White Paper

# Legacy Substation Monitoring with LineWatch-M Sensors

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QinetiQ North America

# White Paper: Legacy Substation Monitoring with LineWatch-M Sensors

## 1 Introduction

The cost of making “inside the fence” upgrades of a legacy substation can run in the hundreds of thousands of dollars. QinetiQ North America’s LineWatch-M sensing and monitoring devices can be quickly and easily installed on each feeder outside the substation fence to provide a low cost, highly accurate SCADA capable sensing and monitoring solution. The LineWatch-M sensor (pictured as Figure 1) provides high visibility into substation performance by monitoring current, voltage and power flow, all without requiring a neutral connection. Without the need for a “hard” neutral connection the ease and safety of deployment is greatly increased. Competing devices can either only sense current or require a physical line-to-neutral connection to measure voltage increasing the cost of installation and the chances for failure in the future.

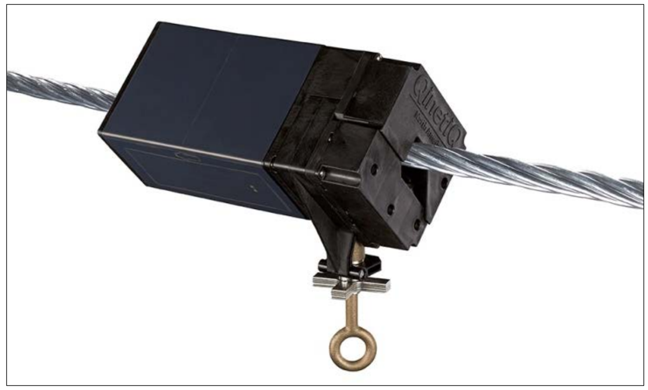


*Figure 1: LineWatch M Current, Voltage and Phase Angle Sensor*

The LineWatch sensor measures voltage though the capacitive coupling between plates on the outside of the sensor case and ground. Unlike previous capacitive "bird-on-a-wire" voltage sensors, patented design features and algorithms enable accurate voltage measurement (+/- .5%) even in extreme weather conditions. Because the sensors install quickly (typically 30 minutes from start to finish for a 3-phase system) and provide accurate power flow information, they provide a good solution for utilities who are looking to monitor substations without incurring the full expense of inside the fence upgrades. This white paper will discuss the need for additional sensing and monitoring at legacy substations and how QinetiQ’s LineWatch-M medium voltage sensor system addresses these needs.

## 2 The Need for Sensing in Legacy Substations

A large number of legacy substations exist in North America. The substations are classified as “legacy” because, although the equipment is functional and has significant remaining life, there are no measurements of ongoing substation operation. In contrast, equipment like reclosers in more modern substations collect detailed data about substation operation, reporting that data to a centralized location or Energy Management System. Additional sensing is needed in legacy substations for several reasons:

- **Feeder Maintenance**
  For legacy substations, there may be no visibility into the immediate loading of the substation. For maintenance purposes, it is often desirable to reconfigure feeders so that work can be done on a particular feeder without causing outages. Without load monitoring, it is difficult to know whether or not loads are low enough to reconfigure the system without creating overloads. Maintenance is then pushed to times of the year when the expected load is low, or personnel must be sent out to the substation to take manual measurements, adding unnecessary delay. If load information is available remotely (*e.g.* via LineWatch-M sensors), maintenance planning and execution can be streamlined.
- **Infrastructure Planning**
  LineWatch-M sensors can continuously meter power flow, identifying areas where loads are high and identifying changes in load over time. Load flow information is vital to planning future expansions and upgrades of the distribution system.
- ***Health Monitoring and Fault Logging***
  LineWatch-M sensors also take detailed power quality measurements like harmonic content of voltage and current through the $13^{th}$ harmonic. If faults occur, the sensors also record oscillographs of the fault as it occurs. This information can be used to diagnose both impending problems and faults.

