International Conference of Science, Engineering & Environmental Technology (ICONSEET), 2(22): 168-175, 2017
ISSN 0794-9650
www.repcomseet.com

Development of a Wireless Induction Motor Unbalanced Voltage Detection and Control System for Hazardous Environments

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Abstract - The monitoring of the induction motor operating in hazardous area is essential in industries for better performance and safety. This paper describes development of stator input voltage variation monitoring and control system of an induction motor operating in hazardous areas using wireless technology. The system was developed using CC1101 radio modules, current, voltage, and temperature sensors alongside with signal processing device based on PIC18F4550 microcontroller. The circuit was designed and simulated with DipTrace Software and it was tested for various possible cases of voltages unbalance conditions. Motor automatically switched off if any harmful condition arises.

Keyword; Diptrace Software, CC1101, Hazardous Area, PIC18F4550, Signal Processing, Voltage Variation.

1. Introduction

Induction motors are most widely used electro-mechanical devices in variety of applications and since they are low-priced, simple, robust, and rugged, they are considered worldwide as the workhorse in industrial applications (Chaturvedi, Akash, Mayank, & Sharif, 2014). The induction motors are used to drive the mechanical system in hazardous area and non-hazardous area.

Hazardous area is an area in which the atmosphere contains, or may contain flammable or explosive gases, dusts or vapours in sufficient quantities. In such an atmosphere fire or explosion is possible when there is fuel, oxygen, and a source of ignition (spark or temperature) (Redapt Engineering, 2007). Major industries involved include oil, gas, petroleum refineries, chemical plants, sewerage treatment and coal mines. Electric motors can pose a serious threat when they are operated in a location that contains combustible materials. Arc, spark, high temperature as a result of voltage variation and faults can ignite hazardous substances and cause an explosion (Uriah, 2011). Therefore, the use of any electrical apparatus in these areas must be strictly monitored and controlled through various protection techniques to enable the operators to facilitate the handling or processing of the hazardous materials. In order to protect operator and other staffers of the above mentioned industries from a potential explosion, a method of remote monitoring of unbalanced voltage supply and controlling of induction motor operating in hazardous area is required. The purpose of this is to ensure the correct operation of motor and other installation to ultimately prevent an explosion and to ensure safety of life and properties.

1.1 Effects of Operating Motors in Hazardous Area.

Remote monitoring can be critical to controlling an emergency situation as it allows the emergency or dangerous situation to be identified early and response actions initiated quickly (Australia, 2012). To ensure maximum safety it is important that operators of hazardous location plants know when explosions are likely to happen and how to prevent it. Risks associated with operating an electric motor in hazardous area are production down time, injury and death (Uriah, 2011).

1.2 Effects of Voltage Variations on the Performance of Induction Motor

The effects of voltage variation is summarised as follows (Muttiullah, Abdul, Mansoor, & Amjad, 2017) ;

(a) The efficiency of the motor decreases steeply as voltage unbalance increases
(b) Motor consumes high power in under-voltage case
(c) Overvoltage cause poor power factor
(d) Output power is higher in over-voltage due to high efficiency of motor
(e) Losses are higher in under-voltage due to lower efficiency of motor
(f) Losses cause heating in the winding of the motor causing damage to winding and reducing life span of motor.

1.3 Causes of Unbalanced Voltage in Power Systems

Unbalance voltage can occur due to (Zhao, Ciufo, & Perera, 2012);

(i) Intermittent load or strong fluctuations in power demand
(ii) Presence of larger single-phase consumers,
(iii) Presence of higher harmonics in the supply voltage (Miloje, 2012)

1.4 Wireless network

It is a network that uses infrared or radio frequency signals to share information and resources between devices instead of cables to relay information (Navpreet, 2014). Wireless networks take advantage of allocated segments in the radio spectrum for license-free transmission of data. The segment is known as Industrial, Scientific and Medical (ISM) bands. License-free transmissions are allowed in three bandwidths: 900 MHz, 2.4 GHz and 5.8 GHz. The range is shown in Table 1 (Don, 2015).

