

Asynchronous Motor Control Using Control Panel

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Abstract: Recently programmable logic controllers and control panels have frequently been started using together. The control panels allow the operator to monitor and control all inputs and outputs connected to the programmable controller through control and monitoring programs named SCADA - Supervisory Control and Data Acquisitions. In this study it was done speed, run time and lap control of a three-phase asynchronous motor with the aid of control panel. The control system created for this purpose consists of two parts as hardware and software.

Hardware part is formed by a programmable controller, a touch panel, an encoder, a temperature sensor and a three-phase asynchronous motor. And the software part is formed P.L.C. and a control and monitoring program prepared with the SCADA program. According to selections made from the control panel it was provided continuous operation of the motor in the desired direction of rotation and speed, operation of motor at desired time and speed and desired rotation of the motor at the desired number of revolutions. For this purpose, a SCADA program was prepared for the control panel, the motor speed was changed with the help of Frequency Inverter, and it was measured the motor's number of turns per second by the encoder. Also with the help of the temperature sensor in the system the temperature of the motor was shown on the control panel and included in the control system

Keywords : asynchronous motor, control panel, motor control, programmable logic controller, speed control

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I. Introduction

A system is a collection of interconnected elements that are brought together to perform a work or a task. Control is all the work of changing the behavior of a system or of a group of systems as desired. A control system can have one or more inputs and outputs. Automatic Control is a type of control that detects disturbing effects in the system by reducing the human factor to the minimum in a control process of a system. Automation is a job shared with the machine. The share rate determines the level of automation. Systems with a lot of human power are known as semi-automation and in full automation systems machine power is excessive. The control mechanism, which is a concept of automation, now offers almost unlimited application possibilities for businesses. On the basis of the data obtained permanently via electromechanical, electronic circuits or computer only, which control the operation, the automation applied to the business has allowed us to see how much something is done or not by classifying it.[1]

In this study, it is aimed to control the asynchronous motors, which is one of the most used mechanical power sources of machine automation in enterprises, with control panel. The control system designed for this purpose consists of two main groups as software and hardware. Hardware group consists of Siemens S7-200 CPU222 model programmable controller, EM235 Analog expansion module, Siemens TP177B 4 "touch control panel, 250W three phase asynchronous motor, Inform 2.2KW frequency inverter, Sick-Stegmann DSR60 Incremental encoder and LM35 analog temperature sensor. The software group consists of the programmable controller control program and the control panel program prepared with the WinCC SCADA program.

II. System Components

1.1. PLC and Analog Module

In a simple sense programmable controllers are mini industrial computers which control inputs and outputs such as numerical and analog data processing, temporal cycling, counting of inputs, sequential control, arithmetic operations, comparison, data routing, and communication with the aid of control program prepared and saved in the memory by the users.

It is now possible to carry out complicated control operations with PLCs designed to undertake the task of the elements such as especially the relay in the classic control panel - the time relay. There are also a number of internal relays and time relays in the unit. PLCs are generally used in industrial process applications and

production. The main advantages of PLC are easy, flexible, reliable and simple system settings and low maintenance cost. Therefore, complex systems are shifted to PLC control systems.[2] In this application, CPU 222 model of Siemens S7-200 model programmable controller is used. The properties of this PLC are given in Table 1 below.

Table 1 Features of the Programmable Controller

Features	CPU 222
Program Memory	4KB
Data Memory	1KB
Memory Backup Time	50 clock
Integrated Input/Output Number	8 input/6 output
Quick Counter	
Single Phase	4(30kHz)
Double Phase	2(20kHz)
Pulse Output	2(20kHz)
Analog Setting Port	1
Real Time Clock	With Clock Pulse
Communication port	1 (RS485)
Real Number Arithmetic	there is
Addressable Area (Input / Output)	128 bit /128bit
Command Processing Speed	0,37µs

Among the features the PLC's analog input-output port is not available. In our application we need one analog input port and one analog output port. For this purpose, the EM235 analog module is installed in the expansion slot of the programmable controller. The analog module does not need to be programmed separately.[3]

