International Journal For Technological Research In Engineering
Volume 6, Issue 7, March-2019 *ISSN (Online): 2347 - 4718*

FAULT IDENTIFICATION IN ELECTRICAL MACHINES USING THRMAL IMAGE PROCESSING

Mari Selvam B[1], Siva Bala Singh K[2], Harish R[3], Ms. K.S. Krishna Veni[4], M.E.
[1,2,3]UG students, [4]Assistant Professor,
Department of Electrical and Electronics Engineering
Mepco Schlenk Engineering College (Autonomous), Sivakasi, Tamilnadu, India

Abstract: Recently, the induction motors has attracted more attention in industries as well as in commercial use. The design and construction of induction motors are very simple compared to DC and synchronous machines. Whatever the design these machines has the tendency to fail during the occurrence of fault . This will leads to large economic and safety risk to the place where it is installed. In case of a fault in machine many protective devices are required to detect and diagnose them. But by using Thermal Image Processing Technique any type of failure can be identified in the earlier stage thereby reducing the maintenance cost. By using infrared camera, thermal images of the machines under normal and fault conditions can be captured. This images are processed by the MATLAB software. The fault in the machine can be detected by means of identifying hotspots in the image of the machine under running condition. If any fault is identified by this online monitoring technique then the concern people will be notified. Therefore fault in a machine can be detected by non- contact means and prior identification of the fault in the machine leads to great use of this method to the identification of the fault in the industrial machineries in earlier stage itself.

Index Terms: fault detection, infrared camera, image segmentation, thresholding.

I. INTRODUCTION

Industrial machinery mainly use Induction motors for their applications because of their low initial cost, low maintenance cost, high starting torque and durability [1]. However these motors are very prone to failures and hence making the detection of the fault is a major problem for industries [1-3]. Fault in the electrical machines may be of many types. Fault in the electrical machines primarily classified into two broad categories. They are internal faults and external faults. Internal faults refers to failures in the stator or rotor windings which may arises due to any one of the following reasons. The most common failures are malfunction of the stator or rotor winding insulation, inter turn faults in the windings, improper winding connections, any broken windings, high stress on the insulating materials due to excessive current flow in the windings etc.., Similarly external faults arises due to any of the following reasons. The most common external fault is bearing faults, fault due to supply voltage fluctuation, malfunction of the starting devices, power quality issues in the supply system, sudden increase or decrease of large load on the system etc... The common tendency of failures in the electrical machines are once external fault is occurred it will leads to internal faults within very short interval of time. There are lot of techniques available to detect the fault in the induction motor. Some of them are motor current signature analysis, vibration analysis and thermographic analysis. Among them motor current signature analysis is the most commonly used method to detect fault in induction motors [1-2]. However motor current signature analysis has some drawbacks. One of the main drawback is that it does not detect the fault if it is present in the kinematic chain [2]. Similarly vibration analysis has some drawbacks. The major issue in the vibration analysis is it is an invasive method of detecting the fault since it requires two or more accelerometers to monitor the condition of the motor under test at every instant of time [1-4]. In industry point of view this method has only few applications. Thermographic analysis is a non-invasive technique to detect failure in the machines under test. Therefore there is no need to interfering the system to analyze its operating conditions. In general any objects having temperature above 0K emits infrared radiations [4-9]. The intensity level of such infrared radiations represents the temperature of the various points on the system on which the measurements was done [2-4, 8-10]. The infrared camera is used to capture the images of the machine under various operating conditions. This captured images are analyzed using MATLAB to identify the hot spot. Thus by using this method fault is identified in earlier stage than any other method of detecting the faults in the electrical machinery [1-4]. In electrical machines major fault is occur then necessary action have been taken during the minor stages of the faults. For example phase to earth fault may converted into the phase to phase fault if the machine is not isolated in the earlier stage [7-10]. By using the thermographic analysis this problem is completely eliminated. Once the hotspots are detected then the respective authorities will be notified for further actions through e-mail.

