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Application of GEMMA Methods in Controlling and Monitoring the Production Systems Cycle

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Abstract

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Currently, with the development of digital technology, automatic lines are increasingly widely applied in production. The production systems always have to improve technology and machinery constantly to create products with the best quality, at the most competitive prices. To bring benefits as well as innovation to businesses, automatic production line systems always show their role in saving labour, saving energy, saving raw materials, and improving quality with high precision. That is also the huge challenge posed to the industry today. Therefore, the research and application of scientific and technical achievements in production fields are always strongly encouraged. Larger and more complex automation systems require modern methods to operate, manage and monitor more efficiently.

The topic "Application of GEMMA Methods in Controlling and Monitoring the Production Systems Cycle" mainly focuses on step programming. It allows the running and stopping needs of an automated system to be clearly and fully expressed. Realizing that the GEMMA method is a modern and prominent application in management and supervision in industrial cycles, the company assigned me to research and develop the GEMMA method further based on the "Training demo model" as a KIT already has a mechanical part.

The project implements a controlling and monitoring model of a small production system cycle in the research and development process of Nhat Tri Automation Company. These are based on many modern technologies such as PLC programming, industrial communication networks, etc. The content of the project aimed to build a complete system in clear, complete and accurate running and stopping modes.

Keywords: GEMMA method, PLC programming, industrial communication networks, Training demo model, SCADA system, KPIs.

Contents

List of Abbreviations

AC: Alternating Current

ADEPA: Application Production Development Authority

CYL: Cylinder mechanism

FBD: Function Block Diagram

GEMMA: Guide d’Etudes des Modes de Marches et d’Arrets

GRAFCET: Graphe Fontionnel De Commande Étape Transition.

HMI: Human Machine Interface

KPIs: Key Performance Indicators

PC: Part of Controller.

PLC: Programmable Logic Controller

PO: Part of Operating.

RB: Robot

SCADA: Supervisory Control and Data Acquisition

SS: Sensor

TIA: Totally Integrated Automation

1 Introduction

I have used the GEMMA method to further develop the topic of a "Training Demo Model" in this thesis work, with the mechanical part available on request during the research and application process of Nhat Tri Automation Co., Ltd. The goal of this approach for constructing a model control program of a small production system is to increase the ability to exploit the model in the research process that can be observed in the study. Later on, it may be applied to more extensive and more complicated systems.

The "Training demo model" is designed by the company to serve different research and testing processes on many modern methods, with high applicability in practice. It could be realized that, through previous research, the new system model has only a normal operation mode to experiment with PLC programming problems. It does not yet have a complete program based on a modern industrial method. Therefore, there are some problems in the operation process as follows: the operating procedure of the system is not reasonable when producing in batches (iron/plastic); when the system is working, it is difficult to determine which stage is working as well as its operating state; there is no recognition of the position of objects in and out between stages in the system; monitoring, remote control, and inspection (maintenance) functions are limited and the mechanism of classifying objects by Loadcell is not standard, there are errors.

2 Theoretical Background

2.1 Model Introduction

2.1.1 Production System Cycle Diagram

This is a test model for a stage of assembling parts in a production system. The model control system is designed and programmed using Siemens TIA Portal V17 software and SIMATIC WinCC Unified V17 is the main software used for the SCADA system. (Figure 1)

- Stage 1: Putting the raw material (Figure 2 & 4) into the assembly stage.
- Stage 2: Pick up raw material (Figure 2 & 4) to the turntable.
- Stage 3: The rotating disc brings the object to the correct position to receive the corresponding core.
- Stage 4: Drop the iron or plastic core into the correct iron or plastic rough.
- Stage 5: Pick up the object (Figure 3 & 5) to another stage.

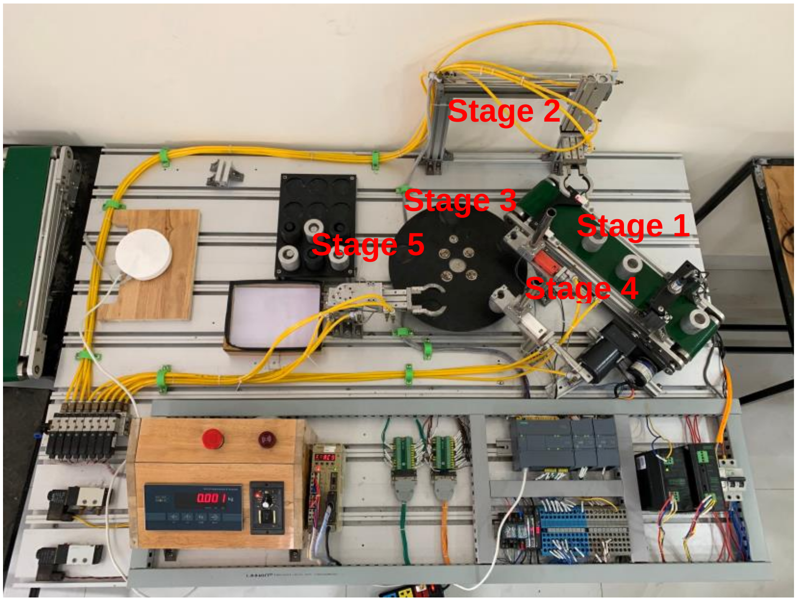


Figure 1 System diagram of the cycle

 Figure 2 Iron raw material	 Figure 3 The finished iron material	 Figure 4 Plastic raw material	 Figure 5 The finished plastic material

Principle of operation: Initially, at Stage 1, the object without a core is put on the conveyor belt, which in turn passes through the classification sensor to determine whether it is an iron (Figure 2) or plastic object (Figure 4) and the object counting sensor. Towards the end of the conveyor, the end position sensor signals to stop the conveyor. At the same time, let Robot 1 (RB1) in Stage 2 proceed to pick up the object and put it on the rotating disc in Stage 3. At this time, the rotating disc controlled by the Servo motor will bring the object to the correct position under the core drop mechanism. iron or plastic in Stage 4. After the object has finished receiving the core, the spinning disc will continue to rotate to bring the object to the position where Robot 2 (RB2) of Stage 5 is waiting to pick up the object through another cycle.

2.1.2 Introduction of Production Stages in the System

Including 5 stages of production:

a. Stage 1

- ➢ Structure:
  - Conveyor Belt (Number 1 in Figure 6).
  - Single phase 220V AC gear reducer motor: mounted with conveyor (Number 2 in Figure 6).
  - Speed control box: used to adjust the number of motor revolutions so that the electric motor can change the speed according to the needs of use.

- Encoder: Measure the rotational speed of the conveyor motor, to check the conveyor jam error (motor is reciprocating) (Number 3 in Figure 6).
- Sensor 1 (SS_TYPE): Identify whether the object is iron or plastic (Number 4 in Figure 6).
- Sensor 2 (SS_START): Identify the object that has entered the conveyor (Number 5 in Figure 6).
- Sensor 3 (SS_END): Recognizing that the object has come to the right position to pick up, at this time the conveyor stops for RB1 (Stage 2) to pick up (Number 6 in Figure 6).

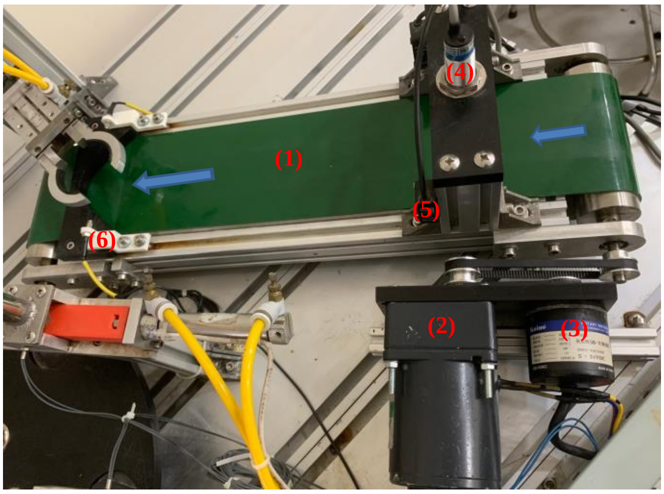


Figure 6 Stage 1

➢ Principles:

When the conveyor is in operation, the object is moved through the SS_TYPE, SS_START sensors, in turn, to determine whether the input is an iron or plastic object and then continues to move to the SS_END sensor.
If the signal at sensor SS_END = 1, the conveyor will stop, and the arm RB1 (Stage 2) will proceed to pick up the object. In contrast, the conveyor will continue to operate.

During operation, the encoder will measure the rotational speed of the motor and respond continuously, ensuring that the conveyor is still operating normally.

b. Stage 2

➢ Structure:

- Robotic Arm 1 (RB1). (Number 1 in Figure 7)
- CYL_UpDown: control arm up or down.
    + Upper sensor (SS_UPPER): detects that the gripper is on top of the mechanism. (Number 2 in Figure 7)
    + Bottom sensor (SS_LOWER): detects that the gripper is on the bottom of the mechanism. (Number 3 in Figure 7)
- CYL_LeftRight: control arm left or right.
    + Left sensor (SS_LEFT): detects that the gripper is on the left side of the mechanism. (Number 4 in Figure 7)
    + Right sensor (SS_RIGHT): detects that the gripper is on the right side of the mechanism. (Number 5 in Figure 7)
- CYL_Pickup_Drop: controls the arm to pick up or drop the object.

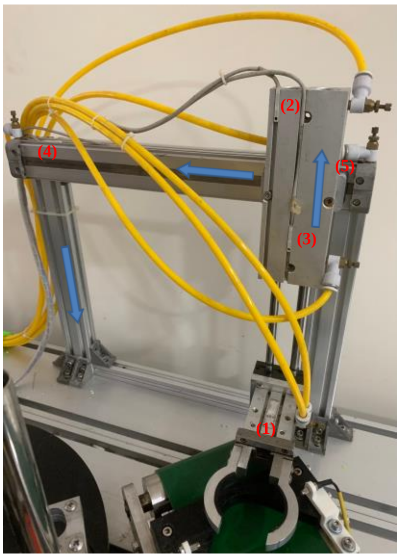


Figure 7 Stage 2

- Principles:

The RB1 arm will pick up the object from the conveyor (Stage 1) to the rotating disc (Stage 3).

Upon receiving a signal from the SS_END sensor (Stage 1), the arm begins to move to pick up the object. When grasping the object, the arm is now on the right (SS_RIGHT = 1), below (SS_LOWER = 1) → move up (SS_UPPER = 1) → left (SS_LEFT = 1) → down (SS_LOWER). = 1) → release the object onto the turntable (Stage 3). Then move back to the conveyor in the reverse cycle.

c. Stage 3

- Structure:

  - Rotary disc powered by SERVO motor, divided into 5 positions (Number 1 in Figure 8).

  - Proximity sensor: detects the Home position of the rotating disc (Number 2 in Figure 8).

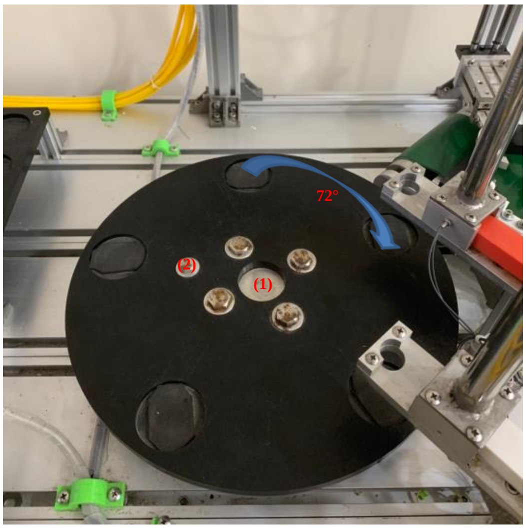


Figure 8 Stage 3

- Principles:

Initially, the disc rotates in the Home position, rotating to bring the object from the drop position of the RB1 arm (Stage 2) to the positions to receive the core from the cylinder mechanisms (Stage 4) and then to the correct position for RB2 (Stage 5) pick up the object.

Only 1 object is allowed on the disc, when RB2 finishes picking it up, RB1 will be able to drop the object on the disc and then continue to rotate the disc 1 second later.

Circumstances in which the disc must stop spinning:

The turntable operates in relativity, divided into rotations, each of which is 72°. When an object is dropped from the RB1 arm (Stage 2) onto the turntable, it will rotate to the correct position of the core drop cylinder mechanisms (Stage 4) as follows:

- If it is an iron object: From the position of the rotating disc receiving the object, rotate 72°. After stopping to receive the iron core, turn 144° to reach arm position RB2 (Stage 5).

- If it is a plastic object: From the position of the rotating disc receiving the object, rotate 144°. After stopping to receive the core, turn 72° to reach arm position RB2 (Stage 5).

d. Stage 4

➢ Structure:

- Cylinder mechanism 1 (CYL_IRON): drop the iron core into the iron object. (Number 1 in Figure 9)

  + Sensor 1 (SS_CORE_IRON): Iron core detection. (Number 2 in Figure 9)

  + Sensor 2 (SS_END_IRON): Placed at the end of cylinder mechanism 1, detecting that the iron core has been pushed. (Number 3 in Figure 9)

- Cylinder mechanism 2 (CYL_PLASTIC): drop the plastic core into the plastic object. (Number 4 in Figure 9)

  + Sensor 1 (SS_CORE_PLASTIC): Detects plastic core. (Number 5 in Figure 9)

  + Sensor 2 (SS_PLASTIC_B): Placed at the end of cylinder mechanism 2, realizes that the plastic core has been pushed. (Number 6 in Figure 9)

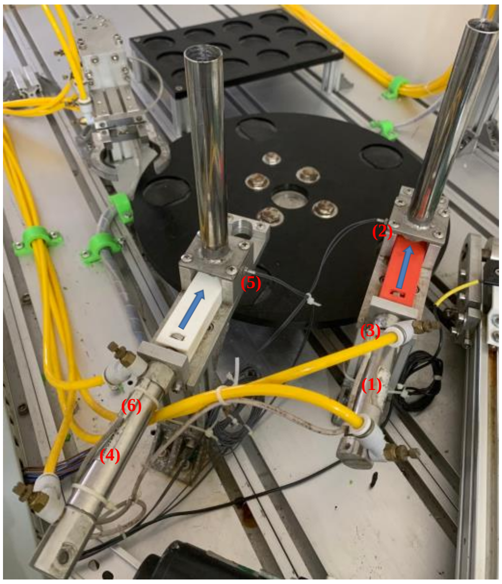


Figure 9 Stage 4

➢ Principles:

There are 2 core drop cylinder mechanisms for the object:

When the rotating disc puts the object in the right position under 2 cylinders respectively, under the principle of push and return, the cylinders will drop the iron and plastic core respectively into the objects.

- For cylinder mechanism 1: Initially, SS_END_IRON = 0 → cylinder 1 will push to (set CYL_IRON = 1) causing the iron core to be pushed down to the iron (SS_END_IRON = 1). Then the push rod quickly retracts (reset CYL_IRON = 0) back to the original position (SS_END_IRON = 0).

- For cylinder structure 2: Initially, SS_END_PLASTIC = 0 → cylinder 2 will push to (set CYL_PLASTIC = 1) causing the plastic core to be pushed down to the plastic object (SS_END_PLASTIC = 1). Then the push rod quickly retracts (reset CYL_PLASTIC = 0) back to the original position (SS_END_PLASTIC = 0).

e. Stage 5

➢ Structure:

- Robotic Arm (RB2). (Number 1 in Figure 10)
- CYL_R_LeftRight: control arm left or right.
  + Left Rotation Sensor (SS_R_LEFT): detects when the RB2 arm is on the left side. (Number 2 in Figure 10)
  + Right Rotation Sensor (SS_R_RIGHT): detects when RB2 arm is on the right side. (Number 3 in Figure 10)
- CYL_UpDown: control arm up or down.
  + Upper sensor (SS_UPPER): detects that the gripper is on top of the mechanism. (Number 4 in Figure 10)
  + Bottom sensor (SS_LOWER): detects that the gripper is on the bottom of the mechanism. (Number 5 in Figure 10)
- CYL_Pickup_Drop: controls the arm to pick up or release the object.

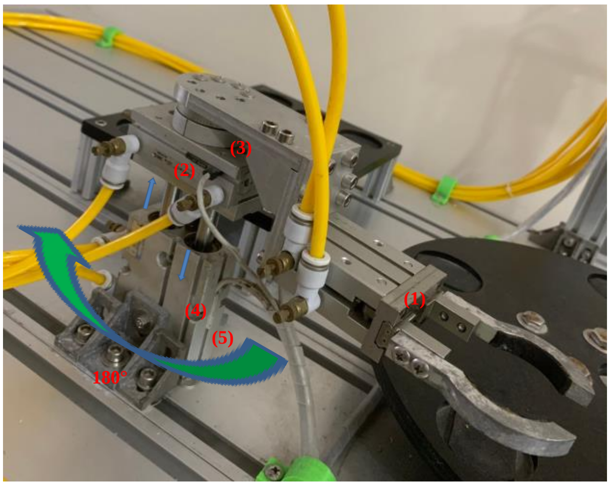


Figure 10 Stage 5

➢ Principles:

The RB2 arm will pick up the object from the turntable to the next production stage.

When receiving a signal from the rotating disk indicating that the object has reached the place to be picked, the RB2 arm begins to move to pick up the object. When grasping the object, the arm is now on the right (SS_R_RIGHT = 1), below (SS_LOWER = 1) → move up (SS_UPPER = 1) → rotate to the left (SS_R_LEFT = 1) down (SS_LOWER = 1) → release the item to the tray of the next production stage. Then move back to the rotating disc in the reverse cycle to pick up the objects.

2.2 System Control and Monitoring Problem

The idea emerged on the basis of the available mechanical part, which is designed by the company for a miniature assembly and requires the output to be a finished product with a core. Through the research in previous studies, I recognized the limitations, so I decided to improve the system as follows:

- Rebuild the entire control program with a more streamlined operating principle based on start and stop modes, or produce in a failure through the application of a modern method, with the help of control software. The latest programmable controller from Siemens is the TIA Portal V17.

- Rebuild the SCADA system based on the modern SIMATIC WinCC Unified V17 software that the company also wanted for the research and development team. Helps to improve the efficiency of detailed and clearer management and monitoring through consoles, incident warnings, and statistical reports.

- Evaluate output quality and system performance through KPIs. From there, it is possible to offer improved solutions and a more suitable and optimal way to operate.

The solution was to apply the GEMMA method, under a project title Application of GEMMA Methods in Controlling and Monitoring the Production Systems Cycle.

2.3 Introduction to the GEMMA's Method

2.3.1 Definition

GEMMA stands for Guide d'Etudes des Modes de Marches et d'Arrets, which is a visual guide developed by the Application Production Development Authority (ADEPA) in April 1981 [3].

GEMMA is a method of organizing programming and automatic system management according to running and stopping modes. The method provides an organizational model and manages the working method of the system so that it is planned, reasonable, intuitive, and economic. [3.]

This graphing tool allows us to clearly describe the running and stopping modes of the system from the research stage to the implementation stage. In simple terms, it enables technicians working on the same system to easily communicate with each other. It allows enumeration of all system run and stops procedures on PCs (control part) and PO part (operation part). [1.]

2.3.2 The Structure of GEMMA

The GEMMA graph is briefly shown in Figure 11 below.

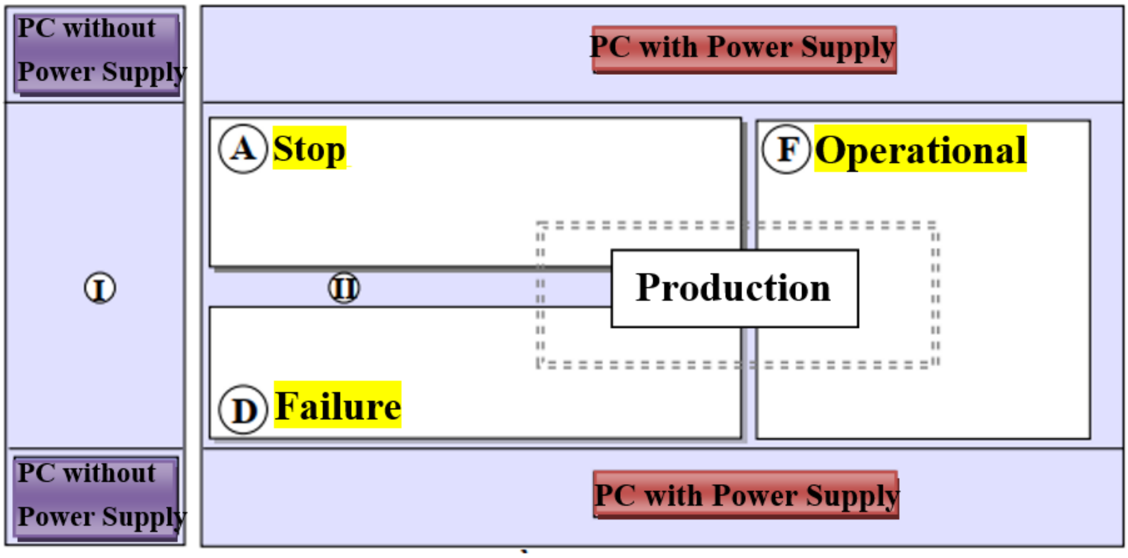


Figure 11 GEMMA Graphs [1]

a. GEMMA Graph

Consists of 2 zones:

- Zone I: The control area has no power supply (without energy), corresponding to the << no power supply >> state of the control part, in which state the operation part (PO) is not performed by the control part. Guaranteed security of the technology. We do not consider this part. [1.]

- Zone II: The control area has a power supply and is active (under energy), allowing to describe what happens while the control part (PC) is operating normally << power supply >>, allowing to define the different running and stopping modes of the device (system) along with the conditions for switching between one mode to another. This is the zone that occupies almost the entire GEMMA map. [1.]

In addition, in Zone II we also have: The production area and the non-production area are distinguished by a double dotted line of the production area. The Start and Stop modes inside the "Production" dotted lines correspond to the states in which the machine is producing.

b. Groups of Running and Stopping State

The GEMMA method divides the automatic system diagram into 3 groups of running and stopping located in the control area with electricity. The production area is the meeting area of these three groups. (Figure 12)

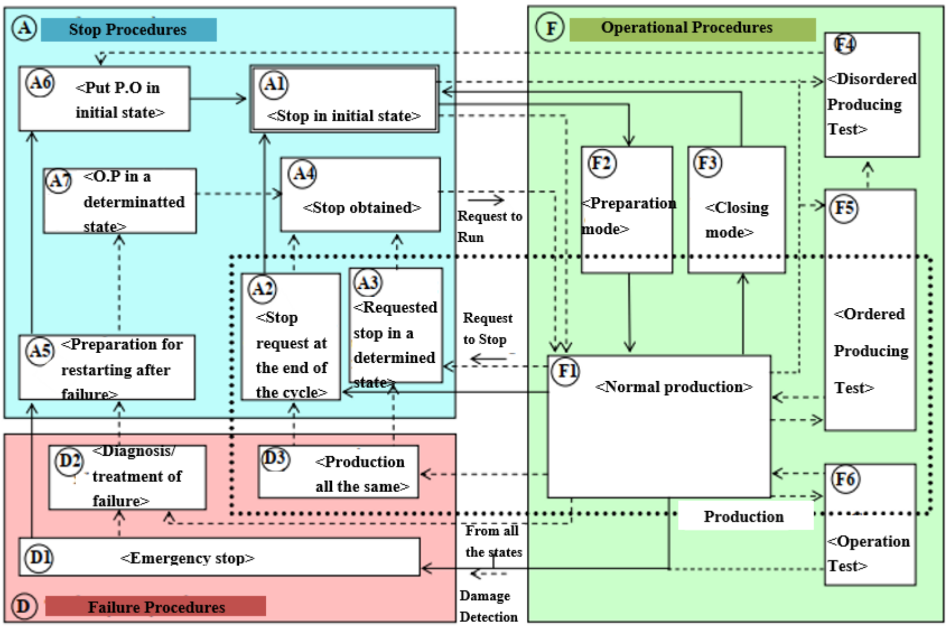


Figure 12 General GEMMA diagram and switching between modes

Group F - Operational procedures:

This group is the green group to the right of Figure 12. The grouping of all modes or states required an automated system to produce product increments. It is not necessary to produce all of the F group.

[2.] Group F is divided into 6 subgroups: F1, F2, F3, F4, F5, and F6, including:

+ Modes of preparation for production.
+ Make adjustments.
+ Test, test run.
+ Normal operation.

Group A - Stop procedures:

Next, the blue group is in the upper left corner of Figure 12. Auto-run mode rarely works 24/7. Stopping the automatic running mode to switch to another mode is due to external factors (end of the day, end of work shift…) or lack of raw materials. All modes lead to or transition to a deactivation state. [2.] Group A is divided into 7 subgroups: A1, A2, A3, A4, A5, A6, A7

+ Normal shutdowns.
+ Restarting procedures.

Group D - Failure procedures:

Finally, the red group is in the bottom left corner of Figure 12. A group of states that describe the stopping state for internal reasons of the system. This is an abnormal stop state (due to a problem). Group D is divided into 3 subgroups: D1, D2, and D3. Enables system failure management. The GEMMA method divides the system process into modes, corresponding to "state rectangles" linked by directional arrows, which are arranged graphically according to the main structure. corpse. There are up to 16 different operating modes. [2.]

