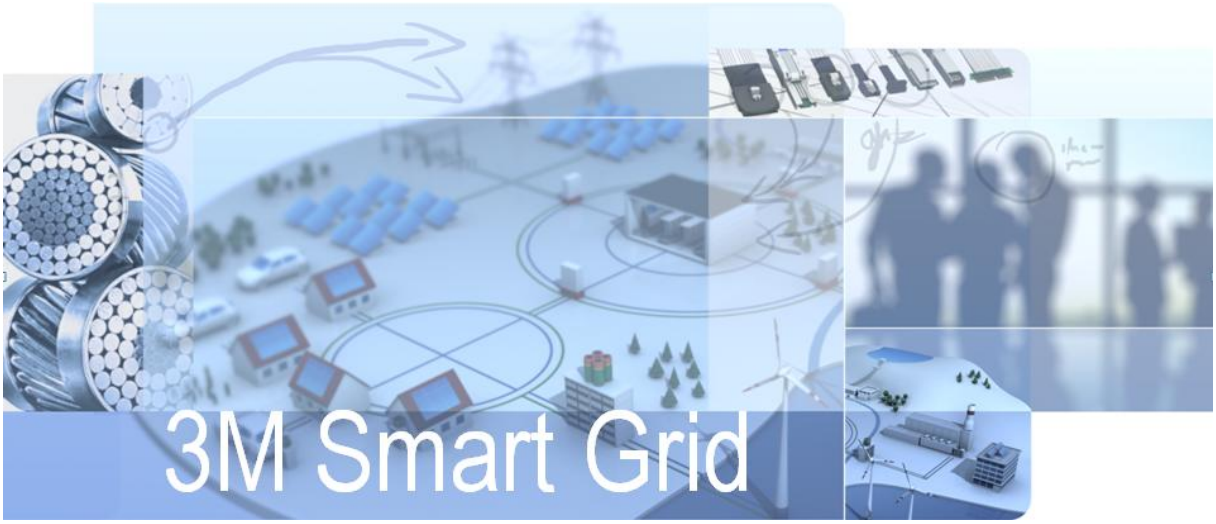
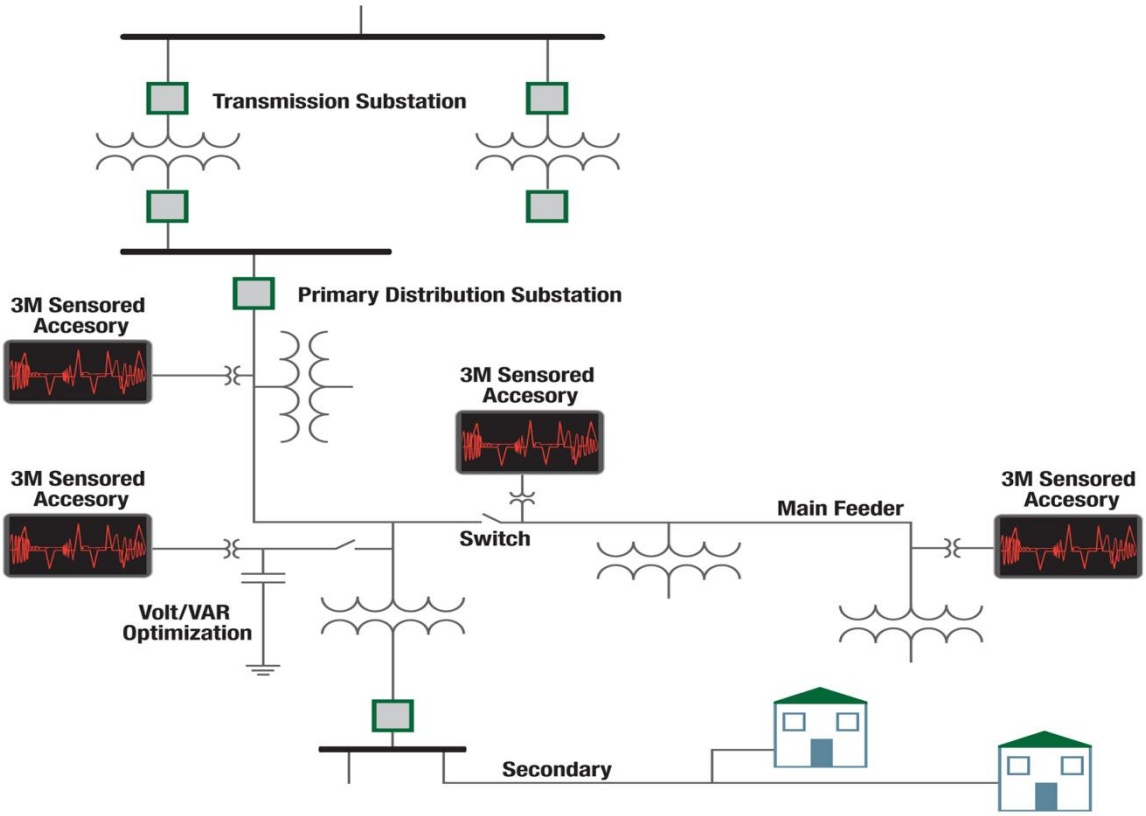


