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A Parameter Monitoring System for Induction Motors Based on Zigbee Protocol

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ABSTRACT

In this study, a wireless control and monitoring system for an induction motor is realized using the Zigbee communication protocol for safe and economic data communication in industrial fields where the wired communication is either more expensive or impossible due to physical conditions. The induction motor can be started and stopped wireless due to the computer interface developed with Zigbee. It is also possible to protect of the motor against some faults such as over current, higher/lower voltage, over temperature in windings, overloading of motor. Moreover, a database is built to execute online measurements and to save the motor parameters received by radio frequency (RF) data acquisition system. Therefore, controlling, monitoring, and protection of the system are realized in real time. Since the wireless communication technology is used in this study, controlling abilities of the system are increased and also hardware and the necessities of other similar equipment for data communication are minimized.

Key Words: Induction motor, Zigbee, wireless data communication

1.INTRODUCTION

Three-phase induction motors are very popular in industrial applications because of their simple and safe structures. Therefore several controlling methods have been suggested to obtain a better controlling system for them. In recent years, traditional control systems have been given up, and adaptive and intelligent control systems have been used instead [1]. Toward the end of the 20th century, development in electronics, power electronics, and computer technology has started new progress in control technology and automation. Controlling of electrical motors used in various systems and process control, especially the induction motors, became very important because of its suitability in system design in industry and its many other advantages such as energy, time, and sensitivity [2]. High-performance AC motor control methods are very sensitive to motor parameters. Electrical parameters of the motor are used both in the mathematical model of motor and calculating torque and flux components. Parameters of an induction motor can be measured by some experiments like the locked rotor, unloaded experiments [3, 4]. Current, voltage, frequency, temperature, and speed data of the induction motors are very important for a drive system. The performance of an induction motor is directly affected by whole fundamental qualities. On the other hand, controlling the machines during the process of production continues to be a dangerous operation in some branches of industry. In such cases, remote control and monitoring techniques become a considerable solution to eliminate these hazards. Hence, wireless data communication is used in various industries. Wireless communication called Wi-Fi is capable of high data rate transmission, Bluetooth, and 3G in industrial companies. These devices use system resources a lot and are proportional to transmission speed. The Institute of Electrical and Electronics Engineers (IEEE) developed 802.15.4 standards and helped the production of Zigbee protocol and devices that support this protocol. As a result, Zigbee supported devices have low-cost, intelligent network topologies and are energy saving features. So, they have their place in daily life and industrial companies in various ways [5, 6]. A lot of devices and machines can be controlled, and data can be received and sent at the same time by zigbee wireless technology. So, system running can be achieved without any trouble [7]. In the literature, several methods have

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been presented for running, monitoring, and detecting mechanical and electrical defects in three-phase induction motors [8-10]. Traditional protection practices for detecting motor defects and protecting motors use various types of protection relays such as over current relays, temperature relays, low and high current protection relays, electromagnetic switches, contactors, and time relays. If the traditional protection methods are compared with the computer-based ones, traditional methods considerably reduce the efficiency and sensitivity of the system because many mechanical parts including in the whole system increase the time for detecting defects. Another disadvantage of the traditional protection methods is their cost; namely, it is clear that traditional methods increase the cost of systems while digital systems reduce it. There are many publications on detection of the mechanical defects of induction motors in the literature [11, 12]. In some studies, motor parameters have been used to display the electrical and mechanical performance of the motor through a PC [13, 14]. In [14], a real time monitoring system has been developed against the failure of induction motor. All measurements related to the induction motor were done and protection against the failure of induction motor has been achieved. However, it was realized that the cost is increased due to use of sensors to collect the current and the voltage information from the network and transfer them to the computer by an analogue/digital converter card [14].

The system developed consists of such hardware and software units as an Atmel Atmega 8-16 PU microprocessor, a Zigbee 2-mW protocol, a wired temperature sensor manufactured by Maxim/Dallas firm, an incremental encoder with 360 pulse per rotor speed, a 5/0.5 ampere current transformer manufactured by Entes, a 220/5 volt voltage transformer, a desktop computer, and Delphi Programming Package to design the interface program. Control of the three-phase induction motor has been achieved via the PC over the Zigbee protocol. Especially, a powerful remote control has been achieved successfully to monitor the basic size for those places in where the motor is difficult to reach.

