Intelligent system to monitor and diagnose performance deviation in Industrial Equipment

A T Sankara Subramanian¹, M D Udayakumar², V. Indragandhi³, R. Ramkumar⁴

¹, ² & ⁴Assistant Professor, Department of EEE, K. Ramakrishnan College of Technology, Trichy, Tamilnadu, India.
³Associate Professor, Department of EEE, VIT, Vellore, Tamilnadu, India.

Abstract. As per ISO norms, industries used to calibrate the meters which they are using, but performance deviations of the working equipment which are not affecting the economy or production of industries are not given significant importance. So, this work aims at concentrating on fine performance deviation in induction machine which if avoided without taking corrective action may even stop production. This is done by taking a set of reference parameters and the newly taken values are compared with the reference ones and error margin is determined. Various sensors are interfaced for measuring the physical parameters of the machines. Thus, with all these the performance of industrial induction motor with different loading conditions are carried out and the possible damage that could occur if the fault in the machine is not cleared, and also will show the preventive measures to be taken to avoid the failure of the drives are framed. In industries the machines used will be of higher ratings. And if there occurs any error or fault then its production will be greatly affected, which in turn will create huge production and economic losses, so to avoid that the proposed system to forecast the performance deviations of the drives will be of great commercial significance. With this system, the production and economic losses can be reduced to greater extent and also can prevent the machines from damage.

1. Introduction
Condition monitoring of electric machines has received considerable impetus from the industry to ensure consistent and reliable operation of modern industrial systems. The principal aim is to develop schemes for reliable detection of faults at an early stage, which will allow controlled and scheduled maintenance instead of sudden failure, thus reducing production losses, outage time, and damage to the equipment [2].

Induction motors are the literal spine for any industry. Anyway like some other machine, they will in the end fall flat due to heavy and continuous duty periods, poor workplace, establishment and assembling factors, and so on. With heightening requests for dependability and productivity, the field of fault determination in induction motors is picking up significance. Be that as it may, numerous strategies have been proposed for issue identification and conclusion, yet the majority of the techniques require a decent arrangement of mastery to apply them effectively. Less difficult methodologies are expected to empower even unprofessional administrators with ostensible information of the framework to examine the issue condition and settle on solid choices [1].

2. Existing system
A 3 phase induction motor which is suitable for pumping application is fed with a supply of 50Hz and a separate loading arrangement which is required to test the machine at different loading conditions is...
attached and for different loading conditions test data of voltage and current are measured and recorded.

![Figure 1. Block diagram of existing system](image)

If there occurs any vibration in the machine due to the faults then it will be measured by the vibration measuring unit. All the fault signals from the various measuring units are passed to the microcontroller. This micro-controller will produce a control signal which is passed to the relay driver circuit [3]. The relay driver circuit will operate the relay 1 which in turn will open the switch that will disconnect motor from the supply and thus eliminating the fault and preventing the machine from damage.

The machine faults either electrical or mechanical are fuzzy in nature or typically it is very difficult to analyze as the parameters associated with such analysis is closed linked to one another. There are two efficient condition monitoring techniques to effectively deploy the strategies for the predictive maintenance. Basically many harmonic analysis techniques are employed and elimination is done at specific characteristic frequencies generated by specific faults as the unique rotating flux [4]. Fuzzy logic system has also been utilized, which assesses severity of the fault and operating condition of machine.

The fault detection can be conducted using vibration signals and/or stator current signals. The machine oscillation on the bed will cause mechanical vibration under high speed conditions which can be measured using vibration sensors which has more signal to Noise ratio. But installation of such sensor is really a tough job and need experienced engineers to do it. Measuring current values of induction motor is not a tough job it can be done simply using simple current sensors [3]. The projected current monitoring procedure there is no supplementary sensors required. This is because for machines with larger power ratings associated with different industrial applications are wired with current transformer and potential transformer for voltage and current measurement [5]. Lab automation system is a means that allow users to control electric appliances. Many existing, well established lab automation systems are based on wired communication. Despite that the evolution of wireless communication system in the last decade and its massive growth and concurrence in the field of industrial automation makes it more ideal and cheap [6]. The faults that occur in the machines are corrected by analyzing various parameters in various stages of fault correction methods [8].
In this work, the major focus is on forecasting all the major faults that may occur in any machine and also to provide the necessary details required for correcting or eliminating the faults. This work also helps to determine or understand the fault occurrence much before the fault occurs so that one can avoid the post fault problems.

