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A Real Time Application for Analysing Impacts of Frequency Variation on Induction Motor Parameters

***Abstract**. In this study, speed control of an induction motor by V/f ratio is presented visually in order to figure out the relation between the frequency and the speed of the motor. By the use of the system, transient and steady state behaviours of the motor under different frequencies can be analysed successfully over the visual user interface. The system can be used either educational purposes in engineering courses or industrial purposes in automation systems to determine the best operational parameters of the motor.*

***Streszczenie.** Przedstawiono praktyczny układ kontroli prędkości silnika indukcyjnego bazujący na stosunku V/f. Zastosowano wizualny interfejs użytkownika umożliwiający ocenę prędkości w czasie rzeczywistym. Układ może być zastosowany do celów edukacyjnych jak i w praktyce. (**Praktyczny układ umożliwiający ocenę prędkości silnika indukcyjnego w czasie rzeczywistym**)*

Keywords: frequency control, induction motor, real time application.
Słowa kluczowe: kontrola cvzęstotliwości, silnik indukcyjny.

Introduction

Technological improvements in hardware and software in the field of information systems have enforced people to adapt it to their life continuously and this requirement has led to the birth of the concept of lifelong learning in that sense. These changes and improvements have also brought innovative educational opportunities to provide useful training requirements and have proposed the model of distance education as an alternative educational solution. They can learn the topic by repetition at anytime and anywhere within that solution [1]. Computer controlled remote education was previously realized by ordinary mail, however with the developing technology other tools such as radio, telephone, television have been utilized and implemented in education. Presently, with highly developed computer technology training has gained very different dimension.

Despite the computer technology increases diversity and quality in distance education, various problems have been encountered in the faculty of engineering and other technical training schools. In principle, courses in technical education institutions base on the application and practice so that students must realize studies and develop their knowledge and skills in Labs. Additionally, insufficiencies such as time, space and equipment bring out problems in technical education. Therefore, applications of computer-controlled training and distance education have gained importance for practical training. By the use of recent technology without any time and place dependencies, multiple users can be trained at the same time practically using simulations or real-time applications via distance learning by the help of computer-controlled systems.

Besides, energy, time, sensitivity, process control in the industry and education are in the forefront. In that context, control of electric motors used in the purpose-built systems and asynchronous motor which has many advantages compared to other electrical motors has gained interest [2]. Induction motors are widely used in industries more than other electric motors due to having low cost, less maintenance and reliable structures. In addition, having wide range of power and speed, asynchronous motors have reasonable advantages against the other motors [1-3].

Asynchronous motor speed control is much difficult than the direct current motors. Speed of asynchronous motors can be controlled by various techniques such as changing the frequency of the stator, rotor shift, the number of stator poles, the stator voltage, the rotor resistance and also applying an external voltage source to the rotor circuit. Presently, variable speed control of induction machines can be realized much efficiently due to the scalar and vectoral control structures. That decreases the costs of power electronic components and increases the performance. At the scalar speed control method, motor's steady state model is used and the voltage/frequency ratio (V/f) is held constant for the speed control [4,5].

On the other hand, handling high performance is too difficult in the scalar velocity supervision because of non-linear clamping effect between the machine's electrical and mechanical dynamics. To fix that problem and provide the standard velocity control loop, the creation of an interior cycle vector control method has been developed and the clamping effect between flux and torque has been removed. By eliminating that clamping effect with vector control methods, motor torque should become similar to that of direct current motor. Thus, the flux constant torque can be controlled linearly with the torque component of the stator current just as in direct current motors [3,6]. In case of any dangerous operation, remote control of asynchronous motor is important to ensure security for the user and the system itself.

The computer control of induction motors and the examination the parameters of the different operation periods may be fruitful in technical and engineering courses providing a remote control especially in hard places to reach. Another advantage is that it may allow the control of a series of motors synchronously [7].