2.3.3 Reviews of GEMMA

GEMMA is a tool to support the structured programming of automated systems on the principle of determining the running and stopping modes and the relationship between these modes. The state rectangles in GEMMA and the transitions between them come from the characteristics of the devices and the requirements of the control process. A system organized and controlled by the GEMMA method will give the operator a scientific and logical view right from assembly to programming, control, and supervision. Moreover, GEMMA also helps to find and fix program errors as well as solve problems quickly thanks to monitoring according to operating programs and coordinating control programs in case of problems, effectively. [4.]

2.4 Building GEMMA Graphs

2.4.1 Introduction of GEMMA Graph in the System

The general GEMMA diagram of the system is shown in Figure 13. And, the subgroups of the main groups (Group A, Group F, Group D) are specifically expressed through each table, respectively, as Table 1, Table 2, Table 3.

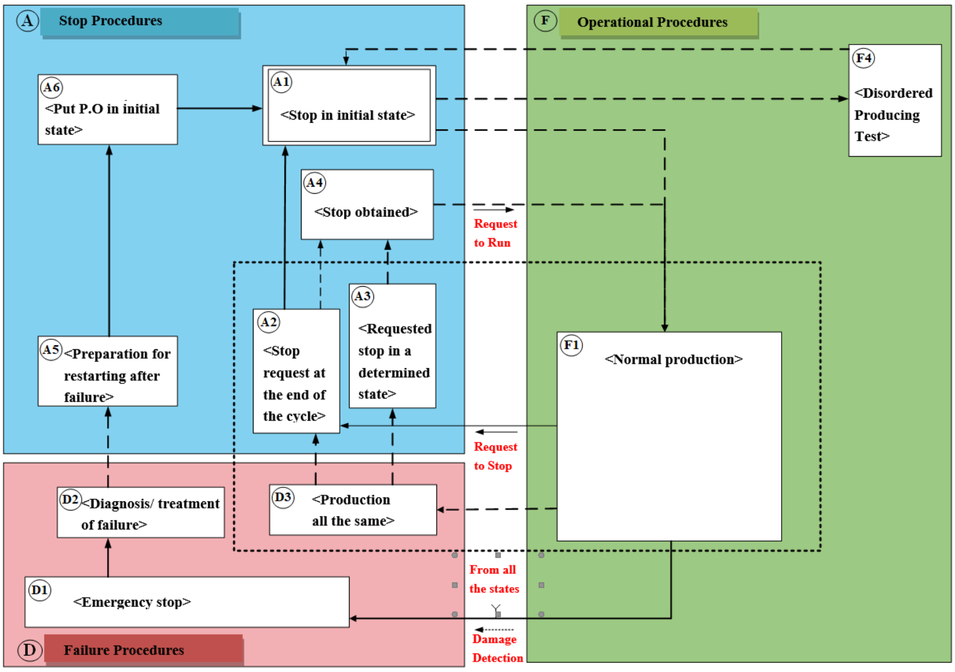


Figure 13 General GEMMA diagram of the system

Table 1 Components of Group A

Landmark	Designation	Description
A1	<Stop in initial state>	This is the “standby” state of the machine, or the system’s stand-by and ready-to-work state, before

		switching to normal production. This is usually the initial state of the system. [4.]
A2	<Stop request at the end of the cycle>	When there is a request to stop, the machine continues to produce until the end of the cycle; so state A2 is a transition (transition) to state A1. When the request stops at the end of the production cycle (like the end of the shift, the end of the day...) or the error exceeds the specified limit, the system continues to produce until the end of the work cycle. A2 is usually a transit state to return to A1. [4.]
A3	<Requested stop in a determined state>	The machine continues to produce until it stops at a position other than the end of the cycle; it is a transient (transient) state directed to A4 [4].
A4	<Stop obtained>	The machine is then stopped in a state other than the end of the cycle [4].
A5	<Preparation for restarting after failure>	This is the "standby" state of the machine, or the system's stand-by and ready-to-work state, before switching to normal production. This is usually the initial state of the system. [4.] When there is a request to stop, the machine continues to produce until the end of the cycle; so state A2 is a transition (transition) to state A1. When the request stops at the end of the production cycle (like the end of the shift, the end of the day, ...) or the error exceeds the specified limit, the system continues to produce until the end of the work cycle. A2 is usually a transit state to return to A1. [4.] The machine continues to produce until it stops at a position other than the end of the cycle; it is a transient (transient) state directed to A4. The machine is then stopped in a state other than the end of the cycle [4].

		Perform all operations (dismantling, cleaning, etc.) necessary to recover from a failure (crash or failure warning) [4]. The system is in state A6, after the operator finishes troubleshooting and executes the confirmation command, the system will automatically restore all equipment to the working ready state and then just returned to the A1 state, ready for the new production cycle. [4.] Return to the original position manually or automatically to restart in the initial state of the PO [4].
A6	<Put P.O in initial state>	The system is in state A6, after the operator finishes troubleshooting and executes the confirmation command, the system will automatically restore all equipment to the working ready state and then just returned to the A1 state, ready for the new production cycle. [4.] Return to the original position manually or automatically to restart in the initial state of the PO [4].

Table 2 Components of Group F [2]

Landmark	Designation	Description
F1	<Normal Production>	The normal production machine is in automatic mode according to the state for which it is designed: From receiving raw materials, sorting iron or plastic products, to delivery mechanisms that drop iron or plastic cores corresponding to iron objects. or plastic, and finally transported to another cycle. [4.]
F4	<Disordered Producing Test>	This mode allows manual testing of some functions, system stages, such as checking sensors, actuators, etc., without regard to the cycle order [4].

Table 3 Components of Group D

Landmark	Designation	Description
D1	<Emergency stop>	When the system detects a fire or explosion or the operator is not safe, the operator presses the Emergency Stop button at the scene. Immediately the whole system stops and alarms are detected. Wait for the operator to handle it. [4.]

D2	<Diagnosis/ trearment of failure>	The automatic control system can guide the operator to indicate the approximate location of the fault. However, the damage will be repaired by the operator or maintenance worker. [4.]
D3	<Production all the same>	In the event that production needs to be continued even when the system is experiencing problems, this mode can be activated if there is no danger to the operator or the machine. For example, if the operation fails and it can be rectified, or when there is a position error of the production line but production suffers from a minor fault, it can take some other stages. while that stage is having problems. [4.]

2.4.2 Loops in the GEMMA Graph of the System

a. Normal Walking Loop

This loop describes the normal operation of the system from A1 >> F1 >> A2 >>A1. It is easily described in Figure 14. When there is a STOP signal to end the cycle at the end of the shift/day, the system remains active until the end of the cycle, then stops. After that, all machine states are returned to the initial state ready for the new cycle. Here, the system will operate from stage 1 to stage 5 normally in AUTO NORMAL mode.

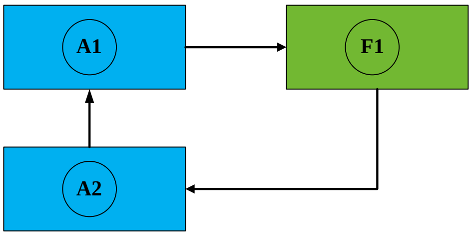


Figure 14 Loop runs normally

b. Adjustment Step Loop

The A1 >> F4 >> A1 lap is the adjusted lap. This loop represents the state of the system running the test (out of sequence, testing individual stages). The system leaves state A1 (stop in initial condition) and moves to F4 (Out-of-sequence test) allowing the operator to test the actuators, pre-actuators, and sensors of the system. It is in disarray. Once the test is done, the system automatically returns the machine states to their original positions and prepares them for the new production cycle. (Figure 15). Here, the system will be conducted to run the checks one by one independently in MANUAL mode.

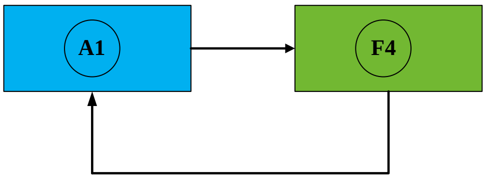


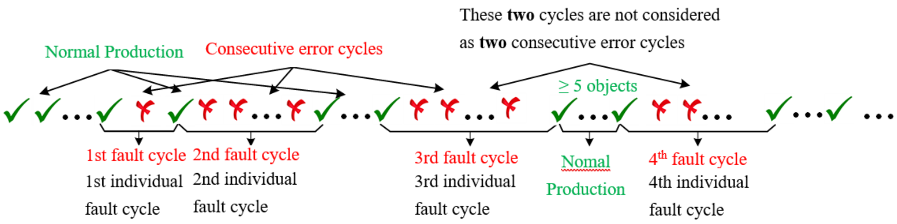
Figure 15 Adjustable run loop

c. Safety Stop Loop

This loop makes it possible to manage all successive states of an automated system from stopping during production to resume normal production. Here, the system will operate in AUTO ERROR mode.

❖ Loop 1:

Stage 4: Lack of iron or plastic core materials in 2-cylinder structures



In which: core objects ✓, coreless objects ✗

- Case 1: There are less than 5 consecutive coreless objects in 1 cycle.
- Case 2: Less than 5 consecutive failure cycles occur.
- Case 3: Less than 12 individual failure cycles occur in 1 production day/shift.

At this time, the system continues to operate normally, stopping (different from the cycle end state) to re-supply the core at Stage 4. Specifically, when the object arrives under the core drop mechanism, the disk will pause for 2 seconds and then resume recording.

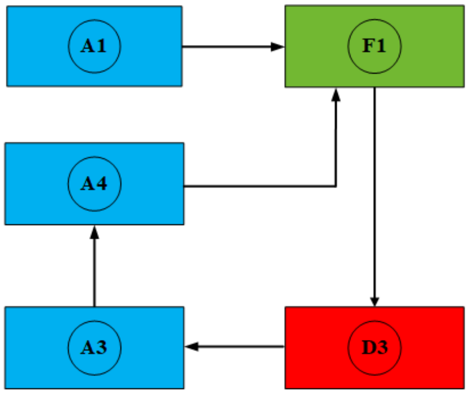


Figure 16 The first safety stop loop

❖ Loop 2:

This loop represents the state of the working production system during the fault. But at this time, the system continues to work until the end of the cycle before stopping → returning to the initial stop state → starting a new working cycle. (Figure 17)

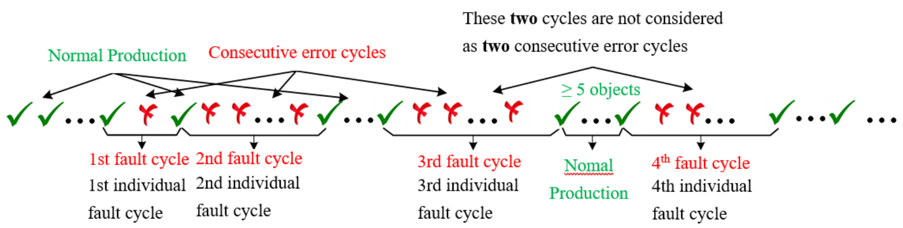
Here, there are error cases classified in Stage 1 and Stage 4 as follows:

➢ Stage 1: There are 5 cases

- Case 1: In case of conveyor belt failure. That is when there is a control signal, but the conveyor is jammed, causing the Encoder to not respond to the zero-speed signal. If after 5 seconds, the conveyor will be stopped in the original state.
- Case 2: In case of error of classification sensor (SS_TYPE): The sensor has a signal at level 1 (more than 10 seconds) or level 0 (≥15 objects).
- Case 3: In case of conveyor head sensor error (SS_START): The sensor cannot detect the object entering the conveyor.
- Case 4: In case of conveyor end sensor failure (SS_END). That is, when there is a signal to run the conveyor, the object has passed through the object counting sensor (SS_START) but after 10 seconds, the last sensor (SS_END) has not been activated.
- Case 5: In case the number of objects on the conveyor belt exceeds 4 objects.

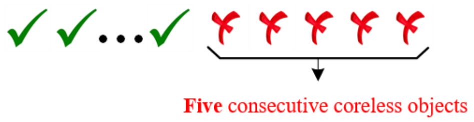
In this case, if an object is picked up by RB1 from the conveyor through Stage 2, the object will still be run to the end of the cycle. At this point, the system is stopped to check the error of the conveyor and the sensor. It is then returned to the ready-to-operate state.

➢ Stage 4: There are 3 cases of missing cores described as follows:

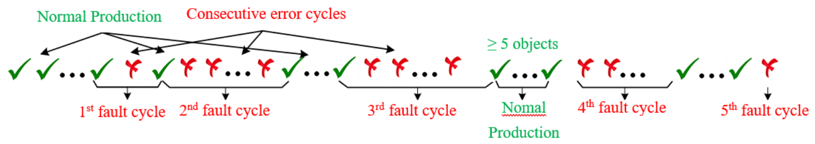


In which: core objects , coreless objects 

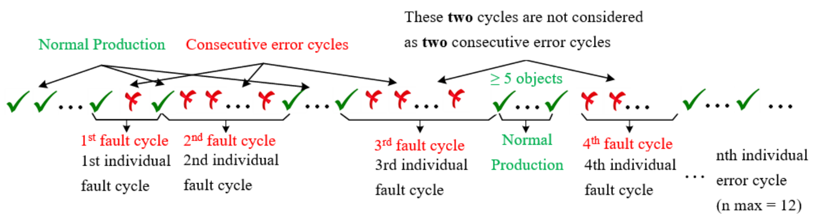
- Case 1: Appears 5 consecutive objects without core in 1 cycle.



- Case 2: Occurrence of 5 consecutive error cycles.



- Case 3: An individual 12th failure cycle occurs in 1 production day/shift.



At this point, when the last coreless object is dropped onto the disk by RB1, the disk rotates and RB2 still operates normally to bring the object to the end of the cycle. At the same time, RB1 and the conveyor must stop without adding objects to the plate. The system stops to supply cores, then returns to a ready-to-operate state for the new cycle.

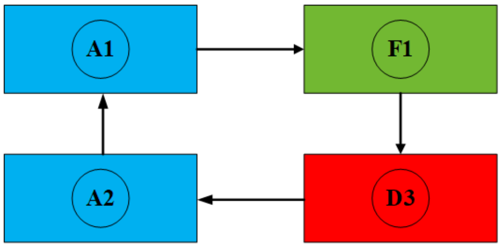


Figure 17 The second safety stop loop

- Loop 3:

  This loop represents the state of the system when a fault occurs, and an emergency stop is required → error reporting → handling restoring to the original stop state → starting a new work cycle. (Figure 18)

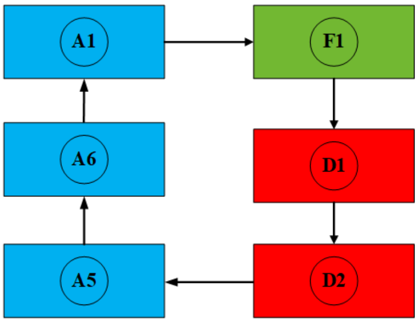


Figure 18 The third safety stop loop

2.4.3 Completing the GEMMA Graph

According to Figure 19, the program blocks are specifically defined as follows:

- Block A1: The block is ready to go.
- Block A2: The system is operating in AUTO NORMAL or AUTO ERROR mode and must be forced to stop when there is a request to stop at the end of the shift/working day or the error exceeds the allowable level. At this point, the product remains complete until the end of the cycle.
- Block A3: The system is operating in AUTO ERROR mode.
- Block A4: The system is operating in AUTO ERROR mode and Stage 4 stops on demand in a defined state (due to lack of cores) other than when stopped at the end of the cycle.
- Block A5: Failure recovery state in preparation to return failed devices to their original state.

- Block A6: After finishing troubleshooting and performing confirmation, the system will automatically restore the ready-to-work state, returning the actuators to the original state.
- Block F1: The system operates in AUTO NORMAL mode.
- Block F4: The system operates in MANUAL mode.
- Block D1: After pressing the Emergency Stop button, the system makes an emergency stop.
- Block D2: Diagnose or treat damage after an emergency stop.
- Block D3: When the system has a small error that is not serious enough, operates in AUTO ERROR mode.

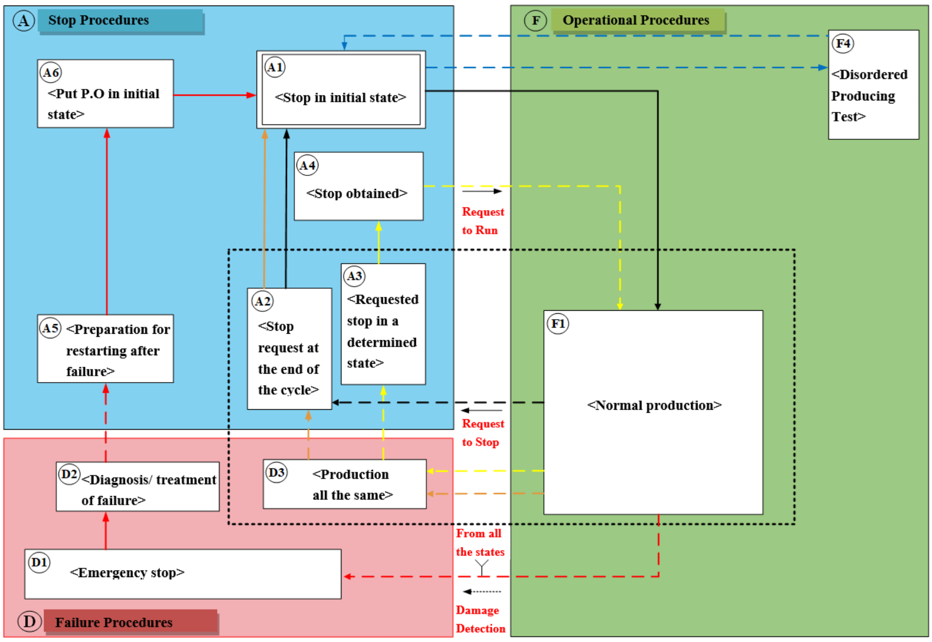


Figure 19 Complete GEMMA graph

Thus, with the above way of building the GEMMA graph, the process of controlling and monitoring the system is made more intuitive.

To see the full code for Block A, F & D, check Appendix 1 which contains code lines for GEMMA.

2.5 Building a GRAFCET Diagram

From the general GEMMA diagram, in the content of this section, it is proposed to build the main GRAFCET diagram showing the most overview of working modes in production. Thereby, it is possible to better visualize the operation in normal production cases or in incidents.

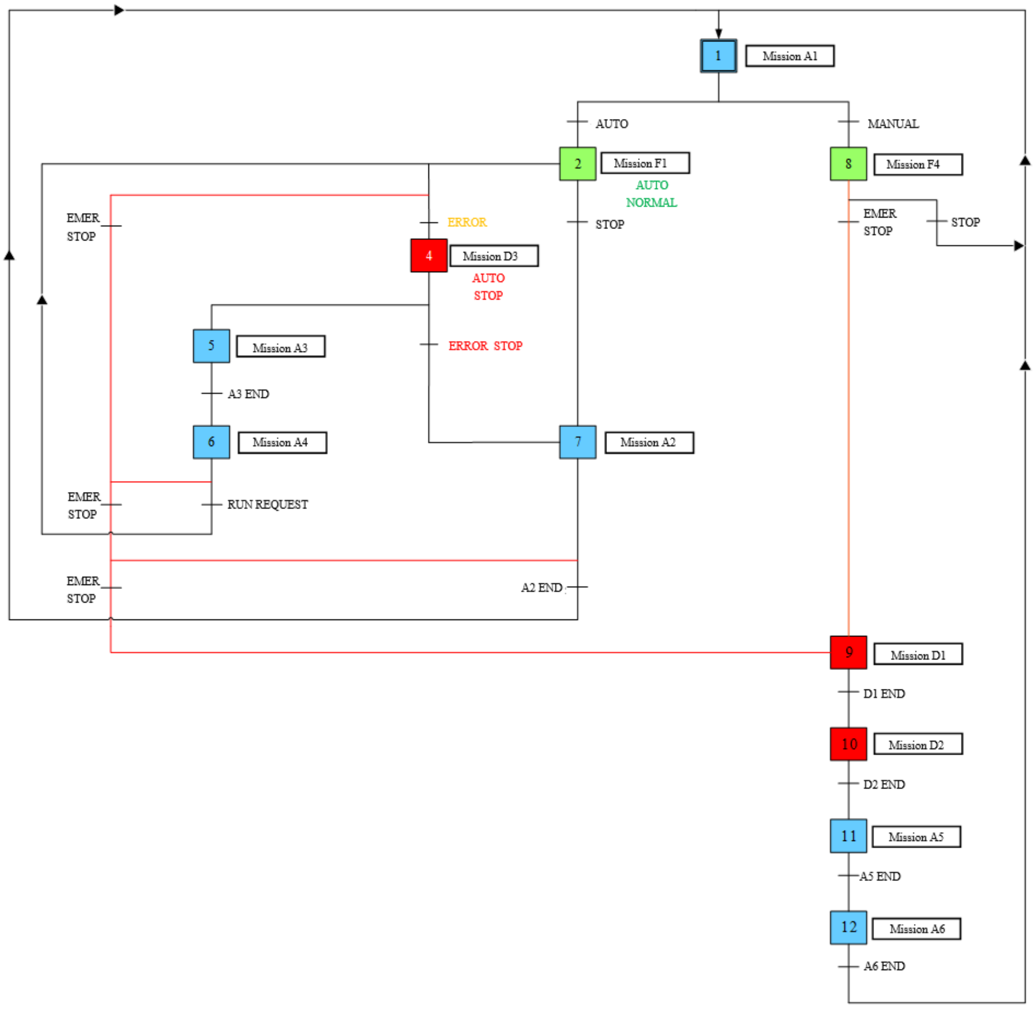


Figure 20 The main GRAFCET diagram of the system

Having completed the construction of the GRAFCET diagram, helps programmers or operators manage and monitor the system intuitively, clearly, and effectively and makes troubleshooting easier, faster, and more flexible.

3 Components

3.1 Sensors

3.1.1 First Object Detection Sensor

Optical sensor BYD3M-TDT2 is located at the top of the conveyor to detect whether the object has entered the conveyor or not [5].

Figure 21 Optical sensor BYD3M-TDT2 [5]

Please refer to the detail specifications in Appendix 3.

3.1.2 Second Object Detection Sensor

The E3X-HD11 Fiber optic sensor amplifier is located at the end of the conveyor. When the sensor detects an object, the conveyor stops. Working on the principle: Automatically detect dirt, vibration, and attenuation of the LED compensates the incident level and light intensity. [6.]

Figure 22 Fiber Optic Sensor Amplifier E3X-HD11 [6]

Combined with M8 standard Fiber optic sensor I/O connector.

Size	Cable	Appearance	Cable type		Models
M8	Standard	Straight	2 m	4-wire	XS3F-M421-402-A
			5 m		XS3F-M421-405-A
		L-shaped	2 m		XS3F-M422-402-A
			5 m		XS3F-M422-405-A

Straight

Figure 23 Optical Fiber sensor I/O connector [6]

Please refer to the detail specifications in Appendix 3.

3.1.3 Proximity Sensor Detects Metal Objects

Proximity sensor OMCH LJ18A3-8-Z/BX is located at the top of the conveyor and used to detect metal objects entering the conveyor.

Figure 24 Proximity sensor OMCH LJ18A3-8-Z/BX

Please refer to the detail specifications in Appendix 3.

3.1.4 Core Detection Proximity Sensor

There are 2 Panasonic E3X-HD11 Fiber optic sensors placed in 2 core drop mechanisms to help detect the structure with cores.

The FX-300 series Fiber optic sensor uses optical light for object monitoring allowing the light threshold to be set for each specific monitoring object. Displays the received light, setting threshold by 7-segment led. FX-300 series when combined with optical Fiber will be very flexible because of the compactness and flexibility of optical Fiber, making it suitable for a wide range of industrial applications. [8.]

Figure 25 Fiber Sensor E3X-HD11

Please refer to the detail specifications in Appendix 3.

3.1.5 Cruise Magnetic Sensor

Magnetic sensor SMC Sensor D-M9BW for pneumatic cylinders. There are 8 sensors from the stroke arranged in robot arms 1 (Stage 2), robot arm 2 (Stage 5), and core drop mechanism (Stage 4).

- In the first robot arm
  + Magnetic sensor must be the horizontal cylinder.
  + Sensor from the left stroke of the horizontal cylinder.
  + Magnetic sensors travel on the vertical cylinder.
  + Magnetic sensor of the stroke under the longitudinal cylinder.
- Core drop mechanism
  + Cylinder end-of-stroke sensor closes plastic button.
  + Cylinder end-of-stroke sensor closes metal button.
- In the second robot arm
  + Sensor from left turn travel.
  + Right rotation magnetic sensor.
  + Magnetic sensor for vertical cylinder travel.
  + Magnetic sensor of travel under the vertical cylinder.

Figure 26 SMC D-M9BW Cruise Magnetic Sensor [9]

Please refer to the detail specifications in Appendix 3.

3.1.6 Proximity Sensor Locates Home

Proximity sensor OMRON E2B – M18KS08-WP-B1 2M OMC is located in the Home position of the turntable, helping to determine the origin of the turntable [10].

Figure 27 Proximity sensor OMRON E2B-M18KS08-WP-B1 2M

Please refer to the detail specifications in Appendix 3.

3.2 Devices and Actuators

3.2.1 Power Supply

It is designed to withstand high noise levels in heavy industry. The Eco-Rail 5-100-240/24 has a high level of reserve power, this allows loads with a significant starting current to be supported and the circuit breaker will operate in the event of a short circuit. Please refer to the detail specifications in Appendix 3.

