

Factory Control

Applied Programmable Logic Controllers

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1 Introduction

The implementation of Programmable Logic Controllers (PLCs) in factory control systems has revolutionised the way industrial processes are monitored and managed. PLCs offer a flexible and efficient solution for automating various tasks within a factory setting, providing real-time control, and monitoring capabilities. This report aims to explore the benefits and challenges of using PLCs in factory control systems, as well as to provide recommendations for optimising their performance and reliability. Through the power of PLC technology, factories can improve productivity, improve efficiency, and ensure seamless operation of their manufacturing processes.

2 Literature Review

2.1 What is a PLC?

According to [1] PLC is an abbreviation for programmable logic controller, it is a specialised industrial computer which is used to automate electromechanical processes such as monitoring and controlling outputs. PLCs are widely used in various industries such as automotive, manufacturing, and energy production. PLCs can tolerate electrical noise, humidity, and temperature changes which means they can cope in challenging conditions. They are designed to carry out certain functions in response to data from sensors and other devices, they manage output devices such as lights, motors, and valves. PLCs are essential to industrial automation because they offer a flexibility and reliable control systems for a range of uses.

2.2 Existing PLC's

Along with [2] 's research there are several types of Programmable Logic Controllers (PLCs) available in the market, each of these are designed to cater to specific industrial applications and requirements. Some common types of PLCs include:

1. **Modular PLCs:** These PLCs are made up of independent modules that are simple to add or remove, allowing the system to be tailored to the requirements of the application. Their scalability and adaptability make them suitable for complex control systems.
2. **Compact PLCs:** These PLCs have a set number of I/O points and are smaller in size. They are perfect for applications that need fewer I/O points or have restricted space.
3. **Rack-mounted PLCs:** These PLCs are intended to be installed in control cabinets or on a regular DIN rail. They are frequently used in bigger control systems where several PLCs are needed to regulate various process components.
4. **Safety PLCs:** Safety PLCs are made especially to abide by safety standards and regulations in industrial settings. To protect people and equipment, they offer advanced security functions such as self-diagnostics, redundant processing, and integrated safety features.
5. **Programmable Automation Controllers (PACs):** PACs offer improved processing power and communication choices by merging the advantages of industrial PCs and PLCs. Applications requiring complex control algorithms, fast processing, and system integration can benefit from them.

These are a few examples of the various kinds of PLCs that are offered for sale. The application's particular requirements, including the quantity of I/O points, processing speed, communication protocols, and safety considerations, determine which PLC is best.

2.2.1 Comparison of Compact, Modular & Rack-Mounted PLC's

Three Types of PLC's have been chosen to compare the capabilities of each shown in the table below.

Table 1

Type	Modular PLC	Compact PLC	Rack Mounted PLC
Applications [1]	• Manufacturing processes (assembly lines, Material Handling etc.) • Waste and water treatment systems. • Building automation (HVAC, Lighting control etc.) • Oil and gas industry (controlling drilling operations, Pipeline Monitoring, etc) • And many more	• Small Machines & Equipment (conveyor belts, packaging machines etc.) • Home Automation (control lighting, security systems etc.) • Mobile equipment (agricultural machinery, construction vehicles etc.) • And many more.	• Large Scale Manufacturing processes (automotive assembly lines, pharmaceutical production lines etc.) • Power generation and distribution (networks to monitor control systems for generators, transformers, and switchgear) • Transportation infrastructure (railway signal lighting, traffic control centres, airport baggage handling systems) • And many more.
Pros [2]	• Scalability - By adding more modules like I/O, communication, and unique function modules, modular PLCs make expansion simple this is because of its scalability, the control system can then be easily modified to accommodate evolving needs.	• Space Saving Design - Because of their small size and efficient design, compact PLCs are perfect for applications requiring a compact	• Modular Expansion – Users can add or remove modules like I/O, connectivity, and special function modules as needed with rack-mounted PLCs since they

	• Flexibility - Modular PLCs provide flexibility in the configuration and design of systems through choosing modules that match their application requirements, users can modify the PLC system to create more specialised and effective control solutions. • Future Proofing - Since they provide an effortless integration of new functionality and technologies, they become easily accessible, resulting in modular PLCs providing future-proofing capabilities. In doing this, the control system can be kept current and compliant with changing industry standards.	control system or where space is limited. • Simplified Installation - the installation procedure is usually less complicated. They are supplied as integrated units with I/O already installed, eliminating the need for extra components and wiring. • Ease Of use - Compact PLCs are ideal for people with little programming knowledge since they are simple to operate and program. Programming tools and user-friendly software interfaces tend to be included.	offer modular expansion options. The control system can be easily tailored to meet individual needs because to its scalability. • Easy maintenance – When a rack-mounted PLC system malfunctions, it is simple to replace individual modules, which reduces downtime and simplifies maintenance processes. • Integration with other systems - Rack-mounted PLCs can easily integrate with other control systems, devices, and networks, allowing for seamless communication and interoperability in complex industrial environments.
Cons [2]	• Complexity - PLC systems can become difficult due to their modular design regarding the nature of	• Limited Expansion - The small PLC might not be able to adapt	• Space Requirements – Physical space requirements

	the PLC systems they deal with, particularly in larger installations with several modules. This tends to require additional knowledge and effort needed for the design, setup, and programming of a modular PLC system. • Compatibility issues - Compatibility problems and system integration difficulties may develop when modules from different manufacturers are used together or when incompatible modules are used. Users must make sure that every module is compatible and functions well as a whole. • Space Requirements - Compared to fixed PLC systems, modular PLC systems may require more physical space, particularly if numerous modules are being used. This could be a drawback in situations where compactness counts or if there is a shortage of space.	in the future if more I/O or functionality becomes necessary. • Programming Limitations - The memory and programming capacities of compact PLCs may be restricted. Compact PLCs may not be able to handle as big programs or complex control algorithms. • Scalability Challenges - It can be difficult to upgrade a compact PLC system to meet changing requirements. If expansion is required, users could have to replace the entire unit with a larger PLC, which would increase expenses.	for rack-mounted PLCs can be big, particularly if numerous racks are being used. This could be a drawback in situations where compactness is crucial or if there is a shortage of space. • Cost – the initial cost of a rack-mounted PLC system may be higher. Rack, chassis, module, and accessory costs can mount up, particularly in the case of extensive installations. • Installation and wiring complexity - the installation and wiring of these systems can be more complicated. Installation and maintenance would need to be completed effectively, careful organisation and preparation are needed.
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Reliability [3]	HIGH- Modular PLCs are typically regarded as having a high level of reliability allowing customers to customise their system with different input/output modules suited to their unique application requirements, modular PLCs provide flexibility and scalability. These PLCs are made to operate dependably in settings including industrial automation.	HIGH - Compact PLCs offer strong performance, stability, and durability to satisfy the demanding needs of industrial automation applications. They are designed to withstand harsh environmental factors like humidity, dust, temperature swings, and vibrations that are common in industrial settings.	HIGH - Rack-mounted PLCs are seen as having a high level of reliability, like modular and compact PLCs. Rack-mounted PLCs offer an expandable and modular solution for industrial automation applications by being made to fit into typical equipment racks.
Typical Cost	Medium - high	Medium - Low	Medium – High

Modular PLC Conclusion

In conclusion, modular PLCs have disadvantages and advantages, including complexity, compatibility, space needs, cost, and reliability, scalability, flexibility, and ease of maintenance. Regarding industrial automation purposes, users should carefully assess their requirements and weigh the advantages and disadvantages of modular versus fixed PLC systems.

Compact PLC Conclusion

In conclusion, Compact PLCs provide benefits including dependability, affordability, simplicity of installation, user-friendliness, and space-saving design. They do, however, have restrictions on their capacity for growth, adaptability, scalability, I/O choices, and programming. Regarding choosing a compact PLC for their control application, users should weigh these advantages and disadvantages.

Rack Mounted PLC Conclusion

To sum up, the benefits of rack-mounted PLCs include easy maintenance, high I/O capacity, flexibility, modular extension, and integration possibilities. They do, however, bring difficulties in terms of cost, compatibility, space needs, and installation complexity. For industrial automation purposes, users should assess their unique requirements and weigh the advantages and disadvantages of each before selecting a rack-mounted PLC.

Overall Conclusion

In conclusion, the choice between modular, compact, and rack-mounted PLCs depends on the specific requirements of the automation system. Modular PLCs offer flexibility but come at a higher cost, compact PLCs are cost-effective but may have limitations, and rack-mounted PLCs are suitable for large applications but can be more expensive. It is important to consider the specific needs of the application before selecting the most appropriate PLC type.

3 Design

The design for the system has been based around a modular plc system, this is to ensure flexibility for future expansions within the system to minimize the future costs of adaption. The design was completed by using siemens TIA to complete the ladder logic and Factory IO to simulate the design.

4 Factory I/O

Overall System View

The figure (1&2) below illustrates the overview of the system, safety measures have been implemented to ensure complete security is in place when the system is operating. A gated fence has been placed around the system to ensure no unauthorised personnel can enter when the system is live, also additional barriers have been placed around the conveyors to add safety measure for when engineers are inside the gated area.

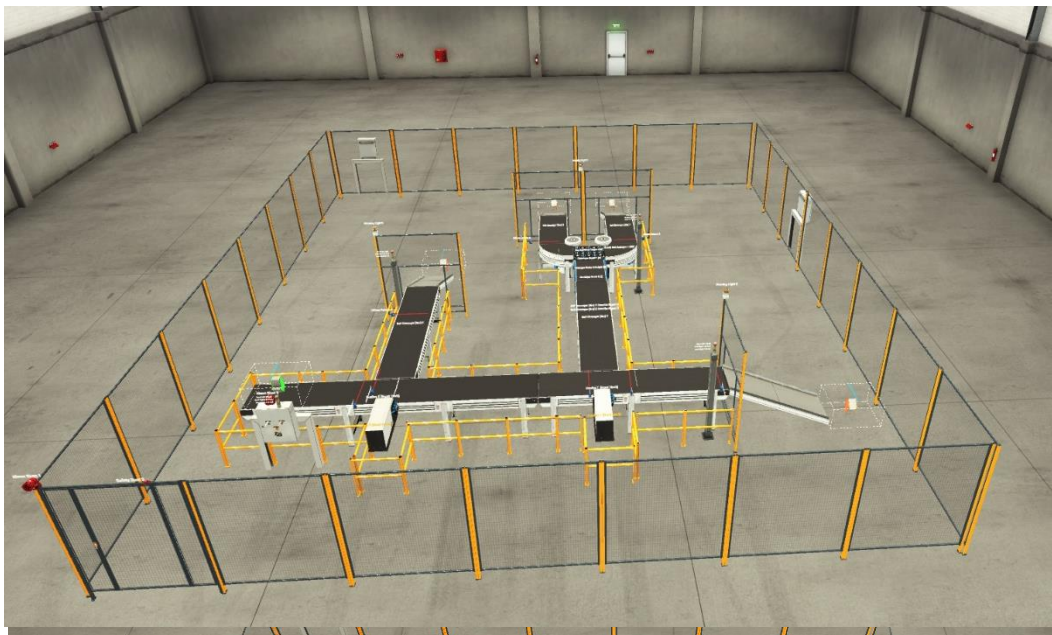


Figure 1 Overall View

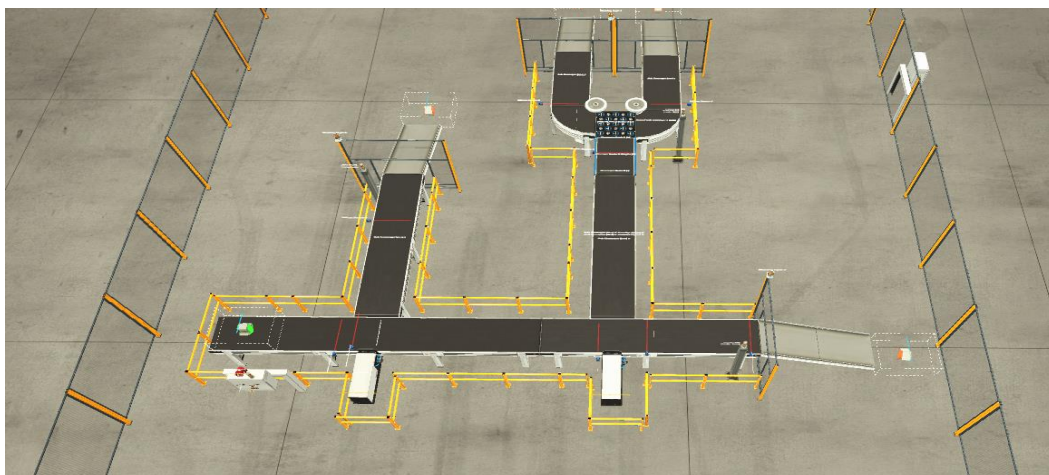


Figure 2 Overall View

Local Control Panel

The figure below demonstrates the local control panel which has a start & stop button, and emergency stop button and the weighing scale digital screen. The control panel also has the main stack light positioned on top with the alarm siren next to it which will sound when an alarm has been activated.



Figure 3 Local Control Panel

Safety door & Operation Siren

Figure 4 below illustrates the entrance into the system which has a limit switch positioned on top, this will stop the system from operating if someone has managed to gain access into the gated area. The siren that sounds when the system is starting is also positioned on top of the gate.



Figure 4 Safety Door & Start Siren

Large Box System

Figure 5 below demonstrates the large box system, starting with the diffuse sensor which differentiates between the large boxes compared to the others, the pusher, count down diffuse sensor, the alarm beacon, and the large box system stack light.



Figure 5 Large Box System

Medium Box System

Figure 6 & 7 illustrates the medium box system which has the diffuse sensors, the scale conveyor, the sorter, two curved conveyors, medium box stack light and the medium alarm beacon.

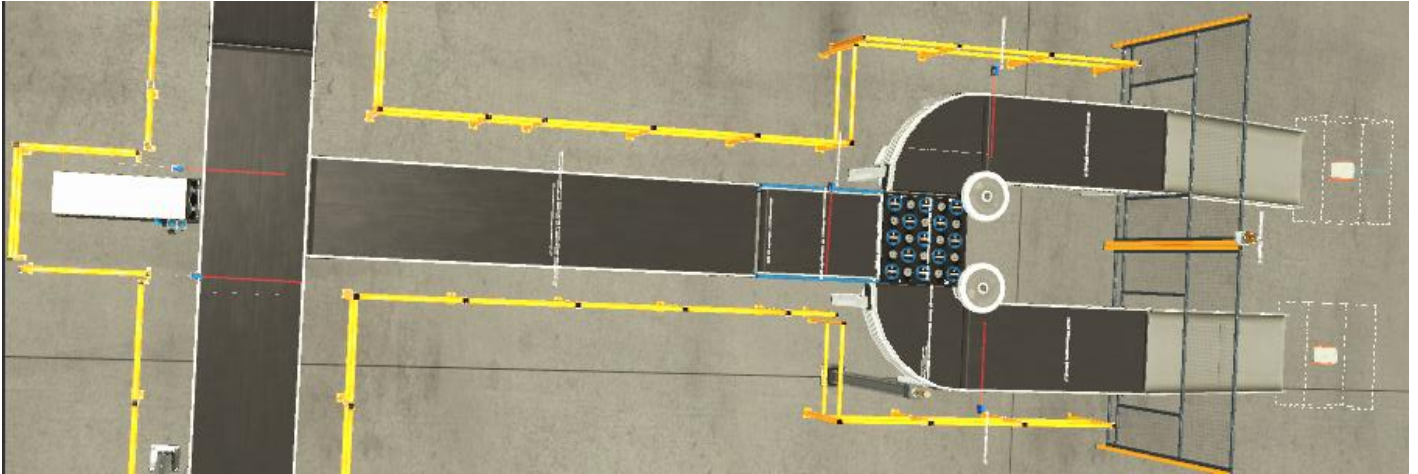


Figure 6 Overall Medium System

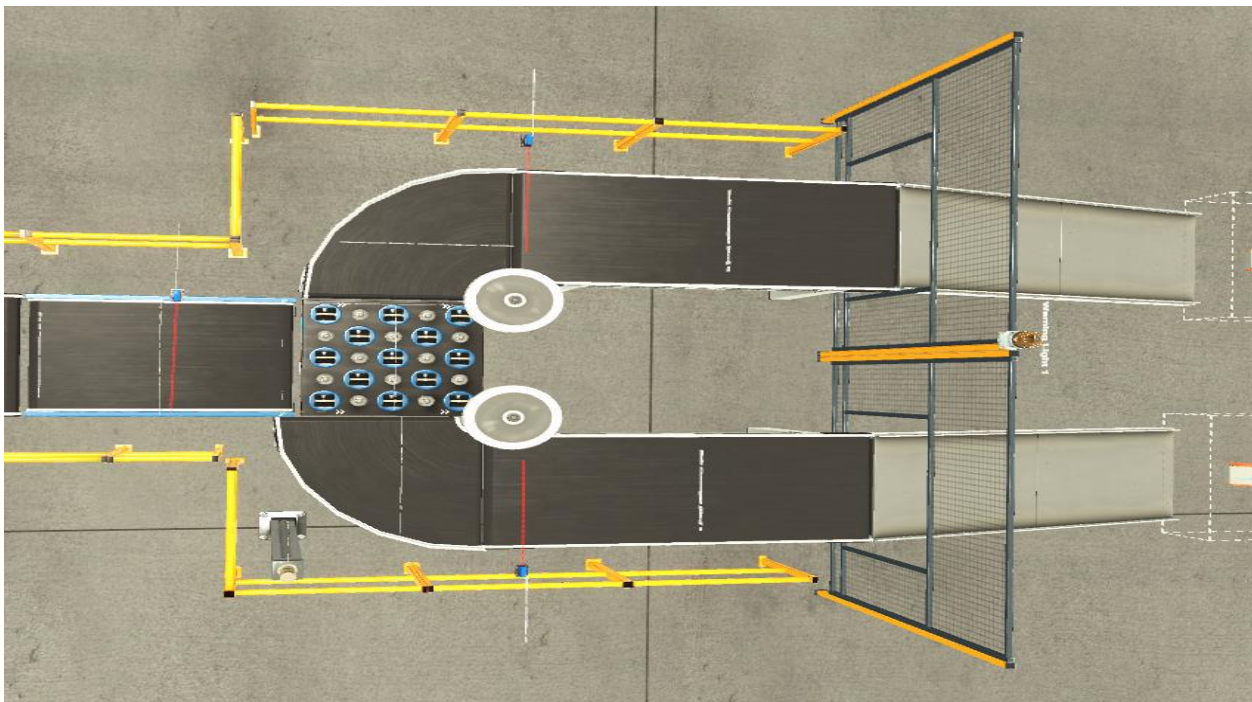


Figure 7 Weighing scale and sorter overview.