Table 1: ISM Band

Band	Frequency Range
900MHz	**902-928 MHz**
2.4GHz	**2.400-2.500 GHz**
5.8GHz	**5.725-5.875 GHz**

Frequency band greatly influenced the performance of wireless devices, transmissions in the 900 MHz band go farther and the 2.4GHz and 5.8 GHz bands offer greater bandwidth and higher data transmission rates (Don, 2015). 915 MHz is used in this research because it penetrates solid objects better than the 2.4 GHz and 5.8 GHz bands.

1.5 CC1101 Technology

The wireless data transceiver module used in this work consists of CC1101 wireless RF chip produced by Texas Instrument Enterprise. It is a high-performance RF transceiver with less than 1 GHz frequency designed for very low-power wireless applications. The circuit is mainly intended for the ISM research and Short Range Device (SRD). It provides extensive hardware support for packet handling, data buffering, burst transmissions, clear channel assessment, link quality indication, and wake-on-radio. The recommended application circuit by the manufacturer is shown in Figure 1 while the module is as shown in Figure 2 and it is used in this work.

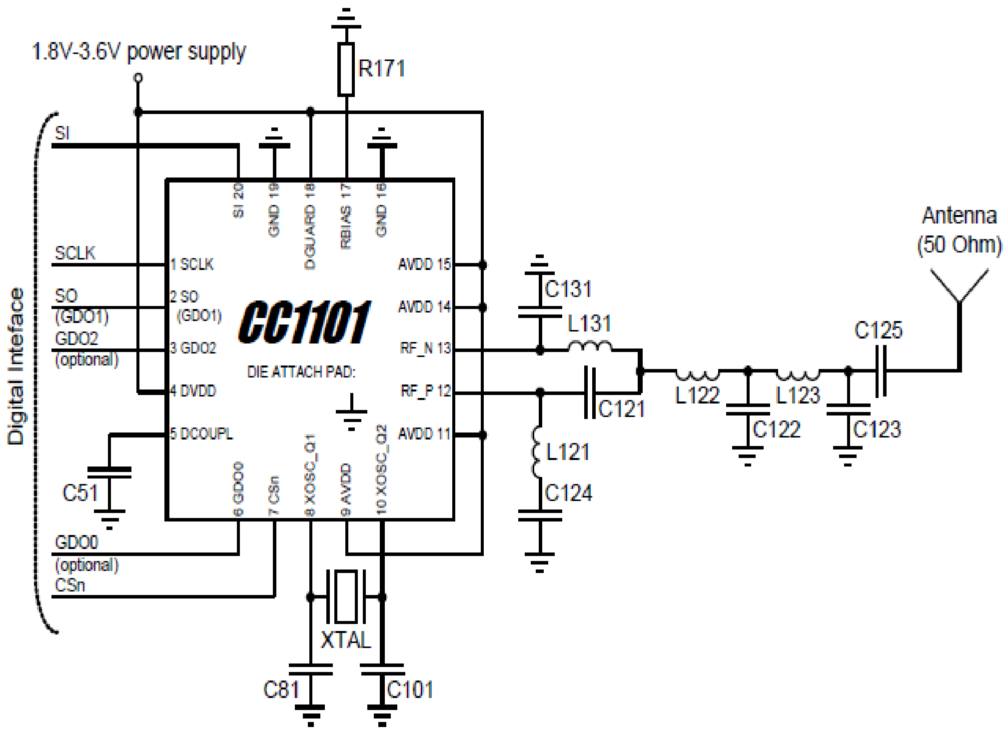

Figure 1: CC1101 circuit diagram

Figure 2: CC1101 module

The proposed design uses a helical antenna as the power transmitting and receiving antenna. This is a wide-spread type of antenna for radio wave frequency and most cases used with a ground plane. Practical configuration of this electromagnetic radiator is that of a conducting wire wound in the form of a screw thread forming a helix. It consists of 20 turns, diameter 0.4cm and spacing of about 1mm between each turn. equation (1) is used to determine the antenna gain (Tomasi, Wayne, 2004).

$$G_{ain} \sim 15 \left[\frac{c}{\lambda}\right]^2 \left[\frac{NS}{\lambda}\right] \qquad (1)$$

where N is the number of turns, S is the spacing between turns. Most designs use C=λ and S=0.23*C (Tomasi, Wayne, 2004).

