Monitoring Substation Voltages

Maintaining Distribution System Performance Using Advanced Watt Hour Metering

Author: Charles J. Kachel, P.E.
October, 2018
Contribution: Randy Brunner
Central Power Electric Cooperative, Minot, ND

Attribution: Greg Goebel 1 August 2012

The Versatility of Revenue Grade Watt Hour Meters

Within the electric utility industry, electronic watt hour meters have been in widespread use for more than two decades. The combination of high accuracy, reliability, and the ability to provide an impressive array of information, which these meters provide, is giving utilities the ability to be more efficient in billing customers and more proactive in managing their transmission and distribution systems. The interesting thing about electronic watt hour meters is that their name suggests a one dimensional instrument.

Electronic watt hour meters do not measure watt hours. Sounds pretty stupid, right? If these meters don't measure watt hours, why are they called watt hour meters? If they are not measuring watt hours, how can they be used for billing customers for the energy their loads consume? The answer is that watt hours are a calculated quantity. If an electronic watt hour meter has **advanced capability**, there are many more calculated quantities, in addition to watt hours, available for use in a variety of applications.

When you talk about actual **measurement**, advanced electronic watt hour meters are really precision volt meters and ammeters that use those measurements to calculate quantities of energy and other things, such as Power Factor and %Total Harmonic Distortion (THD). The ability to take two core pieces of measured information and use them to calculate a wide range of quantities, nearly instantaneously, is what gives these meters their versatility. A utility engineer on the generation/transmission/distribution side of the business has the ability to take **one device** and use it to provide all sorts of data for multiple entities within the company. As a metering engineer at a utility, my goal would be to select a meter that could be scaled using software keys, to unlock additional capabilities when needed. One meter, many applications.

Recently, I visited Central Power Electric Cooperative, Inc. in Minot, North Dakota, where they are using an advanced capability watt hour meter to help manage the stability of their regulated distribution voltage. I had the pleasure of meeting with Dennis Olson, Chief Substation Engineer, and Randy Brunner, substation engineer. Randy provided the details of how their utility is using the Shark® 200 meter from Electro Industries/GaugeTech to provide close monitoring of regulated voltage at their T/D substations.

Substation Voltage Monitoring at Central Power Electric Cooperative

Central Power Electric Cooperative (CPEC) is a supplier of wholesale bulk power to six member cooperatives in a service area covering over 25 counties of central and southeastern North Dakota. Power is purchased from Western Area Power Administration and Basin Electric Power Cooperative. Over 65,000 residences, farms, and commercial/industrial customers are served from 167 delivery points; 25 wholly owned and 10 jointly owned transmission/distribution voltage substations; and 1,381 miles of transmission lines. In order to provide high quality power to their member co-ops, Central Power substations had traditionally used voltage monitoring.

The existing voltage monitoring equipment, while functional, had become outdated. The system used integrated cellular telemetry to send data on regulated voltage conditions, but the cellular technology was 2G, and the manufacturer had no plans to upgrade the cellular radio module. Since 2G cellular networks have mostly been deactivated by the various cellular providers, and 3G networks are nearing their sunset dates, it became necessary to look at developing a new voltage monitoring network using 4G cellular telemetry. A design that uses an advanced meter connected to a standalone 4G cellular router would give CPEC the flexibility to change to newer cellular technologies, without replacing the meters themselves.

Most states regulate utility operations quite extensively. In my home state of Wisconsin, utility regulations are contained in the state's administrative code. PSC 113 governs all aspects of utility operations, including voltage variance allowed on the utility distribution system. In North Dakota, where CPEC operates, there are similar controls in place. Wisconsin specifies different acceptable voltage variances, depending on the size of a customer's load (see below).

PSC 113.0702 Standard and maintenance of a service voltage. Each utility shall adopt standard nominal service voltages for each of the several areas into which the distribution system or systems may be divided and shall file with the commission a statement of the standard voltages adopted. The service voltage shall be reasonably constant within the following limits:

(1) For all retail service, except retail power service, the service voltage shall not vary by more than 5% above or below the standard voltage.

(2) For retail power service furnished to customers having demands of 500 kilowatts or less, the service voltage shall be no more than 5% above or 10% below the standard nominal voltage.

