

The title 'Thermal Monitoring Return on Investment' is written in a large, bold, white sans-serif font. Above the word 'Thermal' is a short, thick blue horizontal line. The background of the title area is a dark blue geometric shape with a light blue triangle to its right. Below the title, a dark blue diagonal band contains several overlapping, semi-transparent blue lines and arrows that point upwards and to the right, suggesting growth or progress.

Thermal Monitoring Return on Investment

Compare manual vs. automated thermal imaging to provide a clearer picture of the potential benefits of an automated thermal imaging system.

Thermal Monitoring technology has long been utilized in electric power applications, allowing utilities to detect and address hotspots in the electrical system before they lead to costly failures and unplanned outages. Utilities are well aware of the benefits that this technology can bring, but with advancements in thermal camera technology and computer-driven analytics, the potential benefits are even greater. The question arises as to whether investing in an automated thermal imaging system will provide benefits to the utility and how long it will take to realize them.

This whitepaper compares manual vs. automated thermal imaging, including a return on investment (ROI) analysis that can provide a clearer picture of the potential benefits of an automated thermal imaging system. With this information, utilities can make an informed decision about whether investing in an automated system is the right choice for their needs.

Background on Thermal Monitoring

Cameras that are developed for thermal monitoring use specialized sensors that capture radiation outside of the visible spectrum; thermal radiation is emitted from objects in the infrared spectrum at a frequency below the visible light spectrum. The thermal cameras are able to capture and filter the radiation, converting it to colors that humans can see and relate to temperatures.

While the conversion to color is for human interpretation, the cameras also measure the absolute temperature values from the objects. The benefits to this type of monitoring is that it is non-invasive, meaning the system does not have to be powered down to test it, and it does not have to be physically touched. For a utility, this means it is safer, less costly to test, and it can be done while the system is fully operational and under load.

Hotspots in the electric power system are indicators of many types of faults; from failing radiators and cooling systems, insulation

breakdown due to partial discharge, or poor mechanical connections, among others. Thermal monitoring for substations, overhead and underground systems can detect faults before failures and unplanned outages occur. Finding and fixing problems before failures occur allows utilities to plan maintenance based on the condition of the system so they can reduce outages, extend the life of high value assets and ultimately save on their bottom line.

Automated vs. Manual Thermal Monitoring

Many utilities have long used manual monitoring done by a skilled thermographer to detect hotspots in their system. While this method has provided results there are drawbacks to taking snapshots of the system vs. a continuous flow of information.

Manual thermal imaging typically involves sending a thermographer to inspect the electrical system on a regular basis. This can be a time-consuming and costly process, as thermographers must inspect each

component of the system individually. Additionally, manual thermal imaging may not be able to detect hotspots in hard-to-reach or hazardous areas, increasing the risk of failure.

Acquiring a thermal snapshot requires the operator to be present in the correct location and at the correct moment. Several variables such as lighting conditions, temperature, humidity, and distance from the object can impact the accuracy of the readings.

- **When it comes to manual thermal imaging, it is important to consider whether the snapshot is consistently taken from the same location and if external factors like weather and system load are consistent at the time of the snapshot. Additionally, the interpretation of the thermal data can vary between thermographers, which may lead to inconsistencies in the analysis.**

On the other hand, automated thermal imaging can provide a more comprehensive and accurate analysis of the electrical system. With an automated system, thermal cameras can be strategically placed throughout the system to continuously monitor temperature fluctuations. Computer-driven analytics can then process this data in real-time, detecting hotspots and alerting utility personnel before a failure occurs.

Continuous thermal monitoring provides a consistent flow of information that can be correlated to weather conditions and system load to provide a more accurate view of the system that can be used for trend analysis and input to a condition-based maintenance program. The thermal camera continuously cycles through pre-programmed stops to take temperature measurements from multiple points of interest.

The data from the thermal system can be provided to operators in real time and in the following ways:

- **Thermal analytics are programmed to determine if monitored points go out of range. Operators are immediately notified via SCADA (Supervisory Control and Data Acquisition) alarm or email so action can be taken.**
- **The monitoring points that feed into a SCADA system can be designated as analogue points, which enables their real-time tracking within the system.**
- **Measurement points are stored in a database so they can be further analyzed in a trend analysis tool for condition-based maintenance.**

Monitoring Points

Thermal monitoring is a critical component in the reliable operation of electric power systems, as it allows for the early detection of issues that can lead to costly failures and outages. Monitoring points can be established in various components of the system, including transformers, underground vaults, overhead lines, and various other critical components. These points can be tracked permanently or temporarily to ensure that the system remains in optimal condition.

