

An aerial photograph of San Francisco, California, showing a dense urban landscape with a mix of colorful residential buildings and modern skyscrapers. The Transamerica Pyramid is a prominent feature in the center. A stylized logo consisting of a horizontal line with three vertical connections and the letters 'ENSC' in a gold, circuit-like font is overlaid on the top half of the image. The word 'MAGAZINE' is written in a blue, sans-serif font to the right of the 'ENSC' logo.

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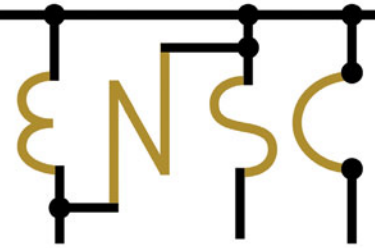


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Time does fly and it is hard to believe that with the upcoming ENSC in San Francisco, we will be celebrating 20 years of this event. This will be a special one to celebrate with two decades of ENSC's behind us. Our agenda will be packed with presentations that will make your jobs much safer while gaining valuable knowledge of everything pertaining to the world of electrical underground distribution.

Make sure you mark April 8th through the 11th on your calendars and help spread the word to your peers! If you have a spouse or significant other, please encourage them to attend as we have events planned for this special occasion.

I want to continue to thank those who contribute and support the ENSC and this magazine. Without your continued support, we would not have the opportunity to continue to educate others in this specialized field of network distribution.

I look forward to seeing all of you in San Francisco!

Respectfully,

*Mark Faulkner
Product Line Manager
Eaton*

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Conference

San Francisco, California

April 8th-11th, 2019

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Maximize reliability using MV Networks

Tony Oruga, P.E., Eaton, Product Sales Manager

The electric power industry has several different distribution topologies that are typically considered during design of a new power distribution system. Topologies used today from least reliable to most reliable are as follows:

- Simple radial—typically used for servicing small residential or commercial loads
- Primary auto loop—typically two radial feeds tied together at an open switch point
- Underground Residential Distribution (URD)— typically adopted for servicing residential subdivisions or commercial loads
- Primary selective—typically used for larger loads requiring automatic primary side switching
- Secondary selective—typically found in industrial applications used with coordinated secondary side switching schemes, i.e. main-tie-main switchgear
- MV/LV spot network—uses multiple feeders in parallel except typically dedicated to a single customer, outstanding reliability second only to LV grid networks
- Distributed LV grid network—similar to spot networks but typically found in major metropolitan areas servicing many customers (city block). Uses multiple feeders operating in parallel, the most reliable distribution system available

Network systems are the most reliable distribution system available; however, not many understand its benefits or applications. Secondary low-voltage (LV) grid networks operate at 120/208 V and spot networks operate at 240/480 V (some 600 V). Many networked utilities are taking advantage of the LV network reliability and are applying them at a medium-voltage level.

A spot network is a distribution system in which paralleled loads are powered by multiple paralleled sources. The sources can be powered from a single substation, or from multiple high-voltage substations that will always be synchronized. The key feature of a spot network is the relay protection associated with the power sources that isolates individual faulted sources without disconnecting the other sources, providing continuity of service to the loads. Additionally, a network system design has isolation capability so the equipment can be isolated for service or maintenance without causing any interruption to the power supply. This can provide a significant cost benefit by permitting outages for normal maintenance, or system repairs to be carried out during normal working hours. This automatic function is provided by a special network relay, which is designed to open on reverse magnetizing current whenever the primary feeder breaker is opened. It will automatically reconnect the transformer to the network bus when this relay senses that the transformer voltage is higher than the network.

Introduction

The advantage of a medium-voltage (MV) spot network with multiple parallel power sources is the opportunity to provide enhanced continuity of service to loads compared to traditional power distribution system designs. With an individual power source serving a load sized for the power source, the loss of the power source results in the shutdown of the load. However, with paralleled loads and sources in an MV spot network, the loss of an individual power source does not interrupt power to the loads if isolation of the faulted source is successful. A typical MV 2-spot network is shown in Figure 1.

The performance of a MV spot network is affected by decisions in both the power system and the selection of loads. The performance of the power source equipment improves as the number of power sources, N , increases, with each source becoming smaller. There is a lower percentage



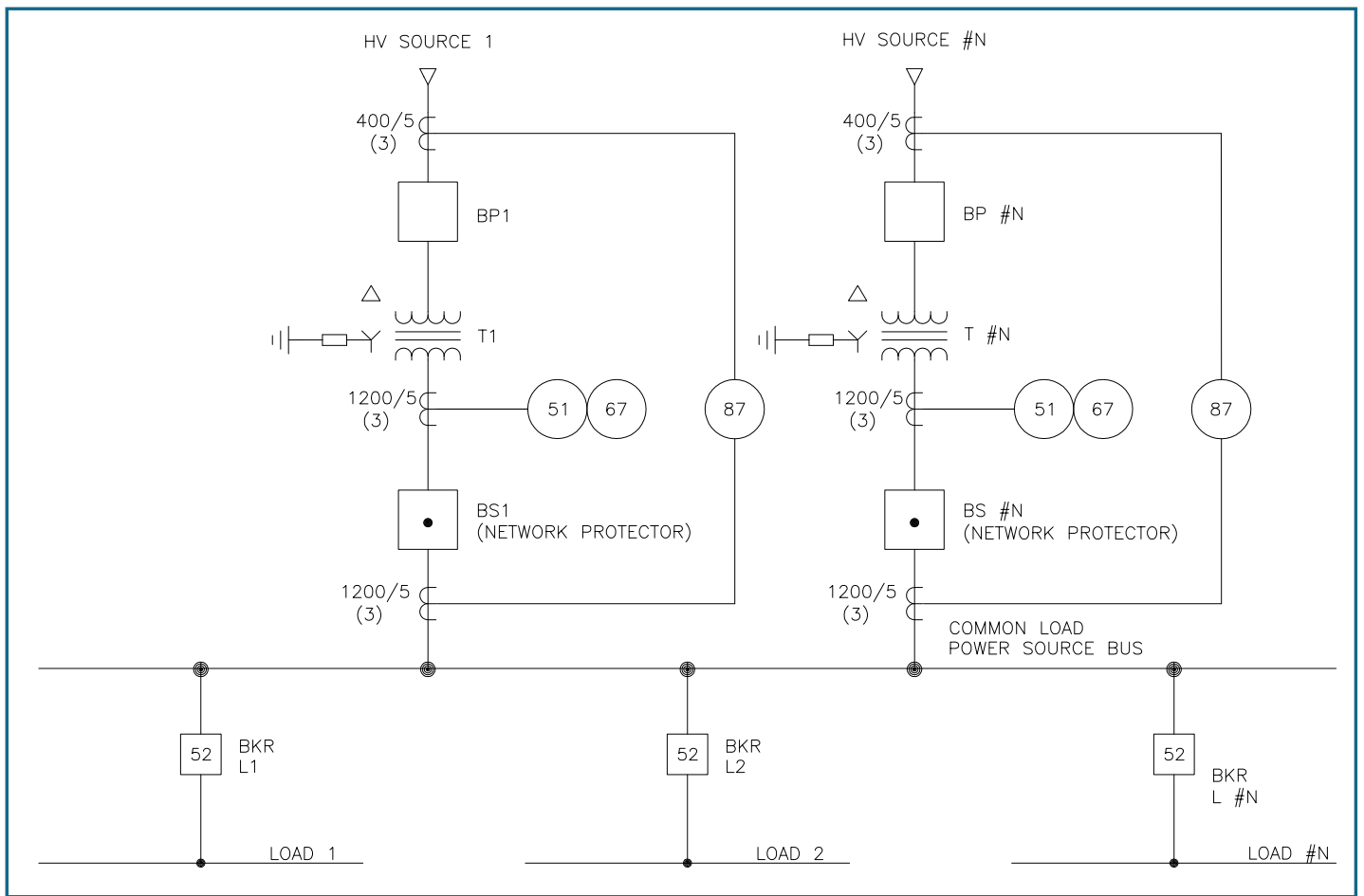


Figure 1. Typical MV spot network template

loss of total power supply capacity when a single source is lost—the N-1 condition.