(3) For retail power service furnished to customers having demands of more than 500 kilowatts, the service voltage shall not vary by more than 10% above or 10% below the standard nominal voltage.

(4) For polyphase voltage unbalance issues, ANSI C.84.1-1989 Appendix D is the reference that will be followed. The utility and its customers may agree to not be constrained to the reference if it is economically beneficial to the customer.

(5) For service rendered to public utilities and others for resale the standard nominal voltage shall be as mutually agreed upon by the parties concerned. If no formal agreement exists, the standard nominal voltage shall vary by no more than 10% above or below the secondary nominal voltage.

(6) The variation in service voltage referred to in subs. (1) to (3) inclusive shall refer to a steady state voltage.

(7) Upon customer request, the utility shall investigate line voltage variations and disturbances, associated with voltage sags, swells and transients, at the point of service. Requests for tests may be limited in availability, number or frequency for the same customer at the same location where previous tests have indicated that the variations and disturbances are within acceptable industry limits. The utility may establish rules for certain customers to decrease the incidents of these variations and disturbances as seen by other customers.**History:** Cr. Register, July, 2000, No. 535, eff. 8-1-00.

North Dakota requires control of voltage variance within +/- 7% (see below).

General Authority: NDCC 49-02-11 Law Implemented: NDCC 49-02-11
69-09-02-18. Standard voltage and allowable variation.
1. Each utility furnishing electric service shall adopt a standard nominal voltage, or voltages, as may be required by the design of its distribution system for its entire constant voltage service area or for each of the several districts into which the distribution system, or systems, may be divided. The voltage maintained at the utility's service terminals as installed for each customer shall be reasonably constant with a variation in voltage at any time of not more than seven percent above or below nominal voltage. A utility may furnish electric service to a particular customer, or to a group of customers at a specific location, on its system under conditions of voltage variation greater than seven percent if approval thereof is obtained from the commission.
2. Variations in voltage in excess of those specified herein caused by service interruptions, the action of the elements, temporary separation of parts of the utility's system, infrequent and unavoidable fluctuations of short duration, or other causes beyond the control of the utility shall not be considered a violation of this section.
General Authority: NDCC 49-02-11 Law Implemented: NDCC 49-02-11
69-09-02-19. Voltage measurement and voltage records.
1. Each utility shall employ at least one portable indicating voltmeter, and at least one device capable of producing recorded voltage measurements in continuous service at the plant, office, or on a customer's premises. Each utility shall make a sufficient number of voltage measurements to indicate the character of the service furnished to its customers and to satisfy the commission, upon request, of its compliance with established voltage requirements. All voltage measurement records shall be available for inspection by the commission for a period of one year.
2. Each recording voltmeter shall be checked with an indicating voltmeter when it is placed in operation and when it is removed, or periodically if the instrument is in a permanent location.
History: Amended effective January 1, 2002. General Authority: NDCC 49-02-11
Law Implemented: NDCC 49-02-11

Even though CPEC is technically not subject to NDCC 49-02-11 compliance (that falls to member coops that directly serve end users), CPEC does monitor their regulated voltage as a good business practice. In order to do that successfully, they need to use equipment that provides precise measurements.

Advanced Meters for Voltage Monitoring? Why?

Using an advanced watt hour meter for voltage measurement may seem excessive, but it makes perfect sense. Since watt hour meters used for utility billing are required to have at least 0.2% accuracy for energy calculations, the measured components of voltage and current must be better than that. If you are a distribution engineer looking for precise voltage measurement and control, using a watt hour meter makes more sense than using a meter with less overall accuracy.

