Business Case for Thermal Monitoring of Electrical Switchgear Assets using an IntelliSAW IS485 Wireless Passive Thermal Sensor System

September 2012

EXECUTIVE SUMMARY

As a key junction point in the distribution of electric power, switchgear assets represent one of the most vulnerable links in the power grid. Moreover, having moveable parts (breaker points) which are rarely exercised under normal operating conditions, the risk of failure is further heightened. They are subject to overheating due to overload, corrosion, loose connections and challenging environmental conditions. Left unattended these conditions can lead to failure of the switchgear asset resulting in, at a minimum, costly damage to the asset and surrounding equipment, and in extreme cases, severe worker injury and even death.

This white paper examines need for thermal monitoring of these critical assets in general, and makes the specific business case for using IntelliSAW's IS485 wireless passive thermal sensors instead of other alternative methods.

When considering all predictable costs (to equipment and to technicians), the payback period for an IS485 solution is seven (7) months and the five year ROI is 600%. These predictable costs do not include additional incidental costs such as lost production profits, lost contract renewals, lost share value, fines, penalties and litigation.

IntelliSAW recommends the implementation of an IS485 based thermal monitoring program.

BUSINESS PROBLEM

The business problem caused by frequent or serious switchgear malfunction incidents is both financial and social. The likelihood of failure is sufficiently high (2.78% per cabinet per year) [1] that the financial costs of both equipment damage and technician injury can be predictably amortized. There are additional incidental financial costs that are less predictable, but no less real when considered across all switchgear operators, both public and private. Further, there are the social costs to technicians who are injured and to management personnel who are likely to be held accountable.

This FPL substation (138KV stepped down to 23KV) adjacent to a Miami golf course and residential community was a total loss in just minutes. http://205.243.100.155/frames/longarc.htm#Disconnect

Incidents can range from minor disruption to catastrophic damage, death, and service outages:

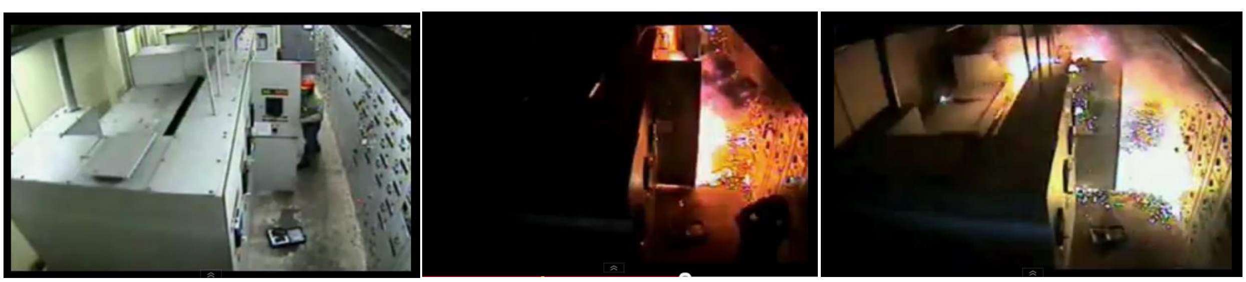
- **Minor Disruption.** Minor incidents may involve emergency repairs and related labor and material costs. Occasional brief outages in a public utility may be considered acceptable, while frequent or extended outages may not. Similar brief outages in an automated industrial operation may cause very expensive loss of in-process production.
- **Catastrophic Damage.** Catastrophic incidents can be extremely dangerous and expensive to the operating company and its team of technicians. The consequences fall into the following categories, some of which are predictable enough to be quantified to an amortized cost per cabinet (and per substation, at an average of 17 cabinets). [1]
  - **Predictable Capital Costs.** A catastrophic event almost always results in at least one 100% switchgear cabinet loss, and it often results in the destruction of (or severe damage to) adjacent cabinets in the panel. There may also be substantial damage to the incoming/outgoing electrical infrastructure, and even to the substation building itself.
  - **Predictable Human Health & Safety Costs.** Capital costs to equipment are relatively small when compared to the liability for medical costs for injured technicians, and the settlement costs for any loss of life/limb or ability to work. These can often range into the millions of dollars for a single individual. [2] Such costs include direct medical bills, lost worker hours, increased medical insurance and casualty insurance premiums, and attorney fees if litigation is required.
- **Incidental Additional Costs.** There are a wide number of non-predictable but quite real costs that can be associated with either frequent minor service disruptions or even one egregious catastrophic event. These may include such things as:
  - Operating profit loss if an industrial company is forced to shut down.
  - Consequential damage litigation by customers impacted by service outages.
  - Fines, penalties and service rebates awarded by regulatory agencies.
  - Potential loss of contract renewal if competing for service rights.
  - Public image loss and resultant share value loss if a publicly held company.

