
Design of a Wireless Control for an Induction Motor

By

***Omorogiuwa, O. S. and **Nwukor, F. N.**

*Department of Electrical and Electronics Engineering
University of Benin, Benin City, Nigeria

**Petroleum Training Institute, Effurun, Delta State, Nigeria

*Email: sam@uniben.edu, francesnkem@gmail.com

ABSTRACT

This paper presents a design of a wireless control for an induction motor. The design was actualized basically using diodes, capacitors, resistors, transistors, transformer, relays, voltage regulator, microcontroller, GSM module and wi-fi module. The design involves using a combination of four IN4007 diodes to form a bridge rectifier. The voltage regulator was used to provide an output DC voltage that remains constant irrespective of load variations or changes in input AC voltage. The microcontroller performs the task of receiving commands from the user's PC via the wi-fi module or GSM module. The switching section performs the function of switching the regulator to various speed level. To effectively vary the speed of the motor, the maximum distance cover for the wi-fi is 100M, while for the GSM any range as long as there is network service provider. The design performance under test was found to be satisfactory. The design of a wireless control system is one approach to tackle the various problems associated with a wired control system.

KEYWORDS: Induction motor, Microcontroller, GSM Module, (Wi-Fi) Wireless-Fidelity, Relay, Transistor and Resistor.

INTRODUCTION

Induction motors are mostly used in industry and domestic applications; they are the most widely used electrical motors due to their low cost, reliability and robustness. As many of the industries use induction motors, controlling of induction motor plays a very vital role. It is necessary to design an efficient and safe speed control mechanism for an induction motor so as to enable the effective variation of the motor speed and thus reduce energy consumption. One method of varying the speed of an induction motor over a narrow range is by varying the voltage applied to the stator winding. This method of speed control is suitable for applications such as centrifugal pump drives and electric fan.

The traditional methods of controlling various equipment and machineries usually involved using wires to open or close circuits. The application of such methods in the industry usually came with an extensive financial cost of wires and connecting cables, and manpower. Also the disadvantages associated with the use of wires such as insulation breakdown, corrosion and oxidation, and other wear and tear contributed to the need for more sophisticated and cost effective methods.

This paper is to develop a control system that will be used for the switching on/off, and controlling the speed of an induction motor by two means: using any device that can be connected to the internet by the use of the Wireless-Fidelity (Wi-Fi) and also using GSM

technology, that is, the use of smart devices which makes use of Wi-Fi and text message to connect to the control circuit which is connected to the motor. The use of Wi-Fi or GSM technology allows the motor to be controlled from a remote location (Prabodh et al, 2016).

The design of a wireless control system is one approach to tackle the various problems associated with a wired control system; cost is greatly reduced since the wireless system is far cheaper than lengthy cables. The system is more reliable and safe as the Human Machine Interface is reduced and there is lower probability of electric shock due to faulty system. This paper will be able to provide a blueprint for the control mechanism that can be locally constructed and applied for industrial uses. Therefore, it is anticipated that this study would generate a great deal of interest, not only among industries, but also among the general public.

An electric motor that produces rotor current is required to generate the torque through the principle of electromagnetic induction in the magnetic field. It performs an important function of converting electric energy to mechanical energy; which is utilized in carrying out different physical task. The two types of induction motor targeted in this paper are: single phase induction motor and three phase induction motor.

Though having many applications, induction motor (single phase) possesses many advantages too, such as: Easy to construct; Cheap cost; Higher reliability; Easy to repair and Lower maintenance cost.

There are two major components in an induction motor, viz:

1. The stationary part called stator
2. The rotatory part called the rotor

In single phase induction motor, the alternating supply is usually fed into the stator winding. The rotatory part is connected to the mechanical load through the shaft. A small gap or distance called air gap is usually allowed in between the rotor and the stator to avoid direct contact of the two components. In the air gap, flux linkage and interaction of both the rotor field and the stator field takes place, the windings in the stator part of a single phase induction motor consists of main winding and auxiliary winding. The auxiliary winding in the stator is usually made perpendicular to the main winding. Normally, the winding with more turns in the single-phase induction motor is the main winding while the other with few turns is the auxiliary winding.

DESIGN OF THE INDUCTION MOTOR

The design of the induction motor is presented by designing the different sections which is presented below.

POWER SUPPLY SECTION

The DC power supply unit consists of a step down transformer, Bridge rectifier, a simple capacitor filter, a voltage regulator, and power indicator. In this design, the power supply unit is required to provide an output of 5V DC.

