WHITE PAPER: SF_6 GAS MONITORING

SOLVING THE CHALLENGES OF SF_6 GAS MONITORING

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Sulphur Hexafluoride (SF_6) management is a large part of breaker and/or Gas Insulated Substation (GIS) maintenance. And thanks to the Mitsubishi Electric Power Products, Inc. (MEPPI) Gas Monitoring Analytics System, it is also the easiest solution for prolonging the life of equipment through the use of condition-based maintenance.

Using cost-effective ways of seeing that your equipment is running within acceptable reliability and compliance parameters prevents the need to replace equipment prematurely simply because of new environmental restrictions. Monitor your SF_6 insulated equipment with the MEPPI solution which provides:

1. Visibility of leaks as small as 0.1% mass/year, identifying costly SF_6 emissions.
2. Improved data processing to minimize false alarms that plague other systems.
3. Auto refill detection and other reporting tools that can be used as part of a comprehensive SF_6 management plan.
4. A flexible platform: a centralized monitoring system that can include breaker monitoring, partial discharge, and other parameters.

The Problem

SF_6 is the dominant gas found in circuit breakers and is used in large quantities in compact gas insulated substations. Recent legislation enacted in January 2022 by the California Air Resource Board (CARB) establishes significant fines for SF_6 losses. Negligent emissions penalties are now set at a maximum cost of over $400,000 per day per pound of SF_6 above the established yearly limit[1,2].

Shifting away from the use of greenhouse gasses in high voltage equipment is already underway, however, both older and newer equipment containing SF_6 are expected to remain in service longer because of the unfavorable economics related to early retirement or replacement.

Traditional gas pressure alarms are not designed to minimize SF_6 emissions. Alarms meant for safe operation (≈10% loss) don't provide fast notifications to minimize SF_6 loss. Therefore, systems that can detect leakages all the way down to 0.1% of SF_6 mass loss/year are required.

The Solution

SF_6 monitoring is essential for lowering electric utilities' environmental risk profile (*See Figure 1 on next page*). Other industries (including power generation) have been taking full advantage of monitoring technology for decades to quickly react to problems. Using proper instrumentation and a computer to continually process data, modern monitoring systems can recognize problems faster than before. These systems greatly reduce costly manual inspection and enable true condition-based maintenance and replacement planning.

Responsible utilities recognize the need for automated systems to monitor SF_6 for protecting the environment and their bottom line. These systems are the best way to manage the environmental and financial liability, and system reliability by providing quick notification of leakage and the priority for scheduling repairs.

MEPPI's Gas Monitoring and Analytics System is a crucial part of a comprehensive maintenance program.

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1 California Code of Regulations, Title 17, § 95350 – 95358
2 California Health & Safety Code, §42400.2

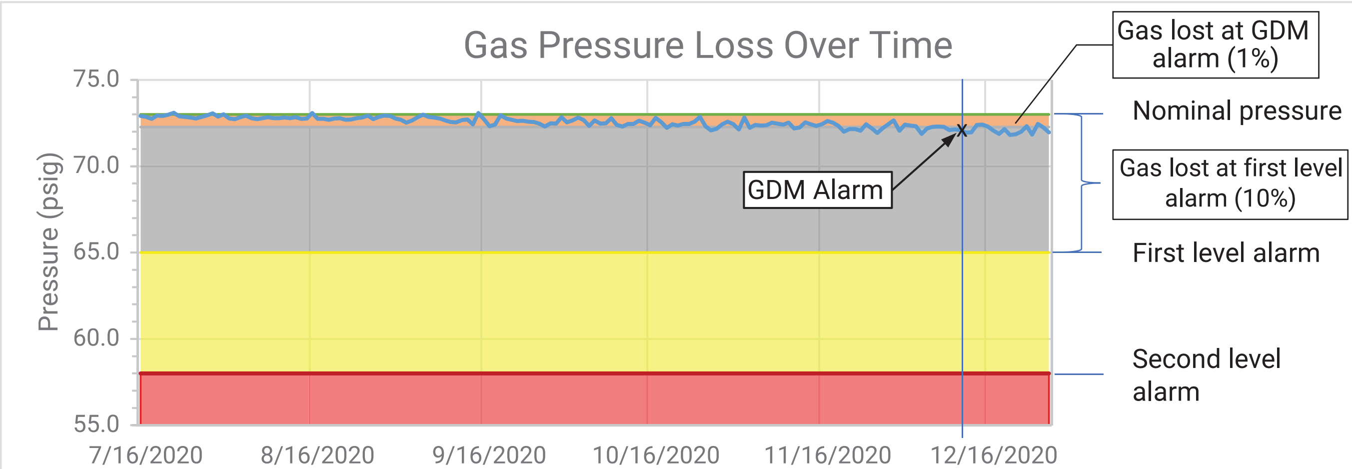

Figure 1: Gas loss comparison between traditional alarming and Gas Density Monitoring (GDM) alarming

Features of a Monitoring System

Monitoring systems are comprised of two parts: the instrumentation and the computer. Instrumentation is fundamental to the system while the computer handles the processsing of the data and serves as the interface between the equipment, the operator, and other business or enterprise-wide systems.