Small Box System

Figure 8 below shows the small box system, this starts after the medium box pusher, the count up and down diffuse sensors are shown also the small box system stack light and alarm beacon.

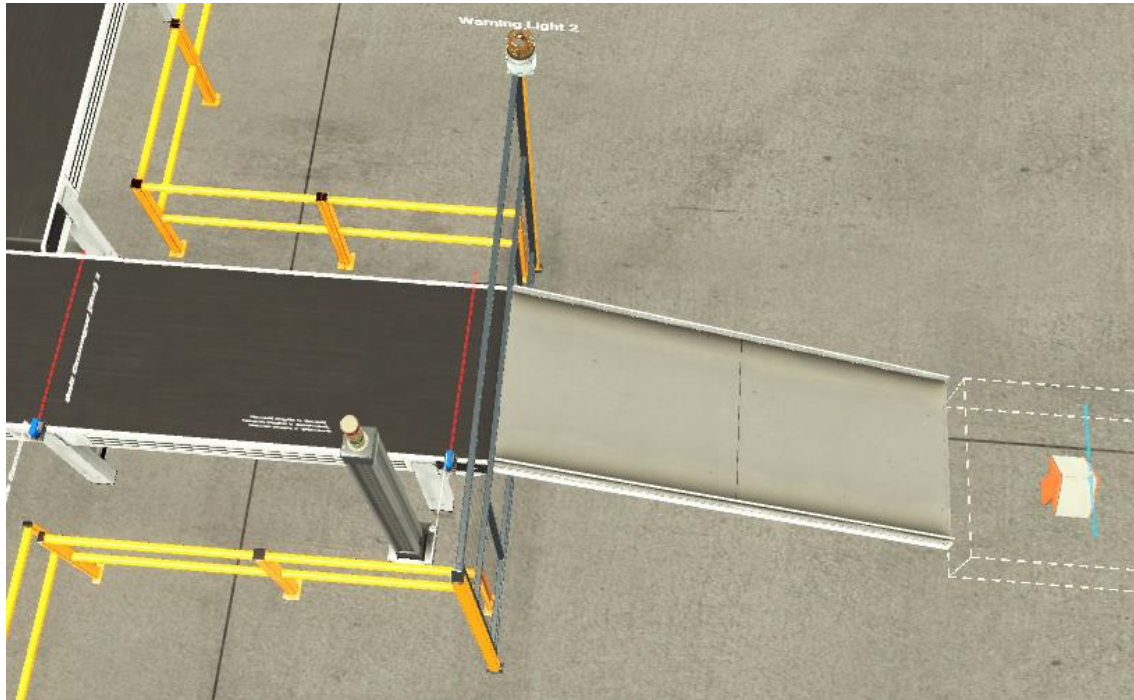


Figure 8 Small Box system

External Emergency stops

Figures 9&10 illustrates the external emergency stops which are safety features, implemented so any personnel can stop the system in an emergency situation.



Figure 10 External E.Stop 1



Figure 9 External E.Stop 2

Factory IO Drivers

The figure below illustrates the driver of factory IO and all its assigned components.

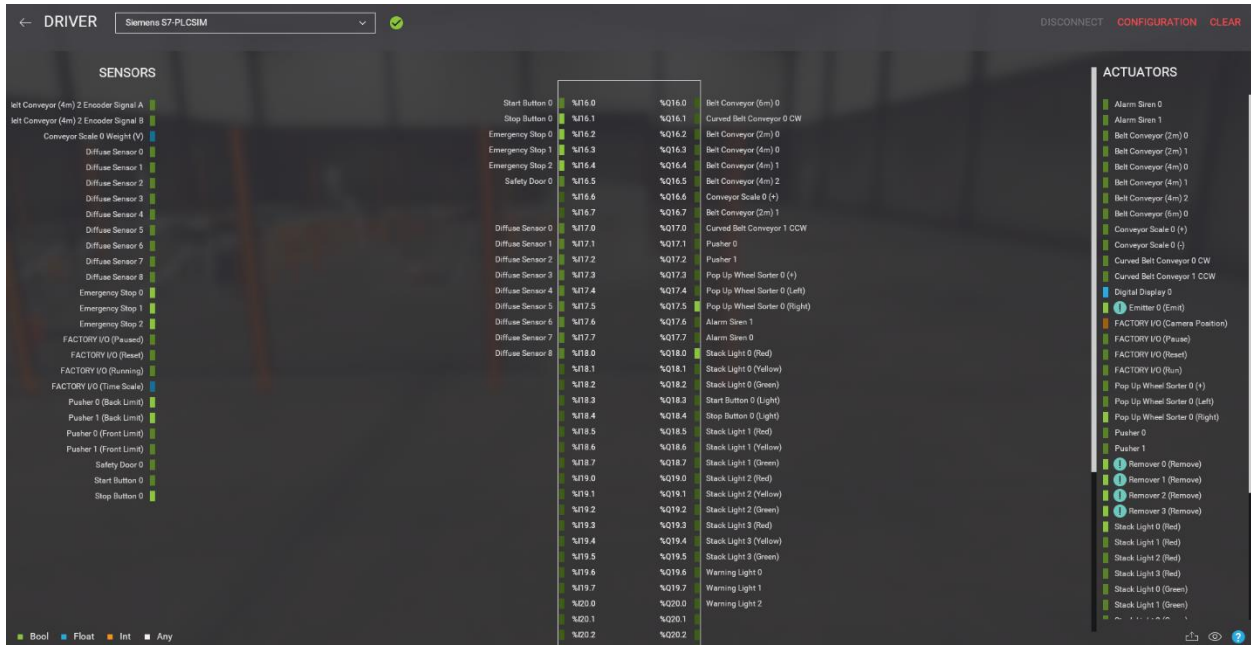


Figure 11 Factory IO Driver

5 PLC Tags

The following figures 11,12,13&14 illustrates the 93 tags that has been set these will determine the identifications of the inputs, outputs and memories within the system, these addresses will match with the factory IO addresses to ensure the systems will work effectively.

PLC tags									
	Name	Tag table	Data type	Address	Retain	Acces...	Writa...	Visibl...	Comment
1	start	Default tag table	Bool	%I16.0	☐	☒	☒	☒	
2	stop	Default tag table	Bool	%I16.1	☐	☒	☒	☒	
3	0 Emergency stop Main Panel	Default tag table	Bool	%I16.2	☐	☒	☒	☒	
4	Emergency Stop 1	Default tag table	Bool	%I16.3	☐	☒	☒	☒	
5	Emergency Stop 2	Default tag table	Bool	%I16.4	☐	☒	☒	☒	
6	Safety Door	Default tag table	Bool	%I16.5	☐	☒	☒	☒	
7	difuse sensor0	Default tag table	Bool	%I17.0	☐	☒	☒	☒	
8	difuse sensor1	Default tag table	Bool	%I17.1	☐	☒	☒	☒	
9	difuse sensor2	Default tag table	Bool	%I17.2	☐	☒	☒	☒	
10	difuse sensor3	Default tag table	Bool	%I17.3	☐	☒	☒	☒	scale convey.
11	difuse sensor 4	Default tag table	Bool	%I17.4	☐	☒	☒	☒	
12	difuse sensor 5	Default tag table	Bool	%I17.5	☐	☒	☒	☒	
13	difuse sensor 6	Default tag table	Bool	%I17.6	☐	☒	☒	☒	
14	difuse sensor 7	Default tag table	Bool	%I17.7	☐	☒	☒	☒	
15	difuse sensor 8	Default tag table	Bool	%I18.0	☐	☒	☒	☒	
16	difuse sensor 9	Default tag table	Bool	%I18.1	☐	☒	☒	☒	
17	scale0 weight	Default tag table	Real	%ID30	☐	☒	☒	☒	
18	conveyor	Default tag table	Bool	%Q16.0	☐	☒	☒	☒	
19	curved conveyor	Default tag table	Bool	%Q16.1	☐	☒	☒	☒	
20	conveyor2	Default tag table	Bool	%Q16.2	☐	☒	☒	☒	
21	conveyor3	Default tag table	Bool	%Q16.3	☐	☒	☒	☒	
22	conveyor4	Default tag table	Bool	%Q16.4	☐	☒	☒	☒	
23	conveyor5	Default tag table	Bool	%Q16.5	☐	☒	☒	☒	
24	scale conveyor +	Default tag table	Bool	%Q16.6	☐	☒	☒	☒	
25	conveyor 2 m (1)	Default tag table	Bool	%Q16.7	☐	☒	☒	☒	
26	curved conveyor 2	Default tag table	Bool	%Q17.0	☐	☒	☒	☒	
27	pusher1	Default tag table	Bool	%Q17.1	☐	☒	☒	☒	
28	pusher2	Default tag table	Bool	%Q17.2	☐	☒	☒	☒	
29	pop-up start	Default tag table	Bool	%Q17.3	☐	☒	☒	☒	

Figure 12 PLC Tags

PLC tags									
	Name	Tag table	Data type	Address ▲	Retain	Acces...	Writa...	Visibl...	Comment
29	pop-up start	Default tag table	Bool	%Q17.3	☐	☒	☒	☒	
30	pop-up left	Default tag table	Bool	%Q17.4	☐	☒	☒	☒	
31	pop-up right	Default tag table	Bool	%Q17.5	☐	☒	☒	☒	
32	siren 2	Default tag table	Bool	%Q17.6	☐	☒	☒	☒	
33	siren	Default tag table	Bool	%Q17.7	☐	☒	☒	☒	
34	Stack Light Red	Default tag table	Bool	%Q18.0	☐	☒	☒	☒	
35	Stack Light Yellow	Default tag table	Bool	%Q18.1	☐	☒	☒	☒	
36	Stack Light Green	Default tag table	Bool	%Q18.2	☐	☒	☒	☒	
37	Start Button	Default tag table	Bool	%Q18.3	☐	☒	☒	☒	
38	Stop Button	Default tag table	Bool	%Q18.4	☐	☒	☒	☒	
39	1 Stack Light Red (Small)	Default tag table	Bool	%Q18.5	☐	☒	☒	☒	
40	1 Stack Light Yellow (Small)	Default tag table	Bool	%Q18.6	☐	☒	☒	☒	
41	1 Stack Light Green (Small)	Default tag table	Bool	%Q18.7	☐	☒	☒	☒	
42	2 Stack Light Red (Medium)	Default tag table	Bool	%Q19.0	☐	☒	☒	☒	
43	2 Stack Light Yellow (Medium)	Default tag table	Bool	%Q19.1	☐	☒	☒	☒	
44	2 Stack Light Green (Medium)	Default tag table	Bool	%Q19.2	☐	☒	☒	☒	
45	3 Stack Light Red (Large)	Default tag table	Bool	%Q19.3	☐	☒	☒	☒	
46	3 Stack Light Yellow (Large)	Default tag table	Bool	%Q19.4	☐	☒	☒	☒	
47	3 Stack Light Green (Large)	Default tag table	Bool	%Q19.5	☐	☒	☒	☒	
48	Warning Light 0 (Large)	Default tag table	Bool	%Q19.6	☐	☒	☒	☒	
49	Warning Light 1 (Medium)	Default tag table	Bool	%Q19.7	☐	☒	☒	☒	
50	Warning Light 2 (Small)	Default tag table	Bool	%Q20.0	☐	☒	☒	☒	
51	display	Default tag table	Real	%QD30	☐	☒	☒	☒	
52	Large Box Warning	Default tag table	UInt	%MW50	☐	☒	☒	☒	
53	Medium Box Warning	Default tag table	UInt	%MW52	☐	☒	☒	☒	
54	Small Box Warning	Default tag table	UInt	%MW54	☐	☒	☒	☒	
55	Total Box Warning	Default tag table	UInt	%MW56	☐	☒	☒	☒	
56	Large Box Alarm	Default tag table	UInt	%MW58	☐	☒	☒	☒	
57	Medium Box Alarm	Default tag table	UInt	%MW60	☐	☒	☒	☒	

Figure 13 PLC Tags

57		Medium Box Alarm	Default tag table	UInt	%MW60	☐	☒	☒	☒	
58		Small Box Alarm	Default tag table	UInt	%MW62	☐	☒	☒	☒	
59		Total Box Alarm	Default tag table	UInt	%MW64	☐	☒	☒	☒	
60		operate	Default tag table	Bool	%M100.0	☐	☒	☒	☒	
61		counter_reset	Default tag table	Bool	%M100.1	☐	☒	☒	☒	
62		hmi_estop	Default tag table	Bool	%M100.2	☐	☒	☒	☒	
63		scale conv flag	Default tag table	Bool	%M100.3	☐	☒	☒	☒	
64		Warning Reset	Default tag table	Bool	%M100.4	☐	☒	☒	☒	
65		Error Reset	Default tag table	Bool	%M100.5	☐	☒	☒	☒	
66		conveyor 5 flag	Default tag table	Bool	%M100.6	☐	☒	☒	☒	
67		Weight Reset	Default tag table	Bool	%M100.7	☐	☒	☒	☒	
68		large_box_counter	Default tag table	UInt	%MW102	☐	☒	☒	☒	
69		Medium_Box>4.5kg _Counter	Default tag table	UInt	%MW104	☐	☒	☒	☒	
70		Small Box Counter	Default tag table	UInt	%MW106	☐	☒	☒	☒	
71		Medium box <4.4kg_counter	Default tag table	UInt	%MW108	☐	☒	☒	☒	
72		TotalBox Error Count	Default tag table	UInt	%MW110	☐	☒	☒	☒	
73		Large Box Error Count	Default tag table	UInt	%MW112	☐	☒	☒	☒	
74		Medium Box Error Count	Default tag table	UInt	%MW114	☐	☒	☒	☒	
75		Small Box Error Count	Default tag table	UInt	%MW116	☐	☒	☒	☒	
76		Total_counter	Default tag table	UInt	%MW202	☐	☒	☒	☒	
77		warnings	Default tag table	Byte	%MB300	☐	☒	☒	☒	
78		warning1 (Large Box)	Default tag table	Bool	%M300.1	☐	☒	☒	☒	
79		warning2 (Medium Box)	Default tag table	Bool	%M300.2	☐	☒	☒	☒	
80		warning3 (Small Box)	Default tag table	Bool	%M300.3	☐	☒	☒	☒	
81		Warning 4 (Total Box)	Default tag table	Bool	%M300.4	☐	☒	☒	☒	
82		alarms	Default tag table	Byte	%MB301	☐	☒	☒	☒	
83		E.Stop	Default tag table	Bool	%M301.0	☐	☒	☒	☒	
84		Alarm 1(Large Box)	Default tag table	Bool	%M301.2	☐	☒	☒	☒	
85		Alarm 2(Medium Box)	Default tag table	Bool	%M301.3	☐	☒	☒	☒	

Figure 14 PLC Tags

85		Alarm 2(Medium Box)	Default tag table	Bool	%M301.3	☐	☒	☒	☒	
86		Alarm 3(Small Box)	Default tag table	Bool	%M301.4	☐	☒	☒	☒	
87		Alarm 4 (Total Box)	Default tag table	Bool	%M301.5	☐	☒	☒	☒	
88		Alarm 5 (Medium Weight Error)	Default tag table	Bool	%M301.6	☐	☒	☒	☒	
89		alarm_master	Default tag table	Bool	%M301.7	☐	☒	☒	☒	
90		warning flag	Default tag table	Bool	%M302.0	☐	☒	☒	☒	
91		alarm flag	Default tag table	Bool	%M302.1	☐	☒	☒	☒	
92		Default	Default tag table	Bool	%M302.2	☐	☒	☒	☒	
93		weight	Default tag table	Real	%MD400	☐	☒	☒	☒	

Figure 15 PLC Tags

6 PLC Ladder Logic

Network 1

Network 1 is used to enable the Siemens TIA software to communicate with the factory I/O Software.