MCS-B 85303 Power Supply	**MCS-B Art.No.85163 Power Supply**
	
Figure 28 MCS-B 85303 Power Supply [11]	Figure 29 MCS-B Art.No.85163 Power Supply [12]

3.2.2 Engine INDUCTION 3IK15GN-C

The motor is used to drive the conveyor [13].

Figure 30 Engine INDUCTION 3IK15GN-C

Please refer to the detail specifications in Appendix 3.

3.2.3 Encoder KEN50-V360H

Figure 31 Encoder KEN50-V360H

Please refer to the detail specifications in Appendix 3.

3.2.4 Servomotor SGDH-A5AE

The Servomotor is used to control the rotation of the disc according to the programmer's wishes.

- Built-in parameter setting device.
- On-board Fieldbus connection.
- Alarm history storage.
- Proper adjustment function.
- Automatically determine settings when connecting.

Figure 32 Servomotor SGDH-A5AE

Please refer to the detail specifications in Appendix 3.

3.2.5 Pneumatic Cylinder Control Solenoid Valve

The solenoid valve is combined with the solenoid coil used to control pneumatic cylinders. There are 8 solenoid valves controlling 8 pneumatic cylinders arranged in: robot arm 1 (Stage 2), robot arm 2 (Stage 5), and the core drop mechanism (Stage 4).

- In the first robot arm
    + Horizontal cylinder
    + Vertical cylinder
    + Clamp cylinder
- Core drop mechanism
    + Plastic stopper cylinder
    + Metal button closure cylinder
- In the 2nd robot arm
    + Rotary cylinder
    + Vertical cylinder
    + Clamp cylinder

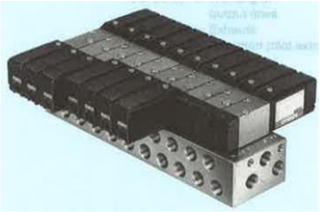


Figure 33 Solenoid valve MYH-5/2-2.3-L-LED

Please refer to the detail specifications in Appendix 3.

3.2.6 Protective Devices

The Protective Devices are mentioned in below. Please refer to the detail specifications in Appendix 3.

MCB Schneider EZ9F34216	**MCB Schneider EZ9F34116**	**MCB Schneider iC65H D 16A**

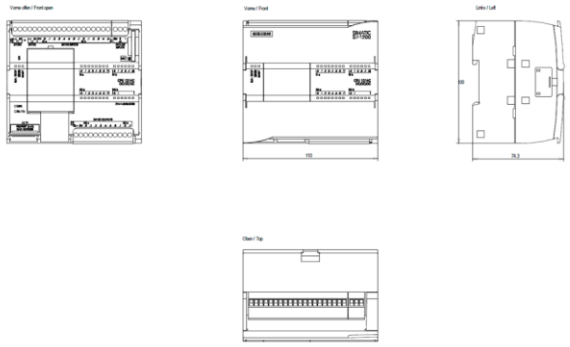
		
Figure 34 MCB Schneider EZ9F34216	Figure 35 MCB Schneider EZ9F34116	Figure 36 MCB Schneider iC65H D 16A

3.3 The Controller Used in the System

3.3.1 CPU 6ES7214-1GA40-0XB0

a. Disposition

The layout of the sides of the module CPU 6ES7214-1GA40-0XB0 is shown in Figures 37 and Figures 38 as follows:

PLC CPU 6ES7214-1GA40-0XB0	Layout of the sides of the PLC CPU 6ES7214-1GA40-0XB0
	
Figure 37 PLC CPU 6ES7214-1GA40-0XB0 [15]	Figure 38 Layout of the sides of the PLC CPU 6ES7214-1GA40-0XB0

b. Technical Features

- High processing speed;
- Capable of expanding I/O modules, special function modules;
- Built-in real-time clock;
- Integrated serial communication interface between PCS and HMI;
- Use programming languages: LAD, FBD, SCL;
- Support communication protocols: Modbus, Profibus, Profinet, OPC UA...

Please refer to the detail specifications in Appendix 3.

3.3.2 Module 6ES7223-1BH32-0XB0

a. Disposition

The layout of the sides of the module 6ES7223-1BH32-0XB0 is shown in Figures 39 and Figures 40 as follows:

Figure 39 Module 6ES7223-1BH32-0XB0 [14]

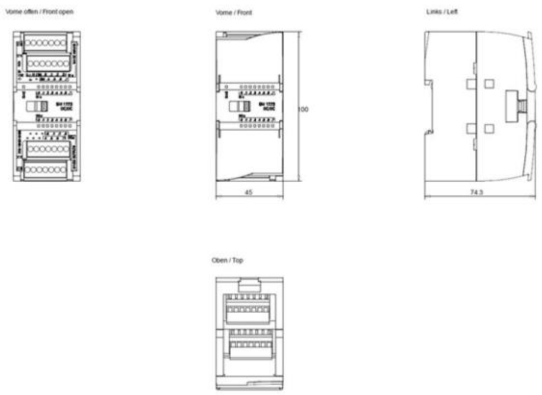


Figure 40 Layout of the sides of Modules 6ES7223-1BH32-0XB0 [14]

b. Technical Features

Technical features of module 6ES7223-1BH32-0XB0 is demonstrated in Appendix 3 below.

3.4 Statistics of PLC's I/O

Please refer to Appendix 3 below, which shows details of PLC inputs and PLC outputs.

4 Building Program for Control and Supervision of the Entire System

4.1 Algorithm Construction

4.1.1 General Algorithm Flowchart of the System

The general control algorithm of the whole system is shown in Figure 41.

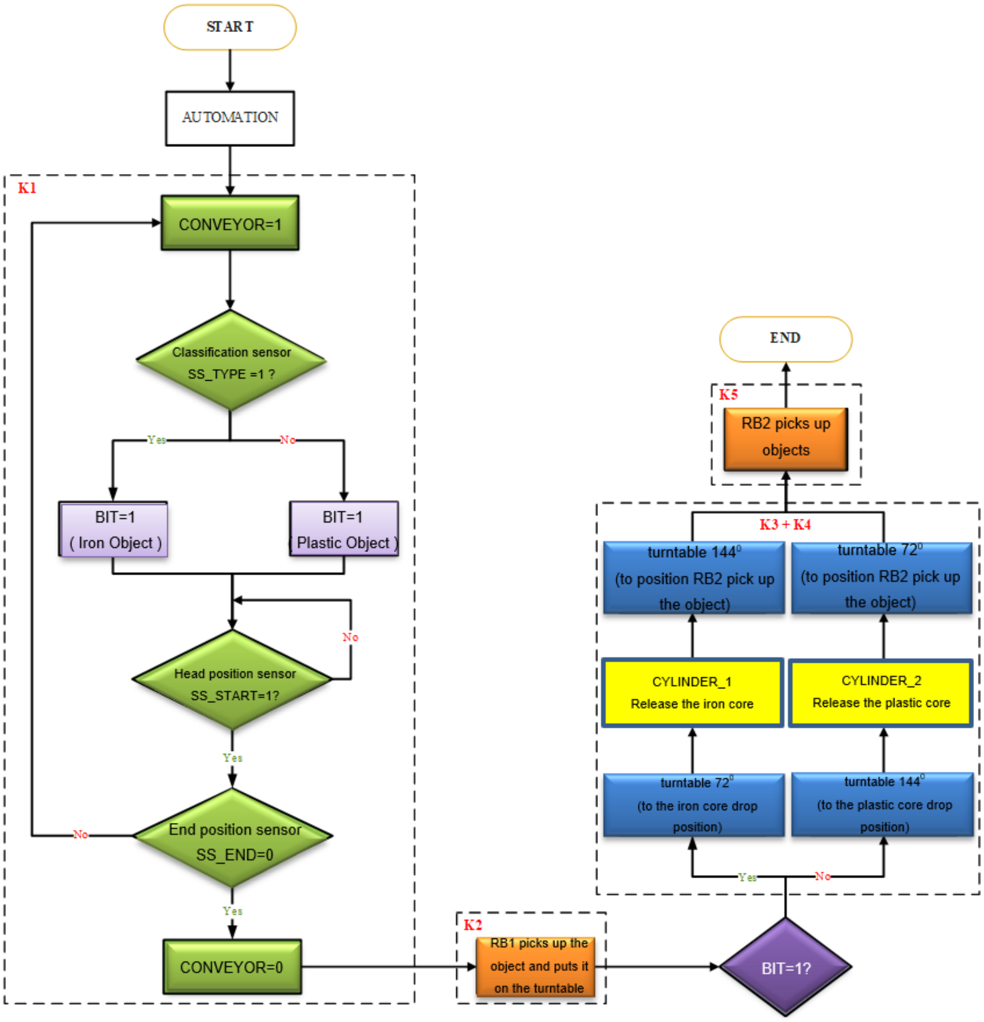


Figure 41 Flowchart of general control algorithm of the system

4.1.2 Stage 1

Algorithm to control the process of putting materials into the system in Stage 1 is presented as Figure 42.

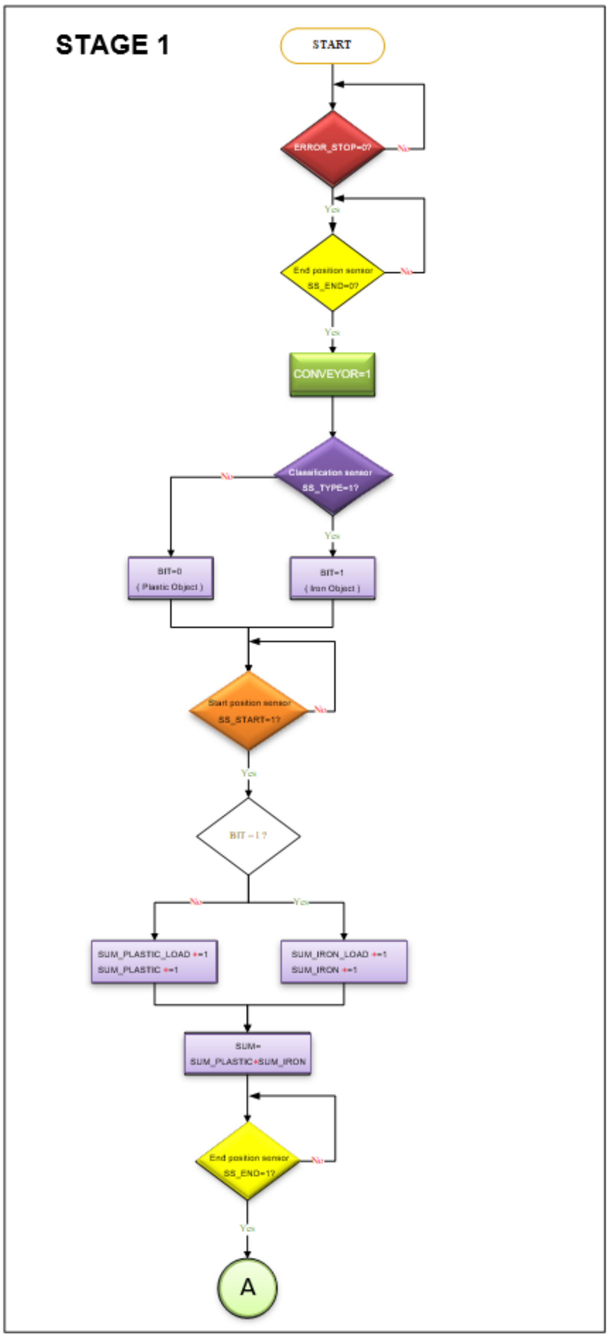


Figure 42 Algorithm flowchart Stage 1

4.1.3 Stage 2

Algorithm to control the process of picking the raw material from the conveyor to the rotating disc in Stage 2 is shown in the Figure 43.

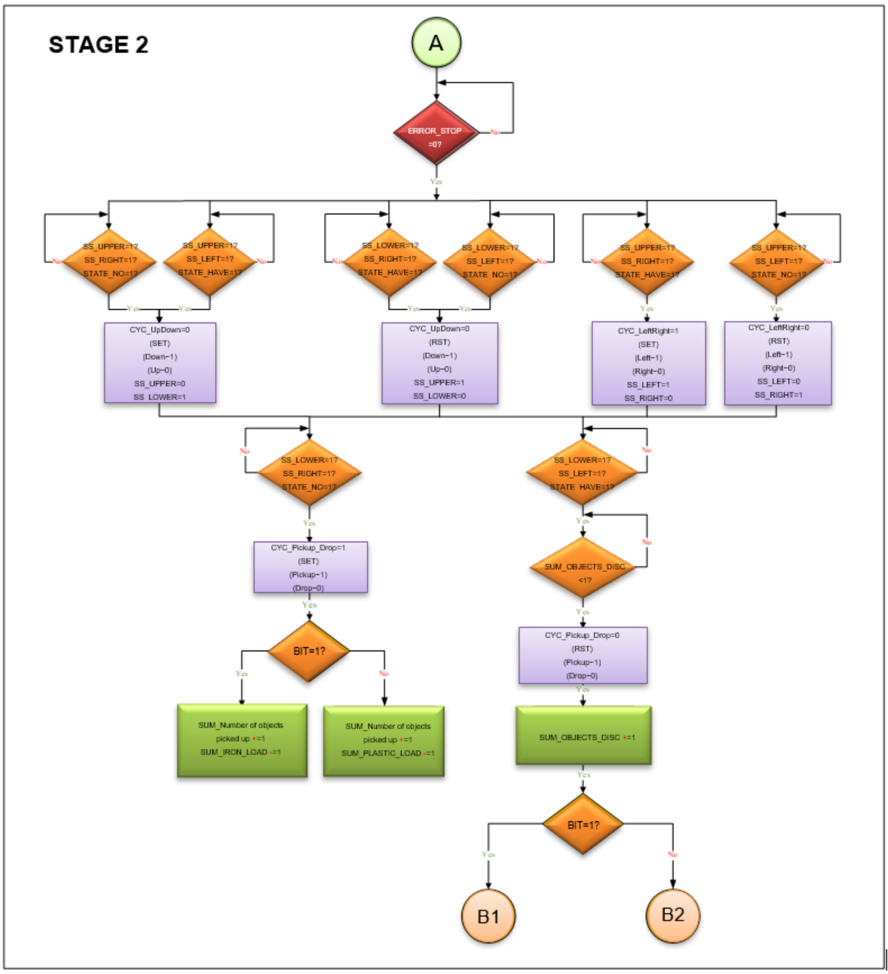


Figure 43 Algorithm flowchart Stage 2

4.1.4 Stage 3

The algorithm that controls the rotation of the disc to bring the raw material to the correct position of dropping the core in Stage 3 is shown in the Figure 44.

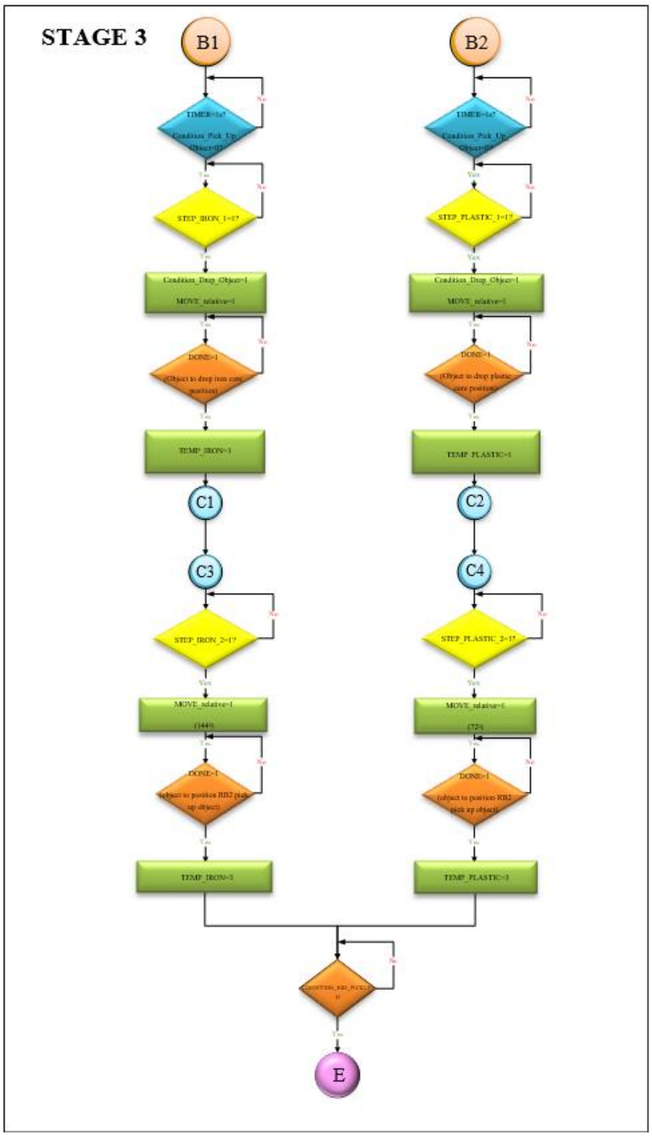


Figure 44 Algorithm flowchart Stage 3

4.1.5 Stage 4

Algorithm to control the process of dropping the core into the rough in Stage 4 is shown in the Figure 45.

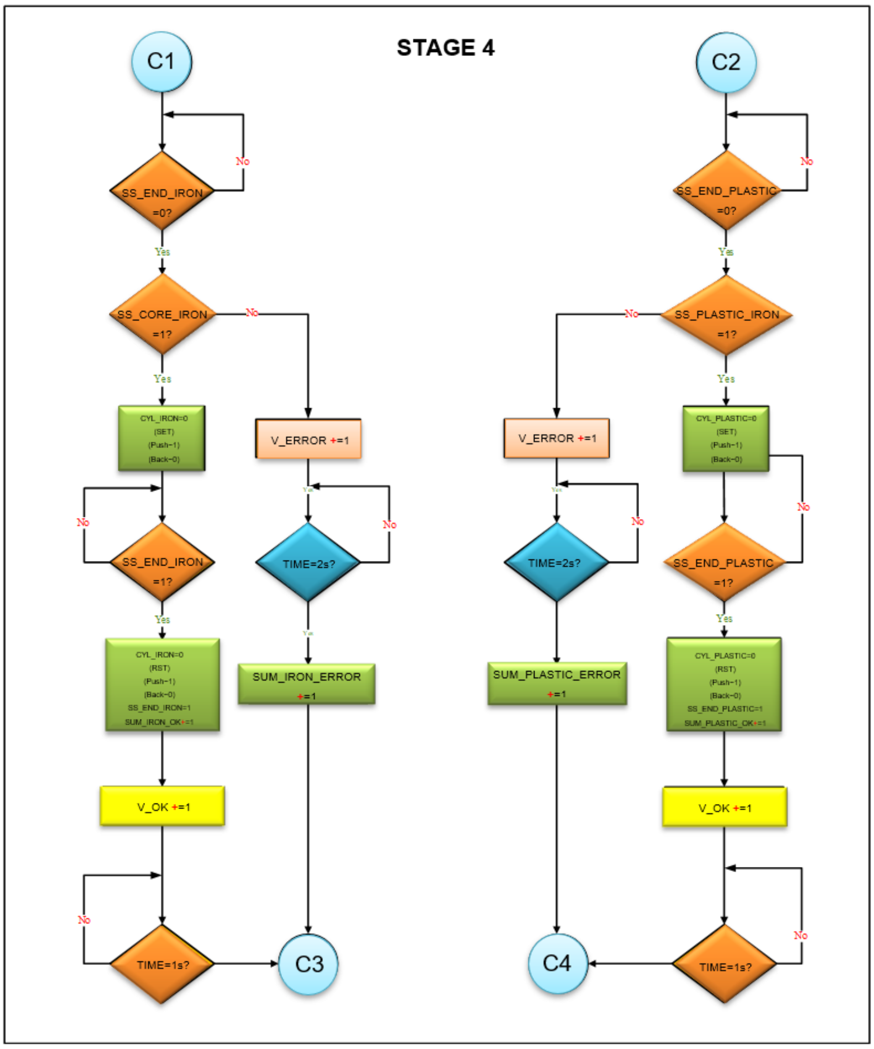


Figure 45 Algorithm flowchart Stage 4

4.1.6 Stage 5

The algorithm to control the process of picking up the finished object to another cycle in Stage 5 is shown in the Figure 46.

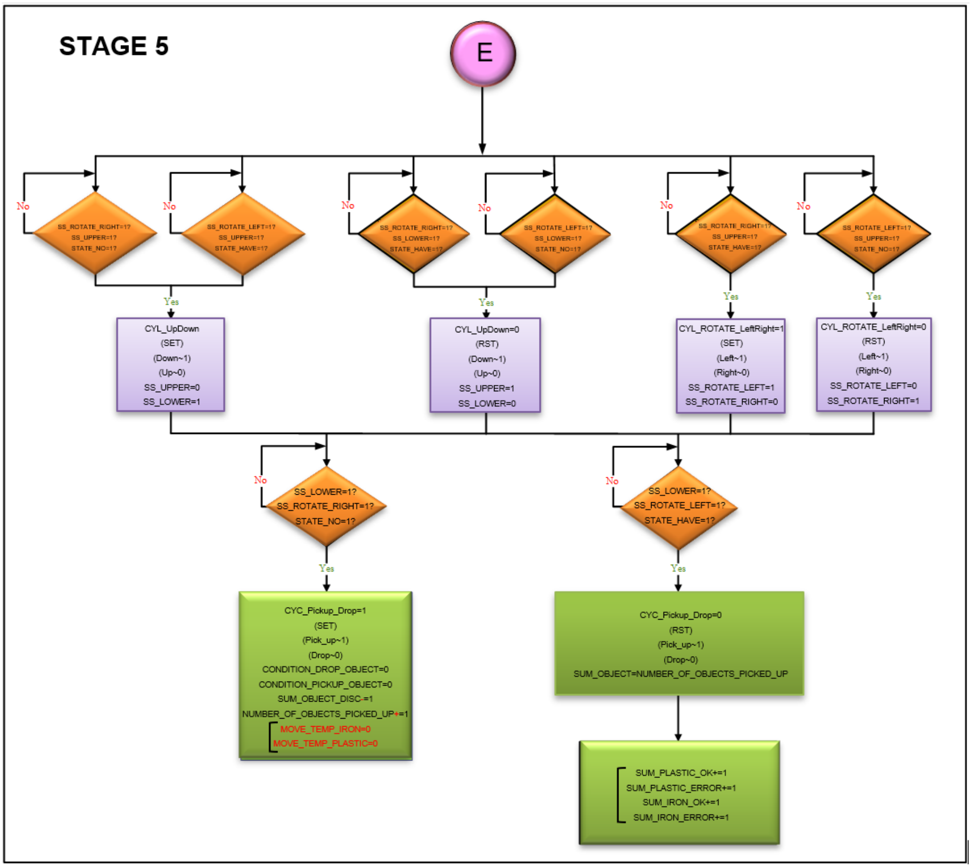


Figure 46 Algorithm flowchart Stage 5

4.1.7 In Case of Failure, the System must be Stopped at the End of the Cycle

a. Conveyor Problem at Stage 1

When there is a signal for the conveyor to run, but because the motor is in reciprocating motion, it is stuck (Encoder returns a value of 0) which greatly affects the following stages. (Figure 47)

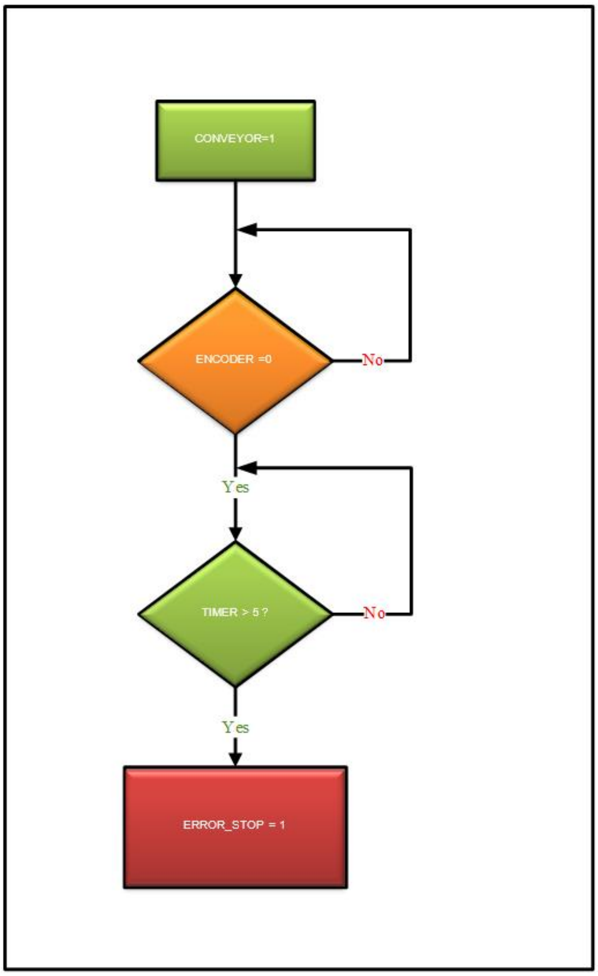


Figure 47 Algorithm flowchart describing conveyor failure in Stage 1

b. Classifier Sensor Failure Problem at Stage 1

The classification sensor receives a signal of 1 continuously (more than 10 seconds) or a signal of zero continuously (>=15 plastic objects). Force stops the system to check the sensor. (Figure 48)

