# EE300 Summer Practice Report

## MIDDLE EAST TECHNICAL UNIVERSITY

Department of Electrical and Electronics Engineering

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| SP Company Division | : Automation |
| SP Company Location | : Dilovası, Kocaeli, Turkey |

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# 1.Description of the Company

Best Makina A.Ş. manufactures insulated glass unit (IGU) machines. It is a company that is specialized in IGU production lines. Approximately 30 % of the sales of the company is in domestic market, so the company exports 70 % of the sales of its machinery products to 85 countries. Best Makina A.Ş. is one of the largest manufacturers of IGU machineries in Turkey and in the world. Its production is 100 % in-house production including parts production, painting and electric assembly. The location of the company is close to the highways, railway and maritime transport centers to export its products easily.

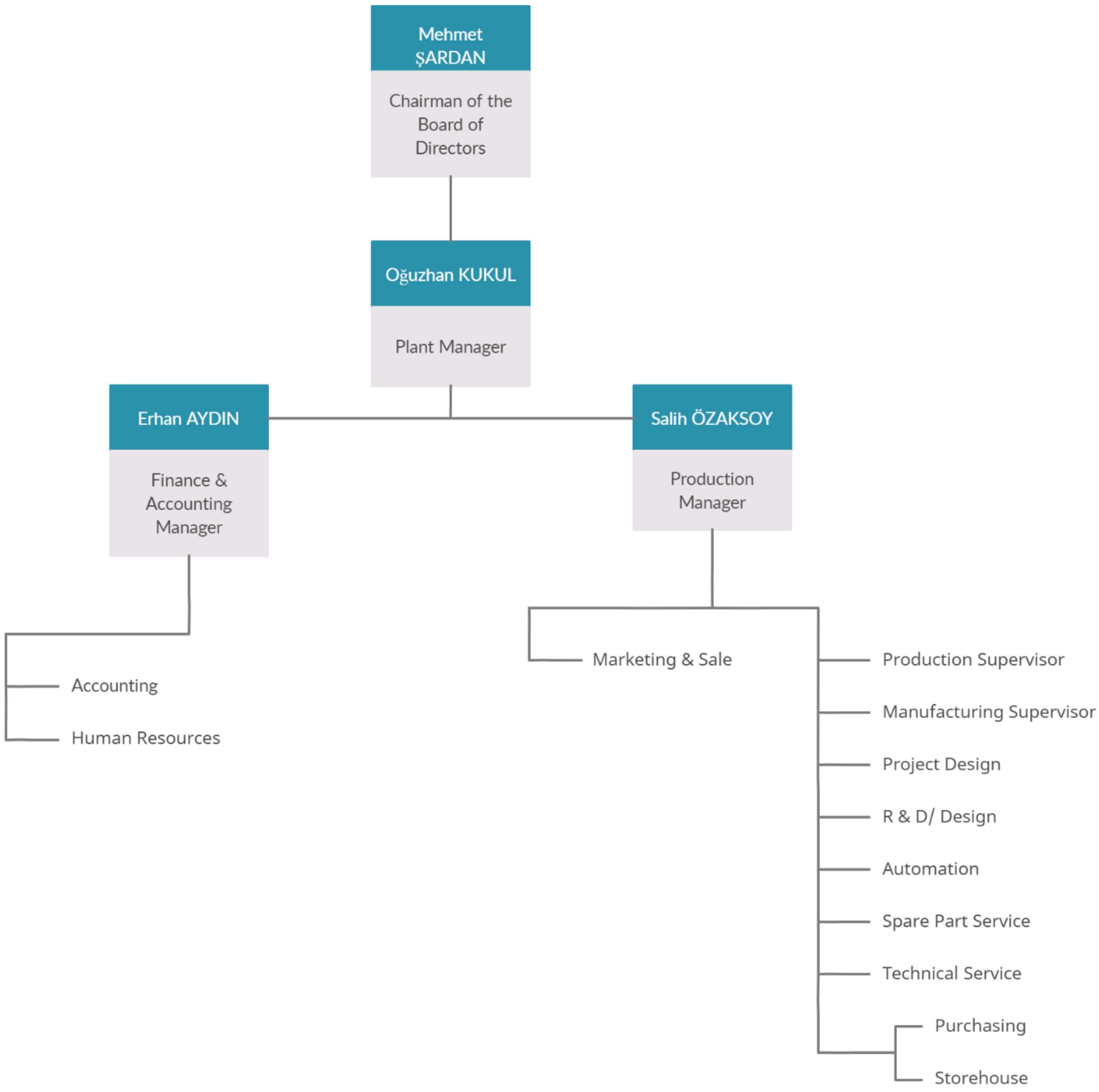


Figure 1: Organizational Structure of the Company

I was in Automation division of the company under the production manager during my 4-week summer practice. Automation division can be seen in the organizational structure of the company in Figure 1.

There are 113 workers in the company, and the distribution of the white-collar and blue-collar workers can be seen in Table 1.

| Distribution of the Workers | | |
|---|---|---|
| **Worker Type** | **Number of Workers** | **%** |
| White-Collar | 33 | 30 % of the Workers |
| Blue-Collar | 80 | 70 % of the Workers |
| Total | 113 | 100 % of the Workers |

Table 1: Distribution of the Workers in the Company

There are 13 engineers in the company. Distribution of the engineers in the company can be seen in the Table 2. In my division, which is Automation, there are 4 engineers, and 3 of them are Electrical & Electronics Engineers with B.S. degree. There is also a mechatronics engineer in Automation division. The distribution of the engineers and technicians in the automation division is in Table 3. All technicians in the Table 3 have associate degree.

| Distribution of Engineers | | |
|---|---|---|
| **Field of Engineering** | **Number of Engineers** | **%** |
| Electrical & Electronics Engineer | 3 | 23 % |
| Mechanical Engineer | 6 | 46 % |
| Mechatronics Engineer | 3 | 23 % |
| Metallurgical & Materials Engineer | 1 | 8 % |
| Total | 13 | 100 % |

Table 2: Distribution of the Engineers in the Company

| Automation Division | | |
|---|---|---|
| **Field of the Staff** | **Number of the Staff** | **%** |
| Electrical & Electronics Engineer | 3 | 37.5 % |
| Mechatronics Engineer | 2 | 25 % |
| Technician (Mechatronics) | 1 | 12.5 % |
| Technician (Automation) | 2 | 25 % |
| Total | 8 | 100 % |

Table 3: Distribution of the Engineers and Technicians in the Automation Division of the Company

# 2. A Brief History of the Company

Best Makina A.Ş. was established in İstanbul in 1999. In that year, there were implementation of welding atelier, chipped part production atelier, and electrical part assembly and wiring in the company.

Before establishing the Best Makina A.Ş. officially, Aydın ŞARDAN started the first Turkish glass processing machine, which is ‘FRB 45 Edging and Beveling Machine’ for shaped glasses in 1985. Then, he started production of ‘2200 Best Cold Two Component Hydraulic Extrusion Pump’ in 1991. From 1993 to 1999, he worked as the Freelance Service Provider of EU made machines.

The company started to export in 2001 with Bulgaria. It became the first company in the world with longest warranty period, which is 2 years, in glass machines. In 2009, its export reached to 30 countries, and in 2017, its products reached 80 countries. [1] The company moved to a new factory in 2020 in the Dilovası district of Kocaeli province. by investing approximately 10 million euros in the last three years. [2]

# 3. Introduction

I chose Best Makina A.Ş. as my summer practice company because I am interested in automation and control systems, and I also wanted to see and observe the electrical assembly production such as control panels as well as PLC programming. In addition, observing the work life in a fairly big factory was a good experience for my first summer practice. I found this summer practice location by using my networks.

I participated some of the simple works there although I was mostly an observant under my supervisor EE engineer. My summer practice was 4-weeks, and it lasted 20 days.

In the first week, I was introduced the company and my division which is automation. After that, I participated in a seminar about occupational health and safety in the factory. Then, I was given an assignment to learn and search about the basic components and concepts in a control panel that are produced by the company for the company’s IGU machineries. I learnt about them and also, I made some simple testing on the components.

In the second week, I was given an assignment to construct simple physical motor control circuits. I constructed circuits with and without inverters, and I controlled the motor by using these circuits.

In the third week, I was introduced the PLC programme that is used in the company. I first learnt the basics of Mitsubishi MELSOFT GXWorks3 by using the educational material given by my supervisor, and then, he gave an assignment about controlling a motor by writing a code and making a simulation. The software used here uses codes that are similar to C programming.

In the fourth and last week of my summer practice, I was given an assignment about learning about industrial automation protocols as well as HMI and SCADA that are used in the machines manufactured in the factory.

# 4. Work Conducted at the SP Company

## 4.1. Basic Components and Concepts in a Control Panel

I observed the manufacture of the control panel for the machine '7000 PRIMA LOGIC – Horizontal Butyl Extruder' because it has a fairly simple and small control panel than other IGU production lines manufactured in the company. Horizontal Butyl Extruder can be seen in Figure 2.


Figure 2: 7000 PRIMA LOGIC – Horizontal Butyl Extruder

The control panel that is behind the machine is in Figure 3. In the control panel in Figure 3, there are PLC units, relays, contactors, phase protection relay, an inverter for asynchronous 3-phase motor control, fuses, Solid-State Relays (SSR), connection cables, and power supply when we look at it. To understand the work done by electrical engineers here, I was told that I should be familiar about these and a few other components and equipment that are used in the production of the electrical parts of the machines. I made research about them on the Internet as well as getting information from the technicians that make wiring, soldering, and construction work of the control panels.


Figure 3: The Control Panel of Horizontal Butyl Extruder

I was not allowed to take photograph or note about the components that are used in the control panel, but I will try to write their properties of the equipment. The photographs that I use in this report is different from the ones used by the company.

### 4.1.1. PLC Units

PLC stands for ‘Programmable Logic Controller’, and it is a device that are used to control the industrial automation systems and machines. If there is a PLC unit in a system, we can say that there is a presence of automation in that system.

There are two brands that are used in the PLC units of the control systems of the IGU machines manufactured in Best Makina A.Ş. These two brands are Beckoff and Mitsubishi.

