Monitoring Your Underground System Investment

Challenges and Solutions
for Effective Monitoring Strategies

White paper | systemswithintelligence.com | info@systemswithintelligence.com

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In today's world, utilities are facing increasing pressure to ensure the safety and reliability of their underground system. As cities grow, so do the demands on utilities, and it's becoming more important than ever for them to invest in monitoring and maintaining these systems. A lack of proper maintenance can lead to outages, damage to infrastructure, and safety hazards for both employees and the general public.

This white paper explores the importance of utilities monitoring their underground system and discusses the benefits of doing so. We will also examine some of the challenges that utilities may face in implementing effective monitoring strategies and provide practical solutions for overcoming them. By the end of this white paper, utilities will have a better understanding of the importance of monitoring their underground system and be equipped with the knowledge and tools to ensure the safety and reliability of their infrastructure systems for years to come.

Investing in Underground Systems

Utilities invest large amounts when it comes to underground distribution or transmission lines. Installation of underground distribution lines and infrastructure can cost between ten to fifteen times more than overhead lines[1].

For most utilities, it's not only the initial investment to consider but also the life expectancy and cost of maintaining the system; high voltage overhead lines can have a life expectancy of 80+ years while an underground system is roughly half of that.[2] If a utility chooses to go with an underground system, they may also consider investing extra to protect their investment in the system as well as for the safety of the public and workers that maintain it. There are many recorded incidences of underground vault fires and explosions that not only cause extended outages but put the public and utility workers at risk.

Most existing underground monitoring methods are used to detect faults, disconnect loads and restore power as quickly as possible to unaffected areas. These methods can be effective at isolating faults and restoring power; however, they are not able to prevent the failure. Thermal monitoring offers a method to detect potential problems before the faults can occur and in an underground system, this is key to preventing more extensive and hazardous failures before they happen.

[1] Overhead vs. Underground: Information about burying high-voltage transmission lines, XCEL Energy, October 2022

[2] Overhead vs. Underground: Information about burying high-voltage transmission lines, XCEL Energy, October 2022

Advantages of an Underground System

When utilities decide to install underground distribution or transmission lines, they consider a wide range of factors, including the physical environment of the area, the type of cable needed, and the overall cost of the project. Underground systems can provide a number of advantages, including:

Fig 1. Vault Fire in California (FogCityJournal.com)

Reliability

One of the significant advantages of underground systems is their ability to avoid outages caused by external factors such as falling vegetation, downed poles due to storms, rot, fire, collisions, lightning, and animal problems.

Routing

In some urban areas, it is not possible for utilities to install overhead lines due to space constraints, zoning regulations, or other logistical issues. In these cases, underground systems can be an atractive alternative as they do not require as much space as overhead systems and can be installed without obstructing views or impeding the movement of people or vehicles. Additionally, underground systems are often considered to be more aesthetically pleasing than overhead systems.

Safety

One of the key advantages of underground systems is that they eliminate the risk of exposure to downed lines, which can pose significant safety hazards. Additionally, underground systems don’t require poles, which eliminates the risk of accidents involving vehicles or other objects that may drive into them. This can lead to fewer interruptions in power supply, as well as a reduced risk of injuries and property damage.

Disadvantages of an Underground System

Underground systems have a number of disadvantages we will explore in this paper.

Fig 2. Underground and overhead cable (Georgia Transmission Corp)

Underground Systems Are More Expensive

While underground systems offer several benefits, they are generally more expensive to install and maintain than overhead systems. This is due to a variety of factors, including the cost to trench the cable and restore the property afterward. Trenching requires specialized equipment and skilled labor, which can add to the initial cost of installation. Additionally, insulated cable is more expensive and requires up to two times more cable than uninsulated, air-cooled overhead cable because it runs at a higher temperature. This can significantly increase the overall cost of the system. Concrete splice vaults are also required every 600m (2000ft) or more, which can add to the installation cost. Furthermore, restoration time and costs for underground systems can be higher as it is more difficult to locate faults and replace buried cable compared to overhead systems.

Fig 3. Underground vault (Xcel Energy)

Underground Systems Have a Shorter Life Span

The main factors that shorten the life span of an underground system are 1) the breakdown of insulation and 2) degradation and failure of splices.[3] Overhead systems do not suffer the same problems since cables are generally air insulated while underground cables are completely insulated and shielded. Underground systems are more exposed to contaminated water that washes into vaults from the street that is made particularly worse by the application of road salt. Water and contaminants accelerate the aging process of the insulation.