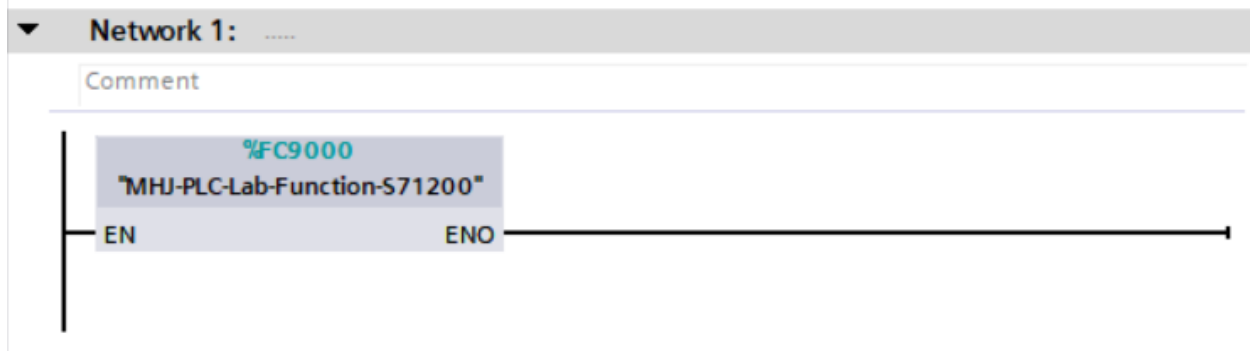


Figure 16 Network 1

Network 2

Network 2 consists of the start up operation, this operation starts with the physical start button which is situated on the local control panel or on the root screen of the HMI which are both connected in parallel, these will be normally open contacts, the operation system will then flow through a number of features that can stop the system, until it reaches the memory bit set as an output which is named 'Operate'. The operate memory bit can then be used throughout the ladder logic to start other networks. To stop the operation for general maintenance or for a shut down the stop button on the local control panel can be used which will open causing an open circuit, the HMI Stop Button can also be used. The operation system also includes many safety stop features which include an emergency stop on the local control panel, two emergency stops are also included which are situated around the external fence line of the factory, this adds a great safety feature which can be used by non-authorised persons in case an emergency arose. The last safety feature is the safety gate, this will stop all operation if the gate is opened, all safety features contacts will be opened when activated which will stop the system. The master alarm flag is also in series with the operation network which will then stop the system in any state of error.

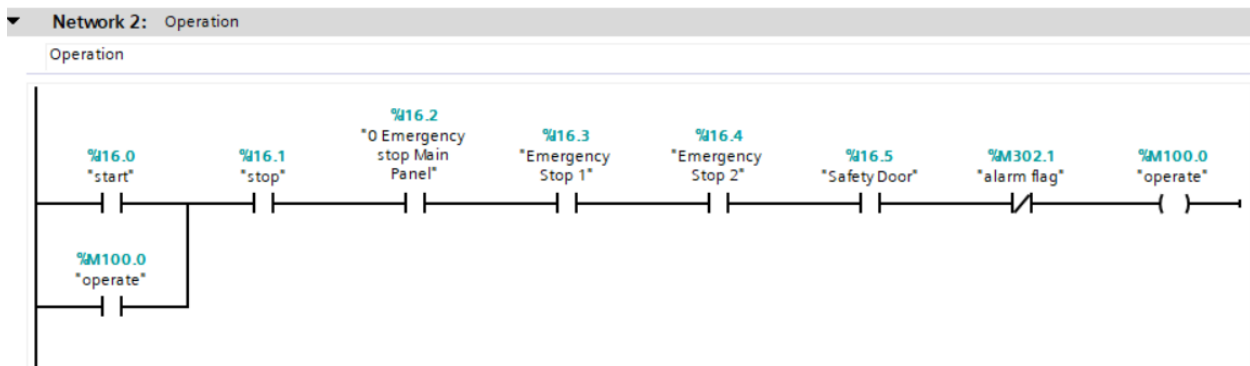


Figure 17 Network 2

Network 3

Network 3 is the network that starts up the whole system when the operation network is completed. The network will start one by one starting up each conveyor, this is completed by using timers which will all flow one after another to ensure the startup current is not too high for the system. Firstly the siren has a generate pulse timer (a TP timer), this will generate a pulse for the time set, the conveyors will all be set on by using a delayed on timer (TON timer), this allows the system to start up each part of the at separate times, as explained above this will stop a big start up current needed when starting up the system. The scale conveyor and conveyor 5 which is part of the medium box system, will use both types of timers, the output to these will be a memory byte, this is used since an output can only be used once, the flag for each conveyors will be set which allows the individual networks to operate accordingly to its own logic since the operation which differs when weighing the medium boxes, this will be explained further into the logic.

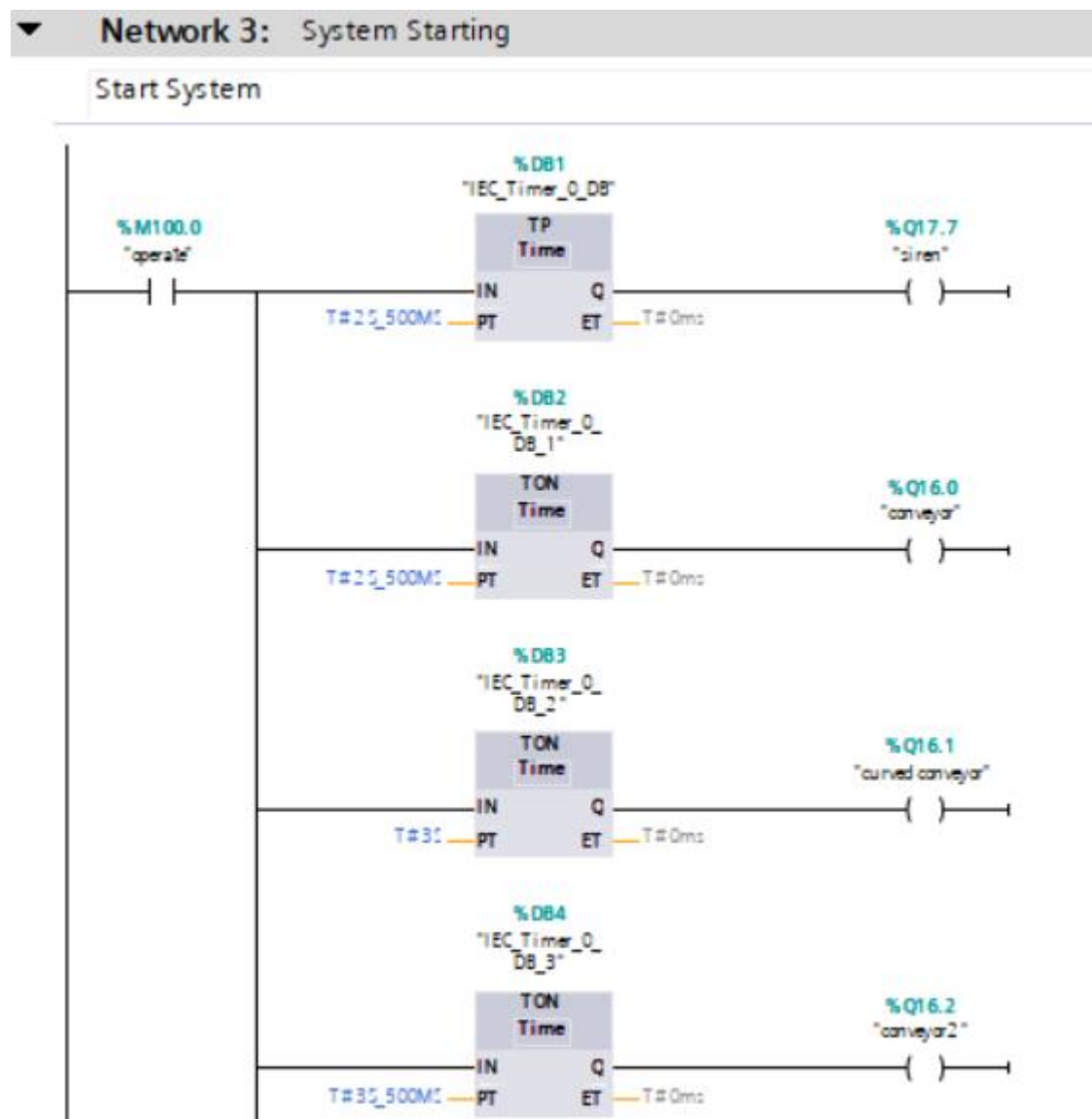


Figure 18 Network 3

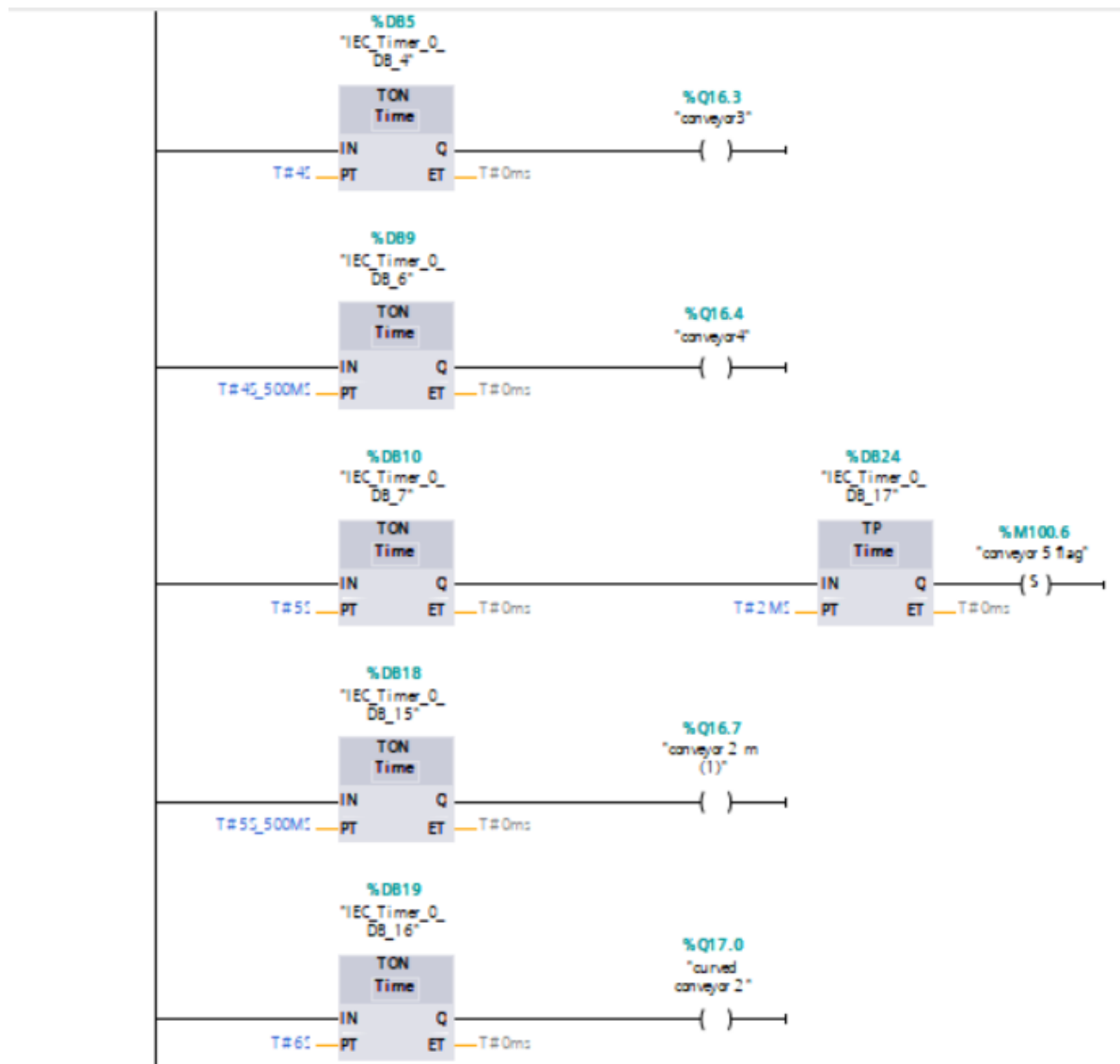


Figure 20 Network 3

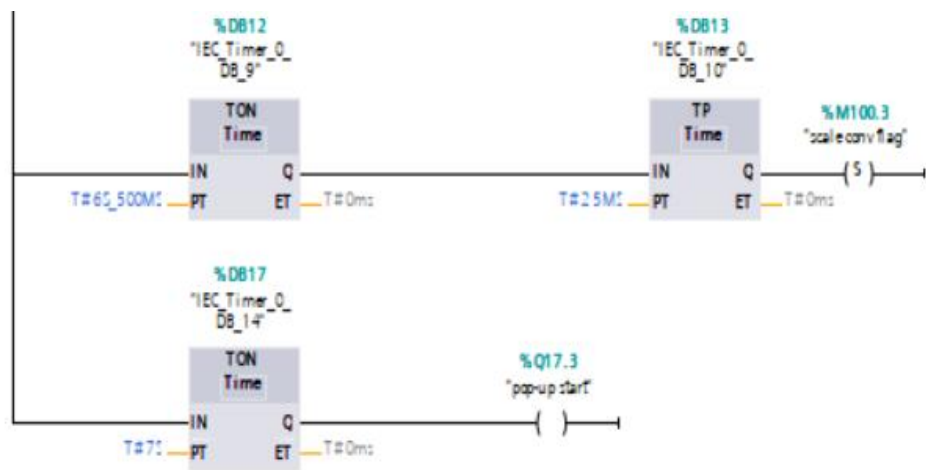


Figure 19 Network 3

Network 4

Network 4 operates the main stack lights for the system, which is situated on the local control panel and the HMI Screen, the red light is operated when the system is not running by using the 'operate' memory byte when it is in a normally closed state, the yellow light represents a fault in the system and is operated by 'siren 2' which is explained in the alarm network of the system, the green light is operated by the memory byte for 'operate' also but when the system is running.

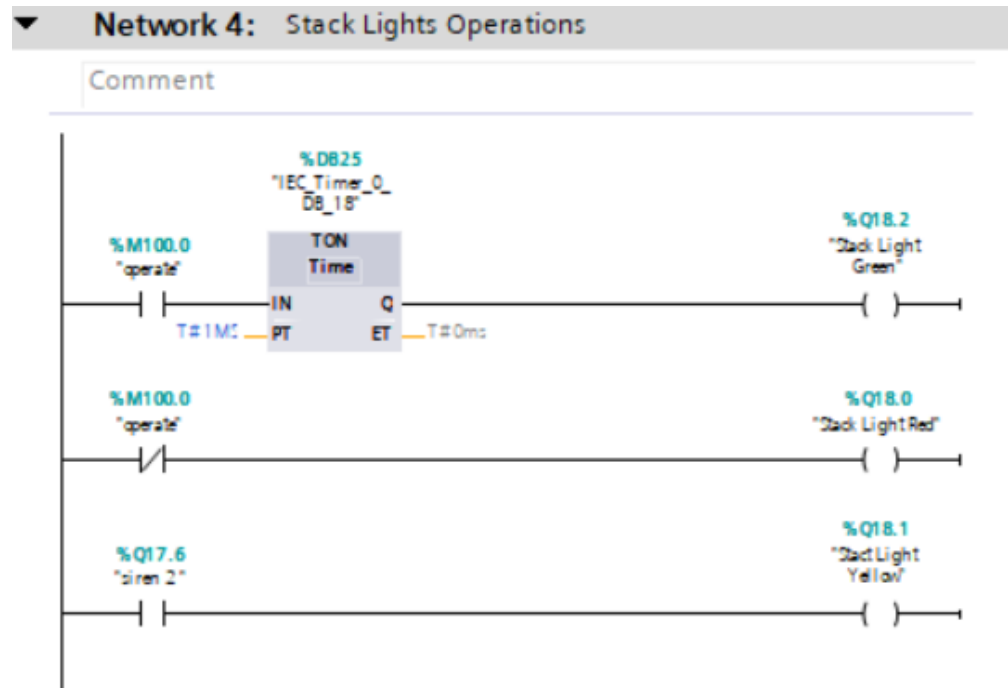


Figure 21 Network 4

Network 5, 6 & 7

The following three networks operate all the individual stack lights for each system. The red light is operated when an alarm memory byte for each of the systems is operated, the yellow light for each system is operated when the warning memory byte for each system is operated and the green light is operated for each system when the main conveyor for each system is operating meaning the system is energised. This will allow the users to visually see how each system is working and easily indicate if and where there is an issue on each system if there is one.