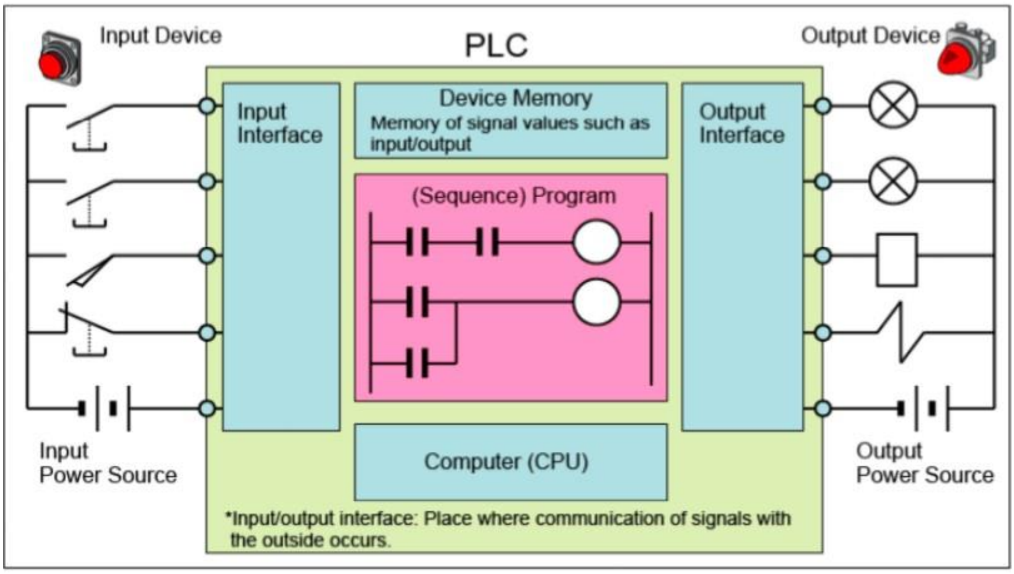


Figure 4: The Basic Structure of a PLC [3]

As illustrated in Figure 4, the structure of a PLC device consists of five basic parts: Input and output interfaces, device memory, program, and computer (CPU). Input interface is connected to input devices, and output interface is connected to output devices. The PLC uses the device memory and CPU as well as the program in it to provide the control of a system or device. The program is written in structured text language or in ladder logic language.

There is also a special type of PLC which is used in the control system of the Horizontal Butyl Extruder. It is called safety PLC, and it usually shuts down the system, or it can do the condition that are programmed when an unexpected situation occurs in the system. The yellow colored safety PLC can be seen in Figure 3 on the top line of the control panel.

### 4.1.2. Relays and Contactors

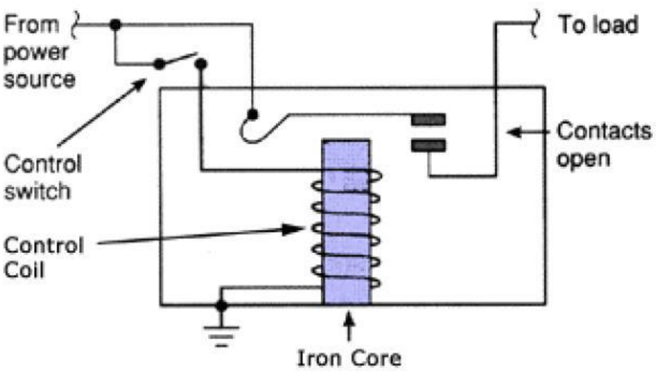


Figure 5: The internal structure of a simple relay [4]

Relay is an electrical device that uses electromagnetism to control a circuit with another circuit by using switching. When the relay is energized, the open contact of the relay is closed, and its other contact opens. The internal structure of a simple relay is presented in Figure 5. The contact on the right is closed when the electromagnet is energized from the power source on the left contact. Therefore, it can be said that it is a mechanical system.

There are two types of relays that are used in the Horizontal Butyl Extruder control panel. They are phase protection relay and solid-state relay (SSR). Phase protection relay is used to determine intervals for phases of the electricity used in the system. It protects the system and other devices connected to it from phase failures. The Horizontal Butyl Extruder uses 3-phase electricity, and the phase protection relay is used for phase sequence and undervoltage failures.

The SSR does the same switching operation with a relay, but its internal structure is different, and it has a longer lifetime. Unlike a simple relay, it does not have a mechanical system. The internal structure of SSR is given in Figure 6. When the current passes through the IR LED, the electromagnetic wave is detected by a sensor, and an open switch is closed in the output side.

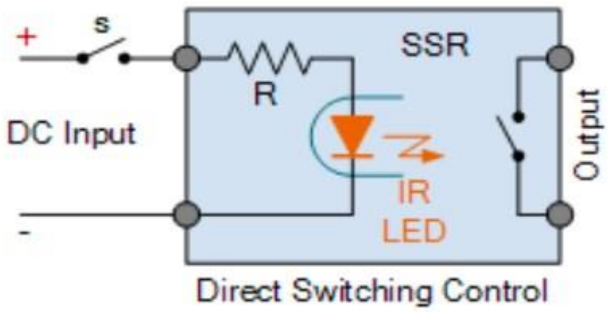


Figure 6: The basic internal structure of SSR [5]

*SSR and Optocoupler:*

Optocoupler is an electrical device which use the light to control the transfer of the electrical signal between two different circuits. The other name of the optocoupler is opto-isolator. The internal structure of the SSR and optocoupler is similar to each other. In an optocoupler, there is a LED and a phototransistor that is sensitive to light, and when the LED emits lights, the phototransistor passes the electrical current. Using optocoupler, two circuit that works with low and high voltage or current can be separated safely.

*Time Relay:*

A time relay is a relay that opens or closes its contacts before or after the adjusted time; in other words, it does not work instantly like the normal relay. The internal structure of a time relay is similar to the normal relay, and its timer can be a mechanical system.

*Contactor:*

A contactor is a switching electrical device that is quite similar to relay in that its purpose. However, there is a difference between the contactor and relay. A contactor does not have a common terminal between the two circuits that are connected to contactor like in the relay. By using DC low voltage like 24 V, we can control 220 V and 380 V AC high voltage in a safe and reliable way. When the contactor energized, then its open contacts closes, and its closed contacts opens.

### 4.1.3. Inverters for Asynchronous 3-phase Motor Control

An inverter is a device that is used to control the speed of a motor by changing the frequency in an efficient way. Inverter changes the power supply frequency that the motor uses.

$$Rotational\ Speed\ of\ the\ motor = \frac{120 \times Power\ supply\ frequency[Hz]}{Number\ of\ poles} \times (1 - S)\ [rotations/min]$$

Figure 7: The equation for the rotational speed of the motor in the inverter

$\frac{120 \times Power\ supply\ frequency[Hz]}{Number\ of\ poles}$ gives the synchronous rotational speed of the motor.

The number of poles is determined by the motor configuration in its internal structure, so we cannot change it most of the time. ‘S’ in the equation presented in Figure 7 means ‘slip’, which refers to the amount of the shift in the rotational speed of the motor from the synchronous rotational speed. When a load is applied to the motor, the slip is usually at around 0.03 to 0.05, which means 3 % to 5 % decrease from the synchronous rotational speed of the motor at normal torque. The slip is zero when the motor is stopped. [6]

In the Horizontal Butyl Extruder control panel, a Mitsubishi brand inverter is used to control an asynchronous 3-phase motor. The motor used has 1500 rotations/min and 4-poles, and it works in 50 Hz frequency.

### 4.1.4. Fuses

A fuse is an electrical component that stops the electrical current when the current exceeds a certain limit. In the Horizontal Butyl Extruder control panel, a few types of fuses are used such as thermic-magnetic circuit breaker and normal fuses. The brand of the fuses used in the Horizontal Butyl Extruder is Schneider Electric. An example of a fuse is in Figure 8.


Figure 8: An example of a simple fuse that is similar to the ones used in the control panel of the Horizontal Butyl Extruder [7]

There is also a different type of fuse that in used in the control panel of the Horizontal Butyl Extruder. It is called thermal magnetic fuse, or thermal magnetic circuit breaker, and it interrupts the electrical current when an overcurrent, for example, short-circuit current appears in the system. A thermic magnetic circuit breaker has an electromagnet that is similar to the one in a fuse and a metal that bends itself by heat in order to cut the electrical current when necessary. [8]

### 4.1.5. Other Components Connected to a Control Panel and Testing the Components

*Sensors:*

A sensor is a device or a circuit that produces electrical signals or show changes to a certain change or changing parameters that are detected by the sensor physically. A number of types of sensors is used in the Horizontal Butyl Extruder and other machines that are manufactured by the company. Capacitive, inductive, optic and fiberoptic sensors are some of the types that are used.

Capacitive sensors use the capacitive sensing. These sensors measure the change of capacitance and uses the capacitance to detect the target. The dielectric material that the capacitive sensor see can be almost anything, so it can measure the distance and position.

Inductive sensors are used to detect only the metal objects. They also can be used to measure the distance.

Optic and fiberoptic sensors usually used to detect the objects as well as detection of the distance.

The machines manufactured in my summer practice location usually have sensors that measure the distance and position. I was not allowed to write which machines have which kind of sensors in it while writing this report.

*Pt100 and Thermocouple:*

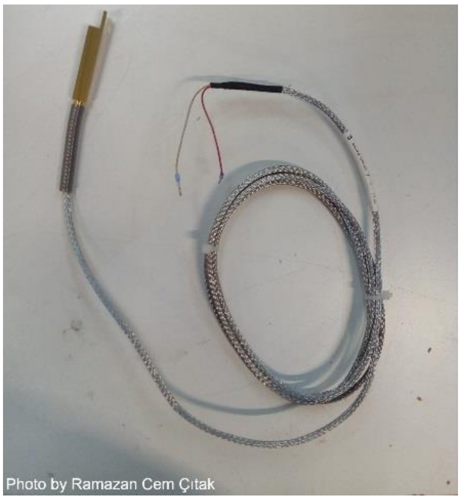


Figure 9: Pt100 Temperature Sensor used in the Horizontal Butyl Extruder

Pt100 sensor and thermocouple are used to measure the temperature. The Pt100 component that are used in the Horizontal Butyl Extruder is shown in Figure 9. The resistance of Pt100 is 100 **Ω** in 0 degrees Celsius, and its resistance increases with increasing temperature. Therefore, we expect to see a resistance that is greater than 100 **Ω**. Thus, I measured the resistance of it in room temperature, and the testing result can be seen in Figure 10. The result is 111.7 **Ω**, which is reasonable in the room temperature. The temperature and resistance increase in almost a linear manner for Pt100 sensor, so the analog signal is used to observe the temperature with the help of PLC Unit.

