Infrared Thermography : A versatile Technology for Condition Monitoring and Energy Conservation

S.P.Garnaik
Asst. Director(Technology Management)
National Productivity Council, Kanpur, India

Introduction

Temperature is one of the important parameters to tell the condition of internal process, material and even quality of the desired output. A qualitative but accurate conclusion can be drawn by observing the temperature profile of any surface. On the other hand higher temperature also indicates obvious loss of energy in the form of heat. Therefore temperature monitoring would give ample indication of the condition of the material, process quality and explore the possibility of energy conservation avenues.

In recent years, many temperature monitoring techniques have been in use in our industries. These techniques find their application based on the measurable temperature range, sensitivity and ease in application. A comparison of various typical techniques has been given in table no. 1.

With the on-line condition monitoring technology becoming an inevitable part of maintenance strategy in today's scenario, non-contact type temperature monitoring methods have become more popular. Infrared Thermography is such a non-contact type technique which provides a fast, reliable and accurate temperature profile of any material surface.

This paper deals with various application of infrared thermography including the justification of energy saving potential in many cases.

What is Infrared Thermography

Thermography is nothing but the temperature profiling of a surface or point. As the name suggests, infrared thermography is based on Infrared(IR) technique. The principle underlying this technique is that every object emits certain amount of IR energy and the intensity of this IR radiation is a function of temperature. In an electromagnetic spectrum the IR region appears between 0.8 micron to 1000 micron wavelength (See Figure 1). This wavelength of IR spectrum is more than that of a visible spectrum. The IR energy which can directly represent the surface temperature can be detected and quantified by the help of IR scanning system.

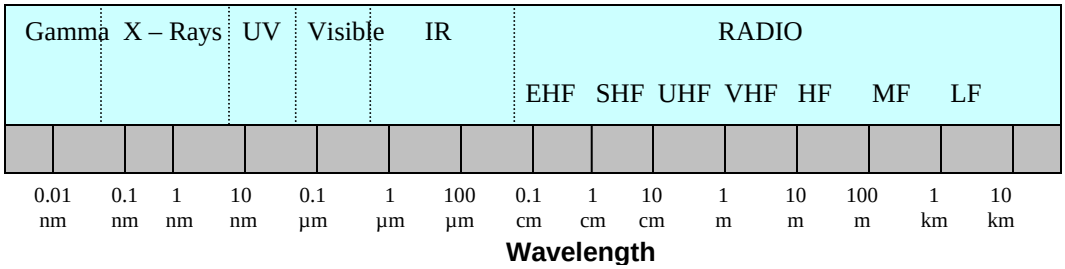


Figure 1 : Infrared(IR) in the electromagnetic spectrum

The Thermography Instrument

A thermography instrument can be a thermal pointer or a thermal scanner. The thermal pointer reads the temperature of a specific dimensional point where as a scanner maps the thermal profile of an area surface.

The basic IR system consists of an “IR energy detector” and a “Monitor”. The scanner is an optomechanical device which converts the IR energy received from an object surface to an electrical signal. These signals are further fed into the monitor where it is processed and presented in many forms like simple digital display to indicate temperature level and a video display for thermal profile (See Figure 2).

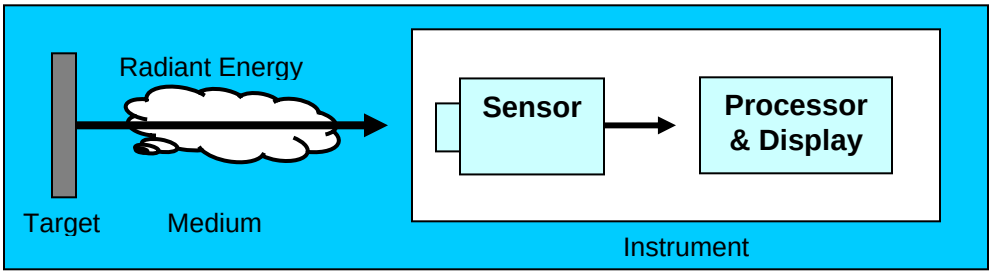


Figure 2 : The Total Infrared Measurement Situation

Advantages & Disadvantages of IR Thermography

The following points spell the advantages and disadvantages of this technique.

Advantages :

- It is a non-contact type technique.
- Fast, reliable & accurate output.
- A large surface area can be scanned in no time.
- Presented in visual & digital form.
- Software back-up for image processing and analysis.
- Requires very little skill for monitoring.

