Solving the Challenges of SF6 Monitoring

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Topics of Discussion

- Gas Insulated Substations
- SF6 Monitoring
  - Features
  - Data Filtering
  - Architectures
- Mitsubishi Gas Monitoring Case Study
- Future of SF6 Monitoring

Gas Insulated Substations (GIS)

- SF6 is the primary insulating gas used for Gas Insulated Equipment (GIE) and is used in large quantities in Gas Circuit Breakers (GCB) and Gas Insulated Switchgear (GIS).
- All Major High-Voltage switchgear manufacturers have devised alternatives to SF6 for applications now and in the future.
- SF6 is resident in 10’s of thousands of installations and will be a large part of North American Utility regulation and responsibility.
  - All SF6 systems must be maintained, monitored, and properly sealed when opened to ensure safe management of SF6 gas.

Gas Insulated Substations (GIS)

- In January 2022, the California Air Resource Board (CARB) established new requirements for current and future GIE
  1. Set target cut-off dates for the purchase of new GIE with Global Warming Potential (GWP) values greater than 1
     - GWP – ratio of time-integrated radiative forcing of one gas relative to that of CO2
     - GWP of SF6 is 23,500:1
  2. Consolidate and regulate methods for handling the insulating gas of current and future GIE
- California SF6 fleets must meet these new requirements, and the Environmental Protection Agency (EPA) requests yearly SF6 inventory tracking from all North American SF6 users
- No nationwide penalty for leakage rates has yet been established, but California has set them at $400,000 per day per pound of gas leaked beyond the established yearly limit

Gas Insulated Substations (GIS)

- Using cost-effective ways of ensuring that GIE is running within acceptable reliability and compliance parameters prevents the need to replace equipment prematurely due to new environmental restrictions.

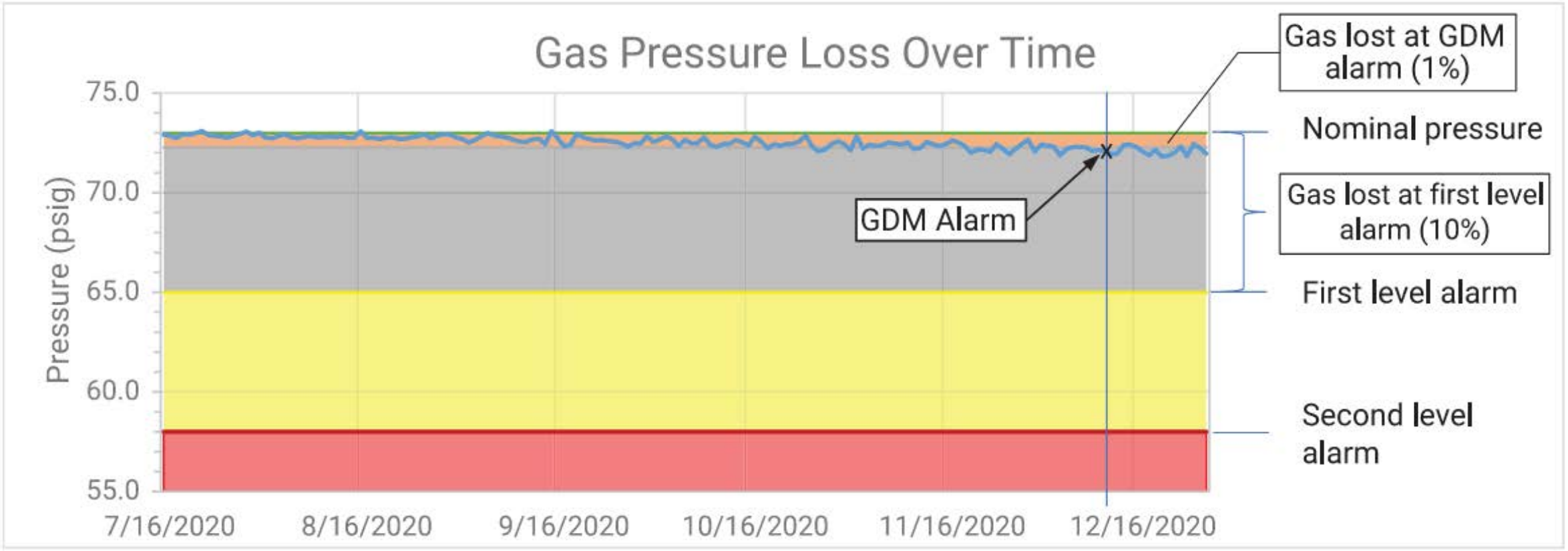
- Monitoring SF6 insulated equipment provides:

1. Visibility of leaks as small as 0.1% mass/year, identifying costly SF6 emissions
2. Data processing to minimize false alarms that can plague users
3. Auto refill detection and other reporting tools that can be used as part of a comprehensive SF6 management plan
4. A flexible platform: a centralized monitoring system that can include breaker monitoring, partial discharge, and other parameters

SF6 Monitoring

- Shifting away from greenhouse gases in high voltage (HV) equipment is already underway, however SF6 is expected to remain in service for the immediate future because of the cost of early retirement or replacement
- Traditional gas pressure alarms are not designed to minimize SF6 emissions
  - Alarms meant for safe operation alert users to a ~10% loss
  - These systems don’t provide fast notifications which would allow users to minimize SF6 loss
  - Systems that can detect losses as low as 0.1% mass/year are required to minimize SF6 loss

SF6 Monitoring



- Figure 1: Gas Pressure loss over time using Gas Density Monitors (GDM); SF6 monitoring is essential for lowering electric utilities' environmental risk profile.

SF6 Monitoring

- Uses for SF6 Monitoring:

1. Leak prediction
   - Potential leaks reported immediately based on predictive analytics
   - Eliminates need to wait for alarms
2. SF6 inventory check
   - Double check the bottle-in/bottle-out method of tracking SF6 weights
3. Easy off-site access to SF6 data
   - Gas weight and pressure data available for records and real-time checks
   - Can be exported to a utility-wide monitoring package