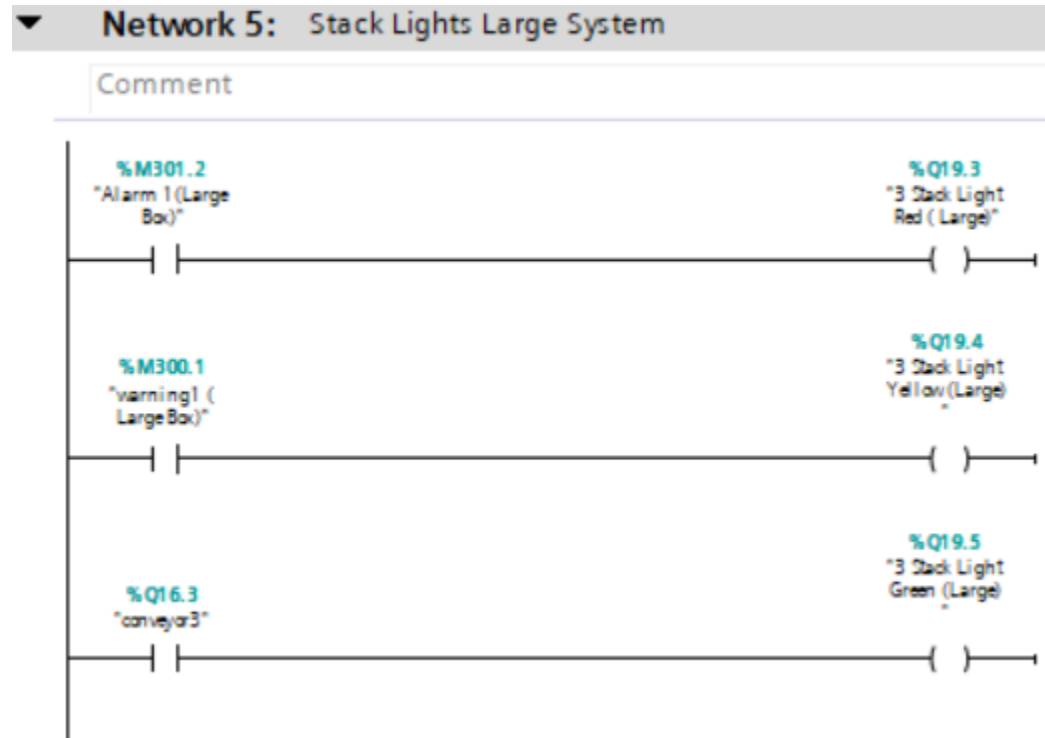


Figure 22 Network 5

▼ Network 6: Stack Lights Medium System

Comment

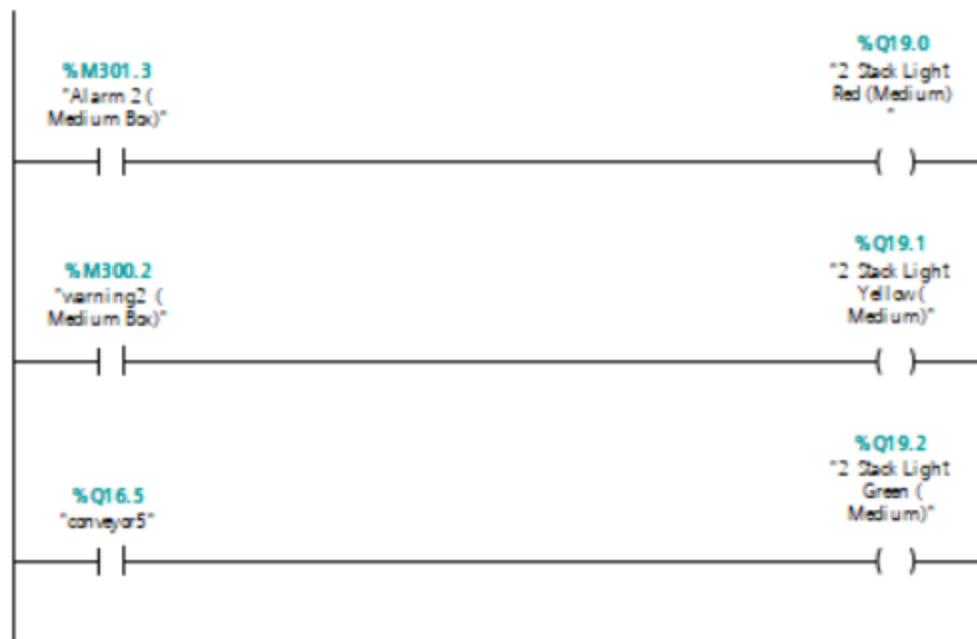


Figure 23 Network 6

▼ Network 7: Stack Lights Small System

Comment

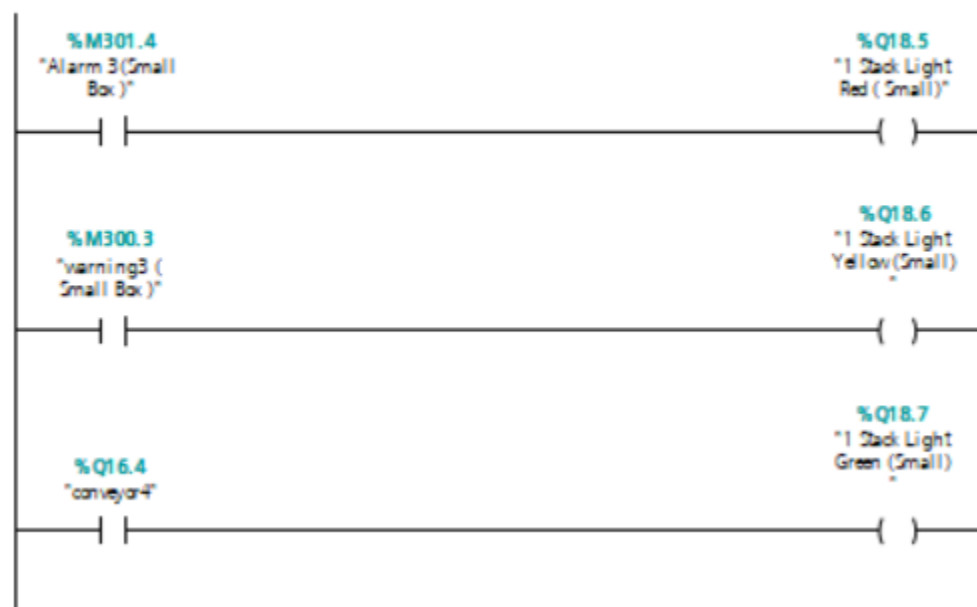


Figure 24 Network 7

Network 8

Network 8 operates the alarm beacons for each circuit, these will be a good additional feature which will help engineers, or any other external personnel identify if there is an issue with the system and identify where the error is. This system is used by beacons as the outputs, the alarm memory byte for each system will initiate the beacons to when the alarm has been activated.

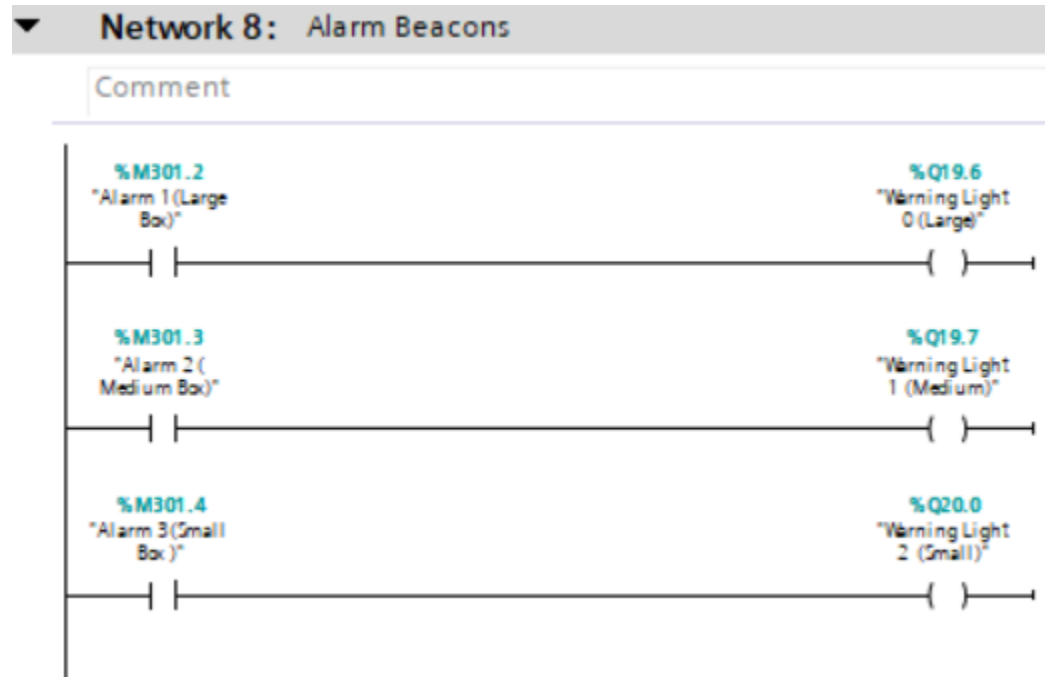


Figure 25 Network 8

Network 9

Network 9 operates the pusher circuits for the large and medium box system, this is operated by diffuse sensors set at certain heights which will activate when the correct box size has passed it, following on the TON timer is set for the correct time it takes each box to pass the sensor to the centre of the pusher which then operates the pusher resulting in the chosen box size to be moved to its individual system.

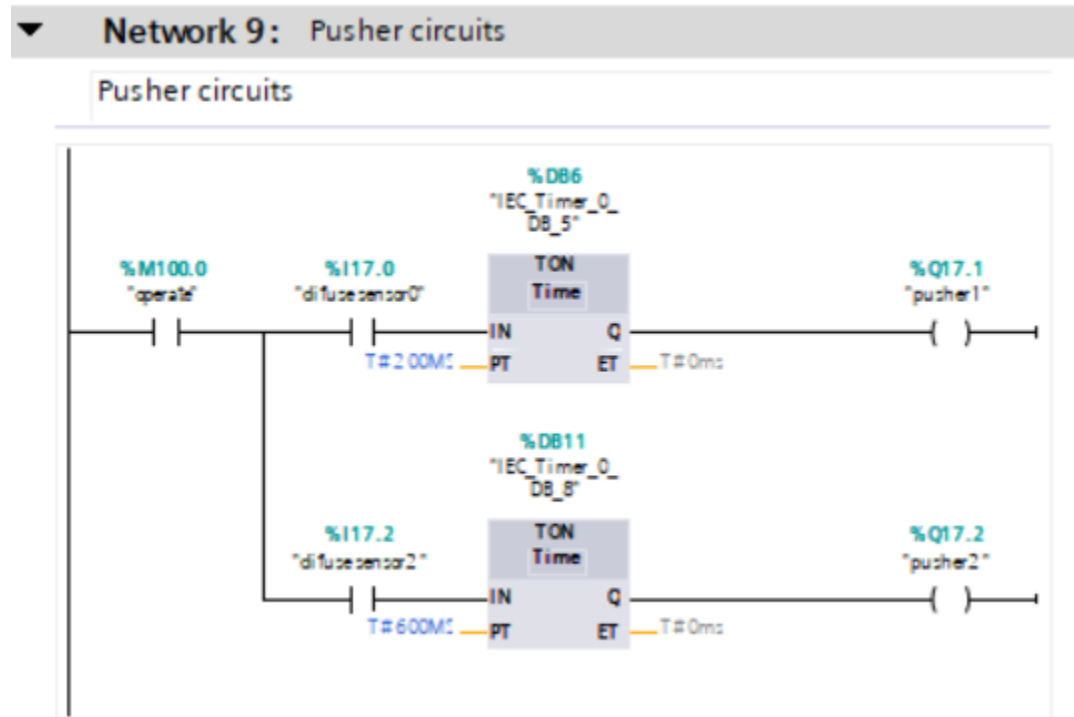


Figure 26 Network 9

Network 10

Network 10 supports the functions of the counter circuits, there are five counters within the network, the first counter is to count the number of large boxes, this is completed by the counter counting up when the large box pusher is activated which then the counter will convert the input to an unsigned integer (UINT) which then is sent to the large box counter memory write, this memory write is used in following networks to store the value and display on the HMI. The second and third counters, count the number of medium boxes, these are counted using diffuse sensor inputs, by using the diffuse sensors after the boxes have been split up using the weigh scale conveyor and sorter the memory can store the number of medium boxes and display on the HMI screen also. The third counter counts the small boxes, this also uses the diffuse sensor as an input on the small box system to count the number of small boxes that have been placed on the conveyors. The last counter is the total box counter, the input used is the initial diffuse sensor at the start where the boxes enter the system this can be illustrated on the HMI screen to allow the users to see how many boxes in total have entered the system. All of these counters have a counter reset memory byte which can be programmed to a reset button on the HMI, when activated all counters will then return to the value 0.

▼ Network 10: Counters

Comment

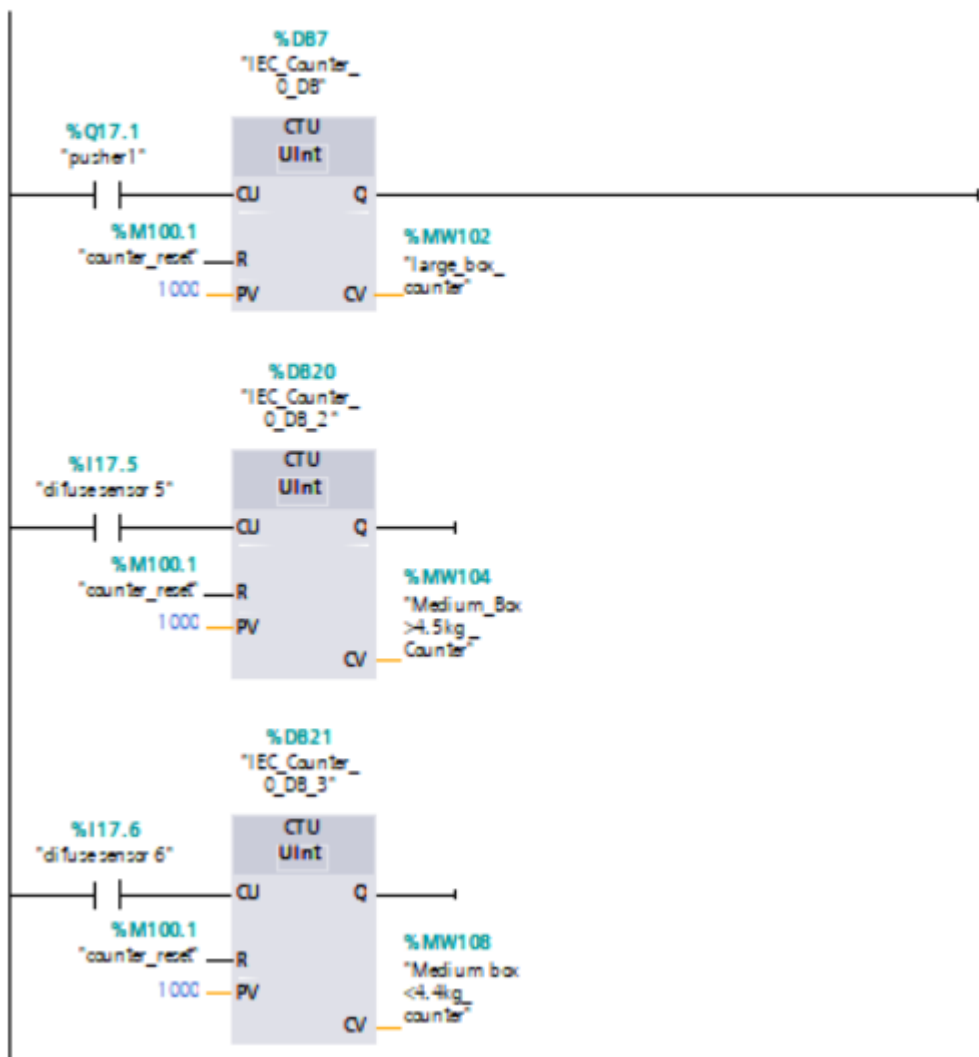


Figure 27 Network 10

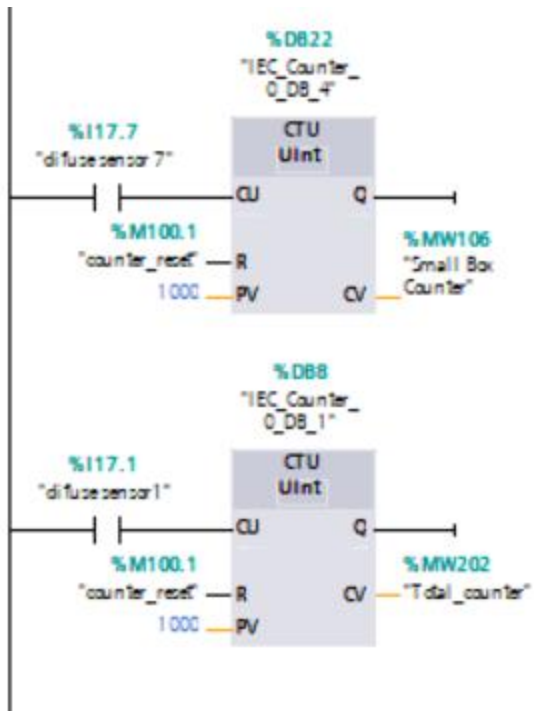


Figure 28 Network 10

Network 11

Network 11 controls the error counts for each circuit which can aid in operating warnings and alarms, this is completed using CTUD (count up and down) counter, these counters similar to the overall counters will use pushers for the medium and large box systems to count up when activated and count down on individual system diffuse sensors, the difference between these values will then be output to a memory write for each circuit which can then be programmed to display on the HMI screen. The small box system will use its unique diffuse sensor to count up and down which will the also result in the difference being stored in the memory write that is assigned to its Individual tag. Each of these counters has an error reset memory byte which is programmed to the HMI screen to enable the user to reset the error count when needed. The total error counter is designed with a calculation function, this uses the three error counts and adds each of the values up to give a total sum of all errors in the overall system.