The net result of frequent outages, or a serious event, can ripple through the organizational chain of command. Executive careers can be impacted for those held responsible for not taking adequate preventative measures.

TECHNICAL PROBLEM

Because of their mechanical action which is rarely exercised under normal operating conditions, electrical switchgear represent one of the most vulnerable parts of the power grid distribution chain. Yet once energized and put into electric power distribution service, switchgear are essentially inaccessible for direct maintenance until the next time they are taken offline for preventative maintenance and repair. Depending on the policy of the operator, the interval for switchgear periodic maintenance may range from 6 to 60 months. During that time period there are a number of things that can go wrong, and individual switchgear cabinets can go from benign to critical in a relatively short period of time (days/weeks).

Switchgear are subject to overheating due to overload, corrosion, loose connections and other environmental conditions. When the overheating is great enough, instant catastrophic damage and technician injury or death can occur. Arc flash is often the specific phenomenon involved in a failure, and it can occur without any one specific trigger (combination of load, corrosion, small arcs from loose connections, deteriorated insulation from partial discharge). However, there have been instances recorded (even videotaped)[3] of technicians opening a cabinet door where the sudden availability of oxygen serves to trigger an arc flash event.



Arc Flash while racking a breaker in MV switchgear; location and worker injury unknown.
http://youtube.googleapis.com/v/PHs14ZTo96M

An energized switchgear cabinet represents a significant inherent danger in itself. For this reason almost all switchgear are in fully enclosed cabinets. Medium voltage switchgear are more dangerous than low voltage ones due to their greater voltage energy differential and their greater propensity for a catastrophic event. Such switchgear will often be designed (or retrofit) to include specialized shock and explosion resistant windows, however these windows are quite expensive, and they still rely on a technician walking around with a thermal imaging instrument to regularly take measurements, record the results, and then analyze the results over time. The technicians involved in such work are generally highly trained and following strict worker safety rules, however 97% still report at least one incident of shock or injury on the job. [2]

Thermal heat buildup is symptomatic of impending switchgear failure. It can be caused by a number of different factors, the most common of which include:

- Amperage overload through a particular switchgear cabinet, which can create heat.
- Loose connections which create micro-arcing, which creates heat.
- Dirty contacts, including Breakers themselves, which also creates heat.

In monitoring temperature it is important to look for temperature <u>differences</u> between…

- bar/breaker/cable temperature versus ambient temperature
- bar/breaker/cable temperature in one cabinet versus in adjacent cabinets
- bar/breaker/cable temperature on one phase versus on the other two phases
- time periods (right now versus earlier today… or yesterday, last week, last month)

It is important to note that thermal heat buildup is problematic in and of itself, damaging key components inside the cabinet before finally resulting in a catastrophic event:

- Excessive heat will accelerate breakdown of many insulators.
- Excessive heat can radiate to overheat sensitive electronics (eg, cabinet instruments).
- Excessive heat can create arc flash and explosion .

Arc flash is of course dangerous enough to be worthy of specific technical mention. [4 & 5]

- Arc Flash characterization:
  - Electrical arcs produce some of the highest temperatures known to occur on earth, up to 19,000°C… four times the temperature of the surface of the sun.
  - Such heat causes surrounding materials to vaporize. When copper vaporizes it expands in volume 67,000 times. Such expansion manifests as an explosion.
  - An 11kV MV switch can explode with the force of 10 kg of TNT… equivalent to 175 hand grenades.
- Arc Flash danger to electrical workers: [4]
  - An arc flash can cause minor injuries, third degree burns and potential death as well as other injuries including blindness, hearing loss, nerve damage and cardiac arrest.
  - Fatal burns can occur when the victim is several feet from the arc. Serious burns are common at a distance of 10 feet.
  - Arcs spray droplets of molten metal at a high speed. Molten metal from an arc propelled as blast shrapnel can penetrate the body.
  - Blast pressure waves have thrown workers across rooms and knocked them off ladders. Pressure on the chest can be higher than 2000 lbs/sq. ft.

The special challenge of monitoring the critical points inside a switchgear cabinet is due to the fact that no conductors can be touching or even near energized bars/breakers/cables that might cause them to ground to each other or to earth. This fact eliminates the most common types of sensors and monitoring systems, and it can even sabotage systems that are intended to be non-conductive.