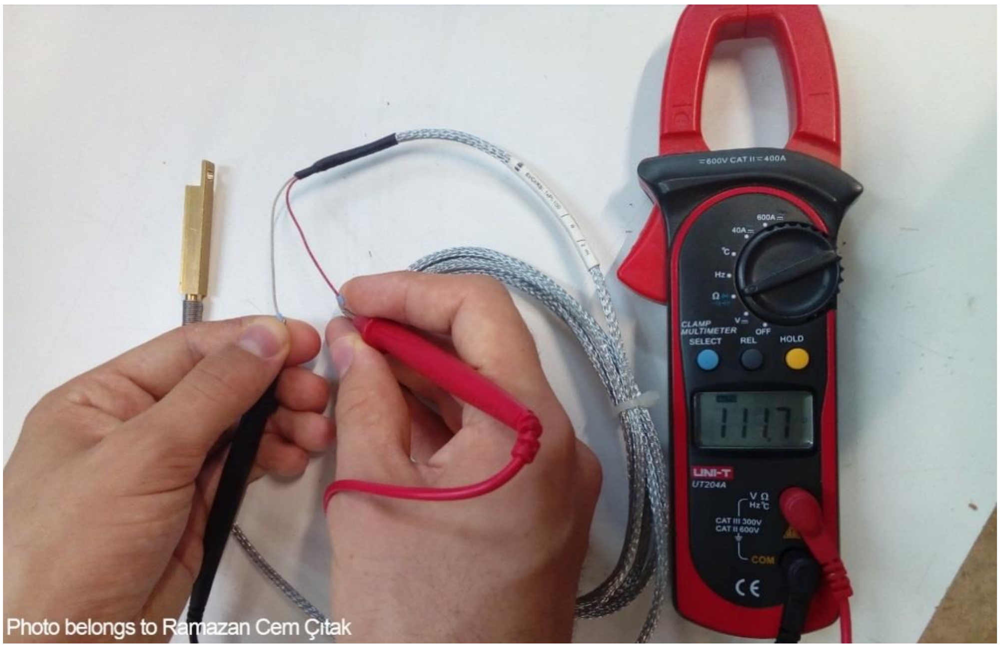


Figure 10: The measurement of Pt100 by using clamp meter

Thermocouple is also a component that measures the temperature; however, it has a different working principle than a Pt100 sensor. The change in the temperature creates a voltage change in a thermocouple so that we can detect the temperature. Thermocouple is usually cheaper than Pt100 sensor, and it is less sensitive.

*Motors:*

There are three types of motors that used in the factory: servo motors, 3-phase asynchronous motors (induction motors). Servo motors are usually used in the conveyors of the production line machines manufactured by the company. They are motors that provides precise control of angular and linear position that needs to be adjusted. Therefore, the torque of the motor can be adjusted more easily. There can be DC or AC servo motors. All the servo motors that are used in the control panels of the machines in the company are AC 3-phase servo motors. The driver of the servo motors is in the control panels, and these motors are controlled by the PLC Unit.

Unlike servo motors, 3-phase asynchronous motors have inverters in the control panel, and their motion is not as precise as servo motors. Asynchronous motors that is used in the company are usually in the pump and simple tasks requiring less sensitivity.

I was given a used 3-phase induction motor to read the label on it, which can be seen in Figure 11. The motor had Star connection when I opened the lid for the connection of the phases. From the label, I see that the motor operates in star connection either in 400 Volts or 480 Volts. If this motor is used in 400 Volts, then the maximum current it uses is 2.80 A according to the label. The maximum power of the motor is 1.1 kW, and the power factor cosφ is 0.81. If the power factor is close to 1, it is better because it means that it is a more efficient motor that uses the real power with less loss.

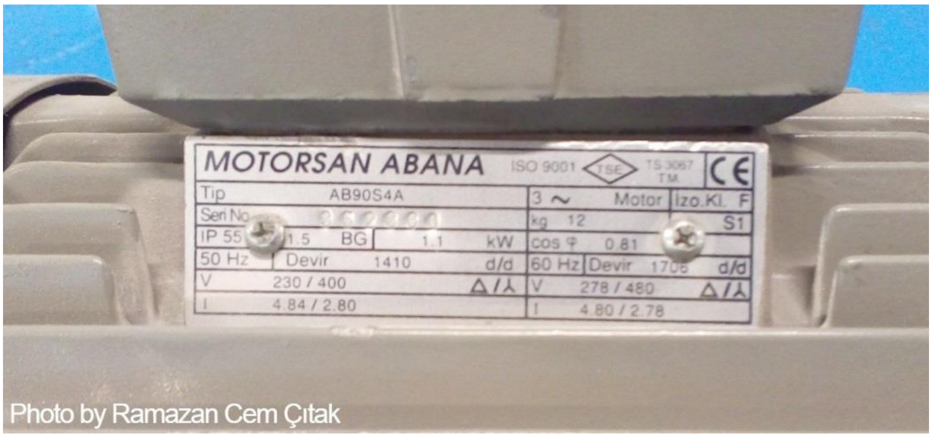


Figure 11: A used motor label that I observed in the factory

There are two types of motor connections in label in Figure 11. They are Delta and Star connections. Also, there is a circuit that is used for changing the connection type of a motor which has equal or greater maximum power of 5.5 kW. It is called Star-Delta Starter, and it is used for the reduction of the overcurrent that is used by the motor when it first runs. Firstly, motor is started as if it had Star connection, and then it runs with Delta connection.

To change the direction of the rotational motion of a 3-phase induction motor, we change two of the places of the 3 phases. Then, we can change the clockwise direction to counterclockwise or vice versa. For example, for phases U, V, W or L1, L2, L3, if we change the places of L1 and L2, the direction of the induction motor will be reverse

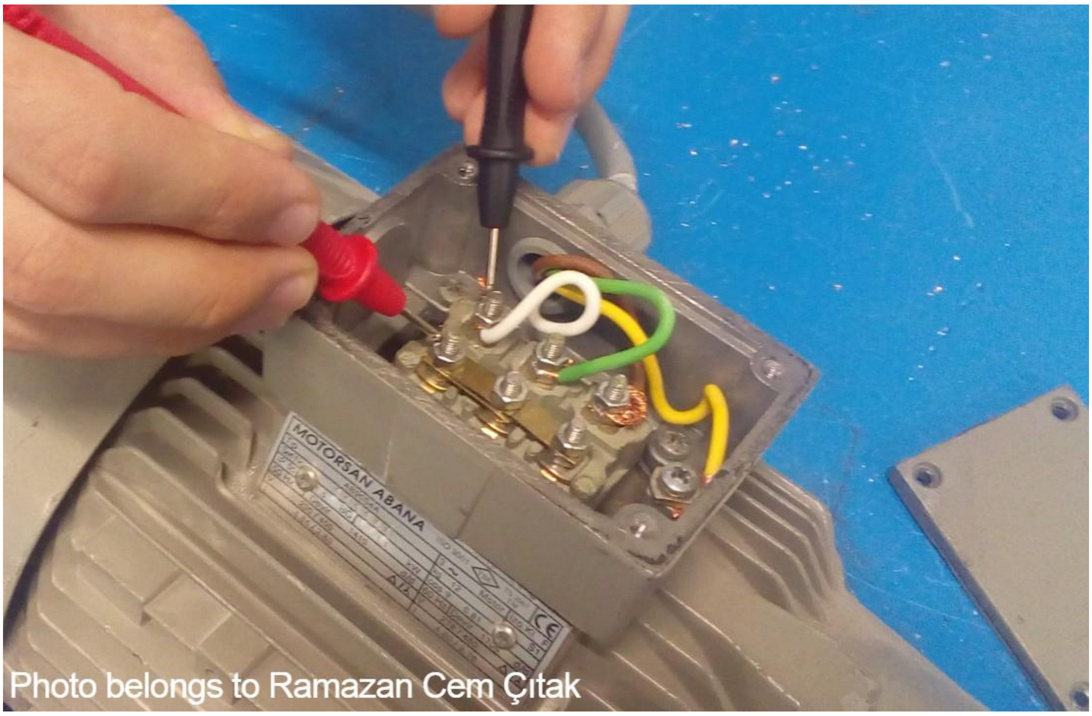


Figure 12: The measurement of the resistance of one of the motor winding

To understand a 3-phase induction motor can work properly or not, the measurement results of the resistance of the three windings of the motor can be observed. The results should be the same or very close to each other, and they should not be zero. The resistances, I measured by using a clamp meter, of the windings of a used working motor is presented in the Table 4.

| Windings Measured | Resistance |
|---|---|
| Winding with U | 7.4 Ω |
| Winding with V | 7.4 Ω |
| Winding with W | 7.5 Ω |

Table 4: The Measurements of the Resistances of the Windings in the 3-phase Induction Motor

*Encoder:*

An encoder is an electromechanical device that usually sends electrical signals about the speed of the motor that it is connected. Encoder is a component used in some of the motors in the machines manufactured in my summer practice location. The signals that it sends are used to calculate, for example, the torque of the motor as well as the use of feedback by using the signals coming from encoder.

The servo motors that is used in the IGU machines manufactured in the company all have encoder that is integrated to motors because thanks to the feedback coming from the encoders, the servo motors adjust the position as well as velocity and acceleration in a precise way.