With the development in automation systems, faster, secure and stable systems have been preferred of classical ones. In addition, the communications among the devices in any automation system have become much complex. To eliminate this difficulty and to provide fast, secure and high quality communication among different companies' products used in industry, concepts of control process (OPC) have emerged in the industry [8-12].

In this paper, the induction motor used in the industrial enterprises as a vector control application through a frequency converter has been provided and monitoring of the control parameters has been realized. For that, Siemens products have been used. As a controller, Siemens S7-200 CPU-224 programmable logic controller (PLC) is used and the control of an asynchronous motor is done with it.

Hardware Structure

In the realized system, induction motor speed is controlled by changing frequency and motor phase currents, phase voltages, power factor and speed parameters' responses to this change are investigated visually on the screen. For this purpose, a PLC, two analog input-output units, an induction motor, a frequency converter, current-voltage measurement cards and a zero-crossing based power factor measurement card have been used. An overview of the system is presented in Fig. 1 as well as a general block diagram is also given in Fig. 2.

Fig.1. Picture of the system designed

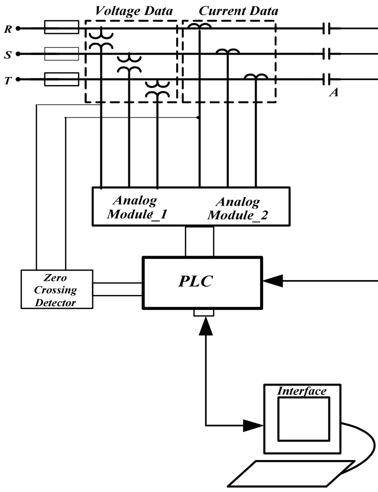

Fig.2. Block diagram of the system realized

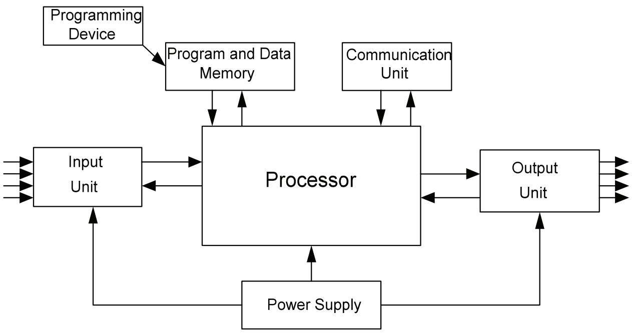

Fig.3. The simple structure of the PLC

Programmable logic controller (PLC)

PLC systems generally consist of processing unit, memory unit, power supply, input-output interface, communication interface, and a programming device (Fig. 3). Siemens EM-235 analog module for the analog processes and MMC-440 frequency converter as a motor driver are used in the experiments. The communication between the interface and PLC is provided via an OPC Server. In the system presented, Siemens S7-200 CPU-224 PLC. It has 8192 bytes of data memory size, 14-input 10-output channels [10]. Since the PLC used has no analogue input/output unit, EM-235 analogue modules are also used in the experiments. By using the analogue channels of EM 235 module, 3-phase current and voltage information are gathered with the sensing cards and they are transferred to the PLC. 12-bit conversion ratio is used on reading analogue input voltage and 11-bit conversion on reading current. 0-5V voltage value from the input units on 12-bit resolution and 0-20 mA current value on 11-bit resolution of the conversion process have been done in this system.

Frequency converter

In recent applications, frequency converters which can adjust the frequency of network for the induction motor speed control are widely used. Similarly, Siemens Micromaster Series speed control device of induction motor within the structure of the advanced parameters and function blocks is used in the system presented. The speed control device provides an RS-485 communication protocol or a higher level communication by adding an external module. Appropriate hardware of frequency converters eliminate the requirement of many additional modules, and prevent the faults. The control can be provided at 0 ~ 650 Hz frequency range.