Load size selection relative to power equipment size also affects performance. If success is defined by avoiding the loss of loads when a power source is lost, loads must be limited to the capacity of N-1 transformers. The use of base kVA or fan-cooled kVA ratings for transformers when in the N-1 condition must also be decided.

If load shedding in an N-1 condition is allowable, more load can be served in the normal N transformer operation periods, and the cost of the power system on a \$/kVA can be lowered. In general, increasing the load in the N condition reduces the advantages available in the N-1 condition, and successful operation of an MV spot network is based on successfully satisfying the needs of a specific load.

Circuit protection in a MV spot network

Relay protective features that are unique to MV spot networks are phase and ground fault functions related to the isolation of an individual power source from the network for a fault in the power source or upstream of the power source. The intent of traditional protection schemes is the clearing of faults downstream of the transformer before taking the transformer out of service and shutting down the entire load if necessary. A fault in a transformer, or loss of upstream power, results in a shutdown of the load on the transformer in a traditional radial system. However, with a MV spot network, a faulted transformer (or dead power source) can be isolated from the paralleled system through the use of a network protector. Service to the load is maintained because other sources remain in service connected to the loads in parallel.

Multifunction numeric relays that will provide all required network protection functions are available from Eaton. Other functions such as high winding temperature, loss of control voltages, and even the detection of doors being open in electrical rooms (triggering arc flash reduction settings for example) can also be added if desired when using modern multifunction relays with multiple settings.

MV spot network design considerations

The design and load capacity of a MV spot network are based on many specification/loading decisions and considerations. These include the following:

- Transformer size and impedance
- Transformer ratings to be used in the N and N-1 conditions
- Fault ratings of secondary switchgear
- Level of load to be supported by the network

The first devices to be found in a MV spot network are the breakers on the source side of the transformers. The fault duty imposed on these breakers is determined mainly by the details of the upstream power system. It will be assumed that all transformer primary side sources are independent, and that the fault current and MVA levels will be 100% additive on the secondary sides of the transformers.

The fault current ratings of the transformer main secondary breakers (network protector) and the load distribution system breakers are determined by the sizes and impedances of the transformers to be used in the network. Because of the paralleling of transformers, the fault current levels experienced by the feeder system breakers will most likely be higher than seen in normal single transformer radial applications. Load breakers will have to

be able to interrupt the fault current from all of the transformers, N, plus the fault contribution from all loads other than loads fed by the individual breaker.

Transformer main secondary breakers, for a fault between the network protector and the transformer, must be able to interrupt the fault current from N-1 transformers plus the contributions from all loads. The fault duty requirement for the load feeder breakers will always be higher than the required fault duty for the transformer main secondary network protector. It is recommended that the ratings of all breakers be similar for simplicity of system design. A fault study should be used to verify the fault duty requirements of all breakers.

In this article, three transformer sizes and three switchgear fault ratings are analyzed. The transformer sizes are 5000 kVA, 3000 kVA, and 2000 kVA. Three levels of fault duty are considered in the switchgear, 25 kA, 40 kA, and 50 kA. The first step in the selection of MV spot network designs to be analyzed in detail is to determine the number of transformers that can be used with each class of switchgear.

During the design of an actual system, lower impedances may be found to be useable. Reductions in manufacturing tolerance in impedance may also be able to be negotiated with the transformer manufacturers. The fault currents from the transformers were also calculated using a 400 MVA high-side fault availability.

Table 1 shows the fault current available from each size transformer, and the fault current including an extra 25% to simulate load contributions to fault current.

The fault current data is used to determine the maximum number of the three sizes of transformers that can be used in a network with the various sizes of switchgear breakers.

Table 1. Transformer ratings and current values

Transformer rating	Secondary voltage	Transformer % impedance	400 MVA fault availability primary HV side	Secondary side current		
				Base current	Fault current	Fault current + 25% LC
Base kVA	V	%Z	%Z	A	A	A
5000	4160	7	0.013	694	9896	12370
3000	4160	7	0.008	416	5942	7427
2000	4160	7	0.005	278	3962	4953

Table 2. Maximum number of transformers per MV spot network

Spot network sizes based on Table 1 and standard switchgear ratings			
Transformer base rating kVA	Number of parallel transformers		
	25 kA switchgear	40 kA switchgear	50 kA switchgear
5000	2.0	3.2 (3.0)	4.0
3000	3.4 (3.0)	5.4 (5.0)	6.7 (6.0)
2000	5.0	8.1 (8.0)	10.1 (10.0)

Transformer loading schemes

Transformers have base, fan, and increased temperature load ratings. The load losses in a transformer increase as the square of the ratio of load to base load, so long-term loading above base rating is normally avoided. The additional load capacity made available by purchasing fans is often used for short time emergency loading. Dry-type transformers are considered in this application, and the additional kVA load capacity typically available with dry-type transformers with a fan-cooling stage is 33%.

One possible loading scheme involves the use on only base ratings of transformers, without load shedding. In the cases following this rule, the maximum loading of each transformer will be the kVA load equal to the sum of the base kVA ratings of the transformers left in operation after one is lost—N-1 transformers. A tabulation of loading limits for installations following this loading rule is shown in **Table 3**. In these cases, the full kVA capacity of the transformers would not be used.

Table 3. System loading limits—N-1 with no stage cooling or load shedding

Load considerations based on transformer base ratings						
Spot network size	Transformer rating	Total transformer	Switchgear ratings	N-1 contingency	Total	Per transformer
“N”	Base kVA	Installed base kVA	kA	Base load kVA	Design load kVA	Nominal load kVA
2	5000	10000	25	5000	5000	2500
3	5000	15000	40	10000	10000	3333
3	3000	9000	25	6000	6000	2000
5	3000	15000	40	12000	12000	2400

Another possible loading scheme is to allow loading to equal the sum of the fan ratings of N-1 transformers. However, with low numbers of transformers, the full kVA capacity of the transformers still would not be used. The full base rated capacity of the installed transformers would be used in the case of five 3000 kVA transformers with 40 kA secondary switchgear. A tabulation of loading limits for installations following this loading rule is shown in **Table 4**.

Table 4. System loading limits–N-1 with stage cooling and no load shedding

Load considerations based on transformer base ratings with single stage cooling							
Spot network size	Transformer rating	Transformer rating	Total transformer	Switchgear ratings	N-1 contingency	Total	Per transformer
“N”	Base kVA	Stage fans kVA (x33%)	Installed SF kVA (x33%)	kA	Stage fans kVA (x33%)	Design load kVA	Nominal load kVA
2	5000	6650	13300	25	6650	6650	3325
3	5000	6650	19950	40	13300	13300	4433
3	3000	3990	11970	25	7980	7980	2660
5	3000	3990	19950	40	15960	15000	3000(3192) ⁽¹⁾

(1) Ratings exceed base kVA of transformers, therefore, total design load reduced to 15000 kVA.

The networks could be loaded to higher levels if load shedding upon the loss of one source is allowed. In this scheme, the network could be loaded to the full base rating of the transformers when all transformers are in service. Upon the loss of a transformer, the load can be reduced to the sum of the fan ratings of the remaining transformers. In the network with five 3000 kVA transformers, load shedding is not required because the total fan kVA with N-1 transformers is higher than the total base kVA with N transformers. Loadings using this scheme are shown in **Table 5**. Load kVA to be shed upon loss of a transformer is shown in the column named “load shed”.