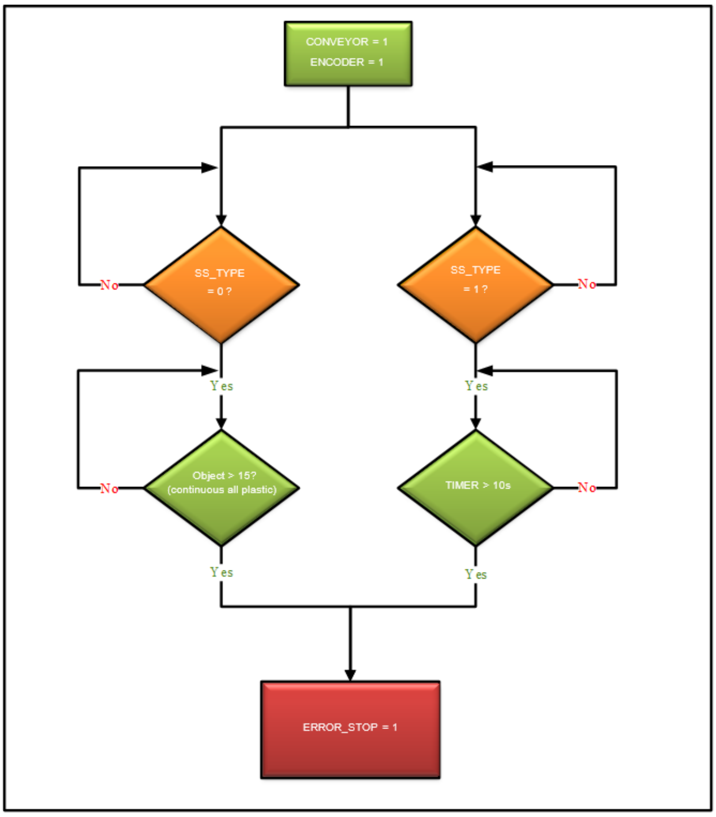


Figure 48 Algorithm flowchart describing classifier sensor error in Stage 1

c. Head Sensor Error at Stage 1

When the object moves on the conveyor, but the head sensor (SS_START) does not have a signal of 1. The data in Stage 1 cannot be counted up → data error. (Figure 49)

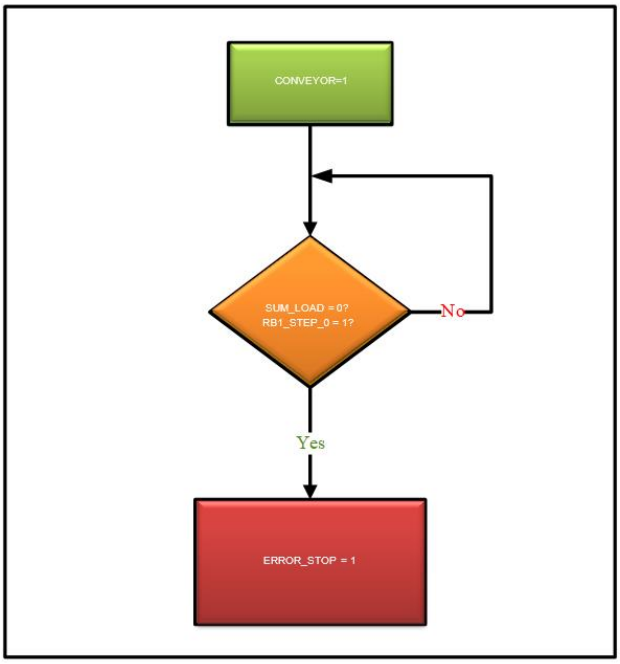


Figure 49 Algorithm flowchart describing head sensor error in Stage 1

d. End Sensor Failure Problem at Stage 1

When the object has reached the last sensor position, but there is still no return signal from the sensor, Robot 1 does not receive the signal to pick up the object. This causes the object to accumulate on the conveyor belt. (Figure 50)

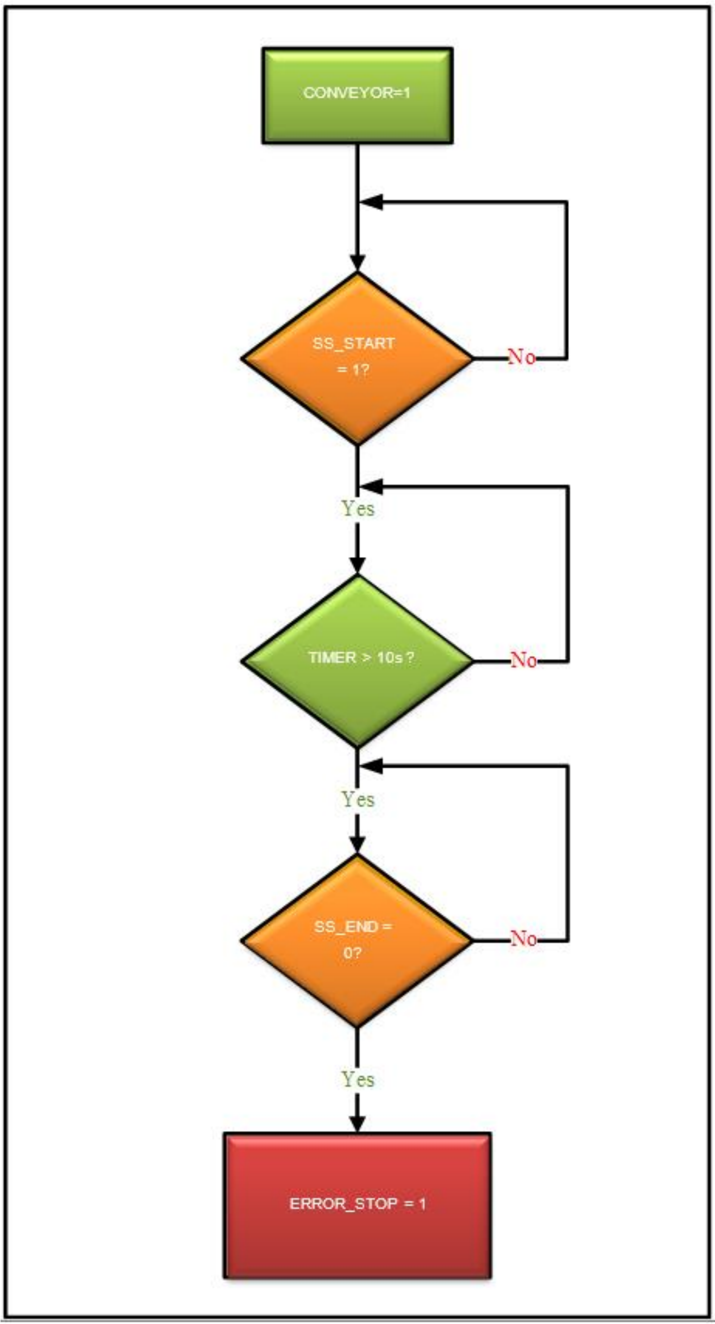


Figure 50 Algorithm flowchart describing the end sensor failure in Stage 1

e. Spill Incident at Stage 1

Due to the limited length of the conveyor belt, the loading of items on the conveyor must also be regulated. Conveyor can only have a maximum of 4 objects. (Figure 51)

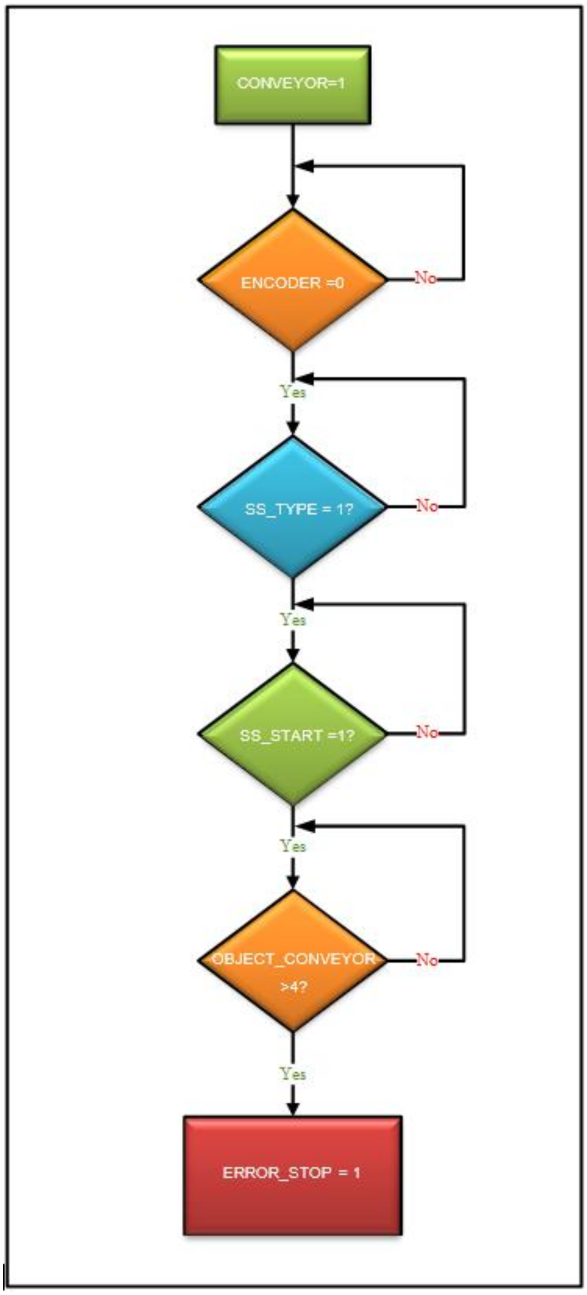


Figure 51 Flowchart of algorithm describing the overflow error in Stage 1

f. Core Shortage Problem at Stage 4

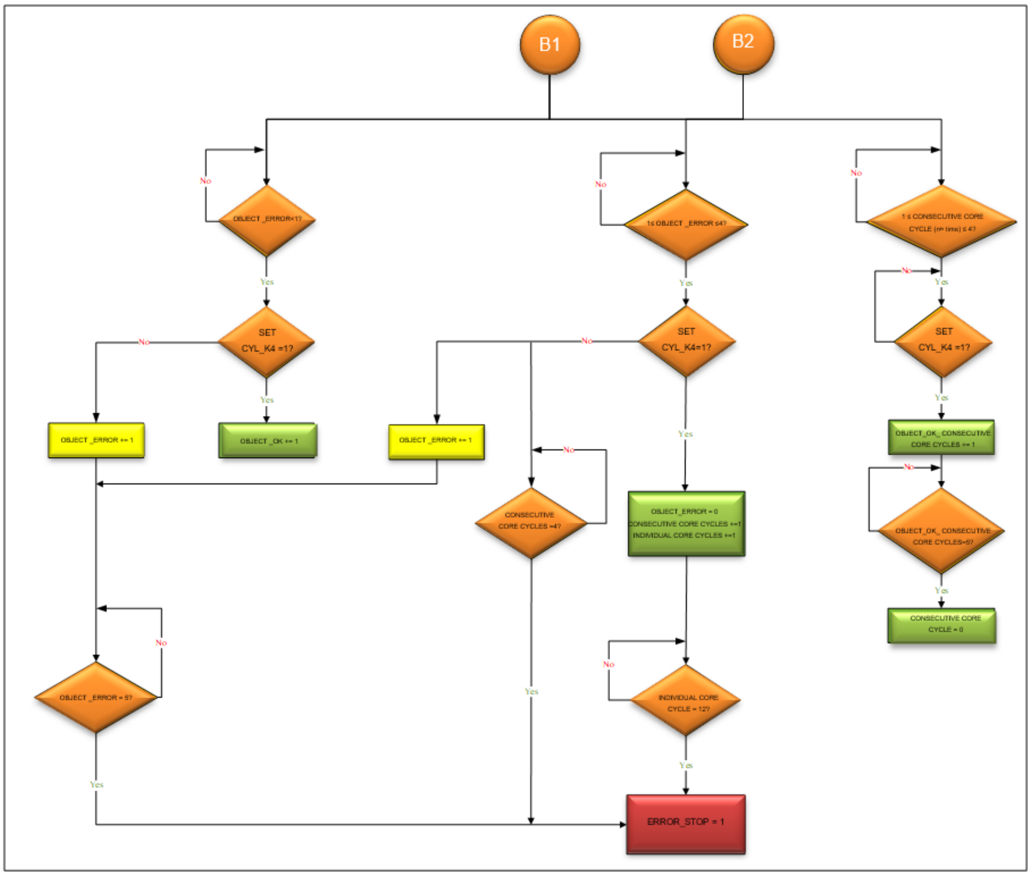


Figure 52 Algorithm flowchart depicting the missing core error in Stage 4

4.2 PLC Controller

PLC stands for Programmable Logic Controller. It is a programmable (programmable) control device that allows flexible implementation of logic control algorithms through a programming language. It is user programmable to perform a series of events. These events are triggered by a stimulus (input) acting on the PLC or through delay operations such as timing or counting events. Once the event is actually triggered, it turns ON or OFF an external control device called a physical device. A programmable controller will continuously "loop" in a "user-defined" program, waiting for the input signal and outputting the output signal at the programmed times.

To overcome the disadvantages of wired controllers (relay controllers), a PLC has been built to satisfy the following requirements:

- Easy programming, easy-to-learn programming language.
- Compact size, easy installation, maintenance, and repair.
- Large memory capacity to accommodate complex programs.
- Has good anti-interference ability, so it is completely reliable in an industrial environment.

- Ability to connect to the network and connect to peripherals very high for easy control.
- Competitive individual pricing.

In a PLC, the CPU hardware and the program are the basic units for the control or processing of the system. The function that the controller needs to perform will be defined by a program. This program is pre-loaded into the memory of the PLC, the PLC will perform the control based on this program. Thus, if we want to change or expand the functionality of the technological process, we only need to change the program inside the memory of the PLC. Changing or expanding functionality will be done easily without any physical intervention compared to wiring or relay sets.

4.2.1 Structure of PLC

All PLCs have the following main components:

- An internal RAM program memory (can be expanded with some external memory EPROM).
- A microprocessor with a communication port for pairing with a PLC.
- I/O modules.

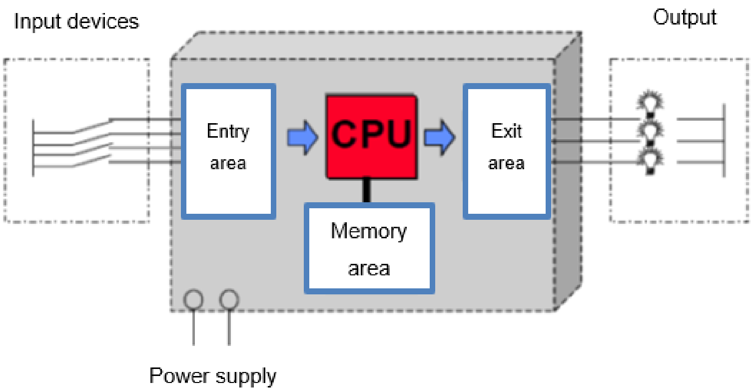


Figure 53 The block diagram of the control system

The central control unit (CPU) consists of three parts: the processor, the memory system, and the power supply system.

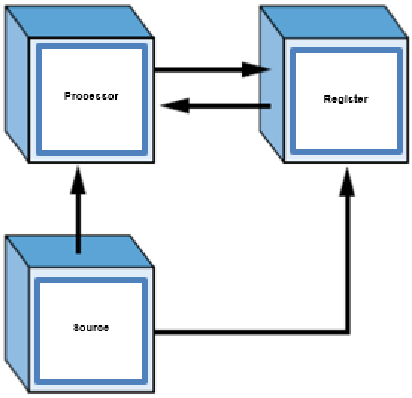


Figure 54 General block diagram of CPU

- ❖ Central Processing Unit

  The CPU controls the operations inside the PLC. The processor will read and check the program stored in memory, then execute the order of each instruction in the program and will close or interrupt the outputs. These output states are broadcast to the associated devices for execution. And all those executions depend on the control program kept in memory.

- ❖ Bus System

  A Bus System is a route used to transmit signals; the system consists of many parallel signal lines:

  - Address Bus: The address bus is used to transmit addresses to different modules.
  - Data Bus: Bus used to transmit data.
  - Control Bus: The control bus is used to transmit timing signals and synchronously control operations in the PLC.

  In a PLC, data is exchanged between the microprocessor and the I/O modules through the Data Bus. The Address Bus and Data Bus consist of 8 lines, which at the same time allow the transmission of 8 bits of a byte simultaneously or in parallel.

  A System Bus will be responsible for exchanging information between the CPU, memory, and I/O. Besides, the CPU is provided with a Clock with a frequency of $1 \div 8$ MHZ. This pulse determines the operating speed of the PLC and provides elements of the system's timing and clock.

- ❖ Memory

  PLCs usually require memory in the following cases:

  - As a timer for I/O status channels.

- As buffer state functions in PLC such as timing, counting, recording relays. Each instruction of the program has its own location in memory, all locations in memory are numbered, these numbers are the addresses in memory.

The address of each memory cell will be pointed to by an address counter inside the microprocessor. The processor will value this counter to one before processing the next instruction. Given a new address, the contents of the corresponding memory cell appear in the output, a process called reading.

The memory inside the PLC is created by semiconductor microchips, each of which is capable of holding 2000 ÷ 16000 instruction lines, depending on the type of chip. In PLC memory such as RAM, EPROM are used.

RAM (Random Access Memory) can load programs, change or delete content at any time. The contents of RAM will be lost if the power supply is lost. To avoid this situation, PLCs are all equipped with a dry battery, capable of providing power reserve for RAM from several months to several years. In practice RAM is used to initialize and test programs. The current trend is to use CMOSRAM due to its low consumption and long life.

EPROM (Electrically Programmable Read Only Memory) is memory that the normal user can only read, but not write to. The content of the EPROM is not lost when the power is turned off, it is built into the machine. It has been loaded by the manufacturer and contains the pre-installed operating system. If the user does not want to expand the memory, just use the EPROM built into the PLC. On the PG (Programmer) there is a place to write and erase the EPROM.

The third data recording medium is a hard disk or a floppy disk, used in programming machines. Hard disk or floppy disk has a large capacity, so it is often used to store large programs for a long time.

Memory size:

- Small PLCs can contain from 300 to 1000 instructions depending on the manufacturing technology.
- Larger PLCs range in size from 1K to 16K and can hold from 2000 to 16000 instruction lines.
- In addition, it also allows to add additional memory expansion such as RAM, EPROM.

❖ I/O Inputs/Outputs

The signal lines from the sensor are connected to the input modules (PLC inputs), the actuators are connected to the output modules (PLC outputs).

Most PLCs have an internal operating voltage of 5V, the processing signal is 12/24VDC or 100/240VAC.

Each I/O unit has a unique address, status displays of I/O channels are provided by LEDs on the PLC, which makes it easy to check I/O operation and simple.

The processor reads and determines the input states (ON, OFF) to make or break the output circuit.

4.2.2 Processing Operations Inside the PLC

❖ Program Handling

Once a program has been loaded into the PLC's memory, the instructions are stored in an individual address space in the memory.

The PLC has an address counter inside the microprocessor, so the program inside the memory will be executed by the microprocessor sequentially, one by one, from the beginning to the end of the program. Each execution of the program from start to finish is called an execution cycle. The execution time of a cycle depends on the processing speed of the PLC and the size of the program. An execution cycle consists of three successive phases:

- Read the State of All Inputs: The PLC performs the saving of the physical states of the inputs. The part of the program that does this job is available in the PLC and is called the operating system.
- Program Execution: the processor will read and process one instruction sequentially in the program. In writing, reading and processing instructions, the microprocessor reads the input signals, performs logical operations, and the results then determine the state of the outputs.
- Handling Communication Requests: During the time the CPU processes the information in the scan cycle. The PLC processes all information received from the communication port or extension modules.
- Perform Self-Test: in 1 scan cycle, PLC checks CPU operation and expansion module status.
- Output: the microprocessor assigns new states to the outputs of the output modules.

❖ Import/ Export Handling

There are two different methods for handling I/O in PLCs:

- Continuous Updates

  In this method, the CPU takes some time to read the status of the inputs to be processed. The above time, usually 3ms, is to avoid the impact of noisy pulses by the input contact. Outputs are clicked directly (if any) following a logic check. The state of the outputs is latched in the output block so their state is maintained until the next update.

- Save Image of Import and Export Process

  Most large PLCs can have several hundred I/Os, so the CPU can only process one instruction at a time. During execution, the state of each input must be considered individually in order to detect its effects in the program.

  When the program is executed, the state of the inputs stored in RAM is read out. The tasks are performed according to the above states, and the state results of the outputs are stored in the output RAM. Then at the end of the scan cycle, the I/O status update transfers all output signals from the RAM into the corresponding output block, activating the outputs on the I/O block. Output blocks are latched so they remain in state until they are updated in the next scan cycle.

  The above I/O status update task is automatically performed by the CPU by a pre-programmed subroutine segment by the manufacturer. Thus, the subroutine will be executed automatically at the end of the current scan cycle and at the beginning of the next cycle. Therefore, the state of the I/Os is updated.

  Note that, since the status update subroutine is executed at a specified time of the scan cycle, the state of the inputs and outputs does not change during the current scan cycle. If an input has a state that changes after the execution of a system subroutine, that state will not be recognized until the next update occurs.

  The time to update all I/O depends on the total amount of I/O used, usually a few ms. Program execution time (scan cycle) depends on the size of the control program.

4.2.3 Software TIA Portal V17

TIA Portal stands for Totally Integrated Automation Portal, which is an integrated software of many automations and electrical operations management software of the system. In this project, the team decided to use the latest version of V17 from Siemens.

TIA Portal was developed in 1966 by Siemens engineers, it allows users to develop and write individual management software quickly, on a unified platform. The solution to reduce the time to integrate separate applications to create a unified system.

TIA Portal creates an easy environment to programmatically perform:

- Easy to manage information pull and release design, with a variety of languages.
- Perform go online and Diagnostic for all devices in the project to identify diseases and system errors.
- Integrated system simulation.
- Easy configuration and linkage between Siemens devices.

4.3 LAD Programming Language

Ladder logic or Ladder Diagram (LD/LAD) is one of five PLC programming languages specified for use according to the IEC 61131-3 standard. It is a graphical PLC programming language that represents logical operations with symbolic notation, generated from logic ladders. The LAD program allows the CPU to simulate the flow of current from the source, through a variety of input conditions, to affect the output.

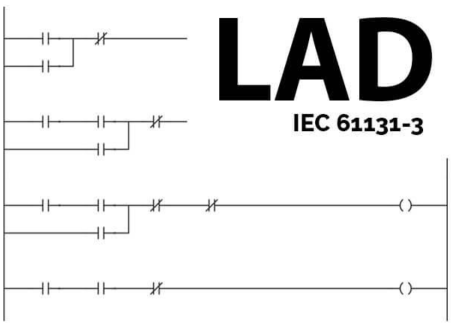


Figure 55 Programming language LD/LAD

The various commands are represented by graphical symbols, including the basic types:

- Contacts: Represent input/output logic conditions, such as switches, buttons, sensor states, etc.
- Coil: Represents output logic results, such as lights, motors, relay coils, etc.
- Box: Icons for various functions, such as timer, counter and math function, etc.

4.4 Building a SCADA Solution for the System

4.4.1 Overview Introduction

SIMATIC WinCC Unified V17 is the configuration software for HMI placed directly on the machine to complex SCADA solutions. It provides a consistent, efficient and intuitive solution for all automation tasks.
WinCC Unified PC Engineering is used to configure WinCC Unified PC and Unified Comfort Panels. It can also be used for Basic Panels, Comfort Panels, Mobile Panels and WinCC Runtime Advanced.

4.4.2 Outstanding Features

The following are the salient features of building a SCADA solution for the system:

- Panel-to-center Scalability: A common software platform for all devices.
- Modern User Interface based on Web Technology: Flexible access with any modern web browser.
- Advanced Javascript-Based Scripting: A powerful and platformindependent scripting language.
- Automate Programming Tasks with TIA Portal Openess: Automatically create, validate, and reuse WinCC Unified components.
- Technological Hierarchy for Object-Oriented Programming: Define plant assets once and reuse by calling.
- Calendar and Performance Insight Options: Manage work time and validate production insights based on individual KPI calculations.
- Easily Coordinate with WinCC Unified Systems: Set up a distributed configuration. Predetermined access as well as unscheduled access.

- Using WinCC Unified as an Integration Platform: Integrate IT tools into one user interface and exchange data across interfaces.

