Direct On Line Circuit as a 3 Phase Motor Controller Using the Siemens S7 1200 Programmable Logic Controller

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Abstract— In today's world of education, teachers are required to be creative in the teaching process. Teachers are very influential in the development of education in Indonesia. One indicator of a country's progress can be seen from education. This research uses descriptive experimental research that uses a qualitative approach. This research is descriptive because this research does not use a particular method but only uses existing facts and is temporary. The Direct On Line (DOL) Circuit System is used in three-phase induction motor starting systems and is designed to minimize very high starting current surges. The three-phase induction motor starter system with the DOL circuit works directly to provide 380 VAC voltage to the motor coil so that the motor rotates immediately. The first condition is when the MCB is activated the L2 lamp output immediately activates as a sign that the DOL circuit is on standby. Then the second condition describes the circuit when the MCB is active and S2 is pressed, K1 will be active so that the resulting output is L3 on. Entering the third condition shows that the MCB remains active and S1 is pressed, the output that occurs is L2 lights up. The fourth condition where the MCB remains on then emergency activated, the output that occurs is L4 lights up. In the fifth condition, the MCB remains on and the Term On Thermal Overload Relay (TOR) is activated, so that the outputs, namely L1 and L2, light up simultaneously.

Kata Kunci—Dol, Condition, PLC, Series, Siemens S7 1200

I. INTRODUCTION

The rapid development of industry and technology worldwide is accompanied by other interrelated factors [1]. Education, as a key pillar of civilization, plays a significant role in revolutionizing human thought patterns to prepare for a better future. In today's world of education, educators are required to be creative in the teaching process. Teachers play a significant role in the development of education in Indonesia. Several indicators of a country's progress can be seen in education. In this modern era, learning must be characterized by character, collaboration, critical thinking, problem-solving, and creativity. Educators must master all subject areas and acquire the necessary skills to produce a quality generation. This includes the rapid advancement of technology in various fields. The automotive sector is one sector that continues to evolve in line with the times. In fact, engine components and operating systems are being overhauled to become more efficient for their users. In this era, induction motors are one of the motors frequently used in various electrical systems, supplying electricity, especially in large industries that require electricity as their primary driving force [2].

The primary role of electricity as an energy source is to power various components and facilities used in factories. The use of induction motors is highly sought after in industry today because they are less expensive to maintain and have a simpler structure. Induction motors can provide good efficiency and constant rotation per load change. In field implementation, induction motors are widely used for rotating loads such as conveyor belts, fans, or compressors of small to large capacities. This current causes a momentary voltage drop in the source voltage line. This voltage drop in the system can disrupt other equipment, especially equipment sensitive to voltage fluctuations. To address this, selecting a starting method is crucial for induction motor installations.

Currently, induction motors are more efficient than other motors in both household and industrial applications. Induction motors are one of the electrical devices that can convert electrical energy into mechanical energi [3]. From a technical and economic perspective, induction motors have many advantages. Therefore, induction motors, especially three-phase induction motors, are often used in industry. However, induction motors have weaknesses such as high starting currents, which can cause a drop in the system voltage and disrupt the operation of other equipment in the line system. Induction motors require a starting process designed to reduce the maximum starting current. The starting technique used in this study is the direct-on-line (DOL) method, which is automatically operated by a programmable logic controller (PLC). Three-phase asynchronous motors have the advantages of a simple structure, easy maintenance, and low cost. They are among the most widely used motors in industries such as belt

conveyors, crushers, and vibrators. Disadvantages of this type of motor include a relatively high starting current and very low starting torque. To overcome these weaknesses, a suitable starting system can be used to reduce the starting current and increase the starting torque [4].

Automation technology is currently developing rapidly. These automation systems are used by industry to ensure product quality and meet market demand. [5]. The building blocks of automation include sensors, actuators, and controllers. One of the control systems that is widely used is the Programmable Logic Controller (PLC), and the distribution of data information in the automation system can be done using cables (wired) [6]. Wire-based automation systems using PLCs can be applied in various industrial fields. Existing processes, milling workstations still require a large number of operators, making them prone to human error and resulting in production output that fails to meet the work plan and production budget (WP &B) based on market demand.