ALTERNATIVES TO CONSIDER

There are a number of alternatives to consider when it comes to thermal monitoring of switchgear cabinets.

- **Do Nothing.** Doing nothing in the way of thermal monitoring is the least expensive option in the short term, but can be a very expensive option in the long term. It is essentially a gamble that the 2.78% of switchgear failures per year won't be true for that substation (or distribution network of substations)… or at least the gamble that it won't manifest as a serious incident on the current management's watch. It is tantamount to hoping for the best and back-managing incidents as they occur. Unfortunately, this gambling by economic decision makers is more like "Russian roulette" for switchgear technicians.

- **Periodic IR Monitoring by Technicians who must OPEN energized cabinets.** Since infra-red thermal imaging guns are now relatively inexpensive, this option can be deceptively tempting. And because this job is typically assigned as extra duty to already employed technicians, there may be little or no incremental labor cost assigned to the task. But because the mere act of opening an overheated switchgear cabinet can trigger a serious arc flash event, this option is probably the MOST expensive of all options in terms of actual catastrophic damage, injury and death.

- **Periodic IR Monitoring by Technicians for switchgear cabinets with glass windows.** This is not a bad option; it is simply an expensive and technologically archaic solution. The glass windows themselves, whether purchased as original equipment or as retrofits, can be more expensive to purchase and install than an IS485 system. In addition to the purchase, the operator must pay the labor cost for a technician staff to walk around the panel on a regular basis... forever. If there is technical labor local to the substation that incremental labor cost may not be excessive, but if the substation is remote and thus requires a technician to drive, either that cost will become significant or that substation will not be monitored as frequently as it might deserve. Also, depending on the size and location of the window, the technician may or may not be able to get a thermal reading on the specific points of thermal interest. And unless there is an obvious overheating situation, the usefulness of the data depends on the thoroughness of the technical team in both recording the data and then analyzing it for trends over time. Still, there can be compelling arguments made for even this very basic thermal monitoring:

  http://assets.fluke.com/video-IR/3500242A-Hawk-IR_Mkt.html [6]

- **IR Camera Systems to provide CBM peeking through glass windows.** This is an automated version of the manual inspection by technicians. It provides substantial value in providing continuous online real-time data, increasing the timeliness and accuracy of the data while also increasing its usefulness through computer analytics and eliminating the labor cost of manual inspection. The downside is it still involves the cost of installing expensive windows in the cabinets, plus the additional expense of an IR camera system tied into a SCADA type network. The other major downside is that IR camera system often does not see points of thermal interest inside the cabinet even as well as a technician with a thermal gun, especially if a single camera is attempting to scan several different cabinets to save on acquisition and installation cost. There may also be reliability issues with the camera itself, especially if it is using an electro-mechanical scanning mount.

- **Fiber Optic Systems to provide CBM by direct contact with bars/breakers/cables. F**iber optic systems require no windows, and hence they provide that cost advantage while also providing continuous online real-time data, with all the aforementioned benefits in terms of data accuracy and SCADA usability. However, fiber optic systems can be expensive to purchase and expensive to install. Moreover, if the fiber optic system is installed in an environment that is both dusty and humid (as are many switchgear under actual field conditions)… that combination of dust and condensation on fiber optic cables can create a conductive ground path… which becomes a serious problem.

- **Wireless Active (battery-powered) Sensors to provide CBM by direct contact.** Except for the batteries, these systems provide a very adequate solution. And battery powered systems tend to be relatively inexpensive to purchase… which makes them a tempting acquisition for a purchasing organization. The main problem with batteries is that the operating organization has very limited ability to access energized switchgear to replace failed batteries… often only every 12 months or longer. The battery manufacturers may claim much longer battery life cycle (under optimal conditions) than is encountered in the field where high temperatures may shorten their projected life from years to months. This leads to an operating condition whereby some significant number of the batteries may fail prior to the operator's ability to replace them, hence defeating the monitoring capability for each sensor point so impacted. As a result, it is not uncommon for the operator to replace ALL batteries at every preventive maintenance opportunity, the cost of which (materials + labor) can significant change the actual cost of ownership for the system versus that which was originally projected. Additionally, most active sensor systems use Lithium batteries, which can have a propensity to explode when subjected to excessively high heat… introducing yet another concern within a system intended to provide operating safety.

