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Bringing Grid Modernization to the Distribution Transformer

by Vince Martinelli

The reliable operation of the North American power grid is testament to the quality of design, planning and execution over multiple generations of utility engineers. As part of this progression, previous grid modernization efforts added high-performance sensing and communications technologies, first to generation and transmission, and eventually to the distribution system. These technologies helped utilities squeeze more capacity and resiliency out of existing assets cost-effectively, reacting to changes driven by load growth and diversification, as well as industry restructuring.

These trends led to broadly deployed "automation" in the medium-voltage (MV) portion of the distribution system. Medium-voltage substations, where high-voltage power is stepped down to MV on its path toward end customers, have seen the greatest degree of automation. Combined with automation at some of the MV devices downstream from the substation, such as reclosers, capacitor banks and line regulators, this provides the ability to measure and control the system with higher fidelity as compared to managing from the transmission layer. Utilities have evaluated technologies, tested specific solutions in trials, validated use cases and financial models, and made prudent investment choices in rolling out MV automation.

History Repeating Itself

A similar "automation" transition is now happening at the low-voltage (LV) level. Driven by higher reliability expectations, growth of rooftop solar PV generation, energy efficiency programs, the emergence of electric vehicles in the transportation mix, and the promise of battery storage for a range of grid-connected applications, new pressure is being placed towards the edge of the grid. It is more acute in some service areas than others, and can be clustered within one utility's territory – or even within specific feeder circuits. Driven by these trends, the next frontier in grid modernization is at the interface between the MV distribution layer and the LV distribution layer, centered on the humble distribution transformer, as represented in Figure 1.

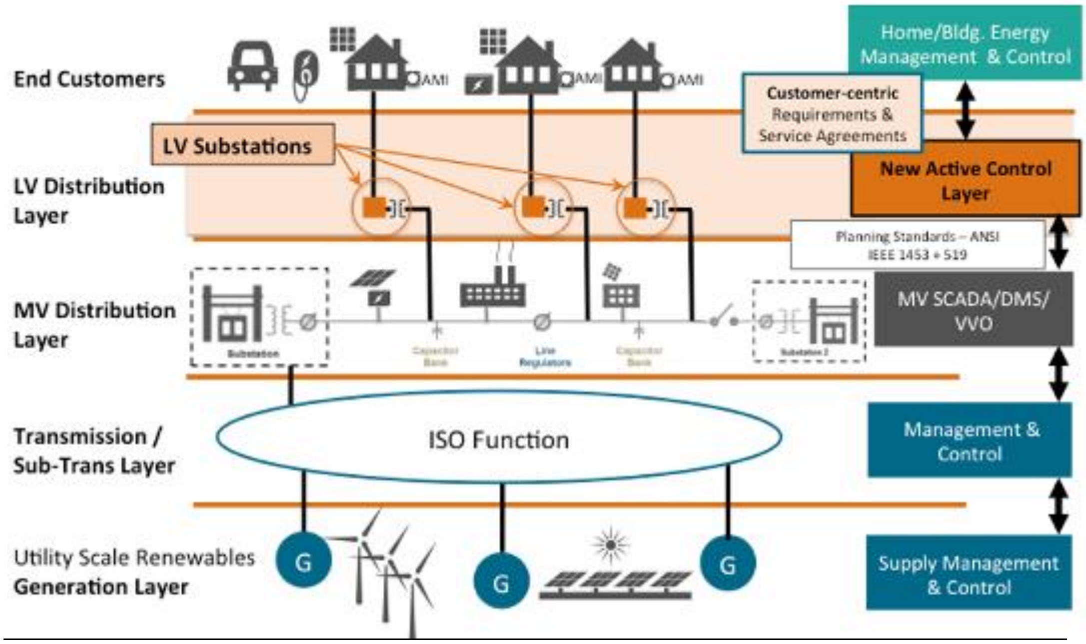


Figure 1. LV Substations provide critical new capabilities for grid modernization.

