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Real-Time Monitoring and Control of the Parameters of an Induction Motor

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***Abstract*—As a result of technological developments, remote control via communication techniques such as ZigBee, RF, Infrared, Wi-Fi and mobile communication techniques has been widely used in various fields. These techniques have both advantages and disadvantages. GPRS (General Packet Radio Service) communication offers a non-stop, secure and cheap communication to individuals where there is no access to Internet. This study consists of PLC-based, online monitoring and control of the parameters of a widely-used induction motor utilizing the GPRS/GSM (Global System for Mobile Communications) communication technique. The research monitored current values of three phases drawn from the network, voltage values of three phases applied to the induction motor, power factor, rpm (rotation per minute) and operating frequency. The induction motor was operated by keeping the V/f ratio constant via a frequency convertor; a visual user interface was prepared on the Profi-Lab Expert platform, and then presented to the users through the Profi-Lab Web Server program.**

***Index Terms*—PLC, GPRS, control, sinaut micro OPC server, induction motor.**

I. INTRODUCTION

Technological developments have enabled to be taken classic systems' place by automatic and advanced systems. In addition, the availability of fast-processing, stable and sensitive products provided particular benefits in industrial automation and SCADA (Supervisory Control and Data Acquisition) systems [1]. As a result of the developments in communication technologies, systems are no longer monitored and controlled by personnel using classic methods, but automatically by computer-controlled or remote-controlled devices.

In the literature, it was found that products with different technologies and characteristics such as microcontrollers, data acquisition boards (DAQ), programmable logic controllers (PLC) and FPGA (Field Programmable Gate Array) were preferred [2]–[5]. PLCs have stable, high processing capacities and various options for modular expansion [6]. Therefore, PLCs are especially used in power conversion systems, solar panels, monitoring and control of wind turbines, elevator systems, monitoring of power transmission lines, domestic heating systems and industrial applications including automatic systems, such as energy dispersal stations [6]–[8]. Moreover, FPGAs are also widely used for analyses as they support precise operations such as reading and monitoring fast signals [9]. On the other hand, as DAQs have no internal memory or processing capacity, they are only used to collect, transfer, analyze and evaluate data about the system [10]–[12]. Microcontrollers are restricted to simple applications due to their disadvantages such as slow processing speed and low program memory [13]. Different control technologies are used for monitoring and control of the systems, whereas the communication between a system and a user is generally realized online via wireless communication techniques such as Rf, ZigBee, Bluetooth and GPRS in remote monitoring [14]–[17]. Rf, ZigBee and Bluetooth are widely preferred in easy-to-use applications due to the short range between the sender and the receiver, and the small volumes of data transferred. Through different communication methods, monitoring and control are now realized via remote-controlled technological communication techniques such as Profi-Bus and GPRS [18], [19]. Also, SCADA programs are utilized for developing user interfaces. However, SCADA programs do not provide adaptability for users because of their expensive libraries. It was found in the literature that standard programs were used to prepare bespoke SCADA monitors for specific applications [20].

The present study reports on monitoring and vector control of the parameters of an induction motor using GPRS communication technology. A Siemens S7-200 PLC control unit was chosen, as it is preferred in small-scale projects and it is cheaper than other PLC products. Moreover, the capacity of the system can be increased by combining control modules. Communication between the user interface and the system was realized by a SINAUT Micro SC OPC Server via GPRS/GSM service. GPRS is commonly used in locations where there is no other form of Internet access (e.g. wind turbines, base stations etc.). A vector-controlled Siemens MMC-440 frequency convertor was used to monitor the parameters and control the induction motor. The web-based user interface for remote control and monitoring was developed via the Profi-Lab Expert program and then it was presented online to users via the Profi-Lab WebServer program. Monitoring and control were realized more

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visually and resiliently in comparison with other programs, as Profi-Lab Expert program has a rich library of pre-defined functions that enables developers to create a user interface without the need to write code.

II. System Design

The vector control of the induction motor and monitoring its parameters were realized via GPRS/f. Moreover, frequency and speed changes of the induction motor were tracked by means of the user interface. Figure 1 shows the block diagram of the designed system.