Any impurities or defects in the insulation can lead to partial discharge, (PD), the leakage of current through the insulation phase to ground or phase to phase. Breakdown of the insulation is accelerated due to the higher temperature and the presence of moisture that is never possible to completely eliminate in an underground system. High fault current in the system also increases heat and vibration on the cable that further accelerates the breakdown of the insulation. If undetected, partial discharge will lead to complete insulation failure.

Fig 4. Cable joint failure (Cablejoints.co.uk)

[3] Electric Energy Online - Finding the root cause of power cable failures, Vern Buchholz, 2004

Degradation of splices has a similar effect of prematurely aging the system. A poorly executed or defective splice will have increased resistance over time that will increase heat and accelerate breakdown of the insulation. This again can lead to partial discharge and eventually complete failure of the insulation.

Effects of Insulation Failure

As the insulation surrounding the cable or splice breaks down, combustible gases are produced and due to the enclosed space of the vault, venting of these gases is very limited. When the insulation fails completely, a phase to ground or phase to phase arc occurs that can release a large amount of heat and pressure inside the vault. The heat can vaporize the cable insulation resulting in more combustible gases being released and even worse situation. A resulting explosion and fire can blow the cover off vault and the fire can spillover.

If a transformer is involved and it ruptures and spills the combustible insulating oil, the situation can get much worse.[4] Early detection of failing insulation is one of the keys to preventing this type of situation.

Visual and Thermal Monitoring in the Underground Vault

Monitoring inside of a vault can be done for a number of reasons and it can be done safely in an automated manner from a remote location. Underground systems may have hundreds or thousands of vaults, so manually inspecting each vault does not scale.

[4] Mitigating Blast Effects, Robert E. Snodgrass, 2005

Therefore, automated monitoring is the only feasible method to inspect a large number of vaults simultaneously.

Video analytics that are programmed to detect various events are key to the automated monitoring process so operators do not have to visually monitor each site. Triggered analytics can send alerts directly to the utility SCADA system or by email to operations personnel.

Reasons for Vault Monitoring:

Monitoring the vaults in underground systems is critical to ensuring reliable and safe power distribution. Some key reasons for vault monitoring include:

Security

Monitoring vaults in underground systems is essential for detecting unauthorized access, which can pose a significant safety risk. Vault access should be limited to trained personnel, and unauthorized access can result in accidents, damage to equipment, or theft. By monitoring vaults, utilities can detect any unauthorized access and take appropriate action to prevent future incidents.

Safety

Monitoring vaults in underground systems allows for visual observations of the conditions inside the vault before entering, which is an essential safety measure. Before entering a vault, utility personnel should perform a visual inspection to identify any potential hazards or risks, such as standing water, exposed wiring, or damaged equipment.

Another reason for vault monitoring is to confirm that procedures are being followed. Utilities have established safety procedures and guidelines that must be followed when accessing and working in a vault.

By monitoring the vault, utilities can ensure that these procedures are being followed, and personnel are adhering to safety guidelines.

Operations

Monitoring vaults in underground systems allows for visual inspection of equipment and thermal monitoring around joints and splices inside the vault, which are critical for maintaining the integrity and reliability of the power distribution system.
Visual inspection of equipment is essential to identify any signs of wear, damage, or corrosion that could indicate a potential equipment failure. Visual inspections can also help to identify any potential maintenance needs or upgrade opportunities, allowing utilities to plan and schedule work in advance.

Thermal monitoring around joints and splices is also critical for detecting potential cable failures before they occur. Electrical equipment generates heat as it operates, and high temperatures around joints and splices can indicate a potential problem, such as a faulty connection or overload. By monitoring the temperature around joints and splices inside the vault, utilities can detect any anomalies and take correcive action before a failure occurs.

About Thermal Technology

Thermal technology is based on the detection and measurement of the thermal radiation emitted by an object. Thermal radiation from very hot objects may be visible (as light) or invisible as infrared in the EM spectrum beyond what a human eye can see. Infrared radiation can be captured by a specialized sensor and converted to usable information in a visible color-coded representation and/or converted to temperature. Infrared sensors can work in any light conditions (as in a darkened closed vault) since they are measuring beyond the visible spectrum.

Emissivity is an object's ability to emit thermal radiation and it can vary between objects of different material composition or color. When making measurements, emissivity may have to be taken into consideration and, in most cases, comparative measurements may be more effective than absolute temperature measurements.

Infrared (IR) imaging is a suitable technology to "detect excessive heat generated by failing components, such as a splice in a vault."[5] Thermal (IR) imaging has been widely used by utilities for periodic spot-checking of temperatures on insulators, bushings, arrestors, transformers etc., to quickly find impending problems. Although valuable as a tool, spot-checking may miss problems that occur under load conditions or weather conditions that make it challenging for IR to work most effectively.