Induction motor

In order to test the developed system, a 3-phase induction motor has been used. Monitoring and control of the asynchronous motor are made fast and reliable by PLC via a computer in a real time basis. The parameters of the motor used in the experiments are shown in Table 1.

Table 1. The parameters of the induction motor

Parameter type	Value
Connection type	Star
Rated current	8.45 A
Power factor	0.85
Frequency	50 Hz
Rpm	980
Rated voltage	380 V

Measurement card

A measurement card is designed to reduce the current and voltage signals to the appropriate level for PLC analogue modules (Fig. 4). To obtain current signals, three CAS-25NP model hall-effect current sensors are used into the card. Voltage transformers have been used with a 240/6 V conversion rate for the voltage measurements.

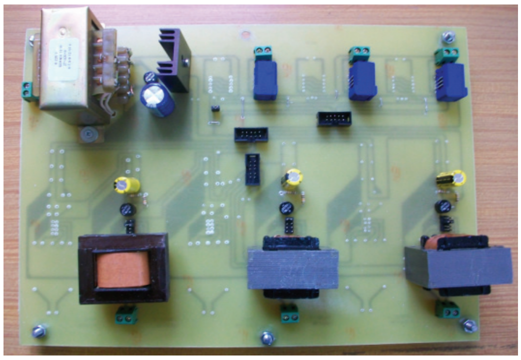

Fig.4. Three-phase current and voltage measurement card

Voltage and current signals are reduced to an appropriate level with the help of the measurement card. Thus the signals are converted into square signals by a zero crossing detector (Fig. 5). The converted square signals are applied to the PLC. The angle between the voltage and current signals is calculated by the PLC during the operation. Motor parameters measured by the card and sent to the PLC through the OPC Server can be followed on the prepared interface.

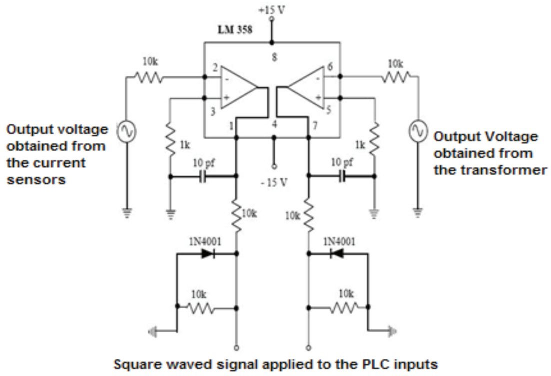

Fig.5. Zero crossing detector circuit diagram

Software Structure

In this study, three main software platform are used to realize the system: Profi-Lab Expert, OPC (Ole for Process Control) and Step-7 MicroWin. In this section, these software platforms are introduced briefly.

Profi-Lab expert

In order to make a communication between the PC and PLC in real-time via the OPC Server, the Profi-Lab Expert software package has been used. This program provides a real-time monitoring of the process via OPC Server and the intervention procedures are performed from the centres as needed, either directly or within a program. The images of objects used at the interface (for instance measuring instruments) are identical to those used in industry. Therefore it makes the program valuable from other similar programs. Its visual features make a good contribution to computer-controlled systems and especially to distance education. A sample desktop appearance of the interface at Profi-Lab Expert package program is shown in Fig. 6 and the image of the screenshot of code blocks are shown in Fig. 7.

Profi-Lab Expert program can communicate with internal/external cards, PLCs via OPC server, external hardware via serial port or parallel port easily and offers the user a visual interface preparation. Apart from the most programming languages, there is no need to write any special code, thereby it provides the easy usage. In addition, it offers the opportunity to make an electronic circuit simulation such as Orcad, Proteus.