- **Wireless Passive Sensors to provide CBM by direct contact.** Wireless passive sensor systems provide all the advantages of Condition Based Monitoring in terms of real-time continuous 24x7 monitoring, ease of collecting an accurate data history, and the use of computer analytics to study the data and to highlight trends that deserve maintenance attention or dangerous situations that need to trigger alarms. These systems can be designed for integration directly into existing SCADA systems, which then affords central monitoring of multiple substations by a very small staff at little or no incremental labor cost to the operator. The cost of the IR window in the door is saved, the specific points of thermal interest are directly sensed, the cost of a technician walking around with a thermal imaging gun is removed, the sensors can reliably operate continuously for 15-20 years without losing sensor points due to battery failures, and the cost of replacing batteries is eliminated. The net result is an optimal solution.

BENEFITS OF CONTINUOUS CBM OVER PERIODIC MONITORING

- ***CONTINUOUS CBM.*** Continuous Condition Based Monitoring enables insight to problems as they are developing. It allows issue identification and routine resolution vs. emergency incident response. Alarms can be set to trigger close attention at warning or danger points. "Thermal visibility" inside the enclosed cabinet can provide a key safety margin to prevent technician injury, whereby an excessively hot switchgear cabinet may warrant emergency shut-down before opening the cabinet door. One operator at a central location can economically monitor multiple substations, which reduces the number of technicians needed in the field. The remaining technicians can be assigned to more important duties than basic monitoring.

- ***PERIODIC MONITORING.*** Unlike CBM, periodic infrared temperature monitoring can easily miss serious overload events. Temperature climb of even 1^{O}C/hour can quickly become critical over the course of a few days, and yet some periodic monitoring intervals span weeks or months between readings. Hourly/daily technician monitoring is expensive, even in locally staffed substation sites. Remote sites without staffing are typically monitored much less frequently, and yet they may be subject to more harsh environments that manned substations. Manual data acquisition and recording is cumbersome, hence the data may be poor quality and the analysis of that data is often quite weak as compared to computer-assisted techniques.

BENEFITS OF A WIRELESS PASSIVE SENSORS OVER ACTIVE SENSORS

- ***PASSIVE SENSORS.*** Passive sensors, such as IntelliSAW's IS485 saw-based sensors, need no special maintenance. They are calibrated to the reader initially during installation. All that remains over the 15-20 year projected life of the sensor is to ensure during periodic maintenance shutdowns that the connections remain snug (bolt mount or cable-tie mount).
  - ✓ SAW-based sensors have a broad operating temp range, and a broader survival range.
  - ✓ SAW-based sensors are unaffected by voltage and current spikes.

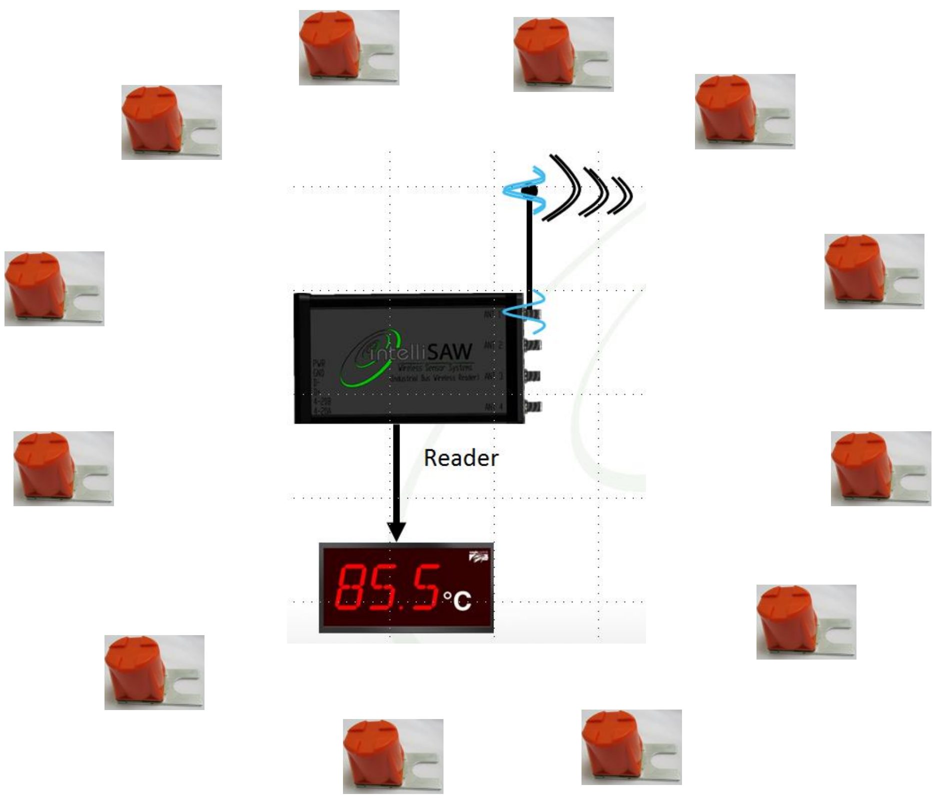
- ***ACTIVE SENSORS.*** Active sensors will require continued battery replacement… forever. Batteries often fail much earlier than advertised under field conditions (heat, cold). Battery failures cause monitoring blind spots at those sensor locations until next PM. Batteries can only be changed during scheduled PMs, which may be yearly or longer. Once one battery fails, the wise operator replaces ALL batteries during the next PM. An initial battery system cost advantage can quickly disappear in true COO analysis. Most active sensors use Lithium based batteries, which can explode when overheated.

