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# ONLINE DYNAMIC TORQUE AND EFFICIENCY MONITORINGIN INDUCTION MOTOR

**Miss. Latarani S. Patil[1], Prof. A. S. Mali [2]**

*[1]B.E. ,Electronics Department, [2]M.E. ,Electronics Department*

*T.K.I.E.T.Warananagar, Shivaji University, Kolhapur, India.*

## ABSTRACT

*Induction motors are used worldwide as the "workhorse" in industrial applications. The main reason for the usage of induction motor is its reliability and simplicity of operation. Thus it is essential to monitor the performance of the motor without changing its operation. Analysis of induction motor is much essential to find out utilization index of a motor for better performance. In-service motor monitoring is relevant as the motor need not be removed from service and the down time can be minimized. This reduces the production loss as the machine is not disturbed from its service for monitoring. Not only does this reduces the financial implications associated with down time but also helps in prolonging the life span of the machine.The system has developed for online monitoring of torque and efficiency in induction motor. LPC2138 is used to acquire voltage, current and speed from the motor and passed it to ZigBee module. From ZigBee these signals are then sent to monitoring unit which contained PC. Calculation of torque and efficiency is done in Visual Basic with local processing capability. This all estimated parameters are displayed on PC using GUI for real time monitoring.*

***Keywords***- *Efficiency estimation, embedded systems, Induction motors, Torque measurement, Wireless sensor network.*

## I. INTRODUCTION

In an industrial environment, electric motors are widely used in most production processes to drive the mechanical system. It is becoming very popular the utilization of induction motor for many applications because of its simple design, rugged performance and easy maintenance [1]. By online condition monitoring, we simply mean that monitoring the overall parameters of an induction motor when it is running on its full load capacity through some effective measurement techniques so that the motor's life and its efficiency increases. Torque is one of the main parameter for production of machines. Torque measurement can identify equipment failure so that their monitoring is essential in order to avoid an equipment failure in critical production processes. For better performance, motor must have full load efficiency for particular operation. In general fault diagnosis of induction motors has concentrated on sensing failures in one of three major components, the stator, the rotor, and the bearings. Even though mechanical sensing techniques based on thermal and vibration monitoring have been utilized widely, most of the recent research has been directed toward electrical sensing with emphasis on analysing the motor stator current [2].

Efficiency of an induction motor can be affected by many factors such as supply voltage unbalance, over or under voltage conditions, internal faults, the effect of rewinding and repair of motor or due to over or under loading condition. As a result of this, manufactures and industries have to construct and buy more efficient motors both for new installation and replacement purposes. Therefore, efficiency monitoring of installed motors is essential to detect the motors with poor efficiencies and to take appropriate action [3].

Traditionally, energy monitoring and fault detection in industrial systems are performed in an offline manner or through wired networks. The installation of cables and sensors usually has a higher cost than the cost of the sensors themselves. Besides the high cost, the wired approach offers little flexibility, making the network deployment and maintenance a harder process. In this context, wireless networks present a number of advantages compared to wired networks as, the ease and speed of deployment and maintenance, and low cost, more flexibility and inexpensive solution for building industrial monitoring and control systems [3].

### 1.1 Background

In-service motor monitoring is relevant as the motor need not be removed from service and the down time can be minimized. This reduces the production loss as the machine is not disturbed from its service for monitoring. Not only does this reduces the financial implications associated with down time but also helps in prolonging the life span of the machine. Also testing the motor in its running condition helps to obtain the motor characteristic in its real time situation which is different from the lab testing. In lab testing, the supply conditions are not polluted with degrees of harmonic distortion and unbalance which has an effect on the motor's efficiency [4].

The major advantage of on-line monitoring is that the device potential problems could be detected early before a serious deterioration or breakdown occurs. The diagnosis results can clearly indicate the direction of maintenance. Efficiency may be higher for larger motors than for smaller motors but it is still reduced when not matched to the load. Determining whether the motors are properly loaded enables to make decisions about when to replace motors and which replacements to choose.