Control technology is developing rapidly, including Programmable Logic Controllers (PLCs). PLCs are one type of control system used by industry in ongoing production processes. Their application in industry offers many advantages, including the possibility of remote process monitoring, the ability to calculate factory data, remote system integration, reduced human error, and the ability to document processes. In electronics, a control system technology known as Programmable Logic Controllers (PLC). PLC can control both analog and discrete quantities, simplifying programming and, of course, can be used as basic automation systems in industry [7]. Industrial control systems that use numerous relays have several drawbacks, such as high temperatures and short circuits that damage contacts. Furthermore, they are expensive during installation, maintenance, and retrofitting [8].

This PLC-based induction motor trainer is designed for use in Direct One Line (DOL) circuits [9]. The PLC's input status is stored in the same memory as the PLC, allowing it to execute programmed logic instructions based on the input state. Input devices can be electronic sensors, pressing buttons on the control panel, limit switches, or other devices that can generate signals into the PLC. Output devices can be indicator light switches, relays that drive motors or other devices that can drive output signals from the PLC. In addition, PLCs also use memory that can be stored programmatically. Instructions to carry out special functions, for example sequential logic, sequential and arithmetic can control machines or processes through analog and numeric I/O modules.

The Programmable Logic Controller is a microprocessor-based system that uses memory to program and store pre-designed control programs. This program is designed to operate reliably in harsh industrial control environments. Programmable logic controllers have strict real-time constraints, ensuring that each execution cycle does not exceed the allotted execution time. The program in a Siemens programmable logic controller is organized into program blocks. [10].

A three-phase induction motor control circuit is a system that must be well designed to ensure the motor operates properly as planned. Currently, three-phase induction motor control circuits have been developed to ensure the motor can operate normally in single-phase power systems. Three-phase induction motors are the most widely used induction motors today, especially in industrial applications because many of them are very powerful. The form of the control circuit that drives the motor depends heavily on the motor's power capacity. If the motor power used is small, the motor control circuit usually adopts a direct start (DOL) system. In order for this motor to run normally and safely, it is necessary to create a control circuit with a safety system so that this motor is not easily damaged.

II. RESEARCH METHODS

This research employed a descriptive experimental approach. This research is descriptive in nature because it does not employ a specific method but rather simply utilizes existing, preliminary facts. The experimental data analysis was conducted using descriptive-qualitative techniques. This technique involves describing the entire research process, starting with the analysis of equipment and material requirements, assembly, and analysis, all the way to the results of the control system testing [11]

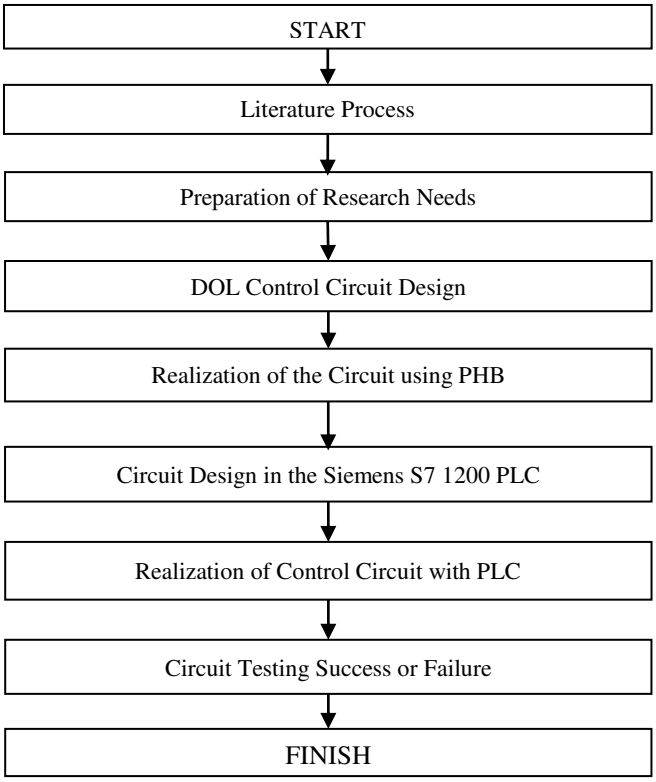


Figure 1. Research Flowchart

Figure. 1 useful flowchat in this research. Analysis and identification of Tool Needs in the Direct On Line Circuit research process using the Siemens S7 1200 programmable logic controller (PLC) can be a problem analysis process based on literature studies, researchers can read and analyze the results of previous studies that can trigger the process when making the circuit framework and support the determination of the necessary tools needed. Tool needs in the Design, Programs that have been prepared and in the study the material is directly assimilated by practicing how to use tools and materials according to the instructions.