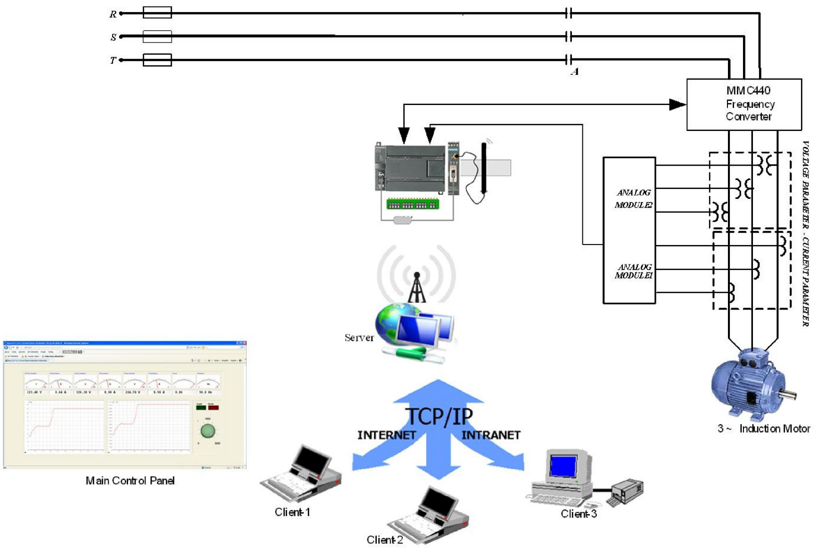


Fig. 1. Block diagram of the designed system.

A. Hardware Components

The system consisted of a PLC, two analogue modules, one GPRS modem, one frequency convertor, one three-phase induction motor, PPI communication cable and voltage/current zero-crossing boards. An overview of the system is shown in Fig. 2. Figure 3 shows the block diagram of the station.

The PLC has 256 KB of external memory with 14 digital inputs and 10 digital outputs. Number 3 indicates a SINAUT MD720-3 GPRS modem that enabled the remote monitoring and control of the PLC. The use of GPRS service via the SIM card of the GSM digital cellular network enabled the remote control and monitoring of current stations or systems. As the SINAUT MD-720-3 GPRS modem supports Com port, the communication cable of the RS232/RS485 Com Port was used. Number 4 is the antenna allowing the SIM card to communicate with the GSM network. A Quad-band antenna enabled quality and continuous data transfer within the coverage areas of the preferred GSM operator. Number 5 is the Siemens EM-235 analogue module that was used to read the three-phase current and voltage values. The structure of PLC is given in Fig. 4.

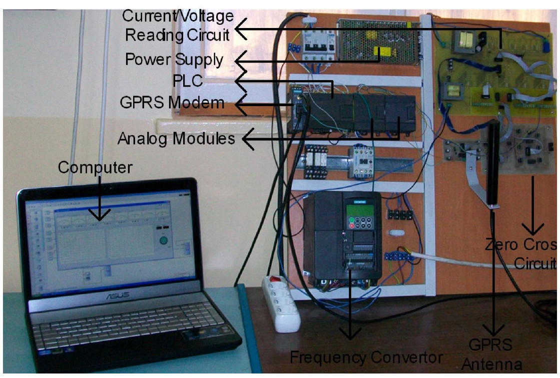


Fig. 2. Overview of the system.

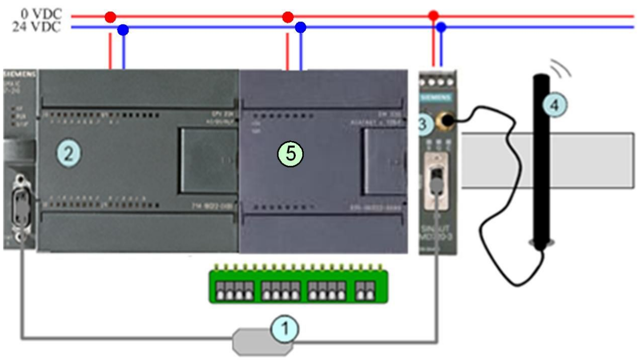


Fig. 3. Block diagram of the station.