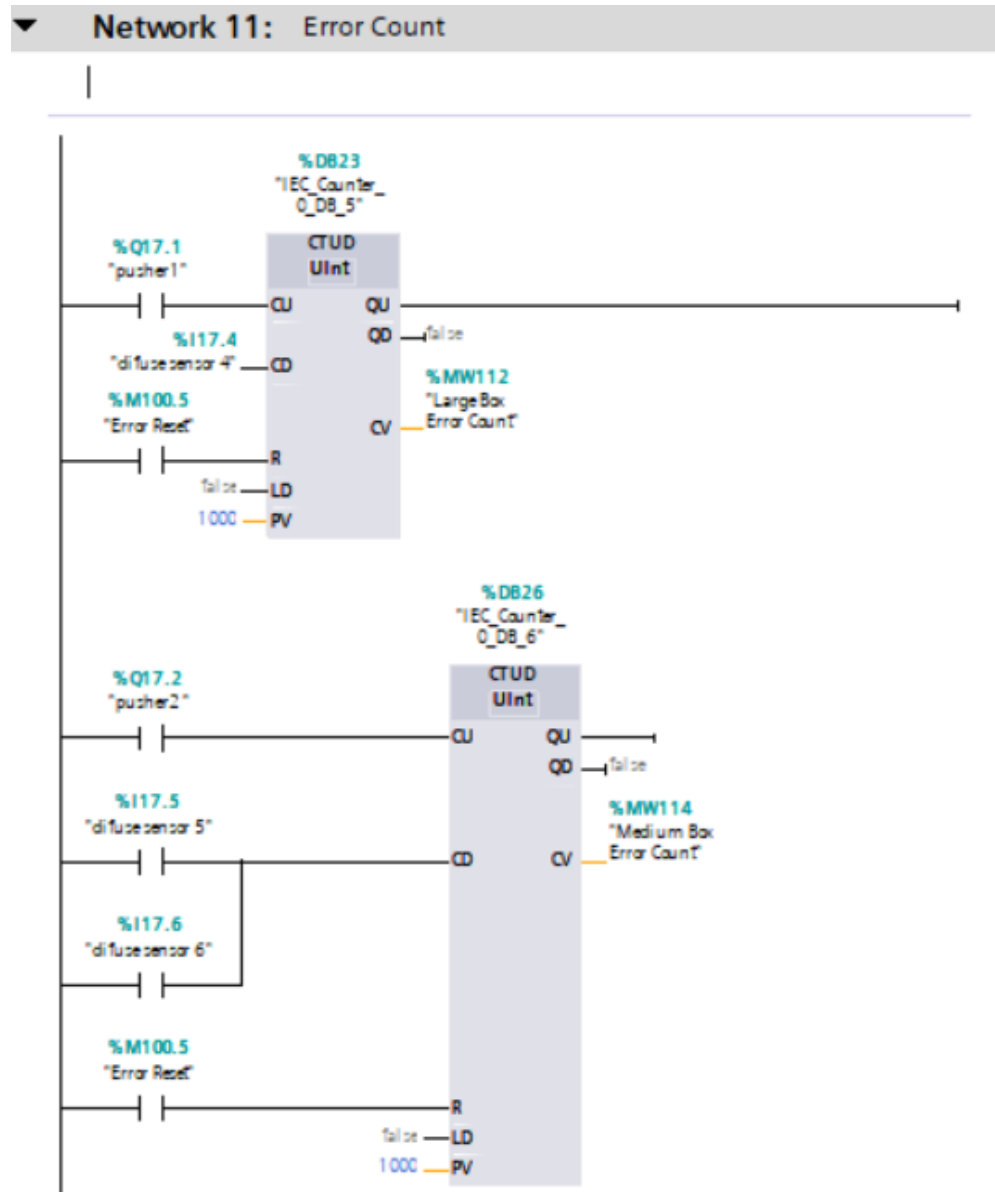


Figure 29 Network 11

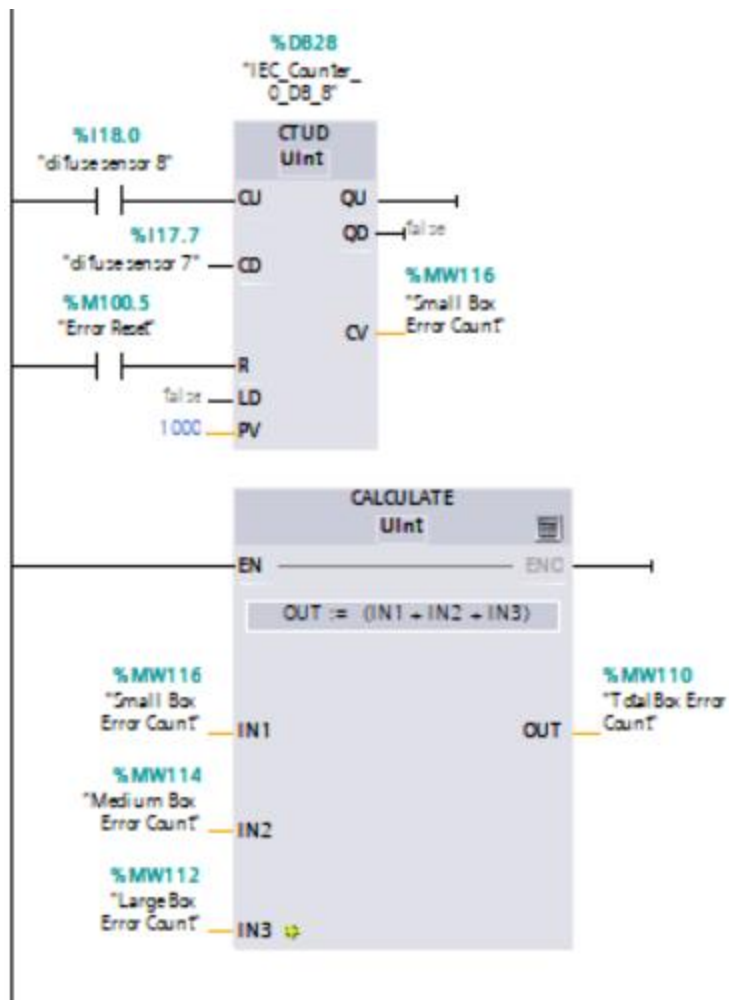


Figure 30 Network 11

Network 12

Network 12 is used for the master warnings and alarms, this is used when any of the alarms or warnings of each system has been activated, the main warning byte will then operate the warning flag output. The main alarm byte is activated when any alarm of a system within that byte has been activated, when the main alarm byte is activated the master alarm output and alarm flag is activated, it will also energise a pulse timer which then generates a pulse to activate siren two, this will then initiate the siren indicating that the system has stopped and there is a fault in the system.

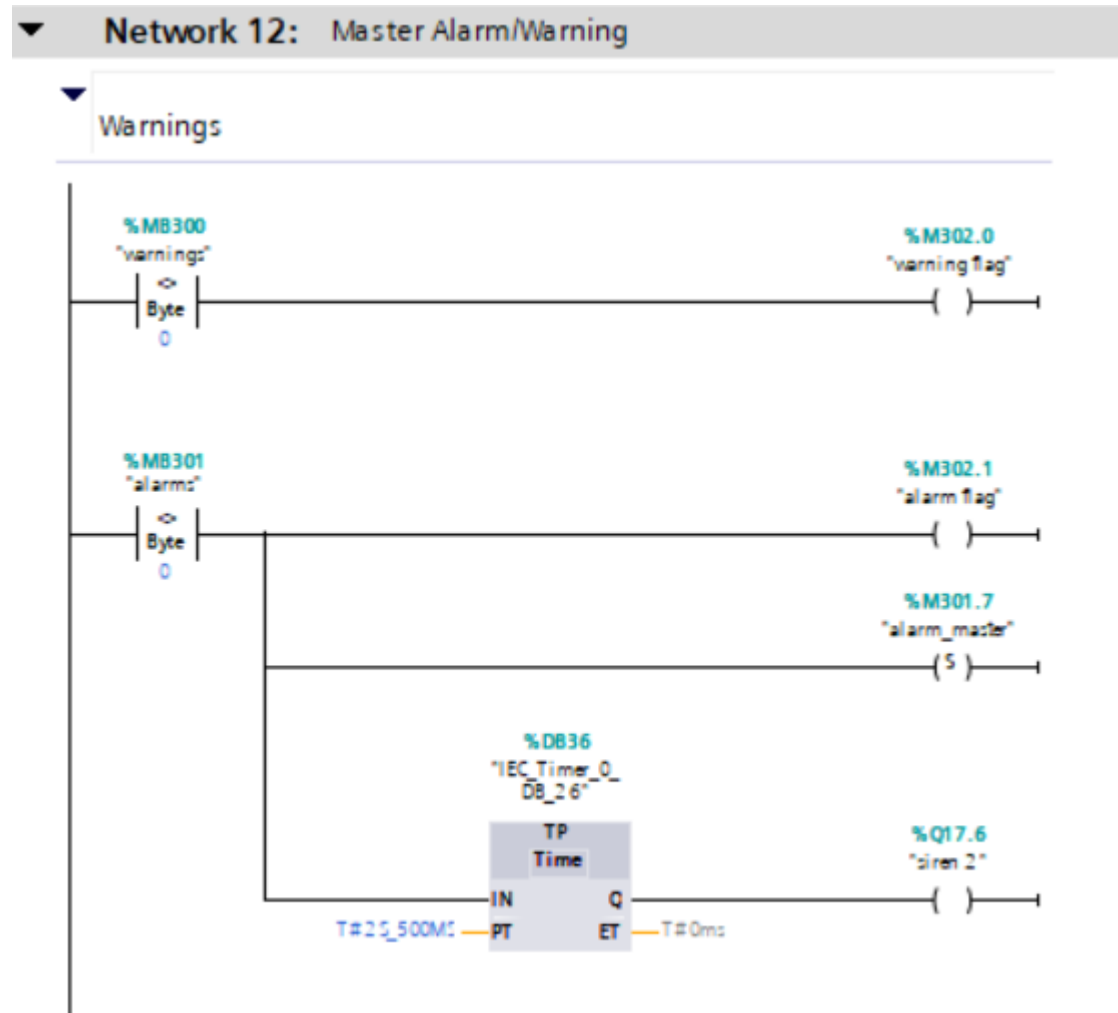


Figure 31 Network 12

Network 13

Network 13 is used to activate the warning memory outputs for each circuit, this is completed by using a greater than or equal to comparator function, the function will differentiate between the value of the error count from each system and the set values that have been input to the warning values that are accepted by the user.

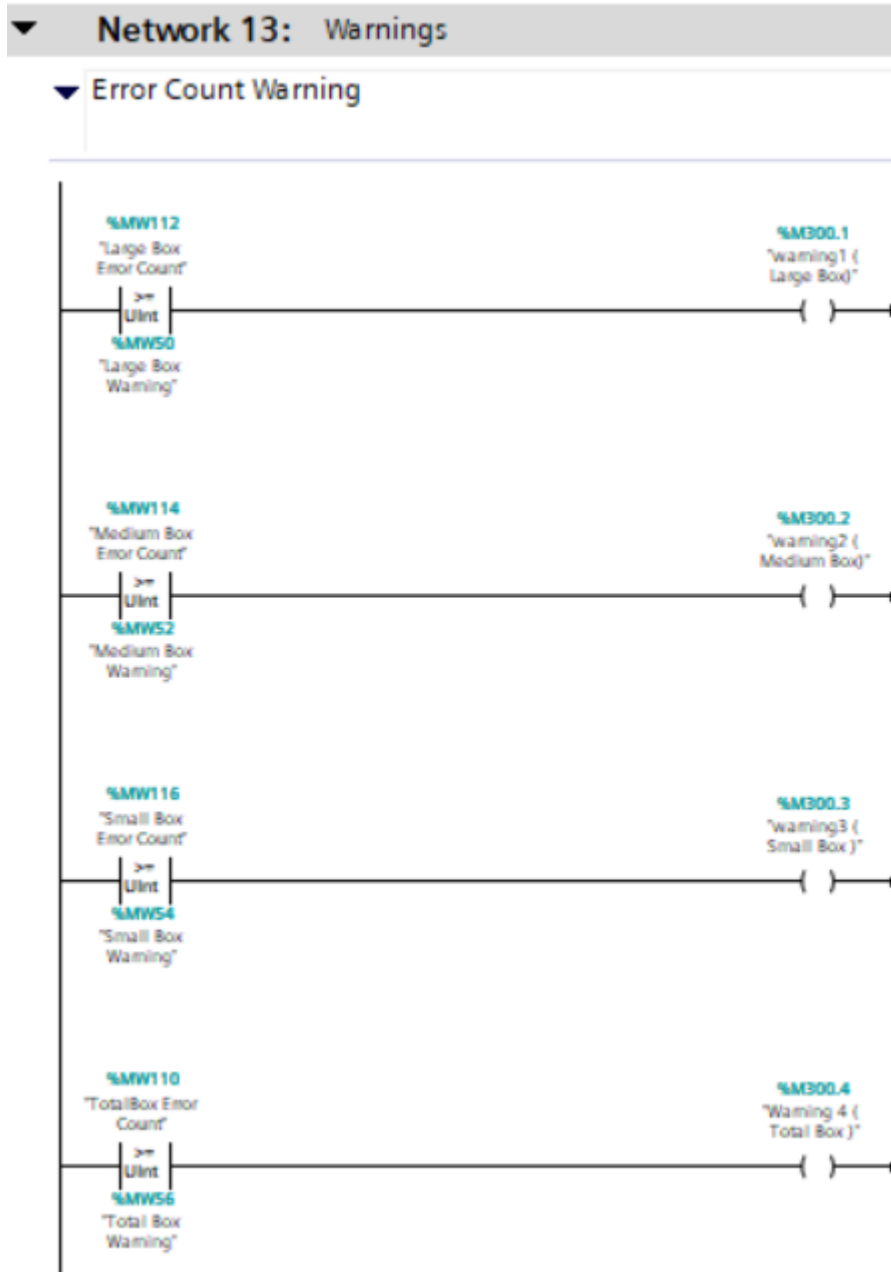


Figure 32 Network 13

Network 14

Network 14 is designed to activate the alarm memory outputs for each system; this operates the same way as the warning previously described but will have a higher value set.

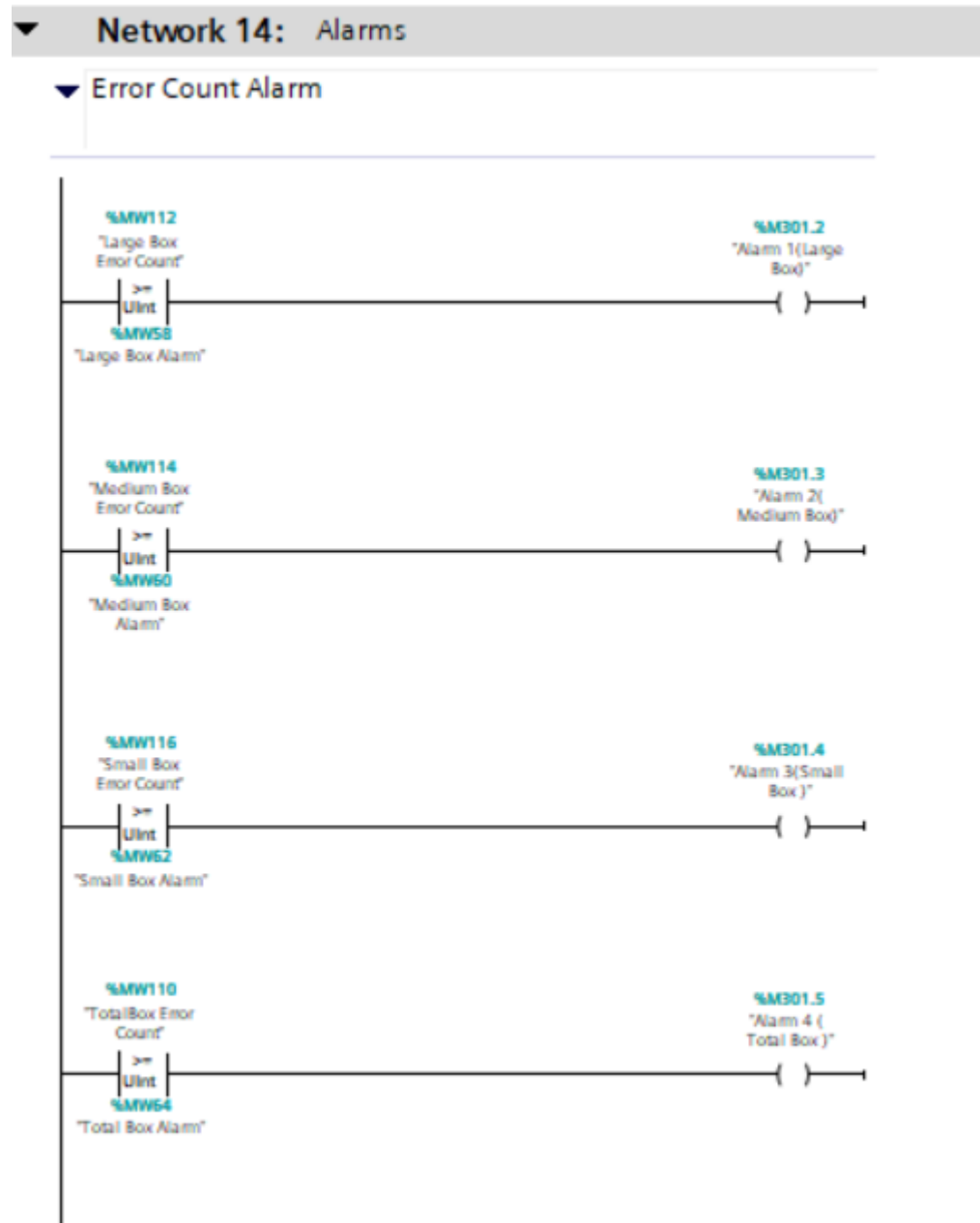


Figure 33 Network 14

Network 15

Network 15 is used when the HMI emergency stop has been initiated, this will then energise the E. Stop Memory which will stop the operation of the system.