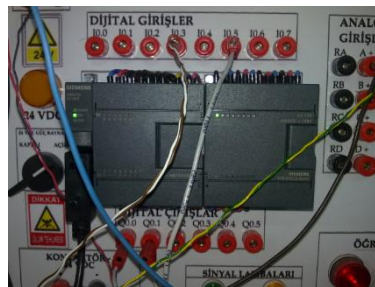


Fig. 1 S7-200 CPU222 PLC and EM 235 Analog Expansion Module

1.2. Operator Control Panel

Operator panels are used by connecting to a programmable controller so that they can be monitored continuously and controlled online. There are a wide variety of operator panels. Some of them only give us information about the process and some models allow us to monitor and intervene the process. The panel used in this system for this purpose is a touch control panel where both the system can be controlled and intervened. The connection of the panel to the programmable controller, that is the communication, is done by serial cable of RS232 / 485/422 standard. The communication between the programmable controllers and the human being is made with input elements such as buttons, switches and etc., and output elements such as relays, contactors, bobbins. However, in many applications, operator panels have been used to communicate between the human and the controller since these panels were made. For this reason, these panels are used as HMI- Human Machine Interface.[4] In this application, Siemens TP177B 4 Control and Monitoring Panel was used as model. The features of this screen are given in Table 2 below.

Table 2 Control Panel Features

Features	TP177 B 4"
Screen	TFT 256 color 4.3"(10.922cm)
Resolution	480x272 piksel
Control	Resistance Touch screen and 4 function buttons
Memory	2MB
Connection	1xRS485, 1xRS422, 1xUSB, 1xRJ45 ve 1xMMC Memory card entry
Program	WinCC



Fig. 2 Display Screen of the Control Panel

1.3. Encoder

Encoders are electromechanical elements that convert the angular or linear motion of the shaft, to which it is connected, into digital work. They are encoders that produce signals between 1 and 4096 per revolution in accordance with the motion of the spindle. The number of signals produced in one lap depends on the resolution of the encoder. In this study, Sick-Stegmann DSR60 Incremental encoder was used.[5]



Fig. 3 Incremental encoder

1.4. Asynchronous motor

When alternating current is applied to the stator windings of asynchronous motors, a variable magnetic field is created on the windings. With the effect of this variable magnetic field, a variable current is induced in the rotor bars in the middle of the rotor windings and this induced current creates a magnetic field around the rotor bars. The interaction of these two magnetic fields causes the rotor to rotate according to the pushing or pulling force generated by each other. Because of this reason, the number of rotor revolutions and the number of stator rotating field revolutions are not equal to each other. In asynchronous motors, the number of revolutions per revolution is always smaller than the number of revolutions of the rotor.

The rotor speed of asynchronous motors is written on the motor nameplate. In addition, the number of revolutions of the asynchronous motors is found by the following formula.

$$n_s = \frac{60 \cdot f}{p} \quad (1)$$

n_s : number of revolutions per revolution, f : mains frequency, p : double pole number

As can be understood from this formula, the number of revolutions of the asynchronous motors is possible with the network frequency and the number of poles.[6] There are asynchronous motors operating in two different cycles with the placement of the coils in the design to obtain two different poles. However, since it is not possible to change the number of poles after winding the windings of the motor, it remains as it is how many poles are wound during the design. But if the frequency of the alternating current applied to the motor can be changed, the number of revolutions of the motor also changes. Frequency modifiers called inverters are used for this purpose. Frequency inverters change the number of revolutions of an asynchronous motor by converting the constant voltage and frequency received from the network to variable voltage and frequency.