Table 5. System loading limits–N-1 with single stage cooling and load shedding

Load considerations based on transformer base ratings with single stage cooling and load shedding									
Spot network size	Transformer rating	Transformer rating	Total transformer	Total transformer	Switchgear ratings	N-1 contingency	Total load shed	Total	Per transformer
“N”	Base kVA	Stage fans kVA (x33%)	Installed base kVA	Installed SF kVA (x33%)	kA	Stage fans kVA (x33%)	Shed to SF kVA rating	Design load kVA	Nominal load kVA
2	5000	6650	10000	13300	25	6650	3350	10000	5000
3	5000	6650	15000	19950	40	13300	1700	15000	5000
3	3000	3990	9000	11970	25	7980	1020	9000	3000
5	3000	3990	15000	19950	40	15000 ⁽¹⁾	0	15000	3000

(1) Rating exceeds base kVA of transformers, therefore, total design load reduced to 15000 kVA.

Conclusion

A medium-voltage spot network can be used to provide an enhanced level of continuity of service in supplying power to 4160 V system loads compared to traditional power supply designs. By paralleling transformers, the load can be protected against the loss of an individual transformer. Relaying is available to detect and then isolate transformers for both phase and ground faults. Other advantages of an MV spot network with paralleled transformers are improved voltage regulation, better starting performance in large motors, the capability to perform maintenance on transformers without a shutdown of loads, the ability to use power from isolated sources, flexibility to use different loading schemes, and little cost impact compared to traditional power distribution schemes.

The MV spot network has advantages over a traditional MTM arrangement for industries that have processes that require a high degree of reliability and that have a large quantity of MV motors (typically in excess of 250 hp). Heavy industries such as pulp and paper, metals manufacturing, chemical processing, and polymer processing all have opportunities where an MV spot network may be beneficial and useful.

Additional industries that may see a benefit for an MV or LV spot network are customers who require ultimate reliability such as theme parks, casinos, hospitals, or data center applications. Projects that include any of these processes should give spot networks consideration, especially where loss of production or service is a great concern or any voltage disturbance cannot be tolerated.

FirstEnergy VisoBlock Usage and Application

Nick Rochford, FirstEnergy, Engineer

Headquartered in Akron, Ohio, FirstEnergy is comprised of 10 operating companies that provide electric service to over six million customers across six states. Overall, the company operates a total of 13 highly reliable ducted network systems in urban areas in Ohio, Pennsylvania, and New Jersey. These systems utilize approximately 500 network transformers and protectors and have been in operation for the past 45 to 60 years, depending on location.

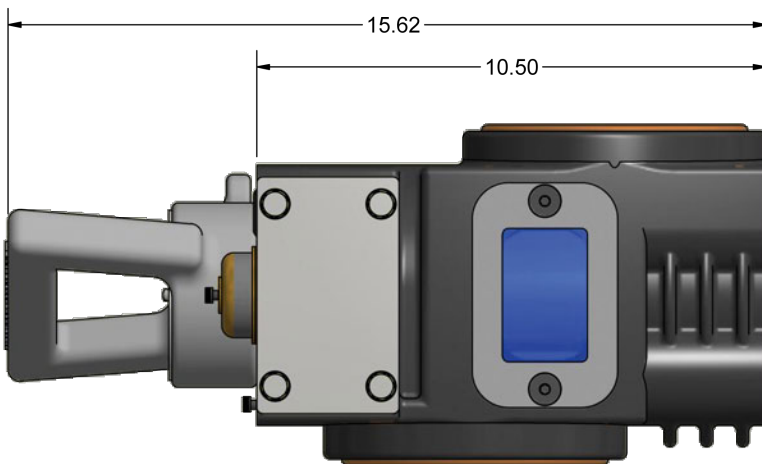
A key corporate objective is to continually improve safety performance by asking employees to make a personal commitment to working safely, follow all safe work practices, and look out for the safety of coworkers, customers, and the public. FirstEnergy's Standards Group is responsible for identifying and recommending equipment with improved safety measures. In recent years, the development of dead-front network protectors and the ability to isolate the network outside of the network protector housing have been instrumental in helping the company achieve safety objectives for ducted network systems. The dead-front design with the communicating relay allows personnel to open the protector from outside of the vault, providing ample distance should anything unexpected happen.

Historically, when performing routine maintenance tasks on the network protectors, personnel were often near energized parts within the network protector housing itself. Now, as an additional safety step to protect workers, VisoBlocks (which can support up

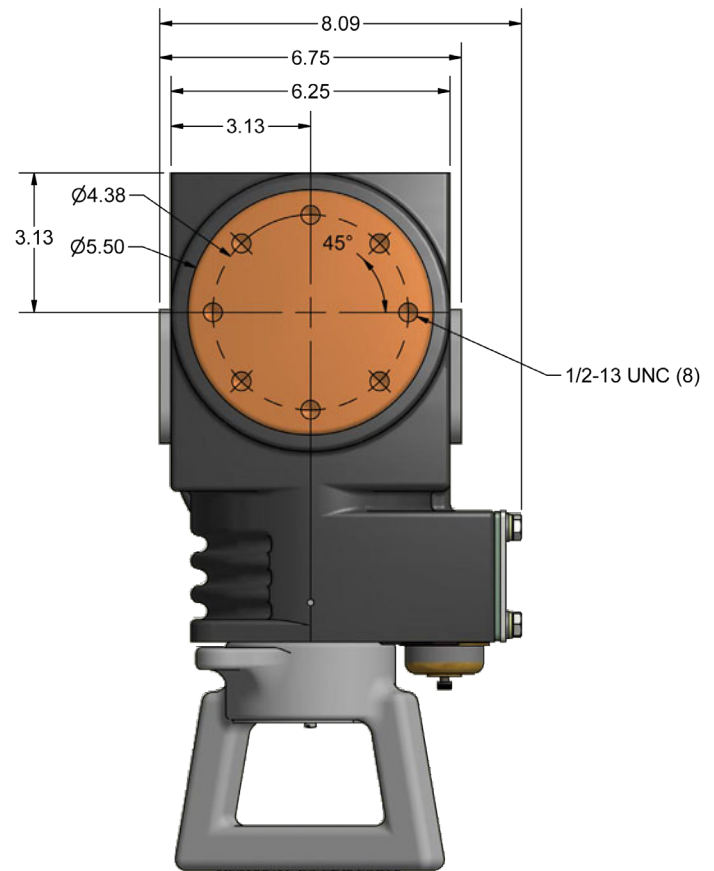
to 3500A) were installed downstream of the network protector to isolate the energized point outside of the network protector housing.

FirstEnergy is utilizing the VisoBlocks for more than 480 V applications to help reduce arc flash but is also installing them in 208 V grid network units. Along with isolating the protector, when VisoBlocks are mounted on the wall, it provides the opportunity to replace the entire network unit (high-side switch, network transformer, and network protector) without having to remove the energized secondary connections. By pulling the rod from the VisoBlock the cables connected between the VisoBlock and the network protector become de-energized and the terminal from the protector can be removed and the network protector or transformer can be replaced.

Attached are photos of additional dimensional drawings from Eaton to show space requirements for installation and photos from two installations at FirstEnergy (direct all mount and Unistrut mounted).