Similar to the MV automation rollout, LV substation modernization will happen first at acute "pain points," becoming more widespread as the technology matures and the detailed use cases are developed.

Active LV Substations Solve Multiple Problems

Among the variety of potential applications, local voltage regulation is a clear "pain point" that cannot be addressed at the MV layer alone. Whether for increasing PV hosting capacity at the neighborhood level by countering voltage rise during reverse power flow, or for supporting energy efficiency programs where the goal is to deliver voltage to customers at the lower end of the acceptable ANSI A range, the benefits of adding automation to the distribution transformer – what we refer to as an LV substation – are becoming clear.

Figure 2 shows two examples of LV Substations deployed by U.S. electric utilities. In each case, a standard distribution transformer is paired with a grid automation device providing control with power electronics-based multi-function regulating capabilities, visibility with onboard current and voltage sensors, and automation with processing and memory components and communications capabilities. These regulating functions include voltage regulation in forward and reverse power flow, power factor correction, and harmonics mitigation. The system also reduces voltage sags, swells, and flicker for the customer connected downstream.

These compact, maintenance-free systems take advantage of existing “real estate” on poles and pads, simplifying the easement process and providing an alternative to costly upgrades on the MV system. The flexible communications platform can integrate with SCADA on the MV system and interact with downstream LV devices, such as AMI (“smart meters”) or behind-the-meter resources, such as next-generation smart inverters, EV chargers or energy storage resources.

Figure 2. LV Substation implementations for (a) an overhead system and (b) underground plant, featuring coupled integration with a distribution transformer for siting on a standard pad in a residential area. Adding a power electronics-based regulator with integrated sensing, computing, communications and control software brings grid modernization to legacy distribution transformers.

Figure 3 shows voltage data at a particular customer meter over several months without grid automation; then with the voltage regulation from the LV Substation in place. Voltage variability before upgrading the system reflects MV voltage variations, with dips well below ANSI limits, as delivered to the distribution transformer. When the power electronics regulator is activated with an initial setpoint at 240 V, the only variability at the customer is the load-dependent voltage drop on the LV line itself. This particular customer, and neighboring customers behind this LV substation, now receive compliant voltage and superior power quality, independent of the bulk MV system.

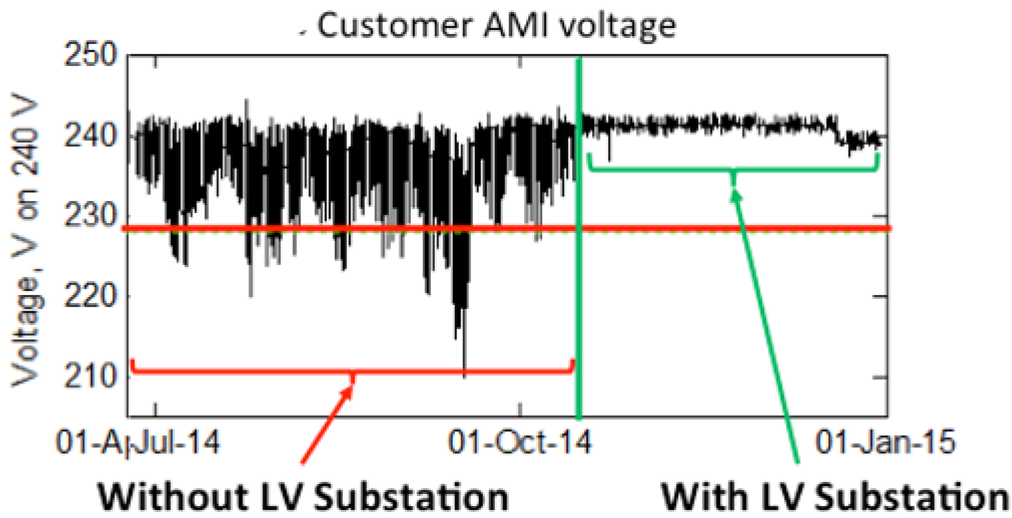


Figure 3. Customer voltage delivery improvement measured by utility AMI voltage data showing the control provided by power electronics voltage regulation after introducing the automated LV Substation.

