Automatic metal sorting conveyor machine based on Programmable Logic Controller

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Abstract. The clothing and food industry had to require for each product which is produced by them is free of dangerous metal. To handle the problem, the industry did anyways to decreasing metal contents that might be involved in the product. One of the methods that the industry able to do is metal sorter automatically system that used to do when the product is on the conveyor. This method is counted so efficiently if we know that the conveyor is used for moving an item from a place to another place by using an induction motor as a mover. This research purposes of presenting an example of a Programmable Logic Controller (PLC) uses as an electronic device that able to control the conveyor metal sorter system automatically. We used a photoelectric sensor to detect an item on the conveyor. Meanwhile, inductive proximity is used to detect metal content behind the item. This research also is written on how this PLC is more efficient if we compared it with using the conventional relay.

1. Introduction
Demand for high-quality objects, better efficiency, and automatic machines continues to grow as globalization develops [1]. To meet these needs, we need a tool that can control various types of work tools that are universal [2].

PLC is a system controller that is widely used in industrial automation [3]. PLC stands for Programmable Logic Controller, which is a device that implements logic algorithms in its application in the industry [4]. Controllers that have been widely applied in the industrial world are used instead of complex conventional relays to be simpler by adding software to them [5]. PLC is widely used in the industrial world because of the effectiveness and efficiency of the installation, financing, and modification of the circuit.

Automation is a technology that refers to the use of hands-on less in the production process [6]. In the process, the industry is increasingly innovative in production automation. One of them is the use of high-tech automation machines in sorting objects with great attention to accuracy and improving efficiency [7]. Even for the food industry, sorting food from a mixture of pollutants and metal elements that are harmful to digestion is the main focus of industry standards so that the innovation of detecting metal elements in foodstuffs was carried out in the past few years [8].
A conveyor is a medium between goods that move based on the rotation of an induction motor. The conveyor rate can be controlled using a PLC [9]. The control of the induction motor through deceleration of the motor rotating speed is done using VFD. This VFD can reduce motor speed and improve the efficiency of electric power consumption [10].

2. Material and methods
The electrical material required for making this machine is 11 kinds. The electrical material needed to make this machine is shown in table 1.

| Component                  | Specification                                                                 | Amount |
|----------------------------|-------------------------------------------------------------------------------|--------|
| PLC [11]                   | Omron Type CPM1A–30CDR–A–V1 Input18 Output 12                               | 1 unit |
| Inductive Proximity        | range 8 mm NPN 3 cable with NO type                                         | 1 unit |
| Photoclectric Sensor       | Emitter = E3S-2LE4 Receiver = E3S-2DE4 Range 2 meter NPN                     | 3 unit |
| Limit Switch               | 220 VAC/24 VDC                                                               | 2 unit |
| Motor Induction 220 VAC    | 3 Phase, 1710 Rpm, 4 Pole, ½ HP, 50 HZ.                                      | 1 unit |
| MCB                        | 4A                                                                            | 2 unit |
| VFD 1 HP                   | Danfoss input 24 VDC, Voltage Source 220 VAC                                 | 1 unit |
| Relay [12]                 | 24 VDC for forward and reverse                                               | 2 unit |
| PWS                        | 24 VDC, 2 A                                                                  | 1 unit |
| Cable                      | NYAF 0.75 mm²                                                                | sufficiently |
| Terminal and cable duct    | standard                                                                     | sufficiently |
| Panel Box                  | 40 x 60 x 50 cm²                                                             | 1 unit |

Figure 1 shows the conveyor frame design that the author made. They are using L 4 x 4 mm² with the welding method.
Components installed on the conveyor consist of input and output. Inputs are in the form of 3 photoelectric sensors, one inductive proximity sensor, and two pieces of limit switches, and 1 unit 24 VDC motor as a wiper drive. As a roller drive to be able to rotate, an induction motor is placed under the conveyor with an additional pulley and transmission in the form of a v-belt. Figure 2 is the layout of the components installed on the conveyor frame.

The automation method uses the CPM1A PLC OMRON CPU-30 using the ladder program language with CX-Programmer software. The work system begins with a photoelectric sensor 1, and inductive proximity is placed at the beginning of the conveyor. Photoelectric 1 detects the presence of objects that cut laser light. The output of photoelectric 1 is in the form of a conveyor drive induction motor with 8.5 Hz and 14.5 Hz rotational speed. The induction motor is set by its rotation speed by the Danfoss variable frequency drive (VFD) with a capacity of 1 HP. If the object placed above the conveyor contains metal elements, then the 24 V DC motor actuator in the form of a wiper will move to the left. The rotation of the wiper will touch the limit switch one, which is mounted on the conveyor barrier. The touch of the limit switch by the wiper causes the cessation of the DC motor to the left. Figure 3 will explain the statement. The object will automatically enter the right side of the conveyor.

Moving objects on the right side of the conveyor will be detected by photoelectric 2. Detection of objects by photoelectric two causes rotation of DC motor to the right (back to its original state). The wiper motor will rotate until it pushes the limit switch two, which is on the conveyor barrier. When pressed, the wiper motor will stop. The limit switch is in NC condition so that it can cut the current on the motor. Photoelectric 2 counts up to 5 objects that are permitted. On the count of 5 objects, the conveyor will stop automatically.
Another condition is when the metal on the conveyor is not detected, there will be no change in the wiper motor. Rotating the wiper motor is caused by the detection of metal by an inductive proximity sensor. Photoelectric 3 on the conveyor on the left will detect objects passing through it. Photoelectric 3 will count many objects that pass it up to 5 x, after the object is detected five times, the system will die. In this system, the condition of the system is when the user presses the emergency button, objects calculated on photoelectric 2 and 3, and forcibly turns off by removing the plug from the source. Counting will reset again when the user presses the emergency button off.