ADVANTAGES OF THE IS485 SYSTEM (Cost basis for this business case analysis)

- ✓ **Four antenna ports**… accommodates dual breakers plus busbar and cable cavities
- ✓ **Each antenna handles up to 12 sensor points**… but 3 sensors per antenna is typical
- ✓ **Sturdy sensors specifically designed for industrial use in switchgear**
- ✓ **Sophisticated Reader protections from surges and cross-wiring**
- ✓ **Commonly used RS485 data communication protocols**… including MODBus
- ✓ **Easy USB-based commissioning**… remote boot-loader based software update ability

IS485 PRODUCT DESCRIPTION AND TECHNOLOGY COMPARISON

- ❖ http://www.intellisaw.com/technology/intellisaw-electrical-switchgear-monitoring-system.html
- ❖ http://www.intellisaw.com/technology/comparison.html



FINANCIAL ANALYSIS

Predictable Cost of Failure (amortized per Substation, per year)

- ✓ Average of 17 switchgear cabinets per substation[1]
- ✓ Average of one switchgear fault every 6 months per substation (17 @ 2.78%) [1]
- ✓ Average of 1 <u>substantial</u> switchgear fault every 6 years per substation[2]

Capital Cost of Replacing Damaged Equipment (per incident)

- One MV SWG cabinet destroyed $36k to replace
- 12% Damage to remaining 16 Cabinets per substation is $105k
- 2 Man Months of Labor for Repairs is $12k (1mo @ $36/hr) [7]
- Total Capital Replacement Cost: >$117k
- Likelihood of occurrence: average of 1 event every 12 years per substation
- Amortized Equipment Cost: **<u>$8.3k/substation-year</u>**

Liability Cost of Worker Injury/Death (per person)

- $1.5M for loss of life or loss of limb (times the number of people)
  - Depending on country could range from $0.5M to $10M
  - Likelihood of occurrence: 0.9 death every 100 years per substation[2]
  - Amortized cost: **$13.5k**/substation-year
- $250k for serious burns/injuries requiring hospitalization or retirement (times the number of people)
  - Depending on severity, can range from $0.1M to $4M [2]
  - Likelihood of occurrence: 0.8 serious injury every 20 years/s-station[2]
  - Amortized cost: **$10.0k**/substation-year
- $50k for treatable burns/compensation (times the number of people)
  - Depending on severity, can range from $10k to $100k
  - Likelihood of occurrence: 0.8 injury every 5 years per substation[2]
  - Amortized cost: **$8.0k**/substation year
- Amortized Worker Injury Cost: **<u>$31.5k/substation-year</u>**

> ➢ **Predictable Costs for Equipment and Injuries: $39.8k per substation-year**

➢ **Incidental Additional Costs of Failure: $10k's - $MM per major event**

- → **Operating Profit Loss if an Industrial Company is forced to shut down**
- → **Consequential Damage Litigation by customers due to Service Outages**
- → **Regulatory Fines and Penalties**
- → **Future Contract Loss if Competing for Service Rights**
- → **Share Value Loss if a Public Company**

Cost of Continuous Thermal Monitoring Solution (per Substation)

Cost of IS485 Components when purchased in volume (one time)

- IS485 Basic System for 17 Cabinets is **$14.0k** (17 @ $825)

Cost of Monitoring System Components (one time)

- Miscellaneous Gateways, Power, Antennas **$4.0k**

Cost of System Integration & Installation Services (one time)

- Labor 5 Man Days is **$6.0k** (40hr @$150)