III. Research and Discussion

The DOL (Direct On-Line) circuit system is commonly used in three-phase induction motor starter systems and is designed to minimize very high starting current surges. [12]. A three-phase induction motor starter system with a DOL (Direct On-Line) circuit works directly, supplying 380 volts of AC to the motor coils, allowing the motor to rotate immediately. Therefore, the DOL (Direct On-Line) circuit is the original starter circuit, starting the motor instantly with very little power. The motor can be started/stopped through a control circuit, also known as a lock circuit, because the function of the DOL (Direct On-Line) circuit is to maintain current flow through the control circuit [13].

Direct On Line **(DOL)** is a method of starting an electric motor by connecting the motor directly to an electrical voltage source without using additional equipment such as complex contactors or soft starters**.**. Many PLC components are used in this project. The project uses many components that are not compatible with each other, but with different technological knowledge and skills, the system control can be achieved. Because the system will be used for demonstration purposes, it is designed to be user-friendly and simple to understand. The system can be operated by software from a laptop or HMI. HMI displays provide better control, for integrated systems access to the factory or production system, allowing companies to train workers quickly and easily [14]. The PLC model used is the Siemens S7-1200 PLC. This controller is typically used for open-loop and closed-loop tasks in engineering. The controller combines a compact design with very high performance. The controller is available in various AC and DC versions.

This direct-online circuit is directly automated, using a Siemens S7 1200 PLC for setup. The tools and materials required are:

1. Materials that can be used are:

- NYAF cable. NYAF cable is designed and recommended for panel installations that require high flexibility. NYAF cable is a highly flexible cable, with a PVC-insulated copper conductor. There are four types of cable: R-S-T-N.

2. Tools that can be used include:

- PHB (Shared Connection Panel), also known as a separate terminal board, which functions as a connection, protection, separation, supply, and control from one circuit to another. It is divided into various types of panels. These include the Main Distribution Panel (MDP), Branch Panel (SDP), and Load Panel (SSDP).
- 1-phase and 3-phase MCBs, MCB stands for (miniature circuit breaker), are systems in electromechanical devices. MCBs function as overcurrent protection in electrical circuits. This means that when current flows through the MCB, the MCB can automatically cut off the current when the current through the MCB exceeds the specified value. However, when the current is normal, the mini circuit breaker can act as a switch, and the current can be turned on or off manually. Essentially, an MCB has almost the same function as a fuse, which is to cut off the current flow in the circuit when an overcurrent occurs. The overcurrent may occur due to a short circuit or overload. However, when the circuit is normal, the MCB can be reopened, and the fuse that has been blown due to the excess current cannot be reused.
- Contactors are used in electricity as an electrical control system. Different types of voltages vary according to their intended use. A contactor is an electrical component that acts to turn on or off an AC power supply. Contactors are also commonly referred to as relays. The working principle of a contactor is the same as a relay, and there are several electromagnetically controlled switches inside the contactor. A magnetic contactor, also known as a magnetic switch, is a switch that operates based on magnetism. This means that the switch operates when there is a magnetic force when an electric current flows through it. The magnet functions to attract and release the contacts [15].
- A push button is a very useful control element that we often find buttons inside or outside electrical panels. The button's function is to control the on-off state of the circuit. This button has a momentary working principle, namely pressing the button for a moment will return it to its original position. This push button needs to be used in the DOL circuit.
- A TOR thermal overload relay is a switching device that can open and close the contactor when the current exceeds the specified limit, an electrical control device that functions to disconnect the electrical network in overload conditions [7]. Excessive current generated by the motor load can flow through the motor windings,

causing damage and even causing a fire in the motor windings. To avoid overheating of the installation, an overload controller is used. The working principle of a thermal overload relay is based on the temperature generated by the electric current flowing through the bimetallic heating element. Because the bimetal bends due to the heat generated, the bimetal will move the mechanical contacts of the circuit breaker. TOR works based on the principle of expansion and bimetallic objects. If an object is exposed to high current, the object expands, which bends and breaks the current. To set the maximum current that can pass through the TOR, the ammeter can be adjusted with a screwdriver and turned until the desired value is achieved.