Friss Transmission Equation for free space propagation was used to determine how far the two transceivers will be apart from each other. The power received at each antenna and distance between the two transceivers can be calculated using equations (2) and (3) respectively. (Texas Instruments, 2010).

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2} \quad (2)$$

$$d = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r}{P_r}} \quad (3)$$

where P_t and P_r are transmitted and received power respectively, G_t and G_r are transmitter and receiver antenna gain respectively, d is the distance between transmitter and receiver, or the range and λ is the wavelength. Equation (4) is the wavelength equation and f is the frequency.

$$\lambda = \frac{c}{f} = \frac{speed\ of\ light}{frequency} \quad (4)$$

2 The Proposed Induction Motor Remote Monitoring System

A powerful remote monitoring system has been achieved for an induction motor by using CC1101 chip produced by Texas Instrument. The parameters such as voltage, current and temperature were measured, monitored and are compared with the threshold values using coordinator device based on PIC18F4550 microcontroller. A control panel (Graphic user interface) was also developed to display the measured values on PC and for switching on and off of induction motor via the CC1101 module.

Basic block diagram of the proposed monitoring system is as shown in Figure 3, it consists of induction motor, current sensor, voltage sensor, temperature sensor, relay circuit, coordinator device based on PIC18F4550 microcontroller, personal computer and CC1101 radio transceiver module.

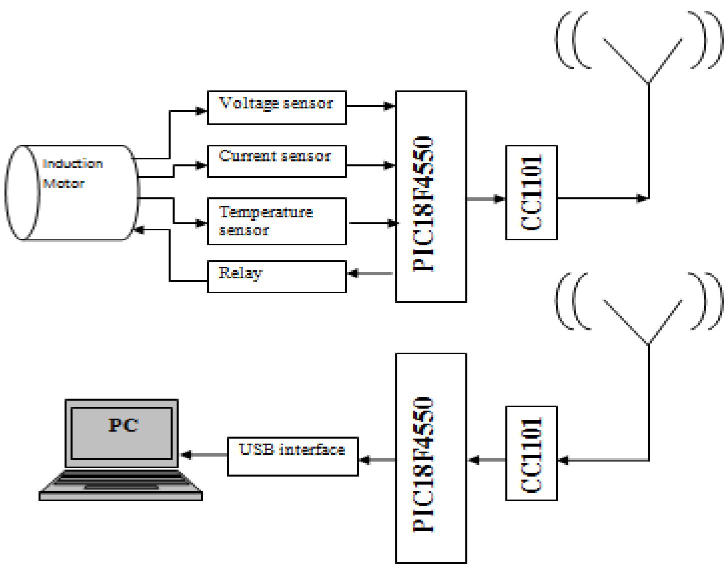

Figure 3: Block diagram of proposed system

2.1 Signal Processing Device

The signal processing device is PIC18F4550 microcontroller based; it is the core of the system. It responses to data from sensor, process data, codes the data, and transmit to the remote data signal processing device wirelessly via CC1101 transceiver module.

The PIC18F4550 device manufactured by microchip is incorporated with 13 input channels, 10 bit high speed analog-to-digital converter (ADC) that allows continuous conversion of analog output signals of potential transformer (voltage sensor), ACS712 (current sensor) and thermistor to discrete digital numbers. Printed circuit board (PCB) and schematic diagram design for complete hardware is done using DipTrace software are as shown in Figures 4 and 5 respectively.