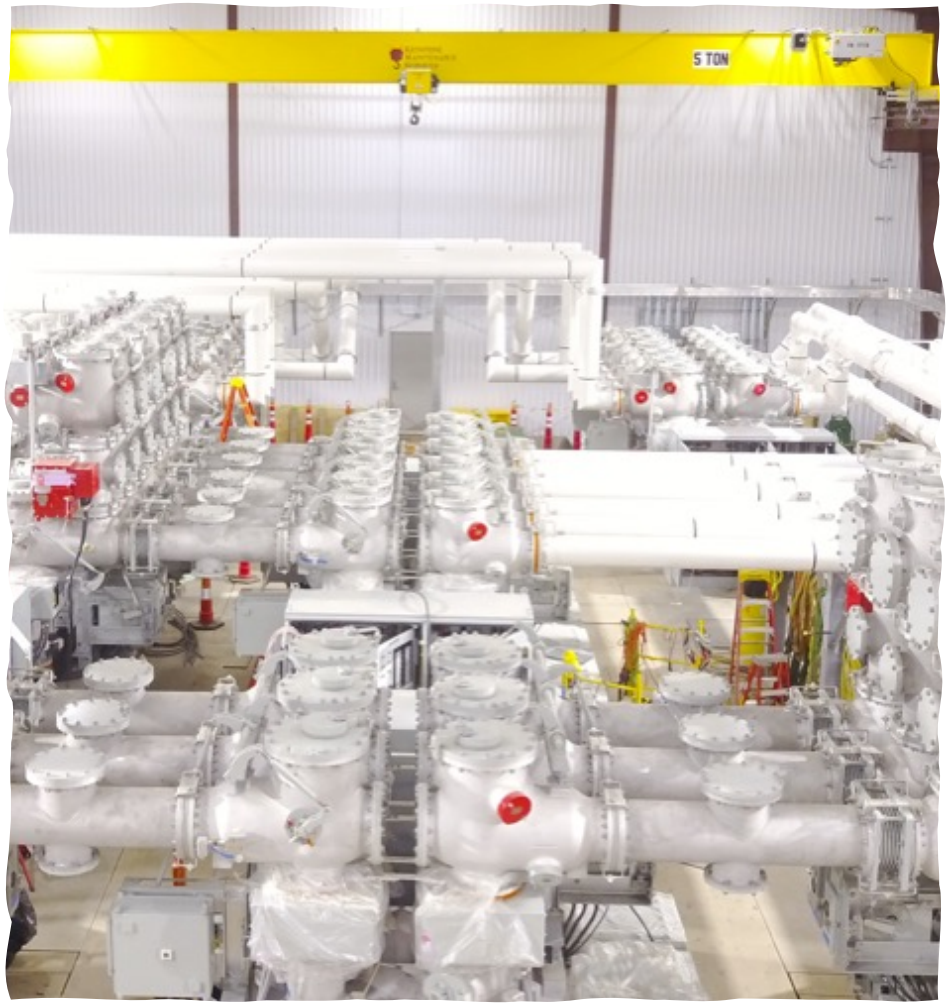
Features of Monitoring System

- Instrumentation
  - Sensors for temperature, density, moisture
  - Placed as close as possible to the chamber where the gas is contained to give accurate readings and avoid temperature differences between gas and sensor
- Computer
  - Human Machine Interface (HMI) is essential for operators to visualize data, status, and other information about the system
  - HMI best practices:
    - Hierarchical structure
    - Easy-to-read alarm list
    - Familiar display elements & symbols

Features of Monitoring System

- Alarms
  - Convey status effectively
  - Timestamped so multiple alarms can be viewed in sequence
- Historian
  - Store data for extended periods
  - Confirm gas handling activities, confirm reporting, review and analyze past data
- Analytics
  - Analyze on a regular basis to find trouble before problems arise

Data Filtering



- Mitsubishi Electric Gas Monitoring and Analytics System reduces noise from raw data
  - Create accurate reports
  - Mitigate false alarms with time-dependent alarm threshold
    - Smaller analysis has coarser alarm criteria, such as 1% loss
    - Larger analysis more closely scrutinized and 0.1% loss threshold can be used

Architectures

- On-site with external connectivity
  - Computer integrated with SCADA or monitoring system
  - Connected through firewalled ethernet or direct serial data connection for security

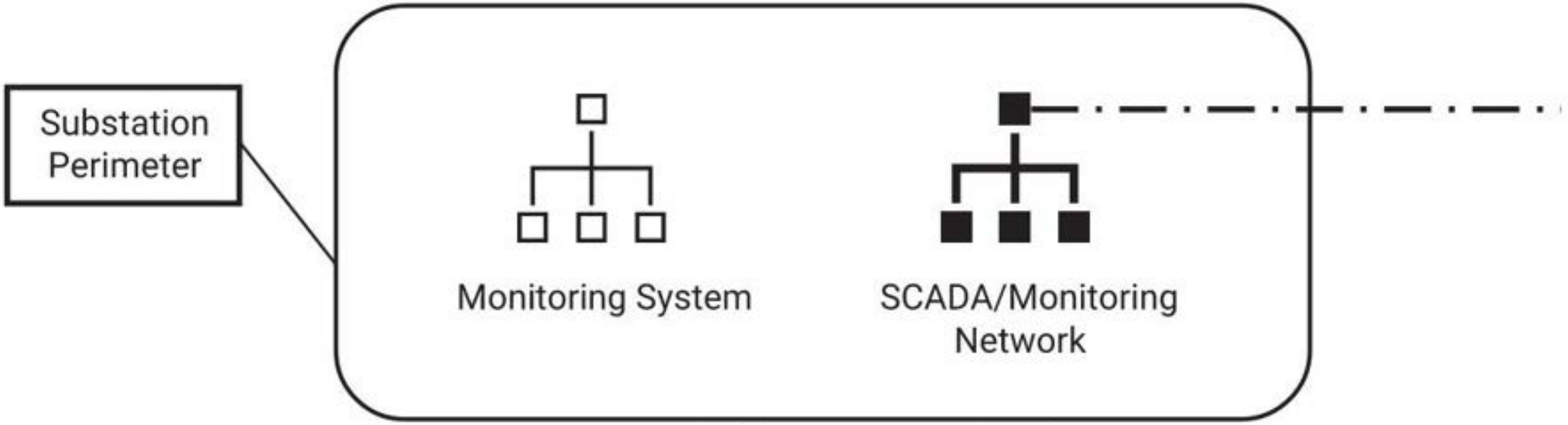


Figure 4: Islanded monitoring network topology

Architectures

- Remotely connected
  - User's datacenter receives information from on-site instruments
  - Entire monitoring system resides on user's existing SCADA