2. ZIGBEE NETWORK TECHNOLOGY

ZigBee is a synonym of IEEE 802.15.4 protocol, which is a hot research topic in short-distance wireless communication technology. Its main advantages are dissipating low-power, lower complexity, self organization, being low-cost, and so on. It is widely used in industry, home and building automation, automatic control, monitoring and control of agricultural area, hospital and other fields [15-22]. The complete ZigBee technology is constituted by Application layer, Network layer, Data link layer and Physical layer. Its transmission distance is more than 10 m distance and compatible with the 2.4GHz and 900MHz frequency bands. Network architecture has Master/Slave characteristic and it works operated as two-way communication for public use. Although the transfer rate of ZigBee technology is not high enough, the ZigBee technology has great potentials in sensing and control applications [23].

Different network topologies built up by ZigBee devices like star topology, cluster tree topology and mesh network as shown in Figure.1. For all network topologies, there can be only one coordinator in each network [24]. Figure.1 (a) is a star topology where a coordinator is responsible for all over the network. All other devices are back-end devices and directly communicate with the coordinator. This topology is suitable for networks with a centralized device and for time critical applications. Figure.1 (b) is a cluster tree network where coordinators are still responsible for the network initiating and maintenance. However, routers can be used to extend the network. Routers control data flow by using hierarchical routing strategies in the network. They also may imply beacon enabled network that is defined in IEEE 802.15.4 for periodical data transmission. In mesh network coordinators that is seen in Figure.1. (c) are still responsible for the network initiating and maintenance. Routers can be used to extend the network. A mesh network allows full peer-to-peer communication. A mesh relies on this way self healing technology so that if a node fails another route is used for the data delivery [25].

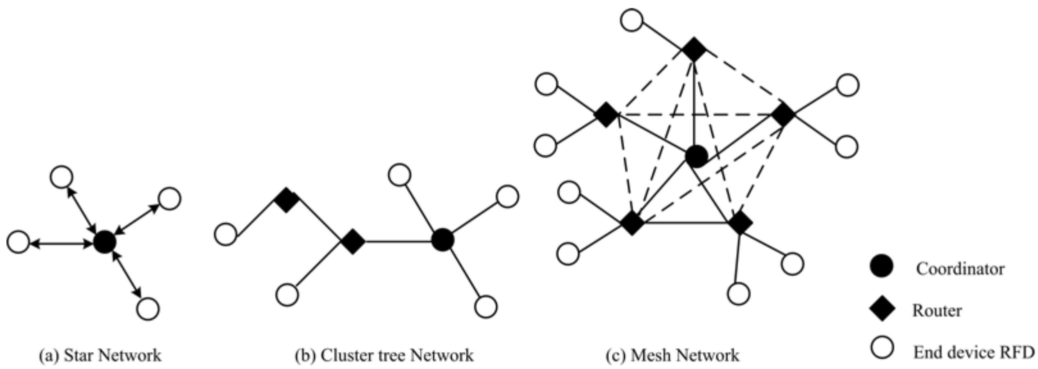

Figure 1. Zigbee network topologies [25]

3. THE PROPOSED WIRELESS INDUCTION MOTOR MONITORING SYSTEM

In this study, a powerful wireless monitoring system has been achieved for an induction motor. A general block diagram of the system is given in Figure. 2. The system can be examined in two main categories as hardware and software. Operational principles of each part of the system are described in the following sections in detail.