4.4.3 Connection Method

Connection method by PLC programming is shown as below Figures 56 & 57:

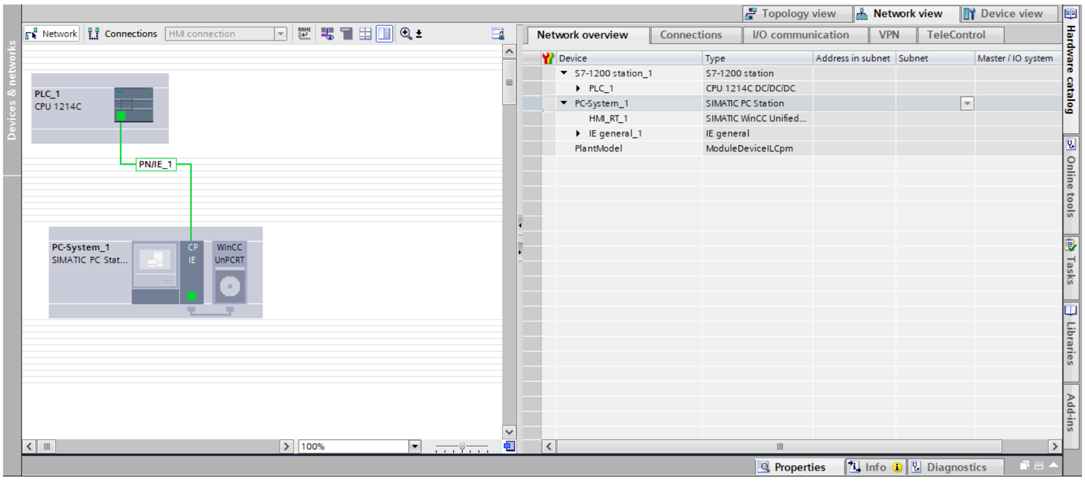


Figure 56 Connect PLC_1 (CPU 1214C) to PC-System_1 (SIMATIC PC Station)

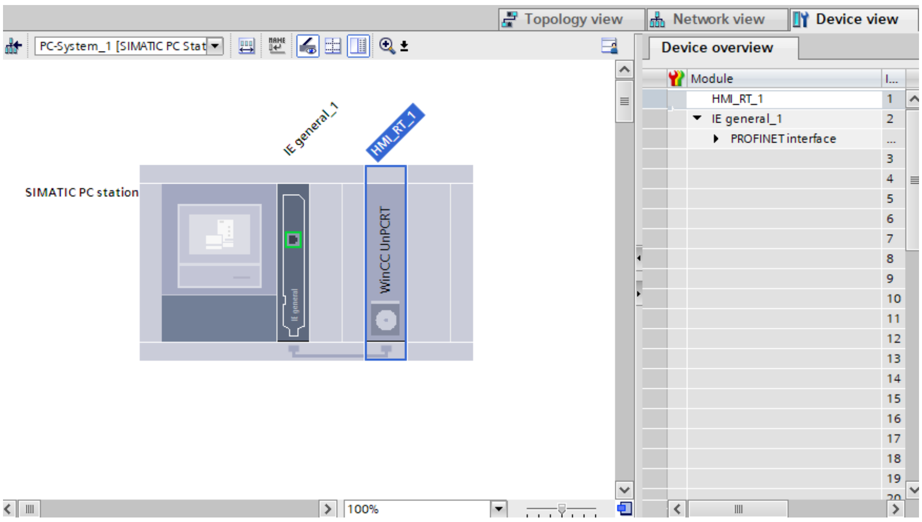


Figure 57 Connection method in TIA Portal V17

4.4.4 Screen Interfaces

a. Home Screen

The main screen interface makes it possible for the operator to choose the working mode: automatic operation or manual control. In addition, it is possible to point to the GEMMA graph to monitor the running and stopping modes of the system. (Figure 58)

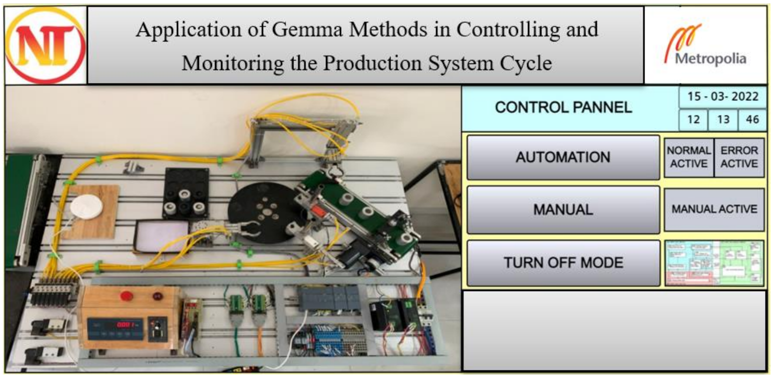


Figure 58 Main Screen Interface

b. MANUAL Mode

This interface helps the operator to test run each stage in the production line, including sensors, actuators, etc., before the system goes into production. (Figure 59)

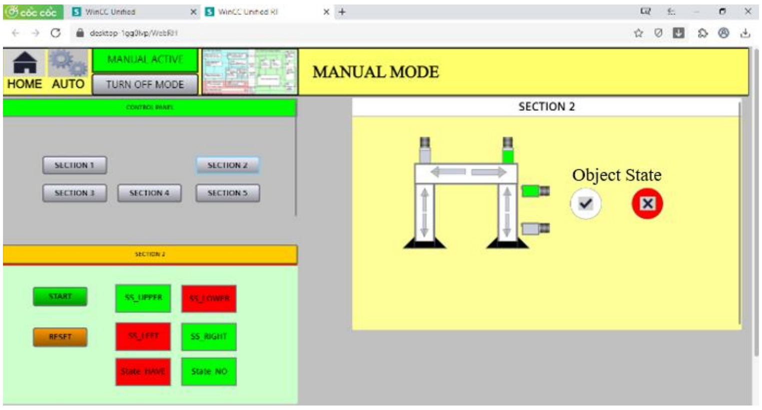


Figure 59 MANUAL screen interface

c. AUTOMATION Mode

This interface helps the operator to overview the entire working cycle of the system as well as the status of each equipment in automatic production mode. (Figure 60)

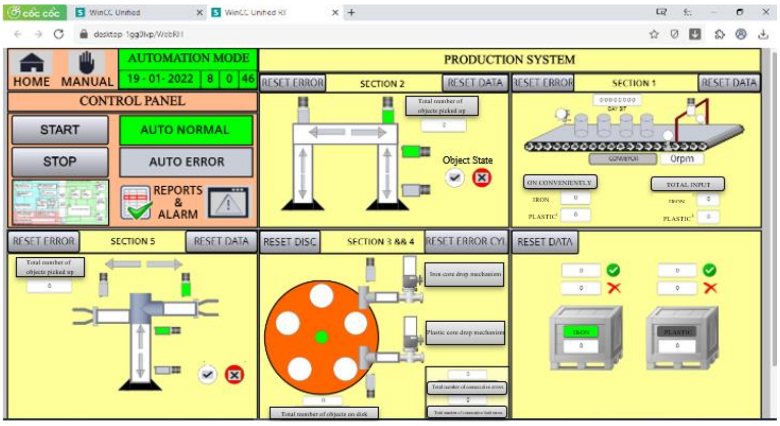
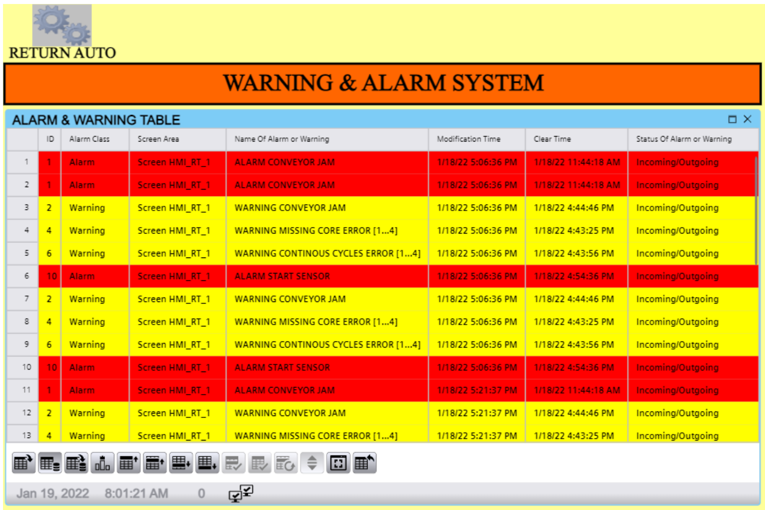


Figure 60 AUTO NORMAL screen interface

d. Malfunction Warning Screen

The image of the fault warning screen is shown in Figure 61. This interface allows alerting of equipment failures during production. Error statuses are updated accurately and in a timely manner so that managers can provide quick and effective remedial measures. It also shows the frequency of occurrence of each type of error in the error history. Thereby taking measures to repair and maintain the system periodically. (Figure 61)



	ID	Alarm Class	Screen Area	Name Of Alarm or Warning	Modification Time	Clear Time	Status Of Alarm or Warning
1	1	Alarm	Screen HMI_RT_1	ALARM CONVEYOR JAM	1/18/22 5:06:36 PM	1/18/22 11:44:18 AM	Incoming/Outgoing
2	1	Alarm	Screen HMI_RT_1	ALARM CONVEYOR JAM	1/18/22 5:06:36 PM	1/18/22 11:44:18 AM	Incoming/Outgoing
3	2	Warning	Screen HMI_RT_1	WARNING CONVEYOR JAM	1/18/22 5:06:36 PM	1/18/22 4:44:46 PM	Incoming/Outgoing
4	4	Warning	Screen HMI_RT_1	WARNING MISSING CORE ERROR [1...4]	1/18/22 5:06:36 PM	1/18/22 4:43:25 PM	Incoming/Outgoing
5	6	Warning	Screen HMI_RT_1	WARNING CONTINOUS CYCLES ERROR [1...4]	1/18/22 5:06:36 PM	1/18/22 4:43:56 PM	Incoming/Outgoing
6	10	Alarm	Screen HMI_RT_1	ALARM START SENSOR	1/18/22 5:06:36 PM	1/18/22 4:54:36 PM	Incoming/Outgoing
7	2	Warning	Screen HMI_RT_1	WARNING CONVEYOR JAM	1/18/22 5:06:36 PM	1/18/22 4:44:46 PM	Incoming/Outgoing
8	4	Warning	Screen HMI_RT_1	WARNING MISSING CORE ERROR [1...4]	1/18/22 5:06:36 PM	1/18/22 4:43:25 PM	Incoming/Outgoing
9	6	Warning	Screen HMI_RT_1	WARNING CONTINOUS CYCLES ERROR [1...4]	1/18/22 5:06:36 PM	1/18/22 4:43:56 PM	Incoming/Outgoing
10	10	Alarm	Screen HMI_RT_1	ALARM START SENSOR	1/18/22 5:06:36 PM	1/18/22 4:54:36 PM	Incoming/Outgoing
11	1	Alarm	Screen HMI_RT_1	ALARM CONVEYOR JAM	1/18/22 5:21:37 PM	1/18/22 11:44:18 AM	Incoming/Outgoing
12	2	Warning	Screen HMI_RT_1	WARNING CONVEYOR JAM	1/18/22 5:21:37 PM	1/18/22 4:44:46 PM	Incoming/Outgoing
13	4	Warning	Screen HMI_RT_1	WARNING MISSING CORE ERROR [1...4]	1/18/22 5:21:37 PM	1/18/22 4:43:25 PM	Incoming/Outgoing

Figure 61 Malfunction warning screen

e. The Cycle Management Screen of the GEMMA Diagram

The cycle management screen of the GEMMA diagram is shown in Figure 60. This diagram makes it possible for the operator to clearly define the running and stopping modes, and the relationship between them. It helps to find and fix program errors as well as solve problems quickly and efficiently. (Figure 62)

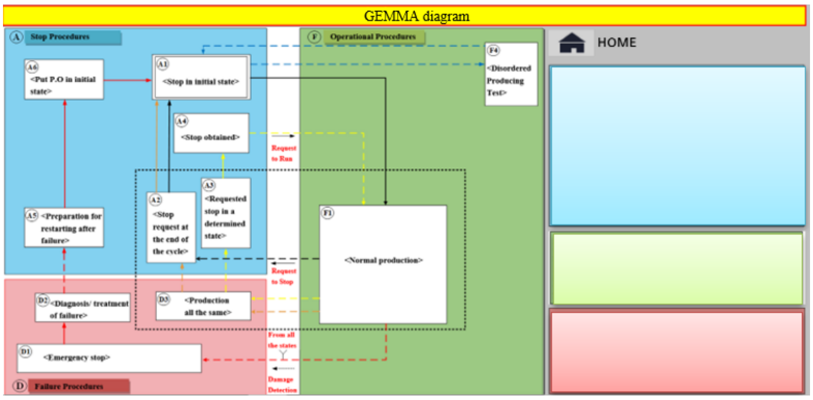


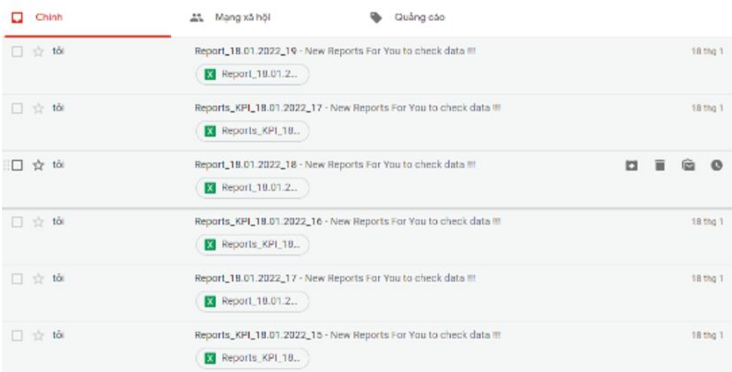
Figure 62 GEMMA diagram

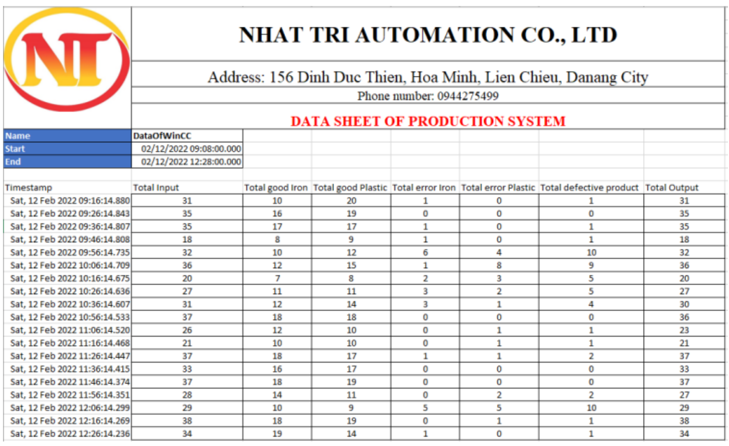
f. Statistical Report Table

Statistical reports by day or shift are always updated according to a preset schedule (Figure 63). The data shows input raw products and output products by type, the results are evaluated based on KPIs sent via e-mail in the form of excel files (Figure 64). From there, they are visually represented by graphs reflecting the production efficiency of each shift/working day.

Name	Job name	Creation time	Files
Report_18.01.2022_19	Reports_Time	1/18/2022, 5:54:27 PM	Size - 57 KB
Reports_KPI_18.01.2022_17	Reports_KPI	1/18/2022, 4:47:07 PM	Size - 77 KB
Report_18.01.2022_18	Reports_Time	1/18/2022, 4:47:01 PM	Size - 63 KB
Reports_KPI_18.01.2022_16	Reports_KPI	1/18/2022, 4:37:07 PM	Size - 77 KB
Report_18.01.2022_17	Reports_Time	1/18/2022, 4:37:01 PM	Size - 63 KB
Reports_KPI_18.01.2022_15	Reports_KPI	1/18/2022, 4:27:07 PM	Size - 77 KB
Report_18.01.2022_16	Reports_Time	1/18/2022, 4:27:01 PM	Size - 63 KB
Reports_KPI_18.01.2022_14	Reports_KPI	1/18/2022, 4:17:07 PM	Size - 76 KB
Report_18.01.2022_15	Reports_Time	1/18/2022, 4:17:01 PM	Size - 63 KB
Reports_KPI_18.01.2022_13	Reports_KPI	1/18/2022, 4:07:08 PM	Size - 76 KB
Report_18.01.2022_14	Reports_Time	1/18/2022, 4:07:01 PM	Size - 63 KB

Figure 63 Statistical report table





NHAT TRI AUTOMATION CO., LTD

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Phone number: 0944275499

DATA SHEET OF PRODUCTION SYSTEM

Name	DataOfWinCC
Start	02/12/2022 09:08:00.000
End	02/12/2022 12:28:00.000

Timestamp	Total Input	Total good Iron	Total good Plastic	Total error Iron	Total error Plastic	Total defective product	Total Output
Sat, 12 Feb 2022 09:16:14.880	31	10	20	1	0	1	31
Sat, 12 Feb 2022 09:26:14.843	35	16	19	0	0	0	35
Sat, 12 Feb 2022 09:36:14.807	35	17	17	1	0	1	35
Sat, 12 Feb 2022 09:46:14.808	18	8	9	1	0	1	18
Sat, 12 Feb 2022 09:56:14.735	32	10	12	6	4	10	32
Sat, 12 Feb 2022 10:06:14.709	36	12	15	1	8	9	36
Sat, 12 Feb 2022 10:16:14.675	20	7	8	2	3	5	20
Sat, 12 Feb 2022 10:26:14.636	27	11	11	3	2	5	27
Sat, 12 Feb 2022 10:36:14.607	31	12	14	3	1	4	30
Sat, 12 Feb 2022 10:56:14.533	37	18	18	0	0	0	36
Sat, 12 Feb 2022 11:06:14.520	26	12	10	0	1	1	23
Sat, 12 Feb 2022 11:16:14.468	21	10	10	0	1	1	21
Sat, 12 Feb 2022 11:26:14.447	37	18	17	1	1	2	37
Sat, 12 Feb 2022 11:36:14.415	33	16	17	0	0	0	33
Sat, 12 Feb 2022 11:46:14.374	37	18	19	0	0	0	37
Sat, 12 Feb 2022 11:56:14.351	28	14	11	0	2	2	27
Sat, 12 Feb 2022 12:06:14.299	29	10	9	5	5	10	29
Sat, 12 Feb 2022 12:16:14.269	38	18	19	0	1	1	38
Sat, 12 Feb 2022 12:26:14.236	34	19	14	1	0	1	34

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PERFORMANCE SYSTEM KPI STATISTICS TABLE

DataOfKPI
02/12/2022 09:08:00.000
02/12/2022 12:28:00.000

GOOD KPI(%)	BAD KPI(%)	QUALITY KPI(Good/Bad)	QUALITY TIME KPI	AVERAGE TIME KPI K1(ms)	AVERAGE TIME KPI K2(ms)	AVERAGE TIME KPI K3_4(ms)	AVERAGE TIME KPI K5(ms)
96.774	3.226	30.00	1.720	6527	5167	5219	2676
100.000	0.000	100.00	1.910	6688	5142	5234	2675
97.143	2.857	34.00	1.820	7186	5036	5366	2673
94.444	5.556	17.00	0.950	7394	5069	5180	2677
68.750	31.250	2.20	1.530	7073	5459	5590	2674
75.000	25.000	3.00	1.780	7121	5354	5453	2673
75.000	25.000	3.00	0.640	7761	5159	5695	2657
81.481	18.519	4.40	1.060	6133	5302	5350	2638
86.667	13.333	6.50	1.180	6649	5231	5358	2670
100.000	0.000	100.00	1.960	6402	5055	5284	2664
95.652	4.348	22.00	0.770	6720	5061	16944	2657
95.238	4.762	20.00	0.740	9032	5209	5381	2679
94.595	5.405	17.50	2.090	6578	4958	5309	2713
100.000	0.000	100.00	1.780	6838	5190	5333	2687
100.000	0.000	100.00	1.830	6849	5448	5336	2708
92.593	7.407	12.50	0.970	6885	5458	5335	2684
65.517	34.483	1.90	0.960	6830	5468	5678	2653
97.368	2.632	37.00	2.060	6751	4627	5275	2672
97.059	2.941	33.00	1.840	7291	4937	5474	2681

Figure 64 The report is exported as an excel file

5 Efficiency Assessment Based on KPIs and Perfecting the System

5.1 KPIs

5.1.1 Introduction of KPI in Production

KPI (Key Performance Indicator) – key performance indicators are a clearly defined and quantifiable metric that the manufacturing industry uses to evaluate output quality and machine performance against time.

KPIs in production are indicators to evaluate and measure the processes that organizations and businesses often use. KPIs are factors that are tracked by organizations and businesses to analyse and evaluate their production processes. These criteria are used to measure success relative to a set of predefined production goals.

5.1.2 Purpose When Setting KPIs

The evaluation of KPIs helps to monitor, analyse and optimize the operation as well as compare the performance of the system:

- Optimize the use of data to analyse and evaluate the quality of output products through quality indicators.
- Evaluate the useful working time of the system; detect problems and losses; Find the causes in the incident times. From there, provide appropriate and effective repair and maintenance measures.
- Detect weaknesses in production processes and optimize processes properly by taking measures to improve machine quality and efficient operation.

5.2 Calculation of KPIs

5.2.1 General Assessment

Below is the calculation formula to determine the quality of production:

- Good Product:

$$KPI(Good)(\%) = \frac{\sum Good\ Product}{\sum Product} * 100 \quad (1)$$

To see full code for KPI GOODS (Network 1), check Appendix 2 which contains code lines for KPI.

- Bad Product:

$$KPI(Bad)(\%) = \frac{\sum Bad\ Product}{\sum Product} * 100 \quad (2)$$

To see full code for KPI BADS (Network 2), check Appendix 2 which contains code lines for KPI.

- Product Quality:

$$KPI(Quality) = \frac{KPI(Good)}{KPI(Bad)} \quad (3)$$

To see full code for KPI QUALITYS (Network 3), check Appendix 2 which contains code lines for KPI.

- Quality Working Time:

$$KPI(Time) = \frac{KPI(Running)}{KPI(Interrupting)} = \frac{t_{running}}{t_{interrupting}} \quad (4)$$

To see full code for KPI AVERAGE TIME OF THE OBJECT AT ALL STAGE (Network 4,5,6 & 7), check Appendix 2 which contains code lines for KPI.

5.2.2 Detailed Evaluation of Each Stage

Working time of each stage per product unit (ms)

$$t_{each\ Product} = \frac{\sum t_{running}}{\sum Product} (ms) \quad (5)$$

To see full code for KPI SYSTEM WORKING TIME/ NON-WORKING TIME (Network 8), check Appendix 2 which contains code lines for KPI.

5.3 Result of Evaluation

5.3.1 Overall Rating

Below is a chart showing KPI data based on calculation formula (1), (2), (3), (4) of 19 days in 1 month simulated time as follows:

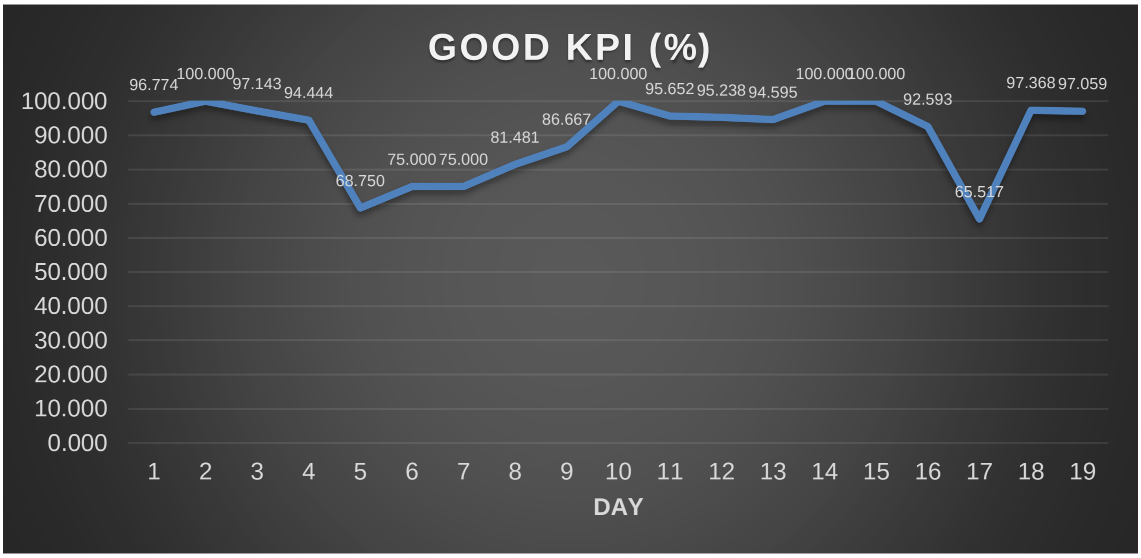

Figure 65 The chart shows the KPIs for Good Products

➔ From the chart (Figure 65), it can be seen that the output quality of the product is good day by day. Good KPI is considered achieved if it is greater than 90%.