### 1.2 Motivation of Work

In an industrial environment, mechanical systems driven by electric motors are used in most production processes, accounting for more than two-thirds of industry electricity consumption. Regarding the type of motors usually employed, about 90% are ac induction based, mainly due to its cost effectiveness and mechanical robustness. Torque is one of the main parameter for production machines. In several industry sectors, torque measurements can identify equipment failure, which makes their monitoring essential in order to avoid disasters in critical production processes for e.g., oil and gas, mining, and sugar and alcohol industries [4].

For decades, researchers have studied methods and systems for determining the torque in rotating shafts. There are basically two methods of estimation of torque and efficiency:

a) Direct torque measurement on the shaft
b) Estimated torque measurement from motor electrical signals.

The methods for direct torque measurement on the shafts are less accurate and highly invasive, considering the coupling of the measurement instrument between the motor and the load. But the estimated torque from the motor's electrical signals (i.e. current and voltage) makes the system less invasive [5].

## II. IMPLEMENTATION

The proposed system overcomes the drawbacks of the existing system. System is a standalone which monitor Torque and Efficiency values. Differences in the proposed system are that speed of the motor is acquired through sensor implemented at the motor shaft in a manner which will not disturb the working of the system. System has developed on work bench which consist of break pulley arrangement. It mainly focuses on the need of more non-invasive monitoring of the motor. Therefore the calculation is done from another base station so that the machine interference with the working motor is smaller compared to other techniques. That is the sensors are connected with the motor in the working station and the calculation part is done at a base station [6]. There is transmitter section and receiver section for online monitoring of dynamic torque and efficiency in induction motor. Block diagram of transmitter section is as follow**:**

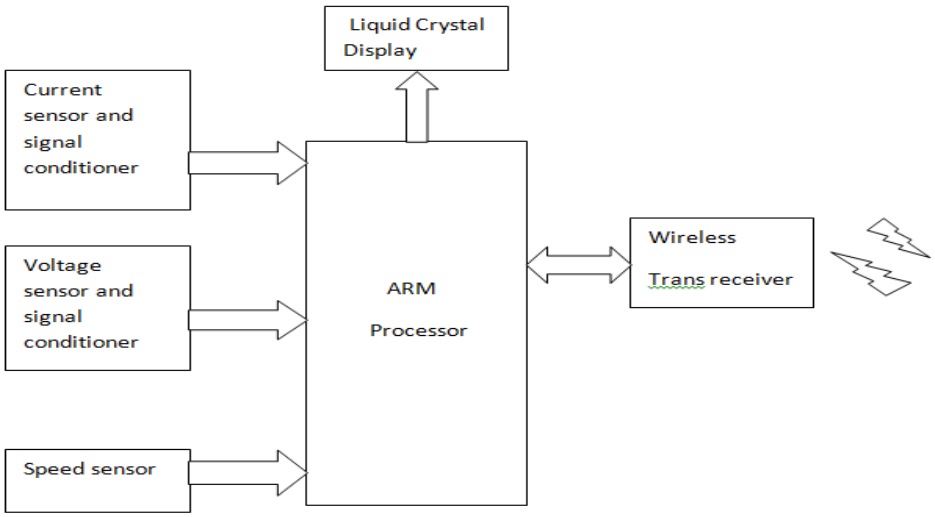



**Figure 1: Transmitter section**

This section consists of sensing voltage, current and speed for online dynamic torque and efficiency monitoring in three phase induction motor. For that purpose different sensors like voltage sensor, current sensor and speed sensor are connected to the motor. For sensing supply voltage we used step down potential transformer. As the input changes i.e. line to line AC voltage is changes then output of transformer also changes. Current sensor i.e. current transformer (CT) is used to measure the current drawn by the induction motor. Output of the current transformer is AC which gives the current in the range of 1 amp to 30amp flowing through primary winding. For measurement of speed Hall Effect sensor is used. It measures the speed of motor in revolution per minute (rpm). Hall Effect sensors can be applied in many types of sensing devices, if the quantity to be sensed incorporates or can incorporate a magnetic field.

Information gathered at transmitter section is transmitted to receiver section. Block diagram of receiver section is as follow. At receiver all the information is passed from wireless module ZigBee through serial communication for calculation of Torque and Efficiency [6].

