Thermal Monitoring Return on Investment

Thermal Monitoring has been used extensively in electric power applications so utilities are already aware of the benefits that this technology can bring; namely being able to detect hotspots in the electrical system and repair them before failures and unplanned outages occur. Advancements in thermal camera technology and computer driven analytics can now automate much of the work that is done by specialized thermographers, but is it worth the investment? The following compares manual vs. automated thermal imaging and provides a return on investment analysis to show the benefits an automated system can provide.

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 and convert it to colors that humans can see and relate to temperatures. While the conversion to color is for human interpretation, the cameras are also measuring the absolute temperature values from the objects. The benefits to this type of monitoring is that it is non-invasive, the system does not have to be turned down to test it and it does not have to be physically touched. For a utility, this means it is safer, less costly testing 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/cooling systems, insulation breakdown due to partial discharge, poor mechanical connections, etc. 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.

A snapshot of thermal information requires the operator to be in the right place at the right time. Lighting conditions, temperature and humidity affect the readings as does the distance from the object.

- Is the snapshot taken from the same place each time?
- What is the weather and system load when the snapshot is taken?
- Is the thermographer interpreting the data the same way each time?

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 alarm or email so action can be taken.
- Inputs to a SCADA system – monitoring points can be tracked in the SCADA system as analogue points so they can be tracked in real time.
- 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 can track temperatures in substations, underground vaults, overhead lines on a permanent or temporary basis. The following list highlights some of the points and components a system can monitor:

Transformer:

- Bushings
    - Connections – heating due to poor mechanical connection
    - Insulation breakdown – heating due to partial discharge
- Cooling Fans – over heating or under temp due to mechanical failure
- Radiators
    - Leaks, low fluid levels – uneven flow of coolant
    - Blockages – uneven flow of coolant

Current/Voltage Transformers / Arrestor / Disconnect Switch:

- Connections – heating due to poor mechanical connection
- Insulation breakdown – heating due to partial discharge

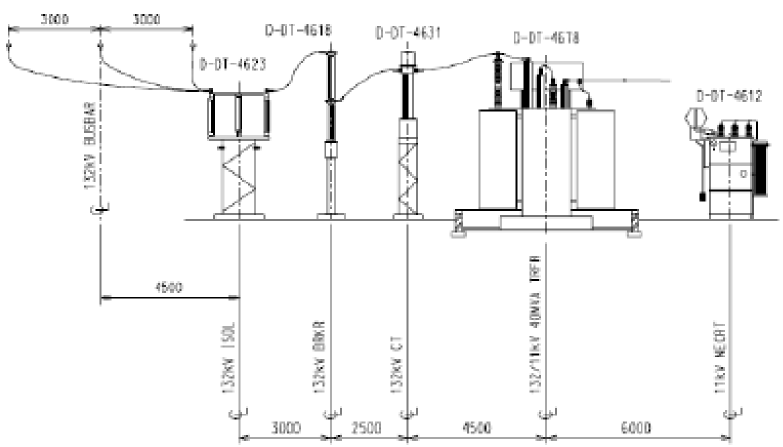
Underground Vaults:

- Joints/splices – heating due to increased resistance
- Insulation breakdown – heating due to 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.

Depending on the size of the substation, it may contain one or several transformer bays.



Substation Layout (Side View) Source: Eskom

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**

Table 1: Number of points in a bay that can be monitored with a thermal camera.

Replacement costs:

- 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:

- 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:

- Safety – prevention of failure
- Environmental Impact – 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.

Return on Investment: 1.50

Component	Cost in USD	Qty	Total Cost
132kV Post-type CT	4235	3	12,705
132kV Isolator	1412	3	4,235
132kV Breaker	18865	3	56,595
40MVA 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 hour**	**Total $**
40	24	150	144,000
Total cost per incidence			927,159
Incidence per year	**# of years**	**Incidences**	**Total $**
0.02	5	0.10	92,716
Cost per year			18,543
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		

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.

Return on Investment: 2.67

Component	**Cost in USD**	**Qty**	**Total Cost**	
132kV Post-type CT	4235	1	4,235	
132kV Isolator	1412	0	0	Variable
132kV Breaker	18865	1	18,865	Calculated
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				
MW	**# 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	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			

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.

References:

[1] 132/11kV Bay Component Costs: INVESTIGATION INTO CURRENT TRANSFORMER FAILURES WITHIN ESKOM DISTRIBUTION by Deepak Rampersad

For more information about Utility Grade Video Automation Solutions for Substations please contact: Sales@SystemsWithIntelligence.com