Fig. 4 Encoder and Asynchronous Motor

1.5. Frequency inverter

The frequency inverters convert the constant voltage and frequency of the mains supply to variable frequency and variable tension. They are mounted between mains and motor and make constant-variable speed setting by converting a single-winding standard motor into a variable speed drive system

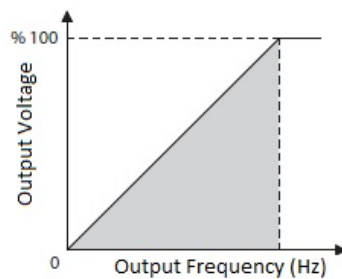


Fig. 5 V/f Change Rate of Inverters

The speed of the connected motor can be continuously adjusted by changing the output voltage and frequency of the inverter. In this study, the information of the direction of rotation and the number of revolutions selected from the Control Panel is transferred to the Programmable Controller. After this information on selecting number of rotation and direction of revolutions have been processed in the programmable controller, it is transferred to the frequency inverter.



Fig. 6 Frequency Inverter

1.6. Temperature Sensor

In this operation, to show the motor temperature or the ambient temperature in the control panel the LM35 temperature sensor was used. A voltage difference of $10\text{mV} - 10\text{mV}/^\circ\text{C}$ is produced from the output of the sensor at every 1°C temperature change. This produced output voltage is straightly sent to the control panel after being read from the analog input of the programmable controller and processed.[7]



Fig. 7 LM35

The connection block diagram among the elements of the generated control system is shown in Figure-8.

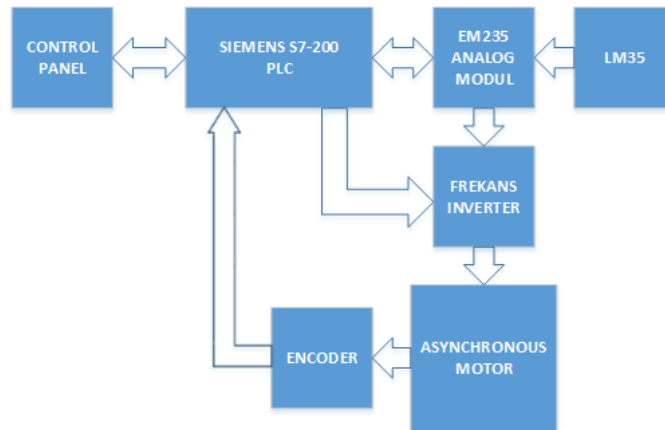


Fig. 8 Connection block diagram among control system elements

To which input-output ports the connections between the elements of control system and programmable controller are made and the memory areas used are shown in Table-3.

Table 3 Memory areas used

Memory Space	Use of	Explanation
M0.1	Start Button	Panel to PLC
M0.2	Cycle Direction Selector	Panel to PLC
M0.3	Stop Button	Panel to PLC
I0.3	Encoder Input (HC4)	Encoder to PLC
Q0.0	Forward Direction Relay	PLC to Inverter
Q0.1	Reverse Direction Relay	PLC to Inverter
MB20	Operation Selector	Panel to PLC
VW70	Time Selection	Panel to PLC
VD4	Tour Selection	Panel to PLC
AIW0	Thermal Sensor Analog Input	Thermal Sensor to PLC
AQW0	Number of Revolutions Analog Output	PLC to Inverter
VD108	Temperature Value Output	PLC to Panel
VW200	Number of Revolutions Digital Input	Panel to PLC
VD76	Number of rounds	PLC to Panel
VD96	Number of cycles	PLC to Panel

The connections and relationships of hardware groups between each other do not change according to the desired operations. The operations to be made are directed and performed by the control program and the control panel program. In the operation, the desirable things with the selections through the control panel are that the asynchronous motor works continuously in the desired number of revolutions and in the desired direction of rotation, works in the selected time and works up to the number of selected laps. The PLC and Control Panel software prepared for these three working states are the same, and according to the selections made on the Control Panel made, they are directed to the desired operation by program comparison commands.

The programmable controller program for this application consists of one subprogram and one main program. Both programs were prepared with Ladder Diagram in Step7 MicroWin program. It is necessary to transfer the selections made from the Control Panel to the Programmable Controller and transfer memory areas used by the programmable controller system to the Control panel. In this application, the SCADA WinCC program called Control and Data acquisition compatible with the Programmable Controller and Control Panel is used. The target of this operation with WinCC program is the Continuous operation of the asynchronous motor with the selections made from the Control Panel at the desired speed and rotation direction, at the selected time and in the number of selected tours. One program has been prepared for these three operating modes and three choices are provided for the selections made from the program. Ladder diagrams of the PLC control program are shown in Figure-9-16. In addition, the PLC program and the Control Panel program can be accessed from the current web page.