In transformers, thermal monitoring can track various critical components such as bushings, connections, insulation breakdown, cooling fans, radiators, and fluid levels. Poor mechanical connections and partial discharge can cause heating, and the monitoring system can detect this and alert operators to take corrective actions. Uneven flow of coolant can also cause blockages and leaks in radiators, and thermal monitoring can detect these as well.

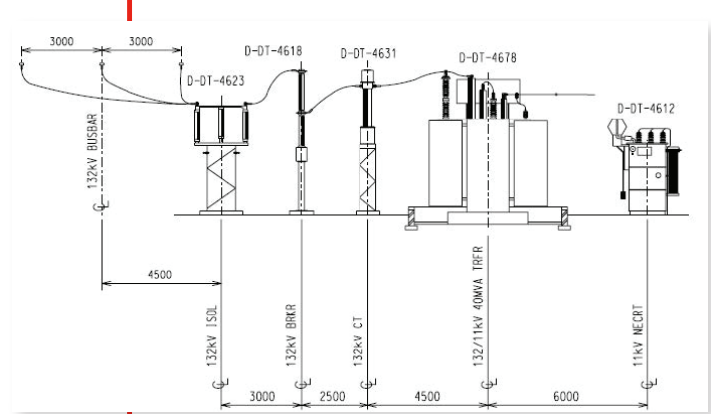
Current/voltage transformers, arrestors, and disconnect switches are other critical components that can be monitored for poor mechanical connections, insulation breakdown, and partial discharge, which can lead to heating and possible failure.

Underground vaults present unique challenges due to their enclosed nature, and thermal monitoring is essential to detect issues such as heating caused by increased resistance, insulation breakdown, and partial discharge.

Return on Investment Example: 132kV Substation Bay^[1]

Substations come in different sizes and voltage levels, from distribution to ultra-high-voltage transmission, but they have many common critical and high value components. Generally, as the voltage level goes up, the size and cost of the asset also increases. However, it is not just the cost of the asset but also the time it takes to replace; high power transformers can have a lead time of over a year and that may push a utility to run other equipment to the limit of capacity to make up for the shortage from the damaged equipment. Running an asset at its limit can have the knock-on effect of shortening its life expectancy thus compounding the negative economic effect on the utility. A planned outage and replacement is a much more favourable situation for a utility.

The design of a substation is critical to ensuring the efficient and reliable operation of the electric power system. Depending on the size of the substation, it may contain one or several transformer bays.



Substation Side View

Each transformer bay contains:

- High and low side current and voltage transformers
- Isolating switches
- Breakers
- Power transformer

The number of points that could be monitored in this example is shown in the table below.

Component	Connection Points	Insulator	Bushings	Radiator/Fan	Total
132kV Post-type CT	6	3			9
132kV Isolator	6	9			15
132kV Breaker	6	6			12
40MVA 132/11kV Xfmr	8		6	1	15
11kV Post-type CT	6	3			9
Total					60

Replacement costs:

Replacement costs are an important factor in the operation and maintenance of electric power systems. It is important to understand the costs associated with replacing critical components in the system, as well as the potential impacts of failures and outages.

There are several types of components in the system that may need to be replaced at some point, including:

- 132kV Post-type CT: 4200 USD
- 132kV manually operated isolators: 1400 USD
- Breakers rated at 132kV: 6300 USD
- 40MVA 132/11kV power transformer: 670000 USD

Other costs:

In addition to the cost of the components themselves, there are other costs associated with replacing them, such as:

- Transportation
- Removal and Replacement
- Clean-up
- Cost of replacement protection scheme equipment
- Loss of revenue - \$150/Hr./MW
- SLA clauses to industrial customers

Other impacts:

Finally, it is important to consider the wider impacts that would result from a failure, including:

- **Safety of workers and the general public**
- **Environmental impact resulting from the spillage of hazardous liquids and leakage of gases**

SCENARIO 1

Catastrophic Failure

- 132kV CT explodes and shrapnel causes extensive damage to surrounding equipment in the bay.
- The site requires equipment removal, replacement and site cleanup.
- The utility loses 24H of revenue from the affected bay.
- Equipment below is also damaged and requires replacement
- 2 Adjacent CT in the same bay
- 3 x 132kV isolators
- 3 x 132kV breakers
- 40MVA 132/11kV transformer

Assumptions:

- The scenario may happen once in 50 years and can be prevented thermal asset monitoring.
- Amortization period is 5 yrs.
- Asset monitoring systems include 2 thermal cameras, DVS, analytics SW, etc.