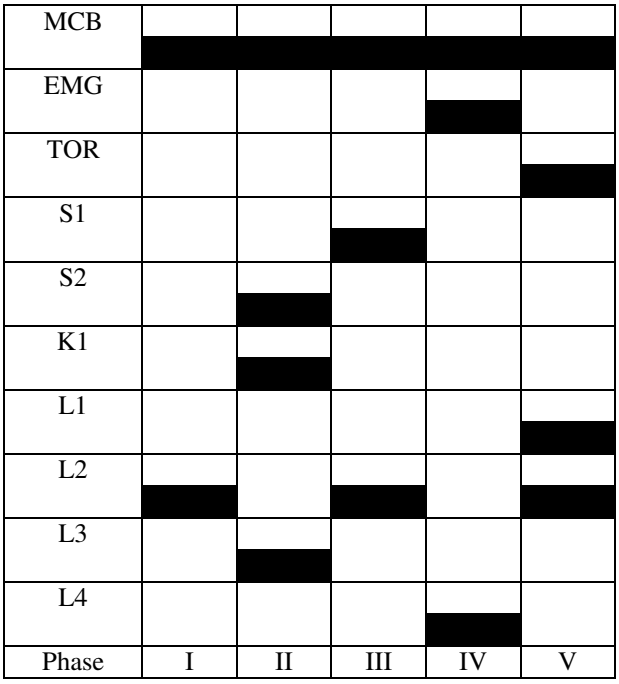
- An indicator light is used to mark the panel where the current is drawn. This device uses a 220VAC lamp with a diameter of 22mm. Use a green light to indicate the PLN voltage source and a red light for the inverter power supply. The use of indicator lights is crucial for this circuit, as they play a crucial role in identifying the voltage source during operation.
- PLC Siemens S7 1200 is used as an important tool in this research. In general, PLC can be defined as a digital electronic device that uses programmable memory to store instructions and to implement functions such as sequence logic, timing, counting and arithmetic to control machines and processes. The term logic is used because programming is mainly concerned with implementing logic and switching operations. PLC (Programmable Logic Controller) can be thought of as a regular personal computer (the internal configuration of PLC is very similar to a personal computer). But PLC is designed to make high current distribution boards. In the brain (CPU = Control Processing Unit) PLC can be imagined as a collection of thousands of relays [16]. However, it does not mean many relays with a very small size. PLC contains a digital electronic framework that can be used, for example relay contacts (NO and NC) in PLC can be used multiple times for all basic instructions except output instructions. So it is said that outputs with the same contact number are not allowed in PLC programs.

A direct on line circuit is a 3-phase motor controller circuit consisting of a contactor, an electric motor, and a Thermal Overload Relay (TOR). [17]. The 0.55 kW (approximately 0.75 HP) phase motor used. In the Direct On Line (DOL) method, which can be used when stopping an induction motor with dynamic braking, it decreases if the DC injection current and lamp load increase. In the DOL method, an electric motor consists of a TOR. This type of circuit is considered the most basic in an electric motor circuit. DOL is an electrical control circuit that functions to provide current to an electric motor or elmot. DOL is a circuit that uses a starter type motor control.

The working principle of a direct on-line circuit has a TOR which is often used as a safety device against overloading a circuit. If the load exceeds the TOR limit, the electric current will be cut off, then when the S2 button is pressed, the coil (K1) will be activated. When S1 is pressed, the electric current is cut off simultaneously with the green light going off and the yellow light coming on. When Emergency (EMG) is pressed, the circuit will turn off and the red indicator light will come on. A direct on line circuit is a circuit that is often used as an electric motor [18].

This direct on line circuit functions to provide current to the load, therefore the load light lights up indicating that the electric motor will operate or rotate. And then it can be connected to the PLC program.