Looking Toward the Near Future

The daily news cycle reminds us that the forces putting pressure on the distribution grid are accelerating, driven largely by changes in how customers choose to participate in their energy future. Whether it's Hawaii mandating a 100% renewables goal; solar power's levelized cost of energy continuing to plummet; New York's REV plan; the ongoing retirement of coal-fired power plants; or nationwide deployment of EV charging stations, the trends are clear.

Fortunately, the concept of automated LV Substations – elevating the status of the long-serving distribution transformer – provides a capital-efficient blueprint for a path forward, modeled after the successful rollout of automation in the MV distribution layer. The difference today is that localized pressure points call for localized solutions appropriate for the demands of the LV layer. The evolution of power electronics-based system designs has resulted in compact, reliable and cost-effective options to consider.

Vince Martinelli is responsible for managing the company's product roadmap and articulating the business case for agile grid infrastructure. Vince brings over 25 years of product experience and an in-depth understanding of how to effectively drive new technology into legacy systems, transforming them in the process. He joined Gridco Systems in 2013 from Amazon Robotics (formerly Kiva Systems), where he led a team responsible for the integration of Kiva's robotic order fulfillment system into Amazon's global network. Prior to Amazon, Martinelli led *the North American arm of Professional Services at Sycamore Networks. He has also held senior management positions at Corning Inc., including product management roles in the Optical Fiber business. Vince earned both the SB and SM degrees in Materials Science & Engineering, with a concentration in Economics, from MIT, where he was a Tau Beta Pi Fellow and an Academic All-American athlete.*

For further information on multi-function power electronics-based regulation systems that turn distribution transformers into automated LV Substations, please visit www.gridcosystems.com

North American Protective Relay Marketplace: New Report Now Available

Volume One of this 2016 study of protection and control is based on a sample of North American investor-owned, public and cooperative electric power utilities. The data provides information on a segmented basis by type of utility and by number of customers served. These tables help illustrate occasional important differences in the findings based on the type and size of utility.

The findings in this report are based on survey responses received from 79 electric utilities that include 16 investor-owned, 28 public power, 26 cooperatives, 4 electric power consulting groups, and 5 Canadian electric utilities. This survey was conducted between April and May of 2016. Initial phone calls were placed to utility officials and relay engineers to invite them to complete the survey either as a Microsoft Word attachment via email, or completing an online survey resident on www.surveymonkey.com. Reminders were sent via email every 2 weeks until the last call deadline was issued.

The 79 utilities participating in this year's study represent 31 million electricity end users/customers, having 3,340 transmission substations and 7.841 distribution substations covering over 800,000 total T&D line miles. This sample is about 20% of the North American customer base and approximately 15.7% of utility-operated transmission and distribution substations. Newton-Evans has previously estimated that direct shipments to utilities account for about 40% of the overall North American market for protective relays.

Each question in this report contains:

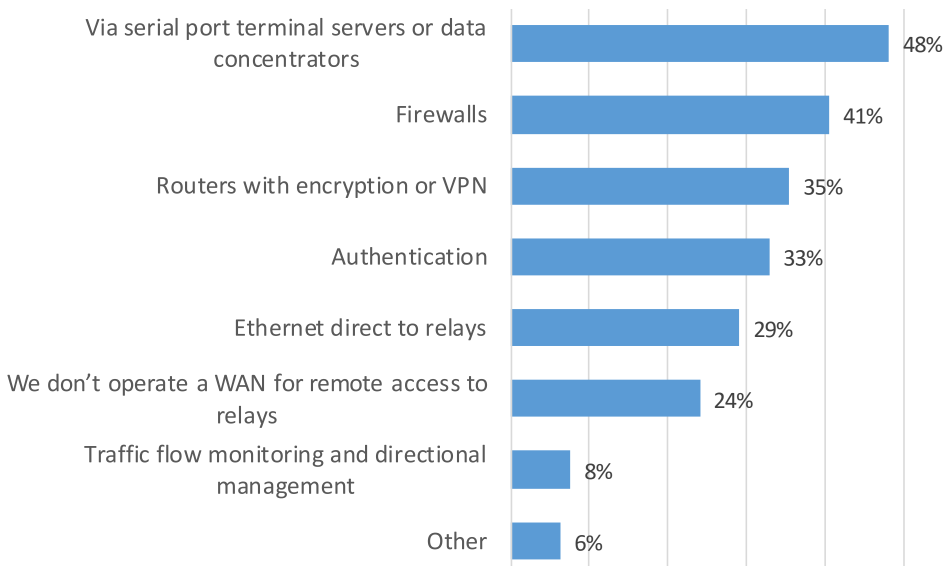
1. A pie chart or bar chart summarizing how all of the survey participants responded to the question
2. A table (or series of tables) showing the data by:
   a) Summary: all survey respondents
   b) Investor Owned: investor owned utilities
   c) Public Power: publically owned utilities (municipals, public utility districts, state or federal government)
   d) Cooperative: member owned electric utility cooperatives
   e) Canada: electric companies in Canada
   f) Other/Consultant: respondents representing power technology companies, industrial facilities
   g) <100,000: electric utilities serving fewer than 100,000 customers
   h) 100,000 to 499,999: between 100,000 and 499,999 customers

i) >=500,000: 500,000 or more customers (either directly via distribution, or indirectly via generation and transmission.)

3. Some written analysis and observations based on the tables and charts

What approaches are you using to operate a Wide Area Network (WAN) for remote access to relays?

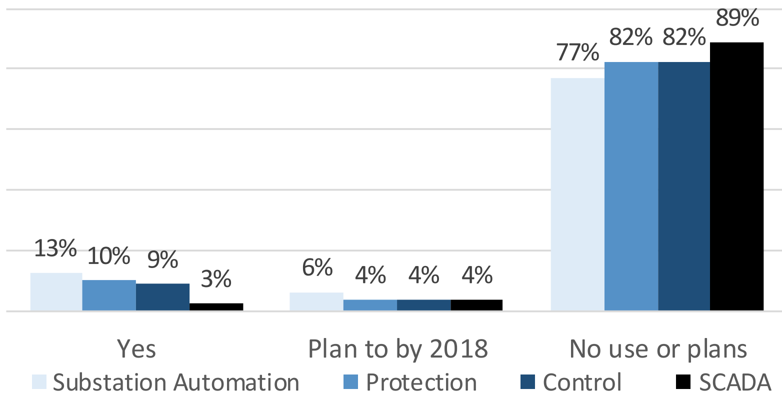
While 24% of the respondents said they don't operate a WAN for remote relay access, almost half said they connect via serial port terminal servers or data concentrators. Forty percent use firewalls in conjunction with the WAN, while just over one-third said they use routers with encryption or VPN capabilities to access relays over a WAN. Other mentions included "gateways".



Does your utility's control system use protocol IEC 61850 for Substation Automation, Protection, Control, or SCADA?

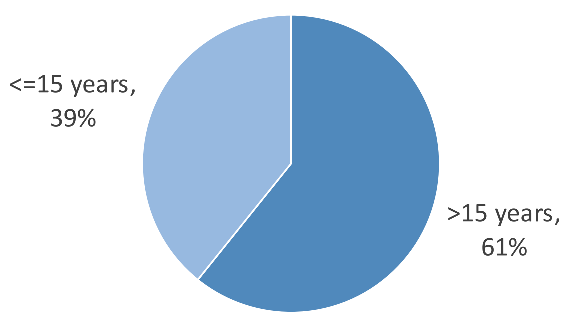
Seventeen respondents said they use IEC 61850 in at least one of the four areas. Thirteen percent said they use 61850 within the substation, and another 6% said they plan to use it in the substation by 2018. About 80% of the respondents have no use or plans for IEC 61850 in any area, and 89% said they don't use or plan to use IEC 61850 for SCADA.