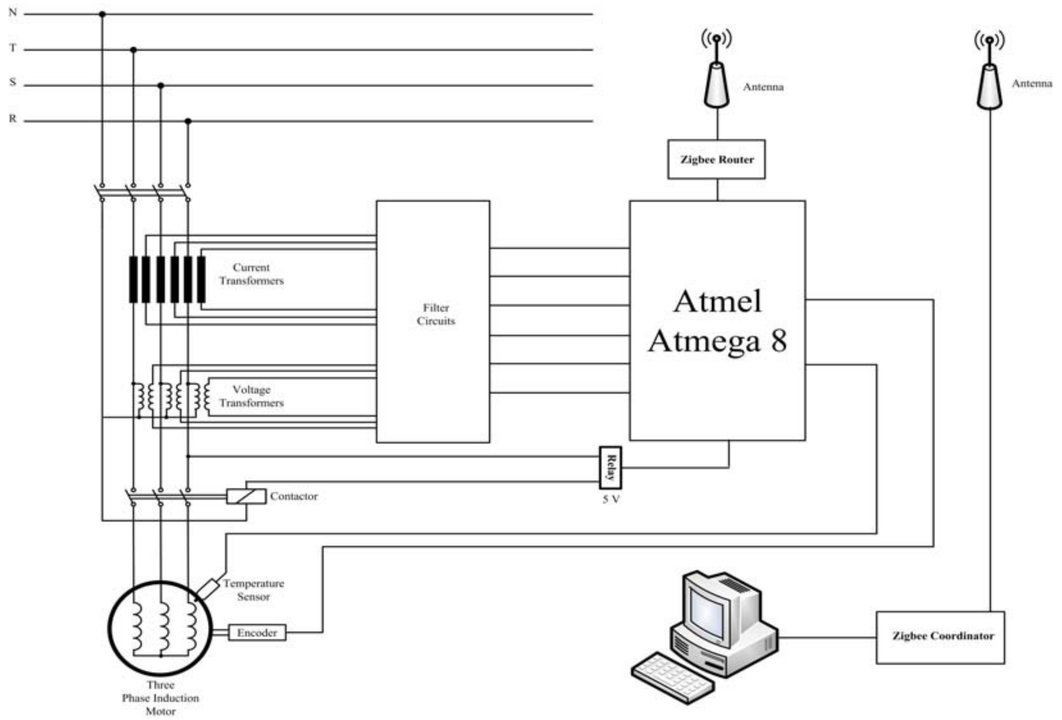

Figure. 2 A general block diagram of the system achieved

3.1. Hardware

The test rig used in the present study consists of a 0.37 kW/1400 rpm three-phase IM, three voltage transformers with transformation ratio of 220/5 V connected to each phase of IM, three current transformers with transformation ratio 5/0.5 connected to each phase of IM, a temperature sensor with transformation ratio of 10 mV for each 1 ^{o}C increasing temperature a DS18B20 programmable wired digital temperature sensor manufactured by Maxim/Dallas firm, an incremental encoder with 360 pulse per rotor speed used for measuring the rotor speed, AC to DC conversion card, Atmel Atmega 8-16 PU microcontoller and relays. Four implementation photographs of the proposed system are depicted in Figures 3 and 6. These figures show components and control cards in the proposed system. Three signals for voltages, three signals for currents and one signal for temperature are used as input values to A/D module inside microcontroller and one signal for speed is used as digital input to microcontroller. Software and measurements of these signals are explained in subsection 3.2.