### 4.1.6. Cables

The cables that are used in the construction of a control system panel differs according to the current that the cables carry. The cross-sectional area of the cables changes by their current carrying capacities. An example table that presents the suggested cable cross-sectional areas and current capacities in different situations are given in Appendix A [9]. For example, a 1.5 $mm^2$ wire has a current capacity of 20 A, which is maximum value that it can pass in the environment of the air according to the table in Appendix A.

The current carrying capacities are also dependent on the length of the wire used and temperature. Therefore, the choice of a correct type of cable is crucial while manufacturing a control panel. The type and length of the wires used in control panels are determined by the Automation division of the company.

## 4.2. Reading the EPLAN Circuit Schematics to Construct a Control Panel

### 4.2.1 EPLAN Program

EPLAN Electric P8 is a computer-aided design (CAD) program that is used for the projects of electrical engineering and automation projects such as control panels in my summer practice location. The company uses the EPLAN Electric P8 version of the program, and all the projects are designed in the Automation division. With the use of EPLAN program, the wiring diagrams of the circuits in the project and the documentation about the components with their details. The program breaks a large project into small pieces so that everyone that can learn about the project can understand it in an easy way. The wiring diagrams are given in an ordered way in an EPLAN documentation of a project.

### 4.2.2. Examples from the Control Panel of the Horizontal Butyl Extruder

An example EPLAN project page of the Horizontal Butyl Extruder is given in Appendix B. The first two figures of cable numbers represent the number of the page of the project and ‘10A1’ represents the PLC Unit of Mitsubishi FX5UC – 32MT, which can be seen in Figure 13. Inside the rectangle ‘++SAHA+’, there are a number of buttons used near the screen of the machine and a sensor which are outside the control panel of the Horizontal Butyl Extruder. Such documentations are designed by the Automation division, and the connections are made by the technicians while being controlled by engineers in certain time periods.

## 4.3. Constructing Motor Control Circuits

The other summer practice students[1] in the company and I were assigned to construct a few simple types of motor control circuits to understand better the simple blocks of big projects. The circuits were constructed by three of us, but we analyzed and made comments about the circuits separately. Doing a task with someone helped me in the practical way because the teamwork is also an important aspect of engineering. While constructing the circuit, there is always a technician that is close to us and monitor our work to answer our questions and to use the equipment and components safely in the workplace of the company.

### 4.3.1. Start–Stop Control of a 3-phase Motor with Buttons

The circuit schematics of the Start–Stop Control of a 3-phase Motor with Buttons are presented in Appendix C [10]. When we push the start button once, the motor starts to run, and when push the stop button, the motor stops.

The motor works with 380 V AC voltage, and our control circuit works with 24 V DC voltage. Besides the motors and buttons, we used fuses in control and power circuits, a normally open contactor in control circuit and a thermal-magnetic fuse in power circuit. We obtained 24 V by using a power supply that works with 220 V AC voltage. The final circuit we constructed can be seen in Figure 13. The motor can be seen on the left bottom of the Figure 13. In this first circuit we saw the basic use of the motor, fuses, contactor and buttons while controlling the motor in a very simple way.

[1] The other summer practice students were Berk Kepoğlu and Furkan Akıncı, both of whom were senior year electrical & electronics engineering students from Atatürk University. I informed them about the fact that I wrote their names in my summer practice report here.

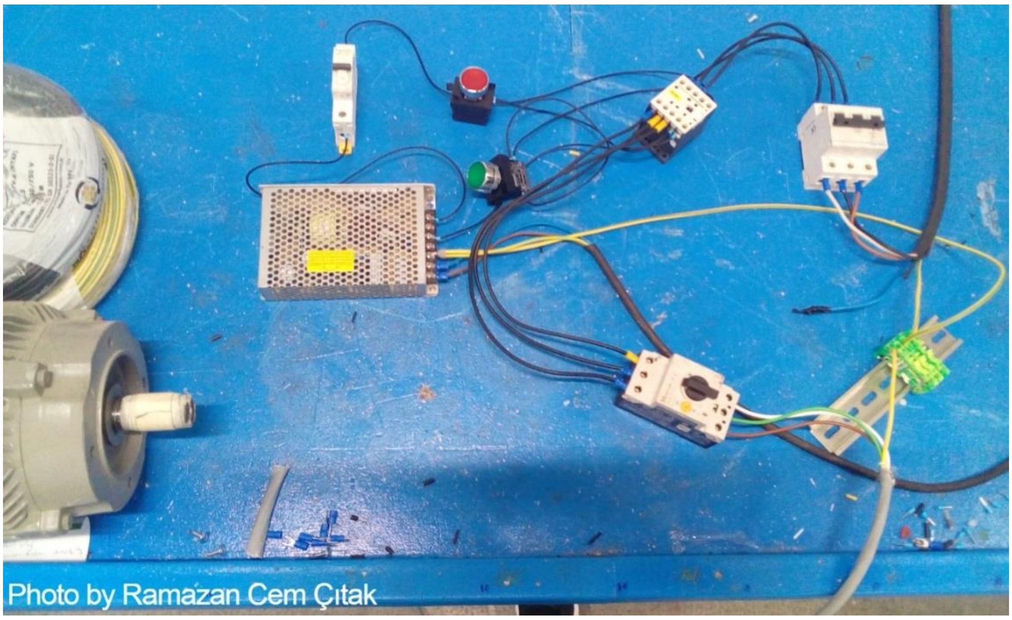


Figure 13: The start-stop control circuit of a 3-phase motor with buttons

### 4.3.2. Changing the Direction of the Motor by Using Buttons

Changing the direction of the motor using buttons circuit is presented in Appendix D [11]. The photograph of the circuit is in Figure 14.

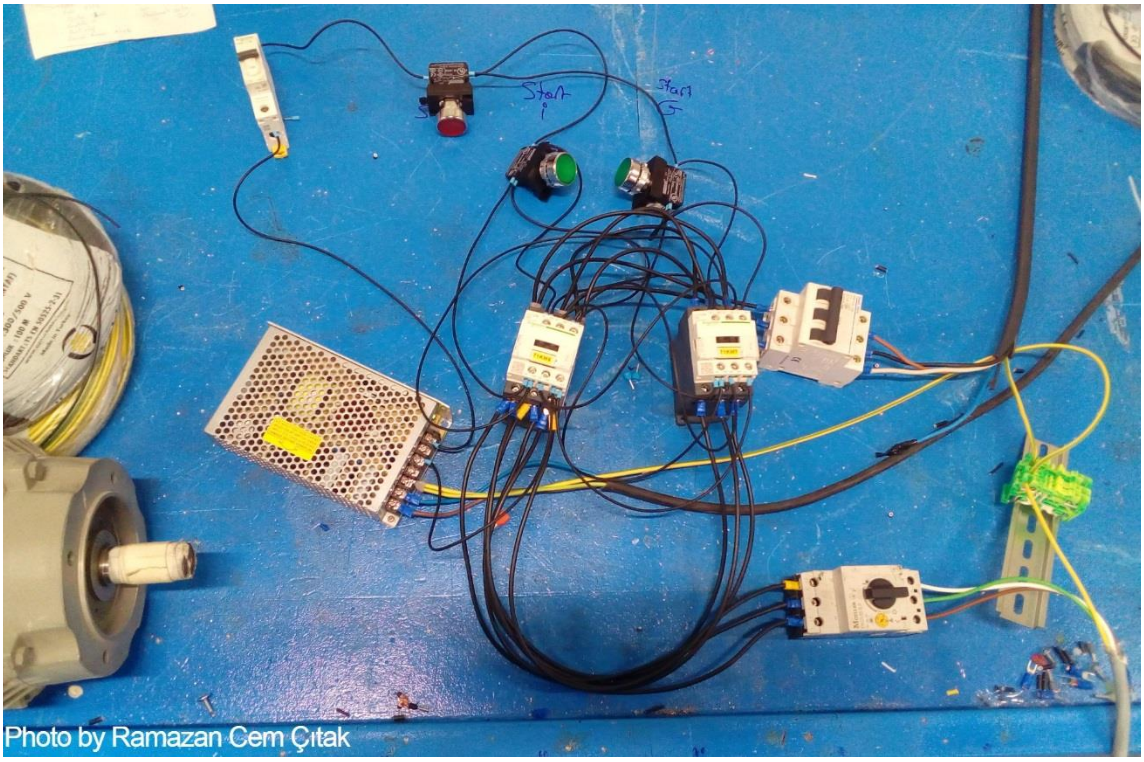


Figure 14: The circuit to change the direction of the rotation of the motor by using buttons

There are two start buttons in this circuit to control the clockwise and counterclockwise direction of the rotational motion of the motor. Also, there are two contactors, which have both normally closed and normally open contacts, which means they have 2 contacts rather than 1 in a simple contactor. When we push one of the start buttons, only of the contactors passes the 3-phase current and the other contactor does not pass the 3-phase current. To change the direction of the rotation of the motor, we connected, as can be seen in Appendix D, phase 1 terminal of K1 contactor were connected to phase 3 terminal of K2 contactor. By changing the place of phase 1 and 3 terminals, we change the rotation of the motor because the motor works with different connections of 3-phase current when we push different start buttons. In addition, when we push the stop button, the motor stops.

### 4.3.3. Controlling the Speed by Using an Inverter

In this task, we used LS iG5A inverter, which was an old inverter model that was used in the past by the company. We had an inverter with a potentiometer and a rotary switch that has 2 positions. One of the positions in the rotary switch was used to run the motor in one way, and the other position was used for being able to run the motor in the reverse position. The potentiometer changes the speed of the motor by changing the frequency. The photograph of the circuit that we constructed was in the Figure 15.

