An Independent Study

entitled

Programming the Festo Modular Production System

by

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Acknowledgements

I would like to express my gratitude to Professor Dr. William T. Evans for his invaluable assistance during this independent study. This study would not have been possible without his guidance and support. In addition to this independent study, Dr. Evans has been a tremendous help throughout my master's degree.

The Festo lab equipment provided by him has enabled me to simulate an industrial manufacturing environment in an educational setting and helped me to become industry ready.

Contents

Chapter 1

Introduction

1.1 About Festo MPS

The Festo Modular Production System (MPS) is a comprehensive and flexible training system designed to provide hands-on experience in the field of industrial automation and manufacturing [1]. Festo developed the MPS as a tool for educational institutions, training centers, and industry professionals to enhance their understanding and skills in modern manufacturing processes [2].

The Festo MPS system consists of various stations. Some of the MPS stations include: Distributing (VE), Testing (PR), Processing (BE), Handling (HA), Buffer (PU), Pick & Place (PP), FluidicMuscle Press (FP), Separating (TR), Storing (LA), Robot (R), and Assembly (MO/HS) [1]. These stations can be used in various combinations to simulate the actual manufacturing environment. However, there are certain limitations regarding which stations can be used downstream, and this is a crucial factor to consider [1].

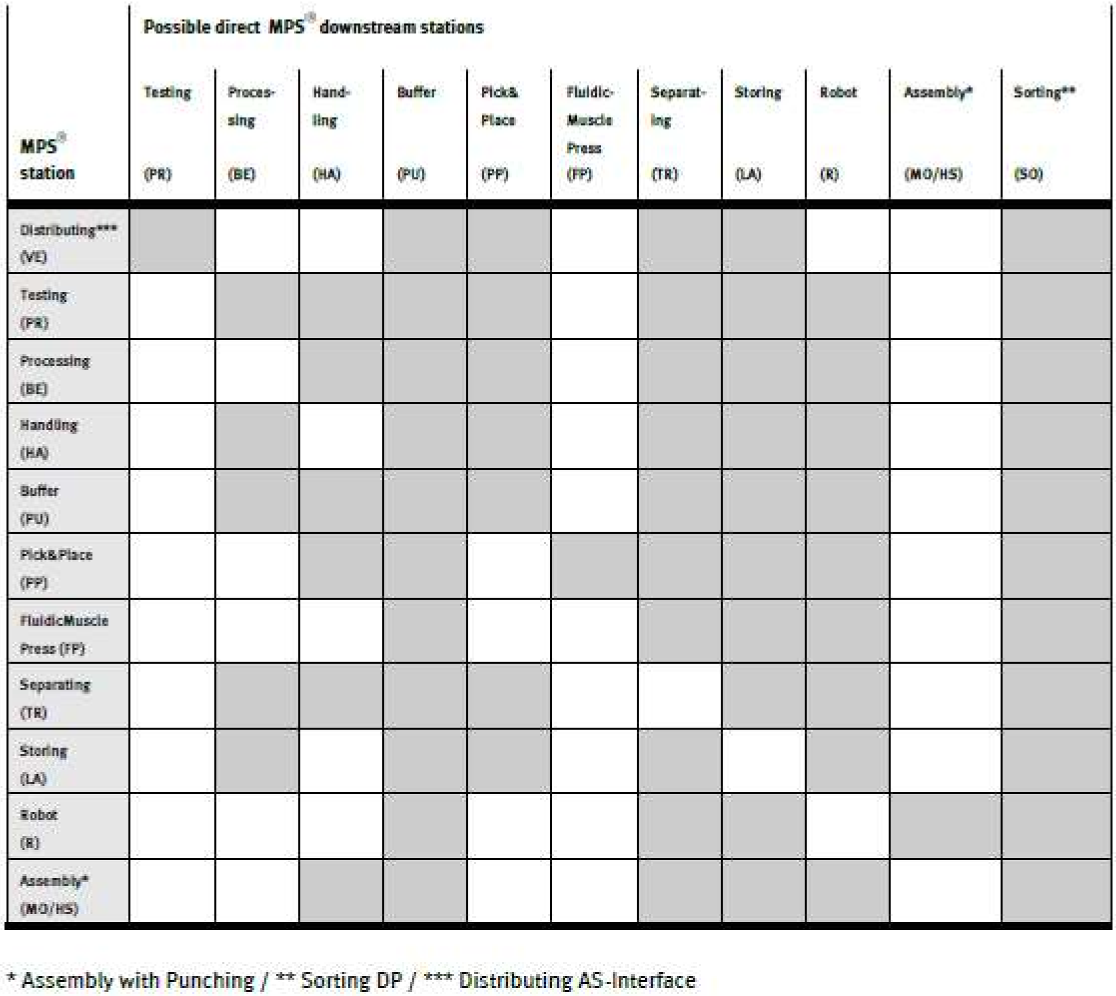


Figure 1-1: Possible Direct MPS Downstream Stations [1]

1.2 Problem Statement

The Festo Modular Production System (MPS) offers a versatile platform for hands-on learning in the domains of mechanics, pneumatics, electrical wiring, sensors, PLC programming, commissioning, and fault finding [1]. Each Festo MPS station has the capability to be programmed and synchronized with other stations, enabling the creation of a seamless and continuous manufacturing process [1].