Total Installed Equipment Cost is **$24.0k** per substation (one time)

- Expected service life 15-20yrs, assume 18 years
- Amortized Installed Equipment Cost is **$1.3k/substation-year**

Cost of Ongoing Central Monitoring Services (on-going)

- Average 2 Technicians (6ea needed at 2000 hrs/yr) for 24x7 continuous
- Average 28 Substations monitored at once (range is 10 to 40+)
- 5% of Central Monitoring cost (assumes other SCADA monitoring)
- Average cost per substation-year is $0.8k (5% of $432k total cost)

- **Predictable Costs for Continuous Monitoring: $2.1k per substation-year**

Payback Period

Payback considering ONLY Equipment Replacement costs: 3.2 years

- $24k (Installed Cost) + $3k (3yrs Monitoring) vs. $27k (3.2yrs Damage Cost)

Payback considering ALL Predictable costs: 7 months

- $24k (Installed Cost) + $1k (4mos Monitoring) vs. $25k (7 mos Total Costs)

5 Year ROI

5 Year ROI considering ONLY Equipment Replacement costs: 48%*

- Return = $55k (5yrs Damage); Invest = $37k ($24k Equip + $13k Monitor)

5 Year ROI considering ALL Predictable costs: 900%*

- Return = $370k (5yrs Liability); Invest = $37k ($24k Equip + $13k Monitor)

RECOMMENDATIONS

The first and foremost recommendation is to consider the adoption of a continuous CBM (Condition Based Monitoring) approach to ensuring proper switchgear operation. This has some initial investment costs, however the payback period is short and the ROI is large.

When selecting a CBM approach, the second recommendation is to use wireless direct thermal contact sensors that operate passively without batteries. The leading technology available today that provides this solution is SAW (Surface Acoustic Wave) based.

The third recommendation is to select IntelliSAW's IS485 family of products. There are other SAW-based sensor products on the market, and the customer should certainly evaluate these other vendors and products. Currently, IntelliSAW is the only company focused exclusively on serving the electrical powergrid market with industrial grade sensor systems, and we believe the IS485 family of products best serves this market.

The expected outcomes of implementing continuous thermal CBM using IntelliSAW's IS-485 wireless passive sensor system include:

- ✓ A substantial economic benefit (600% ROI over five years) for a modest investment.
- ✓ A substantial increase in the availability of accurate real-time operating guidance on the health of their substations with computer automated trend analysis, alarms, and detailed pointers to the specific location of potential maintenance problems.
- ✓ A substantial reduction in the potential for worker injury or death due to arc flash and other dangerous incidents related to overheated switchgear, and with it, corresponding reduction in the exposure to injury liability, insurance increases, regulatory penalties, and outage-related commercial losses and litigation.
- ✓ A reduction in the total technical staff needed to safely conduct switchgear operations by centralizing routine monitoring and then dispatching technicians only when needed.

CONFIGURATION ASSISTANCE AND PURCHASE

To obtain assistance in getting a quotation and a total cost estimate please contact IntelliSAW.

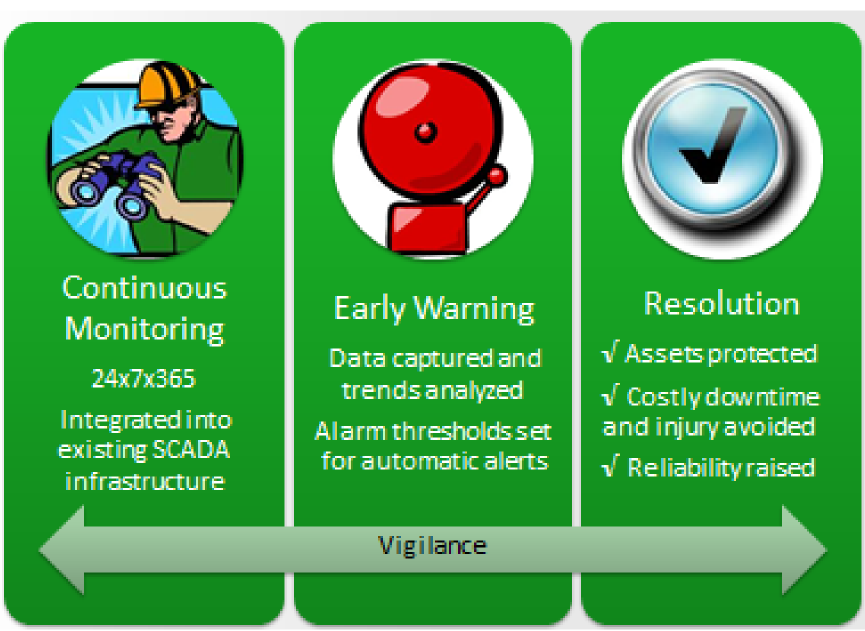
sales@intellisaw.com +1-978-409-1534 www.intellisaw.com

Depending on the location of the project, IntelliSAW very likely has a local distributor, agent or integrator who is very knowledgeable of IS485 products and who can configure and incorporate them into an existing SCADA substation network or into completely new substation panel.