Component	Cost in USD	Qty	Total Cost
132tV Post-type CT	4235	3	12,705
132tV Isolator	1412	3	4,235
132tV Breaker	18865	3	56,595
40NVA 132/11kV Xfmr	669900	1	669,900
Transportation for above	1070	1	1,070
Removal and replacement	2387	1	2,387
Misc	1309	1	1,309
Clean-up operations	1540	1	1,540
Replacement Protection scheme	19404	1	19,404
Wiring	14014	1	14,014
Repair/replace cost per incidence			783,159

Lost Revenue per incidence			
MW	# of hours	\$ per hours	Total \$
40	24	150	144,000

Total cost per incidence			927,159
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Incidence per year	# of years	Incidences	Total \$
0.02	5	0.10	92,716

Cost per year			18,543
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Asset Monitoring System Cost per bay	50000	1	50,000
Installation	2000	1	2,000
Operating costs/year	2000	5	10,000
Total			62,000

Amortized years	5
Cost per year	12,400

ROI	1.50
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Return on Investment: 1.50

Variable
Calculated

SCENARIO 2

Current Transformer Failure

- 132kV CT explodes and shrapnel causes only minor damage to surrounding equipment in the bay.
- The site requires equipment removal, replacement and site cleanup.
- The utility loses 1H of revenue from the affected bay.
- Equipment below is also damaged and requires replacement
- 1 x 132kV breakers

Assumptions:

- The failure can be prevented for a CT, bushing or similar equipment once per year with thermal asset monitoring
- Amortization period is 5 yrs.
- Asset monitoring systems include 2 thermal cameras, DVS, analytics SW, etc.

Component	Cost in USD	Qty	Total Cost
132kV Post-type CT	4235	1	4,235
132kV Isolator	1412	0	0
132kV Breaker	18865	1	18,865
40MVA 132/11kV Xfmr	669900	0	0
Transportation for above	1070	0.1	107
Removal and replacement	2387	0.1	239
Misc	1309	0.1	131
Clean-up operations	1540	0.1	154
Replacement Protection scheme	19404	0.1	1,940
Wiring	14014	0.1	1,401
Repair/replace cost per incidence			27,072
Lost Revenue per Incidence			
MV	# of hours	\$ per hour	Total \$
40	1	150	6,000
Total cost per Incidence			33,072
Incidence per year			
# of years	Incidences	Total \$	
1	5.00	165,362	
Cost per year			33,072
Asset Monitoring System Cost per bay	50000	1	50,000
Installation	2000	1	2,000
Operating costs/year	2000	5	10,000
Total			62,000
Amortized years	5		
Cost per year	12,400		
ROI			2.67

Variable

Calculated

Return on Investment: 2.67

Summary

Although continuous thermal monitoring provides positive economic benefits for utilities the examples that have been shown only outline failure prevention; there are other benefits that are not as easily quantified. In addition to the financial benefits, other benefits include safety to the public and employees, site security, loss prevention and protection to the environment.

Providing real-time visualization of remote sites allows operators to work more efficiently and thereby keep the power system running optimally. This serves to maximize shareholder earnings and extend the life of high value assets.

About Systems With Intelligence

Systems With Intelligence Inc. is a global provider of Touchless™ Monitoring Solutions for electric utility applications. SWI systems collect and analyze the data that allows utilities to increase safety and reliability while reducing operating costs. Coupling thermal monitoring and visual imaging technology with advanced analytic algorithms, Systems With Intelligence solutions automate remote site monitoring.

Systems With Intelligence products are engineered to operate in the harshest environments, withstand high levels of electromagnetic interference, static discharge and voltage surges found in industrial applications to ensure uninterrupted operation. Providing a monitoring system that operates reliably and connects seamlessly allows customers to remain focused on their operations.

For more information about Utility Grade Video Automation Solutions for Substations please contact:

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