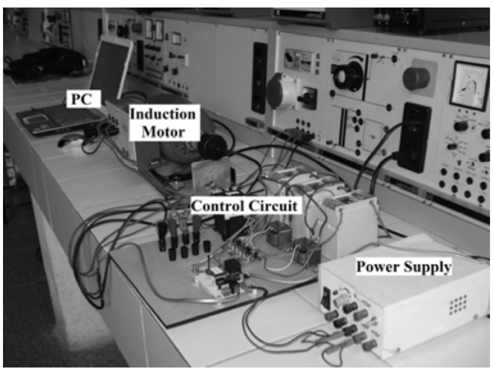

Figure.3 A general view of parameter

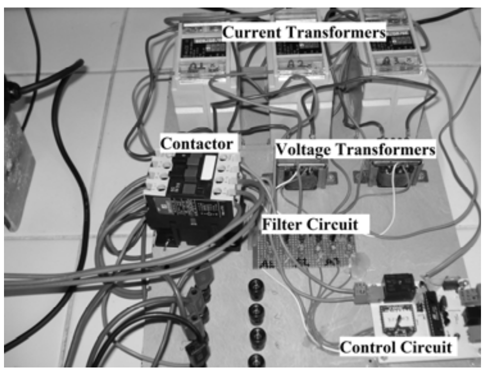

Figure.4 An overview of the control

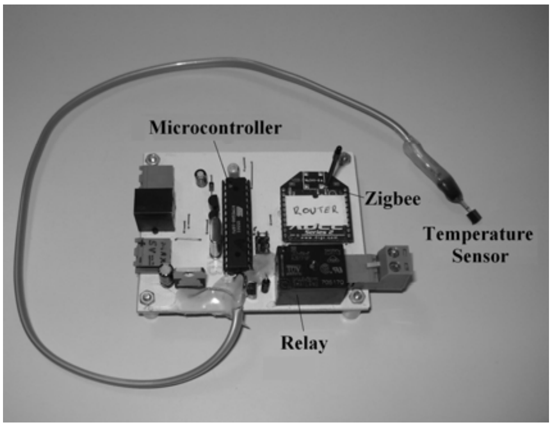

Figure.5 A Photograph of Router Zigbee and microcontroller

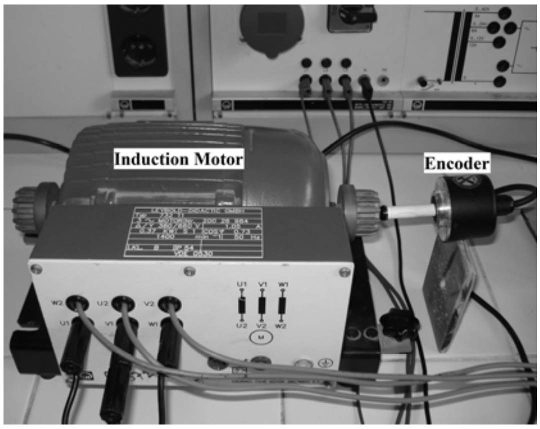

Figure.6 Connecting induction motor to the system

3.2. Software

In the system developed, Borland Delphi 7.0 package has been used as main software that works under Windows operating system and has a highly flexible programming structure with database support. The parameters of the motor collected from the system have been transferred to the Zigbee coordinator via the Zigbee router; and then, they have been transferred to the computer over the RS232 protocol. Borland Delphi 7.0 has been used to display received data on the screen to perform controlling commands and to storage data received throughout the Zigbee system. Data is stored into the database as a compatible format with Microsoft Office Excel.

The Home Page of graphical interface designed is illustrated in Figure. 7. As seen on the figure, all controls can be performed on this page. Control commands on the screen and functions of them are given in Table.1.

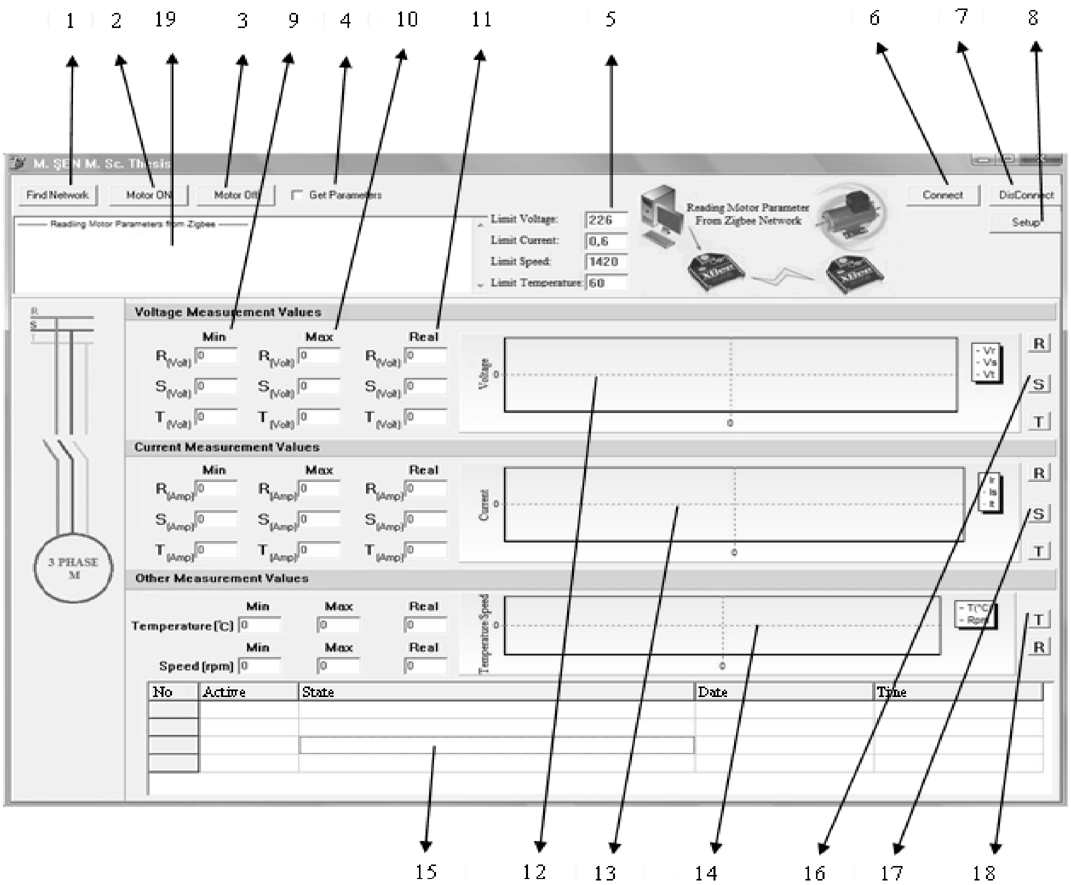

Figure 7. Home Page of the interface

Table 1 Functions of the control commands on the Home Page.