3M™ Sensored Cable Accessories for Underground Medium Voltage Distribution System

Introduction

The focus on enhancing reliability and efficiency of the power grid has led to widespread deployment of distribution automation and control technologies. However, the effectiveness of these technologies relies mainly upon the availability of key system parameter data, such as voltage and current, at the critical locations (e.g. PQ nodes) in the grid. This is especially important for the Medium Voltage (Primary) distribution segment, as the faults impact a much wider customer base compared to the Low Voltage (Secondary) distribution system. Furthermore, system-wide deployment of advanced data acquisition solutions for overhead feeders is generally financially feasible; whereas, equivalent solutions for underground distribution system are capital intensive. As a result, the majority of the data acquisition devices in the Medium Voltage (MV) Underground (UG) distribution system are concentrated at a few nodes.

3M™ Sensored Cable Accessory solutions are designed to provide highly accurate voltage and current measurement through simple retrofit of existing power equipment such as switchgear, in underground MV distribution networks. These sensored cable accessories, when connected to the power utilities' communication infrastructure, enable real-time monitoring, control and automation capabilities throughout the underground MV distribution network.



3M™ Sensored Accessory solution in Underground MV Distribution System

3M™ Sensored Termination

Building upon over 40 years of innovation in underground MV Cable Accessories for power utilities, 3M has developed a Sensored Termination that incorporates pre-calibrated, highly accurate, passive current and voltage sensors.

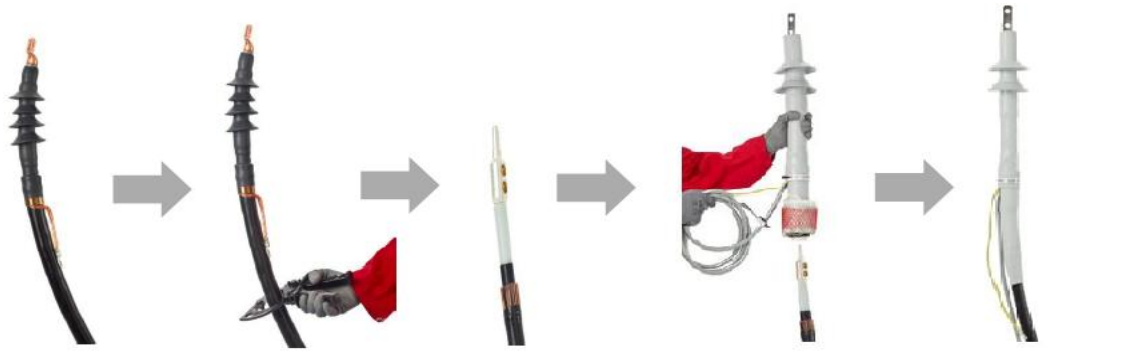
3M™ Sensored Termination

3M™ Sensored Termination installed inside switchgear

The Sensored Termination is suitable for retrofitting existing MV switchgear without upgrading structures, and is designed to reliably provide accurate data, even in environments that may present frequency and temperature variability.

The current (load) measurement is obtained through an inductive sensing device, specifically designed for integration into the termination body. The voltage measurement is obtained through a passive voltage divider sensor that compensates for temperature variation. The installation requires powering down the circuit for a short period of time, while the existing cable termination is replaced.

Installation steps to replace standard MV termination with sensored termination:



Existing Standard Termination | **Cut-off Standard Termination** | **Cable Preparation** | **Plug and Install** | **Installed Sensored Termination**

Voltage Measurement Accuracy

Temperature	Voltage Accuracy (per phase)
-5°C to 0°C	± 1%
0°C to 35° C	± 0.5%
35°C to 40°C	± 1%

Current Measurement Accuracy

Temperature	Current	Current Accuracy
-5°C to 40°C	3 Arms	± 5%
	15 Arms	± 1%
	300 Arms	± 1%
	6,000 Arms	± 5%

Rated Primary Voltage = 15/√(3) kV_{rms}

Constant Rated Phase Offset = 1.2°

For detailed specifications, please refer to the Data Sheet.