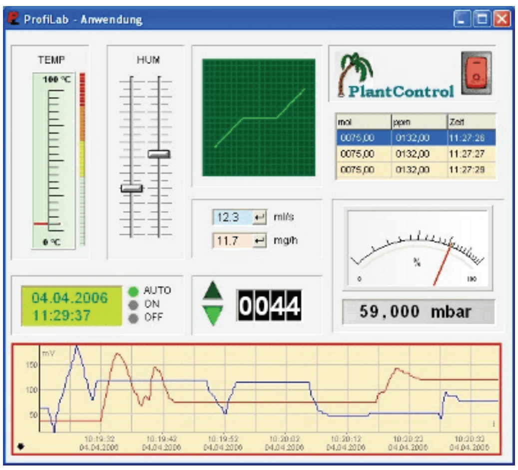

Fig.6. A sample desktop image of the interface

OLE for process control (OPC)

OPC is a software interface that allows industrial devices to communicate with each other. The communication block of OPC server is shown in Fig. 8. It allows both read and write operations simultaneously. Additionally it can be operated with an integrated form with the interface programs such as C++, Visual Basic, Delphi, Java, Visual C# programming languages. Thus, products of different companies communicate with each other in the same platform [11-14].

Step-7 MicroWin

Siemens Step7-MicroWin package program is used in order to create and run programs for the Siemens S7-200 PLC series. A screenshot of the Step-7 MicroWin program is shown in Fig. 9.

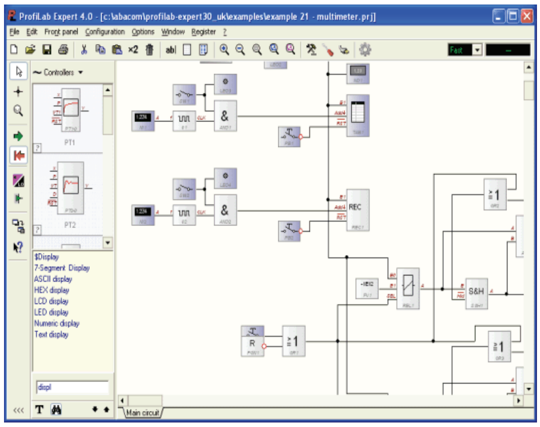

Fig.7. A screenshot of Profi-Lab Expert

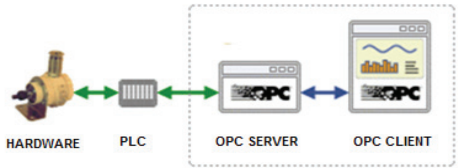

Fig.8. Communication block of OPC server

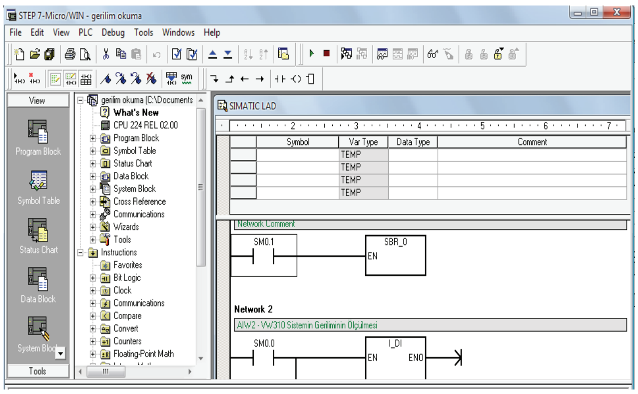

Fig.9. Screenshot of the Step-7 MicroWin

Implementation

In the study, current and voltage values are taken from the network, and then speed and frequency of the induction motor including power factor of the system are transmitted to a computer in real-time through the OPC Server and the PLC. User can change the frequency between 0-50 Hz ranges through the interface, so the control of the induction motor can be performed by adjusting frequency. The effects of parameter change on current, voltage, speed and power factor can easily be analysed on the screen. When the user switches on the interface to run the system, the screenshot seen by the user is given in Fig. 10.