The Powering unit consists of source and converters, the source can be either a single phase or three phase supply which is connected to the machine and the converters are used for the requisite conversions.

The voltage measuring unit is connected across the lines in parallel to measure the supplied voltage, and the current measuring unit is connected to a line in series to measure the current consumed by the machine.

The speed measuring unit is joined to the shaft to estimate the speed at which it rotates or to mark the change in speed, along with this a load measuring unit is also attached to estimate the load applied. A temperature measuring unit is also attached to the machine. The output of this measuring unit is connected to the Arduino controller. The Arduino controller processes the input based on the coding uploaded.

The input to the Arduino controller is the test data during installation which consist of all the master data that are calculated manually, the rated values are referred for the comparison of voltage, current, speed, temp and load for performance deviations and then data on Corrective Actions if needed is also given to it. Its output is fed to the 20x4 LCD display which displays the fault forecasting and corrective measures.

The hardware is made with a small rating Induction of 1 KW and the specifications of the testing machine is noted down clearly to fix the reference values as per standard.

3. Software calculation
The Arduino controller interfaced with the hardware can be fed with the micro C coding based on the following calculation,

Voltage = Sensed value * (3.0 / 1023.0) * 76.0
3.0 – Sensor output voltage.
1023.0 – Controller bit value.
76.0 – Multiple factor (to convert 1ф voltage).
Current = ((Adc voltage – offset voltage) / sensitivity)
Adc voltage = (Adc value / 1023.0)*5000.0.
Sensitivity = 30 Amp – 66 MV/Amp.
Adc value = Input sensed current.
Speed = No. of times sensor input becomes high for every 5 seconds.

4. Hardware Description
This system is mainly focused on the performance deviation of induction motor. So the main hardware will be the induction motor. Here various sensors such as current sensor, voltage measuring unit, temperature sensor, speed sensor, load cell along with load amplifier module and vibration sensor are used to measure the physical properties of Induction motor. All the output sensed signals are passed to the Arduino board. Using the Arduino IDE software the output is displayed using the LCD display.

The entire setup is fixed on a hard surface, and also the motor is placed over a bed as shown in the fig.3. The load arrangement is also provided so that the load can be applied externally and also an arrangement is given to measure the load applied.

The setup is tested for its mechanical and electrical stability and the same has been recorded as test data and compared with the simulated results of the PROTEUS software. The loading arrangement and load measuring setup. With the help of a rope tightened upward will help to measure how much load is applied. And with help of a rope lying downward load can be applied. The voltage measuring unit consists of a transformer, a pot, bridge rectifier IC, capacitor and Zener diode. The voltage measurement is done so that if it exceeded the prescribed values then the system is not under healthy condition.
The setup for measuring the current consists of the current sensor ACS712. Arrangement for speed measurement consists of the speed sensor. A metal piece is attached to the rotor shaft and with this setup the speed is measured using the sensor. The setup of measuring temperature and vibration consists of the temperature sensor DS18B20 and vibration sensor. The Vibration sensor shows the changes in the Mechanical movements in terms of frequency changes and the same if exceeds the reference frequency it will raise and indication as a warning.