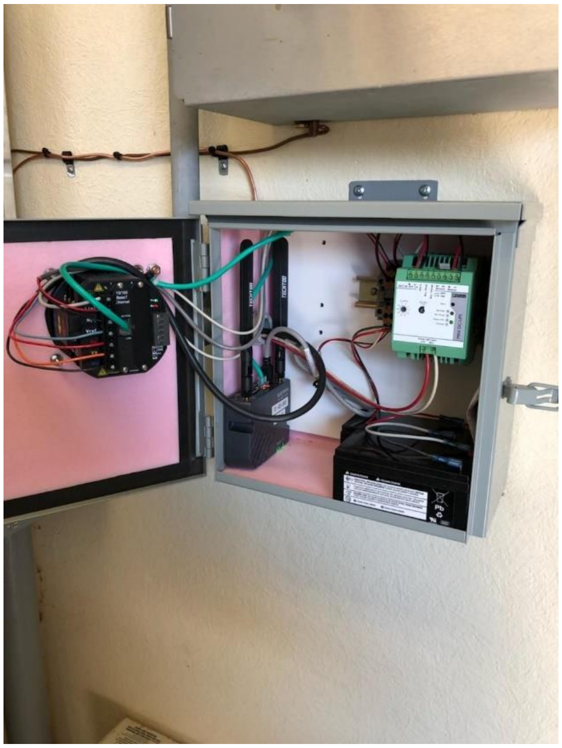
Voltage monitoring can be done in a number of ways, but the system requirements may eventually change. Should your new voltage monitoring points be capable of doing more than just monitoring and trending voltages in a substation? In selecting an advanced watt hour meter like the Shark® 200 meter with voltage measurement accuracy of 0.1%, CPEC now has a voltage monitoring system that can become much more, without the need to replace hardware. The Shark® series of meters uses V-Switch™ key technology that allows meter capability to be scaled as needed. In cases where only basic measurement functions are required, a utility can purchase Shark® 200 meters with a V1 switch, and upgrade the capability of their meter population as needs change, without having to redeploy a new type of meter.

CPEC used this philosophy and purchased roughly two hundred Shark® 200 meters with V3 switches enabled. This provided them with Multifunction Measurement with I/O expansion (V1); 2 MB of data logging capability (V2); Harmonic Analysis (V3); and Transformer Loss Compensation with CT/PT compensation (V1). As needs change, CPEC could add capability to their Shark® 200 meter population by upgrading to a V4, V5, or V6 switch. Please take a look at the table below for details on what capabilities are enabled for each V-Switch™ key.

Shark® 200 Meter V-Switch™ Key Features

FEATURE	V1	V2	V3	V4	V5	V6
Multifunction Measurement with I/O Expansion	X	X	X	X	X	X
2 MB Data Logging		X	X	X		
3 MB Data Logging					X	
4 MB Data Logging						X
Harmonic Analysis			X	X	X	X
TLC and CT/PT Compensation	X	X	X	X	X	X
Limit and Control Functions				X	X	X
64 Samples per Cycle Waveform Recorder					X	
512 Samples per Cycle Waveform Recorder						X

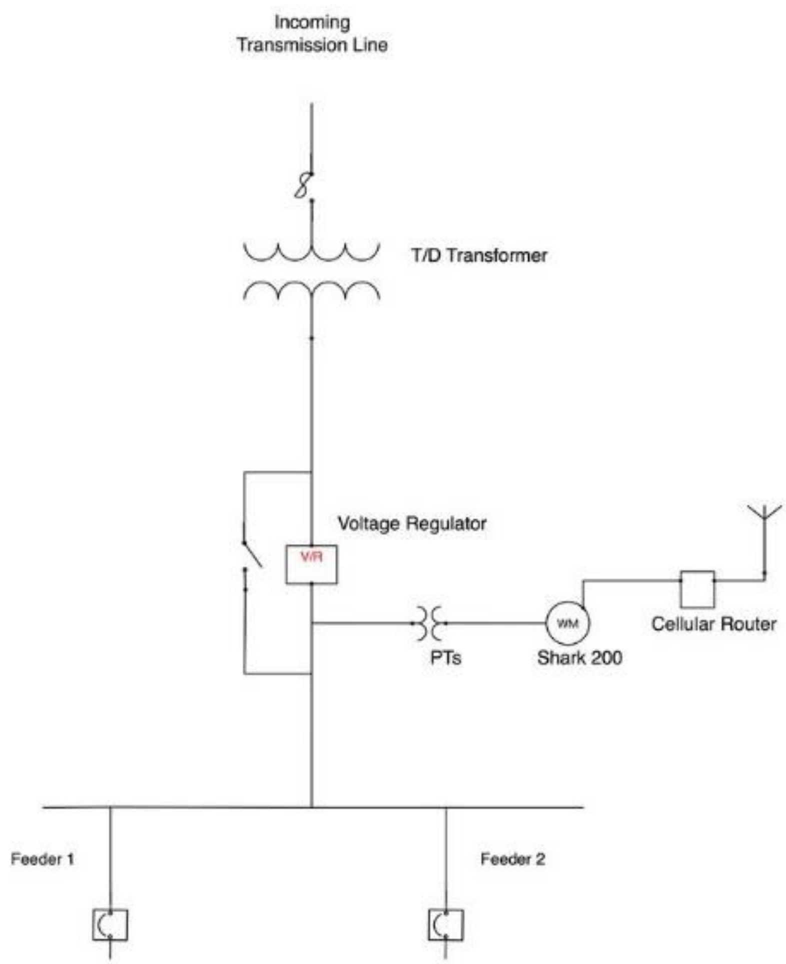
By upgrading to a V5 or V6 switch, CPEC could easily add power quality measurement and logging to any T/D substation. This expanded capability would provide valuable data for any root cause analysis that may be required in the future. The CPEC plan going forward is to upgrade meters strategically to the V5 switch when circumstances require it.