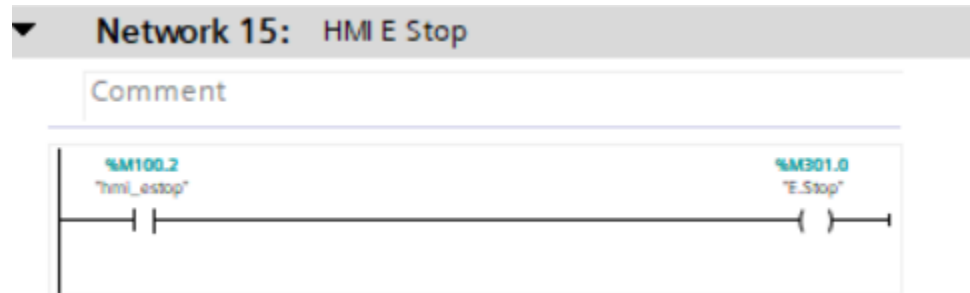


Figure 34 Network 15

Network 16

Network 16 controls the function of the medium box conveyor system, when the scale conveyor flag and conveyor 5 flag has been set which is done at the start of the system the scale conveyor and conveyor 5 will be energised.

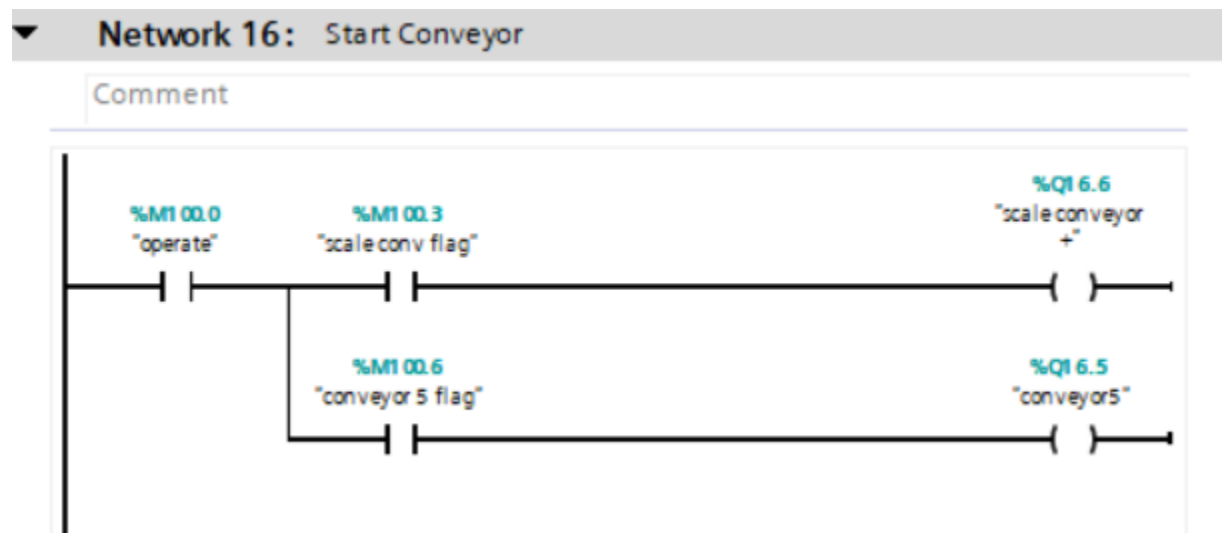


Figure 35 Network 16

Network 17

Network 17 is designed to stop the scale conveyor when diffuse sensor 3 has been activated, this will then reset the conveyor flag allowing the scale conveyor to read the weight of the box, conveyor 5 flag is also reset to stop any boxes on the line over running onto the scale and stopping the system.

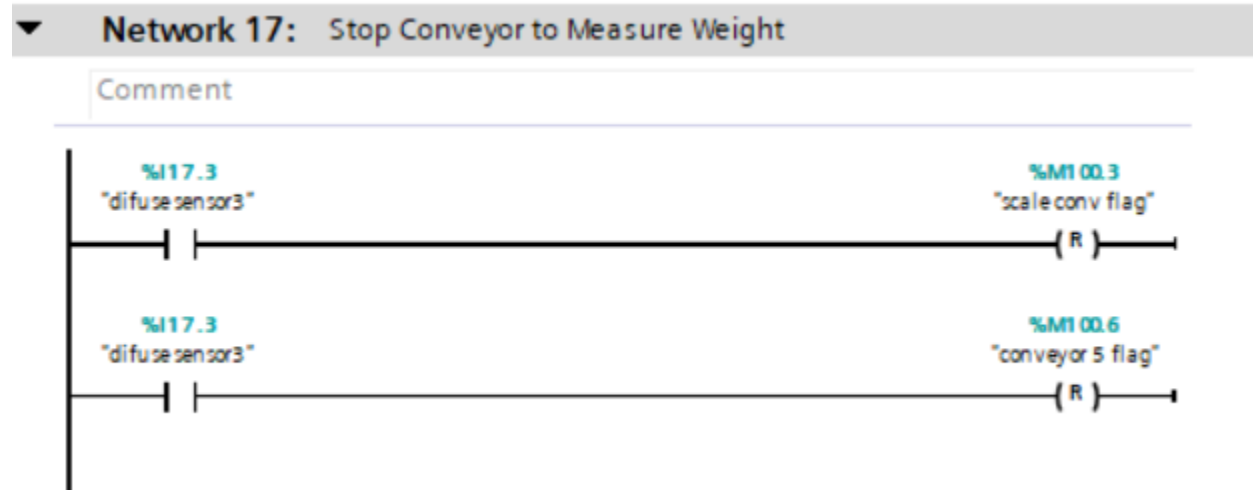


Figure 36 Network 17

Network 18

Network 18 is used to measure the weight of the medium boxes for them to be sorted, when diffuse sensor 3 is activated the TON timer starts counted it then goes to a pulse timer which will then generate a pulse to the move function, the move function then reads the value that has been read by the digital input from the scale and moves it to the weight memory, the TP timer is set to ensure it has enough time to read the weight of the boxes, once completed the scale conveyor flag and conveyor 5 flag outputs is set back.

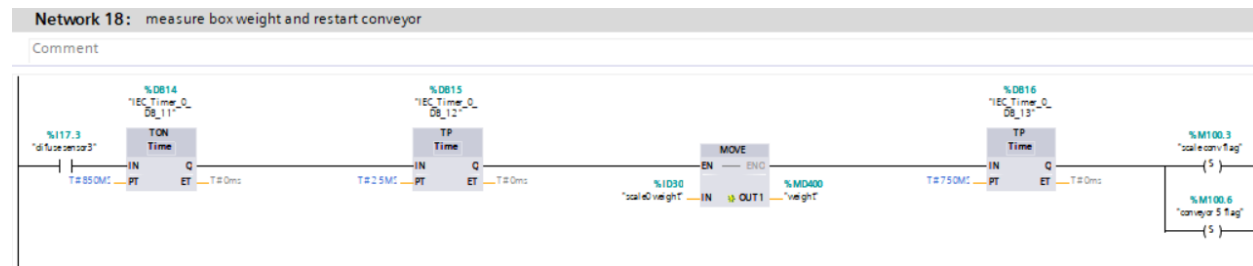


Figure 37 Network 18

Network 19

Network 19 is used to move the value stored from the weight memory value to the digital output which will display the value of the box measured on the physical screen on the local control panel.

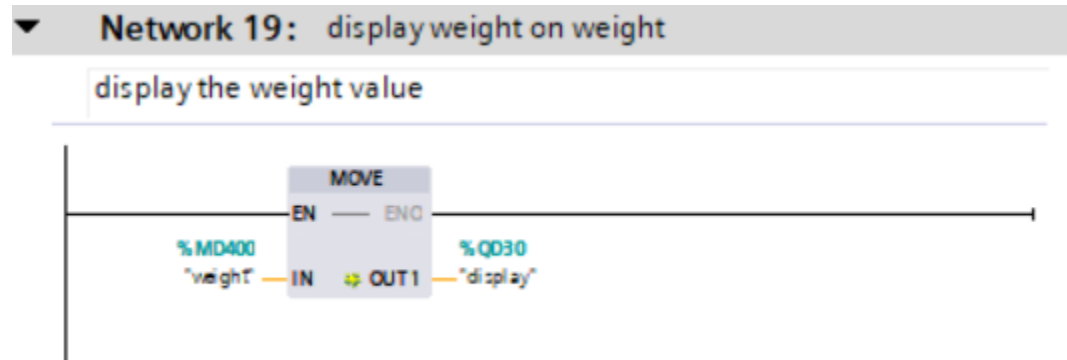


Figure 38 Network 19

Network 20

Network 20 is used to set the weight error value for the medium boxes, this is completed by used a less than or equal to comparator function, the values are input and the comparators will measure between the weight value on the scale conveyor, if the value is too high or low it will operate the alarm for memory for the weight box error.

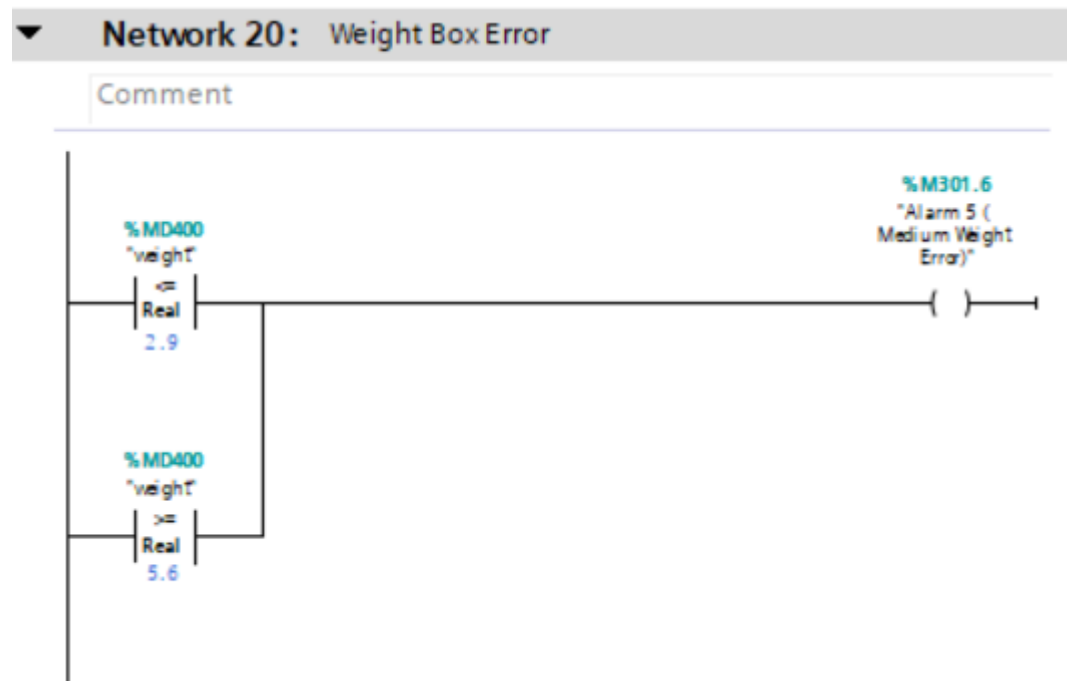


Figure 39 Network 20

Network 21

Network 21 is used to enable the user to reset the weight value stored when an error has been found, this again uses a move function which then changes the value of the weight memory back to the default value set.

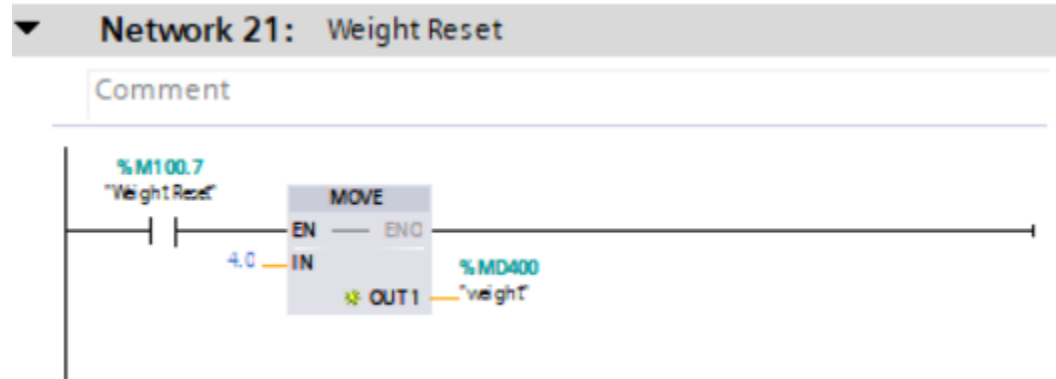


Figure 40 Network 21

Network 22

Network 22 is used to set the direction of the sorter machine, this network uses a in range comparator function, it uses the value of the weight from the scale conveyor and determines which weight category the box that has been weighed falls under, this is done by comparing set values to the weight obtained, the weight category that the box is then in will output to the sorter and set which way the sorter will need to turn and operate while resetting the opposite direction using the tagged outputs.

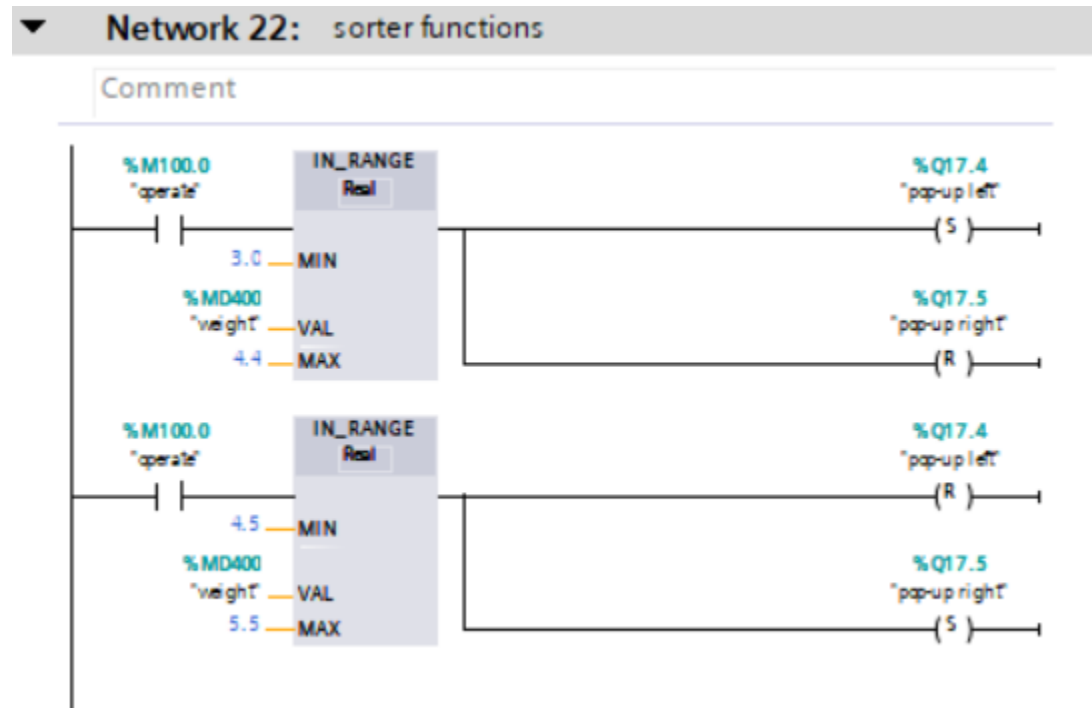


Figure 41 Network 22

Network 23

Network 23 enables the user to set the default values of the warning and alarm limits of the error count. This is completed using move functions with the default setting set to the move function, the function will then set the value to the individual memory write for each warning and alarm that will be tagged to each value in the system or HMI screen.

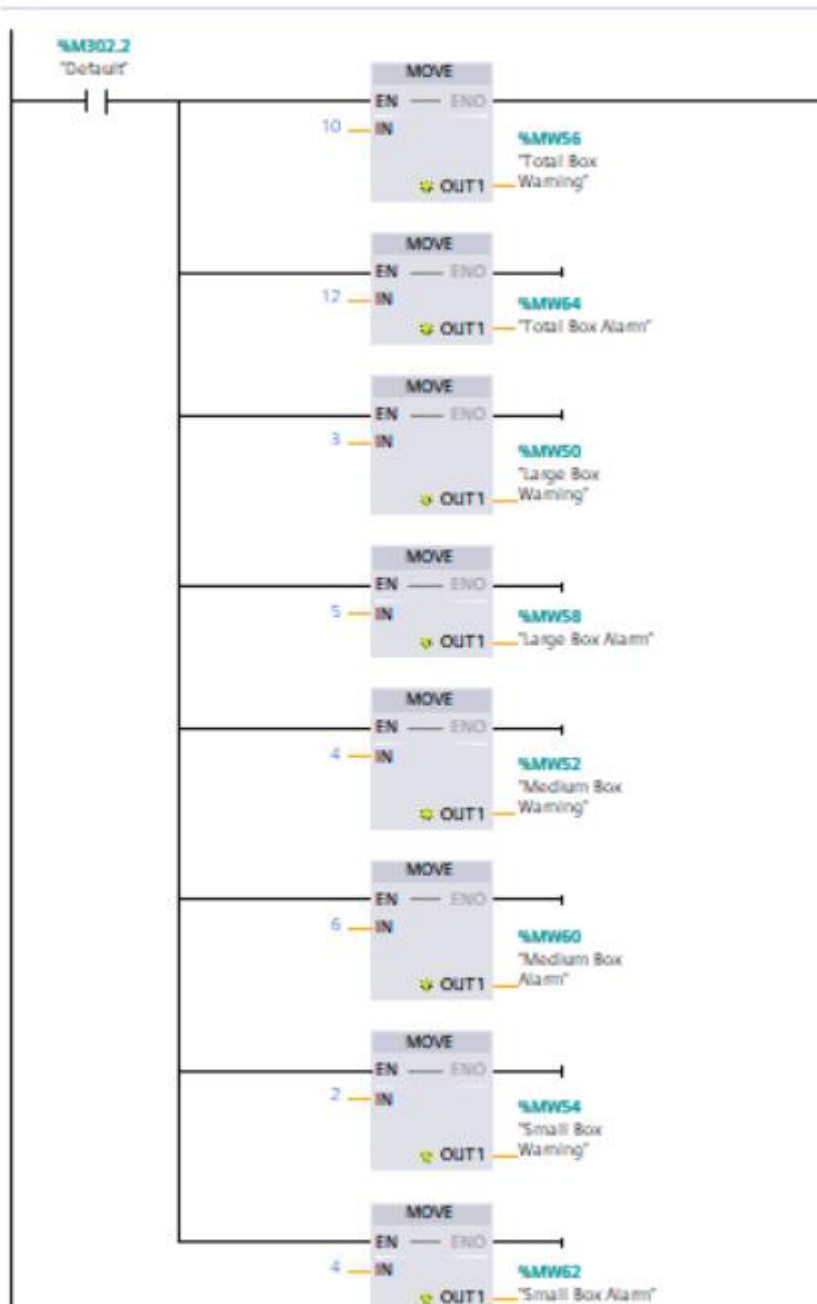


Figure 42 Network 23

7 HMI Tags

The following figures illustrates the HMI tags that are used for the system, these tags are used within the HMI firmware these will be linked to certain functions on the screens which will be explained in the following section.