Number	Definition	Number	Definition
1	Find Network	**11**	Instantaneous real value
2	Motor is running	**12**	Graphic area of voltage following
3	Motor is stopping	**13**	Graphic area of current following
4	Read value	**14**	Graphic area of temperature and speed following
5	Entered the areas of boundary value	**15**	Induction motor parameter values received from the date and time fields are stored separately
6	Connect button	**16**	Phase voltage monitoring as graphics and value
7	Disconnect button	**17**	Phase current monitoring as graphics and value
8	Adjusting	**18**	Temperature and speed monitoring as graphics and value
9	The lowest value	**19**	Network connection control field
10	The highest value		

As seen in the Figure. 7, several parameters of the motor like voltage, current, winding temperature and speed can be monitored and controlled remotely. For this purpose, the button called "Connect" and then the button called "Find Network" should be clicked on firstly. The coordinator Zigbee connects to the router Zigbee and builds a "secure gateway" And when the button called "Start the motor" is clicked, the motor operates with getting communication via the coordinator Zigbee and the router Zigbee. The button called "Read the values" can be used to monitor the parameter values of the motor. During the operation, the motor values are collected and saved. These saved data can be seen on the field indicated as No. 15 in the Figure. 7 in the order of voltage, current, speed, temperature, date, and time. To finish the operation, the button called "Read the values", "Stop the motor" and "Cut the connection" should be clicked respectively. After installing the program to the computer, the computer communication protocol is also introduced. Transferring and getting data can be done successfully through these settings given in Figure. 8. A simplified flowchart illustrating operational procedure for the proposed system is given on Figure. 9. The procedure consists of two main phases as 'initialization and configuration' and 'normal operation'. The normal operation phase is given in detail at the right side on Figure 9.