SIDE



TOP



Direct wall mounting (no cables)



Load-side bottom installation shown with submersible non-energized cap



Load-side top, wall mounted with unistrut



Load-side top, direct wall mounting



Load-side bottom, wall mounted with unistrut

Dry Type Transformer Solutions

Chad Powell, ABB Dry-Type Transformers, Business Development Leader

Hidden away amongst miles of streets, sidewalks, buildings and various city infrastructure, network distribution transformers are the backbone for supplying high density power loads to the public in a safe and sustainable manor. Typically installed within buildings, underground street vaults and on top of the tallest high-rises, network transformers operate in a complex system of grid and spot networks providing reliable power for thousands of different applications. The reliability of a network system is achieved primarily through its redundant configuration: several transformers with a network protector connected in parallel on the secondary side, allowing the transformer to automatically be isolated, should one of the transformers

high energy transformer event occurring. These events may involve uncontained ruptures, fires, explosions and other damages resulting in millions of dollars in collateral, lawsuits, sever injuries, and/or negative public relations. Because of this, many technical manufacturing advancements have been made to further enhance the design of network transformers to incorporate additional safety and reliability features, especially for liquid filled transformers. These enhancements range from improvements in the tank design to better handle extreme overpressure conditions and seismic events, to corrosion resistant paints, to "less-flammable" liquids, to a designed rupture direction, and many more. However, the most significant advancements

in terms of public safety and reliability have been with the use of dry-type technology for network transformers.

Dry-type transformers in network

applications are suitable for both indoor or outdoor environments and the only solution available that fully eliminates the risk of fire, explosions, or oil leakage by removing the potential for ignition. In addition, a considerable amount of research and development



Low Profile Submersible Dry-Type Transformer

has been made towards improving the robustness and integrity of dry-type transformers. In submersible applications, dry-type transformers can now achieve similar footprint characteristics comparable to liquid filled transformers. This allows submersible dry-type transformers to now be placed in underground vaults where it is common to have conditions which include partially or fully submerged mixture of fresh water or salt water run-off, subjecting transformer tanks to accelerated corrosion. For liquid filled transformers, this equates to an increase risk in tank integrity, leakage, or catastrophic events. Fortunately, dry-type transformers have now been designed to be enclosed in a completely sealed tank, while protecting the transformer from the harsh conditions often seen in these underground network vaults.

Sealed dry-type network transformers have also been installed in and on top of high-rise buildings, due to the preventative maintenance free characteristics and the absence of fire concerns. It has also been proven to be a more cost-effective solution with the ease of installation, no need for drainage areas, curbing, vaults, firewalls or use of expensive high flash point liquids.

In terms of short-circuit strength, dielectrics and ability to handle harmful electrical events, the dry-type vacuum cast coil (VCC) design is equivalent and, in some ways, can be superior over liquid filled transformers. Improved insulation systems, core materials and data analytics allow dry type transformers the capability of matching or exceeding the electrical characteristics of liquid-filled units. VCC dry-type transformers are manufactured under a special process using a low viscosity glass fiber reinforced epoxy resin that is cast under a vacuum and cured to safeguard against cracking, voids, partial discharge, and thermal shock conditions. The most durable VCC transformers are specifically designed with both the primary and secondary windings fully vacuum cast. This process provides extreme mechanical and impulse withstand strength protecting the transformer coils against short-circuit and dielectric



Transformer Vault Explosion & Fire

be taken off line.

Many network transformers are located very close in proximity to pedestrian traffic. As cities become more densely populated, safety for people, property, and the environment has been the upmost concern for utilities due to the possibility of a



High-Rise Dry-Type Installation



events. It also prevents the introduction of moisture to the winding preventing breakdown of the insulation and winding through ionization. Because of this, the dry-type VCC transformer technology is best suited for adverse humid and corrosive environments.

For clean and controlled environments, a ventilated network transformer with an open wound design is plenty suitable. The open-wound dry type transformer consists of a high temperature (220°C) insulation system and coated with a moisture resistant polyester sealant. For improved quality characteristics, the polyester sealant is applied with a vacuum pressure impregnation (VPI) process. The open wound design offers the largest range of standard temperature rise options, generally starting at 80°C and up through 150°C. This allows for increased thermal overload capabilities. With fans, the transformer achieves up to a 150% increased load rating, exceeding most liquid filled

design overload capabilities. For more than 40 years, the open wound design has been functioning successfully in industrial, commercial and utility applications.

As technology continuously advances, new advancements in transformer digitalization have been made to better understand how transformers operation, performance and catch failures before they occur. Manufacturers are now starting to introduce intelligent transformers capable of remotely collecting and storing critical data for the life of the transformer. Using complex algorithms and analytics, this data can be used to assist in condition-based maintenance (versus planned preventative maintenance), asset monitoring, and transformer consumed life. For dry-types, this can include power quality monitoring, loading conditions, total harmonic distortion, fan monitoring, and moisture sensing.

Ideally the transformer is built and tested to operate for the duration of the

designed life. However, external stresses may affect the overall life expectancy for that transformer. Extreme weather events, system faults, emergency overloading, increased harmonics, switching events, and other electrical events all reduce the resiliency of the transformer. Incorporating the digitalization aspect brings light to those events and reduce the likelihood of a critical failure. Unplanned outages are costly and result in significant downtime. With proper monitoring and transformer technology selection, risk can be mitigated or avoided. The dry-type transformer technology has proven to incorporate a high level of safety and environmental sustainability. Due to increased safety requirements, in recent years, dry-types have become a growing popular technology

choice by many utilities and industrial customers. As the public and utilities become more aware of the benefits of dry-types, the expectation for this trend is to continue.



Ventilated Dry-Type Network Transformer

Austin Energy ArcFlash Incident

Aaron Hanson, Austin Energy, Network Supervisor



In 2012 an Arc flash study was performed over the entire Austin Energy Distribution system. In the findings it was determined that all of Austin Energy's vaults contained above a 200 cal/cm² flash rating. We determined that it was in the best interest of our personnel to install Eaton's Arc Reduction Maintenance System (ARMS) to better protect our employees.

With the arc reduction system in place, the potential flash is lowered from a level above 200 Cal/cm², to a limited level of 2.2 Cal/cm². Arc reduction systems are not designed to be in constant or continuous service, so we decided to use the lights in the vault as a means to put the protectors in a maintenance state only while personnel are working in the vault.

In 2017 we completed this project and in February of 2018 it was unfortunately put to the test.

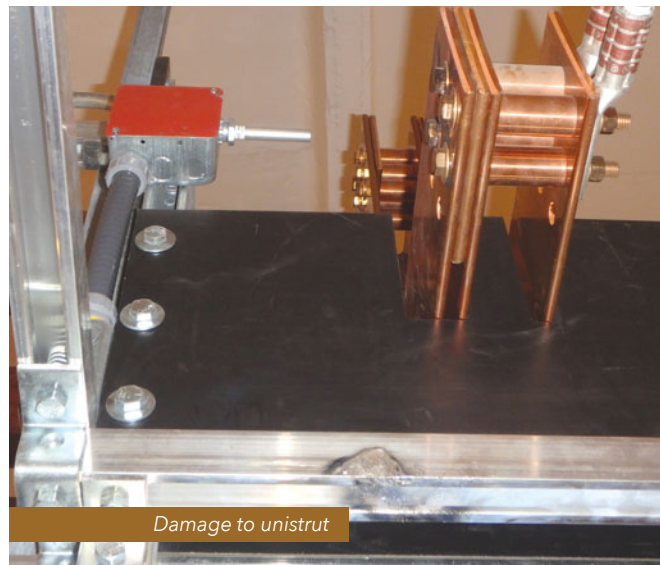
On February 6, 2018 we had an Austin Energy Network Crew energizing a 800 amp, 480V disconnect in providing temporary power to a crane at a construction site in our downtown area. The crew began by landing 2 per phase 500 mcm inside of a disconnect, which was done de-energized. They then moved to hooking up 2 per phase 500 mcm to energized 3/8" x 6" copper bus using 2-hole compression lugs and bronze bolts. After successfully landing two of the first three phases the crew was in the process of landing the third phase when the network electrician lost positive control of the wrench. This allowed the tool to come

into contact with the grounded unistrut frame which holds the insulating board on which the bus sets. An arc occurred in the spot 480V vault, the arc system activated, de-energizing the vault and dropping service to the building. The personnel had covered the phases they were not working on, but failed to cover the grounded uni-strut, contact with which resulted in the outage. Neither employee was injured, so after a quick assessment of the minor damage the vault was reenergized, restoring power to the building.