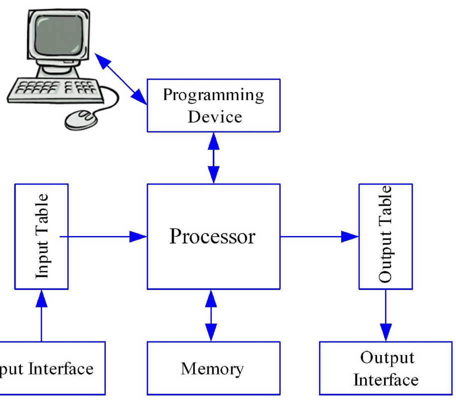
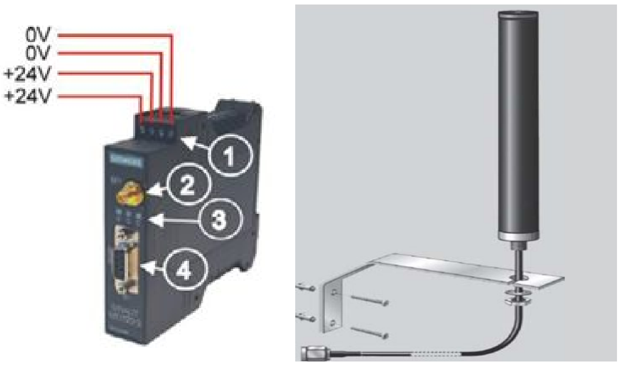


Fig. 4. Structure of PLC.

The Siemens SINAUT MD720-3 was used as the GPRS/GSM modem for communication between the system and the web-based user interface. This product was chosen as it worked compatible with Siemens S7-200 CPU 224-XP PLC. The modem enabled communication between distant stations/systems and the central station/the distant station on the SINAUT Micro SC OPC Server program and it provided the data exchange between the stations. The SINAUT MD-720-3 modem is shown in Fig. 5(a). In this figure, label 1 indicates the feed horns of the modem, which are supplied with 24V DC voltage. Label 2 is the antenna socket for communication between the modem and the GPRS service via the GSM network. The antenna functioned in 850 Mhz, 900 Mhz, 1800 Mhz and 1900 MHz frequency domains (Fig. 5(b)). A SIM card was inserted into the modem. Label 3 represents the LEDs; these have varying brightness and blink rates that convey information to users. The S (Status) LED indicates whether there is a connection with the SIM card; the Q (Quality) LED indicates the quality of the communication (i.e. the coverage power of the SIM card), and the C (Connect) LED indicates whether there is a GPRS connection between the station and the central hub/another station according to the connection parameters. Number 4 is the socket allowing communication between the modem and its own station via an RS232/RS485 PPI cable in accordance with COM Port standards.



(a) (b)

Fig. 5. SINAUT MD720-3 modem and antenna; (a) SINAUT MD-720-3 modem, (b) SINAUT MD-720-3 antenna.

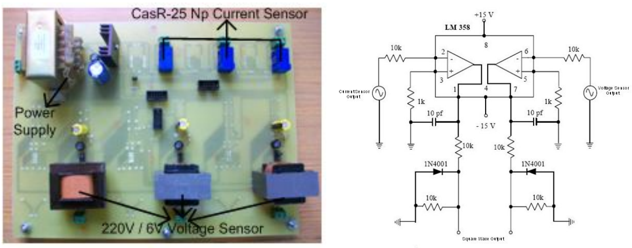
Connection parameters such as station number, IP address, modem name, modem code and SIM card code were downloaded to the modem and then the modem connected to the SINAUT MICRO SC Server via the GPRS service of the installed SIM card.

The induction motor was used as the receiver since it is widely used in industrial operations and devices. The label values of the induction motor are given in Table I.

TABLE I. LABEL VALUES OF THE INDUCTION MOTOR.

Motor Type	3 ~ Induction motor
Connection Type	Star
Rated Current	8,45 A
Cos φ	0,85
Frequency	50 Hz
Rev	2850 rpm
Rated Voltage	380 V

An EM-235 analogue module of the same brand was used to read the three-phase current and voltage signals of the induction motor. This module has 4 analogue inputs and an analogue output with a resolution of 11 bits. A Siemens MMC 440 frequency convertor was used as the induction motor driver. This driver enabled a frequency conversion of 0 Hz–50 Hz. Moreover, the frequency convertor enabled the user to start and stop the system and to determine the Rpm. Voltage/current reading and zero-crossing boards were designed to control the parameters of the induction motor. The designed voltage/current reading boards are shown in Fig. 6(a). Three Hall Effect CAS-25NP current sensors produced by LEM were used to read the current signals, while 240/6 V transformation ratio was used in order to read the voltage signals. Voltage and current signals were converted to an appropriate level via voltage/current-reading boards. They were then converted into square waves via the zero-crossing detector shown in Fig. 6(b) and applied to the digital inputs used by the high-speed counter of the PLC. φ angle between the voltage and the current signals of a phase of the induction motor was calculated by PLC. Thus, the phase difference data was obtained. The parameters of the induction motor were thereby read through the boards designed via PLC and they were monitored via GPRS/GSM using the web interface developed on OPC Server.