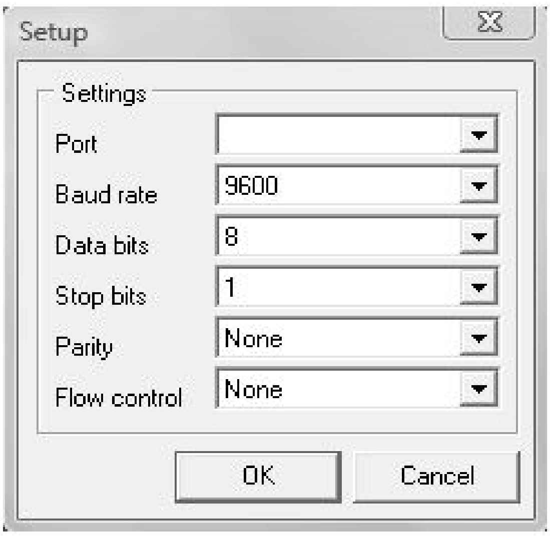

Figure 8 Setup screen

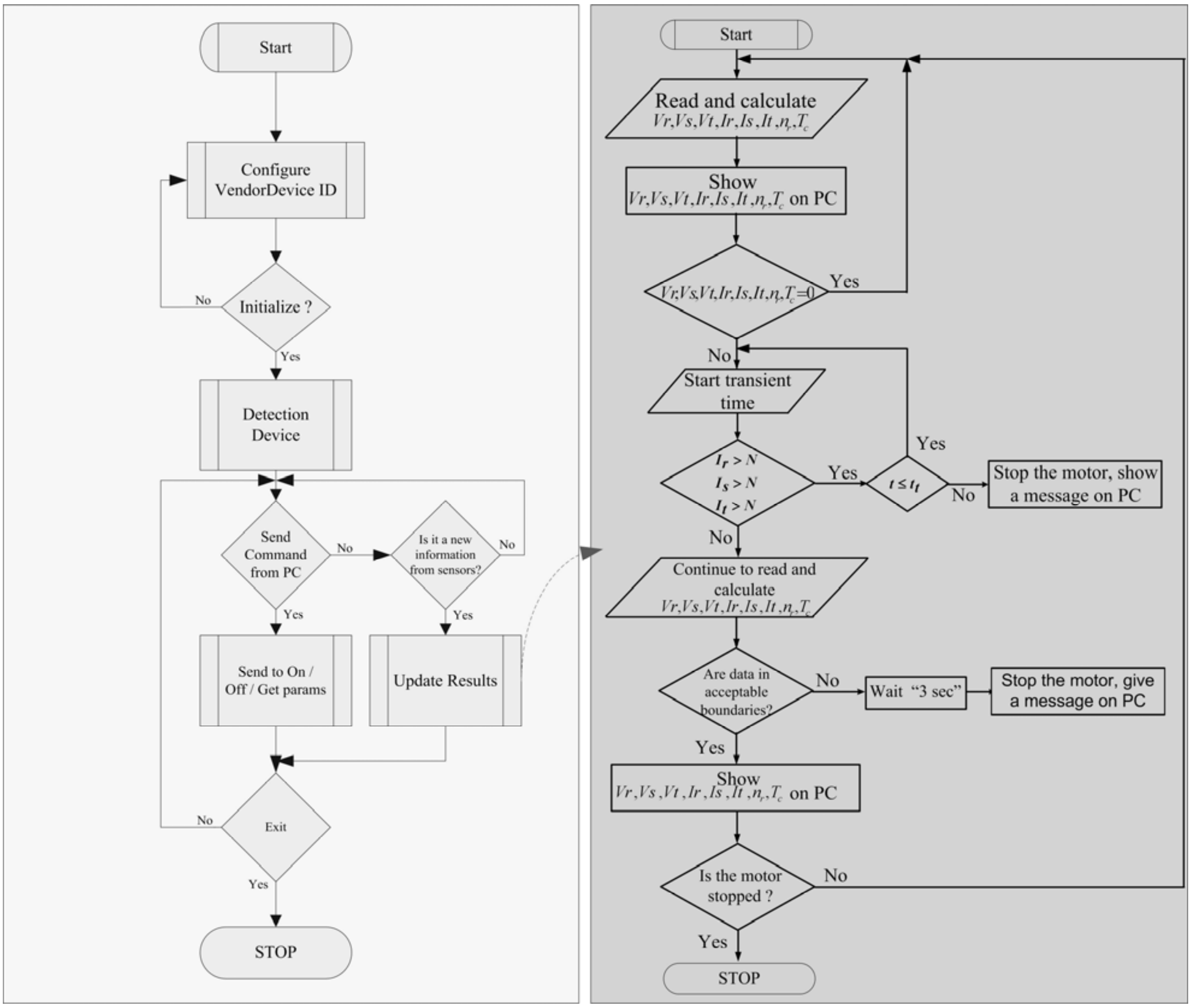

Figure 9. A simplified flowchart illustrating operational procedure for the proposed system

The 'initialization and configuration' phase consists of configure vendor ID and device ID, ZigBee based user remote control detection phase, configure infra-red profile steps.

After completing configuration step, the software directly displays the phase voltages, the phase currents, the rotor speed and the motor temperature on the interface automatically. After having all these data, all parameters are controlled considering their tolerance values. The program continues to run while these data are in the pre-defined limits. If there is no value to read, the program re-continues to read and calculate the signals until reading new voltages, currents, speed and temperature values (V_r, V_s, V_t, I_r, I_s, I_t, n_r *and* T_c). In the software, some symbols have been used as <, >, ≥ and ≤ which respectively mean less, greater, greater equal and less equal limits for each phase current, voltage and motor temperature and speed. If any fault occurs at anytime, the program makes a comparison among the three phase voltages, the three phase currents, the speed, and the temperature according to their nominal values and then motor is stopped by means of sending an error signal from microcontroller to the control circuit of the motor, and finally error description messages are displayed on the screen. The induction motor is started again if the error is removed. The lowest, the highest, and the real values of each phase can be seen in their own parts. These values are displayed on the screen against a green background. If these values reach the limit values, the background color changes from green to red as seen on the Figures 10 a, b, c. For example, Figure. 10a in which maximum level for the phase R is pre-defined as 226 V; however, the actual value of the whole phase is measured around 226 V, so that the background of the phase R is red.