Figure 2. TIME CHART



Description:

MCB	: miniature circuit breaker
EMG	: emergency
TOR	: thermal overload relay
S1	: switch 1 (green)
S2	: switch 2 (red)
K1	: contactor
L1	: indicator light 1 (red indicator light)
L2	: indicator light 2 (yellow indicator light)
L3	: indicator light 3 (green indicator light)
L4	: indicator light 4 (red indicator light)

In the time chart above figure 2, if the black color indicates that the circuit is on, the circuit is also shown in the

Direct On Line circuit, which has five conditions. The first condition (I) indicates that when the MCB is activated, the output lamp L2, the yellow indicator light, is immediately activated or lit, indicating that the Direct On Line circuit is in standby mode. The second condition (II) in the second time chart explains the conditions in the circuit: when the MCB is activated and S2 is pressed, K1 is activated, resulting in the output L3, the green indicator light, which lights up. Next, enter the third condition (III) in the time chart table above, which shows that the MCB remains active and S1 is pressed, then the output or achievement that occurs is L2, namely the yellow indicator light is on. The next condition is the fourth condition (IV) where the MCB remains on and then the EMG is activated, the output that occurs is L4, namely the red indicator light is on. Then in the last condition, namely the fifth condition (V), the MCB remains on as before and TOR is activated, then the output occurs, namely L1, namely the red indicator light and L2, namely the yellow indicator light are on simultaneously.

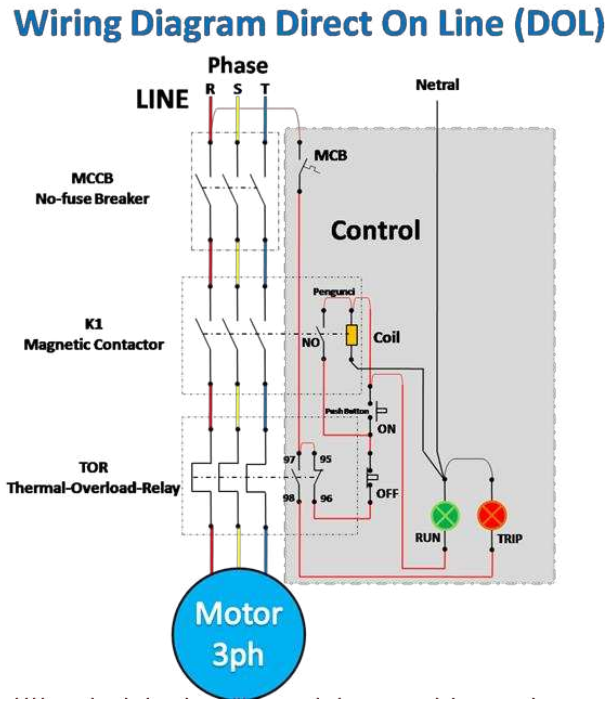


Figure 3. Wiring Diagram Direct On Line (DOL)

(Source: https://duniaberbagiilmuuntuksemua.blogspot.com)

The image above shows a direct-on-line power circuit. The power circuit is the main contact connection of the contactor, which is connected to the motor poles. The image above shows a circuit that uses a single contactor (TOR) to protect the circuit. It uses only one contactor and three wire connections: the phase wires (R, S, T) [19].

PLC is an electronic tool or device that is made as a replacement for the use of conventional relays, [21] PLC has its own working principle, namely a microcontroller, so it can be used to create and store programs which contain three main components, namely:

Figure 4. PLC Working Principle

In its operation, the PLC uses an application that can simplify the work of a tool for controlling 3-phase motors [20]. In this study, a Siemens PLC type S7 1200 was used, a type of PLC that has a novelty among previous PLC types. The Siemens S7 1200 PLC has various types of CPUs, including the 1211C CPU, the 1212C CPU, and the 1214C CPU. In this study, the 1214C AC/DC/RLY CPU type was used with 14 Digital Input (DI) addresses for input and 10 Digital Output (DQ) addresses for output.

The Direct On-Line circuit leader diagram that has been completed in the TIA portal can produce a leader diagram as shown in the image below.

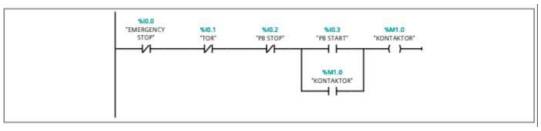


Figure 5. Process Leader Diagram 1

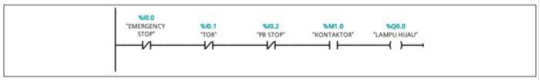


Figure 6. Process Leader Diagram 1

Figure 7. Process Leader Diagram 1

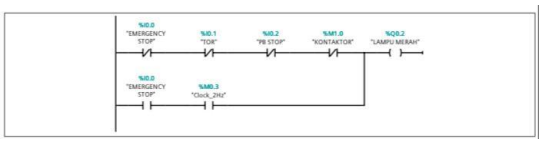


Figure 8. Process Leader Diagram 1

The programming has been completed and can be checked before the connection to the 3-phase motor can be checked using the features in the TIA portal and will provide information that there is an error by showing the red color in the circuit where the error occurs and can be immediately repaired in the TIA portal. And then the wiring can be done from the PLC itself which is connected to the motor via the simulation board using a cable [21].