The typical voltage monitoring installation at CPEC consists of a Shark® 200 meter with a V3 switch and a Sierra Wireless RV50 4G cellular router, with UPS to provide meter power and communication capability during outages (See photo on the left).

The enclosure is a custom weatherproof type that allows for outdoor or indoor installation. The Shark® 200 meter is connected to the RV50 cellular router via Ethernet, and UPS connections serve the meter power supply and RV50. The meter's voltage elements (Va, Vb, Vc, Vref) are connected to the regulated output of the station voltage regulator.

As previously mentioned, voltage monitoring is done at the output of voltage regulators in each substation (see one-line diagram below). In the interest of simplicity and cost control, voltage transformers internal to the voltage regulators are used whenever possible for connection to the Shark® 200 meter. Currents are not monitored, but could be with the addition of current transformers and upgraded V-Switch™ keys if energy quantities and power quality need to be monitored.



Typical Voltage Monitoring Installation – Central Power Electric Cooperative

With the V3 switch enabled, CPEC has 2 MB of logging capability to use in trending voltage measurements. Using the open source Modbus protocol, CPEC acquires the voltage trending data through CSV files created by the Shark® 200 meter, and the IT Department formats those CSV files into a monthly report. That information is presented at a monthly meeting of all the member cooperatives, and areas are identified for further analysis and possible corrective action.

One feature that CPEC utilized with their former voltage monitoring system was email messaging that was triggered by an out-of-tolerance event. Although the Shark® 200 meter has this capability (email to multiple addresses is possible), it has not been implemented by CPEC at this early stage of meter deployment. The plan is to initiate email notifications after more installations have been completed.

My experience with the email feature on Nexus® and Shark® meters is that it is an extremely useful feature. While I was the Primary Metering Engineer at We Energies in Wisconsin, I was able to work with our IT Department to create a group mailbox for all email sent by our Nexus® meters. Each day, our Senior Account Managers and Service Managers could check the group mailbox for email notifications sent from meters installed at customer locations. Our Power Quality Engineer could also check the mailbox for activity that might indicate issues on various distribution feeders. This turned out to be of enormous benefit for a company where anything less than excellent customer service was unacceptable. When I retired in June of 2017, we were just about ready to deploy Shark® 270 meters at many of the large secondary rate C&I accounts, with the email feature implemented on those meters, as well.

Summary

The Shark® 200 meter is a revenue grade meter with a lot of versatility. CPEC has discovered this fact, as their innovative voltage monitoring system demonstrates. Their design is now more modular than their previous voltage monitoring system, and much more versatile due to the V-Switch™ key scalability of the Shark® series of meters from E-Sine Engineering Solutions. With the Shark® 200 meter's 0.1% accuracy for voltage measurement, and its ability to use PT compensation to improve instrument transformer accuracy (if necessary), CPEC can be assured of getting an extremely accurate picture of their T/D system voltages.