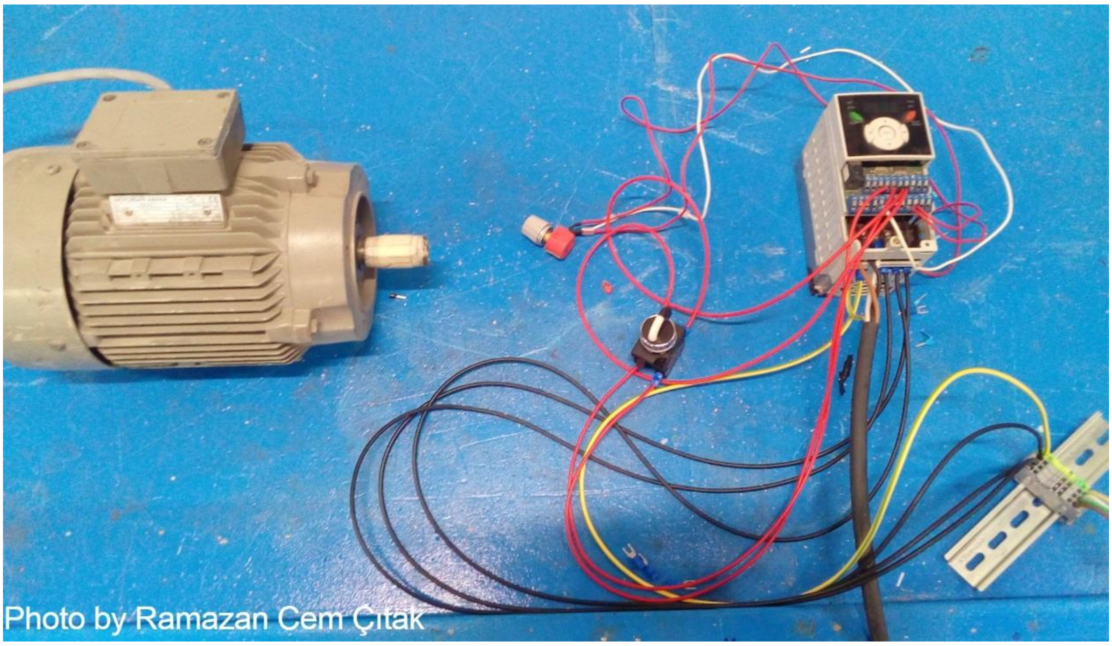


Figure 15: The circuit with inverter involving a rotary switch and potentiometer

I used the manual to determine the connection of rotary switch and potentiometer to the inverter. The related page from the manual of the LS iG5A inverter that shows the connections is in Appendix E [12]. The potentiometer is connected to CM, VR and V1 terminals of the inverter to control the speed of the motor by changing the frequency from Appendix E. As I have stated in Figure 7 before, the power supply frequency directly affects the rotational speed of the motor, so changing the frequency will change the speed of the motor. The power supply frequency is directly proportional to the speed of the motor.

### 4.3.4. Changing the Direction of the Motor by Using an Inverter

The rotary switch connected to the inverter was used to change the direction of the rotational motion of the motor. The rotary switch is connected to CM, P1 and P2. P1 terminal is for the forward run of the motor, and P2 terminal is for the reverse run of the motor, which can be seen in Appendix E. In addition, I learnt about the rotary switch as well as practicing a motor control circuit.

### 4.3.5. Auto-tuning of the Motor by Using an Inverter

Using the parameters given in the manual of the inverter, the auto-tuning of the motor was done. The auto-tune was done by the inverter automatically, and it is a process that adjusts and calculates the parameters of the motor for the inverter in a proper way. For example, the inverter measures the impedances of motor windings, and it sets the suitable parameters like gain for the motor to be able to run in a more proper and efficient way.

## 4.4. Mitsubishi MELSOFT GX Works3 Program for the PLC

### 4..4.1. About the Program

GX Works3 is the latest generation of programming and maintenance software offered by Mitsubishi Electric specifically designed for the MELSEC iQ-R and MELSEC iQ-F Series control system [13]. It is used to set up instructions for the PLC Units to make the automation process happen in an efficient, and it also helps maintain and monitor the control system. The GX Works3 uses a ST(Structured Text) language that is similar to C language, which is a language that I am familiar with thanks to CENG229 course which I took in the freshman year of my department. There is also ladder language to write programs in the software, but it is very rarely used by the engineers because it is an old language that is not good enough for today's needs. However, I used it at first to understand a program better because it is simpler.

I learnt the basics of the program thanks to the engineers in the company, they helped about the program and suggested some documents[2] to study.

[2] The link suggested documents: https://www.mitsubishielectric.com/fa/assist/e-learning/eng.html

### 4.4.2. My Assignments in the MELSOFT GX Works3 Program

I was given an assignment to write a code and simulate it in the GX Works3 program, which works with PLC Unit. The assignment was to control the order of 3 motors. Only two of the three motors will work at a time instant, and the operating time of all three motors will be the same. Also, we should be able to see the operating time of motors separately. The operating order of the system is this: First, Motors 1 and 3 works for 5 seconds, next motors 1 and 2 works for 5 seconds and finally motors 2 and 3 works for 5 seconds. We can see on the program which motors are working and their total operating time as well. Our purpose is to use the three motors in an efficient way, and after systems works every time, the operating time, or age of the motors should be close to each other. This process called ‘Motorlarda Eş Yaşlanma’ in Turkish.

The operating times are saved by the counters in the program. The code I wrote can be seen in Appendix F, and I wrote the code in a simple way and made a simulation of it. The simulation result and the program screen are in Figure 16. In this program, I gained a little knowledge about logic processes like open (0) and closed (1), and how simple basic knowledge of logic can help me construct a simple programme. The ‘TRUE’ and ‘FALSE’ in the programme, which can be seen in Appendix F, are for the open (0) and closed (1).

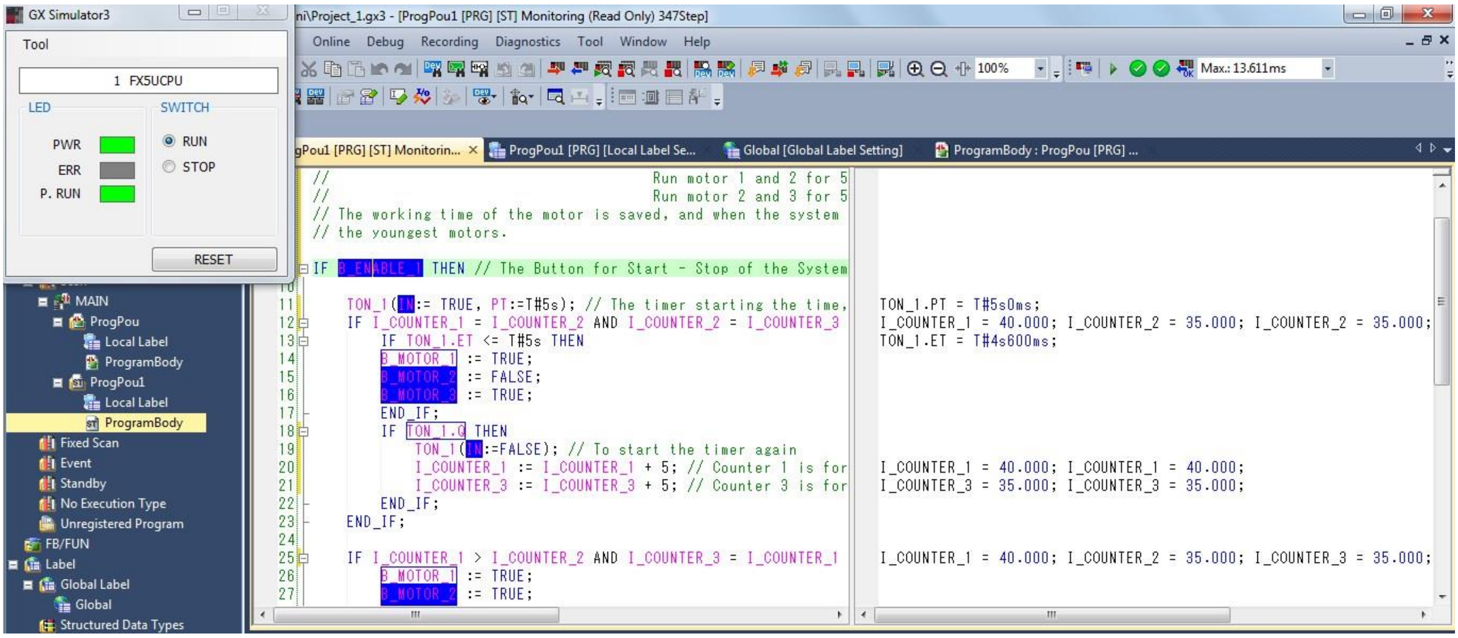


Figure 16: The simulation in MELSOFT GX Works3 Program that I wrote

### 4.4.3. HMI and SCADA

*HMI:*

HMI stands for ‘Human Machine Interface’, which means a screen or panel that is used for controlling the machinery connected to it. It makes easier control and monitor the machinery while the machinery is working. A machine with HMI system manufactured in Best Makina is controlled easily by the customer, and the technical service can reach the machine via the Internet and control the it to fix the problems the users have.

I was given an assignment to make a simple HMI work in the program GT Designer3 for my code in Appendix F. It was the program of running two of three motors and saving the amount of operating time. Figure 17 shows the HMI program as well as my simple program that can be used in a screen. The green lights in the Figure 17 shows that the motor 1 and 2 are working at that time instant, and the red light of the motor 3 indicates that the motor 3 stopped at that time instant. The working time of the motors are shown in seconds on the screen.