Instrumentation

Instruments, otherwise known as sensors, transmitters, or transducers, are available for a wide range of applications. The most common measurement for SF_6 monitoring is density, but another measurement gaining popularity recently is moisture.

Traditionally, the output of an instrument is measured by the amount of current the instrument draws from its power source[3]. More recently, however, measurements can be obtained from multivariable instruments using a communications protocol, such as Modbus. In both cases, the instruments are low-power devices typically powered with 24 VDC.

Since the gas pressure varies disproportionately to temperature, much consideration is given to instrument placement, distance of the instrument from gas insulated equipment, and using insulation to keep the instrument the same temperature as the high voltage equipment. Additionally, the gas pressure is expressed in terms of a temperature compensated value (i.e., at 20 °C or 68 °F) for simplicity[4].

Both pressure and temperature instruments have their advantages and disadvantages when ultimately producing a compensated gas pressure measurement. Both measurement techniques suffer from the inability to measure the gas from within the gas-insulated chamber. Having to install the instrument outside the chamber results in an occasional temperature difference between the instrument and the chamber where most of the gas is contained. Thus, installing the instrument as close to the chamber as possible and adding insulation produces the most accurate measurement.

Due to the relative nature of condition monitoring, instrument precision is more important than accuracy. Condition monitoring identifies differences over time regardless of how the measurement compares to that of another instrument measuring the same gas.

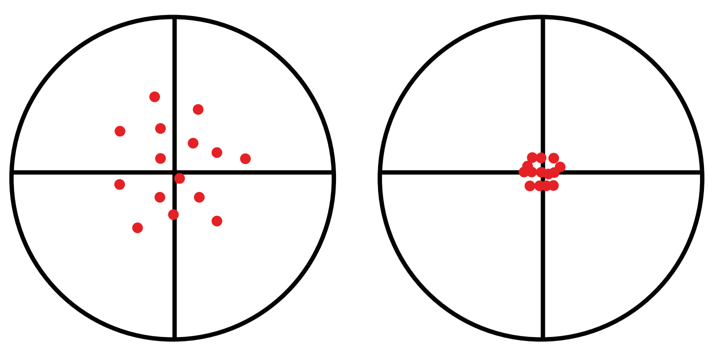

Figure 2: Graphical representation of accuracy vs. precision[5]

3 https://www.ni.com/en-us/innovations/white-papers/08/fundamentals--system-design--and-setup-for-the-4-to-20-ma-curren.html
4 https://www.nist.gov/publications/20-degrees-celsius-short-history-standard-reference-temperature-industrial-dimensional
5 https://wp.stolaf.edu/it/gis-precision-accuracy/

Computer and HMI

The HMI is a crucial part of the system as it is how operators can visualize the data, statuses, and other information on the system. HMI best practices are centered around human performance best practices, which include:

- Hierarchical structure (General » Area » Specific Equipment » Detail)
- An easy-to-read alarm list
- Display elements and colors that are familiar to the user (system/site drawings, diagrams, and alarm colors)
- Adherence to standard symbols (ISA, IEEE, etc.)
- Background colors that minimize eye strain
- Symbols and static element colors that contrast well with background

Other features, such as a touchscreen and/or computer speakers, enhance the operator's experience as well. All data for the substation can be viewed in one centralized location which eliminates the need to walk around the entire substation.