II. THEORETICAL BACKGROUND

The infrared cameras are devices that is used to capture the radiated heat off the machines under study. This infrared cameras does not require any source of radiation for capturing the image, it utilizes the heat radiated from the target objects. This method is a non-invasive method of detecting the fault in industrial machines. The spectrum of infrared camera fall into the infrared region and the main advantage of this method is safety and harmless to the environment. Based on the emission of heat from the target objects infrared camera produce images of the target [7-8].

Thermal cameras are calibrated based on some industrial standards before taking the images of the objects under study and this is maintained throughout the experiment [5-10]. If low quality infrared cameras are used to capture the images of the machines it is necessary to use temperature sensors in order to ensure exact thermal radiation from the machines. In case of high quality infrared cameras are used then there is no need for temperature sensors [4-8]. The effectiveness of this method largely depends upon the quality of the cameras used.

According to Stefan-Boltzmann law every object at temperature T, will radiate energy which is proportional to the fourth power of the temperature T[1-3].The following mathematical expression will give the relationship between temperature and the energy emitted i.e.,

$$W=KeT^4 \quad (1)$$

where
e - Emissivity of the object
K- Stefan-Boltzmann constant
T-Temperature of the object in Kelvin
W-power emitted in W/m²

Emissivity of the material is the measure of how well the surface of the material emitting energy as thermal radiation. Emissivity constant is considered as 1 for a perfect reflector. But in practice there is no perfect reflector. Similarly emissivity constant is taken as 0 for a white body. The value of emissivity ranges from 0-1. The approximate value of Stefan- Boltzmann constant is $5.67 w/m^2/K^4$. In thermal image the color represents the temperature of the object .If the image is red in color temperature of the machine is very dangerous [1-2]. Once the fault is occurred in the machine especially in the rotor or the stator windings the stress imposed on the insulating material used in the machine increase rapidly. In this scenario the machine is strictly isolated from the mains to avoid large maintenance cost. In this case the current flowing through the winding increases and leads to formation of hot spots. The temperature of the hot spots exceed the normal temperature of the machine by very large amount. This high temperature gradually spread over the insulating materials and leads to malfunction of the materials. By utilizing this temperature the fault is identified in the earlier stage and the machine is isolated from the mains for repair as soon as possible. If any abnormalities are identified then the respective authorities will be notified by sending an e-mail from the MATLAB.

III. PROPOSED METHOD

In electrical machines the power loss will happen in the form of heat dissipation through the windings and it is mainly due to the presence of winding resistance. If fault is occurred then it indirectly means that more heat dissipation happens through the windings. Figure 1 shows the block diagram representation of the proposed method. The heat dissipation is captured by the thermal cameras. These images are preprocessed initially. The preprocessing method involves region of interest selection and separation of red region. We are focusing only on red region because red color in thermal image indicates the corresponding high temperature areas in the machines under test. This is done by segmentation of images by applying global thresholding. The threshold value for red color region separation is set as per the formula. The region of interest is the entire machine for complete analysis of the machines. In this proposed method we are using the rectangular region to select the particular area for analysis from the thermal image hence our approach is a user friendly method. Surrounding temperature also influence the thermal image of the machines which can be nullified by proper adjustment in the settings of the infrared cameras.

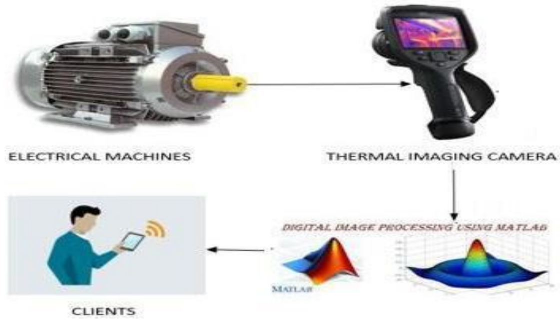


Fig. 1. Block diagram of proposed method.

IV. IMPLEMENTATION

Figure 2 shows the flow chart of the proposed method.