(a) (b)

Fig. 6. Voltage/current reading and zero-crossing boards; (a) voltage/current reading board, (b) zero-crossing detector.

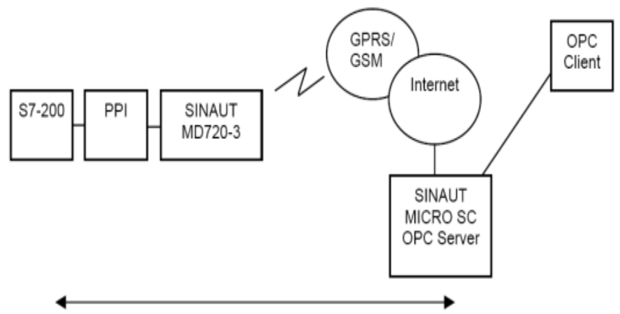
B. Software Components

The user interface enabling GPRS communication with PLC on OPC Server was developed using the Profi-Lab Expert program. The fact that the images of the objects used in the interface (e.g. measuring devices) are similar to the ones used in the industry separates the program from similar programs. These images will make a great contribution to the computer-controlled systems and to learning in distance education. The user interface developed in Profi-Lab Expert was presented to the users online via the Profi-Lab Web Server program.

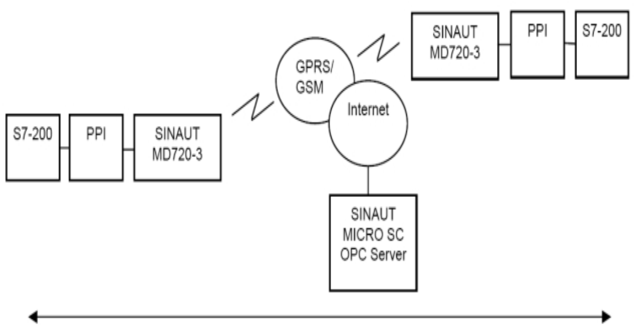
The SINAUT Micro SC OPC Server program enabled communication with the MD720-3 GPRS modem. This program enabled cheap and reliable data exchange directly between the remote and central stations, as shown in Fig. 7(a) or between remote stations as shown in Fig. 7(b). Thus, any distributed system may be easily monitored and controlled. The SINAUT OPC Server program licensed by Siemens can be used with up to 8, 64 and 256 stations. The present study used the product that permits a maximum of 8 stations. Another advantage of this program is that it is compatible with standard Microsoft software.

A standard OSI (Open Systems Interconnection) model was used in the data exchange between the systems. This model consisted of Physical, Data Link, Network, Transport, Session, Presentation and Application layers as shown in

Fig. 8. Data is transferred to the target through these seven layers in this model [21]. The characteristics and the data speeds of wireless LAN classifications are shown in Fig. 8.



(a)



(b)

Fig. 7. Block diagram of the GPRS/GSM communication; (a) communication between a distant station and SINAUT OPC Server, (b) communication between distant stations.

A detailed comparison of wireless communication techniques is given in Table II [21], [22]. The ZigBee, RF and Bluetooth wireless communication techniques are generally restricted to simple applications because of their slow communication speeds, distances and data security. In addition, they are easily affected by noise and bad weather conditions such as snow, fog and rain. GSM, which is also referred as a cellular system, is a popular telecommunication product and its up-to-date technology infrastructure increases the use of GPRS services. Moreover, it is widely preferred in wireless communication since it is barely affected by environmental factors such as electromagnetic noise and weather conditions. In the present project, the use of GPRS enabled high quality communication at low cost and high security without the need for much hardware infrastructure in all the coverage areas of the GSM operator. GPRS enables communication everywhere, including mountainous areas without any distance-related or infrastructure-related restrictions [21]–[23].