CHOICE OF TRANSFORMER

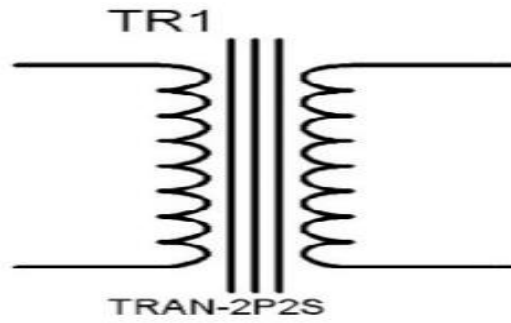


Figure 1: transformer

The DC voltage required for various components are 5volts (for the Arduino, SIM900A and relays), 3.3Volts (for the ESP8266 Wi-Fi chip). The transformer chosen is a 220/12Volts, 500mA transformer which provides an output of 12Volts from a 220V input AC supply. This transformer rating was chosen because it is capable of supplying a root mean square voltage of 12Vrms to the full wave bridge rectifier circuit in order to produce the constant 5V DC required at the output of the power supply circuit. A voltage of 12V is desirable at the input of the rectifier circuit because it is sufficient to compensate for the voltage drops across the individual components used at various section of the power supply circuit. For example, there will be a 0.7V drop across the rectifier diodes in each half cycle, there will also be voltage drops across the filter capacitor, the regulator circuit as well in the power indicating LED.

CHOICE OF RECTIFIER DIODE

A combination of four (4) IN4007 diodes was chosen to form a bridge rectifier. The bridge rectifier diodes were chosen based on the peak inverse voltage (PIV) and the current of the diode.

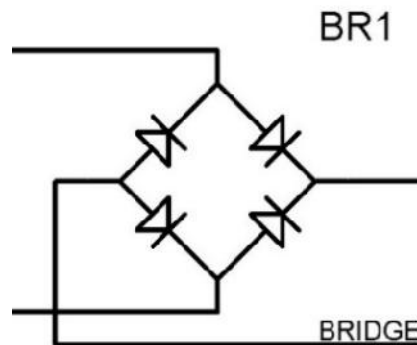


Figure 2: Rectifier circuit

For a 12V_{rms}, the peak voltage is given as;

$$V_{Peak} = \sqrt{2} \times V_{rms}$$

$$= \sqrt{2} \times 12V$$

$$V_{Peak} = 16.97Vac$$

1

Also, PIV = 2V_{Peak} = 33.94V

The peak inverse voltage of the diodes should be greater than 33.94V. Therefore, IN4007 was chosen whose peak voltage is 100V and a current of 1A which is specified by the

manufacturer in the data sheet of semiconductors. The voltage drop across the bridge rectifier which is made up of silicon diodes is;

$$V_{\text{drop}} = 0.7 + 0.7 = 1.4\text{V} \text{ (Silicon diode was used)} \tag{2}$$

$$\text{Rectified output voltage} = V_{\text{peak}} - V_{\text{drop}} = 16.97 - 1.4\text{V} = 15.57\text{V}$$

CHOICE OF FILTER CAPACITOR

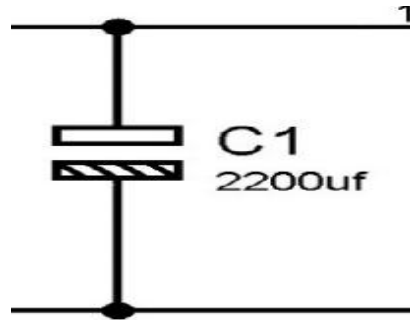


Figure 3: capacitor

The voltage of the filter capacitor must be able to withstand at least 1.5 times the rectified output voltage. Hence,

$$V_c = 1.5 \times 15.57 = 23.6\text{V}$$

Where V_c is the voltage rating of the capacitor. Since a capacitor with this value cannot be found in the market, the next available higher voltage rating is chosen, which 35V is.

The capacitance of the filter capacitor must be chosen based on the ripple voltage of the rectifier output should not exceed 30% of the output voltage.

$$\text{Ripple voltage } V_R = 30\% \text{ of rectified voltage} = 30/100 \times 15.57\text{V} = 4.67\text{V}$$

From the ripple voltage equation;

$$V_R = I_{dc} / 2fC \tag{3}$$

C = capacitance of the capacitor in Farads.

f = frequency of supply = 50 Hz

I_{dc} = maximum current from diodes = 1000 mA (1N4007)

$$C = I_{dc} / 2fV_R \tag{4}$$

$$= 1 / (2 \times 50 \times 4.67)$$

$$C = 214\mu\text{F}$$

Since a capacitor with the above value cannot be obtained in the market, so the next available higher capacitance is chosen. The value of capacitor chosen was 2200 μF . Hence the capacitor chosen has a voltage rating of 35V and capacitance of 2200 μF (i.e. 2200 $\mu\text{F}/35\text{V}$).