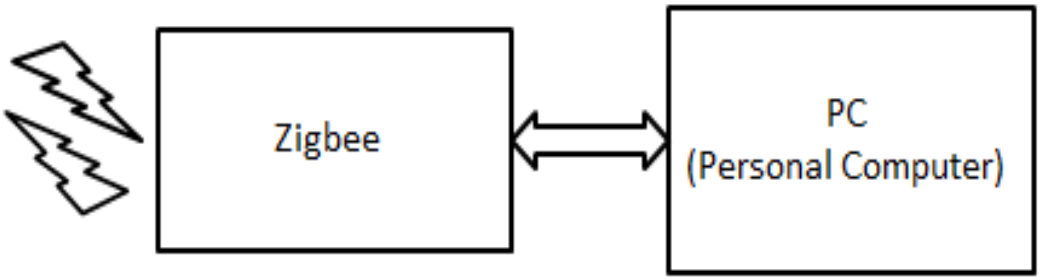



**Figure 2: Receiver Section**

This calculation part is done in Visual Basic (VB) language by using Visual Studio2008 software with local processing capability. The VB have Graphical User Interface (GUI) application for user to interface with system. It gives the display of the parameters measured such as current, speed, voltage, torque and efficiency on PC for real time monitoring.

### 2.1 Shaft Torque Estimation

In an induction motor, the air gap is the region between stator and rotor, where occurs the electromechanical conversion process. The AGT is the conjugate formed between the rotor and the stator magnetic flux. The AGT method is used to estimate the motor shaft torque. The estimation of the AGT is performed noninvasively taking current, voltage and speed measurements from the electric motor [4].

$$T_{aig} = 60 \text{ xVxI}/2x \pi \text{ x RPM} \quad (1)$$

Where, $T_{aig}$ = Air Gap Torque

V = Voltage

I = Current

The torque on the shaft can be estimated by subtracting the losses occurring after the process of electromechanical energy conversion from AGT, is

$$T_{shaft} = T_{aig} - \text{Losses} \quad (2)$$

Where, $T_{shaft}$ = Shaft Torque

### 2.2 Efficiency Estimation

The motor efficiency η can be estimated by the relation between the electrical power supplied to the motor (i.e., input power Pin) and the mechanical power supplied to the shaft by the motor (i.e., output power Pout), according to the following equation [4]:

$$\eta = P_{out} / P_{in} \quad (3)$$

Where, η = Efficiency

$P_{out}$ = Output Power

$P_{in}$ = Input Power

Pin of motor can be calculated by the input currents and voltages, according to the following equation:

$$P_{in} = VxI_{stator} \quad (4)$$

Pout can be determined by the estimated shaft toque and the rotor speed as follows:

$$P_{out} = T_{shaft} x \omega_r \quad (5)$$

Where, $\omega_r$ = Angular Speed

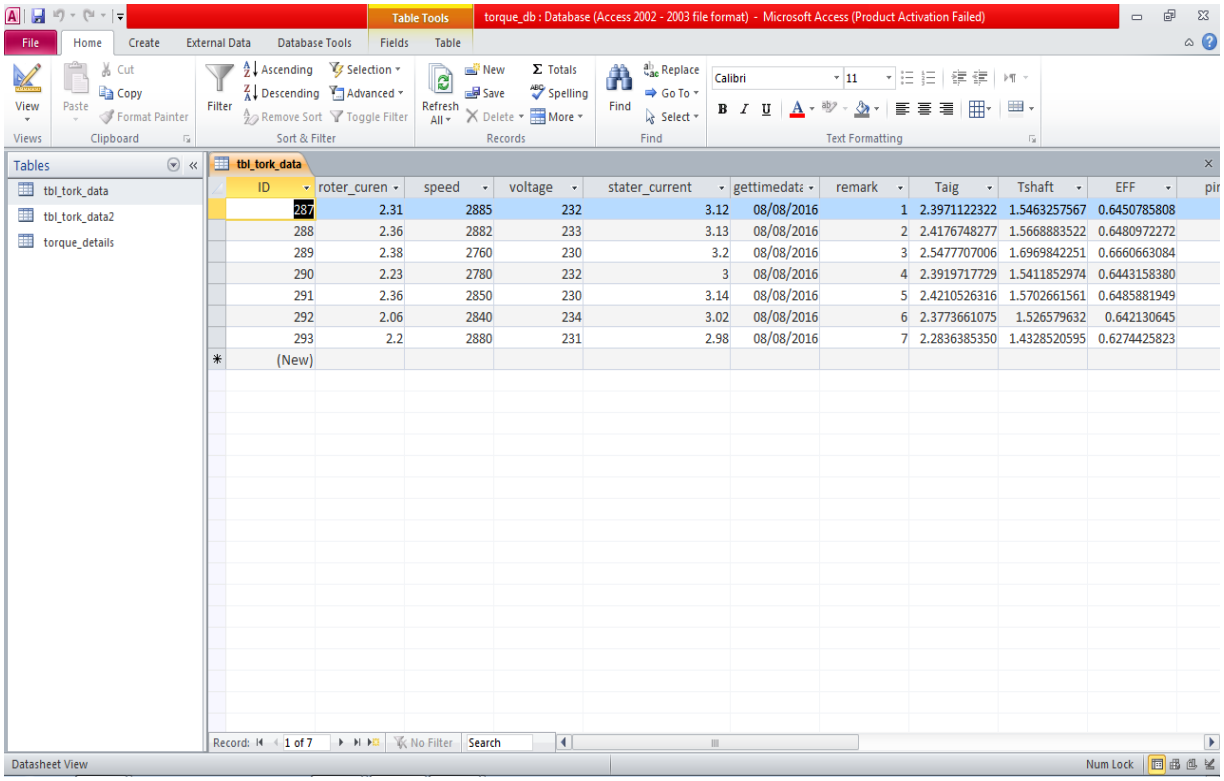
i.e. $P_{out} = T_{shaft} \times 2 \times \pi \times RPM / 60$ (6)

Hence the efficiency η can be estimated as follows:

$\eta = T_{shaft} \times 2 \times \pi \times RPM / 60 \times V \times I$ **(7)**

## III. Results

### 3.1 For constant value of load



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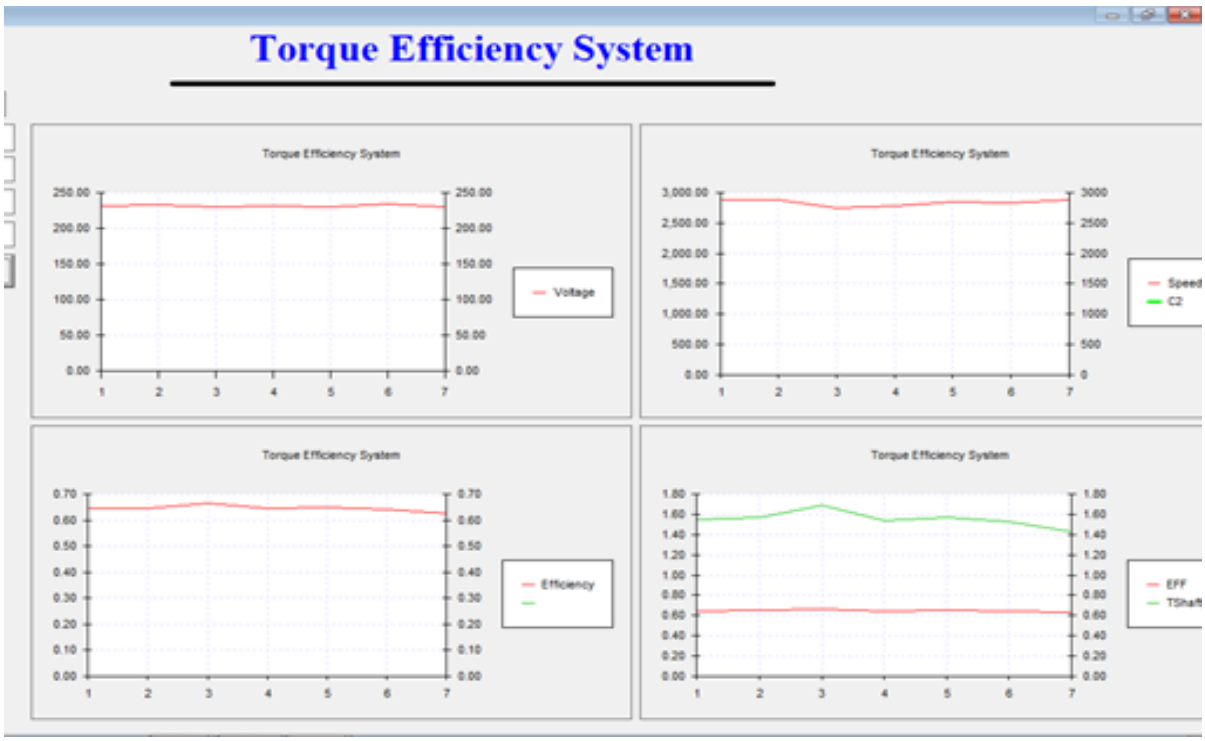
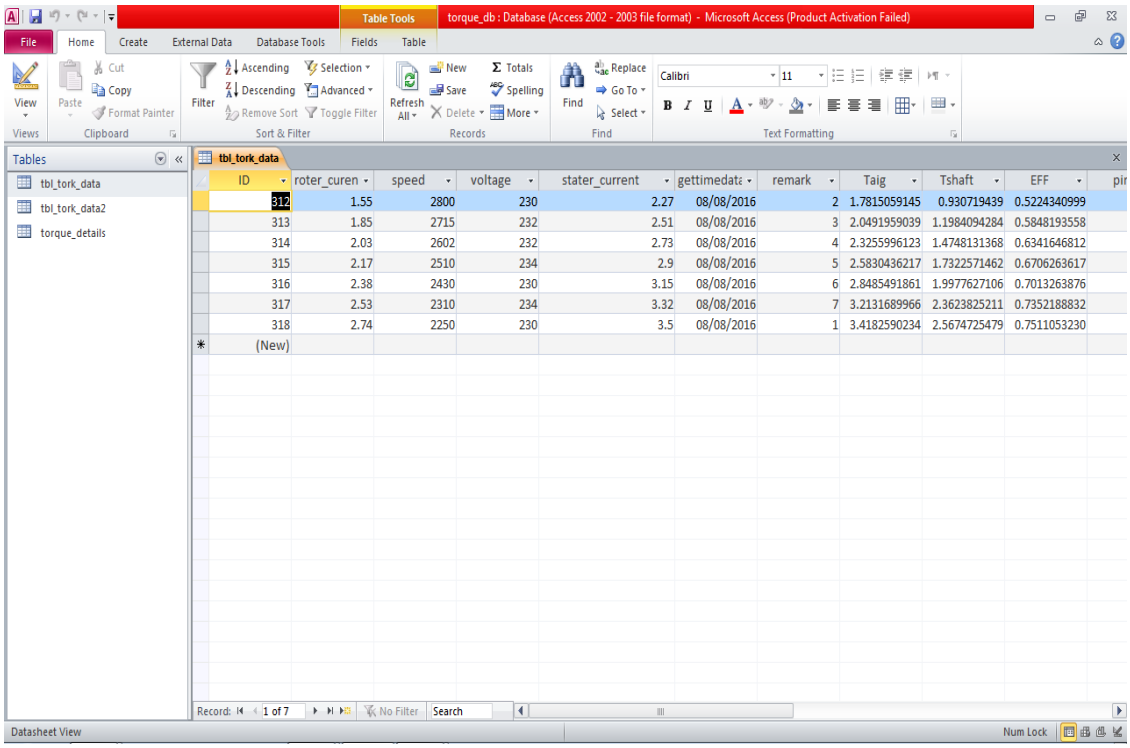