Use/Plans for IEC 61850



What % of your relays have been in service for more than 15 years?
Overall, 55% of survey respondents reported that more than one-half of their protective relays have been in service for more than 15 years. Out of all 76 respondents to this question, twelve said that less than 20% of their installed base is older than 15 years. However, in some cases the useful lifespan of a protective relay is stated as nearly 30 years. There are installations of electro-mechanical relays that have been in operation since the 1960's according to some utility officials. According to the observations reported in Table 23, two-thirds of relays installed at surveyed IOUs (and nearly two-thirds among Canadian respondents) have been installed for more than 15 years.

Percent of Relays Among Newton-Evans Sample that are >15 years in service



To order Volume 1 of *The Worldwide Study of the Protective Relay Marketplace in Electric Utilities: 2016-2018* visit our website for an order form:
www.newton-evans.com/relaymarketplacestudy2016-2018

Current Trends and Research Topics

During the summer months, Newton-Evans is conducting various client studies on the North American markets for T&D Equipment testing; gas insulated switchgear, and SCADA RTUs.

On a multi-client basis, the company is well underway with an international study of protective relay usage patterns, and will shortly begin an international study of EMS/SCADA/DMS and OMS.

We encourage anyone involved with electric utility engineering, operations, planning or procurement to give us a call or send us an email if interested in helping the electric power industry shape its future by participating in our widely respected studies. We incentivize our study participants in several ways, including donations, gift cards and importantly, a sharing of study findings that enable utilities to benchmark their own activities and performance vis-à-vis a large sample of industry peers. Learn what the power industry is doing to improve quality of service and reliability with advances in infrastructure equipment and adoption of technology solutions for operations and engineering.

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800 222 2856

Upcoming Electric Power and Energy Industry Conferences: July-September 2016

Asterisk (*) indicates that Newton-Evans Research staff will be in attendance
Double asterisk (**) indicates active participation by one or more staff as speaker, moderator or panel member

2016 IEEE PES General Meeting *
July 18-21 2016
Boston, Massachusetts USA
http://www.ieee-pes.org/meetings-and-conferences/conference-calendar/monthly-view/165-sponsored-by-pes/315-gm-2016

Power-Gen and Distributech AFRICA 2016
19-21 July 2016
Johannesburg, SOUTH AFRICA
www.powergenafrica.com

ISA Water/Wastewater and Automatic Controls Symposium
August 2-4 2016
Orlando, Florida USA
isawwsymposium.com

CICED 2016 – China International Conference on Electricity Distribution
10-13 August 2016
Xi'An, CHINA
www.ciced2016.org.cn

CIGRE Session 2016 **
21-26 August 2016
Palais des Congres
Paris, FRANCE
www.cigre.org/Events/Session/Session-2016

ISGT 2016 – IEEE PES Innovative Smart Grid Technologies
September 6-9, 2016
Minneapolis, Minnesota USA
http://sites.ieee.org/isgt-2016/registration/

EMMOS 2016 – Energy Management and Market Operations Systems Users Conference **
September 11-14, 2016
Phoenix, Arizona USA
www.emmos.org

IEEE PES ESMO – Int'l Conference on T&D Construction Operation and Liveline Maintenance
September 12-15, 2016
Columbus, Ohio USA
https://esmo.ieeepesreg.com

2016 Southeastern Distribution Apparatus School & Conference
September 19-22 2016
Auburn, Alabama USA
http://utilitytech.org/apparatus/

IEEE Power System Relaying Committee Meeting *
September 19-22, 2016
Cincinnati, OHIO USA
www.pes-psrc.org/

Power-Gen Asia 2016
20-22 September 2016
Seoul (KINTEX), SOUTH KOREA
www.asiapowerweek.com/en/index.html

T&D Latin America Conference and Expo (IEEE PES)
21-24 September 2016
Morelia, MEXICO
http://ieee-tdla16.org

POWERCON 2016 – Challenges, Opportunities and Solutions for Grid Modernization
September 28- October 1 2016
Wollongong, AUSTRALIA
http://ieee-powercon.org