Table 2. PLC Input output addressing.

| I/O Type | Component                  | Function                                      | PLC Address |
|----------|----------------------------|-----------------------------------------------|-------------|
| Input    | Emergency OFF Button       | OFF System                                    | 0.00        |
|          | Photoelectric 1            | Moving motor conveyor                         | 1.01        |
|          | Inductive Proximity        | Metal detector                                | 0.11        |
|          | Limit Switch 1             | DC motor forward stopper                      | 0.03        |
|          | Photoelectric 2            | Detect objects with reverse DC motor output   | 1.05        |
|          | Limit Switch 2             | DC motor reverse stopper                      | 0.06        |
| Output   | Induction Motor ½ HP / VFD | Moving the conveyor                           | 10.00       |
|          | Motor DC Wiper             | Moving the wiper to the right (forward)       | 10.01       |
|          | Motor induksi ½ HP / VFD   | Moving the wiper left (reverse)               | 10.02       |
|          |                            | Double-speed induction motor in the state of  | 10.04       |
|          |                            | the object above the metal-conveyor           |             |

Figure 4 is wiring carried out on the PLC. Use the 0.75 mm2 NYAF type cable attached to 0.75 mm2 ferules.
**Figure 4.** I/O wiring on PLC.

**Information:**
- L1 enters MCB 220 VAC and Neutral PLC to Neutral source.
- COM up to (-) PWS 24 VDC.
- The input channel depends on the type of input. Three-wire sensor, foot + and - to PWS 24 VDC and signal to PLC channel. Switches, feet + to PWS 24 VDC and feet - to PLC channel.
- The input channel is adjusted in table 1.
- Channel Output is adjusted in table 1.
- COM 1, COM 2 down to PWS (+) 24 VDC.
- COM 0, COM 3 below to (+) VFD.
- MCB to Source Phase 220 VAC.

The program used is a ladder diagram with available software is CX-Programmer and as an offline simulation using CX Designer. As a process viewer, I use a laptop for simulation and CIF02 cable for data communication between PLCs and programs.

**3. Results and discussion**
After testing the usefulness of the tool on several electrical parameters, the authors obtain data as presented in tables 3, where the sign means to function properly.
Table 3. Functional test result.

| I/O    | Component              | Number of experiment |
|--------|------------------------|----------------------|
| Input  | Emergency OFF          | ✓ ✓ ✓ ✓ ✓             |
|        | Fotoelektrik 1         | ✓ ✓ ✓ ✓ ✓             |
|        | Inductive Proxi        | ✓ ✓ ✓ ✓ ✓             |
|        | Limit Switch 1         | ✓ ✓ ✓ ✓ ✓             |
|        | Limit Switch 2         | ✓ ✓ ✓ ✓ ✓             |
|        | Fotoelektrik 2         | ✓ ✓ ✓ ✓ ✓             |
|        | Fotoelektrik 3         | ✓ ✓ ✓ ✓ ✓             |
| Output | Motor Conveyor         | ✓ ✓ ✓ ✓ ✓             |
|        | Forward DC             | ✓ ✓ ✓ ✓ ✓             |
|        | Reverse DC             | ✓ ✓ ✓ ✓ ✓             |
|        | Double Speed           | ✓ ✓ ✓ ✓ ✓             |
|        | Indicator Lamp         | ✓ ✓ ✓ ✓ ✓             |

Table 4 is the measurement data based on electrical system parameters.

Table 4. Measurement result.

| No | Component         | Parameter | Average Measurement Results 10 Times |
|----|-------------------|-----------|--------------------------------------|
| 1  | Emergency Button  | Voltage (v)| 23.5                                |
|    |                   | Current (mA)| 11.4                                |
| 2  | Limit Switch      | Voltage (v)| 23.5                                |
|    |                   | Current (mA)| 4.9                                 |
| 3  | Photoelectric     | Voltage (v)| 23.5                                |
|    |                   | Current (mA)| 104.5                               |
| 4  | Inductive Proximity| Voltage (v)| 23.5                                |
|    |                   | Current (mA)| 2                                   |
| 5  | Motor DC FWD      | Voltage (v)| 23.8                                |
|    |                   | Current (mA)| 1.16                                |
| 6  | Motor DC RVS      | Voltage (v)| 23.9                                |
|    |                   | Current (mA)| 1.15                                |

Automatic metal sorting conveyor machine based on programmable logic Controller is more efficient by consuming only 20 W maximum for DC and 60 VA maximum for AC compared to conventional relays, which consume 9 Watt Coil power on DC with switching capacity 120 W for DC and 1100 VA for AC.

4. Conclusion
PLC performance is controlling the inputs that enter through the input module, processed according to the program being planted and issuing output to the output module. The use of PLC is much more efficient and does not require a lot of space in the panel. The author has made several changes to the program to adjust I / O as planned work principles. But in these changes, the author did not add to costs, nor did he suffer losses. This is inversely proportional to the use of conventional relays. In addition to the need for additional cables at the time of testing, the use of conventional relays is also at risk of errors during installation. Unlike the PLC, which can be simulated before the installation is done.
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