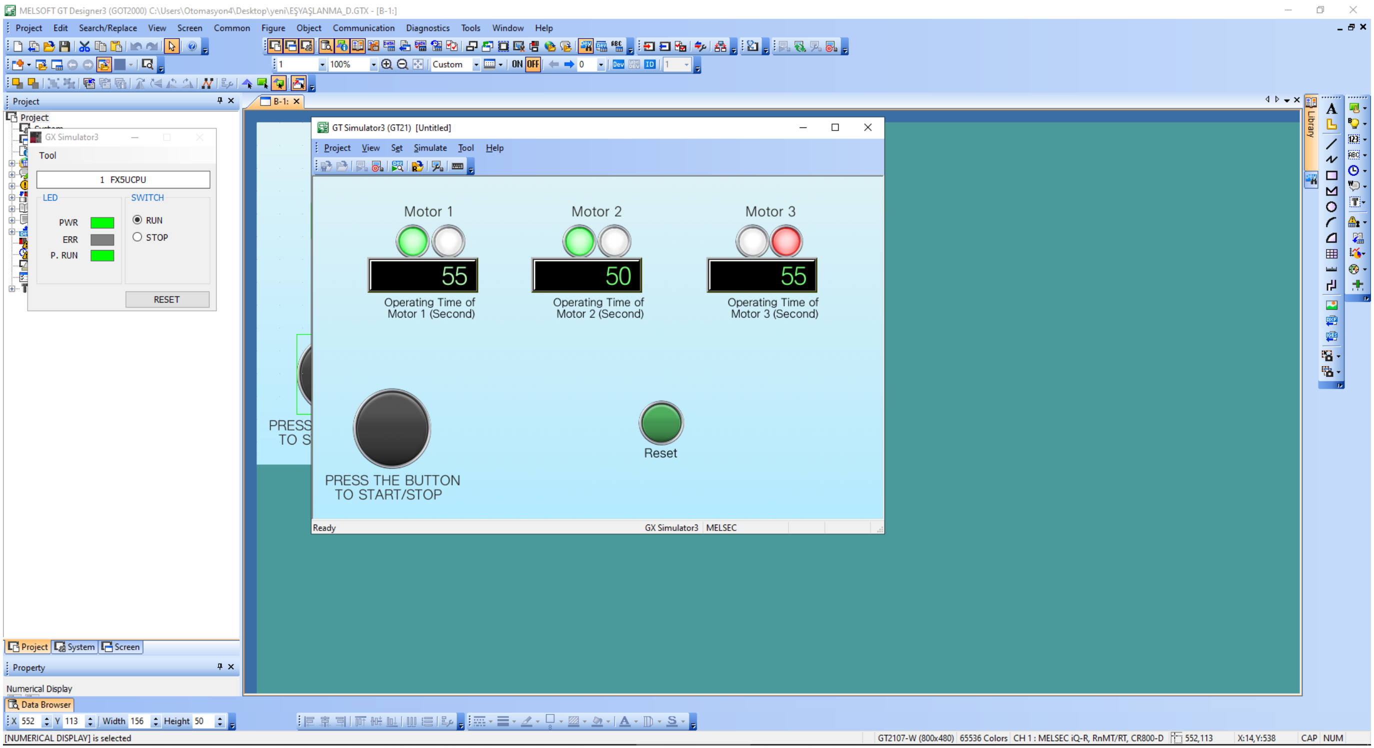


Figure 17: The HMI program that I created in GT Designer3 for my program in Appendix F

I was also given another last assignment to do a simple cube root calculator using the GX Work3 program, then simulate it with my own design in GT Designer3. This problem is from the company's 'BASB 2500 – Automatic Spacer Bar Bending Machine'. The software for that machine needed a cube root calculator in a small part of the software. The code I wrote for this program is in Appendix G. The HMI screen that I designed is in Figure 18.

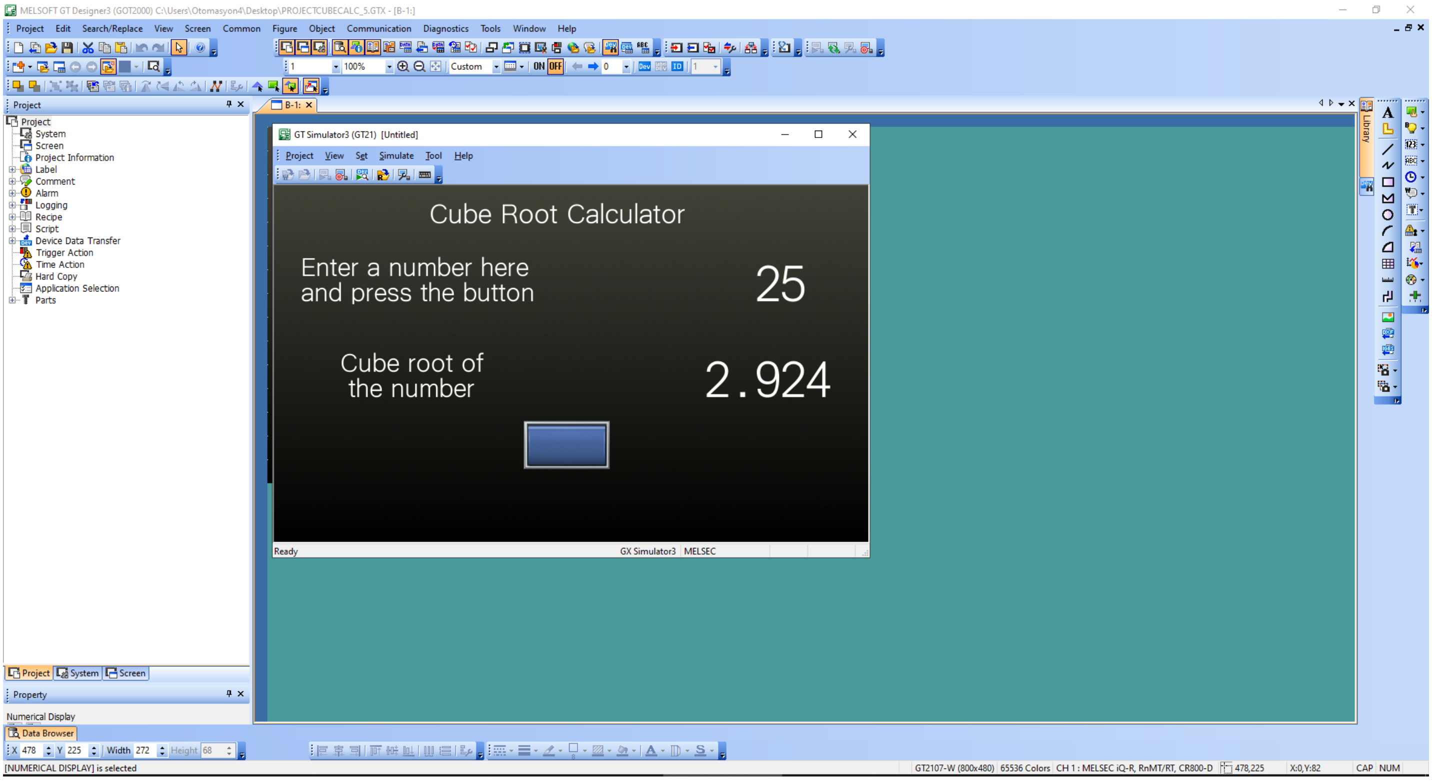


Figure 18: The cube root calculator program I designed in GT Designer3 with my program in Appendix G

I searched for finding the cube root of a number and decided to use a numerical method, which is Newton's Method to calculate the cube root of a number. First, we choose an initial point to start the iteration expression used in the method, and then we take the number that converges after all iterations [14]. The iteration expression is $x_{k+1} = x_k - \frac{f(x_k)}{f'(x_k)}$, and the equation to be solved is

$f(x) = x^3 - a = 0$ and $f'(x) = 3x^2$

The codes that these expressions are used can be seen in Appendix G. I chose 1 as the initial point, and the number of iterations is 50. The initial point is similar to our guess about the solution, and it is better to choose it as close as to solution to converge the correct solution faster. However, here because the number of the iteration is high as 50 as my choice, we reach a correct solution even if the initial point is not close to the exact solution.

*SCADA:*

SCADA stands for ‘Supervisory Control and Data Acquisition’, and it is also similar to HMI. SCADA is a more developed and comprehensive tool to monitor and control factory automation processes. For large systems, it is a better choice to use in a factory automation. The electrical engineers were using both SCADA and HMI in the company. For simple machineries, they only use the HMI, and for larger complex machineries, they sometimes use SCADA. I only used the HMI software, which is GT Designer3.

## 4.5. Industrial Automation Protocols

Lastly, I was introduced about the industrial automation protocols because the cables that is used to connect the PLC Units and computers as well as machines are important in an automation system that works in a correct way and that has a good communication network. In this part, I will be giving brief information about a few of them which are used in the PLCs I observed in the factory.

### 4.5.1. Modbus RTU

Modbus is a network standard that are used for the communication of intelligent devices in industrial manufacturing applications as well as infrastructure, energy and transportation applications [15]. In my summer practice location, the manufactured devices in the factory can be monitored and programmed by connecting with a computer or the HMI screens of the machineries via the Internet.

RTU means ‘Remote Terminal Unit’, and Modbus RTU is used for the wireless communication applications.

### 4.5.2. Modbus TCP/IP

Modbus TCP/IP is similar to Modbus RTU. Modbus TCP/IP is one of the communication protocols for transmitting information in electrical devices that is used in factory automation. Modbus TCP/IP uses a client/server architecture. Modbus TCP/IP are implemented on an Ethernet network [16]. An IP address is used for the destination address in Modbus TCP/IP.

In addition, RS-485 wiring is used in this factory for the automation related devices as I observed. RS-485 is a standard that are useful in industrial control systems with its use of long distances for transferring the data.

### 4.5.3. EtherCAT

EtherCAT stands for ‘Ethernet for Control Automation Technology’. It is different from the typical ethernet network that we use at home. EtherCAT was originally developed by Beckoff Automation. In industrial control systems like every control system, the time accuracy is very important, so the EtherCAT standard is the one that brings the time accuracy and correctness for the real-time system applications such as the industrial control systems [17]. It is used in some of the devices and cables in my summer practice location to be able to control the real-time processes in a factory machinery in an accurate way as much as possible.

# 5.Conclusion

I completed my summer practice in Best Makina. In the first two weeks of my summer practice, I learnt the basics about the automation work that electrical engineers do there, and in the second part of my summer practice, I did understand the work done by the company better and I do simple practical applications that is related to the automation field as well as learning and using the programs that engineers use in an introductory level. My practical work was not utilized by the company, but I acquired quite experience while I was doing my practical work during my summer practice. In addition to all of these, I observed the work life as well as developing a design of an automation system and testing the system together with the mechanical systems of the IGU machines. I understand that a large automation system consists of simple and smaller parts, and it is designed and produced by a group of workers and engineers.