The focus of this study is to investigate the functionality of each input sensor and output actuator connected to the Programmable Logic Controller (PLC) within the Festo MPS system. The objective is to understand the role of these components and subsequently develop a ladder logic program using Siemens TIA Portal to coordinate interactions among different stations.

In this project, four specific Festo stations are utilized to simulate a manufacturing environment, namely:

- Distributing Station
- Testing Station
- Processing Station
- Sorting Station

The challenge lies in efficiently programming these stations to work in tandem, reflecting a real-world manufacturing scenario. The goal is to enhance the understanding of the integration and coordination required between various components in an automated production setting.

1.3 Objective and Goals

- Gain a detailed understanding of each Festo MPS station, representing their operations through a comprehensive state diagram.
- Develop ladder logic PLC programs for the effective execution of operations at each station.
- Establish harmonized coordination among all four stations, ensuring a smooth and efficient overall system operation.

Chapter 2

System Implementation Framework

i. Input and Output Mapping
   - Identify and correlate each digital input and output bit in the PLC to the corresponding sensor and actuator functions.
   - Utilize Forcing 0 and 1 through the associated addresses to determine the impact on the system and record the results in an Excel sheet as a programming foundation.

ii. State Diagram Development
   - Create individual state diagrams for each station to orchestrate a sequential series of steps.
   - Identify conditions necessary for transitioning to the subsequent state.

iii. PLC Interconnectivity
   - Control the four stations through separate PLCs interconnected via a static network switch to form a subnet.

iv. Ladder Logic Programming
   - Develop PLC programs in Ladder Logic to execute the desired sequence of actions for each station, utilizing the drawn state diagrams as guides.

v. Coordination of Stations
   - Coordinate the four stations to ensure a seamless sequence of actions.

vi. Human-Machine Interface (HMI) Development
   - Design and implement an HMI program to enhance the user interface and interaction with the system.

Chapter 3

Stations Overview

3.1 Distributing Station

The initial stage of the project involves the Distributing Station. It is responsible for isolating workpieces from the Stack magazine module. This station utilizes a through-beam sensor, a double-acting cylinder, and a Changer module with a suction cup for workpiece handling. The transfer unit's arm, driven by a rotary drive, transports the workpiece to the subsequent Testing Station.

3.1.1 Input and Output Definitions for Distributing Station

The input sensors/buttons and output actuators involved in the operations of the Distributing Station, along with their descriptions, are detailed in Table 3.1.

Table 3.1: Input and Output Definitions for Distributing Station

Name	Data Type	Logical Address	Comment
extend_cylndr_2_eject_piece_frm_stack	Bool	%Q0.0	When 1: cylinder moves outwards and pushes workpiece out from stack
vacuum_on	Bool	%Q0.1	When 1: vacuum is on and holds the workpiece to swivel end
ejection_impulse_for_vacuum	Bool	%Q0.2	When 1: it pushes out workpiece from vacumm grasp
swivel_drive_to_magazine	Bool	%Q0.3	When 1: swivel goes to pick up the workpiece
swivel_drive_to_downstream	Bool	%Q0.4	When 1: swivel goes back to the downstream
sensor_ejecting_clndr_retracted	Bool	%I0.1	1 when ejecting cyliner is retracted, else 0
sensor_ejecting_clndr_extended	Bool	%I0.2	1 when ejecting cyliner is extended, else 0
sensor_piece_picked_up	Bool	%I0.3	1 when vacuum has grabbed the work piece
sensor_swivel_drive_postn_magazine	Bool	%I0.4	1 when swiveldrive is in magazine side
sensor_swivel_drive_postn_downstream	Bool	%I0.5	1 when swiveldrive is in downstream
sensor_magazine_empty	Bool	%I0.6	1 when stack magazine empty; else 0
downstream_stn_free	Bool	%I0.7	1 when downstream station is free; else 0 (it is controlled by IP_N_FO i.e. the station occupied bit from downstram station ; IP_N_FO is 1 when station is
start_button_stn1_physical	Bool	%I1.0	to start
stop_button (NC)_stn1_physical	Bool	%I1.1	to stop
reset_button_stn1_physcial	Bool	%I1.3	resets the station; clears internal values and brings everything to their default position

3.1.2 Distributing Station State Diagram

The state diagram developed for the Distributing Station is shown in Figure 3-1.

