TRANSFORMER MAINTENANCE USING IR THERMOGRAPHY

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Annotation
This work attempts to show some case studies through IR thermography involvements in the industrial maintenance. Initially critical points of the essential or very important machines and electrical circulation units for the production have to investigated. The points where we observed abnormal temperature variations further analysis, using other advanced tools, like vibration analyzer, Laser alignment tool, Oil analyzer and Ultrasonic detector, was carried out. The main objective is to prove that by implementing a good scheduled thermography survey, one can decrease major expenses and save time. In addition, it has the capacity to contribute to the reliability of maintenance and minimize unexpected plant shutdowns dramatically in small and large scale industries.
Keywords: *Infrared (IR) Thermography, reliability, maintenance, conductivity, reflection*.

Introduction

Nondestructive testing (NDT) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. Infrared (IR) technology is widely used in the oil and gas industry as an inspection tool for condition monitoring and predictive maintenance. IR thermography is a form of nondestructive testing that measures temperature variances of a component as heat (i.e. thermal radiation) flows through, from, or to that component. IR thermography is also generically known as IR testing, thermal testing, thermal imaging, and IR thermometry. The scope of the infrared thermography survey is confined to the production facility of the selected apparel and rubber sectors in the industrial estate in Sri Lanka. The focus of this assessment is on costs, energy intensive materials and electricity also because of countable wastage of the resources. The main objective of conducting the inspection is to reduce the unnecessary maintenance costs on wastage of material and electricity. Through this study, we investigate the savings and effectiveness of the Infrared thermography technologies.

The aim of the article is to investigate the cost-efficiency and effectiveness of the Infrared Thermography in the industrial maintenance sector.

Research objectives:

- Understand the IR Thermography and its value for the Industrial maintenance.
- Examine the highly critical locations or machineries in the production line.
- Analyse the collected IR images with the aid of software and pinpoint the abnormal situations.
- Calculate the various parameters for the perfect output.
- Estimate and compare the output results.
- Pinpoint and repair the defects before their occurrence with the aid of Infrared mechanical and electrical surveys.

Internal and external defection of equipment: for example, loose joint, loose contact, overload, unbalanced load, and improper installation. These defections usually cause excessheat, which could be harmful to equipment. Equipment failure needs high maintenance cost and maintenance staff which are risky for any accidents or life threatening. Temperature is a vital factor in status evaluation of electrical equipment. Therefore, temperature monitoring is considered to be one of the best maintenance methods [1]. An infrared scan can substantially improve profitability and reduce the operation and maintenance cost by the following ways [2, 3 5, 7, 8, 9, 10]:

- Instantly pinpointing the defects.
- Testing under the load conditions help to avoid costly shutdowns.

- Reducing the downtime and prevent catastrophic failures.
- Easy to allow for the pre repairing.
- Improve the reliability of maintenance efficiency.

The exact maintenance plan can solve both costs and downtime, so improving efficiency allows the plants to keep running their productions and operations smoothly. Industrial maintenance has many definitions in different approaches such as:

- Corrective / Reactive maintenance.
- Preventive maintenance.
- Predictive maintenance.
- Proactive maintenance [3].

Reactive / corrective maintenance operates on the run to failure strategy.

Preventive maintenance requires more on-going efforts but when executed properly it can reduce the costs in both short and long term. Still there is risk of machine failure occurring, it has a higher chance of identifying and correcting defects before they become a major disaster.

Predictive maintenance involve routinely inspecting machines with various developments including infrared and ultrasound technology. The national aeronautics and space administration (NASA) reported that this technique works to eliminate unexpected breakdowns and scheduled maintenance down time that would otherwise be used to inspect a machine piece by piece [2, 5, 6, 10].

Proactive maintenance differs from the above three modes because it addresses many more systematic elements of a maintenance program, rather than examine the machine itself. This approach provides much more control to the problems that can lead to machine wear and tear as opposed to the deterioration itself.

Instrumentation for IR Thermography

In order to interpret the thermal images perfectly the thermographer needs to know how different materials and circumstances influence the temperature readings from the thermal imaging camera. Some of the most important factors influencing the temperature readings are emissivity, conductivity, reflection, ambient and temperature [4, 5, 8, 9].

Six key requirements are important to assess when investigating a suitable combination of thermal imaging camera, software and training: Camera resolution / image quality, Thermal sensitivity, Accuracy, Camera functions, Software handling and Training demands.

In practical measurement application, the radiant energy leaves a target surface, passes through some transmitting medium, usually an atmospheric path, and reaches a measuring instrument. Therefore when making measurements or producing a thermos gram, three sets of characteristics must be considered:

1. Characteristics of the target surface
2. Characteristics of the transmitting medium
3. Characteristics of the measuring instrument

It is very difficult to determine the spectral sensitivity of an infrared radiometer such as an infrared camera. Consequently, the link between the effective blackbody radiance and the blackbody temperature cannot be established by integration. Furthermore, the sensitivity varies with time and a calibration is necessary – at least once a year or when the detector or an electronic component is replaced. During such a calibration procedure, the correlation between the temperature and the radiances is experimentally established using a laboratory blackbody, situated at the calibration distance of one meter from the camera.

An infrared camera measures the flux of the incoming radiation. Thus, a radiometer in front of an object detects not only the emitted radiance but also a part of exigent radiance due to the reflection of the ambient fluxes by the object surface. It is called noise of thermography. Noise is generally undesired signal and in IR it can be Electronic (shot noise, thermal noise, flicker), optical (random fluctuation of the incident radiation like Heating or Illuminating) and Environment (EMI caused by the Heavy Machinery, whirring, radio broad casting and of course heavy power lines) However, the quantitative error of the measurement has been difficult to evaluate precisely and systematically – not only in high temperature conditions but also in conditions near ambient. Errors impair the minimum detectable size and the noise equivalent temperature difference of the mechanical scanning of the IR system.