To conclude, I gained quite much work experience in technical manner as well as in nontechnical manner. I understood that how the nontechnical skills of an engineer are as important as his or her other skills. I hope that I will benefit from the experience I gained in Best Makina in my future work life. The facilities of the company were also good in the company, and I spent my time there efficiently. This was my first summer practice, and I learnt important things during this summer practice. I recommend this summer practice location to other students who are interested in automation. Best Makina is a place where you can see the production and engineering processes with a good team of workers and engineers.

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# 7.Appendices

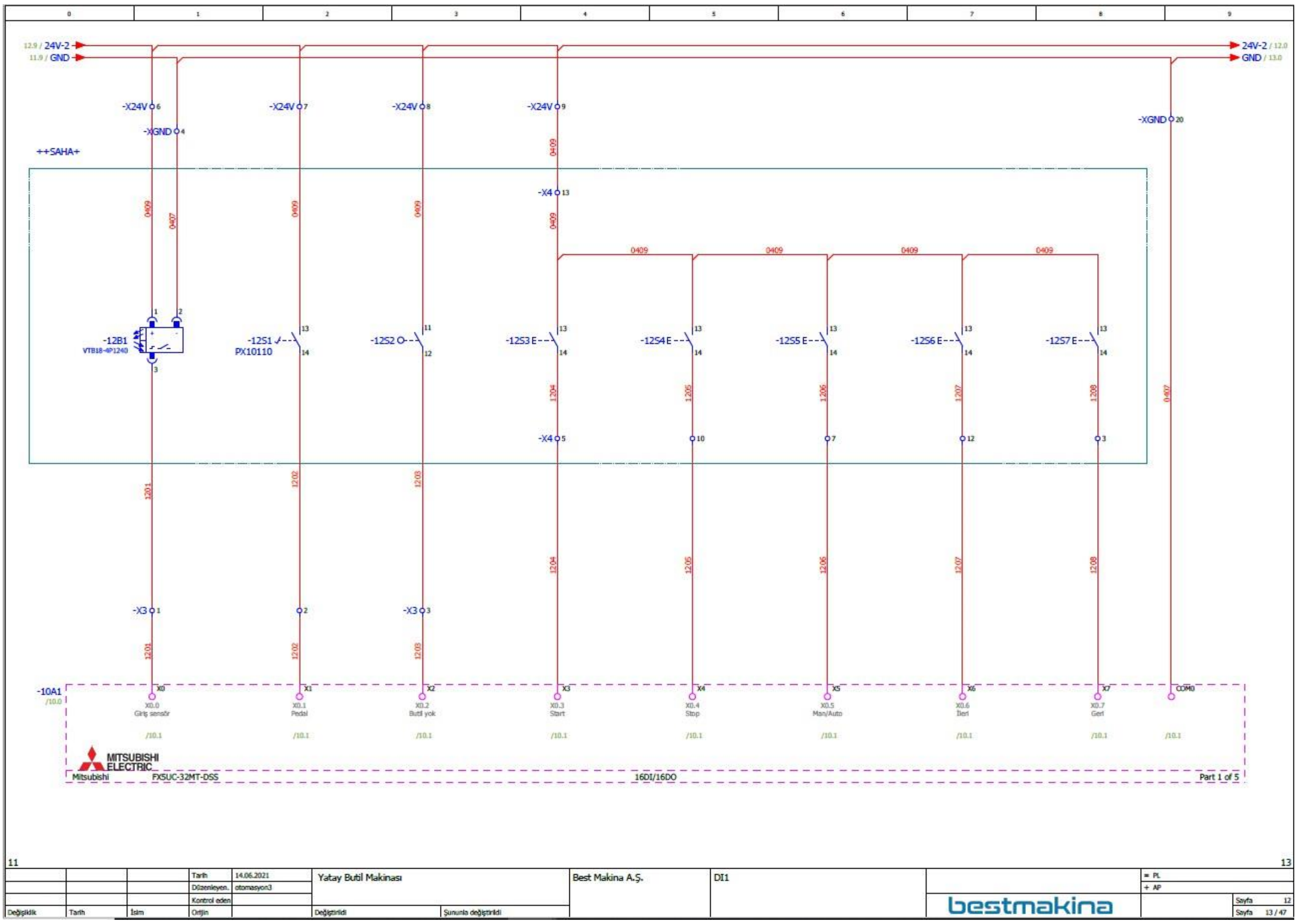
## Appendix A: The Table of Current Carrying Capacities of the Wires

**AKIM TAŞIMA KAPASİTESİ (A)***

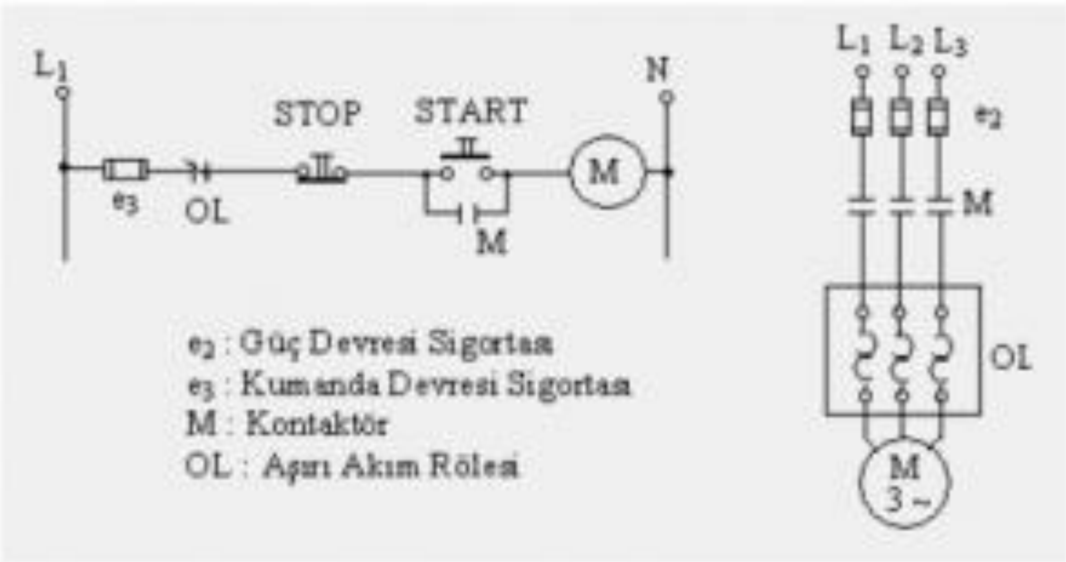
| Kablo Cinsi | Protodur N ve F Kabloları **(1)** | | | Protodur Y Kabloları **(2)** | | | | | | | | Protodur X Y Kabloları **(3)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gerilim | 380-1000 V | | | 0,6/1 kV | | 3,5/6 kV | | 5.8/10 kV | | 8.7/15 kV | | 20.3/35 kV | | | | | |
| **Damar sayısı** | **1** | **2-5** | **1** | **3 ve 4** | | **3** | | | | | | **1** | | | | **3** | |
| Döşeme şekli / Kesit mm2 | Boru içinde bir veya daha fazla kablo | Havada | Havada asgari kablo çapı aralığı döşeli kablolar | Havada | Toprakta | Havada | Toprakta | Havada | Toprakta | Havada | Toprakta | Havada $0^{0}0$ | Toprakta $0^{0}0$ | Havada 000 | Toprakta 000 | Havada | Toprakta |
| 0,75 | - | 13 | 16 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1 | 12 | 16 | 20 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1,5 | 16 | 20 | 25 | 27 | 17,5 | - | - | - | - | - | - | - | - | - | - | - | - |
| 2,5 | 21 | 27 | 34 | 36 | 24 | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | 27 | 36 | 45 | 46 | 32 | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | 35 | 47 | 57 | 58 | 41 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | 48 | 65 | 78 | 77 | 57 | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | 65 | 87 | 104 | 100 | 76 | - | - | - | - | - | - | - | - | - | - | - | - |
| 25 | 88 | 115 | 137 | 130 | 101 | 120 | 105 | 125 | 115 | 105 | 97 | - | - | - | - | - | - |
| 35 | 110 | 143 | 168 | 155 | 125 | 150 | 130 | 150 | 135 | 130 | 117 | 189 | 199 | 208 | 195 | 172 | 148 |
| 50 | 140 | 178 | 210 | 185 | 151 | 175 | 155 | 175 | 165 | 155 | 146 | 223 | 238 | 247 | 234 | 204 | 178 |
| 70 | 175 | 220 | 260 | 230 | 192 | 215 | 195 | 215 | 205 | 190 | 181 | 273 | 296 | 302 | 292 | 251 | 220 |
| 95 | 210 | 265 | 310 | 275 | 232 | 260 | 240 | 255 | 250 | 225 | 220 | 325 | 358 | 359 | 354 | 300 | 265 |
| 120 | 250 | 310 | 365 | 315 | 269 | 295 | 275 | 290 | 285 | 260 | 255 | 368 | 412 | 402 | 404 | 335 | 304 |
| 150 | - | 355 | 415 | 355 | 309 | 335 | 315 | 325 | 320 | 300 | 295 | 410 | 465 | 443 | 456 | 375 | 347 |
| 185 | - | 405 | 475 | 400 | 353 | 375 | 360 | 365 | 365 | 340 | 340 | 463 | 532 | 496 | 515 | - | - |
| 240 | - | 480 | 560 | 465 | 415 | 435 | 430 | 425 | 430 | 400 | 405 | 434 | 627 | 562 | 602 | - | - |

**(*)** Düzeltme faktörlerinin ayrıca dikkate alınması gerekmektedir.
**(1)** VDE 0100 25°C Çevre sıcaklığı
**(2)** VDE0271 toprakta 20 °C, havada 30 °C Çevre sıcaklığı toprak özgül ısı direnci 100 Kcm/W, derinlik 70 cm
**(3)** VDE0298 toprakta 20 °C, havada 30 °C Çevre sıcaklığı toprak özgül ısı direnci 100 Kcm/W, derinlik 70 cm