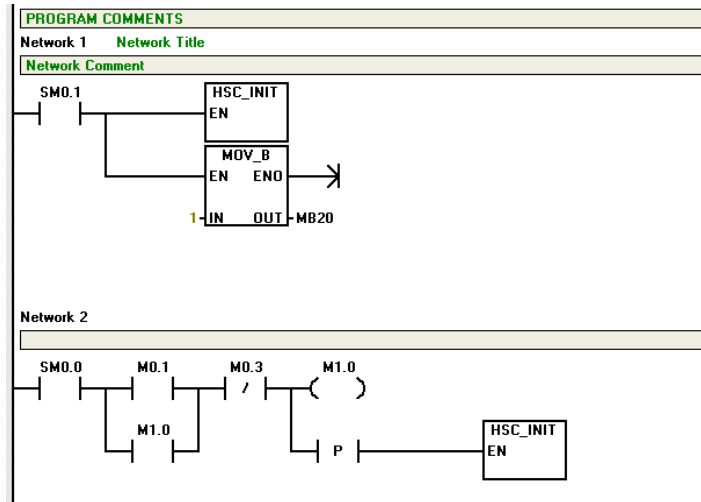


Fig. 9 PLC Main Program Network 1 and 2

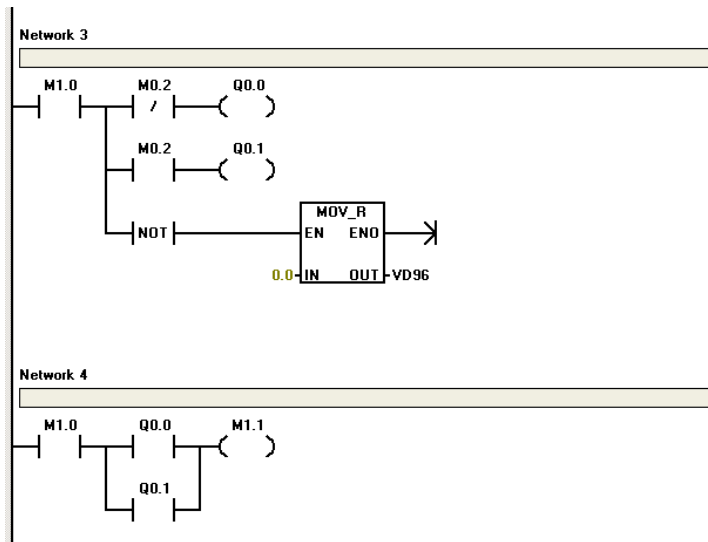


Fig. 10 PLC Main Program Network 3 and 4

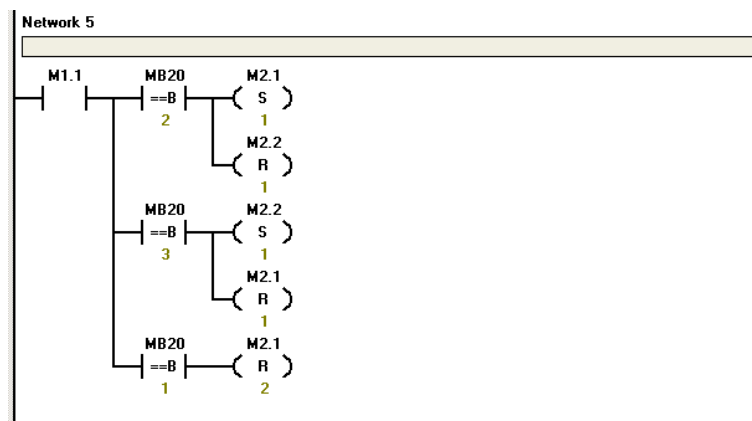


Fig. 11 PLC Main Program Network 5

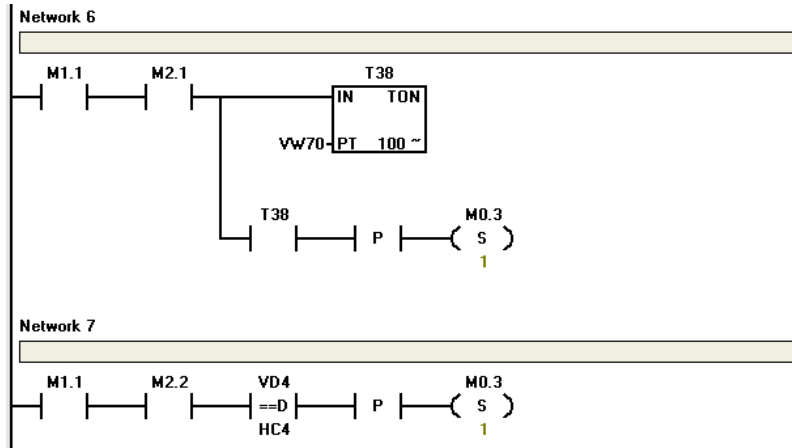


Fig. 12 PLC Main Program Network 6 and 7

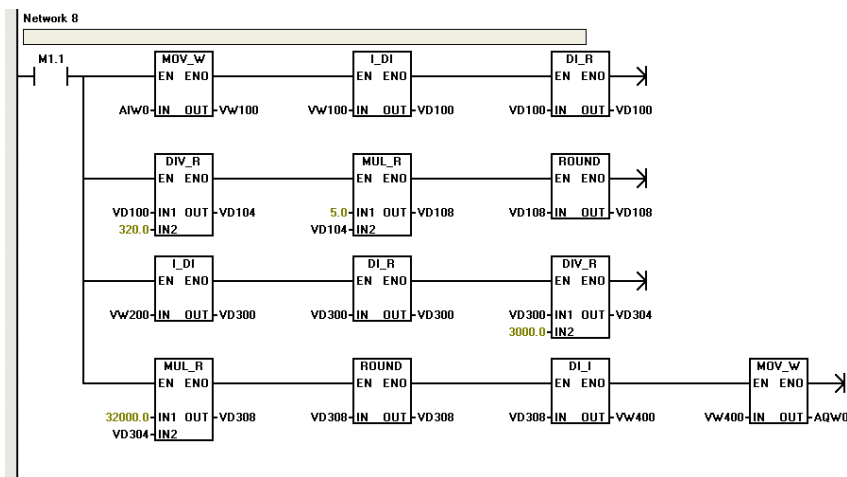


Fig. 13 PLC Main Program Network 8

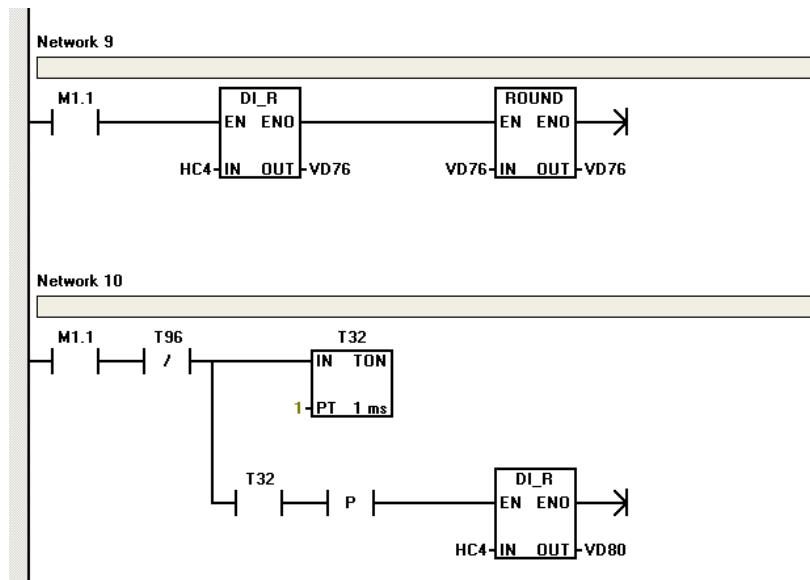