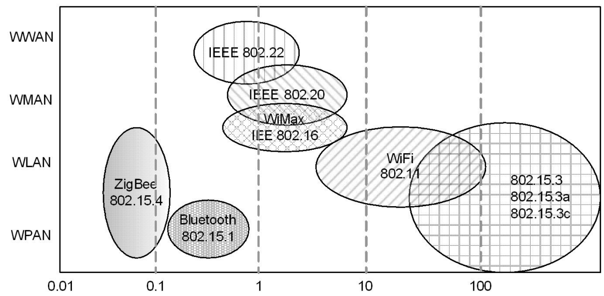


Fig. 8. Classification and speed of wireless LANs.

III. Experimental Study

The three-phase current and voltage values, power factor and operating frequency of the induction motor were monitored via the web interface developed in this study. Thus, remote monitoring and control of the induction motor was realized. When a user connects to the system, a user interface is presented as shown in Fig. 9.

TABLE II.COMPARISON OF WIRELESS COMMUNICATION TECHNIQUES.

Characteristics	ZigBee	GPRS/GSM	Wi-Fi	Bluetooth	RF
Focusing Area	Monitoring and Control	Wide Range of Sound and Data Transmission Monitoring and Control	Web, e-mail, image	Instead of cable	Wireless services
System Resource	4–32Kb	16Mb+	1Mb+	250Kb+	32kb
Network Data Width (kb/s)	20–250	64–128+	11000+	720	32
Coverage Area (meter)	1–100	1000+	1–100	1–10+	1–100+
Performance Areas	Endurance Cost Power Consumption	Accessibility Quality	Speed Resiliency	Cost Comfort	Accessibility

TABLE III. INPUT/OUTPUT ASSIGNMENT LIST OF THE CONTROLLER.

Digital Input		**Digital Output**		**Analogue Input**		**Analogue Output**	
Start	I0.0	Run the software	Q0.0	R Phase Voltage	AIW0	Speed Control	AQW0
Stop	I0.1			S Phase Voltage	AIW2		
System Ready	I0.2			T Phase Voltage	AIW4		
Voltage zero-crossing signal	I0.3			R Phase Current	AIW6		
Current zero-crossing signal	I0.4			S Phase Current	AIW8		
				T Phase Current	AIW10		
				Frequency	AIW12		
				Motor Speed	AIW14		

A flow diagram of the remote monitoring and control of the parameters of the induction motor is shown in Fig. 12. Communication between the motor system and the web-based user interface was supplied using client/server architecture via GPRS/GSM. Table III shows the addresses in the controller that enabled the monitoring or control of the system, and that were used for storing the obtained data. Flow diagram is shown in Fig. 10.

When the user clicked the Start button, the frequency convertor was operated via the controller. However, the motor did not initially rotate since the operating frequency was initially set to 0 Hz. The user applied a 0 rpm – 3000 rpm speed value on the PLC via the Engine-Speed control on the interface. As the user changed the speed value, changes in the frequency-based Rpm were displayed on the web interface as shown in Fig. 11. Moreover, the current values of the three phases drawn from the network, the voltages of the three phases applied to the induction motor, power factor and the operating frequency of the induction motor were also monitored remotely via the web-based user interface. When the user clicked the Stop button, the system stopped.

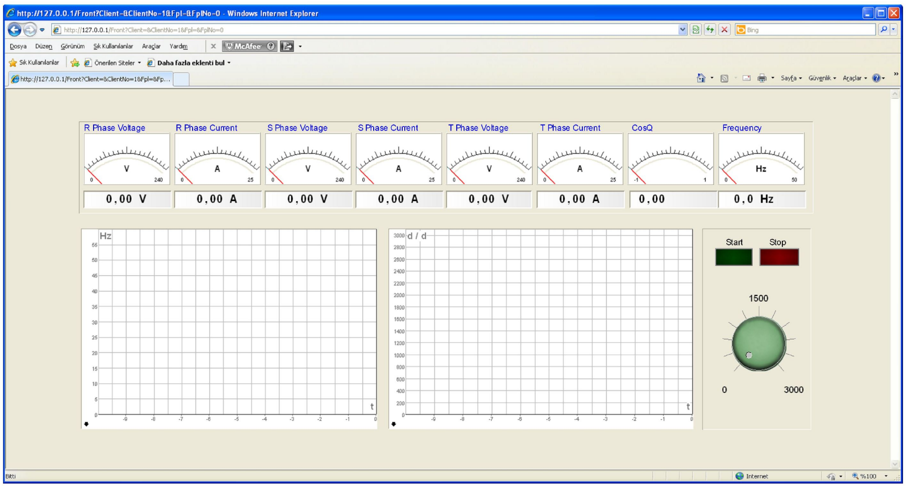


Fig. 9. User interface.