IMPLEMENTATION

Each implementation is unique, but such projects typically follow this sequence:

1. **Technical Evaluation**
   a. Evaluation of business need
   b. Evaluation of available technologies and vendors
   c. Recommendation of a specific technology
   d. Business case and budgetary approval
   e. Tender for bids (or sole source approval)
   f. Supplier award and agreement
2. **Project Plan Finalization**
   a. Project leadership
   b. Project description and scope
   c. Selection of a pilot site (if required)
   d. Implementation timetable (for access during shutdowns)
   e. Pilot success criteria
   f. Substation sequence after the pilot
3. **Substation Pilot to Confirm Operational Readiness**
   a. Switchgear panels outfitted with sensor systems and tested
   b. Monitoring system (SCADA or similar) implemented or integrated
   c. Switchgear panels energized and entire system verified
   d. Monitoring responsibilities and procedures outlined
   e. Pilot period completed, results evaluated, rollout recommended
4. **Full-scale Implementation Rollout**
   a. Sequence of substations confirmed and shutdowns scheduled
   b. Installation team organized and ready
   c. System components ordered and ready
   d. Execute rollout plan



NOTEWORTHY REFERENCES

1. http://www.ipec.co.uk/research.html
   see PDF: AVOIDANCE OF MV SWITCHGEAR FAILURE CASE STUDIES OF ON-LINE CBM
   - 3 year study included 60 substations with an average of 17 switchgear cabinets each
   - 2.78% switchgear faults per year; 1 fault per switchgear cabinet every 36 years.

2. http://exiscan.com/electrical-safety-arc-flash-statistics
   - Burns and Electrocution are the #1 and #2 cause of Lost Time on the job in U.S.
   - 3815 worker Deaths per year in the U.S. alone due to Burns
     - Arc Flash Deaths are not counted in Electrocution statistics, rather in: Burns
     - Burns & Electrocution total 4255 worker Deaths per year in the U.S.
   - 97% of Electricians have been shocked or injured on the job in the U.S.
   - 80% of Injuries/Deaths for "Qualified Electrical Workers" are caused by Arc Flash
   - 5-10 Arc Flash explosions occur daily in the U.S. alone (about 2500 per year)
   - 1-2 Arc Flash Deaths occur daily in North America alone (about 550 per year)
   - 5-6 Arc Flash injuries occur daily that require Burn center hospitalization (2000/year)
   - 21% of Electrical injuries (including Arc Flash) result in permanent disability
   - "Medical treatment for severe electrical Burns can exceed $4M per person." [US NSC]
   - "Work-related injuries can cost businesses well over $30M in fines, medical costs, litigation, lost business and equipment costs." [U.S. National Safety Council]

3. *FILMED ARC FLASH EVENTS*
   http://youtube.googleapis.com/v/PHs14ZTo96M
   http://youtube.googleapis.com/v/h10ALIpD0R4
   http://www.cdc.gov/niosh/docs/98-131/epidemi.html

4. http://literature.rockwellautomation.com/intradoc-cgi/nph-idc_cgi.exe
   see PDF: Arc Flash Fast Facts: Bulletin 1500

5. http://www.eng-tips.com/viewthread.cfm?qid=6424
   - An 11kV MV switch can explode with the force of 10 kg of TNT (175 hand grenades).

6. http://assets.fluke.com/video-IR/3500242A-Hawk-IR_Mkt.html
   see Video: Prevent downtime and failures using Fluke IR-Windows

7. http://en-co.wika.de/upload/gms_value_added_case_study7711.pdf
   - Labor costs $36/hr (incl 30% overhead) US BLS 2006 rate for Electronic Repairers and Substation workers

8. U.S. CDC Study: Epidemiology of Electrocution Fatalities over 10 years (1980-89)
   - 455 worker Deaths per year in the U.S. alone due to Electrocution
   - Electrocution is the 4th leading cause of work-related traumatic Death

9. http://www.usfa.fema.gov/statistics/estimates/ According to the US Fire Administration of FEMA:
   - Electrical malfunction is the **#1** cause of fire in Basic Industries.
   - Electrical malfunction is within the **top 5** causes of fire in other Manufacturing operations.