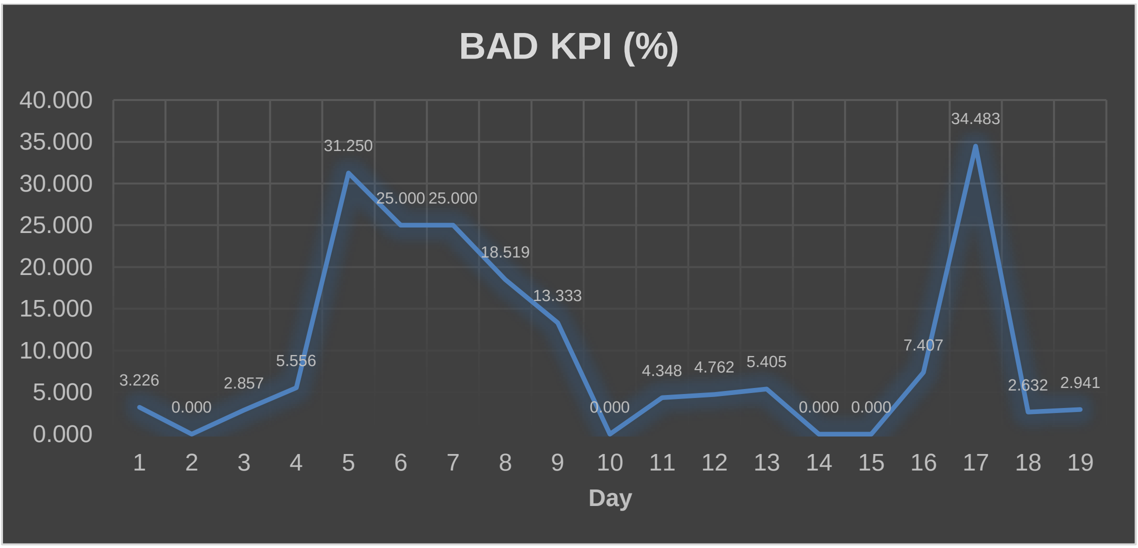

Figure 66 The chart shows the KPI for Bad Products

➔ From the chart (Figure 66), it is possible to see an overview of the output quality of the defective product day by day. Bad KPI is considered acceptable if less than 10%.

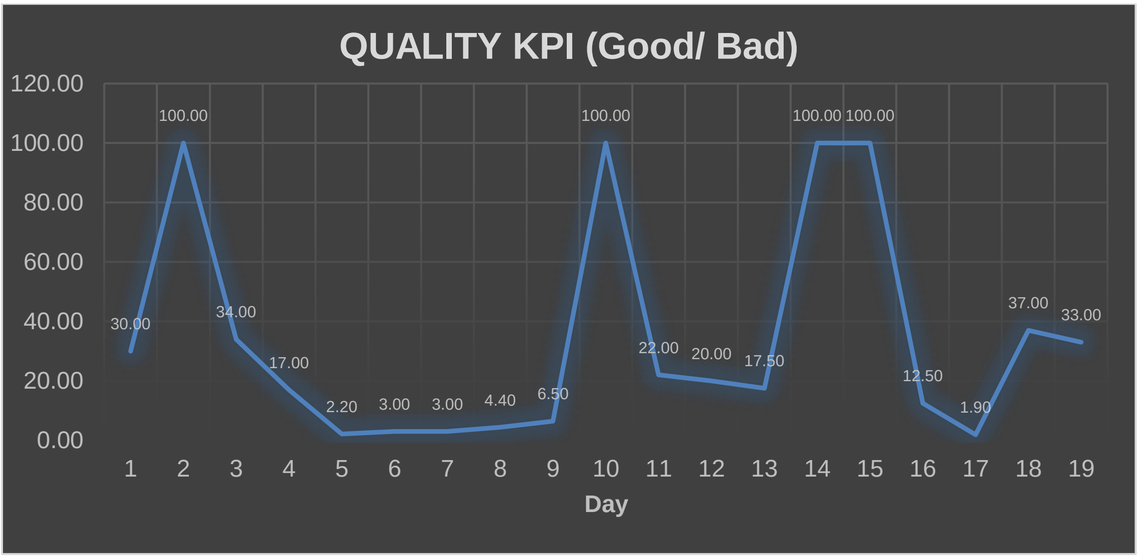

Figure 67 The chart shows the KPI for Product Quality

➔ From the chart (Figure 67), it is possible to see an overview of the output quality of the product day by day. The higher the Quality KPI, the better the output quality.

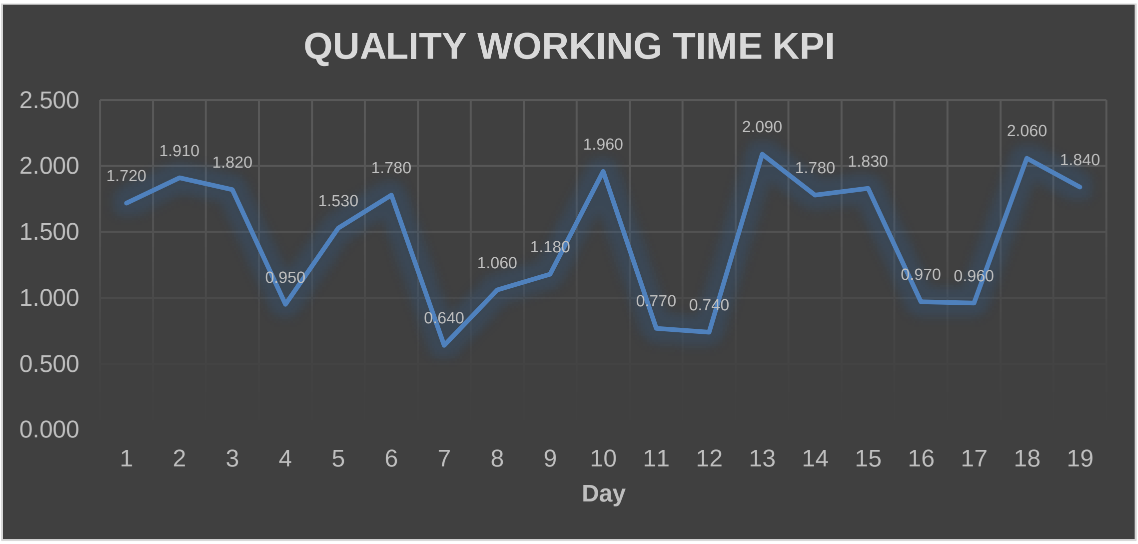

Figure 68 The chart shows the KPI for Quality Working Time

➔ From the graph (Figure 66), it is possible to see an overview of the cycle's working time quality by day. The higher the Quality KPI, the more stable the machine's operating quality, the level of continuous operation and the lower breakdown time.

5.3.2 Detailed Evaluation of Each Stage

The system will be evaluated in detail through the working time of each stage on a product unit. The data is calculated based on the formula number (5) and will be presented for each day/shift. With an assessment like this, maintenance or operation units can take measures to review repair, maintenance, improve machine quality as well as how to operate more efficiently. The graph shows the working time of 5 Stages per unit of product respectively through Figure 69, Figure 70, Figure 71 and Figure 72.

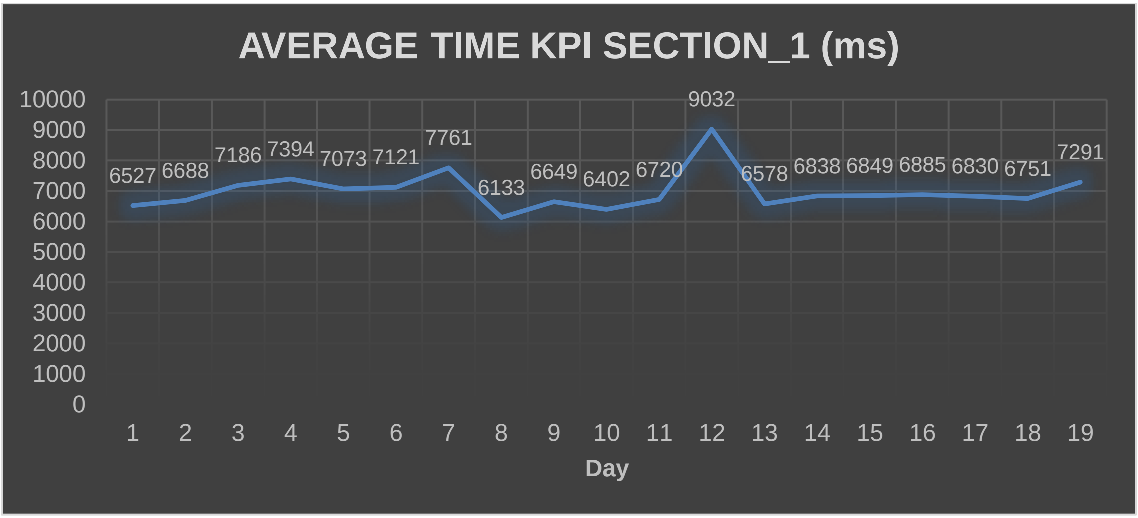

Figure 69 The graph shows the working time of Stage 1 per product unit

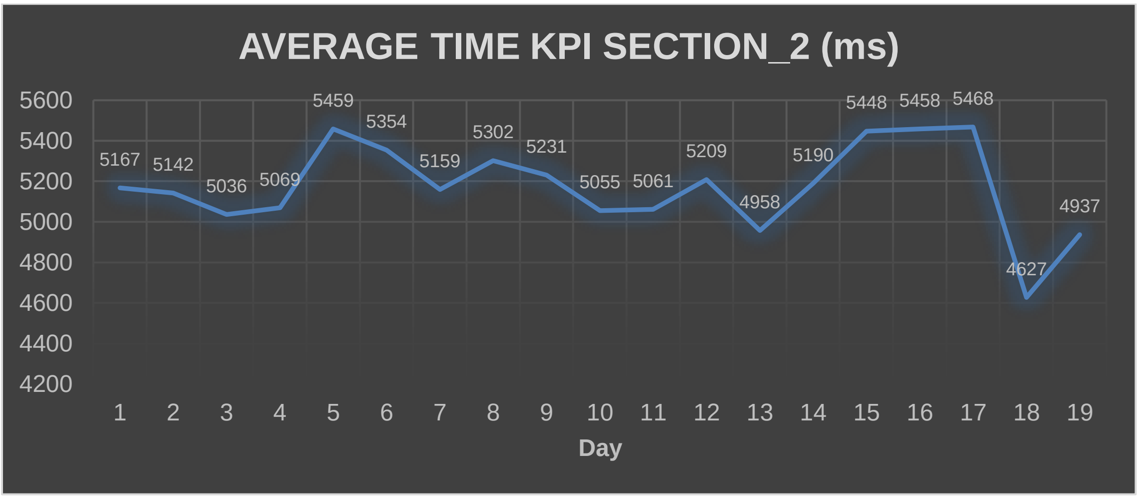

Figure 70 The graph shows the working time of Stage 2 per unit of product

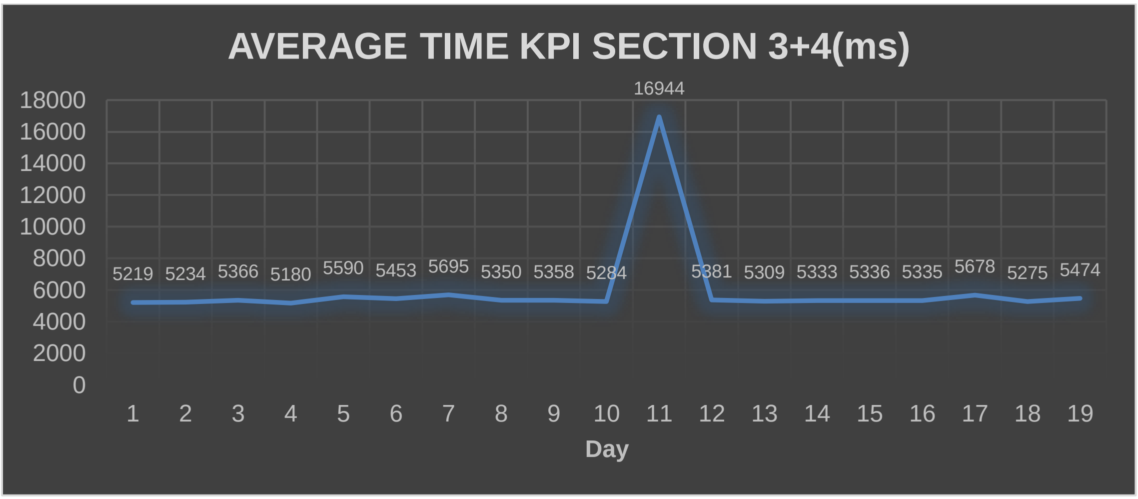

Figure 71 The graph shows the working time of Stage 3 and Stage 4 per product unit

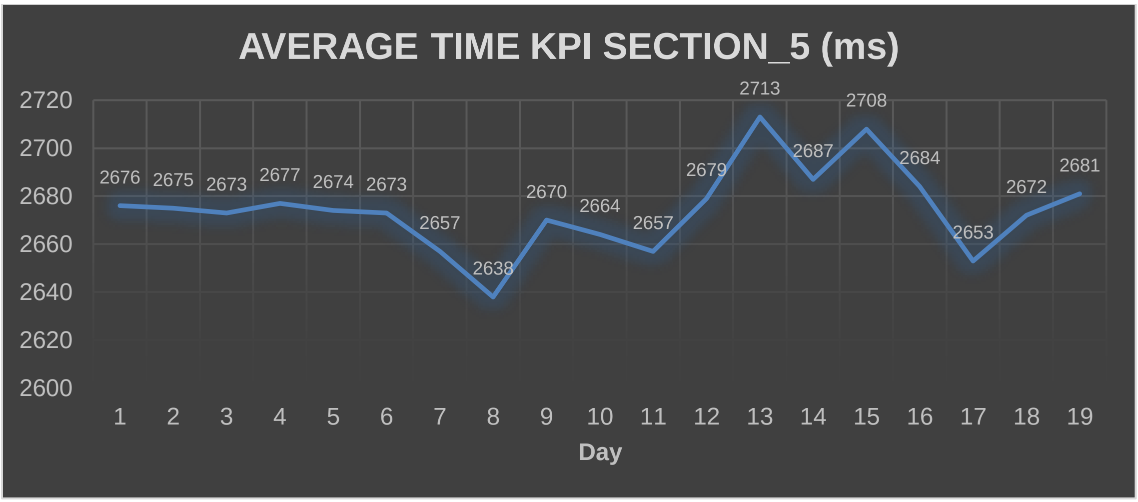

Figure 72 The graph shows the working time of Stage 5 per product unit

6 Conclusion

Thus, the application of GEMMA method to the system shows that the organization and management of the production process is very effective. The system works stably, clearly, flexibly, responding to all working modes of the cycle. In fact, it is completely possible to apply the GEMMA method to large industrial systems that require complex management.

- The Topic has also Improved the Previous Problems:

  - Build a more rational, scientific and efficient operating process.

  - When the system is up and running, the monitoring of devices and their status becomes clearer.

  - The position of objects in and out between the stages is shown visually and clearly.

  - Flexible monitoring, remote control, test (maintenance) functions for programmers and operators.

  - Built a function to calculate and report on the system's performance based on KPIs.

- Future Development Direction:

  - Continue to optimize the control algorithm, increase the operating speed and accuracy of the system.

  - Expanding system research on processing devices with more modern software platforms, integrating more diagnostic features, calculating performance more effectively.

  - I am working on building a decentralized remote control or monitoring system for users to manage the system.

- Research and build API application programming interfaces to provide services for 3rd parties such as accounting, logistics, etc., in making data statistics at will.

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PLA_FI_FI_Pneumatics_%26_Hydraulics_Whoop-_-(FI:Whoop!)+Pneumatic+Sensor+%26+Switch+Accessories-_-PRODUCT_GROUP&matchtype=&pla-476205717522&s_kwcid=AL!7457!3!598320144444!!!g!476205717522!&gclid=CjwKCAjw8JKbBhBYEiwAs3sxNwfnG600g3zZX9OubxBlPVCBodHmXNFXWX9JnF0zaslRQXiWpBvVGxoCD_cQAvD_BwE&gclsrc=aw.ds

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12 Shop Murrelektronik. MCS-B POWER SUPPLY 1-PHASE 85163. [Online] [Cited on Feb 1st, 2022]. https://shop.murrelektronik.fi/fi/Electronics-in-the-Control-Cabinet/Power-Supply-DC/Power-Supply-Units/MCS-B-POWER-SUPPLY-1-PHASE-85163.html

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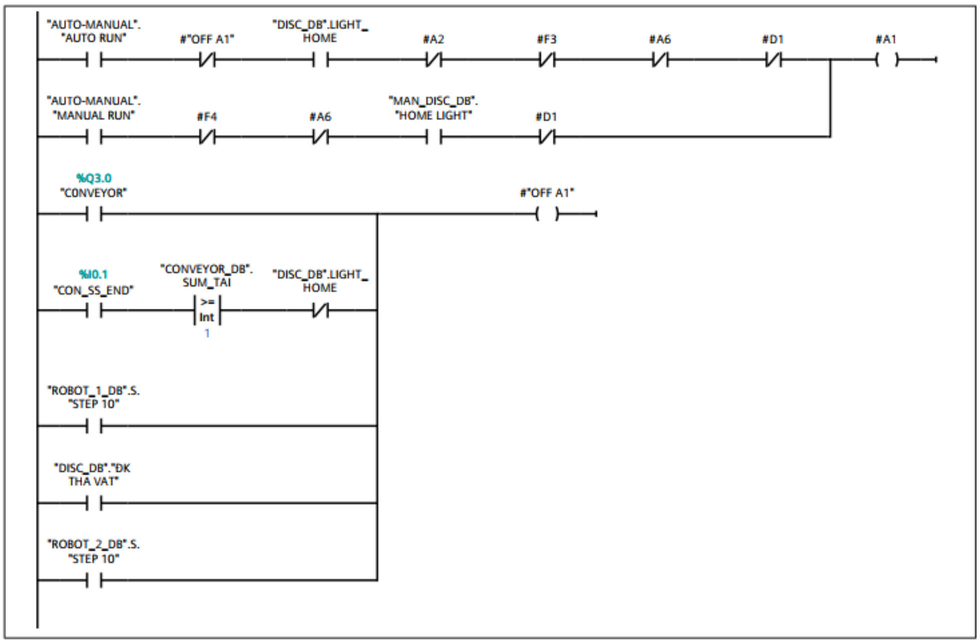
14 Siemens. 6ES7223-1BH32-0XB0. [Online] [Cited on Feb 1st, 2022]. https://mall.industry.siemens.com/mall/en/ww/Catalog/Product/?mlfb=6ES7223-1BH32-0XB0

15 Siemens. 6ES7214-1AG40-0XB0 [Online] [Cited on Feb 1st, 2022]. https://mall.industry.siemens.com/mall/en/ww/Catalog/Product/?mlfb=6ES7214-1AG40-0XB0

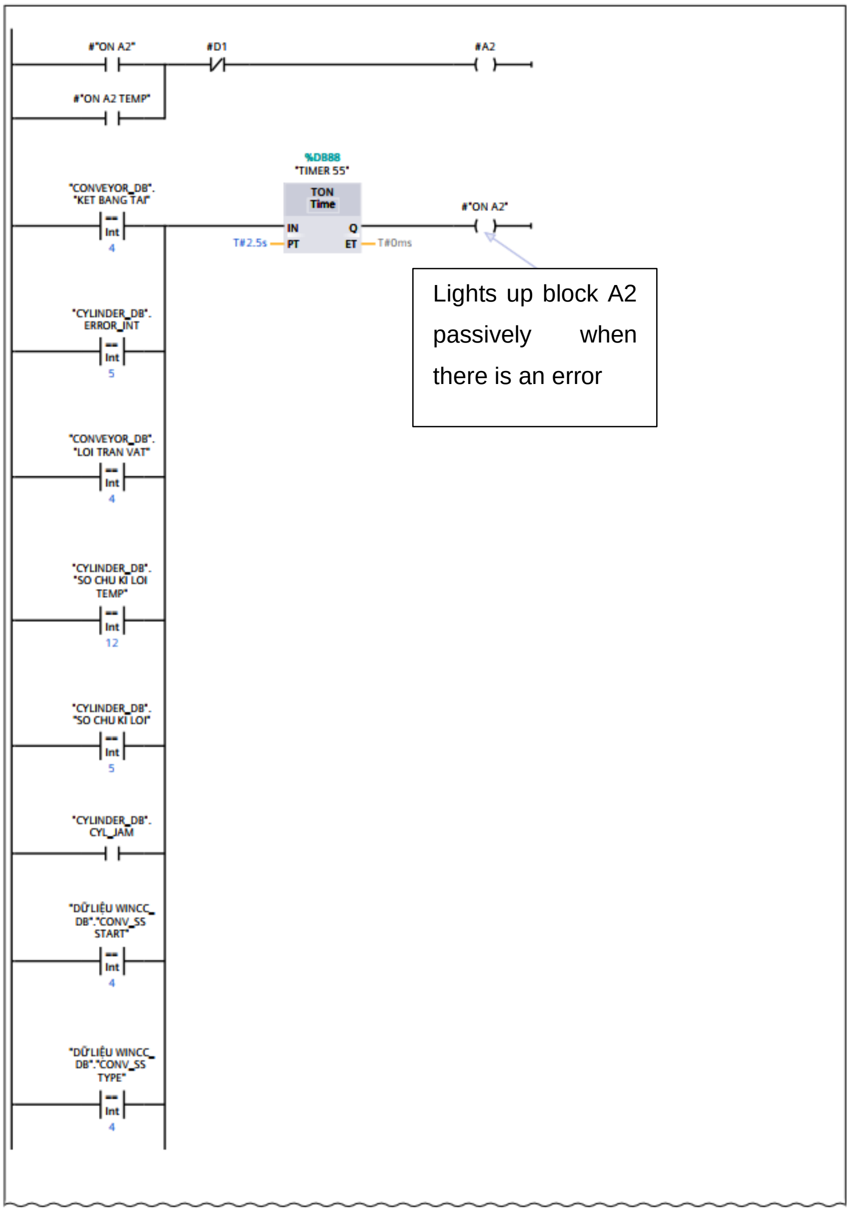
Appendix 1: Code for GEMMA

Network 1: Block A1



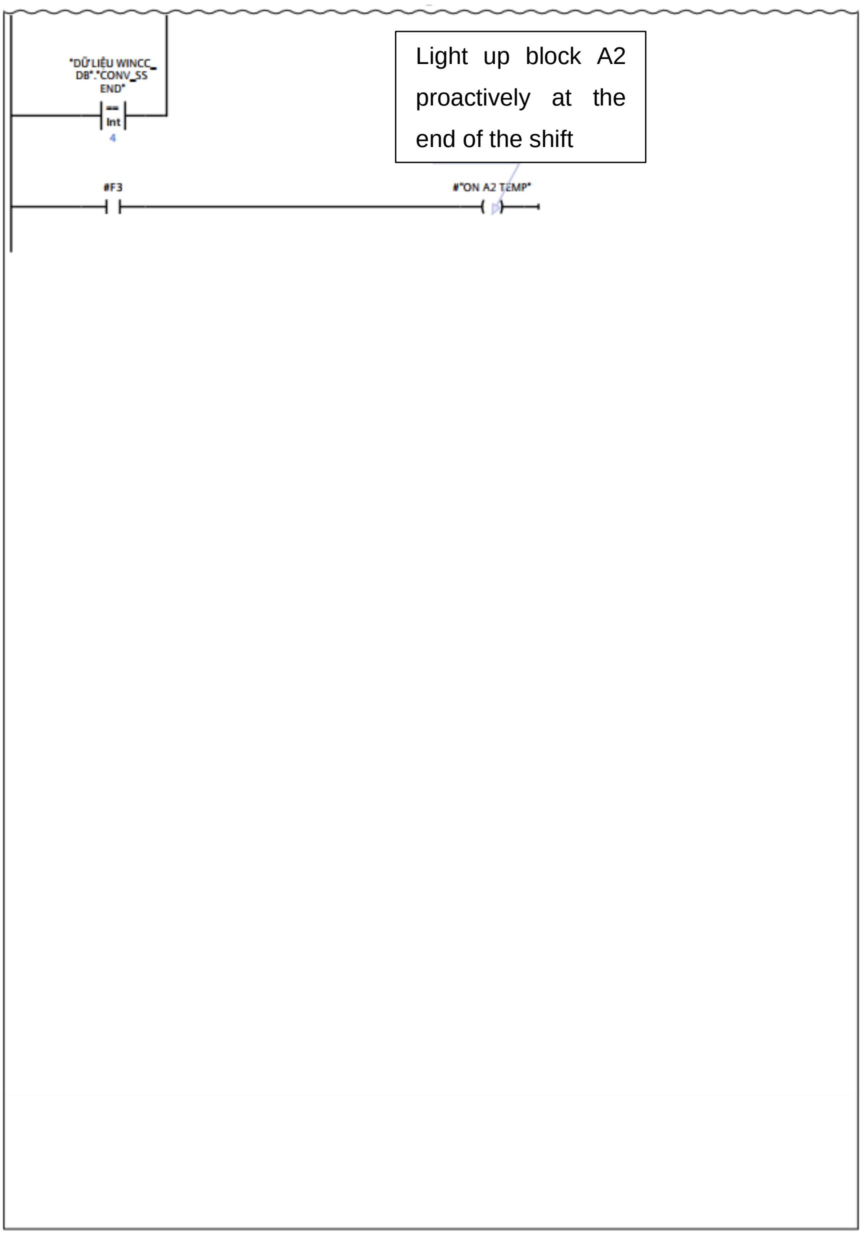
“CONVEYOR_DB”.SUM_TAI = “CONVEYOR_DB”.SUM_LOAD
“DISC_DB”.”ĐK THA VAT” = “DISC_DB”.”DROP CONDITIONS”

Network 2: Block A2 (1.1/2.1)