**Figure 3: Torque and Efficiency Curves for constant value of load**

## 3.2 For increase in value of load




| ID | roter_curen | speed | voltage | stater_current | gettimedata | remark | Taig | Tshaft | EFF |
|---|---|---|---|---|---|---|---|---|---|
| 312 | 1.55 | 2800 | 230 | 2.27 | 08/08/2016 | 2 | 1.7815059145 | 0.930719439 | 0.5224340999 |
| 313 | 1.85 | 2715 | 232 | 2.51 | 08/08/2016 | 3 | 2.0491959039 | 1.1984094284 | 0.5848193558 |
| 314 | 2.03 | 2602 | 232 | 2.73 | 08/08/2016 | 4 | 2.3255996123 | 1.4748131368 | 0.6341646812 |
| 315 | 2.17 | 2510 | 234 | 2.9 | 08/08/2016 | 5 | 2.5830436217 | 1.7322571462 | 0.6706263617 |
| 316 | 2.38 | 2430 | 230 | 3.15 | 08/08/2016 | 6 | 2.8485491861 | 1.9977627106 | 0.7013263876 |
| 317 | 2.53 | 2310 | 234 | 3.32 | 08/08/2016 | 7 | 3.2131689966 | 2.3623825211 | 0.7352188832 |
| 318 | 2.74 | 2250 | 230 | 3.5 | 08/08/2016 | 1 | 3.4182590234 | 2.5674725479 | 0.7511053230 |
| (New) | | | | | | | | | |

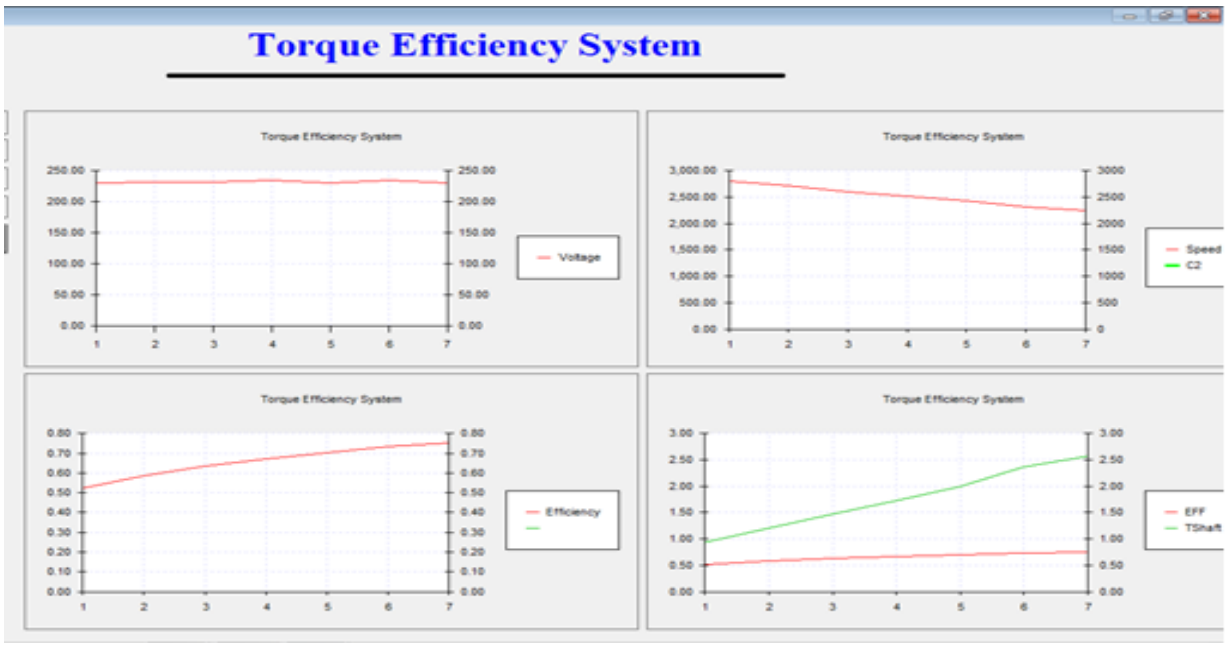



**Figure 5: Torque and Efficiency Curves for increase in value of load**

### 3.3 Discussion

From above comparisons it was shown that as the speed is decrease from its higher value to lower value with increase in load corresponding to that torque and efficiency of motor increases. As we keep the value of load constant that time speed also constant.