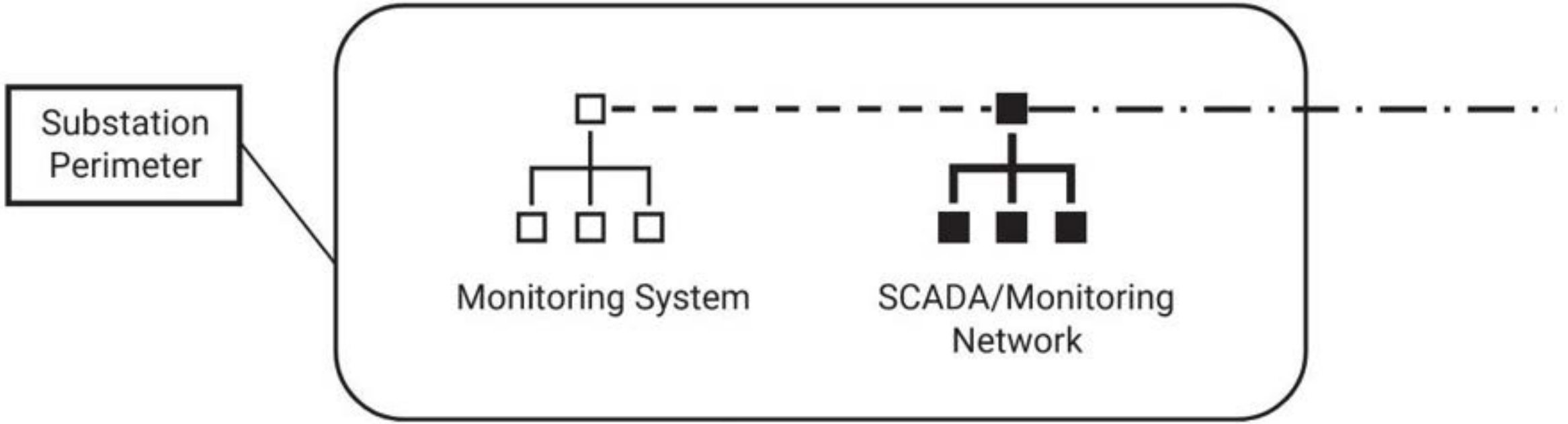


Figure 5: Connection with on-site monitoring network

Case Study for SF6 monitoring

- In 2020, Mitsubishi Electric installed its SF6 Gas Monitoring and Analytics System on over 200 gas zones on 245kV & 500kV GIS Equipment in Western USA
- The GIE was 15 years old and the customer used the substation SCADA connection to receive raw SF6 data directly from the SF6 Monitoring system