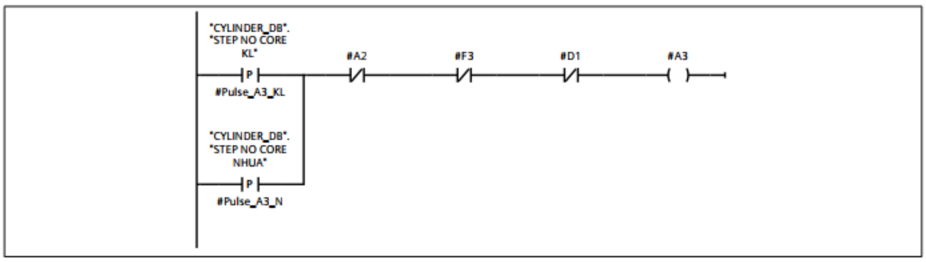
"CONVEYOR_DB"."KET BANG TAI" = "CONVEYOR_DB"."CONVEYOR STUCK"
"CONVEYOR_DB"."LOI TRAN VAT" = "CONVEYOR_DB"."OVERFLOW ERROR"
"CYLINDER_DB"."SO CHU KI LOI TEMP" = "CYLINDER _DB"."NUMBER OF ERROR CYCLES TEMP"
"CYLINDER _DB"."SO CHU KI LOI" = "CYLINDER _DB"."NUMBER OF ERROR CYCLES"
"DỮ LIỆU WINCC_DB"."CONV_SS START" = "DATA WINCC_DB"."CONV_SS START"
"DỮ LIỆU WINCC_DB"."CONV_SS TYPE" = "DATA WINCC_DB"."CONV_SS TYPE"

Network 2: Block A2 (2.1/2.1)



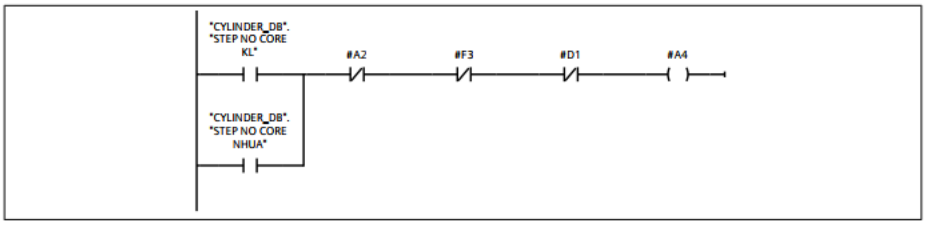
"DỮ LIỆU WINCC_DB"."CONV_SS END" = "DATA WINCC_DB"."CONV_SS END"

Network 3: Block A3



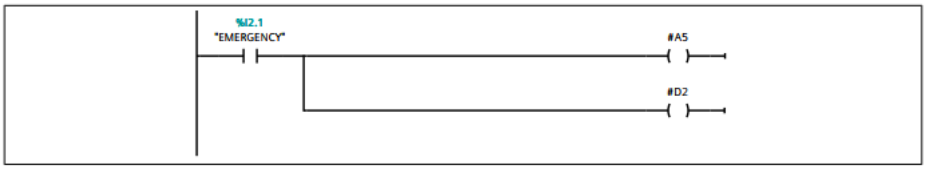
"CYLINDER_DB"."STEP NO CORE KL" = "CYLINDER_DB"."STEP NO IRON CORE"
"CYLINDER_DB"."STEP NO CORE NHUA" = "CYLINDER_DB"."STEP NO PLASTIC CORE"

Network 4: Block A4

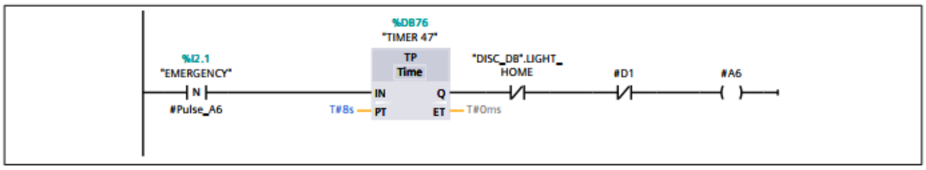


"CYLINDER_DB"."STEP NO CORE KL" = "CYLINDER_DB"."STEP NO IRON CORE"
"CYLINDER_DB"."STEP NO CORE NHUA" = "CYLINDER_DB"."STEP NO PLASTIC CORE"

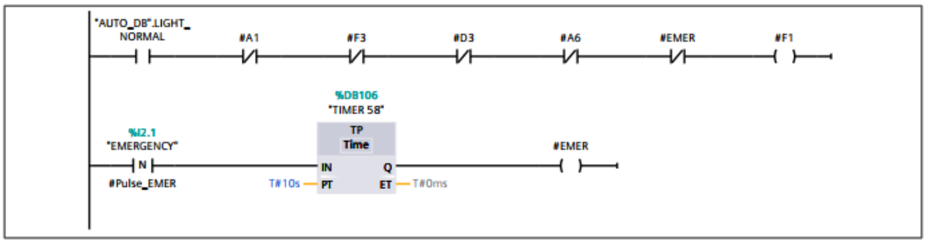
Network 5: Block A5 & D2



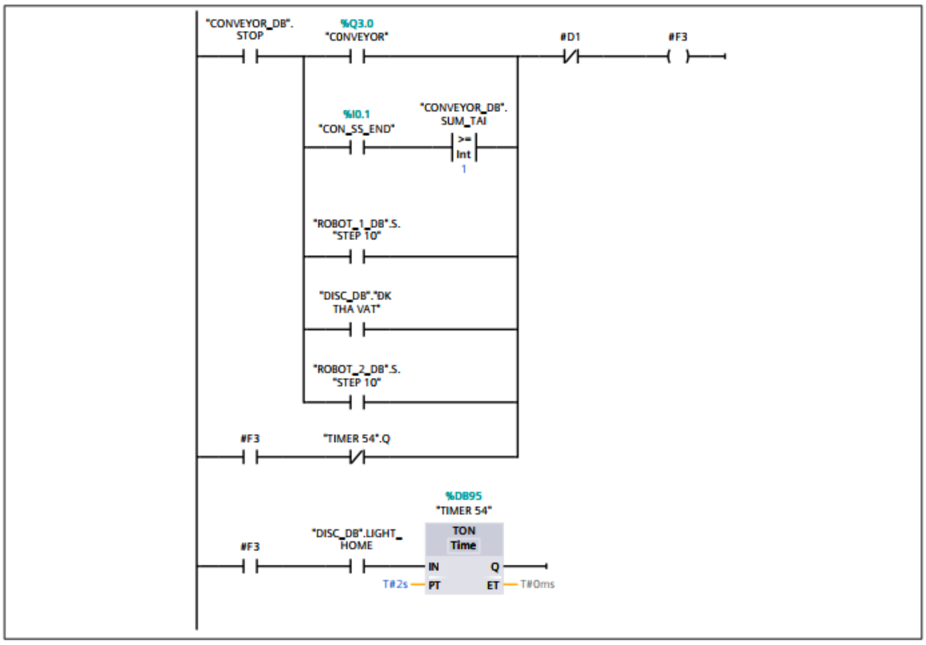
Network 6: Block A6



Network 7: Block F1



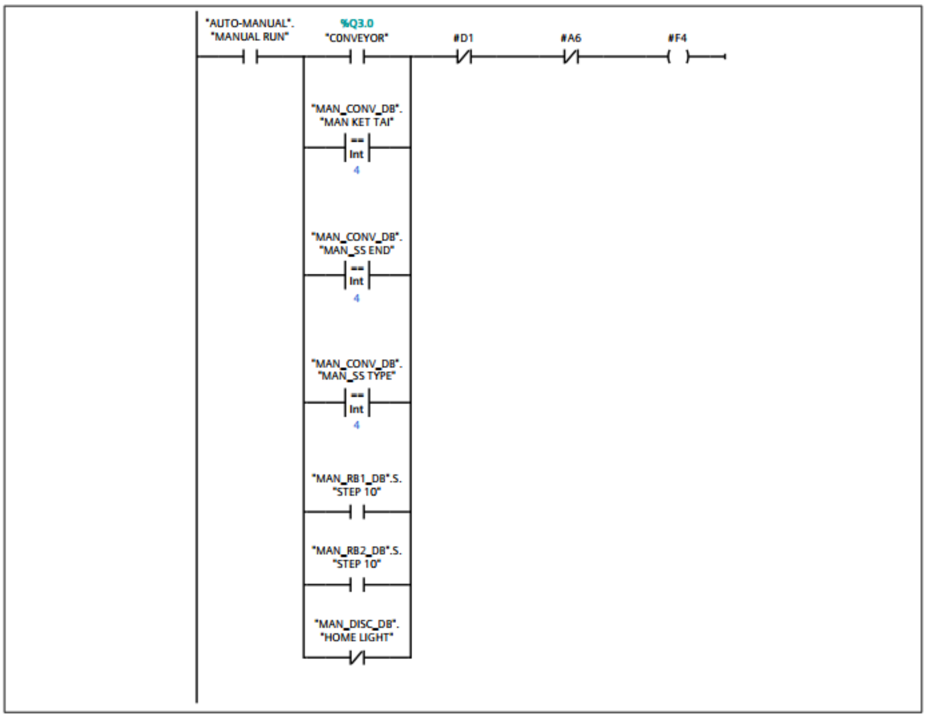
Network 8: Block F3 & A2



"CONVEYOR_DB".SUM_TAI = "CONVEYOR_DB".SUM_CONVEYOR

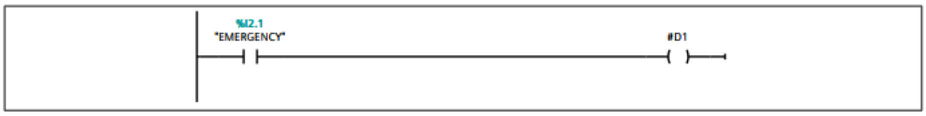
“DISC_DB”.”ĐK THA VAT” = “DISC_DB”.”DROP CONDITIONS”

Network 9: Block F4

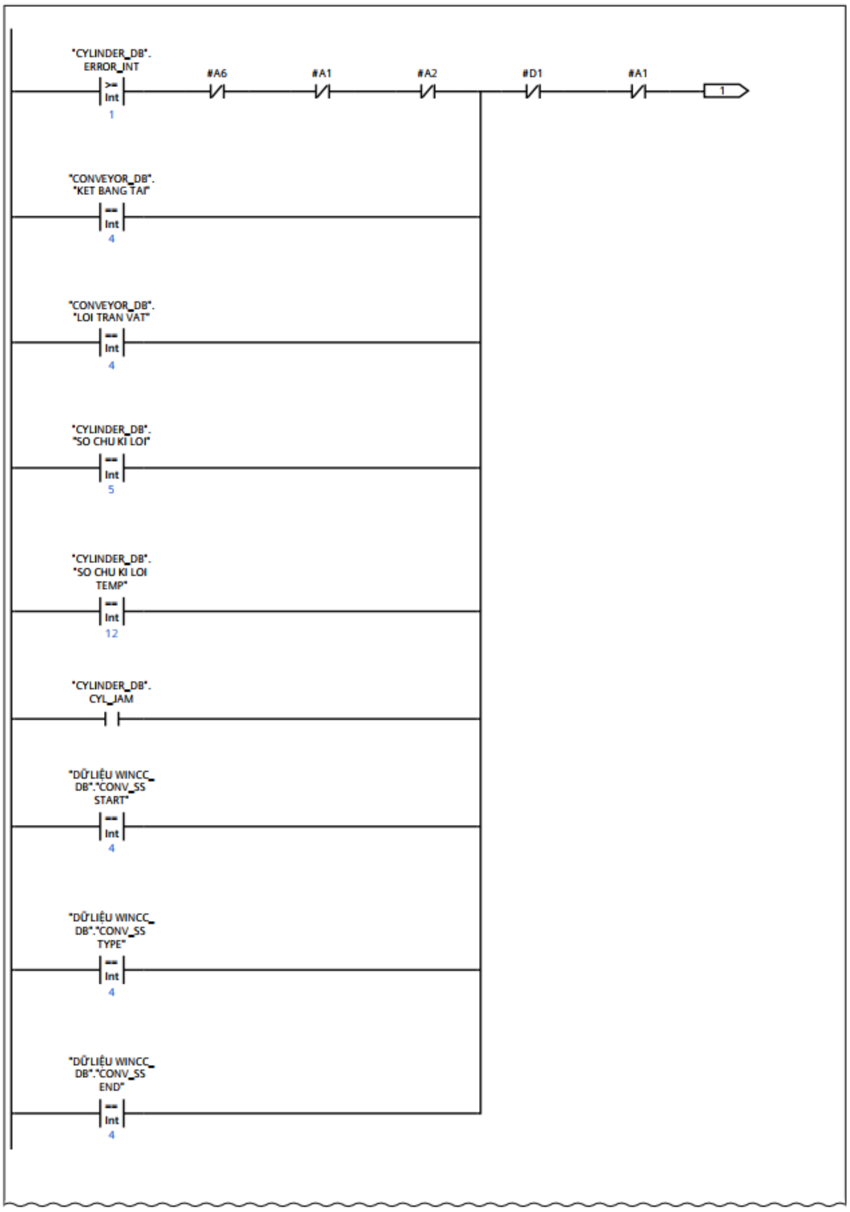


“MAN_CONV_DB”.”MAN KET TAI” = “MAN_CONV_DB”.”MAN KET TAI”

Network 10: Block D1

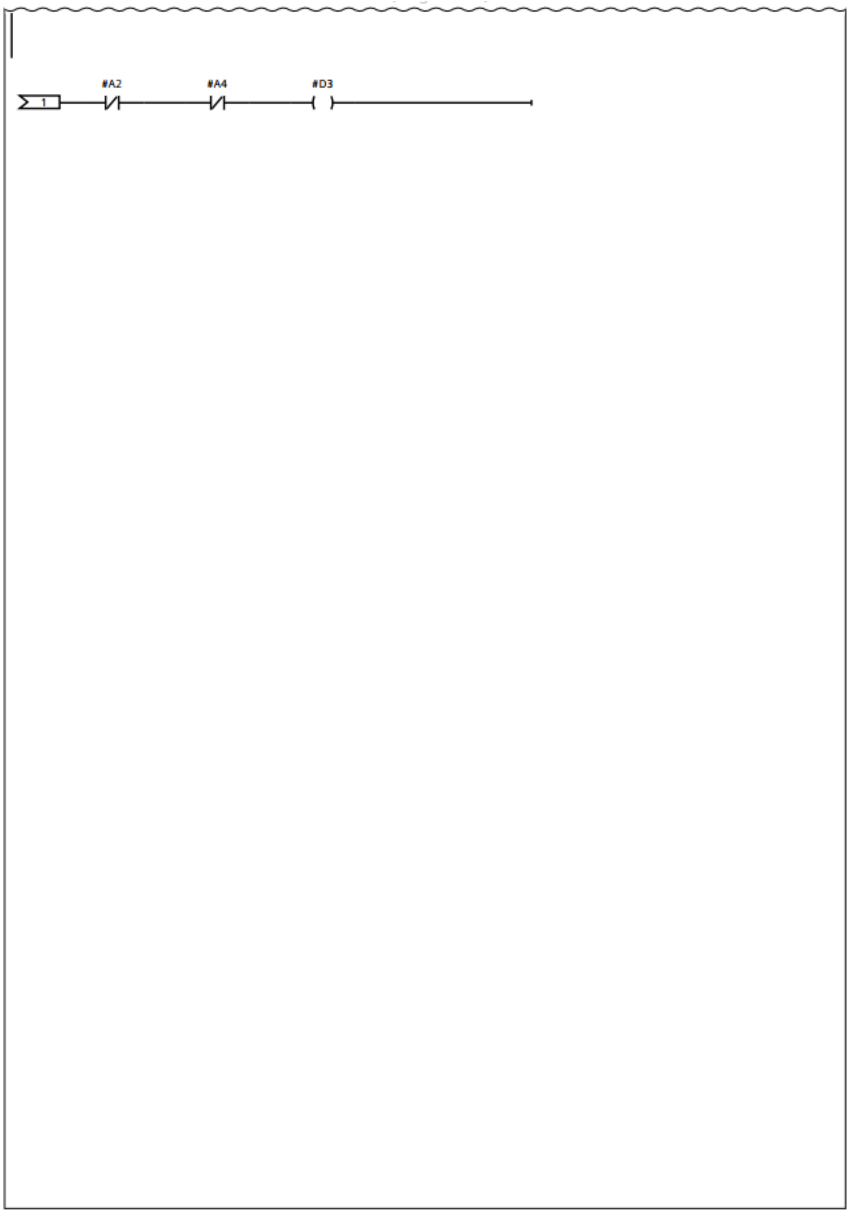


Network 11: Block D3 (1.1/2.1)



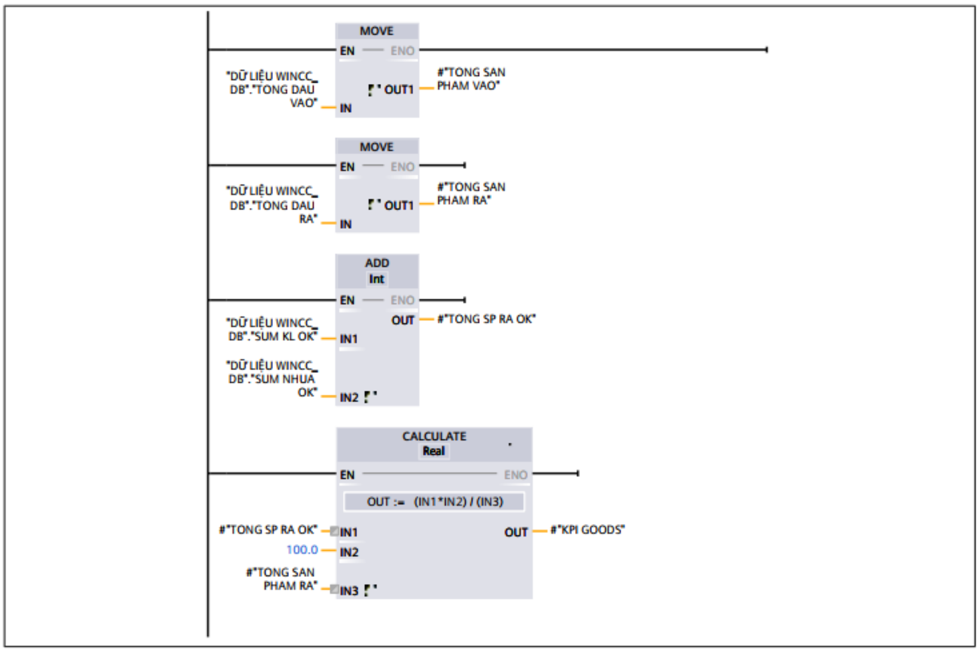
"CONVEYOR_DB"."KET BANG TAI" = "CONVEYOR_DB"."CONVEYOR STUCK"
"CONVEYOR_DB"."LOI TRAN VAT" = "CONVEYOR_DB"."OVERFLOW ERROR"
"CYLINDER_DB"."SO CHU KI LOI TEMP" = "CYLINDER_DB"."NUMBER OF ERROR CYCLES TEMP"
"CYLINDER_DB"."SO CHU KI LOI" = "CYLINDER_DB"."NUMBER OF ERROR CYCLES"
"DỮ LIỆU WINCC_DB"."CONV_SS START" = "DATA WINCC_DB"."CONV_SS START"
"DỮ LIỆU WINCC_DB"."CONV_SS TYPE" = "DATA WINCC_DB"."CONV_SS TYPE"

Network 11: Block D3 (2.1/2.1)


#A2
#A4
#D3
1

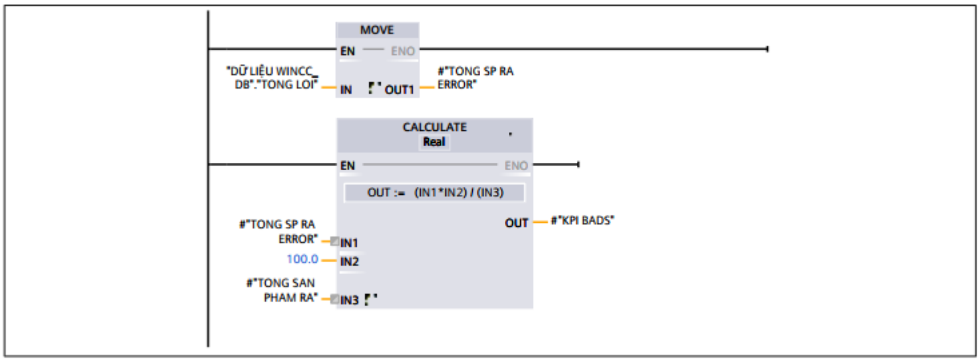
Appendix 2: Code for KPI

Network 1: KPI GOODs



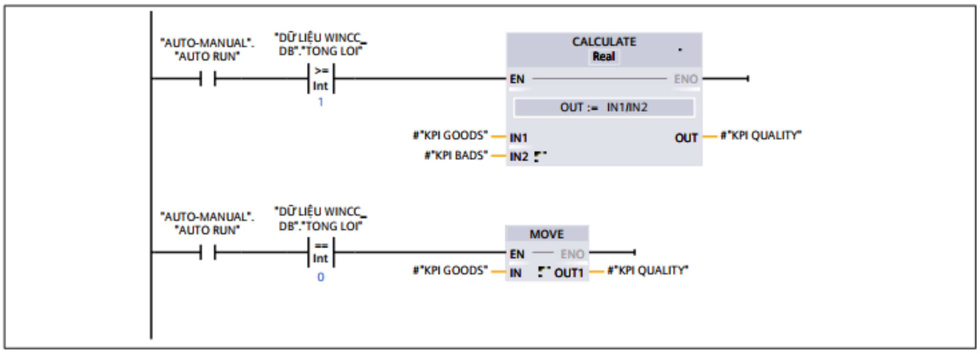
“DỮ LIỆU WINCC_DB”.”TONG DAU VAO” = “DATA WINCC_DB”.”SUM INPUT”
“TONG SAN PHAM VAO” = “TOTAL PRODUCTS INTO”
“DỮ LIỆU WINCC_DB”.”TONG DAU RA” = “DATA WINCC_DB”.”SUM OUTPUT”
“TONG SAN PHAM RA”.” TOTAL PRODUCTS OUT”
“DỮ LIỆU WINCC_DB”.”SUM KL OK” = “DATA WINCC_DB”.”SUM IRON OK”
“DỮ LIỆU WINCC_DB”.”SUM NHUA OK” = “DATA WINCC_DB”.”SUM PLASTIC OK”
“TONG SP RA OK”.” TOTAL PRODUCTS OUT OK”

Network 2: KPI BADs



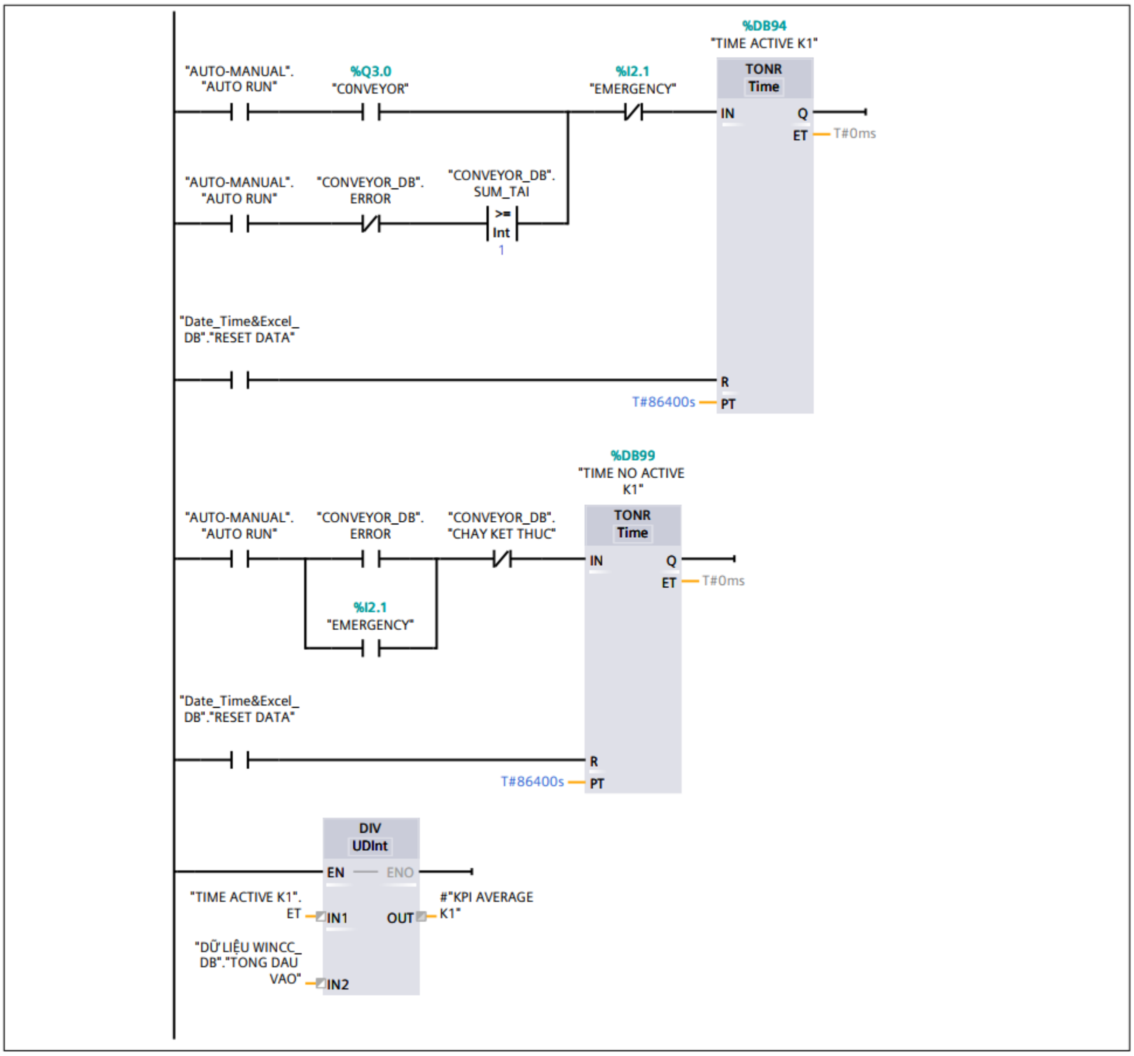
“DỮ LIỆU WINCC_DB”.”TONG LOI” = “DATA WINCC_DB”.”SUM ERROR”
“TONG SAN PHAM RA ERROR” = “TOTAL PRODUCTS OUT ERROR”
“DỮ LIỆU WINCC_DB”.”TONG DAU RA” = “DATA WINCC_DB”.”SUM OUTPUT”
“TONG SAN PHAM RA”.” TOTAL PRODUCTS OUT”