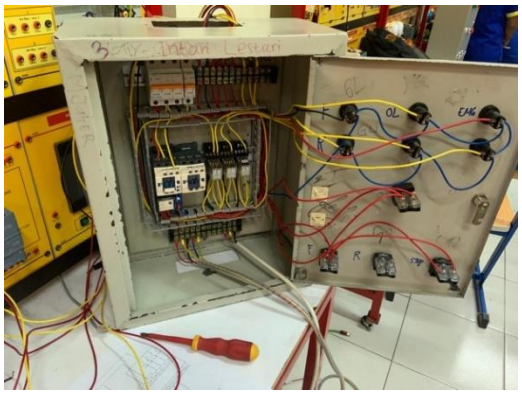


Figure 9. Panel Box

Figure 10. Realization of Direct On Line series

Figures 9 and 10 show that the programming results for the Siemens S7 1200 PLC are similar to those for the automation circuit without a PLC. However, the table above specifies the code that must be entered into the PLC system. If the code is incorrect, the PLC program will not run and will be marked in red. This must be corrected immediately by entering the correct code, which can then be rechecked on the PLC device. If correct, the PLC program will operate according to the specified instructions.

Table 2. Siemens S7 1200 PLC Observation

INPUT	OUTPUT	ADDRESS
EMG		I0.0
TOR		I0.1
STOP		I0.2
S1		I0.2
S2		I0.3
	K1	M1.0
	L1	Q0.0
	L2	Q0.1
	L3	Q0.2

IV. CONCLUSION

The research results show that a Direct On Line circuit has been implemented as a 3-phase motor controller using a Siemens S7 1200 programmable logic controller. Operating as a safety device against overloads, the Direct On Line circuit cuts off the power supply, with a flashing indicator light indicating that the electric motor is about to start or rotate. Using a PLC, the Direct On Line circuit replaces conventional relays, with data reading via the TIA feature providing error information, enabling proper control with a microcontroller. This allows for full control and monitoring of current flow and rotating machinery without the use of other PLC devices. Therefore, the Direct On Line circuit streamlines processing time and minimizes data errors while the machine is operating.

REFFERENCES

[1] A. Effendi, "Perancangan Pengontrolan Pemanas Air Menggunakan PLC Siemens S7-1200 dan Sensor Arus ACS712," vol. 2, no. 3, 2018.

[2] S. Nuari, Atmam, and E. Zondra, "Analisis Starting Motor Induksi Tiga Phasa Menggunakan Programmable Logic Controller (PLC)," *SainETIn*, vol. 2, no. 2, pp. 60–67, 2018, doi: 10.31849/sainetin.v2i2.2019.

[3] I. M. Gde Arjana, A. A., Sukada, J.M., Suratma, N.A., Dwinata, "Prosiding Seminar Nasional Sains dan Teknologi," *Pengemb. Buah Pinang sebagai Anthelintika dalam upaya Meningkat. Produkt. Ternak*, no. Petruzella 2010, pp. 215–220, 2014.

[4] T. Tohir Politeknik Negeri Bandung Jl Geger Kalong Hilir Ds Ciwaruga, "Rancang Bangun Kendali Motor Induksi 3 Fasa Berbasis PLC Dengan Metoda Pemograman Function Block Diagram Control Design of 3 Phase Induction Motor Based PLC with Programming Function Block Diagram," no. November 2019, pp. 501–511, 2019.

[5] H. Mandala, H. Rachmat, D. Sukma, and E. Atmaja, "Perancangan Sistem Otomatisasi Penggilingan Teh Hitam Orthodoks Menggunakan Pengendali PLC Siemens S7 1200 dan Supervisory Control and Data Acquisition (SCADA) di PT . Perkebunan Nusantara VIII Rancabali," *J. Tugas Akhir | Fak. Rekayasa Ind.*, vol. 2, no. 1, pp. 1–8, 2015.