Moving forward, among the corrective actions we identified, we implemented a new type of cover up. This thinner, light weight, "cut to fit" cover will allow crews to more easily cover all potentials. Even those they don't believe to be immediately within reaching or falling distance. Crews will utilize new shorter insulated wrenches when working in the tight confines near bus, as well. In the past, a 480V fault would have had the potential for devastating consequences. As many are aware, a 480V fault, with the amperage potentials available in a network system, tends to "grow", or "feed" itself. With the implementation of the Eaton's Arc Reduction Maintenance System, the disaster potential in this case was greatly mitigated. By tying the system to the vault lighting, we were able to remove the potential of forgotten activation. Each of our employees are protected upon entry into our 480V vaults with the ARMS in place and "automatically" activated.



Area where work occurred



Damage to unistrut



Reinactment



800A Disconnect connected to energized bus



800 Amp Disconnect

Eliminating Low Voltage Underground Cable Hazards

John Lauletta, CEO Exacter, Inc.



Underground distribution systems have been in use for many years in urban areas. In most instances these are secondary network systems with facilities installed beneath streets and sidewalks, and the cables are usually installed in conduit or duct systems. Single-conductor secondary cables with rubber insulation and neoprene jacket are common. These cables deteriorate over time and in the presence of elevated temperatures. Soil temperature has a significant impact on the rate of cable insulation deterioration. Warmer soils found in the southern states add to insulation heating and prevent the dissipation of heating from load current. There are no technologies that easily test the condition of live secondary radial or network cables. Exacter®, Inc. has addressed this need with ConductoRx®, a new effective technology to evaluate the condition of operating cables and conductors.

There are several reasons why the condition of secondary cables should be evaluated. Outage prevention is only one. When secondary cable insulation deteriorates, a high-impedance fault is the result. These faults lead to fire and explosion incidents when conductive moisture is present. The fires and explosions not only destroy the deteriorated cable but causes collateral damage of other cables in the duct, equipment connected to the cable, and vaults. More importantly these events risk the lives of line personnel and the public. Prior to a catastrophic event, high impedance faults can result in lethal Contact Voltage situations.

“One of the primary causes of Contact Voltage is damaged insulation on low-voltage underground secondary distribution cable. The insulating layer of a distribution cable electrically and physically separates the conductor [from ground] and serves to keep electricity contained. When insulation becomes

damaged, electricity leaks from the damaged portion of the cable and follows all available conductive pathways. Conductive pathways often lead to structures and surfaces that are located within the public right-of-way. In these cases, objects such as metal fences, fire hydrants, bus shelters and even sections of concrete-sidewalk routinely become energized.

Of the miles of cable comprising a distribution system, the largest portion of the cable is employed in the secondary distribution system. Secondary distribution systems do not have fault-current detection, fusing, or current limiting components capable of activating when Contact Voltage occurs. These systems lack any type of intelligence capable of notifying the system operator of the presence of Contact Voltage. As a consequence, Contact Voltage on secondary networks often goes undetected until much larger problems occur, such as electric shocks, smoking manholes, manhole explosions, flickering lights and loss of electric service.” [Source: Power Survey Co.; <http://www.powersurveyco.com/contact-voltage/technical/causes/>]

Testing the condition of secondary cables is dangerous and

problematic. In many cases the cables have not been disturbed for decades. Any movement of the cables can cause the very damage that you wish to avoid. Often, the cable system is a radial feeder that requires scheduling a customer outage to connect evaluation equipment. Evaluation equipment is often destructive in its operation. And, secondary systems are often connected in loop or network configurations which makes testing very complex with results that are difficult to evaluate.

Exacter has introduced a unique technology for live cable and conductor direct condition assessment. The technology has been under evaluation at electric utilities for a year and will be ready for utility demonstration in 2019. The technology is non-destructive (no high voltages, currents or energy used), is non-intrusive (the technology requires no cable disconnection), and non-invasive (no power or load interruption is needed during the cable condition assessment). In addition, the technology allows the segmentation of the cable being tested. The cable can be evaluated end-to-end,



vault-to-vault or for any segment of the cable. The cable segment is created by attaching simple clamps at each end of the cable segment to be evaluated.



The cable test technology uses specialized signals induced into the cable segment under evaluation and results in an immediate reading of the cable insulation condition. This allows the user to quickly make a replacement decision. The application of the segment clamps also allows the user to automatically phase the cable at both ends and map the cable's position with GPS precision.

Exacter is scheduling 2019 demonstrations now. <http://exacterinc.com/solutions/conductorx-underground> Contact John Lauletta jlauletta@exacterinc.com for more information.

Spot Network Design Considerations

Network Protector Group, Eaton

Eaton's Spot Network Systems are designed to ensure service continuity in 208/120V, 480/277V and 600/347V secondary network systems. These systems, in either grid or spot network form, are commonly used in areas of high load density such as metropolitan and suburban business districts or facilities.

Suburban loads were formerly almost entirely residential and power outages caused little more than personal inconvenience. Now, the suburban load includes not only shopping plazas, industries and residences, but such vital facilities as hospitals and airports. For these and other critical loads, power interruptions can have serious consequences to public and personal safety. Spot networks provide superior reliability at these important loads.

Spot networks provide:

- Better continuity of service - improved reliability
- Improved regulation - Less voltage sag
- Less transformer capacity required
- Assures positive power into load
- Automatic system operation

Commercial Spot Network Design Considerations

There are various components which make up a commercial spot network system, either as a double-ended substation or multiple transformer substation. The intent of the article is to give some basic guidelines for the selection of transformers and network protectors. The following is an example design exercise for picking the ideal rated network protector and network transformer for a specific application. This example assumes the reader has some user knowledge of network applications. For more information on network systems and commercial spot applications, see the following QR code:

Application Example:

A utility has a new commercial customer that is planned to be served off the downtown network. A load estimation study was developed and it detailed the following load characteristics.

- Voltage: 277/480V; wye-grounded
- Maximum Short Term Peak Load: 1250 kVA
- Continuous Average Load: 800 kVA
- Minimum Baseline Load: 275 kVA
- All above loading conditions at 0.87 Lagging PF
- Design for N-1 contingency (sized for 1 unit loss)

The utility standardizes on three transformer options:

- 1000 kVA (1200A)
- 1500 kVA (1800A)
- 2500 kVA (3000A)

The utility is able to provide up to 4 network feeders at 12.47kV-LL. Typical spot networks have 2+ parallel network feeds with 2 being the minimum to provide the redundancy required.

Design Option #1 3-Unit Spot Network using 1000kVA network transformers

The cost of installing a 3-unit spot will be considerably higher than the cost of a 2-unit spot.

Minimum load is only 13.8% of the available transformer base kVA under N-1 contingency. Nuisance operation could be experienced under lightly loaded conditions.