## 3 LineWatch-M Use Cases for Legacy Substations

In many cases, the high cost of upgrading a substation stems from the need to upgrade the communications infrastructure at the substation. Additional infrastructure may be needed at the substation itself to collect information from Intelligent Electronic Devices (IEDs) and transmit it to a centralized location. More importantly, installation of an expensive SCADA system or EMS system is required to receive data back at the utility operations center. Smaller utilities may not have this existing Head End infrastructure, and costs of installing such a system can be high. QinetiQ has designed solutions to meet every utility's requirements regardless of whether they are fully SCADA enabled or have no existing SCADA infrastructure. These various cases are described below:

### 3.1 SCADA Sensor Use Case

For utilities that already have an existing SCADA infrastructure, LineWatch-M sensors are ready to integrate with the existing paradigm. The sensors have a complete DNP3 interface that enables interaction with third-party SCADA systems. The sensors can be polled via a cellular interface or any other communications platform that may already be in place such as WiMAX routers, network interface cards or mesh radio networks. If faults occur, the system pushes notifications about the faults via DNP3. Fault oscillographs can be downloaded from the sensors, aiding in diagnosis and localization of faults.

### 3.2 Daily Meter Reading Use Case

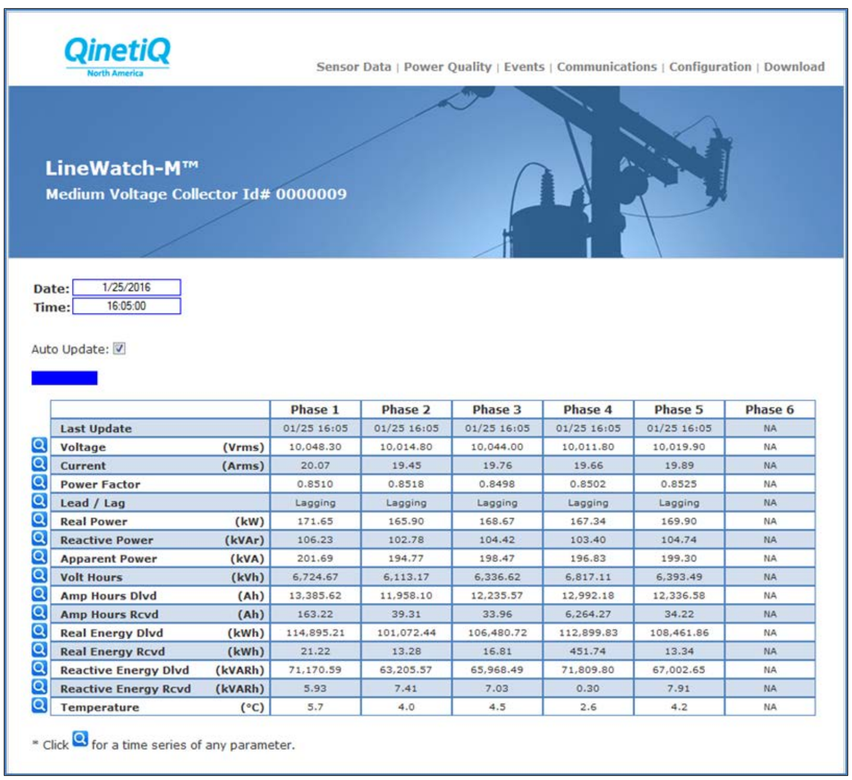
Some users prefer a meter-like paradigm, where sensors are polled once daily, returning all readings for the day in some standard format. The LineWatch-M sensors have a Web API that allows the sensors to be programmatically queried for data, returning the desired data in a .CSV format. For example, the web query at https://166.130.125.205/myQuery.php?date=24Jan2016 would return all readings from 24Jan2016. By specifying other keys in the call to the API, the time range, reporting interval, and specific data items returned can be specified in detail.

Through the use of this web interface, it is straightforward to integrate the sensors with existing historian applications or to write simple scripts that automatically download data from sensors and add it to a database of sensor readings.

### 3.3 Stand-Alone Monitor Use Case

For the utility that is interested in trialing devices and/or has no existing SCADA systems, LineWatch-M is available with 4G LTE and 3G GSM or CDMA modems for data backhaul. In the Stand-Alone Monitor use case, users connect directly to a LineWatch-M sensor installation via a secure Internet connection. The front page of the website is shown below as Figure 2. All quantities of immediate interest (*e.g.* voltage, current, power flow) are immediately viewable.