Applications

Advanced Distribution Automation Technologies Enabled by the 3M™ Sensored Accessory

3M Sensored Accessories provide measurements that are fundamentally required for advanced analysis and response – high accuracy voltage and current waveforms – and through this the associated phase angle. The voltage and current outputs are provided as analog waveforms and are capable of a high frequency response, giving the user freedom to enable various complex real time grid analysis and response. A brief description of some of the many useful applications of this technology is contained herein.

Power Quality: Volt/VAR Optimization

Power Quality through Volt/VAR Optimization, or VVO, involves reducing the amount of reactive power on the grid to reduce total current. Reactive power is the result of the parasitic inductance and capacitance the grid itself forms, in addition to reactive loads. While the power delivered may be imaginary, the increased current, subsequent line losses and reduced throughput are real.

Determination of the phase angle requires concurrent measurements of both voltage and current (enabled by the 3M Sensored Accessories) and a subsequent analysis of the time relationship between the two. If an inductive load is present, the voltage will lead the current. Alternatively, if a capacitive load is present, the current will lead the voltage. Either one of these conditions leads to poor power factor and will require that additional current be present on the grid to provide the same amount of real power to the end users. Once measured, inductive and capacitive loads can be compensated for by switching in a capacitor bank to cancel out reactive loads or a reactor to cancel out capacitive loads.

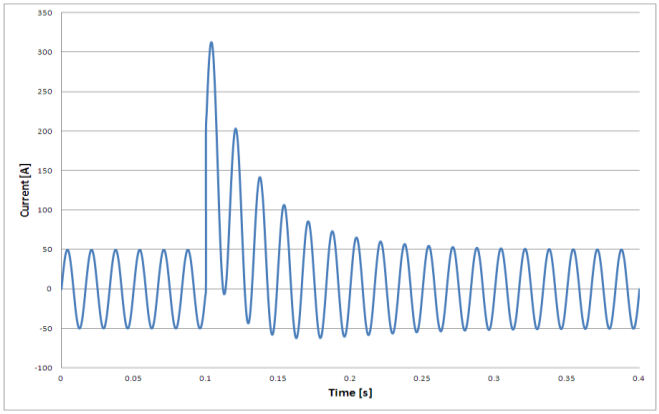
Conservation Voltage Reduction (CVR)

CVR is the practice of actively lowering the distribution line voltage as low as possible while ensuring that the delivered voltage is still within required specifications. The practice is built on the principle that many devices (i.e. air conditioning, incandescent/fluorescent light bulbs, induction motors, etc.) function with higher energy efficiency at rated voltages. Implementation of CVR involves a combination of Volt/VAR optimization and switching capacitor banks to reduce line losses and maintain a more uniform voltage along distribution lines, in addition to voltage regulation at the substation to purposefully reduce the voltage. To implement and optimize this technology, the real time, high accuracy voltage measurement provided by the 3M™ Sensored Cable Accessories is critical, as primary voltages need to be accurately measured along the distribution feeder lines and at the critical consumption points.

Fault Detection and Location

Localizing faults in an efficient and timely manner is a capability few utilities have today, especially in underground networks. The 3M Sensored Cable Accessories are a key component in enabling many methods of fault locating due to the analog nature of the outputs and the capability for the current sensor to measure the high current conditions present during a fault without magnetic saturation. The waveforms generated by a fault and measured by the device can be sampled at a high frequency and analyzed using signal locating methods including time-domain reflectometry (TDR) and time-

domain transmissometry (TDT). These analyses methods work upon the basis that captured waveforms are affected by the impedance of the conductor(s) the signal travels along. Coupling these measurements with time stamps and a network model including knowledge of cable lengths and impedance allows for fault locating via time of flight data. With a 3M™ Sensored Cable Accessory and the appropriate integrated electronic devices placed throughout an electrical grid, faults can be measured from multiple locations and triangulated within a small margin of error. As the complexity of the system increases with more branches and interconnections, the flexibility provided by 3M Sensored Cable Accessories becomes more necessary to provide additional measurement points that can help to increase the accuracy of fault locating in a cost effective and efficient manner.



3M™ Sensored Cable Accessory sensor output: simulation of a fault transient

Conclusion

The ability to acquire accurate data from critical points throughout the underground MV distribution segment is a key requirement for enhancing the reliability and efficiency of the grid. 3M Sensored Cable Accessory solution fulfills this need by enabling power utilities to capture highly accurate voltage and current waveforms in real-time. Furthermore, low investment, easy installation and no requirement of field calibration makes deployment of the sensored accessories fast and efficient.

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