When button 2 is activated, the system starts to work at 5 Hz as the default value (Fig. 10). Three-phase voltage values taken from the network for the induction motor are shown in the 3rd, 4th, 5th pointers. Similarly, three-phase current values taken from the network are shown in the 6th, 7th and 8th pointers. The number of motor cycle per minute is shown by the pointer 12; the power factor of motor is indicated by pointer 11. Pointer 10 shows the operating frequency of motor. The data taken from the measurement cards can synchronously be seen either digitally or in analog form.

The button 14 drives the asynchronous motor at the range of 0-50 Hz frequency. As an example, while the asynchronous motor is driven at 47 Hz, phase voltages, phase currents, rpm, power factor and operating frequency can be seen on the Fig 11. With the button shown by 13, the speed of motor can be adjusted between 0-980 rpm.

The induction motor has been also controlled in analog form using the analog inputs of the frequency converter. Values of the motor parameters are also shown on the interface. If any data changes occur via buttons 13 and 14, new data is quickly transferred to the PLC via the OPC Server. The PLC transfers this data to the motor. The response of the motor against these changes is quite fast without any delay. Thus, communication and control structure of the system designed is considerably successful.

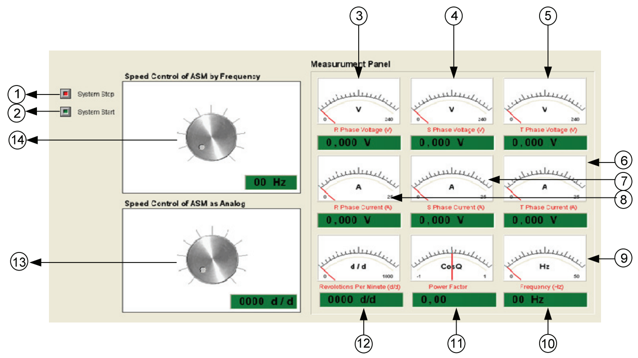

Fig.10. Screenshot of the interface program when the user switches on the system

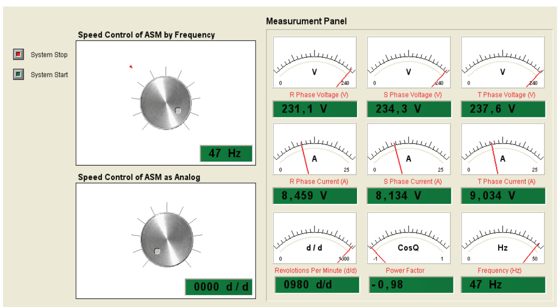

Fig.11. View of the interface while the motor operates at 47 Hz

Conclusions

Recently, practical studies for some of the special experiments could not be realized due to lack of equipment, time, space and trainers. However, such obstacles in education can be eliminated with the help of the improved technology. Remote learning or computer-controlled systems are good solutions to fix those problems.

In this study, an instructive and real time application has been designed and implemented to control the speed of an induction motor by changing its frequency and to observe the motor parameters against the frequency variation experimentally. A programmable logic controller (PLC) has been used as the main controller that operates highly stable in the system. A user-friendly and quite didactic user interface has been also designed in Profi-Lab Expert environment in order to perform the control and the observation procedures easily. In the system, most parameters of the motor can be observed visually via a user interface. Three phase current and voltage values, power factor, speed and frequency can be monitored in that manner. Furthermore, a number of control operations like start/stop operation and speed control over frequency can also be performed at the user interface. The communication between the PLC and the user interface has been established through an OPC server, enabling to communicate several automation devices which belong to different companies.

Both the control of the induction motor and monitoring the parameters are achieved in a secure and fast way. Transient and steady state behaviours of the motor under different frequencies can be analysed easily over the visual user interface. The system designed can be used as a teaching tool in laboratory experiments in technical education. Furthermore, the system can be used for industrial purposes to test the operational parameters of the motor. The system can be expanded to drive and control more than one motor after a few changes on the hardware and software structure.

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