CHOICE OF VOLTAGE REGULATOR

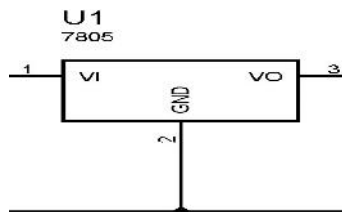


Figure 4: voltage regulator

The role of the voltage regulator is to provide an output DC voltage that remains constant irrespective of load variations or changes in input AC voltage. The LM78XX series is a series of fixed positive voltage regulators. They are designed for positive input. It typically has the ability to drive current up to 1A. The component can hold up to 36VDC common leg (GND) and an output leg with the regulator’s voltage. For maximum voltage regulation, adding a capacitor (known as Transient capacitor) in parallel between the common leg and the output is usually recommended. This eliminates any frequency AC voltage that could otherwise combine with the output voltage. The LM7805 was chosen because it performs the required function to provide the microcontroller with a constant 5V dc. The rating of the transient capacitor from the datasheet of LM7805 is 0.01µF (i.e. 103 ceramic). For effective regulation, the minimum input voltage should be:

$$V_{min} = V_{out} + V_{ref} \text{ (where; } V_{min} = \text{minimum input voltage, } V_{out} = \text{required output voltage} = 5V)$$

$$V_{ref} = \text{stipulated reference voltage} = 2V \text{ (from datasheet)}$$

$$V_{min} = 5 + 2 = 7V$$

Since the output voltage after filter capacitor is higher than 7V, therefore the voltage regulator can be comfortably used.

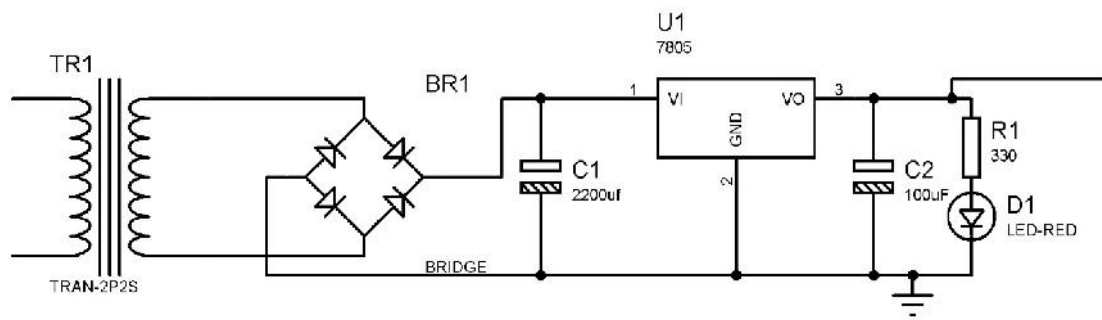


Figure 5: POWER SUPPLY UNIT

MICROCONTROLLER, GSM MODULE, AND WIFI SECTION

Choice of Microcontroller

The microcontroller performs the task of receiving commands from the user’s PC via the Wi-Fi module and GSM module and also sends necessary signals for switching of relays. ATMEGA328P was chosen based on the following reasons:

1. It is readily available in the market and at an affordable cost.
2. The Arduino-Uno has a clock speed of 16MHz. Hence, more instructions can be executed per second as compared to some other microcontrollers that have clock speeds of 8MHz

Choice of Wi-Fi Module

The ESP8266 Wi-Fi module was chosen because of its cheaper cost, availability in the market, and ease of use. It supports the 802/g/n Wi-Fi standard which is also supported by

most computer systems and mobile devices today.