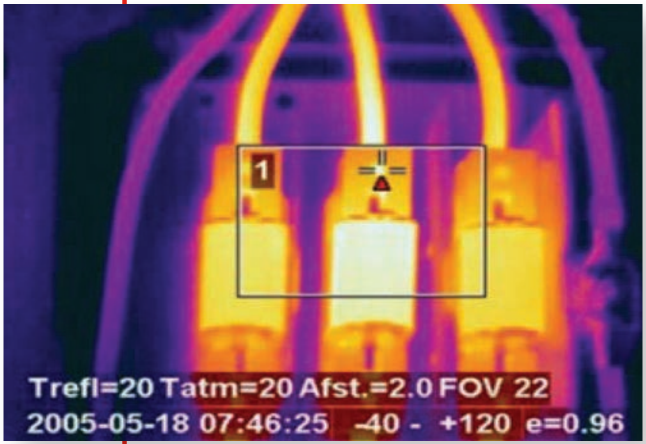

Fig 5. Thermal imaging insulators

Specialized cameras will have temperature 'zones' within the field of view that allow several measurements to be made from each camera position. Analytics can then be run separately on each zone, allowing several points

[5] EPRI – Underground Roadmap, S. Eckroad, 2009

or splices to be monitored inside a vault at the same time from the same camera. Some cameras also have programmable pan/tilt positioning that allows several different views from a single camera.

Thermal analytics provide processing of temperatures that compare between maximum and minimum thresholds and the rate of temperature change within each temperature zone. Temperatures exceeding pre-set thresholds will automatically send an alert to the operator through the SCADA or asset management systems or through email.

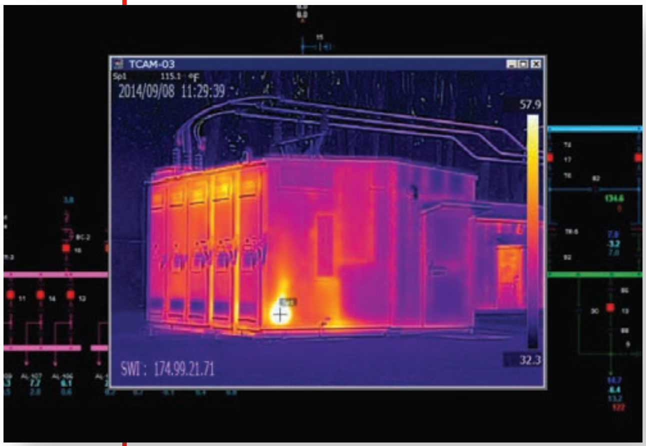

Fig 6. SCADA integrated visual monitoring

Continuous vs. Periodic Thermal Monitoring

Heat dissipation is a sign of increased resistance in a splice and the resulting energy is calculated using I^2R. A joint or splice may not show a significant increase in temperature until the system is under load and increased current is flowing through the splice. The temperature in the splice may peak at certain times of the day that will be caught with a continuous monitoring system where a periodic observation may miss it. Automated thermal analytics can notify operations when temperatures are trending out of range and can be monitored on the utility SCADA HMI. Continuous monitoring also allows for trending analysis to see how the overall conditions of equipment and splices in the vault are changing over time.

Summary

Underground cabling is a significant investment for a utility that is expensive both to install and repair, so considerations should be taken to monitor and protect it from premature destruction. It's not only the cost of repair that needs to be considered, but also the time that customers will be out of service.

There are several effective methods for testing the conditions of joints and splices, i.e., resistance measuring, thumping, sectionalizing and periodic IR monitoring, but these are time consuming, labor intensive and in some cases destructive. Continuous thermal monitoring offers a remote, non-invasive, multifunctional, visual assessment that provides an early warning that further testing or maintenance is required. Once a potential problem is detected a more detailed analysis can be carried out to determine what type of repair will be required to improve the reliability of the system.

About Systems With Intelligence

Systems With Intelligence Inc. is a global provider of Touchless™ Monitoring Solutions for electric utility applications. SWI systems collect and analyze the data that allows utilities to increase safety and reliability while reducing operating costs. Coupling thermal monitoring and visual imaging technology with advanced analytic algorithms, Systems With Intelligence solutions automate remote site monitoring.

Systems With Intelligence products are engineered to operate in the harshest environments, withstand high levels of electromagnetic interference, static discharge and voltage surges found in industrial applications to ensure uninterrupted operation. Providing a monitoring system that operates reliably and connects seamlessly allows customers to remain focused on their operations.

For more information about monitoring your underground system investment, please contact:

Sales@SystemsWithIntelligence.com