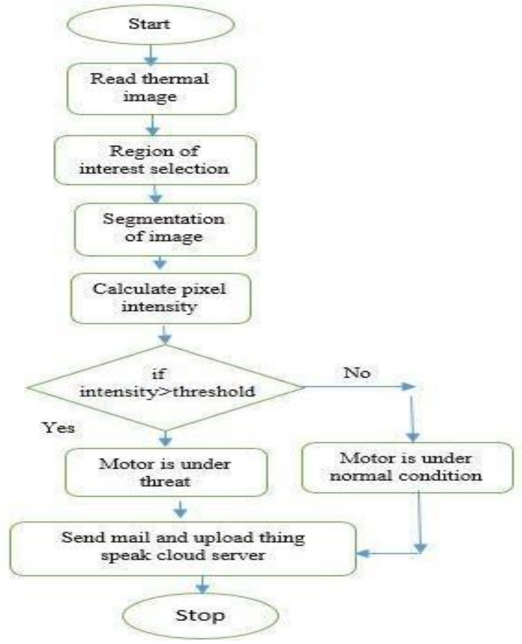
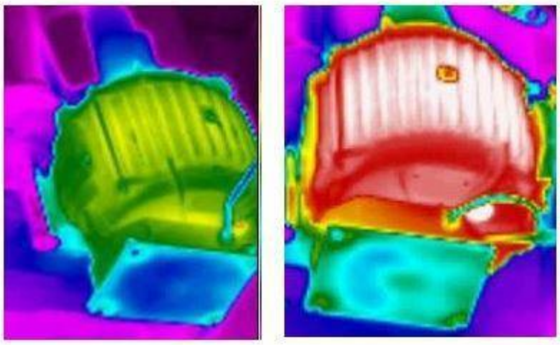


Fig. 2. Flow chart of the proposed approach. The experimental set up is done on the 3 phase, 3.75 KVA, 415V, 1440 rpm slip ring induction motor. Slip ring induction motors are employed in places where high starting torque is required and this can be achieved by adding external resistant to the rotor circuit through the slip rings. We are purposefully introducing a minor fault on the stator and capture the thermal images. The successive steps involved in the processing thermal image is clearly shown in the flow chart shown above. This thermal radiation is mainly due to $3I^2R$ loss. Where I represents the fault current flowing through the windings. Figure 3 (a) shows the thermal image of the machine under normal operating condition. Fig. 2 (b)

depicts the thermal image of the machine during stator fault condition.



(a) (b)

Fig. 2. (a) Thermal image of the machine under normal condition, (b) Under stator fault condition.

Figure 3 depicts the thermal image of the faulted bearing. Once the bearing is failed then mechanical balance between the machine and the load will be lost.

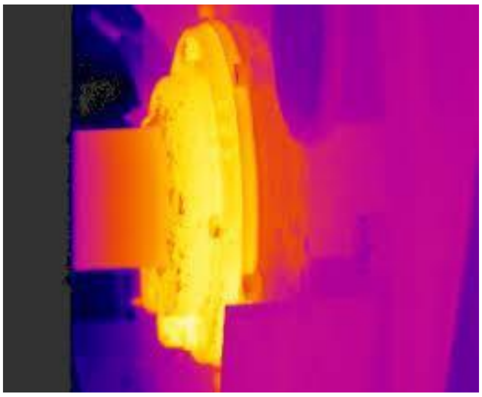


Fig. 3. Thermal image of faulted bearing.

The next step is to choose the region of interest for further analysis. In our paper we considered the entire machine as a region of interest for complete analysis of the machine under study in order to improve the efficiency of the proposed approach.

The next step is segmentation of the selected region. There are lot of techniques available to segment the image. The most commonly used method is applying watershed algorithm on the selected region. The watershed algorithm divides the image by foreground and background. Segmentation provides the binary image from the given grayscale image. In this paper global thresholding method is used to perform segmentation. There is another one method of thresholding is available known as local thresholding. However local thresholding provides less accurate results than the global thresholding method. Threshold value can be computed by the following relationship.

Threshold = 0.5 (Max (I) + Min (I))(2)

where

Max (I) -Maximum value of intensity.