5. Simulations of the Proposed System

5.1 Proteus Simulation for Voltage Measurement

Voltage measuring unit consist of bridge rectifier ic, Zener diode, capacitor, potentiometer and transformer. 230V ac is stepped down to 12V ac using the step down transformer, then it passed through the rectifier and to get 12V dc. This is further passed through the filter circuit and to obtain 3V dc supply. This is given to the Arduino analog pin. The coding is written in micro C. one can also use Java language to write the coding. The controller processes the coding and provides output. The main advantage of using Arduino is that the programs can be changed even in the run time without flashing out the controllers. It gives more easiness and flexibility in writing the coding. The calculation made earlier can be directly converter into coding. There are specific libraries need to be used in Arduino if not available in the basic package, then that can be easily downloaded free from many websites. Figure 4 shows the simulation circuit for voltage measurement. It is quite easier to draw and simulate in Proteus.
Figure. 4 Simulation circuit of voltage measurement.

Figure. 5 Output voltage waveform with fault point.

Figure 5 consists of two sinusoidal waves of voltage. One is the normal waveform which is obtained before the fault occurred. The other one is obtained when there occurs any fault and the current value rises beyond the rated value, this is depicted by the upper wave showing the over voltage at the faulty point.

5.2 Proteus Simulation for Current Measurement

ACS712 current sensor is used here. The sensed value is given to the digital pin of the Arduino. Figure 6 shows the simulation of current measurement.
In the programming part the current value is obtained after certain calculations. The values sensed by the current sensor are used for the calculations purpose.

At the fault point the current flowing will be more than the rated current. This is clearly shown in the figure 7. The dotted lines in the graph depict the faulty region. The sudden increase in current may occur due to transient switching or increase in the load applied. This type of situation leads to severe damage of the machine and hence it needs to be identified and corrected as early as possible.

5.3 Proteus Simulation for Temperature Measurement

DS18B20 digital temperature is used to measure the temperature variation. This is shown in figure 8.
The temperature sensor is placed close to the motor so that the temperature rise in the motor can be easily determined. This temperature value is used to check whether there is temperature rise in the motor winding or any other part of the system. This is so accurate that it will show a minute increase in the temperature.

Figure 8 Stimulation circuit of temperature measurement.

Figure 9 Identification of Speed deviation in drives

Figure 9 shows the speed deviation in the induction motor. $N_s$ represents the synchronous speed while $N_{rated}$ represents the induction motor speed. It is clear from the graph that the induction motor runs at a lesser speed than the synchronous motor. One shows the normal speed reduction as the load increases but the other shows a rapid reduction of speed as the same load is increased. This shows that there is some problem or fault occurred in the system.
6. Software Results
The software result in figure 10 shows the output values that are obtained through the coding used in the Arduino IDE software.

![Software result output](image)

**Figure. 10 Software results obtained using PROTEUS**

7. Conclusion
This work pays way for a novel way of forecasting the fault much before the fault occurs and the permanent damage takes place. Any fault or damage does not occur instantly, it happens due to the lack of proper observation and lack of awareness. It focus on forecasting or predicting the future damage that may occur if the small deviation occurring is neglected. This method is not available in any places at present, which is much necessary to avoid huge collateral damage. This provides a great opportunity for the engineers to expand their knowledge in the area of fault forecasting. The high cost machines can be prevented from getting damaged by preventing the fault to precede further, this can be achieved only with our proposed system. And also this can also be incorporated with IoT based system for enhanced controlling and forecasting purpose.

8. References

[1] Partha Sarathee Bhowmik, Sourav Pradhan, Mangal Prakash, May 2013, “Fault Diagnostic And Monitoring Methods Of Induction Motor”. Volume 1.

[2] Ayaz Ahmed Soomro, Imtiaz Hussain Kalwar, Kamran Kazi, Sarang Karim Khoso and Shahzeb Ansari, Year: 2016, “A Hybrid Monitoring Technique For Diagnosis Of Mechanical Faults In Induction Motor”, Volume: 9

[3] De Z. Li, Wilson Wang, Year: 2015, “An Intelligent Monitor for Electric Motor Fault Diagnosis”, Volume: 5.