See Reference 1: MV Switchboard Failures …a single incident can affect many thousands of customers for prolonged periods and consequently have a major impact on customer interruption statistics as well as on customer and regulatory perception, and pose risks to operational staff.

The devastation which can be caused by failure of switchgear is illustrated in figure 1. The financial impact of compensation payments, regulatory penalties and the costs of emergency and remedial works can be considerable.

Figure 1 Damage to substation following a catastrophic switchgear failure

There was an average of 32 switchgear faults per year affecting the 1150 primary (33 kV and 11 kV) substations on the EDF Energy Networks systems over the past three years (incidents on 2.7% of substations per annum). The effect of these faults varied from no interruption in supply to the equivalent of 12 customer years of interruption.

EDF Energy Networks have deployed extensive multisensory on-line monitoring systems together with web based analysis and alarm tools to monitor the condition of some 60 key substations, comprising over 1000 panels of switchgear with on-line monitoring of both cables and switchgear provided by some 1800 sensors. These include substations in London and the Southern and Eastern areas of the UK, as well as in France. Early warnings from these systems are routinely providing opportunities for timely targeted interventions by field maintenance teams before catastrophic failure.

<u>Analysis</u>

- ✓ The 3 year study included 60 substations with an average of 17 switchgear cabinets each in UK/France.
- ✓ 2.78% switchgear failures per year imply an average of 1 fault per switchgear cabinet every 36 years.
- ✓ Failures caused outages ranging from 0 to 105k customer-hours during the 3 year study.
- ✓ From the photo… at least one of the failures resulted in catastrophic equipment/building damage.
- ✓ Worker injuries were not identified.

Example of the losses that can result from a single incident… this June 2012 event was caused by a busbar: Repair costs. Production and Sales loss costs. Company Share Value loss costs.

Power Outage could cost Formosa Plastics Group NT$9B (US$300M)

TAIPEI 台北時報 TIMES
By Kevin Chen / Staff reporter, Fri, Jun 22, 2012
http://www.taipeitimes.com/News/biz/archives/2012/06/22/2003535922

Formosa Plastics Group (FPG, 台塑集團) yesterday said a partial production suspension at some units of its Yunlin petrochemical complex due to a power failure on Wednesday could cut the combined sales of its four core companies by up to NT$9 billion (US$301 million) this month.

The four — Formosa Plastics Corp (台塑), Nan Ya Plastics Corp (南亞塑膠), Formosa Chemicals and Fibre Corp (台灣化纖) and Formosa Petrochemical Corp (台塑石化) — reported combined sales of NT$119.66 billion last month, down 16.1 percent from April, according to companies' stock exchange filings on June 4.

The FPG said that, based on its preliminary estimate, the interruption at factories in the Mailiao (麥寮) and Haifeng (海豐) compounds within the Yunlin complex could cause a loss of about NT$100 million to Formosa Plastics Corp.

The incident would also cause a NT$100 million loss to Nan Ya Plastics, the nation's largest plastics maker, and to Formosa Chemicals, which produces aromatics and styrenics, while not affecting Formosa Petrochemical, the nation's second-largest refiner, FPG said in a statement yesterday.

The share prices of the four companies came under pressure yesterday after local media reported the impact of the production suspension might cause losses of between NT$1 billion and NT$4 billion.

Shares of Formosa Plastics Corp fell 0.37 percent to close at NT$79.8 and Nan Ya Plastics shares dipped 2.09 percent to NT$56.1. Formosa Chemicals shares dropped 0.75 percent to NT$79.6, while those of Formosa Petrochemical dropped 1.31 percent to NT$82.6.

The group said it started restoring electricity to the affected factories at 2pm on Wednesday, after it completed safety inspections on the sites that had been forced to shut down by the 11:52am outage.

While electricity supply was fully restored by yesterday, "Most factories are expected to return to normal operation within two days," the group said in the statement.

"However, some other factories with complex manufacturing process are likely to restart in four to seven days given safety considerations," FPG said, referring to the No. 2 and No. 3 olefins plants as well as the No. 1, No. 2 and No. 3 aromatics plants.

The temporary power outage was caused by short circuit in the double busbar circuit system in the petrochemical complex's public utility area, the group said.