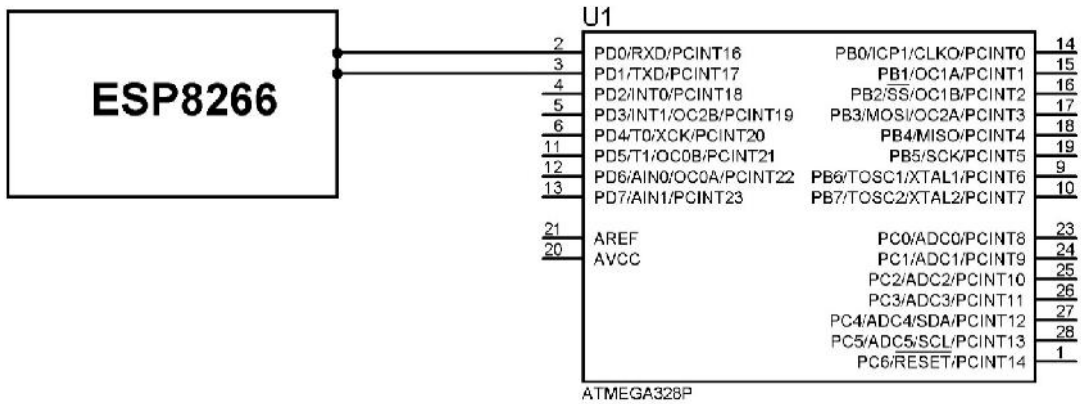


Figure 6: Microcontroller and Wi-Fi Modules

Choice of GSM Module

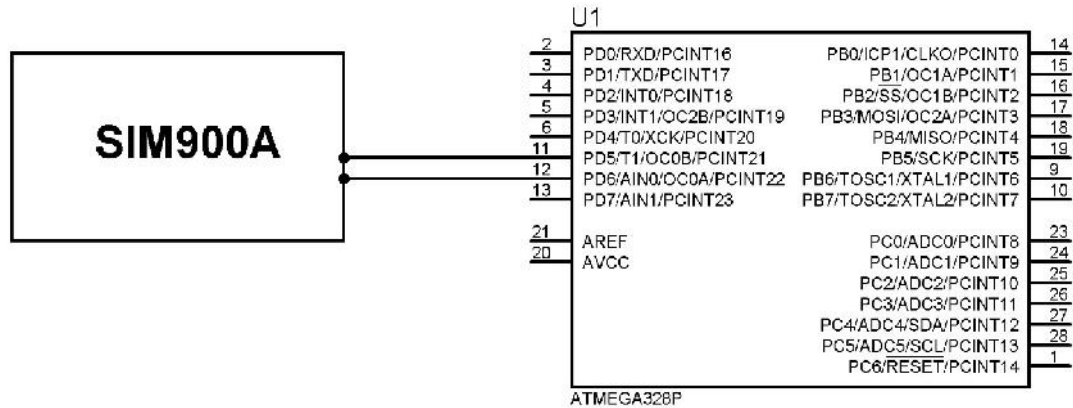


Figure 7: Microcontroller and GSM module

The SIM900A was chosen because of its ability to deliver GSM/GPRS 900/1800MHZ performance for SMS in a small form factor and it has a low power consumption. It has a small build and can be fitted easily in the design. It also has a suitable range of operating temperature, -40 to 85 degree Celsius.

SWITCHING SECTION

This section consists of various components which performs the function of switching the regulator to various speed levels. They receive signals from the microcontroller and effects necessary switching operations for proper speed control of the induction motor. The switching section consists of relays, fly-back diodes, transistors and biasing resistors.

Choice of Relay, Transistor and Biasing Resistors

A 5V relay was chosen because its coils can be effectively energized by the 5V DC which is available at the output of the power supply circuit. Typically, the relay with part number SRU-05VDC-SLC was chosen. From datasheet, this relay has the following characteristics:

- Nominal voltage = 5VDC
- Nominal current = 71mA

Nominal resistance = 70 ohms.

The NPN transistor BC548 was chosen, from datasheet, the hFe for BC548 is

$$\beta = 92,$$

$$V_{be} = 0.7V_s,$$

$$V_{cc} = 5V, V_{bb} = 5V, R_c = 70 \text{ ohms},$$

$$I_c = V_{cc}/R_c, = 5 / 70 = 71mA$$

$$I_b = I_c / \beta = 0.071 / 92 = 0.0007717A$$

$$R_b = (V_{cc} - V_{be}) / I_b = (5 - 0.7) / 0.0007717 = 5572.1 \text{ ohms}$$

The nearest value available in the market is 5600 ohms, hence this is chosen.