Min (I) -Minimum value of intensity.

These two values are obtained from the histogram of the thermal image. Histogram is nothing but a chart that draws the intensity distribution of grayscale image. Histogram differ from the bar chart by plotting the continuous data rather than the distributed data. Figure 4 depicts the histogram of the thermal image shown in fig. 2 (a).

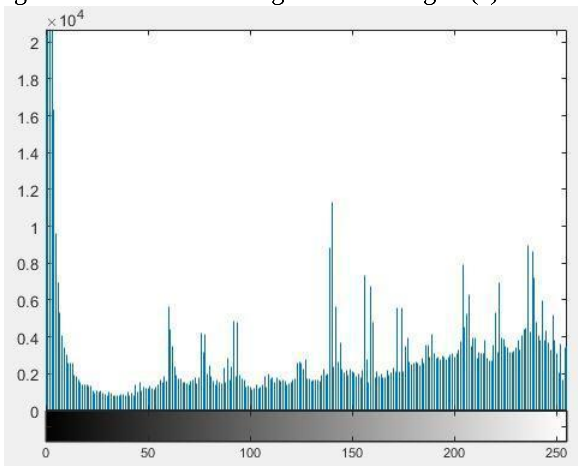


Fig. 4. Histogram of the thermal image

The next step is to extract the color channel. In this paper we extract the red color channel from the region of interest. As already mentioned red color is the direct measurement of the temperature. Figure 5 represents the red color channel extraction from the thermal image of stator faulted machine. Similarly for thermal image corresponds to the different fault also the red channel is extracted to make the analysis easier. Figure 6 shows the histogram of the red channel of the image.

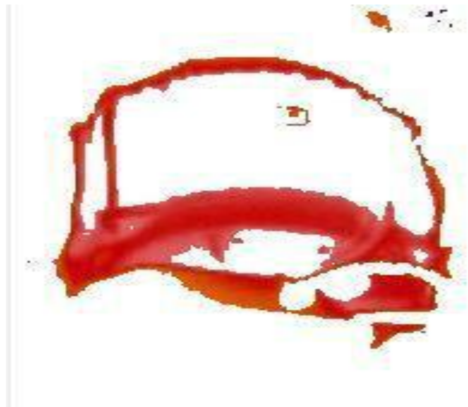


Fig. 4. Red channel extracted from the image

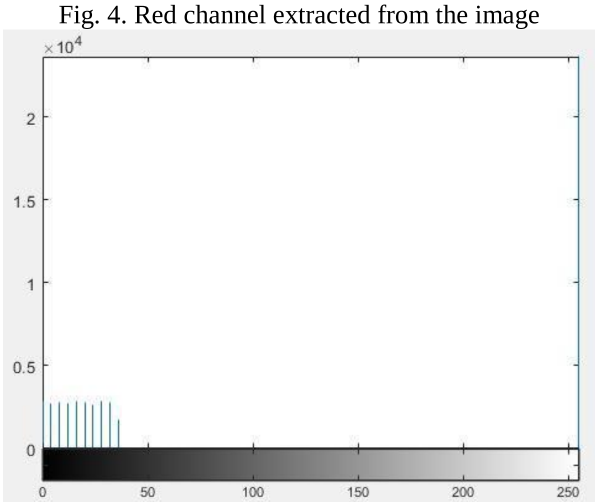


Fig. 5. Histogram of the red channel

The next step is to calculate the intensity value of every pixel in the segmented image. Intensity level of the thermal image is directly proportional to the temperature of the machine. The intensity values are calculated on the grayscale image by using standard function available in the MATLAB. The intensity values are compared to the critical value of intensity which corresponds to the normal operating temperature of the machine under test. For this comparison if constructs in the matlab function is used. The measured intensity values are denoted as F. If the value exceed the critical intensity value at one single pixel or group of pixel this result is send to the concerned authorities via e-mail. The clients will see the operating condition of the machine by login to the gmail account and it helps to take respective steps in order to safeguard the machine against all kinds of internal as well as external faults. Using sendmail function available in the matlab the result is send to the respective authorities for immediate remedy. To ensure proper function of the sendmail function the internet connectivity should be maintained properly.