Cost Analysis

There are various benefit analysis for loose terminal connections. In this case we test the connection failure on transformer terminals.

The monthly Infrared thermography survey confirmed that the transformer connection bolt is loose. Further investigation revealed that the transformer was increasing the heat in the terminal point. Hot connection indicates a loose connection. Current transformer is having bar primary with air core, and secondary, the coil with large number of turns, hence very high voltage will be induced if secondary is open or the connection on secondary side with load (meter/relay) are not tightened properly or loose. The high "independent" primary apertures will induce high secondary voltage, and will damage the load or the secondary winding. In order to avoid that the secondary of current transformer must be shortened when not in use normally, at low currents as a transformer has good insulation and air has a very high breakdown this will do no damage to the CT itself but if for some reason breakdown occurs it can create damage and arcing. However, at very high amps this can create significant damage and even prove fatal.

Table 1

Maintenance cost analysis with actual cost

Material cost		**No of units**	**Cost per unit (EUR)**	**Total (EUR)**
Galvanize bolt (16x75 mm)		6	0.25	1.50
Nut (16 mm) – (Mild steel)		6	0.09	0.54
Spring washer (Stainless Steel)		6	0.08	0.48
Plat washer (Stainless Steel)		12	0.08	0.96
Cu plate for flag (240x180x6mm) with drill hole		1	4.10	4.10
Sub Total				7.58
Man Hour Calculation	**No of Persons**	**No of Hours**	**Cost per Hour (EUR)**	**Total (EUR)**
	3	2.5	1.36	10.20
Total Cost for the repair (EUR)				**17.78**

Table 2

Opportunity cost analysis (Production Lost)

Material Cost		**No of units**	**Cost per unit (EUR)**	**Total (EUR)**
LV Transformer bushing and seal kit		1	980.73	980.73
500mm cabel (meter)		30	48.59	1457.7
Lug (500mm)		2	11.56	23.12
Sub Total				2461.55
Man Hour Calculation	**No of Persons**	**No of Hours**	**Cost per Hour (EUR)**	**Total (EUR)**
	4	6	1.36	10.2
Total Cost for the repair (EUR)				**2471.75**
Production lost	**No of Hours**	**Production for one hour (kg)**	**Outsource compound cost per one kg**	**Total (EUR)**
Line 01	6	2430	0.06	931.63
Line 02	6	2910	0.06	1047.6
Line 03	6	4850	0.06	1746.0
Line 05	6	2490	0.06	896.4
Sub Total				4621.63

Table 3

Opportunity cost analysis (saving)

Man Hour Calculation	**No of Persons**	**No of Hours**	**Cost per Hour (EUR)**	**Total (EUR)**
Line 01	7	6	1.29	54.18
Line 02	7	6	1.29	54.18
Line 03	7	6	1.29	54.18
Line 05	7	6	1.29	54.18
Sub Total				216.72
Total Cost for the repair (EUR)				**4838.35**

Table 4

Total cost analysis

Total Cost for the repair (EUR)	**7310.10**
Total Saving (EUR)	**7292.32**

In order to save the transformer that should be immediately tightened at the terminal points with proper torque. Otherwise overload would lead to premature failure. The failures would result in approximately EUR 2,500 repair cost (Tab.2), and EUR 4,800 loss of production including the labour cost (Tab.3). If it would fail before taking the predictive actions failures would amount to a loss of EUR 7,300 (Tab.4). However, the failure was discovered using thermal camera and immediate actions were taken with the cost of just EUR 20 (Tab.1) for the maintenance. Vast amount of unnecessary maintenance budget was saved due to this small detection and immediate clever action (Tab. 4).

Conclusions

The diagnostic capabilities of maintenance technologies have increased in recent years with advances made in sensor technologies. These advances, breakthroughs in component sensitivities, size reductions, and most importantly costs, have opened up an entirely new area of diagnostics to the O&M practitioners. Infrared thermography technology is applied at the major power consuming machines and critical machines for the production in the plant. The report clearly shows the essential of the maintenance methodology. This research might be helpful to the Sri Lankan engineers who are struggling in handling the maintenance costs with the top-level management. The following facts noted at the end of this process.

1. Improving the equipment effectiveness.
2. Prove the energy savings through the proper maintenance techniques and making improvements.
3. Minimize the unexpected machine shutdowns and reduce the downtime period for maintenance.
4. Introduce effective maintenance plans in Sri Lankan plants.
5. Solution providing and suggesting procuring more effective equipment by evaluating the costs of operating and maintaining the new equipment throughout its life cycle, long-term costs will be minimized.

The expected savings are possible if the recommended measures are implemented. Some of the measures are qualitative and would mitigate wastage of energy whilst others give direct benefits to the bottom line. If an energy management and reporting system would be implemented it could continually improve the energy consumption practices but also ensure a commitment from the staff which is vital for managing energy cost which would result to profitability of the company. Apart from initial purchasing expenses, warranty, speed, size and memory were also some factors, which have been taken into account. In addition, various instruments and training features are available in the world market. Thus, engineers have to take responsibility and should be able to discuss with top-level management in order to move to another step beyond the predictive maintenance. Most industry experts would agree (as well as most reputable equipment vendors) that this equipment should not be purchased for in-house use if there is not a serious commitment to proper implementation, operator training, and equipment monitoring and repair.

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