Load considerations based on a 3-Unit Spot with 1000kVA transformer base ratings						
Spot Network Size "N"	Transformer Rating Base KVA	Total Transformer Installed Base KVA	N - 1 Contingency Available KVA	Total Design Load KVA (Load Type)		Load as % of Total Transformer N-1 Capacity
3	1000	3000	2000	1250	(Max Peak Load)	62.5%
3	1000	3000	2000	800	(Max Continuous Load)	40.0%
3	1000	3000	2000	275	(Min Baseline Load)	13.8%

Design Option #2 2-Unit Spot Network using 2500kVA network transformers

The cost of installing a 2-unit spot using 2500kVA network transformers will be considerably higher than the cost of installing 1500kVA or 1000kVA transformers. Using 2500kVA transformers are too large for this application.

Minimum load is only 11.0% of the available transformer base kVA under N-1 contingency. Nuisance operation could be experienced under lightly loaded conditions.

Load considerations based on a 2-Unit Spot with 2500kVA transformer base ratings						
Spot Network Size	Transformer Rating	Total Transformer	N - 1 Contingency	Total		Load as % of Total
"N"	Base KVA	Installed Base KVA	Available KVA	Design Load KVA (Load Type)		Transformer N-1 Capacity
2	2500	5000	2500	1250	(Max Peak Load)	50.0%
2	2500	5000	2500	800	(Max Continuous Load)	32.0%
2	2500	5000	2500	275	(Min Baseline Load)	11.0%

Design Option #3 2-Unit Spot Network using 1500kVA network transformers

The cost of installing a 2-unit spot using 1500kVA network transformers will be higher than the cost of installing 1000kVA transformers. Using 1500kVA transformers are adequate but not optimal for this application.

Minimum load is only 18.3% of the available transformer base kVA under N-1 contingency. Nuisance operation could be experienced under lightly loaded conditions.

Load considerations based on a 2-Unit Spot with 1500kVA transformer base ratings						
Spot Network Size	Transformer Rating	Total Transformer	N - 1 Contingency	Total		Load as % of Total
"N"	Base KVA	Installed Base KVA	Available KVA	Design Load KVA (Load Type)		Transformer N-1 Capacity
2	1500	3000	1500	1250	(Max Peak Load)	83.3%
2	1500	3000	1500	800	(Max Continuous Load)	53.3%
2	1500	3000	1500	275	(Min Baseline Load)	18.3%

Design Option #4 2-Unit Spot Network using 1000kVA network transformers

This option will be the least costly, provides the best "sweet spot" loading for the network transformers and for ideal network operation.

Load considerations based on a 2-Unit Spot with 1000kVA transformer base ratings						
Spot Network Size	Transformer Rating	Total Transformer	N - 1 Contingency	Total		Load as % of Total
"N"	Base KVA	Installed Base KVA	Available KVA	Design Load KVA (Load Type)		Transformer N-1 Capacity
2	1000	2000	1000	1250	(Max Peak Load)	125.0%
2	1000	2000	1000	800	(Max Continuous Load)	80.0%
2	1000	2000	1000	275	(Min Baseline Load)	27.5%

Transformer Loading Calculations

Transformer Amperage Loading Calculations													
Transformer		12.47 kV				216 V				480 V			
kVA	Z _{TRAN} %	Max Fault PU	Nameplate 100% Amps	Max Fault A	Nameplate 100% Amps	Amps @		Max Fault kA	Nameplate 100% Amps	Amps @		Max Fault kA	
						130%	150%			130%	150%		
300	5	20.0	13.9	278	802	1042	1203	16.0	361	469	541	7.2	
500	5	20.0	23.1	463	1336	1737	2005	26.7	601	782	902	12.0	
600	5	20.0	27.8	556	1604	2085	2406	32.1	722	938	1083	14.4	
750	5	20.0	34.7	694	2005	2606	3007	40.1	902	1173	1353	18.0	
1000	5	20.0	46.3	926	2673	3475	4009	53.5	1203	1564	1804	24.1	
1500	7	14.3	69.4	992	4009	5212	6014	57.3	1804	2345	2706	25.8	
2000	7	14.3	92.6	1323	n/a	n/a	n/a	n/a	2406	3127	3608	34.4	
2500	7	14.3	115.7	1654	n/a	n/a	n/a	n/a	3007	3909	4511	43.0	
3000	7	14.3	138.9	1984	n/a	n/a	n/a	n/a	3608	4691	5413	51.5	

*n/a = Outside NWP Amperage Range

QR Code for Transformer Loading and Network Protector Tables



$$VA = E_{LN} * I * 3_{PHASES}$$

$$VA = \frac{E_{LL}}{\sqrt{3}} * I * 3_{PHASES}$$

$$VA = \sqrt{3} * E_{LL} * I$$

$$KVA = \frac{\sqrt{3} * E_{LL} * I}{1000}$$

$$I = \frac{KVA * 1000}{\sqrt{3} * E_{LL}}$$

Standard Network Protector and Transformer Ratings

216 Volts		IEEE Std C57.12.44-2005			CM52		CM22		CMD	
NP Amps	NP kAIC	Xfmr kVA	Xfmr Amp	NP/Xmfr %	NP kAIC	Xfmr kVA	NP kAIC	Xfmr kVA	NP kAIC	Xfmr kVA
800	30	225	600	133	42	225	30	225	30	225
1200	30	300	800	150	42	300	30	300	30	300
1600	30	500	1333	120	42	500	30	500	30	500
1875	30	500	1333	141	42	500	30	500	30	500
2000	35	500	1333	150	42	500	60	500	60	600
2250	35	500	1333	169	65	500	60	500	60	600
2500	60	750	2000	125	65	750	60	750	60	750
2825	60	750	2000	141	65	750	60	750	60	750
3000	60	1000	2667	112	65	1000	60	1000	60	1000
3500	60	1000	2667	131	85	1000	60	1000	-	-
4500	60	1000	2667	169	85	1000	-	-	-	-

480 Volts		IEEE Std C57.12.44-2005			CM52		CM22		CMD	
NP Amps	NP kAIC	Xfmr kVA	Xfmr Amp	NP/Xmfr %	NP kAIC	Xfmr kVA	NP kAIC	Xfmr kVA	NP kAIC	Xfmr kVA
800	30	500	600	133	42	500	30	500	30	500
1200	30	750	900	133	42	750	30	750	30	750
1600	30	1000	1200	133	42	1000	30	1000	30	1000
1875	30	1000	1200	156	42	1000	30	1000	30	1000
2000	35	1000	1200	167	42	1000	60	1000	45	1000
2250	35	1000	1200	188	65	1000	60	1000	45	1000
2500	45	1500	1800	139	65	1500	60	1500	45	1500
2825	45	1500	1800	157	65	1500	60	1500	45	1500
3000	45	2000	2400	125	65	2000	60	2000	45	2000
3500	45	2000	2400	146	85	2000	60	2000	-	-
4500	60	2500	3000	150	85	2500	-	-	-	-
5000	60	2500	3000	167	-	-	-	-	-	-

Conclusion:

The best design option to choose is Option #4 using two 1000kVA 5% impedance transformers (125% Maximum Short Term = 1504A).

Network protector margin is already built into the nameplate rating. Therefore, when selecting a network protector all overload considerations should be within the nameplate rating of the network protector selected. For this example, selecting a 1600A network protector rating provides a 133% transformer nameplate overload margin which is optimal.

Con Edison Pilots Micatu's Submersible Optical-Sensor Platform to Enhance Grid Visibility

Michael Oshetski, Micatu, Chief Executive Officer

Paul Stergiou, Con Edison, Distribution Engineer - Departmental Manager

Serena Lee, Con Edison, Research & Development - Project Manager

Ryan Rausch, Eaton Smart Sensors, Product Manager

Con Edison of New York operates one of the most complex and reliable electric-delivery systems in the world. It is also one of the most important, providing power to the world's financial district, government institutions, critical hospitals and leading colleges. The company has invested more than \$1 billion to fortify in its energy-delivery systems since Hurricane Sandy left a record 1.1 million customers without power in October 2012. Through support from the New York State Energy Research and Development Authority (NYSERDA), Con Edison continues to install state-of-the-art solutions to make its energy grid smarter and more resilient.