HMI tags					
	Name ▲	Tag table	Data type	Connection	PLC name
	0 Emergency stop Main Panel	Default tag table	Bool	HMI_Connectio...	PLC_1
	Alarm 1 (Large Box)	Default tag table	Bool	HMI_Connectio...	PLC_1
	Alarm 2 (Medium Box)	Default tag table	Bool	HMI_Connectio...	PLC_1
	Alarm 3 (Small Box)	Default tag table	Bool	HMI_Connectio...	PLC_1
	Alarm 4 (Total Box)	Default tag table	Bool	HMI_Connectio...	PLC_1
	Alarm 5 (Medium Weight Error)	Default tag table	Bool	HMI_Conne...	PLC_1
	alarm flag	Default tag table	Bool	HMI_Connectio...	PLC_1
	alarm_master	Default tag table	Bool	HMI_Connectio...	PLC_1
	counter_reset	Default tag table	Bool	HMI_Connectio...	PLC_1
	Default	Default tag table	Bool	HMI_Connectio...	PLC_1
	difuse sensor 4	Default tag table	Bool	HMI_Connectio...	PLC_1
	difuse sensor 5	Default tag table	Bool	HMI_Connectio...	PLC_1
	difuse sensor 6	Default tag table	Bool	HMI_Connectio...	PLC_1
	difuse sensor 7	Default tag table	Bool	HMI_Connectio...	PLC_1
	difuse sensor1	Default tag table	Bool	HMI_Connectio...	PLC_1
	difuse sensor1(1)	Default tag table	Bool	HMI_Connectio...	PLC_1
	E.Stop	Default tag table	Bool	HMI_Connectio...	PLC_1
	Emergency Stop 1	Default tag table	Bool	HMI_Connectio...	PLC_1
	Emergency Stop 2	Default tag table	Bool	HMI_Connectio...	PLC_1
	Error Reset	Default tag table	Bool	HMI_Connectio...	PLC_1
	hmi_estop	Default tag table	Bool	HMI_Connectio...	PLC_1
	Large Box Alarm	Default tag table	UInt	HMI_Connectio...	PLC_1
	Large Box Error Count	Default tag table	UInt	HMI_Connectio...	PLC_1
	Large Box Warning	Default tag table	UInt	HMI_Connectio...	PLC_1
	large_box_counter	Default tag table	UInt	HMI_Connectio...	PLC_1
	Medium Box <4.4kG_ Counter	Default tag table	UInt	HMI_Connectio...	PLC_1
	Medium Box Alarm	Default tag table	UInt	HMI_Connectio...	PLC_1
	Medium Box Error Count	Default tag table	UInt	HMI_Connectio...	PLC_1

Figure 43 HMI Tags

<UI>	Medium Box Warning	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	Medium_Box>4.5kg _Counter	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	operate	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	pusher1	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	pusher2	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	Small Box Alarm	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	Small Box Counter	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	Small Box Error Count	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	Small Box Warning	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	Stack Light Green	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	Stack Light Red	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	Stack Light Yellow	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	Tag_ScreenNumber	Default tag table	UInt	<Internal tag>	
<UI>	Total Box Alarm	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	Total Box Warning	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	Total_counter	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	TotalBox Error Count	Default tag table	UInt	HMI_Connectio...	PLC_1
<UI>	Warning 4 (Total Box)	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	warning flag	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	Warning Reset	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	warning1	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	warning2	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	warning3	Default tag table	Bool	HMI_Connectio...	PLC_1
<UI>	weight	Default tag table	Real	HMI_Connectio...	PLC_1
<UI>	Weight Reset	Default tag table	Bool	HMI_Connectio...	PLC_1

Figure 44 HMI Tags

8 HMI Screen

The HMI screens are designed to enable the user to remotely see how the system is operating and or to start, stop or reset the system. This is completed by the functions being tagged to the PLC/HMI tags that have been set in the logic that has been previously explained.

Root Screen

The first HMI Screen is the root screen this will essentially be the home screen of the HMI, this consists of a start and stop button, master warning and alarm indicator, medium box weight read, box counters, main stack light indications, HMI emergency stop, counter reset button, weight reset button, navigation buttons for additional screens, also the date and time.

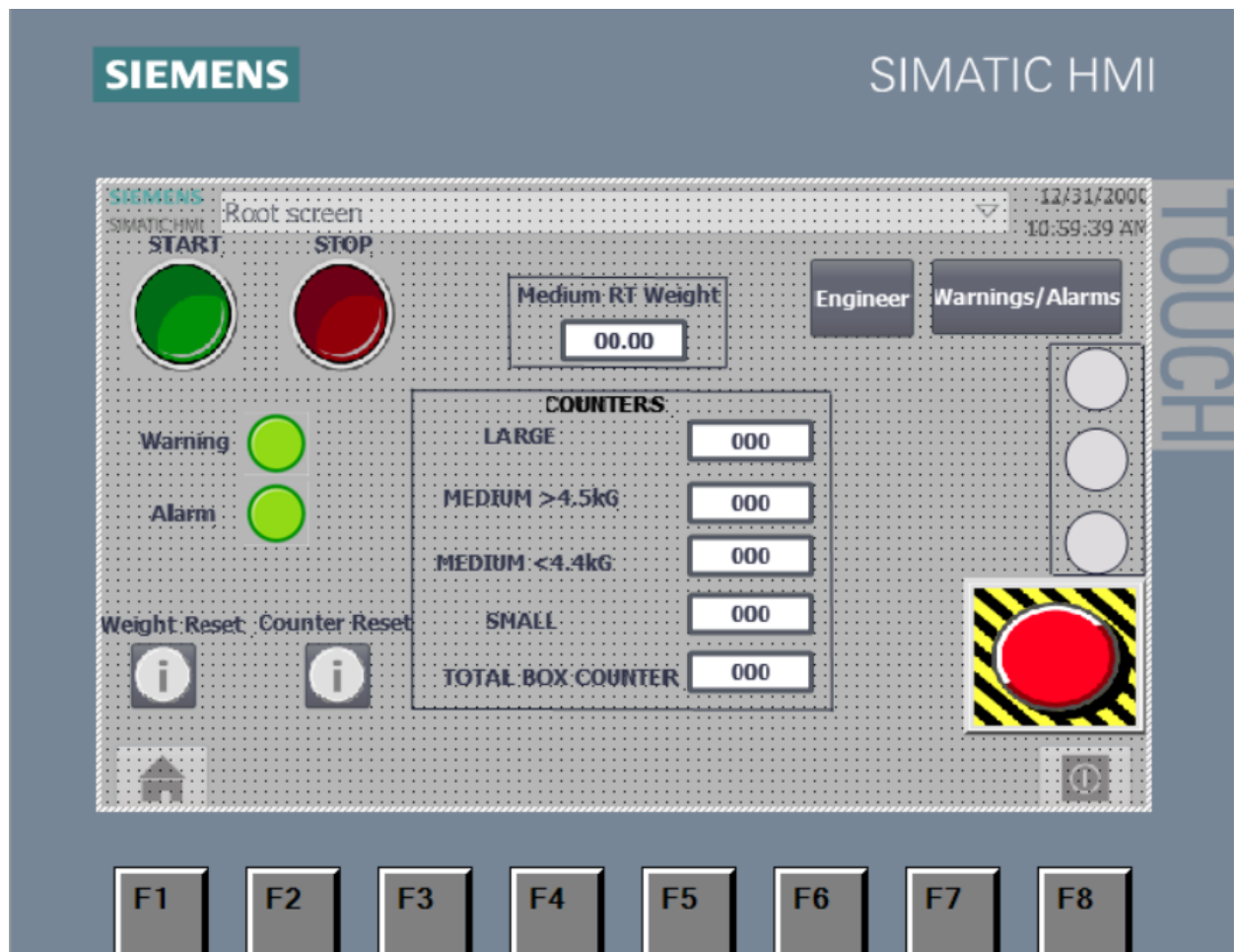


Figure 45 Root Screen

Engineers Screen

The engineering screen will enable the user to visualise the error counts or each type of box and the total box error count with an error reset button that would have to be pressed to clear the values to start the system back up. The engineering screen also illustrates when the pushers are activated and each sensor that is used to count in each system has been activated. The set values for the warnings and alarms for each system are also shown with a default value button available for the engineer to activate when the system is to be operated, this also adds an additional safety feature as the system will not start until values for the alarms and warnings have been set, this can deter any untrained/unauthorised personnel from operating the system. The navigation buttons for the additional screens are also available.

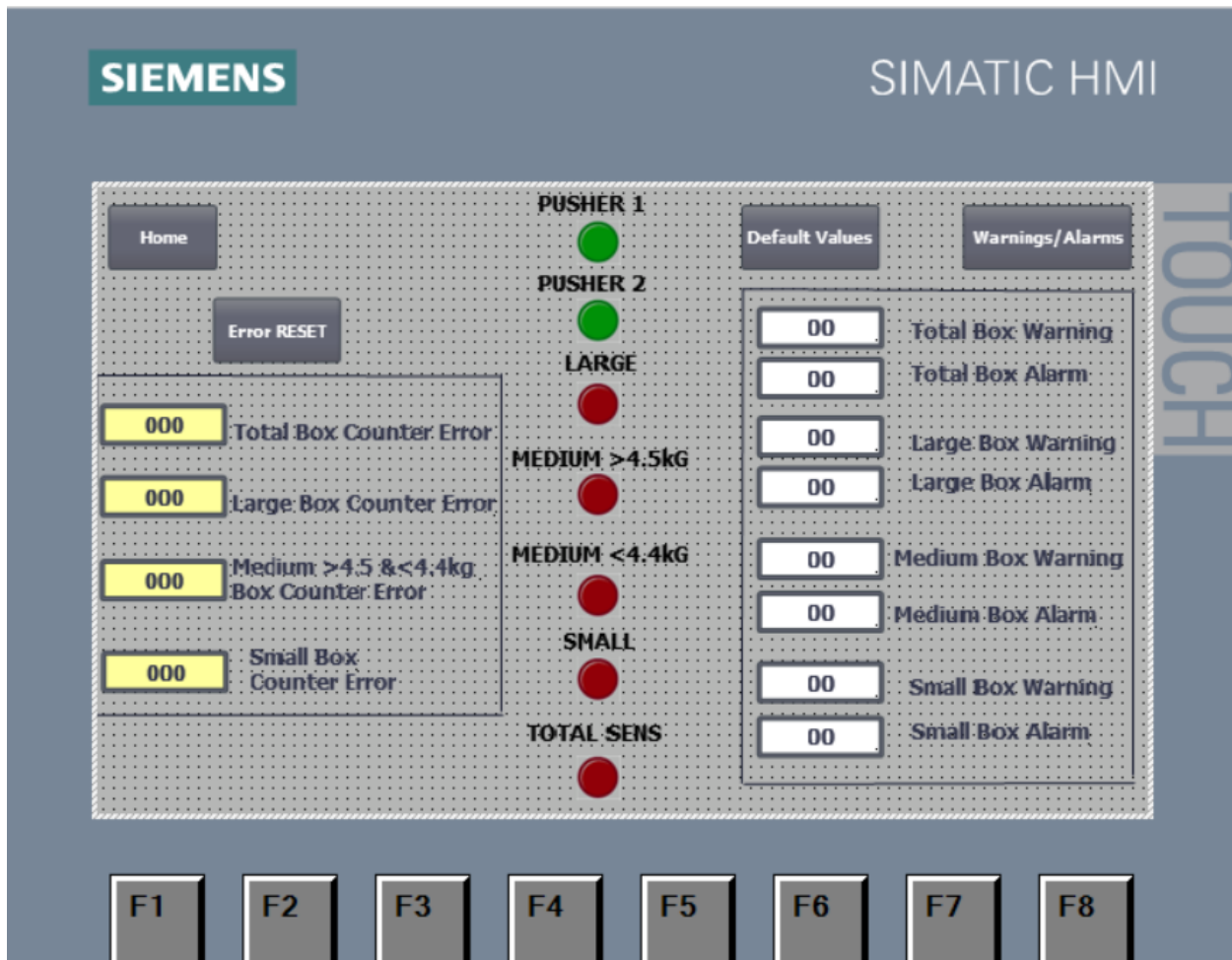


Figure 46 Engineers Screen

Alarm & Warning Screen

The alarm and warning screen indicates to the user what system has created the error by using led indications which are tagged to the alarm and warning memories for each system, it also indicates which emergency stop has been activated this is the reason for the system being stopped or not starting. The alarm reset button is also on this screen which allows the alarm to be reset when the error has been indicated and reset in the correct order, this feature aids with safety to ensure no person can operate the system under fault conditions.