## Appendix B: An example EPLAN project page of the Horizontal Butyl Extruder

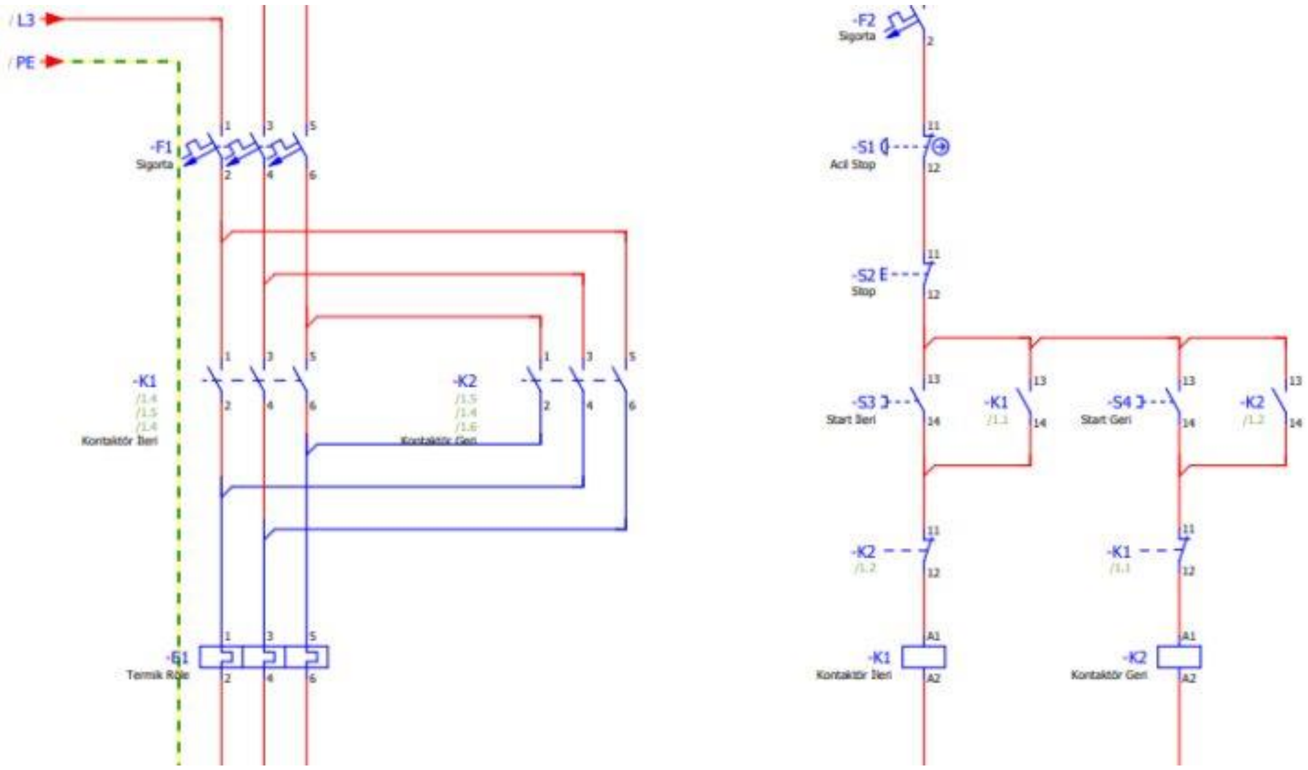


## Appendix C: The Circuit Schematics of the Start-Stop control of a Motor by Using Buttons



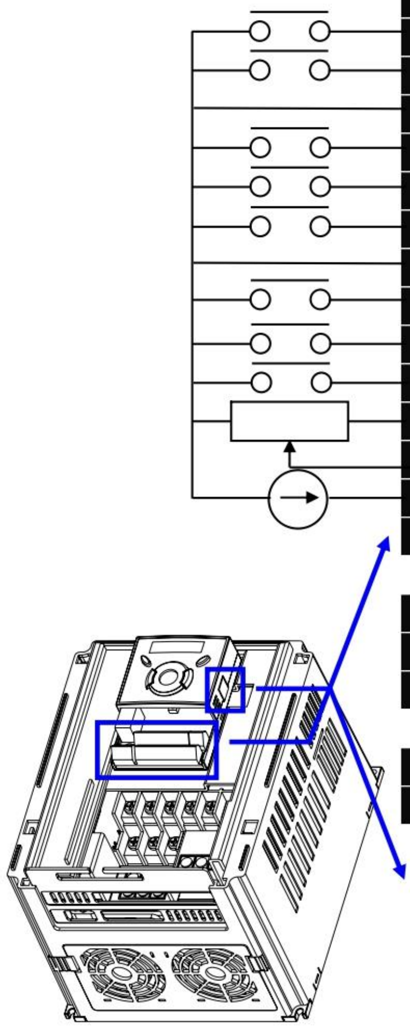

**Bir yönde sürekli çalıştırma güç ve kumanda devre şeması (Amerikan normu)**

## Appendix D: The Circuit Schematics of Changing the Direction of the Rotation of the Motor by Using Buttons



# Appendix E: Terminal Wirings of LS iG5A Inverter from Its Manual

## 2.3 Terminal wiring (Control I/O)



| T/M | Description | |
|---|---|---|
| MO | Multi-function open collector output | |
| MG | MO Common | |
| 24 | 24V output | |
| P1 | MF input terminal (factory setting) | FX: Forward run |
| P2 | | RX: Reverse run |
| CM | Input signal common | |
| P3 | MF input terminal (factory setting) | BX: Emergency stop |
| P4 | | RST: Trip reset |
| P5 | | JOG: Jog operation |
| CM | Input signal common | |
| P6 | MF input terminal (factory setting) | Multi-step freq.-Low |
| P7 | | Multi-step freq.-Middle |
| P8 | | Multi-step freq.-High |
| VR | 10V power supply for potentiometer | |
| V1 | Freq. Setting Voltage signal input: -0~10V | |
| I | Freq. Setting Current signal input: 0~20mA | |
| AM | Multi-function analog output signal: 0~10V | |
| 3A | Multi-function relay output terminal | A contact output |
| 3B | | B contact output |
| 3C | | A/B contact common |
| S+ | RS485 communication terminal | |
| S- | | |

※ For connection to Remote Option or parameter copying

2-7

## Appendix F: Motor Control Program in GX Works3

```
// Written by Ramazan Cem Çıtak
//The system operates with this order: If the start button is pushed
//                                      Run motor 1 AND 3 FOR 5 seconds
//                                      Run motor 1 and 2 for 5 seconds
//                                      Run motor 2 and 3 for 5 seconds
// The working time of the motor is saved, and when the system is started later,
// it will start to run the youngest two motors.

IF B_ENABLE_1 THEN // The Button for Start - Stop of the System

	TON_1(IN:= TRUE, PT:=T#5s); // The timer starting the time, which is 5
seconds.
	IF I_COUNTER_1 = I_COUNTER_2 AND I_COUNTER_2 = I_COUNTER_3  THEN // Two of
the motor, 1 and 3 runs for 5s
		IF TON_1.ET <= T#5s THEN
		B_MOTOR_1 := TRUE;
		B_MOTOR_2 := FALSE;
		B_MOTOR_3 := TRUE;
		END_IF;
		IF TON_1.Q THEN
			TON_1(IN:=FALSE); // To start the timer again
			I_COUNTER_1 := I_COUNTER_1 + 5; // Counter 1 is for motor 1
working time
			I_COUNTER_3 := I_COUNTER_3 + 5; // Counter 3 is for motor 3
working time
		END_IF;
	END_IF;

	IF I_COUNTER_1 > I_COUNTER_2 AND I_COUNTER_3 = I_COUNTER_1  THEN // // Two
of the motor, 1 and 2 runs for 5s
		B_MOTOR_1 := TRUE;
		B_MOTOR_2 := TRUE;
		B_MOTOR_3 := FALSE;
		IF TON_1.Q THEN
			TON_1(IN:=FALSE); // To start the timer again
			I_COUNTER_1 := I_COUNTER_1 + 5; // Counter 1 is for motor 1
working time
			I_COUNTER_2 := I_COUNTER_2 + 5; // Counter 2 is for motor 2
working time
		END_IF;
	END_IF;


	IF I_COUNTER_2 = I_COUNTER_3 AND I_COUNTER_1 > I_COUNTER_3  THEN // Two of
the motor, 2 and 3 runs for 5s
		B_MOTOR_1 := FALSE;
		B_MOTOR_2 := TRUE;
```

```
            B_MOTOR_3 := TRUE;
            IF TON_1.Q THEN
                  TON_1(IN:=FALSE); // To start the timer again
                  I_COUNTER_2 := I_COUNTER_2 + 5; // Counter 2 is for motor 2
working time
                  I_COUNTER_3 := I_COUNTER_3 + 5; // Counter 3 is for motor 3
working time
            END_IF;
      END_IF;

      ELSE // Stop the system if the start button is false.
            B_MOTOR_1 := FALSE;
            B_MOTOR_2 := FALSE;
            B_MOTOR_3 := FALSE;
END_IF;

IF B_ENABLE_2 THEN // This is the switch for resetting the counters

      I_COUNTER_1 := 0;
      I_COUNTER_2 := 0;
      I_COUNTER_3 := 0;

END_IF;
// End of the programme.
```

## Appendix G: Cube Root Calculator Program in GX Works3

```
// Written by Ramazan Cem Çıtak
// The program uses "Newton's Method" to find the cube root of an entered number.
// The equation I solve is f(x) = x^3 + a = 0
// The derivative of f(x) is f'(x) = 3*x^2
// The iteration expression is x_k+1 = x_k - (x^3 + a)/(3*x^2)

IF B_ONLYONCE THEN // To enter the for loop only once

	F_XONLY := 1; // The initial point or guess I chose

	FOR F_COUNTER_1 := 1 TO 50 BY 1 DO // Number of iteration is 50
	                                                                    // Number of
iteration is high to converge the correct answer
		F_XKEY := F_XONLY - (F_XONLY*F_XONLY*F_XONLY-
F_NUMBERENTERED)/(3*F_XONLY*F_XONLY); // The iteration expression
		F_XONLY := F_XKEY; // To continue iteration
	END_FOR;

END_IF;
F_CUBEROOT := F_XKEY; // The cube root of the number
B_ONLYONCE := FALSE; // Not to enter the if again

// End of the programme.
```