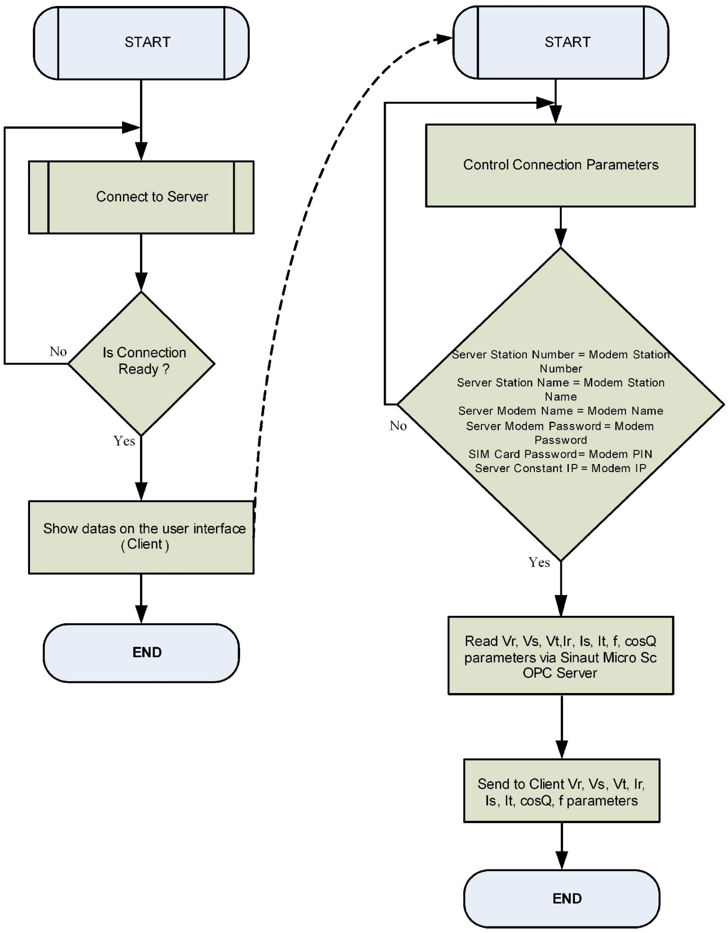


Fig. 10. Flow diagram of the system.

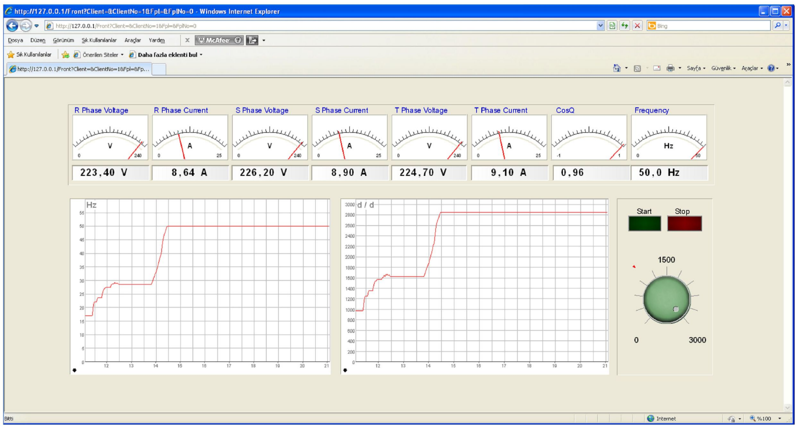


Fig. 11. User interface display of the induction motor when it is operated at the network frequency (50 Hz).

IV. CONCLUSIONS

This study proposed a novel remote monitoring and control system for induction motors using GPRS/GSM communication. The designed system monitored and controlled the three-phase currents drawn from the network, the three-phase voltages applied to the induction motor, power factor and rpm successfully. The real-time monitoring of the mentioned parameters, the frequency conversion of the induction motor and the changes in these parameters were achieved in this study. This study has a remarkable and significant importance for the reason that it can be used in monitoring, controlling and determination of system cases where the places are distant from the residential areas and have no access to the Internet. Moreover, it can be used as a training tool in professional and technical education.

In future studies, the inability structure in transferring data beyond the coverage area of the GSM network should be focused and improved.

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