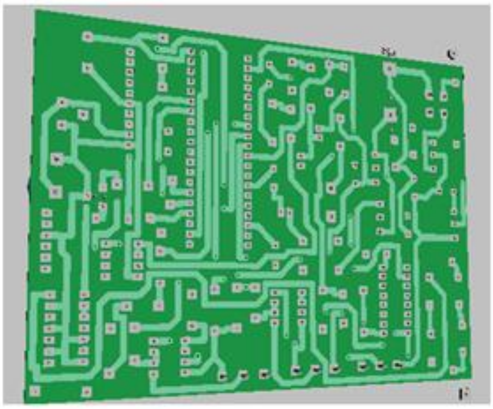

Figure 4: Printed circuit board (PCB)

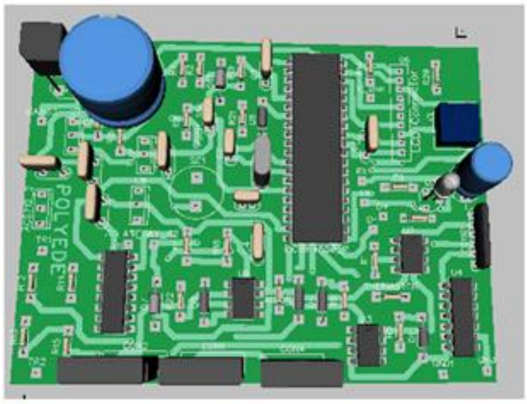

Figure5: Schematic diagram

2.2 Principle of Operation

Monitoring unit that consists of sensors and transducers is used to monitor parameters such as voltage, current, and temperature of stator winding of the induction motor. The monitored data is simultaneously fed to the PIC18F4550 microcontroller, process it and display on PC. After starting of the motor the parameters are measured by signal processing device and compared with programmed threshold values. If the value is satisfied, the motor continues in running mode or else the motor stop running

The PIC18F4550 micro-controller at the transmitter end is programmed such that if the monitored parameter of induction motor exceeds the threshold value, a signal will be generated by the PIC18F4550 micro-controller that will energize the relay circuit and the contactor cuts the mains supply to the induction motor. This data is transmitted to the receiver end through CC1101 radio transceiver module and display on PC.

2.3 System Implementation

The first stage is hardware implementations and these consist of;

(i) Connection of the sensors, relay, induction motor, signal processing device and CC1101 radio transceiver module.

(ii) Connection of CC1101 radio transceiver module, signal processing device and PC at the remote control and monitor office.

The second stage is the development of software for the system using MicroC microcontroller programming language. Flow chart shown in Figure 6 describes the programming steps that were executed in the program. And the third stage is the application of the remote control by starting induction motor.