Disadvantages :

- Cost of instrument is relatively high.
- Unable to detect the inside temperature if the medium is separated by glass/polythenematerial etc.

Described below are some of the application areas of IR thermography with illustration of some real life case examples.

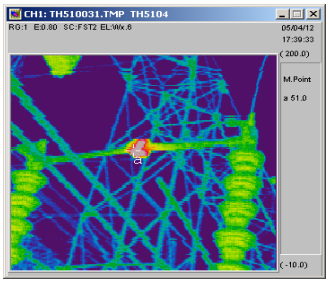
1. Electrical Distribution System

(a) A typical electrical distribution system consists of a number of isolators, circuit breakers, Current Transformers, Potential Transformers, Distribution Transformers, bus bars etc. Most faults are encountered in the form of hot-spots at contact terminals which may be due to loose contact, corrosive nuts & bolts, broken conductor strands etc. These hot spots are indicated by high surface

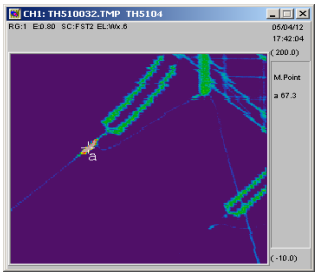
temperature. Higher is the current flow, more severe is the fault. On-line thermal scanning of these contact terminals will identify the hot-spots and severity of the fault (See Table 2). Attending these fault points will, of course, reduce the breakdown of the system and reliability can be improved.

SL	Criteria (Differential temperature above ambient)	Criticality Condition	Recommended Action
1	Up to 10 ^{0}C	Non-Critical	No action is needed
2	Between 10 ^{0}C to 20 ^{0}C	Less Critical	Regular Monitoring is needed
3	Between 20 ^{0}C to 40 ^{0}C	Semi Critical	Close monitoring needed. Should be attended in the next opportunity.
4	Above 40 ^{0}C	Critical	Should be attended immediately as per the severity.

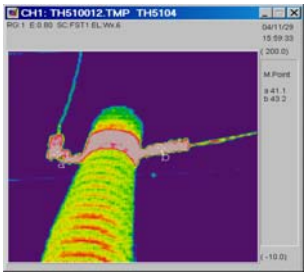
Table 2 : Criticality criteria of Thermography survey of electrical joints



Jaw Contact of a Isolator



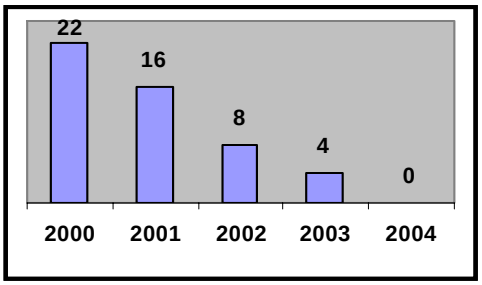
An overhead Joint



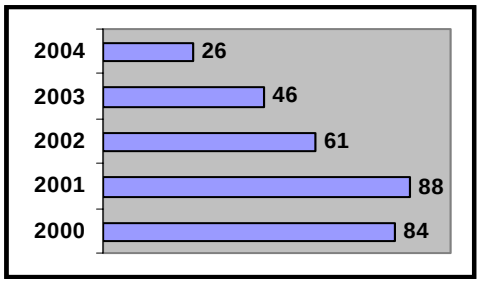
Terminal joints of a CT

Figure 3 : Hot spots of various critical electrical joints as observed in Thermography Survey

Another case also justifies the applicability of the IR thermography technology in a switchyard of a captive power plant of an aluminum company. With increasing the frequency of application from 2 to 3 times a year, the reliability of the switchyard could be achieved to nearly 100% as no shutdown is reported. In addition to this, the base line of the critical point has also come down drastically (See Figure 4).



[No. of critical points reduced gradually with increase in thermography survey (2 times a year in 2000-01 & 3 times a year in 2002-04)]



[Average differential temperature above ambient reduced from 88 ^{0}C to 26 ^{0}C setting a new base line.]

Figure 4 : Consequence of Application of Thermography in a switchyard of a Captive Power Plant

(b) The thermal scanning of about 400 first switching sub-stations (11KV/415 volt) of a power distributing company of a metropoly city of India could reveal very critical points. Necessary corrective action could lead to save frequent interruption in power supply and huge downtime. Maintenance activities could be streamlined more appropriately.