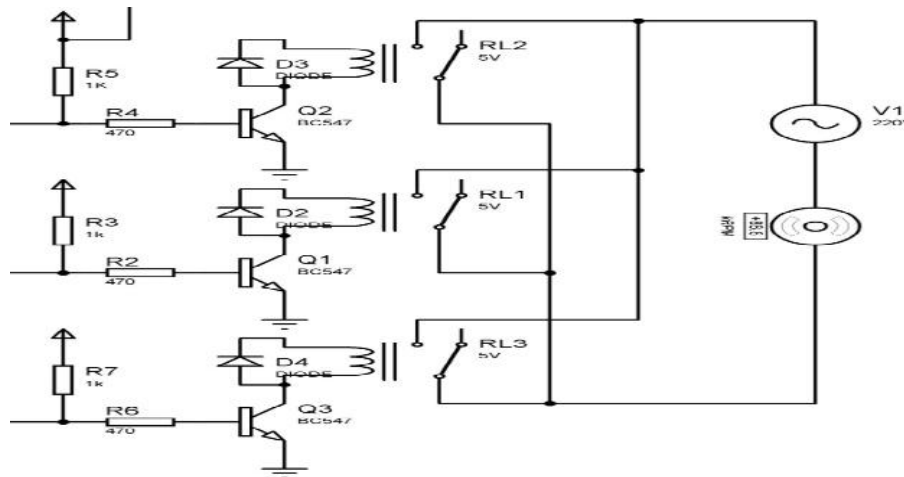


Figure 8: Switching circuit

MICROCONTROLLER (ATMEGA328P)

It is 28 pin IC which can operated as per programmed written. The control will be done by the microcontroller.

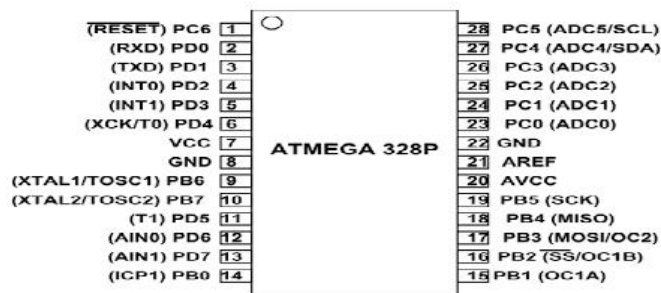


Figure 9: Microcontroller

WI-FI CONTROL MECHANISM

For communication, the ESP8266 module has both a SPI and an UART interface. In this system, the ESP8266 module was connected to the ATMEGA328P in order to send information to and to receive commands from the web server. The communication interface UART was used for connection. The Vcc pin of the Wi-Fi module was connected to 3.3V. The CH_PD (chip enable) pin and RST (reset) pin of the Wi-Fi module was also connected to 3.3V for normal operation. The Tx pin of the ESP8266 is connected to the pin 2 of the

microcontroller, and the Rx pin of the ESP8266 is connected to the pin 3 of the microcontroller (Springer Nature, 2018).

The mobile device must first establish connection with the WiFi network and the GSM communication line must be connected before the system can operate effectively. After successful connection has been established, the microcontroller waits to receive instructions from the user.

The GUI is programmed such that the highest speed level is assigned to the Speed-3 button, followed by the Speed-2 button and the Speed-1 button which controls the slowest speed level. The microcontroller was programmed such that whenever any button is clicked on the GUI, all other buttons (including the Switch-OFF button) are deactivated. However, whenever the Switch-OFF button is clicked, the 230V AC supply to the motor is completely disconnected and all the relays are de-energized, thus the motor stops running (Springer Nature, 2018).

GSM CONTROL MECHANISM DESIGN

Appropriate AT commands were written via the serial monitor interface to set up the GSM module to receive SMS. In order to configure the Arduino and SIM900A, the following command was inputted into interface (Brüggemann, et al, 2015).

AT + CMGF = 1 // Set the GSM Module in text mode

AT + CNMI = 2, 2, 0, o, o // AT Command to receive live SMS

For the GSM control system, the same functions as for the Wi-Fi section are carried out when a text message with the codes SPEED1, SPEED2, SPEED3, ON, or OFF is sent to the GSM module (Shubham Sarkar et al, 2017).