Con Edison is also committed to helping New York State reach its goal of having half the state's electricity generated by renewable sources by 2030. The company has helped customers complete 22,000 solar projects that produce 215 megawatts. As the electrical grid evolves from the traditional model with large centralized power plants to include more distributed energy resources (DER), ensuring system reliability and stable voltage is one of Con Edison's most challenging tasks.

The company is piloting new voltage monitoring technology on its underground delivery system and gaining an unprecedented level of visibility into the networks. The tool developed by Micatu, an upstate New York company that provides next-generation optical sensors, yields information Con Edison can use to ensure feeder reliability and avoid failures that can affect customer service.

Challenges on the Underground System

Con Edison delivers electricity through a vast transmission and distribution network. The company has built the world's largest system of underground electric cables to accommodate the densely populated urban area it serves. The 97,500 miles of underground cable could wrap around the Earth 3.9 times.

But grid overload and equipment overheating are common in underground distribution systems and sometimes result in customer outages. The complexity of making repairs in tight underground vaults can extend outage times.

Flooding is also a problem. Flooding can cause outages, as it during Hurricane Sandy when 234,000 customers from

Midtown Manhattan to the southern tip of the island lost power. Flooding shortens the life of equipment and increases the maintenance needed to keep energy-delivery systems reliable..

Energy companies have traditionally found it challenging to modernize their underground distribution systems. This is largely due to the lack of a practical solution for accurate, precise condition, voltage and current monitoring. Technology to locate faults, isolate outages and aid restoration on overhead systems has advanced, but the size of the vaults and necessary safety protocols associated with underground environments have made it harder to apply new technologies.

As the operator of such a sophisticated power-delivery system, Con Edison recognizes the need for an accurate, dependable underground monitoring solution. That's why the company is investigating how it can improve grid oversight without major costs or installation requirements.

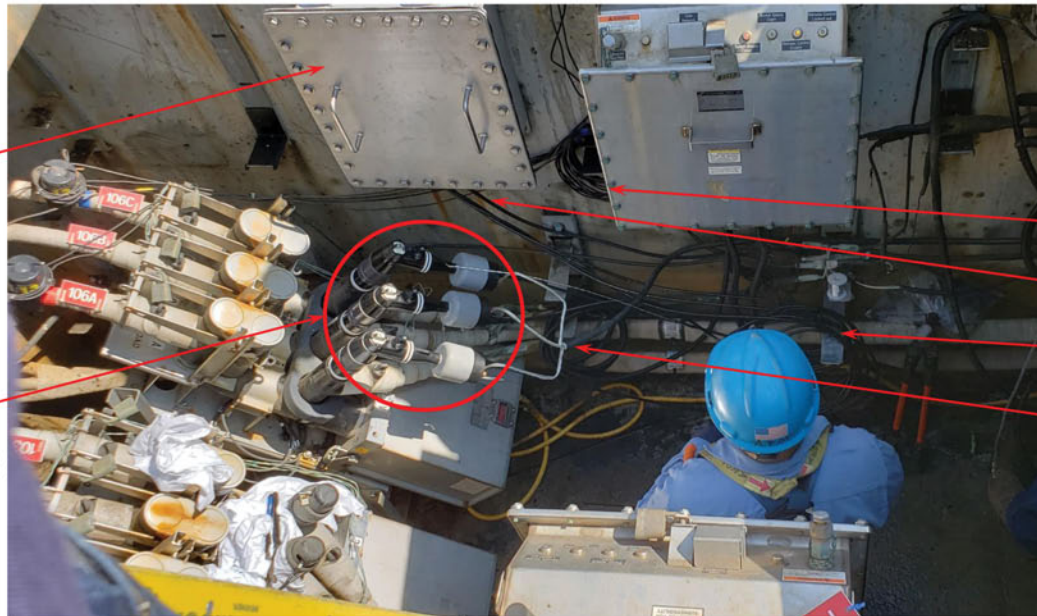
Con Edison utilizes more than 1,100 13-kilovolt (kV), 27kV and 33kV underground feeders, but only a fraction of these feeders have underground sectionalizing switches. This means the data captured from the vast network of grid-connected equipment cannot be uniformly assessed, analyzed for improvement or considered reliable for real-time operational support.

The traditional method of utilizing instrument transformers, current transformers or potential transformers for voltage monitoring is not ideal for Con Edison's underground network locations. This is due to a plethora of reasons, including safety concerns for maintenance personnel and the limited space and harsh environments where water can threaten transformers. The high cost of underground construction has also been an obstacle to the widespread deployment of this technology.

This often results in a loss of usable data and makes it difficult to reliably monitor and troubleshoot the distribution system. The wide-scale integration of DERs, the resulting bi-directional power flow and the intermittency of renewables make accurate, real-time grid data particularly important. A fault can affect service to customers, place greater stress on equipment and compromise overall grid efficiency.

VOLTAGE SENSOR INSTALLATION

PHASE A, PHASE B & PHASE C INSTALLATION



Micatu NEMA 6P Enclosure

Voltage Sensor Installation A, B & C Phases

Modem Cables

Power Cables

Sensors Cables

Grounding Cables

Micatu's Technology

To solve these challenges, Con Edison began working with Micatu through a NYSERDA PON program in 2017 to pilot a submersible optical-sensor platform. Founded in 2011, Micatu has revolutionized optical sensor technologies for measurement in the areas of grid modernization, wind, power distribution and condition monitoring.

Micatu's optical sensing platform was selected for its ability to accurately and cost-effectively monitor the distribution grid for voltage, current, vibrations and temperature. Compared to traditional monitoring solutions, optical sensing solutions can deliver +/- 0.5% voltage measurement precision and accuracy in a straight-forward package for standard 200 Amp or 600 Amp applications. This unparalleled visibility into underground networks enables a new level of intelligence for reliability and management of feeders. Additionally, the compact size of the optical-sensing platform makes it ideal for tight underground locations.

Micatu's sensor system utilizes a fully optical measurement platform for unmatched accuracy and precision of voltage and current across multiple voltage classes. The solution is a direct replacement for standard power transformers and current transformers. Because of the "all-optical" sensor design, there are no conductive materials used for the measurement of both voltage and current. The insulator body is casted in hydrophobic cycloaliphatic epoxy (HCEP) using a state-of-the-art injection-molding process. HCEP construction provides

superior arc track, ozone, and ultraviolet-resistive properties while maintaining physical strength. The hydrophobic surface properties of HCEP ensure reliable performance in wet or humid conditions.

Micatu's m410 Modular Optical Sensor Platform serves as the "brain" of the monitoring technology. The m410 is the first fully optical modular-sensing platform with numerous sensor module options designed to meet various application requirements. The m410 has four modular bays that allow for any combination of Micatu sensors, including sensing of voltage, current, vibration and temperature, and has the capability for enabling future expansion modules.

For simplified compatibility with existing systems, the m410 Modular Optical Sensor Platform supports multiple digital, analog, relay and communication port inputs and outputs. All sensor modules are hot-swappable with field upgradeable hardware and software. The m410 processor also allows for "future proofing" via multiple communication protocols, which include wireless, wired or local data collection and full support of external wireless communication modems.

Navigating Design Challenges

Con Edison Research & Development Project Manager Serena Lee and Distribution Engineering Department Manager Paul Stergiou have proved instrumental in the design of the pilot submersible optical-sensing platform. The Con Edison engineers worked with Micatu to develop an innovative enclosure design that can be submersed up to 30 feet t and

meet long term reliability requirements.