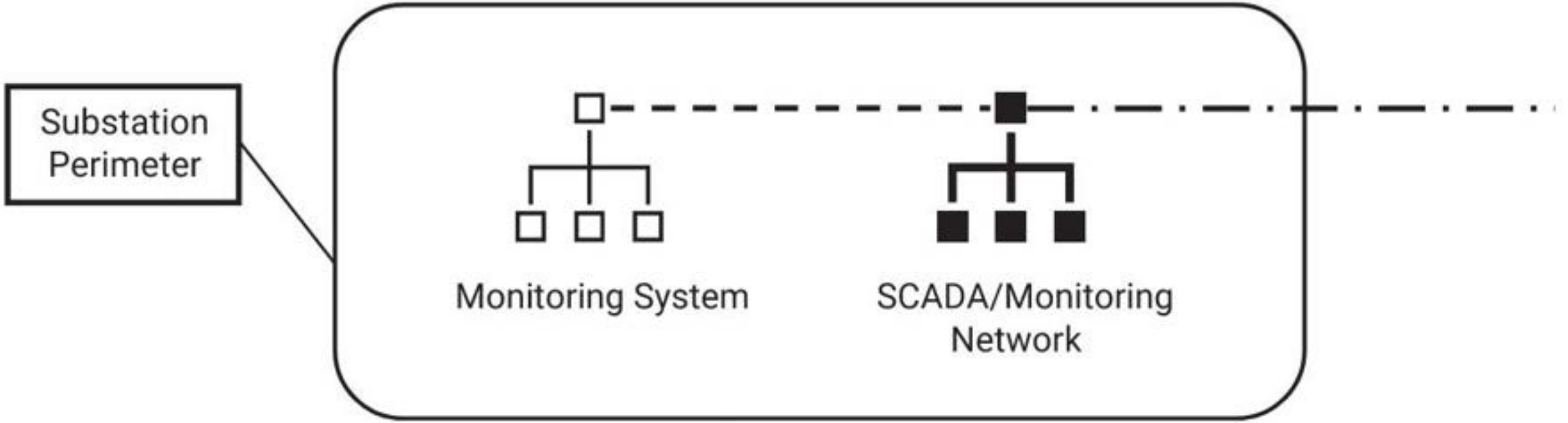


Figure 5: Connection with on-site monitoring network

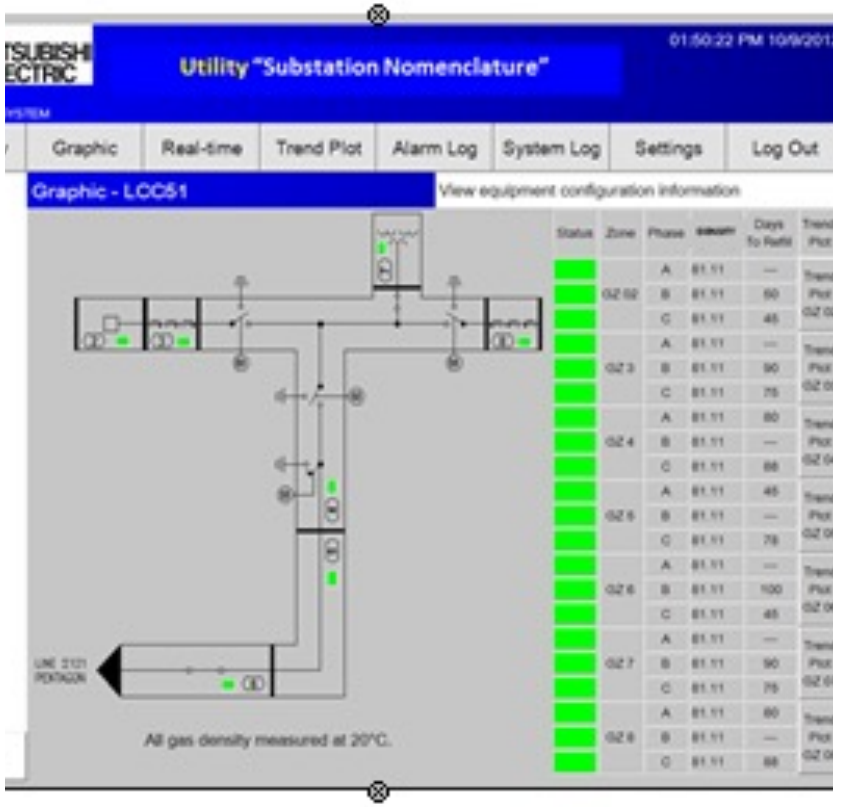
Case Study for SF6 monitoring

- The GIE was 15 years old and the customer used the substation SCADA connection to receive raw SF6 data directly from the SF6 Monitoring system
- Two months after installation, a leak was found on a 1100 lb gas zone
  - At the leak rate, the alarm would only trip after 1 year, with 100 lbs of SF6 lost
  - Mistubishi notified the customer and limited the leak to 20 lbs of SF6 lost
- 100 lbs of SF6 CO2 equivalency:
  - 225 passenger vehicles driven for one year (2.6M miles)