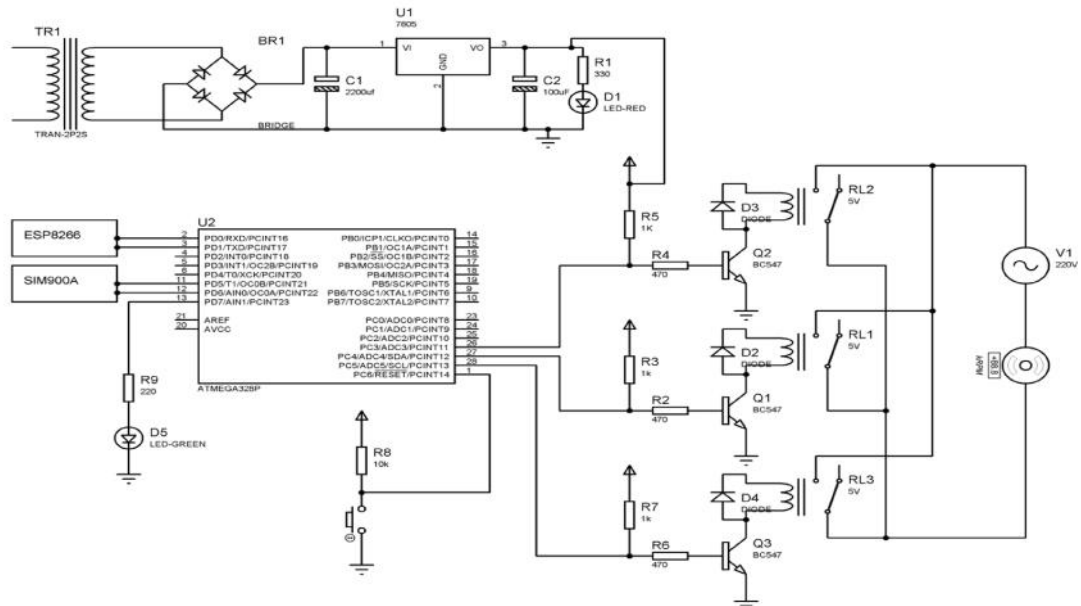


Figure 10: Complete circuit diagram

TEST OF SYSTEM AND RESULTS

The system was tested manually and it was found to be successful; below is the list of the test parameters. Replication of the characteristics of the wired system: it was recalled that

when the command was sent to the microcontroller through over Wi-Fi or SMS, the induction motor was turned on and regulated.

Effective range of use: The Wi-Fi section of the control system was tested to be effective over a range of 100 metres while the GSM section was effective over any range as long as there is a network service provider. There was a lot of motors, Wi-Fi modules, GSM modules, microcontrollers available for use while replicating our design. By varying the potential difference across the motor, we could vary the speed.

CONCLUSION

A prototype wireless control system for an induction has been designed, accompanying hardware were developed to facilitate the control. The ability of the wireless control system to replace a wired control for an induction motor was validated by conducting analysis on the range using various methodologies.

The results from preliminary testing of the wireless control system are promising and suggest that the device can provide a satisfactory alternative control methodology for suitable environment. The design of a wireless control for an induction motor was successfully achieved.

REFERENCES

- Ben Hamed M., and Sbita L. (2007), "Internal Model Controller of an ANN Speed Sensor less Controlled Induction Motor Drives," *Journal of Applied Sciences. JAS.*, vol. 7, no. 11, pp. 1456 - 1466.
- Brüggemann, T., D. Biermann, and A. Zabel, (2015). "Development of an Automatic Modal Pendulum for the Measurement of Frequency Responses for the Calculation of Stability Charts" , *Procedia CIRP*.
- Krommenacker N., and Lecuire V., (2005), "Building Industrial Communication Systems based on IEEE802.11g wireless technology," *In 10th IEEE International Conference on Emerging Tech. and Factory Automation*, pp. 71–78.
- Pohjola M., Nethi S., Jantti R. (2009): Wireless control of Multihop mobile robot squad. In: *Wire-less Communications*, vol. 16, pp. 14-20, IEEE press.
- Prabodh Sakhardande, Sumeet Hanagal, Savita Kulkarni. (2016) "Design of disaster management system using IoT based interconnected network with smart city monitoring", 2016 International Conference on Internet of Things and Applications (IOTA).
- Shen Jin, Song Jingling, Han Qiuyan, Wang Shengde, YangYan, (2007), School of Electric and Electronic Engineering, "A Remote Measurement and Control System for Greenhouse Based on GSM-SMS" IEEE 8th International Conference on Electronic Measurement and Instrument.
- Shubham Sarkar, Akash Patil, Aditya Hartalkar, Aditya Wasekar, (2017). "Earthquake rescue robot: A purview to life", 2017 Second International Conference on Electrical, Computer and Communication Technologies (ICECCT).
- Springer Nature, 2018, "Intelligent Communication, Control and Devices".