt IEC 61850. As mentioned previously, the domestic power industry is generally cautious when incorporating new relay and communication technologies. Networks, fiber rings, and Ethernet communications are still in their infancy stage in the U.S., so it is now a matter of time, experience, and trust before IEC 61850 becomes more commonplace.

DISTRIBUTION AUTOMATION: is a term to describe the intelligent control of distribution circuits utilizing various automated devices such as switches, capacitor banks, voltage regulators, and fault locators.

DISTRIBUTION AUTOMATION:

Before the use of SCADA and microprocessor relaying by the power companies, the only way for the utilities to know about an outage was a call from their customers. As the calls would come in, they could determine the severity of the outage. This was a fully analog system with the only protection being fuses and breakers. Fault locating and communication did not appear until decades after the first AC distribution lines were built. Starting from around the 1940's, telephone lines were used to transmit equipment status from substations to control rooms. In the coming decades, various communication technologies were created to increase bandwidth and performance, such as power line carrier and microwave technologies.

These communication mediums communicated data from the point of view from the substation. But what about the point of view halfway down a distribution circuit? Sometimes events occur farther down the lines, out of sight from the view of the substation. If a fault, for instance, is a high impedance fault, it is very difficult for the substation protection relays to realize the true nature of the disturbance. If the only protection downstream on a distribution circuit are fuses, this does not allow for much flexibility. Once a fuse blows, only a crew of lineman can restore the power. Distribution Automation is the solution for a more flexible and controllable distribution system.

DISTRIBUTION AUTOMATION DEVICES AND FUNCTIONS

1

SWITCHES

Used for separating a circuit from each side of a pole. Can shift load in a circuit. If the circuit is fed by two sources, this makes the switch a tie switch. If one source goes down, the switch can close to pick up the other half of the circuit.

2

CAPACITOR BANKS

Used to improve the power factor of a circuit. Power factor describes the relationship between the voltage and current waveforms. The more they match, the higher the power factor up to 1.0. If the power factor is 1.0, it shows the perfect delivery of power without wasted energy. If a capacitor bank can switch into a circuit automatically when the power factor drops below a predetermined level, it will maintain a high level of efficiency.

3

VOLTAGE REGULATORS

Used to keep the voltage level of a circuit at a level all the way to the last user of a particular circuit. Because the conductors used to carry electricity are not perfect carriers of electricity, energy is lost as you go down the circuit. This causes voltage to drop and the last user could experience a voltage level that could cause unnecessary wear to their electrical devices or not even run at all. The way to correct voltage drop on circuits is to add a voltage regulator partway down the circuit. These are actually automatic transformers that are capable of changing the voltage plus or minus 10% at the other end making sure the last house on the circuit receives the proper 120/240V at their meter.

4

FAULT LOCATORS

These are small devices connected directly to a conductor with lights to indicate to line crews that a temporary to permanent fault has occurred. These devices can reduce time for field workers to locate faults. They can operate as standalone units or with an unlicensed radio frequency and report back to a utility's SCADA system.

ADVANCED COMMUNICATION SYSTEMS:

Power and Telecommunications have been synergistic since wires have been attached to wooden poles. One can notice the massive transformers up on a pole and there could be no telecommunication cables attached whatsoever. Nonetheless, we still reference the structure as "telephone poles". The initial intersection between the two entities was these "telephone poles". The poles became jointly owned and when work was required by one entity that required activity by the other, monies were exchanged. Moreover, when a third party wanted to attach to these poles, payment was required to both pole owners.

As power grids advanced, telecommunications was a necessity whether it was via wireless radio communications or copper wire. The initial widespread telecommunication need was to connect substations and control centers for SCADA (Supervisory Control And Data Acquisition) applications. As the needs for monitoring and device communications increased, so did costs for these services by telecommunication companies. Consequently, many power companies invested in their own private telecommunication systems.