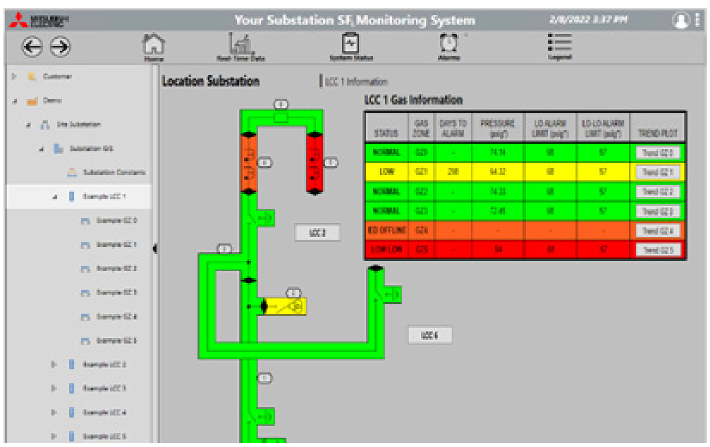

Figure 3: Typical HMI Display

1. **Alarms**

   The alarm list is a critical component that conveys alarm status efficiently and effectively. It is important that alarm texts are clearly understandable so that the operator can respond appropriately to any given situation. Further, alarms are shown with timestamps so that multiple alarms can be viewed in sequence, in the same colors that are used on displays for consistency, and to eliminate confusion.

Historian

The purpose of the system historian is to store data for extended periods of time for retrieval at a later time. Data is stored on the computer's local hard drive, and the duration of storage is typically limited to drive storage capacity. Rapidly changing data is usually logged by the historian once every few minutes, whereas data that is slow to change (or doesn't change at all) is usually logged once per day. This data can then be used in:

- Situations where historical recollection of events is required (i.e., confirming gas handling activities)
- Confirmation of reporting (gas weight data can backup gas handling records made manually)
- Reviewing and analyzing past data to look for trends, such as leaks

Analytics

The HMI is also capable of analyzing historical data on a set interval (daily, weekly, etc.), or on-demand for ad hoc reporting. The objective of the analysis is to find trouble with the equipment before problems arise. An automated analysis can be as simple as looking for a day-over-day change in equipment parameters, or as complicated as using the least squares method to predict when any parameter will reach an alarm limit (potentially even 1-2 years in advance). Additionally, analytical methods can be used for detecting gas handling events, such as refills.

Like other automated processes, analytical methods are first prototyped manually and then tested against actual historical data to ensure that the analysis methodology is sound and capable of finding the problems they are designed to find.

The MEPPI Advantage

The MEPPI Gas Monitoring and Analytics System reduces noise (caused by uncontrollable external conditions) found in the raw data using several noise suppression techniques. Once normalized, the data are analyzed, alarms are generated, and accurate reports can be produced.

False alarms are also mitigated through the use of a time-dependent alarm threshold. For example, a smaller analysis period will have a coarser alarming criterion, such as a 1% loss. A larger analysis period, however, can be more closely scrutinized, and therefore a 0.1% threshold can be applied for alarming gas loss.

Architectures

The monitoring system is flexible enough to be installed in a variety of ways:

On-site (on-premises or on-prem) Standalone: HMI computer installed in substation. The data can only be taken from the system by removable storage (ex. USB flash drive).

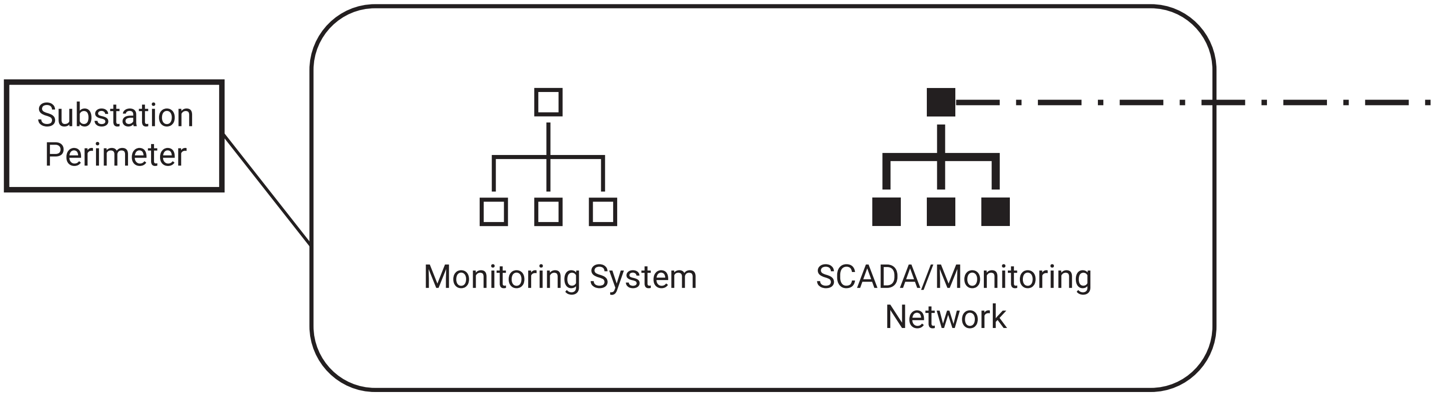

Figure 4: Islanded monitoring network topology

On-site with external connectivity: A computer is installed in the substation and integrated with SCADA or monitoring system. Data can be stored both locally and on user's enterprise-wide data historian. The system would be connected to the user's SCADA or monitoring network through either a firewalled ethernet or direct serial data connection for security.