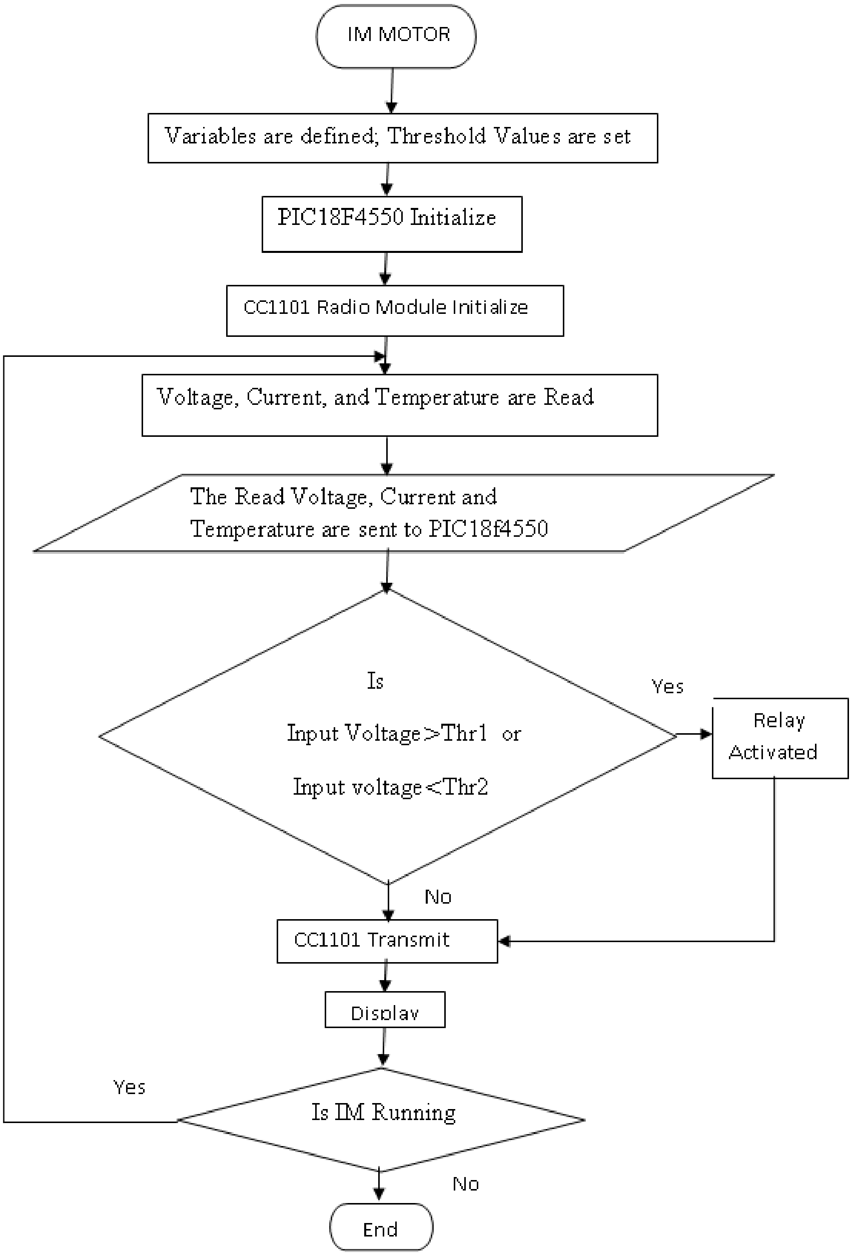

Figure 6: Programme flow chart

3 Results

Graphical User Interface Development Environment (GUIDE), a building environment for MATLAB apps was used to design customized graphical user interface (UI) termed as Motor monitoring and control interface as depicted in Figure 7. Motor monitoring and control interface is used for continuous monitoring and controlling of the induction motor. With the system developed stator input voltage, current and winding temperature were measured simultaneously and displayed on the motor monitoring and control interface as shown in Figure 7.

CASE I- When the supply voltage of 253V is induced, at same instant of time the motor stops working and message was displayed on the motor monitoring and control interface.

CASE 2- When the supply voltage of 207V is induced, at same instant of time the motor stops working and message was displayed on the motor monitoring and control interface

Continuous displaying of codes sent by both CC1101 on remote motor monitoring and control interface ensures perfect communication and coordination between motor and PC.