Power Utilities built radio, wireless, copper wire, and most recently, fiber telecommunication infrastructure. The costs of the private networks paid for themselves in three to five years depending on the circumstance. With their private infrastructure, power companies could update the systems, add termination and drop points without the cost they were previously paying to the carriers. The key component was to have internal resources to build and maintain these networks, networks that were foreign to existing power company employees.

Currently, the power companies are designing and building ringed diverse fiber networks that will be superior to those of Telecom companies from diversity and reliability perspectives. The networks are built with multiple year fiber needs in mind. With power companies, being the sole utility that currently serves every household and every business, the opportunities are endless. These sophisticated and highly diverse ringed networks have the bandwidth to easily serve their own telecommunications needs and the ability to lease fibers to others. Additionally, the networks are sophisticated and robust that they are also able to provide services to households, depending on local legislation. These modern fiber footprints can provide bountiful revenue streams for the utilities, provided they have the vision and foresight to put such opportunistic plans in action.

The only consideration remaining for utilities is deciding upon the most cost-effective fiber network to build, keeping in mind that this is truly a state of the art telecommunications network not a power infrastructure that they are accustomed to creating.

There are two networks under consideration:

The first is a multi-tiered ring design.

This involves ringing a group of substations together then creating "feeder rings" within each substation's serving area that is essentially an overlay of the existing feeder routes. Pole and conduit space restrictions can hinder progress and drive up costs. However, this creates a ring within a ring redundancy and allows for devices (e.g. reclosers, DA devices, and other Smart Grid devices) to communicate direct to one another instead of communications have to go back to substation then rerouted to correct device.

The second is a GPON (Gigabit Passive Optic Network) design.

This would involve placing an OLT (Optical Line Terminal) in the substation Then electing to utilize centralized fiber splitting or distributed fiber splitting, which could be a paper unto itself, either will work for utility provider purposes. Decisions on Centralized vs. Distributed should be made strictly upon long-term utilization plans. Then the serving terminal is an ONT (Optical Network Terminal) the specific end user service is from the ONT.

Both infrastructure designs provide phenomenal, redundant fiber solutions for the utilities. GPON, if designed correctly, can allow for greater diversity with less cost. The cost of labor for fiber placement and splicing is the critical limiting factor in many cases. The ring inside a ring design requires many more labor hours to install and splice the fiber. For example, when installing a GPON network, you could run a 48 fiber from the OLT to the Fiber Split location. With a 1:32 splitter, you could have 5 x 216 cables coming out of the split location to feed all devices in five different feeders, or you could feed all devices in five feeders and provide fiber to all of the households in that area to provide triple play services.

Telecommunications has evolved from a non-necessity to a revenue driver for the utilities. This could easily be the solution to the dwindling revenue drivers in the utility space depending on the jurisdictional rules within the targeted geography.

SUMMARY

As we enter a purely digital world, grid technology is slowly following. New technologies bring accuracy, speed, decreased costs, and increased capabilities. As with anything the benefits come at a price. Networked systems present an opportunity for cyber-attacks, new testing methods need to be adopted, and there needs to be continuous improvement of storage and upkeep of logic settings for every Intelligent Electronic Device (IED). If recent history tells us anything, the future grid will be 100% digital and smart. The real question that remains is, **how long before this technology is fully deployed in the United States?**

1. Sachdev, Mohindar S. and Das, Ratan.
“Understanding Microprocessor-Based Technology Applied to Relaying.” WG I-01 Report, Jan. 2009.

2. Sachdev, Mohindar S. and Das, Ratan.
“Understanding Microprocessor-Based Technology Applied to Relaying.” WG I-01 Report, Jan. 2009.

3. Mackiewicz, Ralph. “Technical Overview and Benefits of the IEC 61850 Standard for Substation Automation.” http://www.controlglobal.com/assets/knowledge_centers/abb/assets/IEC61850_Overview_and_Benefits_Paper_General.pdf

For additional information on Telecommunications/Fiber for utilities, please contact Anthony Lioce at alioce@milhouseinc.com.