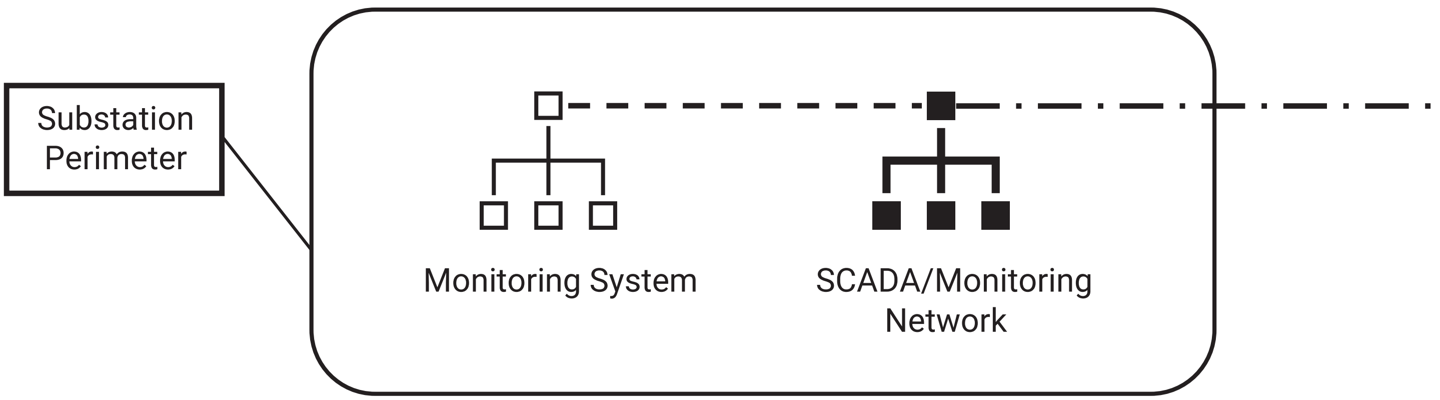

Figure 5: Connection with on-site monitoring network

Remotely Connected: A remote computer (i.e., in user's datacenter) receives data from on-site instruments. The entire monitoring system would reside on user's existing SCADA or monitoring network infrastructure.

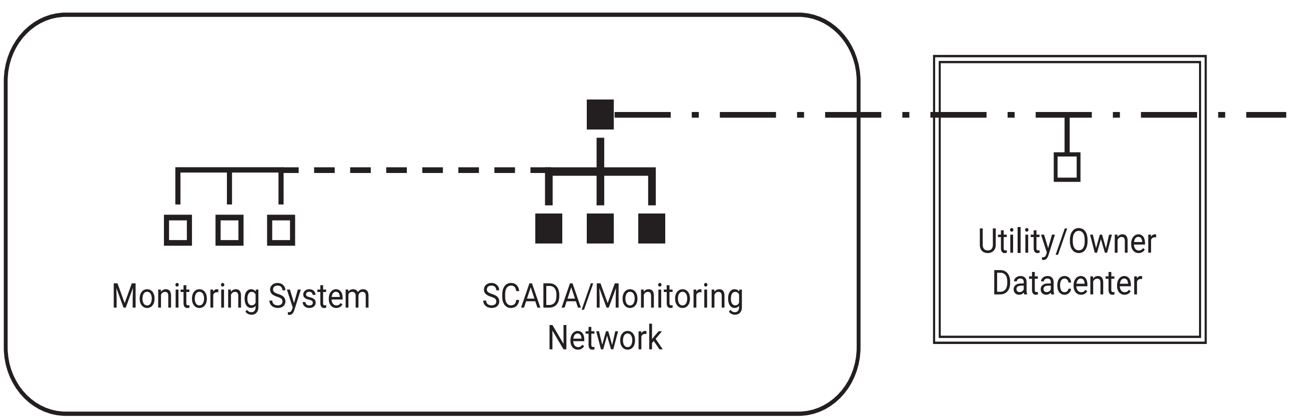

Figure 6: Monitoring system with off-site computer

Remotely Connected Service: MEPPI receives the data from on-site instruments and provides user with periodic reporting (weekly, monthly, quarterly, yearly, etc.) via email.