If desired, users have accessibility to the data at many levels of granularity. Every measured quantity can be plotted over the web interface, as shown in Figures 2 - 4. Plots can span up to one months' worth of data on up to six sensors. For more detailed off-line analyses, data can also be downloaded from the sensor in .XLSX format for easy integration with other analysis tools.




| | | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6 |
|---|---|---|---|---|---|---|---|
| Last Update | | 01/25 16:05 | 01/25 16:05 | 01/25 16:05 | 01/25 16:05 | 01/25 16:05 | NA |
| Voltage | (Vrms) | 10,048.30 | 10,014.80 | 10,044.00 | 10,011.80 | 10,019.90 | NA |
| Current | (Arms) | 20.07 | 19.45 | 19.76 | 19.66 | 19.89 | NA |
| Power Factor | | 0.8510 | 0.8518 | 0.8498 | 0.8502 | 0.8525 | NA |
| Lead / Lag | | Lagging | Lagging | Lagging | Lagging | Lagging | NA |
| Real Power | (kW) | 171.65 | 165.90 | 168.67 | 167.34 | 169.90 | NA |
| Reactive Power | (kVAr) | 106.23 | 102.78 | 104.42 | 103.40 | 104.74 | NA |
| Apparent Power | (kVA) | 201.69 | 194.77 | 198.47 | 196.83 | 199.30 | NA |
| Volt Hours | (kVh) | 6,724.67 | 6,113.17 | 6,336.62 | 6,817.11 | 6,393.49 | NA |
| Amp Hours Dlvd | (Ah) | 13,385.62 | 11,958.10 | 12,235.57 | 12,992.18 | 12,336.58 | NA |
| Amp Hours Rcvd | (Ah) | 163.22 | 39.31 | 33.96 | 6,264.27 | 34.22 | NA |
| Real Energy Dlvd | (kWh) | 114,895.21 | 101,072.44 | 106,480.72 | 112,899.83 | 108,461.86 | NA |
| Real Energy Rcvd | (kWh) | 21.22 | 13.28 | 16.81 | 451.74 | 13.34 | NA |
| Reactive Energy Dlvd | (kVARh) | 71,170.59 | 63,205.57 | 65,968.49 | 71,809.80 | 67,002.65 | NA |
| Reactive Energy Rcvd | (kVARh) | 5.93 | 7.41 | 7.03 | 0.30 | 7.91 | NA |
| Temperature | (°C) | 5.7 | 4.0 | 4.5 | 2.6 | 4.2 | NA |

* Click for a time series of any parameter.

*Figure 2: LineWatch-M stand-alone web interface*

**Start Date:** 01/25/2016 | **Update Plot**

**End Date:** 01/25/2016

Data Request Complete 1.477 seconds.