2. Power Circuit of Electrical Drives

It is essential that good power circuit be there to ensure proper functioning of electrical motors. Sometimes loose contacts at Motor Control Centres(MCC) or at terminal boxes lead to introduction of high resistance in the circuit. So voltage is dropped across this loose contact and a severe voltage unbalance is obtained at the motor terminal end. This results in malfunctioning of the motor. It may so happen that aggravation of such loose contact (thereby high temperature) will eventually lead to single-phasing situation. Figure 5 indicates a thermography survey of a 415 volt 75 KW induction motor having high temperature (101 ^{0}C) at MCC breaker terminal with ambient about 30 ^{0}C in R-phase resulting in a voltage unbalance of about 4.7% at motor terminal.

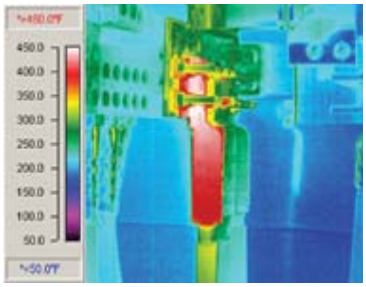


Figure 5 : Hot-Spot in a LT MCC terminal

3. Cooling Efficacy of Radiator Fins of a Power Transformer

Thermography survey of the radiator fins of a power transformer indicates the total temperature profile as shown in Figure 6. A temperature gain of around 7-8 ^{0}C would indicate good cooling effect of the transformer oil along the fins. Here an average gain of about 2 ^{0}C in few of the fins indicates that fins may be having internal deposition or choking resulting in ineffective cooling.

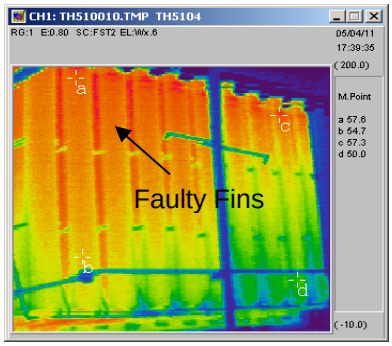


Figure 6 : Thermal Image of a Radiator Fins

4. Level Detection

Fluid levels of some containers at inaccessible locations can be easily seen by thermography survey by observing the thermal profile along the depth of the container/tank. This occurs because of thermal capacitance/resistance difference between separate locations. Figure 7 indicates the fluid level of two tanks (left & middle) along with the effect of solar radiation. It indicates that the fluid level is about 60% in the middle tank.

Figure 7 : Level comparison of two tanks

5. Fluid Flow Investigation

Blockage of any fluid transfer line can be simple to detect thermographically if the fluid temperature is sufficiently hotter or cooler than the ambient. Valve passing can be easily identified by this technique by the help of thermal mapping of the pipes in both sides of the valve.

6. Efficacy of Insulation or Refractory System

The basic purpose of the thermal insulation or refractory is to withheld the process heat. Any degradation of insulating material will allow the heat to come out to outer surface, thereby increasing the surface temperature. Mapping of the whole insulated surface of a boiler, furnace, heaters, steam pipe lines etc. will indicate any hot-zones where the surface temperature is more than the acceptable temperature. The hot-zones may be inferred for loss of / damaged insulation. Figure 8 indicates a thermogram indicating of hot-zone of a reformer of a fertilizer plant suggesting damaged insulation. The surface temperatures are observed to be about 180 ^{0}C against the acceptable temperature of 75 ^{0}C.

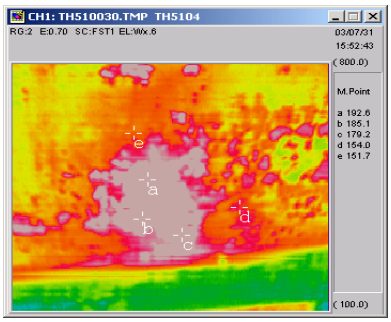


Figure 8 : Thermal Image of a Reformer Surface indicating hot zones

7. Industrial Roof Moisture Detection

This approach is based on heat loss rather than solar gain. Saturated roof sections are better heat conductors (poor insulators) with lower thermal resistance than dry sections and the temperature difference between interior & exterior will cause heat to be conducted more rapidly through wet sections than dry sections. Thermal images will easily indicate the faulty locations.