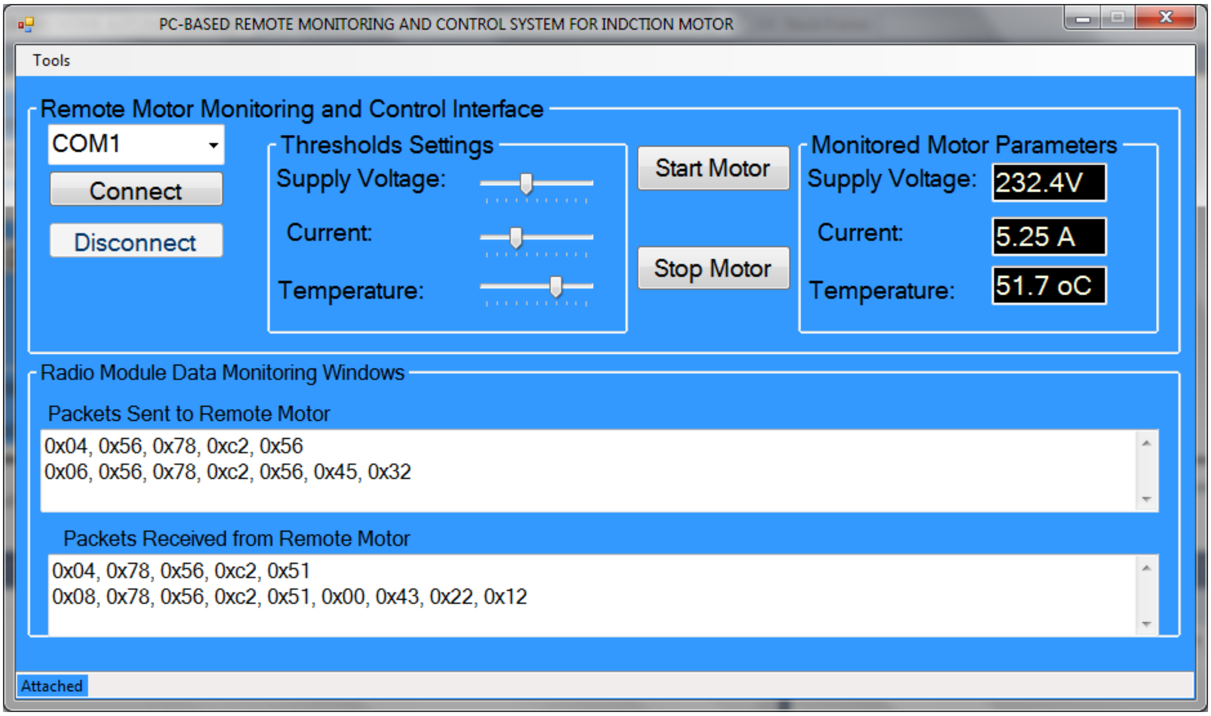

Figure 7: Motor monitoring and control interface

4 Conclusion

In this study, a system of controlling and monitoring induction motors through CC1101 radio modules has been implemented. This designed system enables the operator to monitor and control the induction motor anywhere within the designed rage. Therefore, it ensures safety of life in case of any hazard. The test result has been found successful in monitoring and controlling the induction motor.

With this instrumentation, the developed system can be moved from the laboratory to the industrial floor. Data collected can be recorded and used for scheduling of the motor servicing, troubleshooting and also for future references, therefore reduces down time.

References

[1] Australia, S. W. (2012). Managing Risks of Hazardous Chemicals in The Workplace; Code of Practice. Australian: Australian Government statutory agency.. Available on www.safeworkaustralia.gov.au

[2] Chaturvedi, D., Akash, G., Mayank, P., and Sharif, I. (2014). On Line Fault Identification of Induction Motor using Fuzzy System. International Journal of Computing Science and Communication Technologies , 6(2), pp 964-970.

[3] Don, P. D. (2015). So Many Wireless Technologies …: Which Is the Right One for My Application? USA: Phoenix Contact. Available on www.phoenixcontact.com

[4] Redapt Engineering, (2007). Hazardous Area Technical Guide. United Kingdom: Redapt Engineering Company Limited. Available on *www.redapt.co.uk*

[5] Miloje, K. (2012). Effects of Voltage Quality on Induction Motors' Efficient Energy Usage. **Rui** Esteves Araújo, Induction Motors – Modelling and Control, INTECH, ISBN 978-953-51-0843-6, pp. 127-156.

[6] Muttiullah, M., Abdul, K. J., Mansoor, S., and Amjad, A. (2017). Performance Analysis ofInduction Motor Operating at Unbalanced Under and Overvoltage supply-A comparative approach. Engineering Science And Technology International Research Journal, 1(1), pp 32-37.

[7] Texas Instruments, (2010) Designer's Guide to Low Power RF**,** Texas Instruments Incorporated. Available on www.ti.com

[8] Tomasi, Wayne (2004). Electronic Communication Systems- Fundamentals Through Advanced. Jurong, Singapore: Pearson Education SE Asia Ltd. ISBN 981-247-093-X

[9] Navpreet, K. S. (2014). Comparisons Of Wired And Wireless Networks: A Review.International Journal of Advanced Engineering Technology, 5,(2), pp 34-35.

[10[Uriah, V. A. (2011). Choose The Right Electric Motor For Hazardous Locations. American Institute of Chemical Engineers , pp 18-23. Available on *www.zeton.com/site/pdf*

[11] Zhao, K., Ciufo, P., and Perera, S. (2012). Induction motors subject to regular voltage fluctuations: Stator and rotor current analysis from a heating perspective IEEE International Conference on Harmonics and Quality of Power, pp. 642- 648.