[4] Pero Ostojic, Arijit Banerjee, Dhaval C. Patel, Wrichik Basu, Shahid Ali, Year: 2014, “Advanced Motor Monitoring and Diagnostics”, Volume: 5.
[5] Prof. V. P. Kaduskar, Nitish Gupta, Yash Bhardwaj, Shivam Kumar, “IOT BASED LAB AUTOMATION SYSTEM”.

[6] R.Megala, Dr. V. Eswaramoorthy, “Fault Detection and Prediction Of Failure Using Vibration Analysis”.

[7] Jaiganesh, R., et al., (2017), "Smart Grid System for Water Pumping and Domestic Application Using Arduino Controller." International Journal for Modern Trends in Science and Technology 3.05: 385-390.

[8] Sagayaraj, R., and A. Nazar Ali, (2018), "Performance Analysis of Quazi Z-source inverter Fed Induction Motor under Semiconductor Failure Condition."

[9] D Sivamani, Dr. R Sagayaraj, R Jai Ganesh and Dr. A. Nazar Ali, September 2018, “Smart Incubator using Internet of Things”, International Journal for Modern Trends in Science and Technology, Vol. 04, Issue 09, pp.-23-27.

[10] A.T. Sankara Subramanian, P. Sabarish and R Jai Ganesh. “An Improved Voltage follower Canonical Switching Cell Converter with PFC for VSI Fed BLDC Motor.” Journal of science and technology. ISSN:2456-5660 http://jst.org.in/Vol-2Issue-10October2017.html

[11] A. T. S. Subramanian, P. Sabarish, A. N. Ali. "A power factor correction based canonical switching cell converter for VSI fed BLDC motor by using voltage follower technique", 2017 IEEE International Conference on Electrical Instrumentation and Communication Engineering (ICEICE), pp. 1-8, 2017.

[12] Subramanian Sankar, "A PV SYSTEM BASED HIGH STEP UP CONVERTER WITH A VOLTAGE MULTIPLIER MODULE USING FUZZY LOGIC CONTROLLER", International Journal of Applied Engineering Research 10.9, pp. 7441-7446, 2015

[13] Arunraj, S., et al. "A Novel Zeta Converter with Pi Controller for Power Factor Correction in Induction Motor’.” International Journal of Scientific Research in Science and Technology (IJSRST), Print ISSN (2017): 2395-6011.

[14] Nagarajan, L. "Star Delta Starter using Soft Switch for Low Power Three Phase Induction Motors.” Australian Journal of Basic and Applied Sciences 9.21: 175-178.

[15] Vikram, A. Arun, et al. "Solar PV Array Fed BLDC Motor Using Zeta Converter For Water Pumping Applications.” Journal of Science and Technology (JST) 2.11 (2017): 09-20.

[16] A.Rajkumar and B.Karthikeyan., Fuzzy Logic Controller for Fast Transient Response DC-DC Converter. Adv. in Nat. Appl. Sci., 8(21): 65-71, 2014

[17] Rajkumar, B. Karthikeyan and S. Senthil Kumar , Fuzzy Logic Control of Fast Transient Response DC-DC Converter. Middle-East J. Sci. Res., 23 (9): 2256-2263, 2015.

[18] A Rajkumar, B Karthikeyan, S Senthilkumar, Reliability Analysis of Fuzzy Logic Controlled Fast Transient Response DC- DC Converter. International Journal of Applied Engineering Research 10 (85), 728-730.

[19] A Rajkumar, B Karthikeyan, S Senthilkumar, Fault Tree Based Reliability Analysis of Fast Response DC-DC Converter. International Journal of Applied Engineering Research 10 (85), 731-737.

[20] A Rajkumar, B Karthikeyan, S Senthil Kumar, Performance Evaluation Fast Transient Response DC-DC Converter using Soft Computing Analysis with PI Controller, Australian Journal of Basic and Applied Sciences 9 (33), 373-379.