To achieve this innovation, the project team from Con Edison and Micatu found design inspiration in the harsh environments of the oil and gas industry. Following multiple trials in Con Edison's pressurized testing environment, the expertise of a Texas enclosure manufacturer yielded a NEMA Type 6P enclosure that could provide an impenetrable seal against water and corrosion while preventing damage caused by major weather events, including storm surges.

For simplified installation, the project team also needed to address the challenge of enclosure cabling. By working with a Swedish company specializing in the development and manufacture of cable and pipe seals, Micatu was able to incorporate a submersion-rated, cable-gland passthrough that would support intuitive wiring without sacrificing the integrity of the enclosure. Con Edison tested this gland system and found it could perform reliably in a submerged environment for up to 30 days. That ensured that it would provide high reliability and defense against natural disasters, while creating a replicable model for application across many different outdoor and underground utility applications.

Measuring Success

Installed in the Bronx, the first pilot application of the Micatu sensing technology is providing next-generation, optical-measurement capabilities for grid modernization, wind, power distribution and condition monitoring. It is helping Con Edison collect more accurate data and providing actionable insights the company can use to improve power reliability.

During the pilot, Con Edison is investigating new ways to leverage collected data by requiring the current- and voltage-monitoring meters on the sectionalizing switch to possess an accuracy rating of +/- 1%. Additionally, under the NYSERDA funding requirements, Micatu will work with Con Edison to demonstrate the solution can effectively identify second primary medium-voltage faults by directly monitoring the distribution network feeder voltage and current.

Further, Micatu is continuing to work with Con Edison to demonstrate a solution to replace its aging "capaciformers," which are components of a Unit Substation (USS) transformers that supply the under-voltage and over-voltage relays with scaled primary voltage.

In underground applications, energy companies like Con Edison are looking to leverage real-time analytics provided through an all-optical-sensing platform to help predict outages, locate faults, and provide a high-value solution for DER integration.

Con Edison's pilot optical-sensing platform has already yielded advancements in underground enclosure design that can be replicated in major cities across the world. This

collaboration will continue to produce new strategies that maintain grid reliability and advance a smarter, more dynamic electrical grid. As the impacts of real-time, accurate sensing are measured, the industry will understand the impact of actionable data on the ongoing support and maintenance of underground distribution networks.

In April 2018, Eaton entered a sales agreement with Micatu. This agreement expands Eaton's 4kV to 35kV smart grid portfolio with GridAdvisor Insight optical sensors, previously marketed as Micatu's GridView Optical Solutions sensor platform. By coupling Eaton's comprehensive solution suite and industry expertise with Micatu's revolutionary technology, the agreement aims to help utilities around the world advance intelligent power programs and enable smart grid modernization.

GridAdvisor Insight optical sensors

Shining a light on underground networks with real-time metrology and intelligence



Eaton's GridAdvisor optical sensor is available in a variety of easy-to-install packages with a standardized interface, including the optical standoff insulator voltage sensor and the optical deadbreak elbow adapter sensor.



The status of your underground network shouldn't be a deep, dark secret

Eaton's GridAdvisor™ all-optical medium-voltage and current sensor system provides a highly accurate view of underground networks, resolving the difficult and time-consuming process of diagnosing, troubleshooting and fixing issues.

Retrieving real-time site metrology and intelligence on today's electrical distribution system, substations and underground distribution locations, the GridAdvisor optical sensor platform facilitates unparalleled precision across multiple voltage classes and has the ability to identify potential failures before they occur.

Because the sensor relies on light to sense voltage and current, the solution eliminates problems often caused by other technologies, including high voltage at the test point, false test failures when crews hi-pot the cable, and unwanted leakage current during testing.

To learn more, visit
Eaton.com/opticalsensor

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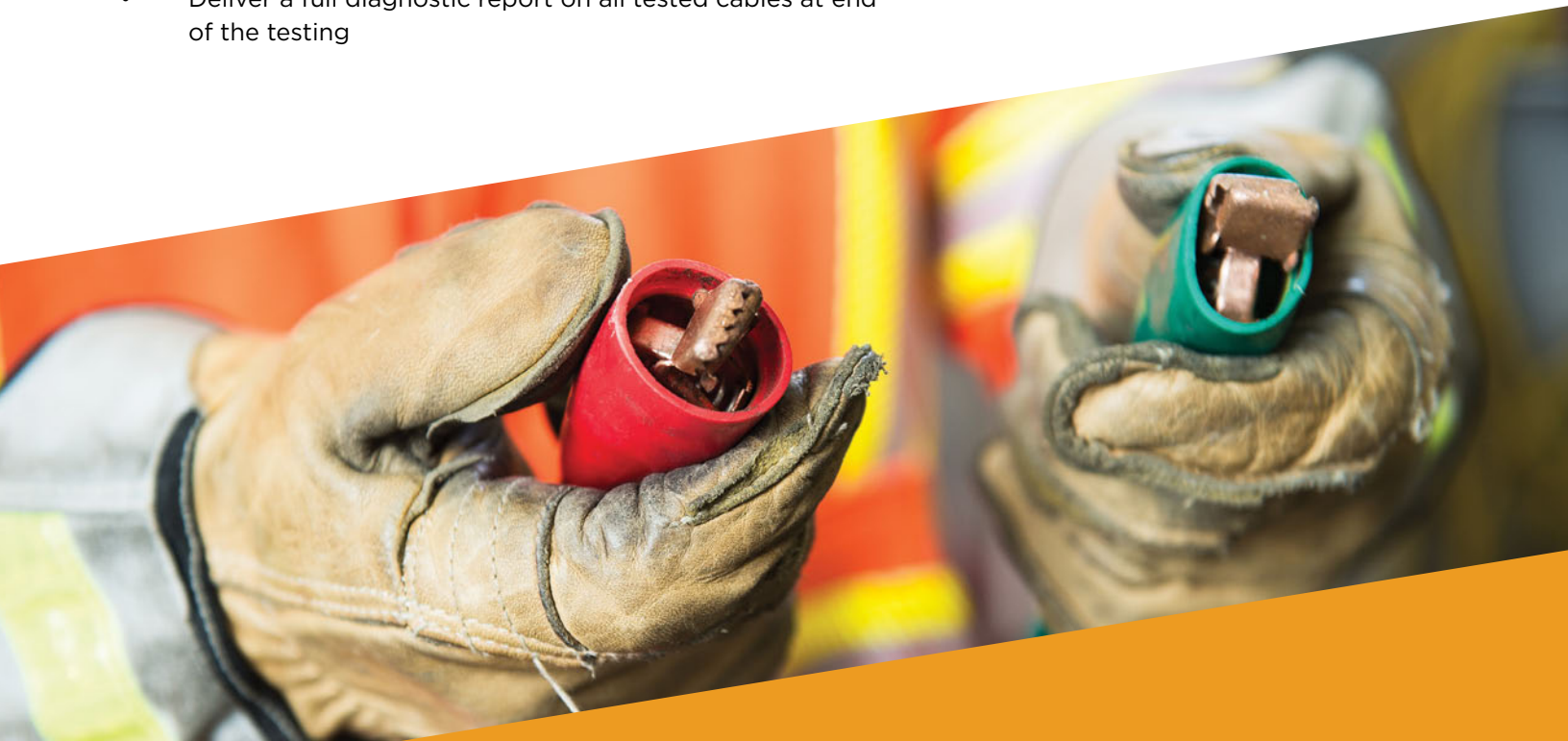


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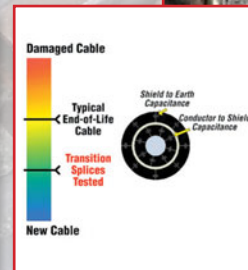


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2018 ENSC Highlights