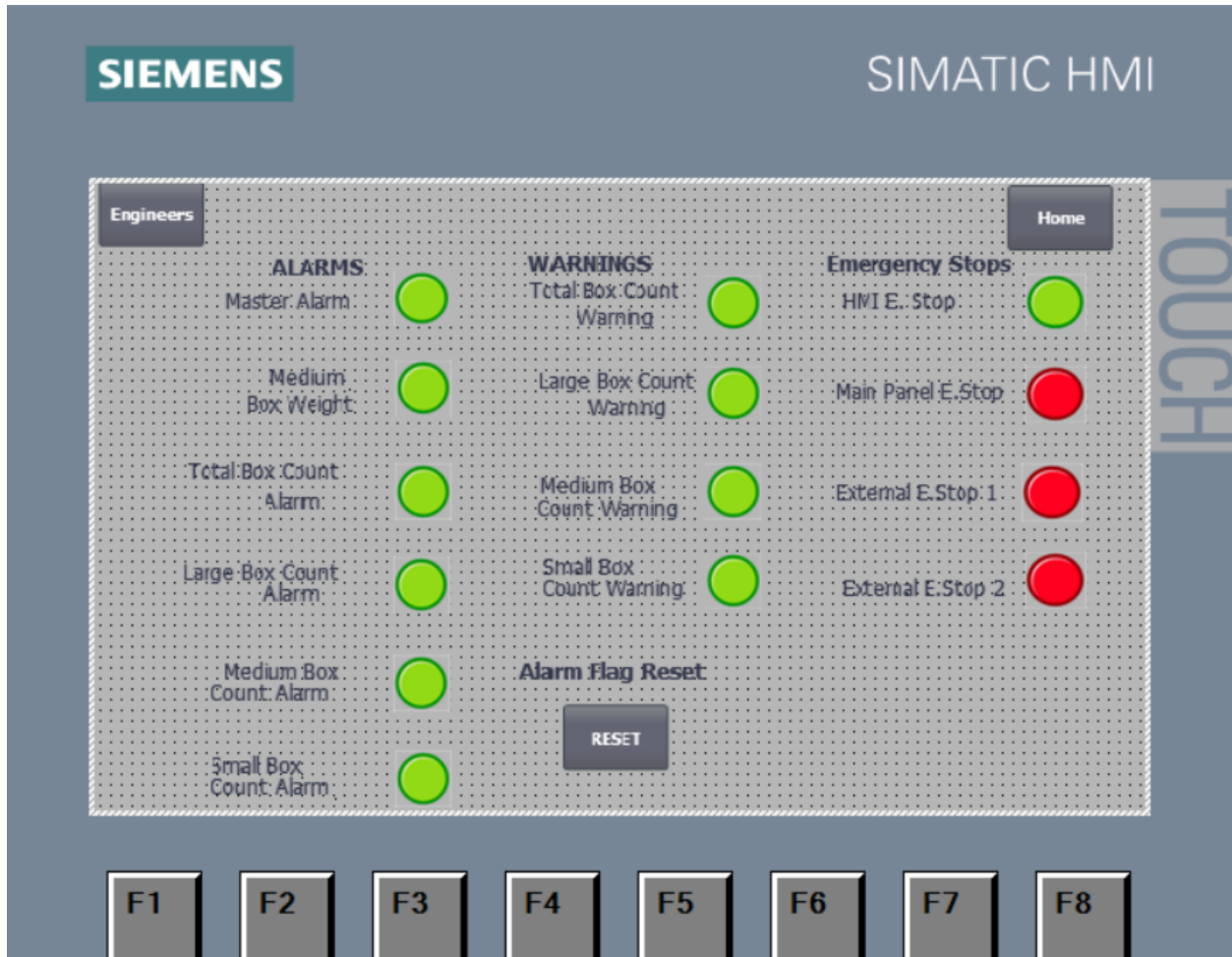


Figure 47 Alarm & Warning Screen

9 System Flowchart

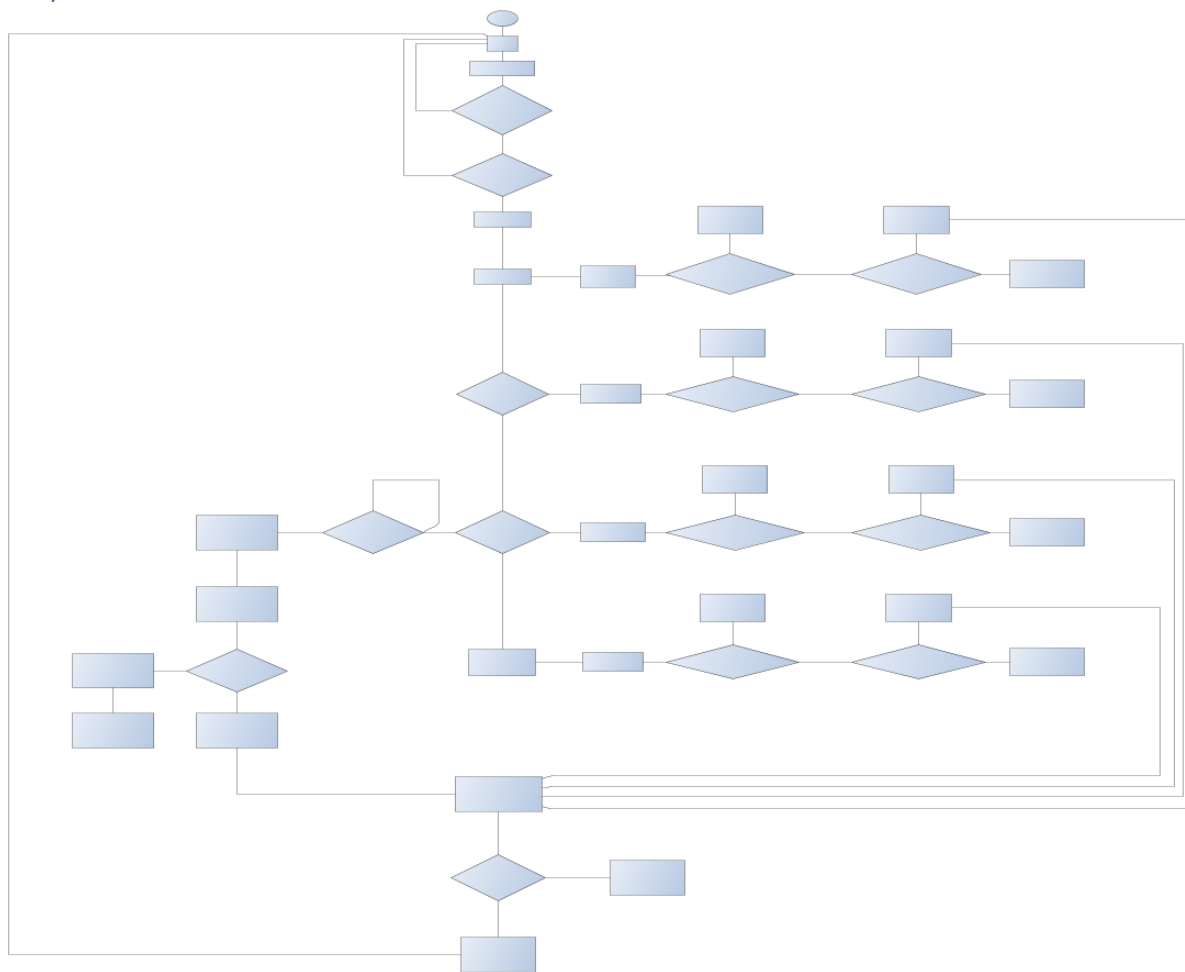


Figure 48 Flowchart

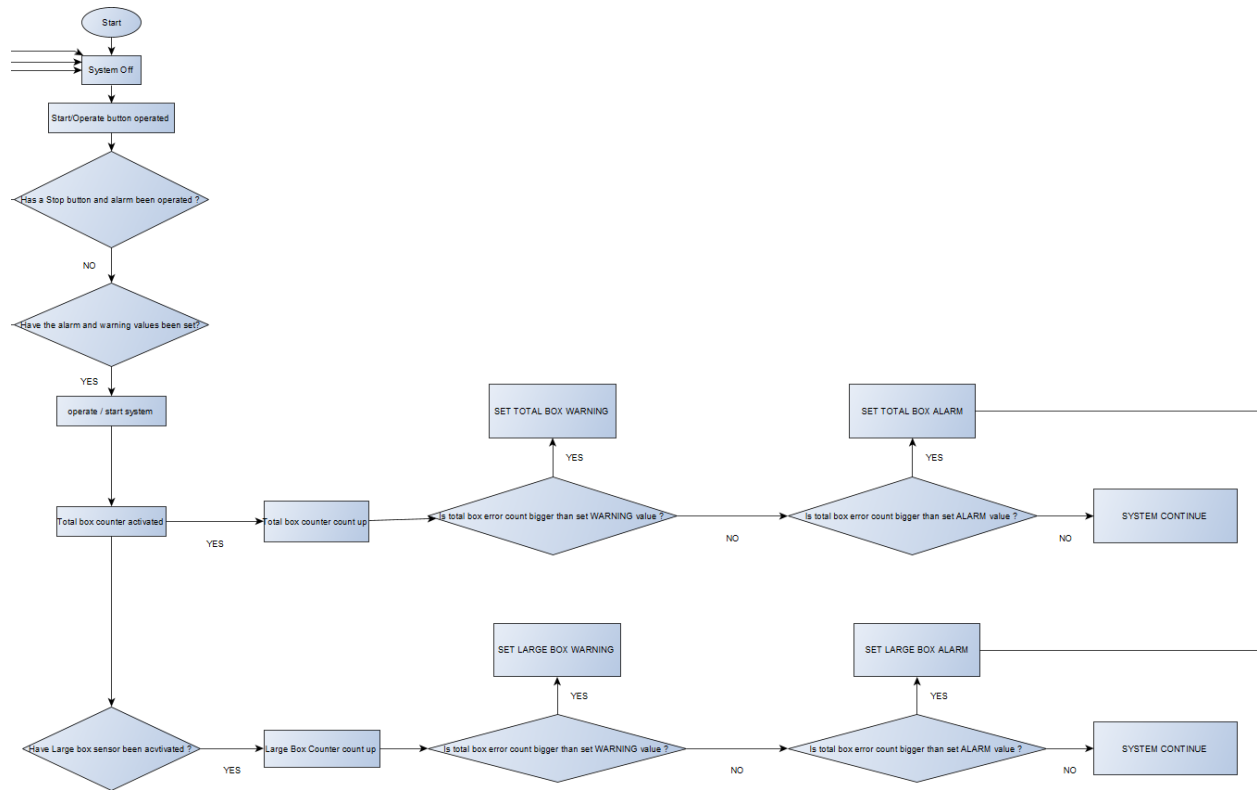


Figure 50 Flowchart

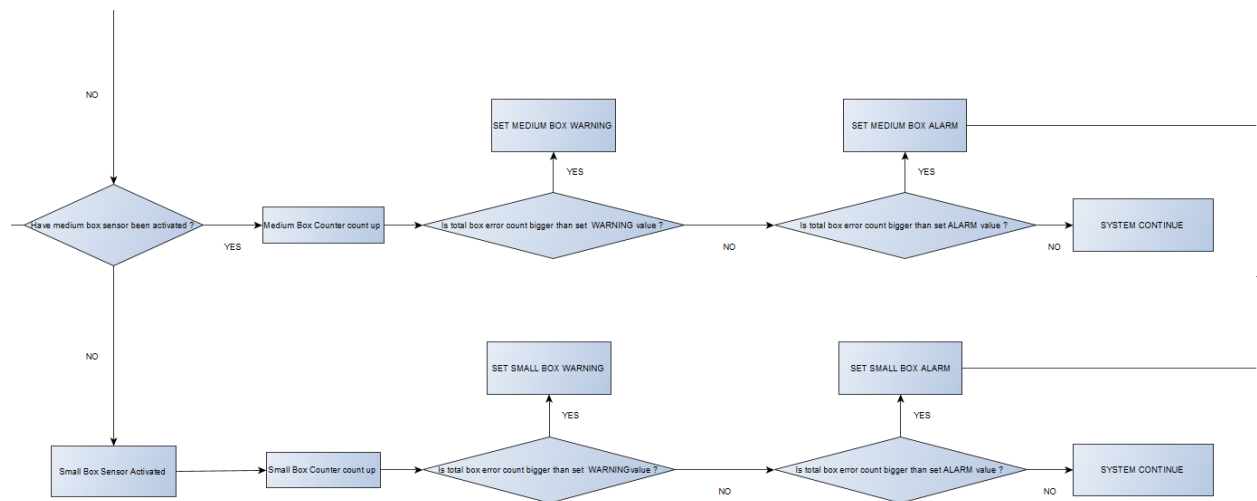


Figure 49 Flowchart

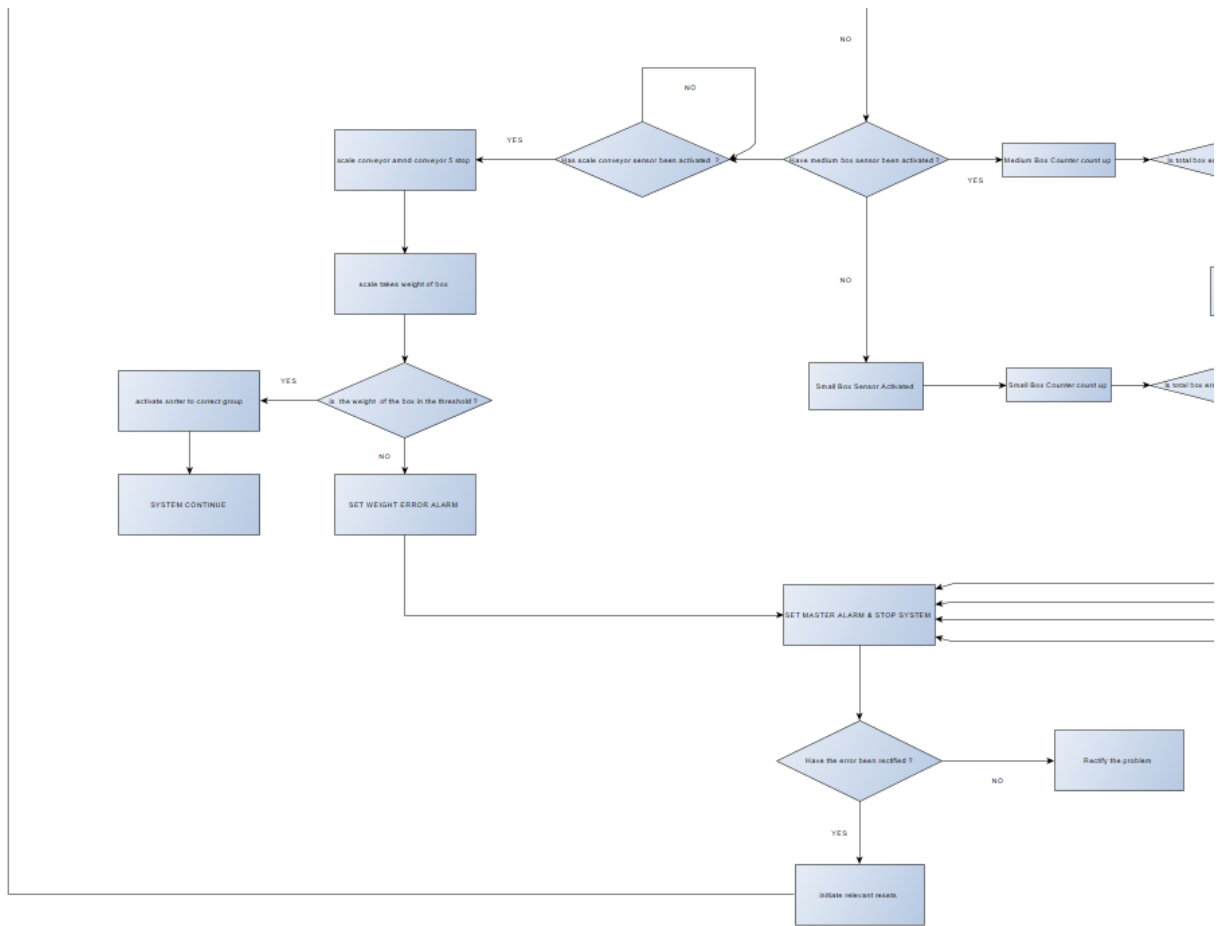


Figure 51 Flowchart

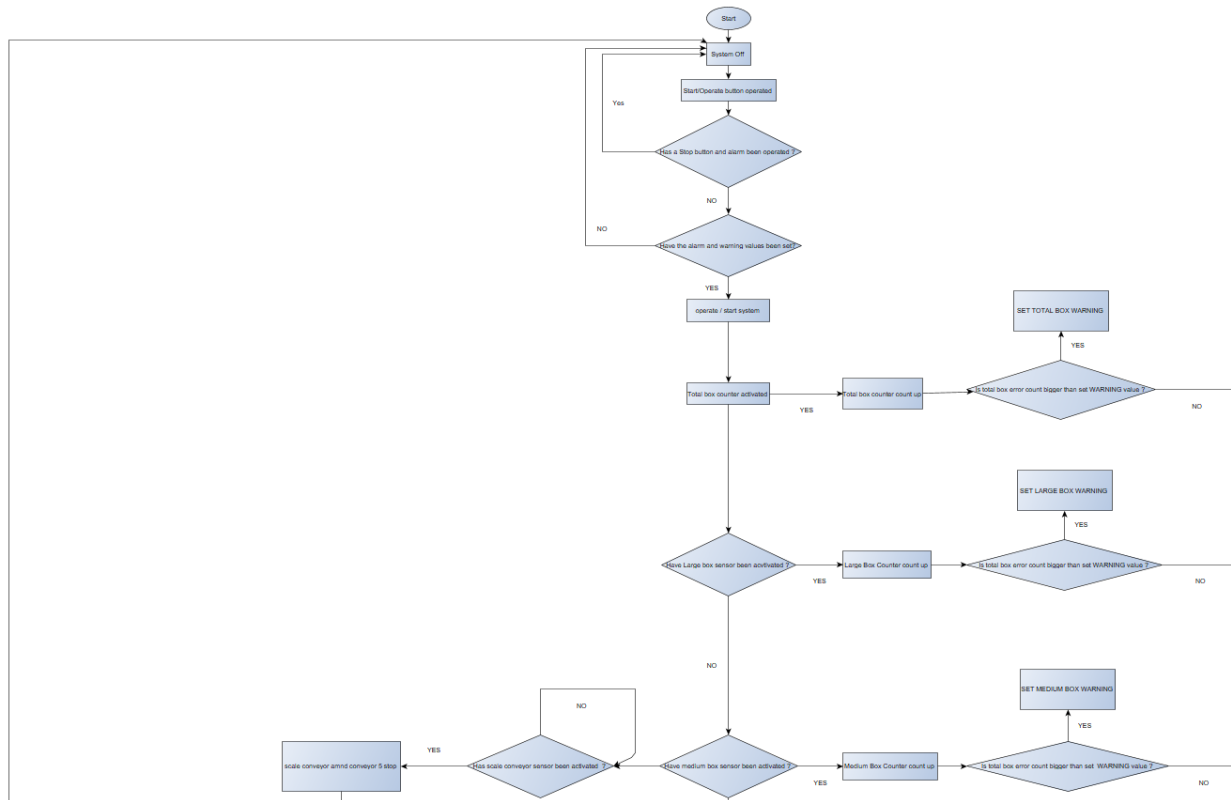


Figure 52 Flowchart

10 Conclusion

To reflect upon the project there were many positives to take from the overall finished design, the design included a safe and efficient system which could operate to the specifications that were set. The design included many safety features which would mitigate the risk of personnel being injured when the system was operational, additionally the design was efficient by using the slow start up which cuts back the start up load on the system but more importantly it has alarms and warnings that would set when an error was detected, this would save users time by the user being able to detect where the fault is which and rectify it quickly, this would save money with the lost time from the system going down. The system was also flexible regarding the ability to expand the cards, change the error count settings and the weight error settings, by doing this the user would be able adapt the system if the boxes were to go smaller or bigger.

On the other hand, there are many improvements that could have been made withing the design. The design could have included resets for the alarm, warning, weight, and counters on the local control panel. Another improvement in the design could be to add buttons on the HMI and local control panel for testing of each conveyor and pusher to enable the user to undertake maintenance tasks easier and test the components instead of turning the full system on. The HMI could also have had LEDs indicating which part of the system is working at what times.

Overall, the project was a success the system worked efficiently and stopped when errors were detected, operating as the design specified.

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- [1] D. H. Hanssen, Programmable Logic Controllers: A Practical Approach to IEC 61131-3 using CoDeSys, Tromsø, Norway: Institute of Engineering and Safety, University of Tromsø, Norway, 2015.
- [2] P. H. & W. Hill, The art of electronics, New York: Cambridge University press , 2015.
- [3] M. P. a. G. Yeole, "Programmable Logic Controllers (PLC) and its Programming," *International Journal of Engineering Research & Technology (IJERT)*, vol. 3, no. 1, 2014.