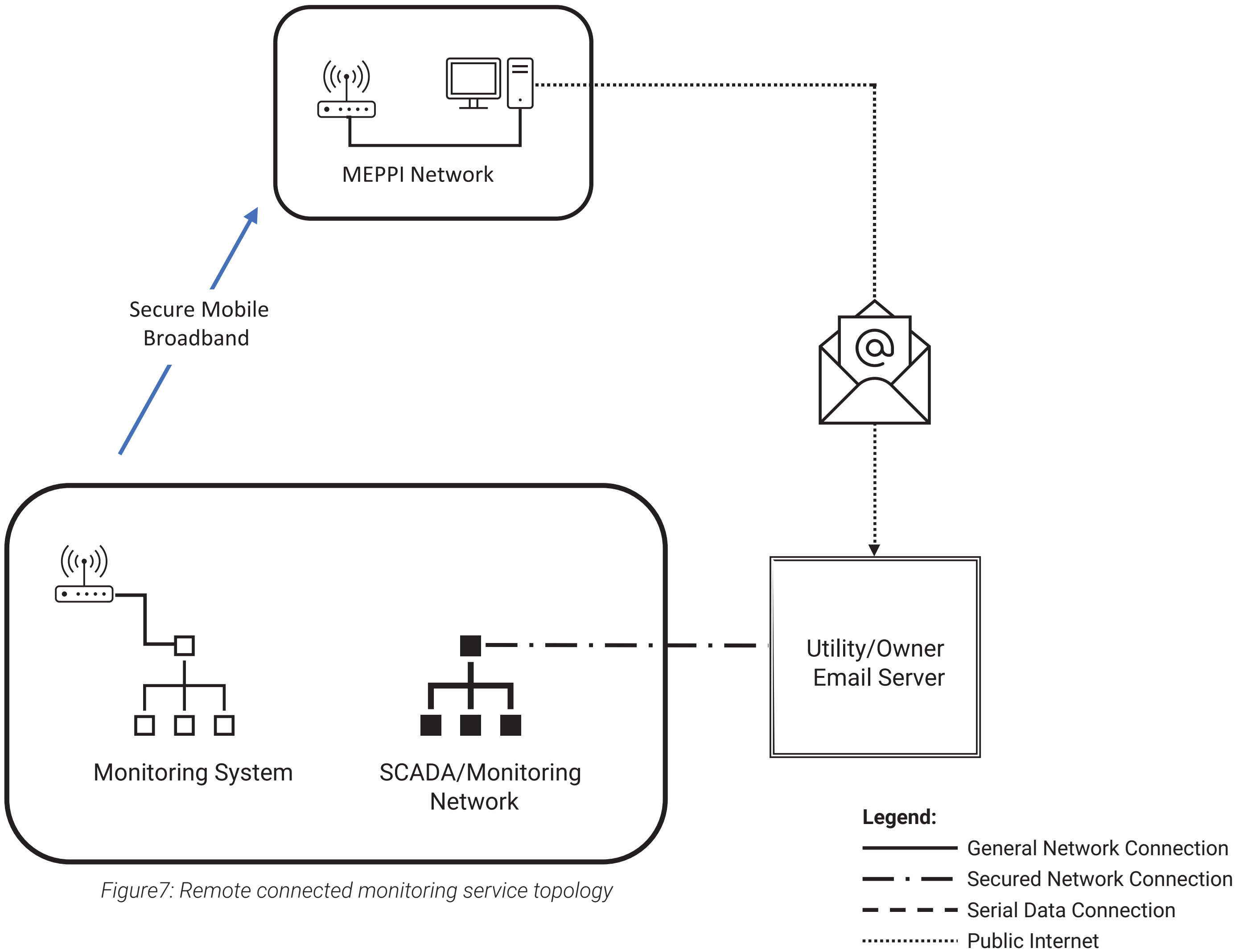

Figure7: Remote connected monitoring service topology

Conclusion

W. Edwards Deming once stated, "If you can't measure it, you can't manage it." Monitoring systems make what is invisible now manageable, and in today's world, that's more important than ever. Real-time monitoring systems facilitate digital transformation and harness modern computing power, resulting in changes for the better.

Thus, in the one-size-fits-nobody world that is the electricity transmission and distribution industry, MEPPI provides a wide variety of options (based on mature technologies and proven best practices) that can meet every utility's monitoring needs.

MITSUBISHI ELECTRIC POWER PRODUCTS, INC.

Corporate Headquarters
Thorn Hill Industrial Park
530 Keystone Drive
Warrendale, PA 15086

www.meppi.com | 724.772.2555

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