Fig. 14 PLC Main Program Network 9 and 10

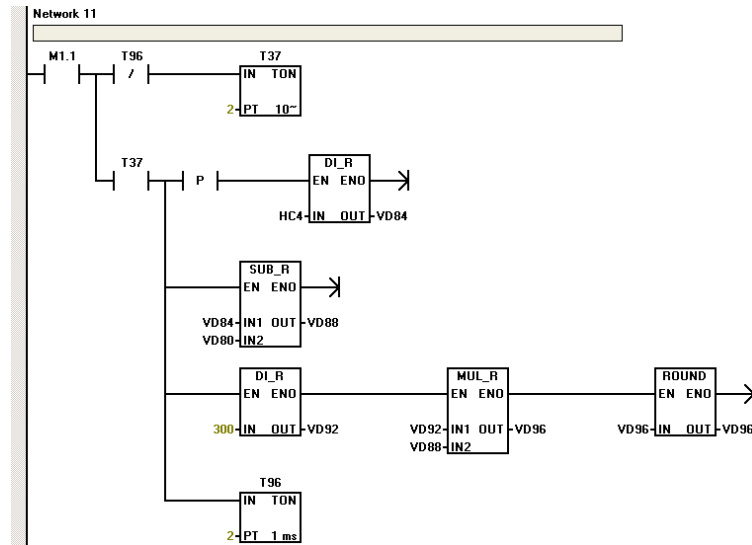


Fig. 15 PLC Main Program Network 11

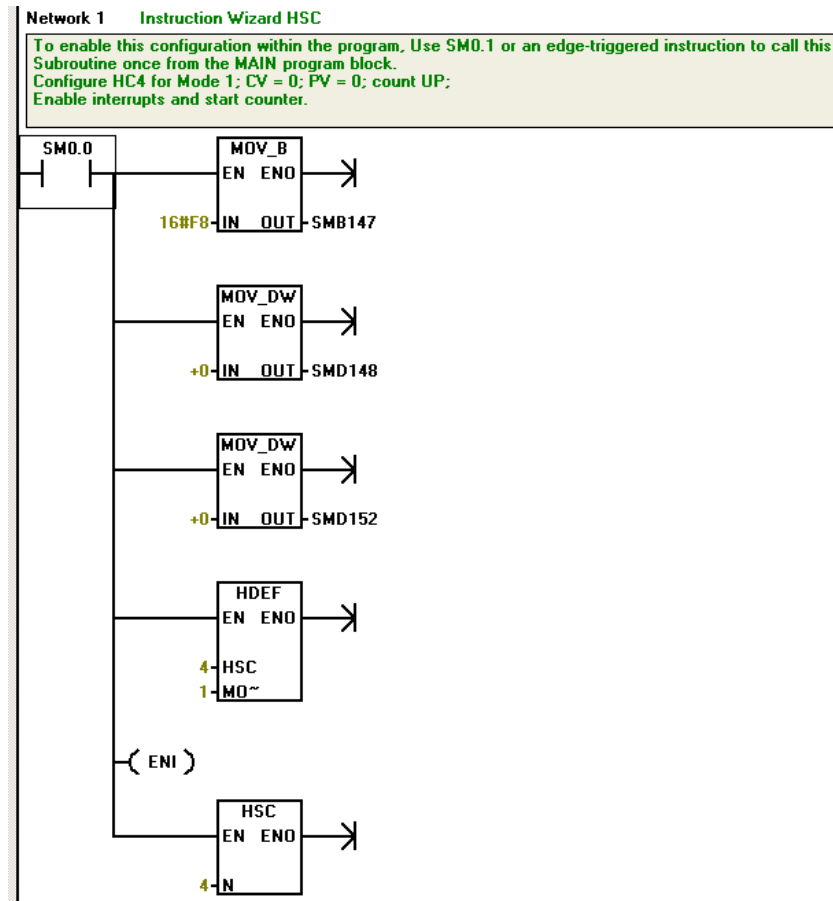
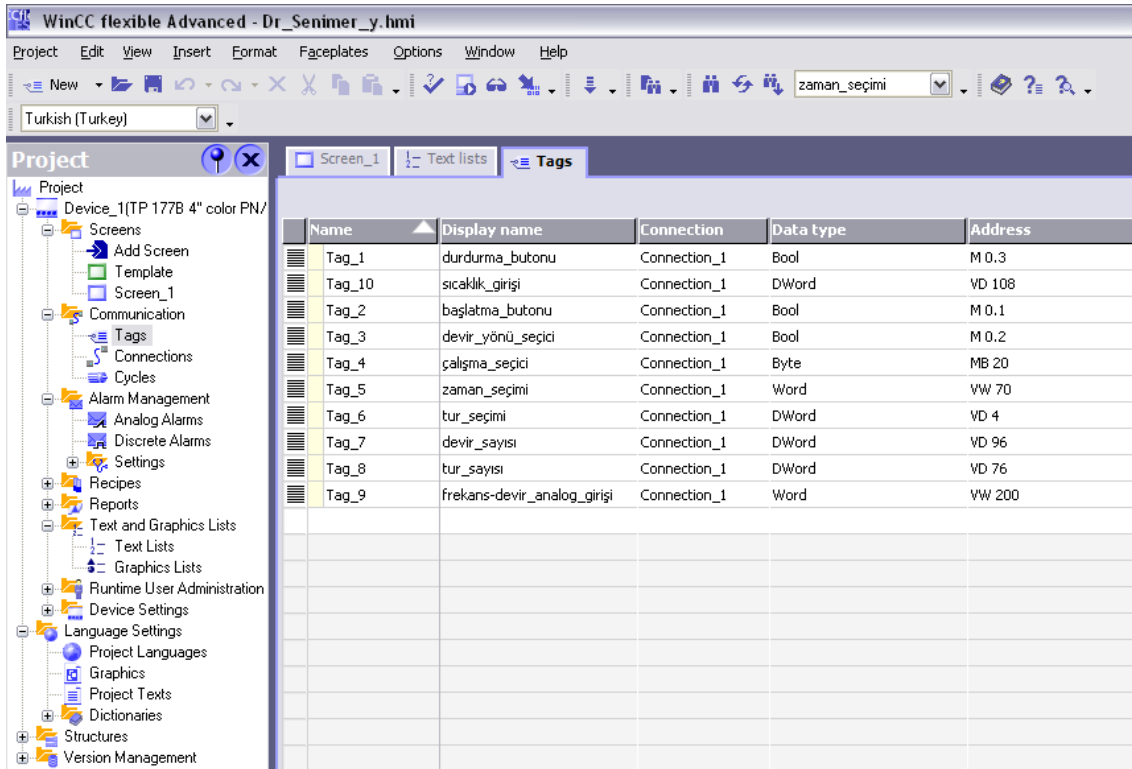


Fig. 16 PLC HSC_INIT Subprogram Network 1

For the control panel program first of all the analog and Digital memory areas, used by the programmable controller and monitored and intervened with the control panel, need to be identified as tags in the SCADA program called tags.[8] The tags used in the operation are shown in Figure-17 below.



Name	Display name	Connection	Data type	Address
Tag_1	durdurma_butonunu	Connection_1	Bool	M 0.3
Tag_10	sıcaklık_girisi	Connection_1	DWord	VD 108
Tag_2	baglatma_butonunu	Connection_1	Bool	M 0.1
Tag_3	devir_yonu_secici	Connection_1	Bool	M 0.2
Tag_4	çalışma_secici	Connection_1	Byte	MB 20
Tag_5	zaman_secimi	Connection_1	Word	VW 70
Tag_6	tur_secimi	Connection_1	DWord	VD 4
Tag_7	devir_sayisi	Connection_1	DWord	VD 96
Tag_8	tur_sayisi	Connection_1	DWord	VD 76
Tag_9	frekans-devir_analog_girisi	Connection_1	Word	VW 200

Fig. 17 Tag List Used in Practice

As you can see from the tag list, the tag addresses used here belong to the input and output memory areas used in the programmable controller program. If these addresses are incorrect, the program will not work properly.