## Voltage (Vrms)

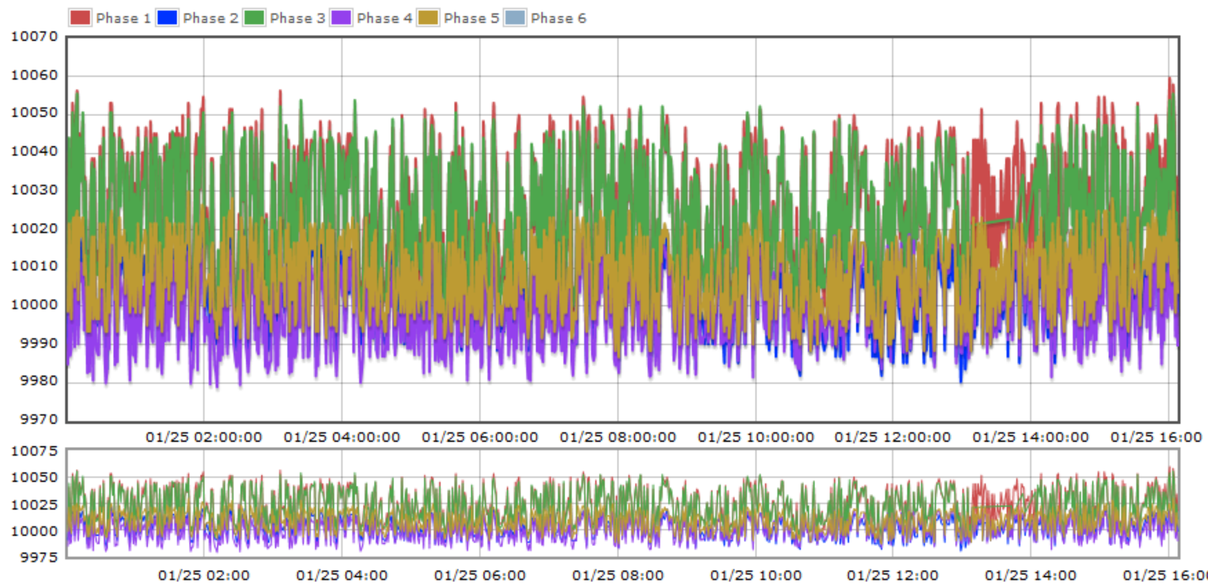



*Figure 3: Plot of measured voltage*

**Sample Date:** 7/13/2016

**Sample Time:** 11:54:00

| | Sensor 1 | Sensor 2 | Sensor 3 |
|---|---|---|---|
| Last Update | 07/13 11:54 | 07/13 11:53 | 07/13 11:53 |

## Harmonics

| | Sensor 1 | Sensor 2 | Sensor 3 |
|---|---|---|---|
| Voltage THD (%) | 6.95 | 6.90 | 6.71 |
| Current THD (%) | 14.22 | 13.42 | 13.05 |

| | 1st | 3rd | 5th | 7th | 9th | 11th | 13th |
|---|---|---|---|---|---|---|---|
| Voltage 1 | 19,890.90 | 107.43 | 1,292.88 | 394.47 | 27.14 | 258.64 | 32.55 |
| Current 1 | 271.29 | 4.40 | 36.61 | 10.93 | 1.06 | 1.27 | 0.61 |
| Voltage 2 | 20,031.20 | 58.01 | 1,289.27 | 405.68 | 37.74 | 255.38 | 42.43 |
| Current 2 | 288.53 | 1.49 | 37.73 | 8.04 | 1.82 | 1.48 | 0.33 |
| Voltage 3 | 20,096.60 | 45.84 | 1,238.78 | 469.79 | 11.52 | 243.55 | 48.00 |
| Current 3 | 292.96 | 3.69 | 36.40 | 10.73 | 0.96 | 1.35 | 0.96 |

*Figure 4: Power Quality Information*

LineWatch sensors can also communicate their collected data in a number of ways:

- Stand-alone secure web server accessible via the Internet. Allows users to directly view sensor data and/or download the data in .XLSX format;
- Secure Web API that allows data to be sensor accessed programmatically, returning the results in .CSV format;
- Complete DNP3 polling interface, for integration with an existing SCADA system.

## 4 Conclusions

LineWatch-M sensors have the capability to provide utilities with critical data on legacy substation operations. LineWatch can be installed on the feeder outside the substation fence quickly, easily and safely using a hot stick, at a significantly reduced cost compared to an inside the fence retrofit. The sensing and monitoring devices are designed to support any communications platform and the existing utility infrastructure. For utilities that have existing SCADA infrastructure, LineWatch is fully capable of interfacing via DNP3 with a SCADA head end. As an alternative to traditional SCADA, a flexible Web API is also available for collecting data from the sensor, *e.g.* in the form of daily sensor reads. For a utility who is interested in trialing the LineWatch devices, or who has no existing SCADA infrastructure, the sensors can also be installed in a stand-alone feeder monitoring application. In any use case, LineWatch-M can help extend the life of legacy substations at a significantly lower cost than “inside the fence” retrofits by monitoring the health and load levels of their feeders without the need to replace otherwise functional substation equipment.

## Company Background

QinetiQ North America is an engineering, technology and product development company that prides itself in working with customers to develop solutions that meet their critical needs. QNA maintains a staff of over 200 mechanical, electrical, thermal, chemical, nuclear, aerospace, software and materials engineers working in the areas of power systems, sensors, robotics, advanced materials, aerospace, homeland security, and transportation. QinetiQ North America is headquartered in its 200,000 square foot Waltham, Massachusetts campus.

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