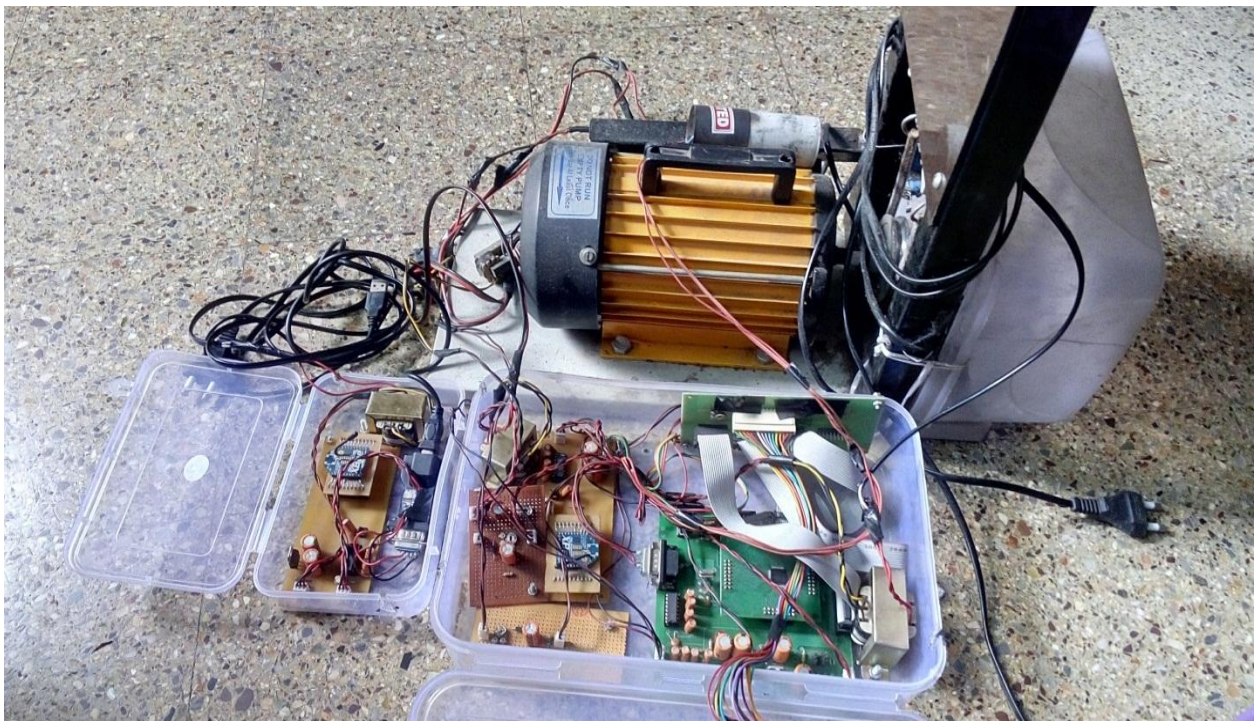


**Figure 5: System Setup**

## IV. CONCLUSION

The developed system gives an efficient mechanism for online monitoring of torque and efficiency in induction motor. All the data processing is done locally through ZigBee in non-invasive manner, so we can reduce the inconvenience of the user to deal with the working motor and its surrounding. Through this model we can implement a system for online monitor and control of multiple motors in real time through an efficient microcontroller and wireless module with more maintenance and low cost.

## V. SCOPE FOR FUTURE WORK

Motor efficiency is main factor we are all think further as the cost of power is increasing day by day, and shrinkage of the non-renewable resources. Through this project we can implement a system which can help us to improve motor efficiency to a good extend. By adjusting the motor speed we can reduce the initial cost of the higher gearbox also. Wireless system employed can easily log the data for monitoring the motor has degraded or not. Even through this we can turn ON/OFF the motor remotely through wireless protocols.

## VI. ACKNOWLEDGEMENT

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