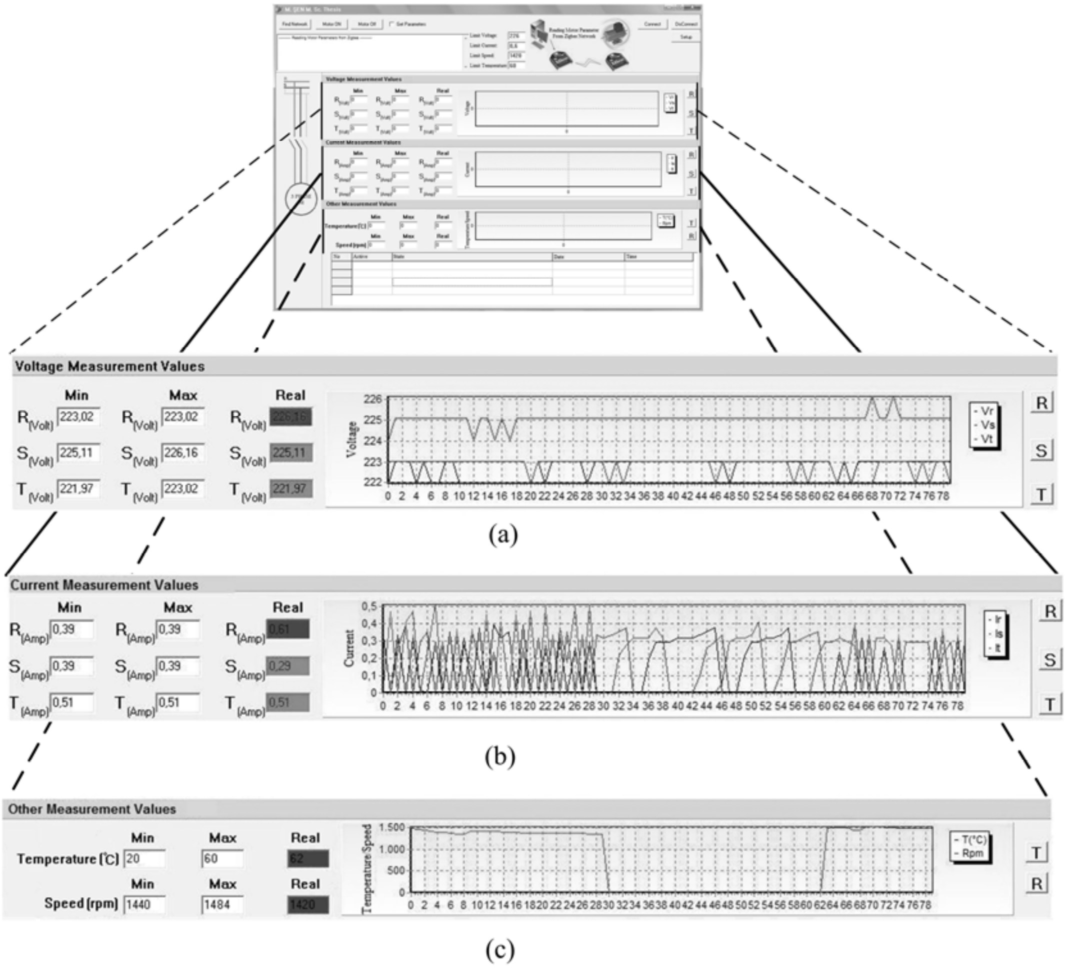

Figure 10. Exceeding limit voltage values

3.3. Experiments on Motor Faults Detection and Protection

Once the required settings are done, the button called "Connect" is clicked on using the Main Menu as seen in Figure. 11. Then, an RF connection is established between the coordinator Zigbee and the router Zigbee by clicking on the button called "Find network". If the connection is established successfully, a message appears below the "Find Network" button which explains that the system is ready to use.