  OR
  - 125 homes' energy use for one year

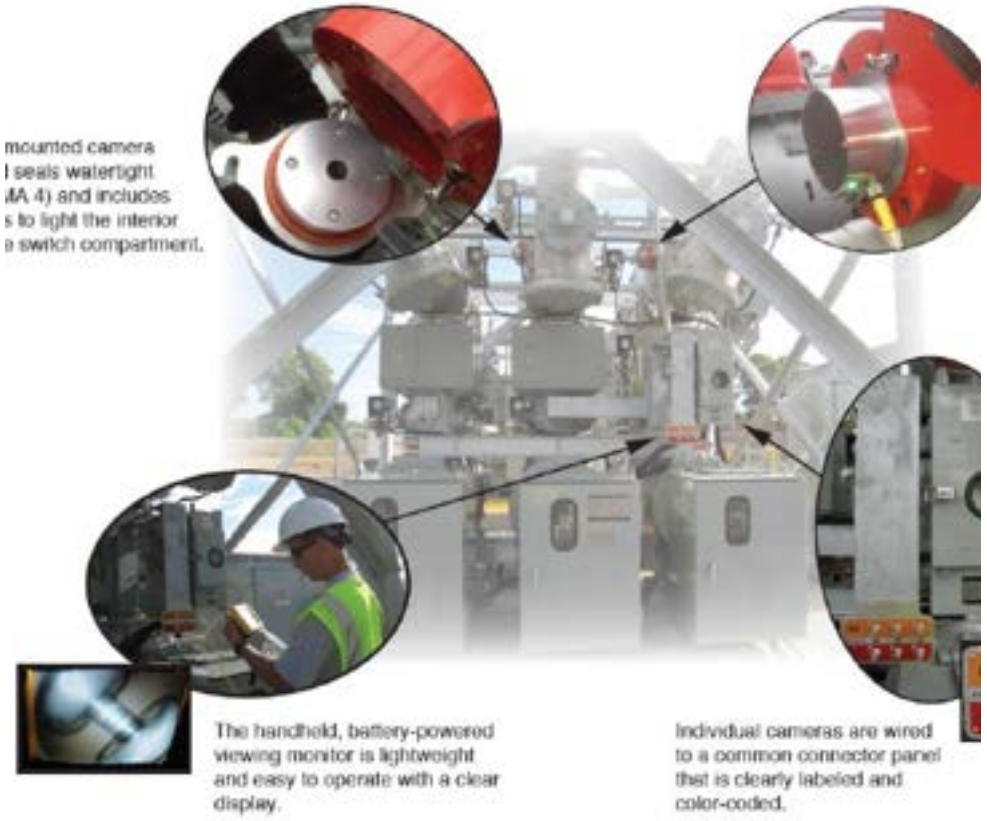
Case Study for SF6 monitoring

- The CARB penalties now in effect in California are tied to any emissions of SF6 over 1.0% of a utilities SF6 system capacity
  - $400,000 per lb per day over this limit
- The value of understanding where leaks are occurring on GIS or AIS equipment is immense



Future of Substation Monitoring

1. Visible light cameras continuously check and alert
   - oil leaks
   - Vegetation
   - animal activity
   - criminal acts
   - analog gauges
2. Thermographic cameras continuously monitor
   - identify thermal changes of substation equipment
   - identify thermal incidents such as wildfires around the substation
3. Microphones identify acoustic anomalies of equipment
   - Vibrations
   - Gunshots
   - Local activity
4. Provide real time visual and thermal access to a substation and its equipment 24/7



Conclusion

- “If you can’t measure it you can’t manage it”
  - W. Edward Deming

- Monitoring systems are more important now than ever
  - Protect our vital infrastructure
  - Provide real-time feedback and prediction of problems
  - Save time, money, effort

Sources

- McKibben, Patrick. “SF6 Monitoring the United States T&D Market.” CIGRE US National Committee 2022 Grid of the Future Symposium. Web. 2022.