After this step, the graphic design of the screen is done.[4]

When the graphic design is completed and Continuous Mode is selected in the operation mode selection, the screen display is shown in Figure-18.

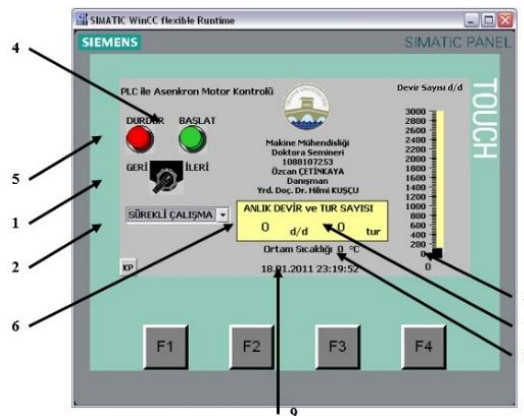


Fig. 18 Screen Elements with Control Panel

Direction of motor rotation is selected from the selection switch 1 and Continuous, Term and Turn able operation modes are selected from the selection area which is shown by arrow 2. In case of number 3 area, the number of motor revolutions is determined. According to the selections made from the number 4 start button, the motor starts to run due to the direction of rotation, number of revolutions and operating mode. In case of number 5, stopping of the working system is ensured. In addition, the number of instantaneous revolutions of the motor is shown in the display area 6 and it is shown the total number of revolutions in the display area 7. In the display area 8, the ambient temperature at which the temperature sensor is located, and in the display area 9, the time and date of the system are shown. In this operation mode selection if the term operating mode is selected, the time selection field appears on the graphic display. And the screenshot is shown in Figure-19.

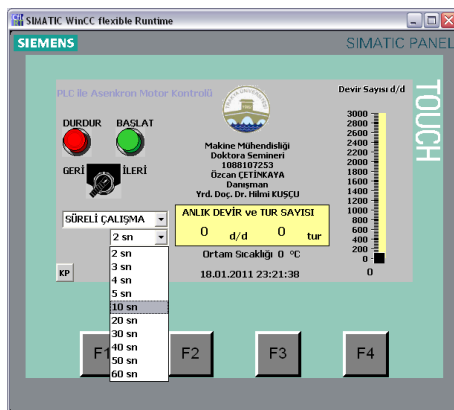


Fig. 19 Continuous Operation Mode Screen

If you select turn able mode in the run mode selection, the turn selection field appears on the graphic display. And the screenshot is shown in Figure-20.

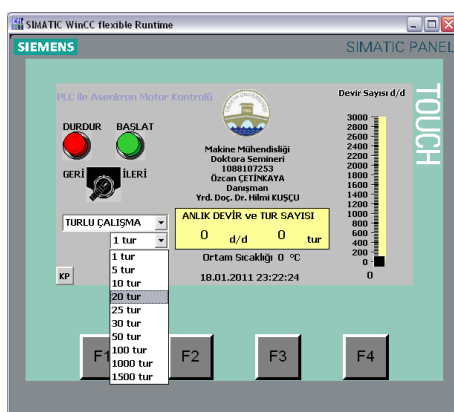


Fig. 20 Turntable Mode Screen

III. Conclusion

In this work, a three-phase asynchronous motor was successfully operated in the desired direction of rotation and in the desired number of revolutions, for the desired working time and the desired turn with the aid of the touch control panel. In addition, the heat at the windings of asynchronous motors due to the frequent stop-and-go within a short time was monitored by the temperature sensor placed in the motor windings and the motor was disengaged when temperatures reached harmful temperatures and so motor protection was done.

ADDS

1. PLC control program and control panel program <https://mmo.tc/KLco>

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