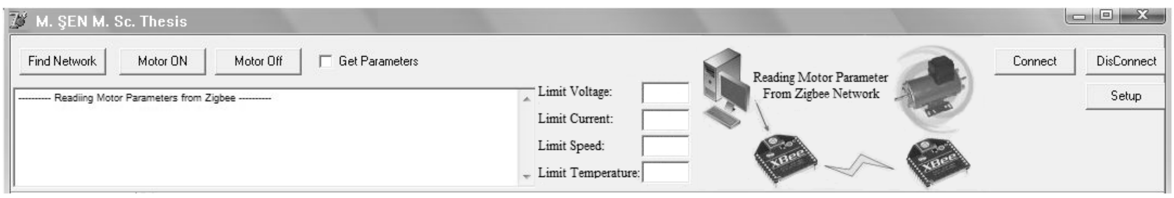

Figure 11. Program menus

The motor parameters can be transferred to the computer every two seconds by clicking on the button called "Get Parameters". These received values are displayed in their own areas called value and graphic on the interface. One of the most important features of the program is the part of "limit values" in "Program Menus." Voltage, current, speed, and temperature values can be adjusted manually according to the special operational conditions of the motor. These limit values can be changed by the user. All data are stored in the local disk of the computer as an Excel file as seen on Table 2. To close the program, the button called "Motor off" should be clicked and then the button called "disconnect" should be clicked to disconnect the network. Finally, the button called "close the program" can be used to close the interface screen as well as to completely exit the system.

Table 2. A view of the database file

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	A	B	C	D	E	F	G	H	I	J	K	L
1	NO	State	V(r)	V(s)	V(t)	I(r)	I(s)	I(t)	Rpm	Temperature	Date	Time
2	1	Open	226,16	227,2	225,11	0,35	0,16	0,35	993,6	14,8	15.12.2009	16:02:12
3	2	Open	226,16	227,2	225,11	0,29	0,35	0,29	1512	14,8	15.12.2009	16:02:14
4	3	Open	226,16	227,2	225,11	0,29	0,35	0,29	1511,4	14,75	15.12.2009	16:02:15
5	4	Open	226,16	227,2	225,11	0,35	0,29	0,35	1516,8	14,75	15.12.2009	16:02:16
6	5	Open	226,16	227,2	225,11	0,31	0,16	0,33	1512	14,8	15.12.2009	16:02:22
7	1	Open	226,16	227,2	224,06	0,35	0,31	0,29	1513,2	14,75	15.12.2009	16:10:00
8	1	Open	226,16	227,2	225,11	0,29	0,33	0,12	1511,4	14,75	15.12.2009	16:13:15
9	2	Open	226,16	226,16	225,11	0,24	0,24	0,16	993,6	14,75	15.12.2009	16:13:21

4. CONCLUSIONS

In this study, a parameter monitoring system for induction motors based on Zigbee protocol is achieved and tested successfully. The system developed is capable to perform such operations as running the motor though RF, stopping it, measuring, monitoring and controlling the most parameters of the motor like phase currents, phase voltages, wiring temperature, speed. All of these values can be transferred to the host computer, displayed on the interface, represented graphically, transferred into an Excel file to store them for a long time

Monitoring and controlling the basic values of the induction motors were done and achieved in various ways. Comparison of positive and negative aspects and its cost was done. Comparison of Zigbee with other controlling systems is shown in Table 3 [8, 12, 15, 26].

If the Zigbee controlling system is compared with the similar ones, it is a requirement for others that to rewrite the microcontroller program to expand and update the system in the future. On the other hand, since the Zigbee controlling systems are designed by taking into account a modular structure during the programming steps, all additions and expansions can be achieved simply.

The system developed in this study has been tested experimentally and it has been observed that the system operates without any failure and it has more performance than the similar ones. During the experimental tests, no problem has been observed either communicating the Zigbee to the computer, or integrating the hardware units used for controlling and monitoring the induction motor.

The system developed can be used for not only industrial applications but also educational purposes; it means, the whole system may be useful to colleges that have vocational, technical, and industrial education. Instructors can use the system presented as a supporting teaching material, and it can be adapted in experimental researches successfully.

Table 3. Comparison of Zigbee with other controlling systems.

Compared Features	PLC-Scada	PIC	Classic Control	Xbee
Cost	High	High	Low	Low
Physical structure	Small	Small	Big	Small
Renewal opportunities	Easy	Moderate	Unavaliable	Very Easy
Adding modular system	Possible	Additional Design	Unavaliable	Possible
Resistance to the work environment	High	Additional Security	Low	High
Finding fault	Very Easy	Very Easy	Diffucult	Very Easy
Communication	Very Easy	Very Easy	Unavaliable	Very Easy
Production planning	Very Easy	Very Easy	Unavaliable	Very Easy
Security	High	Moderate	Low	Very High
Development cost	Low	Moderate	Low	Low
Monitoring data	Very Easy	Very Easy	Unavaliable	Moderate

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