[6] A. Salkic, H. Muhovic, and D. Jokic, "Siemens S7-1200 PLC DC Motor control capabilities," *IFAC-PapersOnLine*, vol. 55, no. 4, pp. 103–108, 2022, doi: 10.1016/j.ifacol.2022.06.017.

[7] M. Adjie and A. Dwi, "Analisa Sistem Starting DOL (Direct On Line) pada Motor Listrik PT. Semen Baturaja," *J. Multidisipliner Bharasumba*, pp. 395–402, 2022.

[8] P. Asmaleni, D. Hamdani, and I. Sakti, "Pengembangan Sistem Kontrol Kipas Angin Dan Lampu Otomatis Berbasis Saklar Suara Menggunakan Arduino Uno," *J. Kumparan Fis.*, vol. 3, no. 1, pp. 59–66, 2020, doi: 10.33369/jkf.3.1.59-66.

[9] I. . Shaputra.R, Gunoto.P, "Kran air otomatis pada tempat berwudhu menggunakan sensor ultrasonik berbasis arduino uno," *Sigma Tek.*, vol. 2, no. 2, pp. 192–201, 2019.

[10] C. Chan, K. Chow, S. Yiu, and K. Yau, "Enchancing The Security And Forensic Capabilities of Programmable Logic Controllers," *Springer Nat. Switz.*, pp. 351–367, 2018.

[11] E. Sutriani and R. Octaviani, "Analisis Data dan Pengecekan Keabsahan Data".

[12] muhammad khadafi alkindi, "Perancangan Alat Detektor Kegagalan Fasa Sebagai Proteksi Beban 3 Fasa," *Peranc. Alat Detektor Kegagalan Fasa Sebagai Prot. Beban 3 Fasa*, vol. 92,

2018.

[13] B. Suriansyah, “Catu Daya Cadangan Berkapasitas 100 Ah / 12 V untuk Laboratorium Otomatisasi Industri Poliban,” *INTEKNA*, no. 2, p. ., 2019.

[14] Z. Anthony, “Pengembangan Rangkaian Kendali untuk Mengoperasikan Motor Induksi3-Fasa,” vol. 6, no. 1, pp. 81–86, 2017.

[15] I. J. Prakoso, A. Warsito, and T. Sukmadi, “Perancangan Pengasutan Bintang – Segitiga dan Pengereman Dinamik pada Motor Induksi 3 Fasa dengan Menggunakan Programmable Logic Controller (PLC),” vol. 14, no. 1, pp. 13–19, 2012.

[16] E. Susanto, “Automatic Transfer Switch (Suatu Tinjauan),” *J. Tek. Elektro Unnes*, vol. 5, no. 1, pp. 3–6, 2013.

[17] I. G. S. Sudaryana, “Pemanfaatan Relai Tunda Waktu dan Kontaktor pada Panel Hubung Bagi (PHB) untuk Praktek Penghasutan Starting Motor Star Delta,” 2019.

[18] R. S. Rizqyka Amalia, Hendro Widiarto, “Modifikasi alat kendali,” *Modif. Alat Kendali Air Cond. Split Di Lab. Maint. Airf. Gr. Light. Sekol. Tinggi Penerbangan Indones.*, vol. 13, no. 1, p. 73, 2020.

[19] A. F. Kheiralla, O. Siddig, A. A. E. Mokhtar, M. Esameldeen, and O. Addalla, “Design and Development of a Low Cost Programmable Logic Controller Workbench for Education Purposes,” *Int. Conf. Eng. Educ. – ICEE 2007*, pp. 1–6, 2007.

[20] A. M. Muhammad, “Simulasi Alat Penjaring Ikan Otomatis Dengan Penggerak Motor Servo Continuous, Sensor Jarak Hc-Sr04 Dan Tombol, Menggunakan Arduino Mega,” *Simulasi Alat Penjaring Ikan Otomatis Dengan Penggerak Mot. Servo Contin. Sens. Jarak Hc-Sr04 dan Tombol, Menggunakan Arduino Mega*, vol. 12, no. 1, pp. 39–47, 2019.

[21] E. Gunawan and E. Wahyono, “Jalan Umum Dengan Sistem Kontaktor,” *Jalan Umum Dengan Sist. Kontaktor*, vol. 1, no. 1, pp. 36–44, 2017.