8. Night Vision, Search, Surveillance/Security and Fire Detection

The level of heat given off by human body makes it readily detectable to thermographic instruments. Similarly, exothermic action of engines and moving vehicles make them good targets for infrared surveillance applications. Night vision, Search, surveillance and security applications are more or less qualitative applications. They provide the user the capability to see through an atmospheric path in total darkness. Here, the clarity of image is more important than temperature measurement. Instruments used for this application evolved from military programs based on the need to detect and identify tactical targets through atmosphere in dark & bad weather.

9. Energy Conservation Studies

Thermography study can be very useful in estimating heat loss which occurs by elevated surface temperatures. The potential heat loss at outer surfaces will be mainly due to Radiation and Convection. These looses can be assessed by applying simple empirical relations after obtaining the surface temperature.

The thermal insulation survey of a 460 MW thermal power station in India reveals that about 10.2 lac Kcal/hour heat loss was occurring due to bare surfaces, inadequate/damaged insulation or open cladding condition (See Figure 9) in all four units. This is equivalent to coal loss of about 1847 MT per annum. Further analysis shows that if these faulty insulated areas are attended there would be an financial saving of around 35 lacs rupees per annum giving a simple pay back period of about one month only. Table 3 shows the cost-benefit analysis of the four units.

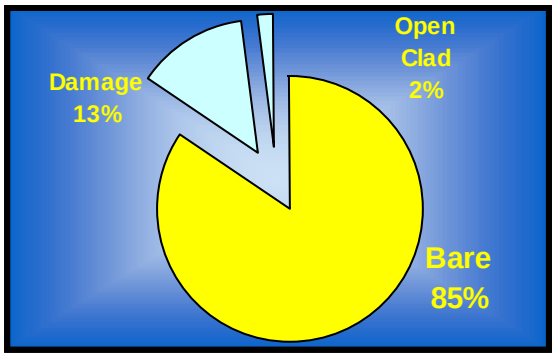


Figure 9 : Heat Loss proportion of different insulation condition

Unit	Heat Loss (lakh kwh/hr)	Saving (lakh kwh/hr)	Monetary Saving (Lakh Rs./Annu	Investment (Lakh Rs.)	Simple Payback Period
# 1	2.51	1.92	8.69	0.38	One Month
# 2	3.33	2.54	11.6	0.8	One Month
# 3	2.15	1.59	7.21	0.62	One Month
# 4	2.23	1.69	7.65	0.65	One Month
Total	**10.22**	**7.74**	**35.15**	**2.45**	**One Month**

Table 3 : Cost-Benefit Analysis of an Energy Audit
Study of Thermal Insulation Survey by Thermography

Conclusion

The application of infrared thermography is gaining importance in almost all industrial scenarios. This technique is helping the plant engineer to predict any potential failure, thereby planning the shut down well before. This saves precious production loss and ensures equipment safety. Moreover, application of IR thermography has very well established its position to identify the potential energy saving avenues. With the advancements in instrumentation, it is expected that low cost IR thermovision instruments will be available in near future, thereby making its usage more user friendly and expanding the application elsewhere.

Techniques	Typical Temperature Range (^{0}C)								
	-500	0	500	1000	1500	2000	2500	3000	3500
Optical Pyrometer									
Thermocouples									
IR Thermography									
Indicating Paints									
Liquid Expansion in Metal Bulbs									
Resistance Thermometer									
Bimetallic Strip									
Fusible Plug									
Thermisters									
Thermometer									

Table 1 : Different Temperature Monitoring Techniques & Their typical Temperature Range

REFERENCES

1. **Kaplan**, Herbert : ASNT Level III Study Guide on Infrared & Thermal Testing Method
2. **Garnaik,**S.P. : Thermography-A Condition Monitoring Tool for Process Industries, Seminar on Condition Monitoring & Safety Engineering for Process Industries, February 14-15,2000, Calcutta, India
3. Study Reports of Technology Management Division of National Productivity Council(NPC), India

About The Author

Garnaik,S.P. is having Degree in Electrical Engg. (Hons.) from Utkal University, Orissa, India. He is presently working as Assistant Director in Technology Management Division of National Productivity Council, India. He has conducted more than 25 major consultancy assignments in the field of Condition Monitoring Techniques, Energy Audit & Modern Maintenance System. He has also handled more than 50 training sessions on various technical subjects. His present study area is Condition Monitoring application of Industrial Motors through Motor Current Signature Analysis (MCSA).