TABLE I. Results

INTENSITY VALUE (for stator faults only)	CONDITION
F<230	Machine is operating under normal operating condition.
230 ≤ F ≤ 250	Stator winding insulation temperature exceeds the normal value.
F>250	Machine is under severe threat so disconnect the motor from the mains.

V. CONCLUSION

Our paper aim is to develop a non-invasive online monitoring system for detecting faults in electrical machines. This can be achieved with a help of thermal images captured by means of infrared camera. The proposed approach can be used for the fault diagnosis in industrial machinery by identifying the high temperature area in the machinery and distinguish the abnormal operating condition from the normal operating condition very accurately. The region of interest is segmented by using global thresholding concept which can provide better result. The segmented image is further processed to get the intensity of each pixel. This intensity value is compared with the normal intensity value and the result is send to the concerned authorities via e-mail succesfully. This proposed approach is further applied to any electrical apparatus. This proposed method provide information not only the area where the fault is happen it also provide the effect of this fault on the other part of the machines.

REFERENCES

[1] M. Younus and B.-S. Yang, “Intelligent fault diagnosis of rotating machinery using infrared thermal image,” Expert Systems with Applica- tions, vol. 39, no. 2, pp. 2082–2091, 2012.

[2] O. Janssens, R. Schulz, V. Slavkovikj, K. Stockman, M. Loccufier, R. Van de Walle, and S. Van Hoecke, “Thermal image based fault diagnosis for rotating machinery,” Infrared Physics & Technology, vol. 73, pp. 78–87, 2015.

[3] Harishkumar, V. Razick Mohammed, B. Mohammed Mujtaba “Detection of hot spots by thermal imaging to protect power equipments ’’ Department of Electrical and Electronics Engineering C. Abdul Hakeem College of Engineering & Technology, sep2012.

[4] Zhiqiang Huo, Yu Zhang, Richard Sath, Lei Shu “Self-adaptive Fault Diagnosis of Roller Bearings using Infrared Thermal Images” Guangdong University of Petrochemical Technology, Maoming, China Vol.3,2006.

[5] P. Tavner, “Review of condition monitoring of rotating electrical ma- chines,” IET Electric Power Applications, vol. 2, no. 4, pp. 215–247, 2008.

[6] R. Das, “Determining the locations of faults in distribution systems”, Ph.D.Dissertation, University of Saskatchewan, Saskatoon, Canada, 1998.

[7] D. Rossetti, Y. Zhang, S. Squartini, and S. Collura, “Classification of bearing faults through time-frequency analysis and image processing,” in Mechatronics-Mechatronika (ME), 2016 17th International Conference on. IEEE, 2016, pp. 1–7.

[8] A. Glowacz and Z. Glowacz, “Diagnostics of stator faults of the single- phase induction motor using thermal images, moasos and selected classifiers,” Measurement, vol. 93, pp. 86–93, 2016.

[9] O. Munoz-Ornelas, D.A. Elvira-Ortiz, R.A. Osornio-Rios, R.J. Romero-Troncoso, L.A. Morales-Herandez, “Methodology for thermal Analysis of Induction Motors with Infrared Thermography Considering Camera Location”, in Proc. IEEE Ind. Electron. Soc. IECON; 2016.

[10] A.S.N. Huda and S. Taib, “Suitable features selection for monitoring thermal condition of electrical equipment using infrared thermography”, in Infrared Phys. Techn., vol.61, pp. 184- 191, 2013.

[11] M.E. Sieracki, S.E. Reichenbach, K.L. Webb, Evaluation of automated threshold selection methods for accurately sizing microscopic fluorescent cells by image analysis, Applied and Environmental Microbiology, 55 (1989) 2762-2772.

[12] Okuda et al.,“Development of inspection systems for distribution power apparatuses self-running on a overhead ground wire of pole”, IJEE technical report, PE93-56, 199.