Network 3: KPI QUALITY



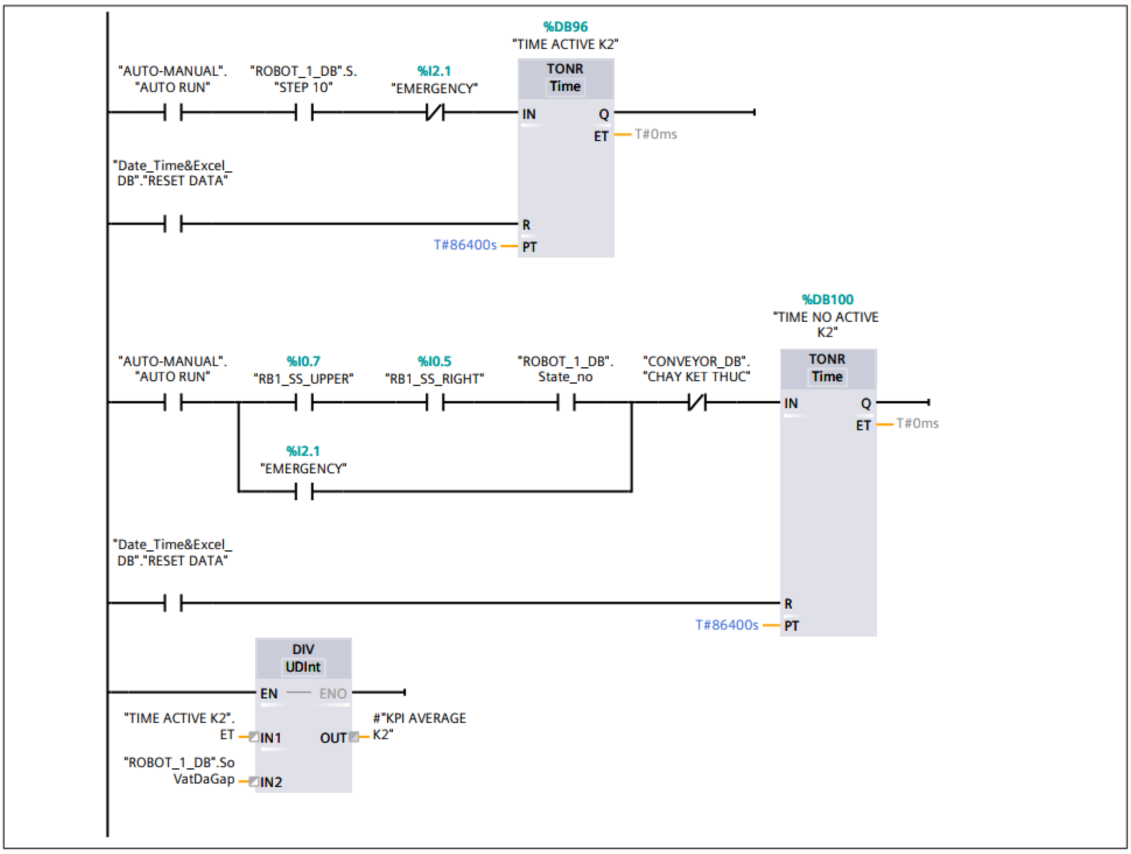
"DỮ LIỆU WINCC_DB"."TONG LOI" = "DATA WINCC_DB"."SUM ERROR"

Network 4: KPI AVERAGE TIME OF THE OBJECT AT STAGE 1



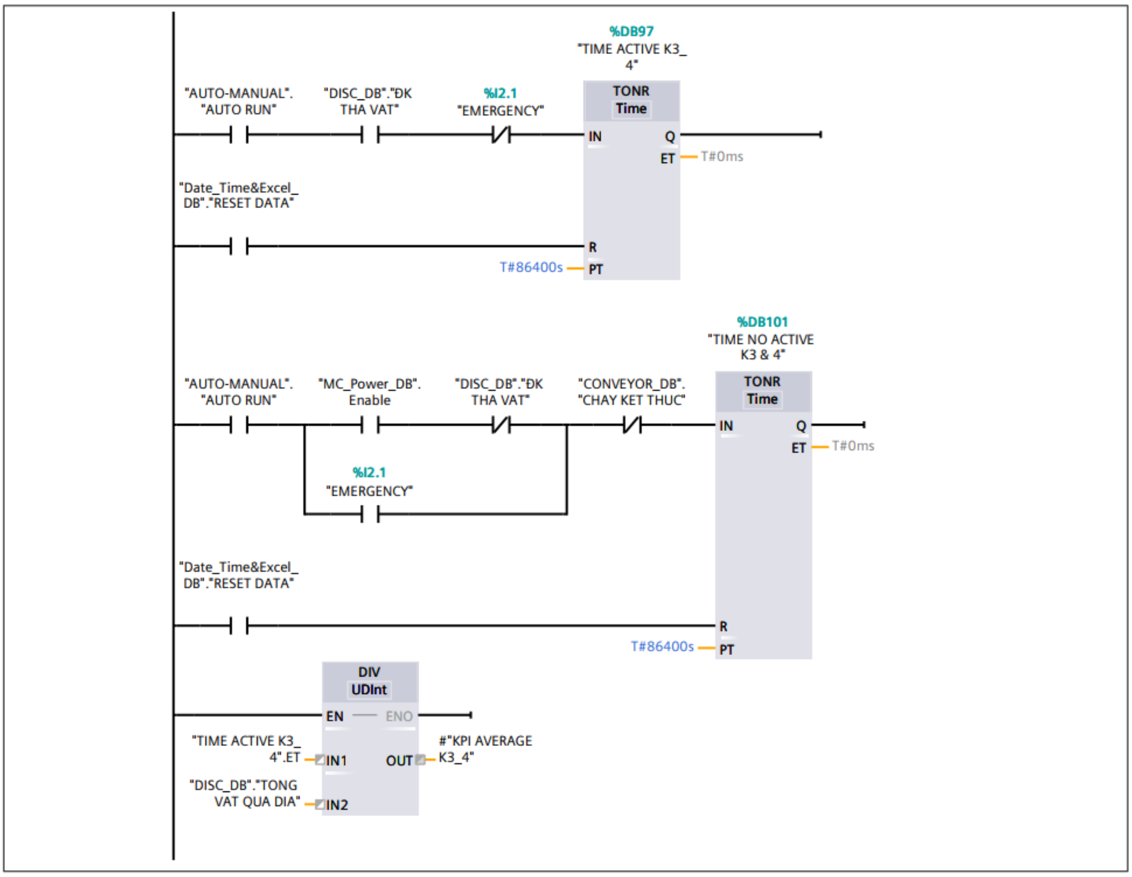
"DỮ LIỆU WINCC_DB"."TONG DAU VAO" = "DATA WINCC_DB"."SUM INPUT"
"CONVEYON_DB"."CHAY KET THUC" = "CONVEYON_DB"."END RUN"

Network 5: KPI AVERAGE TIME OF THE OBJECT AT STAGE 2



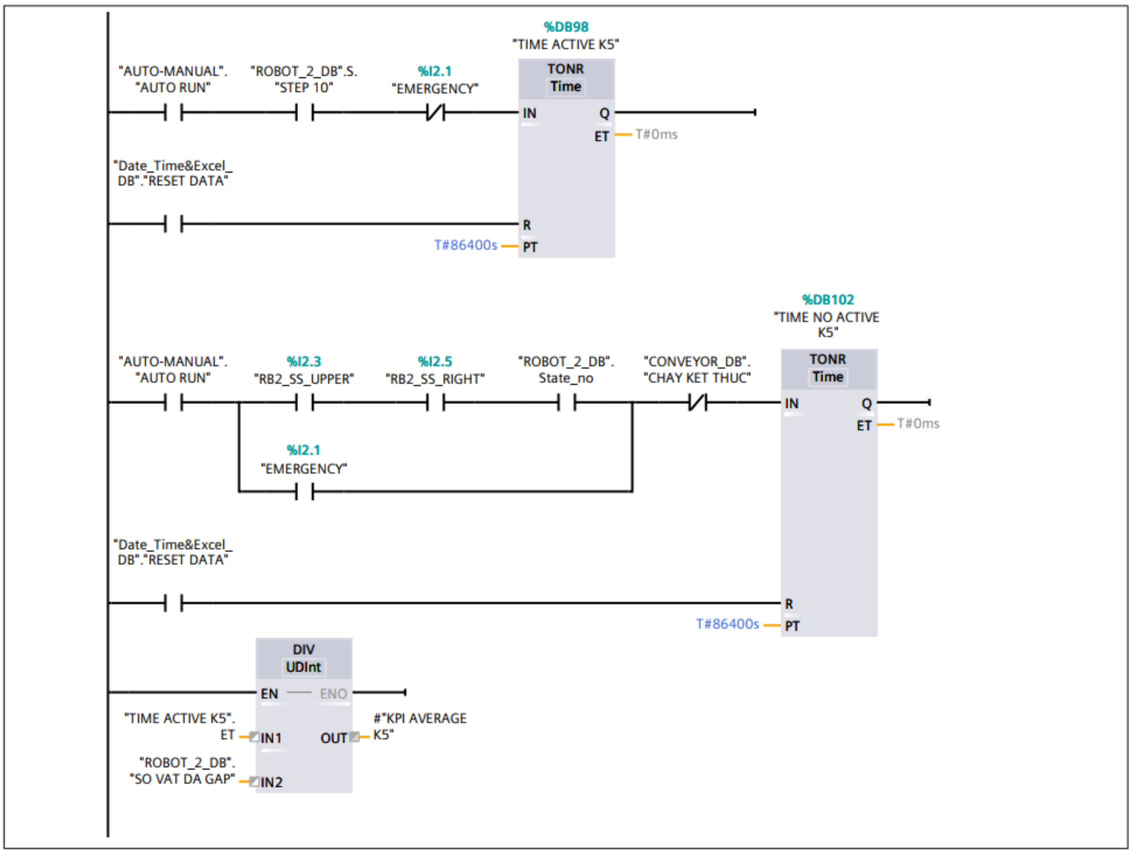
“ROBOT_1_DB”.SoVatDaGap = “ROBOT_1_DB”.Number of objects picked up
“CONVEYON_DB”.”CHAY KET THUC” = “CONVEYON_DB”.”END RUN”

Network 6: KPI AVERAGE TIME OF THE OBJECT AT STAGE 3 & 4



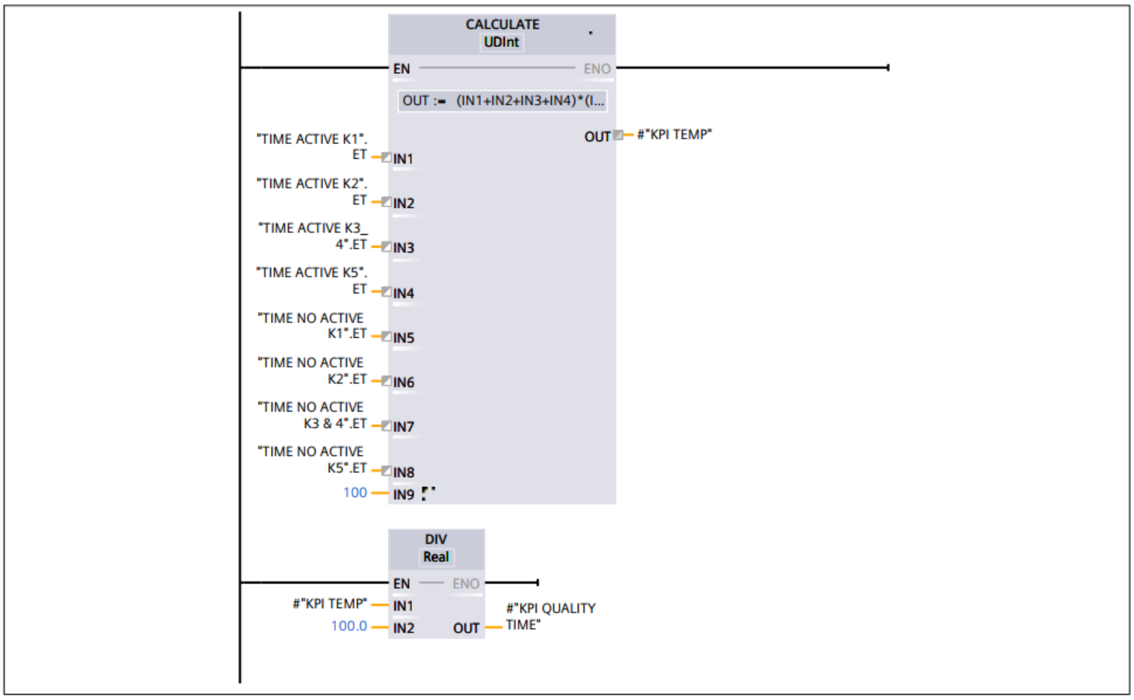
“DISC_DB”.”DK THA VAT” = “DISC_DB”.”DROP CONDITION”
“CONVEYOR_DB”.”CHAY KET THUC” = “CONVEYOR_DB”.”END RUN”
“DISC_DB”.”TONG VAT QUA DIA” = “DISC_DB”.” TOTAL OBJECT THROUGH THE PLATE”

Network 7: KPI AVERAGE TIME OF THE OBJECT AT STAGE 5



"CONVEYOR_DB"."CHAY KET THUC" = "CONVEYOR_DB"."END RUN"
"ROBOT_2_DB"."SO VAT DA GAP" = " ROBOT_2_DB"."NUMBER OF OBJECTS PICKED UP"

Network 8: KPI SYSTEM WORKING TIME/NON-WORKING TIME



Appendix 3: Component datasheets

Optical sensor BYD3M-TDT2

- It is a type of sensor that transmits and transmits through a beam.
- Power supply: 12 - 24VDC ± 10%.
- Detection distance: 3m.
- Standard detection object: opaque object (converging reflection, diffuse reflection).
- Light source: Infrared LED.
- Output: NPN open collector.
- Response time: up to 1ms.
- Protection function: reverse polarity protection, output short circuit protection.

Fiber Optic Sensor Amplifier E3X-HD11

- Connection form: cable, up to 2m.
- Output NPN.
- Power supply: 12 – 24 VDC ± 10%.
- Response time: according to modes 80 μs, 250 μs, 1ms, 4ms, and 16ms respectively.
- Power tuning function: Control the energy and brightness of the light.
- Select detection function: Single edge or double edge.
- Protection features: reverse voltage protection, output short circuit, output reverse polarity.

Proximity sensor OMCH LJ18A3-8-Z/BX

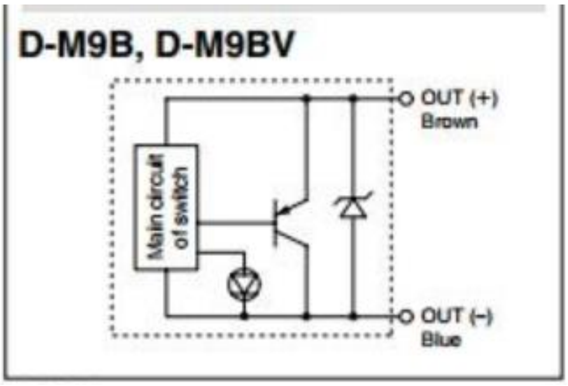
- Power supply: 6 – 36 VDC [7].
- Output current: 300 mA.
- Dimensions: 18 mm.
- Output: NO.
- Output: NPN, 3 wire.
- Detection distance: 0 – 7 mm [7].
- Detecting object: metal.

Fiber Sensor E3X-HD11

- Type: Optical Amplifier.
- Power supply: 12 – 24 VDC ± 10%.
- Response time: up to 2ms.
- Output: NPN, open collector.
- Protection features: Reverse power, short circuit, reverse polarity output.
- Connection type: 2m cable.

SMC D-M9BW Cruise Magnetic Sensor

D-M9□, D-M9□V (With indicator light)						
Auto switch model	D-M9N	D-M9NV	D-M9P	D-M9PV	D-M9B	D-M9BV
Electrical entry direction	In-line	Perpendicular	In-line	Perpendicular	In-line	Perpendicular
Wiring type	3-wire				2-wire	
Output type	NPN		PNP		—	
Applicable load	IC circuit, Relay, PLC				24 VDC relay, PLC	
Power supply voltage	5, 12, 24 VDC (4.5 to 28 V)				—	
Current consumption	10 mA or less				—	
Load voltage	28 VDC or less		—		24 VDC (10 to 28 VDC)	
Load current	40 mA or less				2.5 to 40 mA	
Internal voltage drop	0.8 V or less at 10 mA (2 V or less at 40 mA)				4 V or less	
Leakage current	100 μA or less at 24 VDC				0.8 mA or less	
Indicator light	Red LED illuminates when turned ON.					
Standard	CE marking					



Proximity sensor OMRON E2B-M18KS08-WP-B1 2M

- Type: Cylindrical M18.
- Power supply: 10 – 30VDC.
- Maximum current: 200mA.
- Detection distance: 8mm.
- Cable length: 2m.
- Max Frequency: 500Hz.
- Anti-jamming.

- Output: PNP.
- Function: NO.
- Protection features: electric shock, reverse connection of power supply, reverse connection of output terminal, short circuit.
- Material: Brass.

MCS-B 85303 Power Supply

- Input voltage: 90-132/173-264 VAC 50/60Hz.
- Input current: 2.3A/115VAC – 1.2A/230VAC.
- Output voltage: 24VDC.
- Output Current: 24VDC – 5A (40°C) / 4A(55°C).
- Power: 120W.
- Overheat and overload protection.

MCS-B Art.No.85163 Power Supply

- Input voltage: 100 - 240 VAC 50/60Hz.
- Input current: 2.5A/115VAC – 1.16A/230VAC.
- Output voltage: 24VDC.
- Output Current: 24VDC – 5A (55°C) / 4A(70°C).
- Overheat and overload protection.

Engine INDUCTION 3IK15GN-C

- Type: Induction motor.
- Power: 15W.
- Voltage: 200V.
- Frequency: 50/60Hz.
- Capacitance: 12 µF.
- Current: 0.25A.
- Speed: 1200/1500r/min
- Ratio: 1/12.5

Encoder KEN50-V360H

- Use voltage: 5 – 24VDC.
- Type: Incremental rotary (relative).
- Number of pulse channels: 3 separate pulse channels A, B, Z.

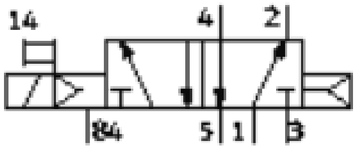
- Incremental, 2-phase AB rotary encoder, generating a calibrated count pulse signal through a rotating grid disc and optocoupler.
- Output: AB output 2-phase rectangular orthogonal pulse, circuit output is NPN open-collector output type, can be combined with PLC with an internal pull-up resistor.
- Use: Used to measure object rotation speed, angle, acceleration, and length.
- Resolution: 360 pulses/rev.

Servomotor SGDH-A5AE

- Type: Servo drives.
- Supply voltage: 200-230 VAC.
- Type E: control torque, speed, position.
- Power: 0.05kW.
- Maximum current: 2A.
- Frequency: 40Hz.
- Number of phases: 1.
- Encoder feedback, dynamic brake.
- Analog inputs: 2.
- Analog outputs: 2.
- Digital inputs: 7.
- Digital outputs: 3.

Solenoid valve MYH-5/2-2.3-L-LED

Feature	Value
Valve function	5/2 single solenoid
Standard nominal flow rate	190 l/min
Operating pressure	2 ... 8 bar
Design structure	Piston slide
Protection class	IP40 with plug socket
Nominal size	2.3 mm
Type of piloting	Piloted
Switching time off	23 ms
Switching time on	12 ms
Duty cycle	100%
Characteristic coil data	24V DC: 1,8W
Operating medium	Dried compressed air, lubricated or unlubricated
Medium temperature	-5 ... 50 °C
Ambient temperature	-5 ... 50 °C
Product weight	65 g
Mounting type	with through hole
Pneumatic connection, port 1	Sub-base M5
Pneumatic connection, port 2	Sub-base M5
Pneumatic connection, port 3	Sub-base M5
Pneumatic connection, port 4	Sub-base
Pneumatic connection, port 5	Sub-base
Materials information for seals	NBR
Materials information, housing	Aluminium die cast



MCB Schneider EZ9F34216

- Product Line: Easy9.
- C type characteristic curve.
- Number of Poles: 2P.
- Rated current: 16A.
- Cutting current: 4.5kA.
- Rated voltage: 230V.

MCB Schneider EZ9F34116

- Protection against overload current.
- Protection against short circuit current.
- Number of Poles: 1P.
- Rated current: 16A.
- Short circuit breaking current: 4.5 kA.
- Rated voltage: 230V.

MCB Schneider iC65H D 16A

- DI type characteristic curve.
- Number of Poles: 1P.
- Rated current: 16A.
- Short circuit current: 1kA.
- Rated voltage: 230V.

CPU 6ES7214-1GA40-0XB0

Digital Input Number 24VDC	14
Digital Output Number 24VDC	10
Number of Analog Inputs (10-bit Resolution)	2
Supply	220 VAC
Power Consumption	12 W
Size	110x100x75 (mm)

Module 6ES7223-1BH32-0XB0

Digital Input Number 24VDC	8
Digital Output Number 24VDC	8
Supply	220 VAC
Power Consumption	2.5 W
Size	100x45x75 (mm)

Inputs of PLC

PLC INPUT			
No.	Adress	Lable	Link device
1	I0.0	8A3-I0.0	The object detection sensor BYD3M-TDT2.
2	I0.1	8A3-I0.1	The object detection sensor Pana E3X-HD11.
3	I0.2	8A3-I0.2	The metal object detection proximity sensor LJ18A3-8-Z/BX.
4	I0.3	8A3-I0.3	The plastic core detection sensor E3X-HD11.
5	I0.4	8A3-I0.4	The metal core detection sensor E3X-HD11.
6	I0.5	8A3-I0.5	RB1’s horizontal cylinder right stroke magnetic sensor.
7	I0.6	8A3-I0.6	RB1’s horizontal cylinder left stroke magnetic sensor.

8	I0.7	8A3-I0.7	Magnetic sensor of travel on the vertical cylinder of RB1.
9	I1.0	8A3-I1.0	Magnetic sensor of travel under the vertical cylinder of RB1.
10	I1.1	8A3-I1.1	Magnetic sensor at the end of the cylinder stroke closes the metal core.
11	I1.2	8A3-I1.2	Magnetic sensor at the end of the cylinder stroke closes the plastic core.
12	I1.3	8A3-I1.3	Proximity sensor determines the Home position of the rotating disc.
13	I1.4	8A3-I1.4	Encoder's Channel A.
14	I1.5	8A3-I1.5	Encoder's Channel B.
15	I8.0	9A1-I2.0	The first rotation magnetic sensor of RB2.
16	I8.3	9A1-I2.3	Magnetic sensor of travel on the vertical cylinder of RB2.
17	I8.4	9A1-I2.4	Magnetic sensor of travel under the vertical cylinder of RB2.
18	I8.5	9A1-I2.5	The second rotation magnetic sensor of RB2.
19	I12.0	9A1-I3.0	Servo ready.

Outputs of PLC

PLC OUTPUT			
No.	Address	Label	Link device
1	Q0.0	8A3-Q0.0	Pulse for Drive Servo Rotary Disc
2	Q0.3	8A3-Q0.1	Navigating Drive Servo
3	Q0.4	8A3-Q0.4	Emergency stop incident light
4	Q0.6	8A3-Q0.6	Enable Drive Servo Rotary Disc
5	Q0.7	8A3-Q0.7	Horizontal cylinder valve of RB1
6	Q1.0	8A3-Q1.0	Vertical cylinder valve of RB1
7	Q1.1	8A3-Q1.1	Hand crank cylinder valve of RB1
8	Q8.0	9A1-Q2.0	Metal core closed cylinder valve
9	Q8.1	9A1-Q2.1	Plastic core closed cylinder valve
10	Q8.2	9A1-Q2.2	Vertical cylinder valve of RB2
11	Q8.3	9A1-Q2.3	Rotary cylinder valve of RB2

12	Q8.4	9A1-Q2.4	Hand crank cylinder valve of RB2
13	Q8.7	9A1-Q2.7	Conveyor rotates in forward
14	Q12.0	9A1-Q3.0	Conveyor rotates in reverse