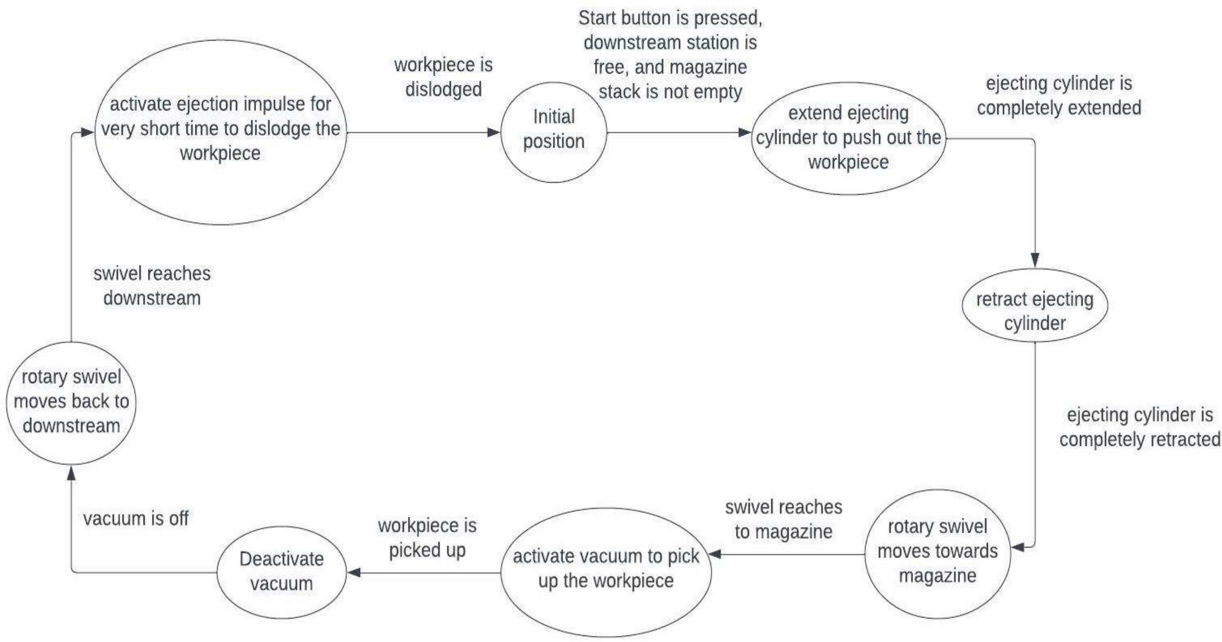


Figure 3-1: State Diagram for Distributing Station

3.2 Testing Station

Following the Distributing Station, the Testing Station assesses the height of the received workpiece. All workpieces in this project meet the height criteria. After verification, the workpiece is forwarded to the Processing Station.

3.2.1 Input and Output Definitions for Testing Station

The input sensors/buttons and output actuators involved in the operations of the testing Station, along with their descriptions, are detailed in Table 3.2.

Table 3.2: Input and Output Definitions for Testing Station

Name	Data Type	Logical Address	Comment
lower_lifting_cylinder	Bool	%Q0.0	when 1, lower down entire platform with color identifier up and continues to stay there even when changed to zero
raise_lifting_cylinder	Bool	%Q0.1	when 1, lift up entire platform with color identifier up and continues to stay there even when changed to zero
extend_ejecting_cylinder	Bool	%Q0.2	when 1, the arm extends and pushes the piece forward into slide; when 0 arm retracts back
air_slide_on	Bool	%Q0.3	when 1, air slide activates. And the workpiece in upper slide moves to the downstreams slide
station_occupied	Bool	%Q0.7	1 when station is occupied either by red,black or metal; also use this to set Q0.7 to indicate station is occupied
sensor_workpiece_available	Bool	%I0.0	1 when station is occupied either by red,black or metal; also use this to set Q0.7 to indicate station is occupied
sensor_not_black_workpiece	Bool	%I0.1	sensor to detect black piece (when black=0; red or metal =1)
sensor_swivel_on_top_of_platform	Bool	%I0.2	When 1, swivel frm station 1 is present on top of the platform. So, cannot eject the workpiece and cannot lift up or lift down the station
sensor_lifting_cylinder_raised	Bool	%I0.4	sensor that gives 1 when the lift cylinder is up(ie. When the platform is up); else 0
sensor_lifting_cylinder_lowered	Bool	%I0.5	sensor that gives 1 when the lift cylinder is down (ie. when The platform is down); else 0
sensor_ejecting_clndr_retracted	Bool	%I0.6	1 when ejecting cylinder is retracted; and 0 when it is extended
downstream_stn_free	Bool	%I0.7	1 when d/s stn is empty; gets signal from IP_N_FO from downstream that says the d/s station is empty
start_button_stn2_physical	Bool	%I1.0	start the process
stop_button_stn2_physical (NC)	Bool	%I1.1	stops the process
reset_button_stn2_physical	Bool	%I1.3	resets the station; clears internal values and brings everything to their default position

3.2.2 Testing Station State Diagram

The state diagram developed for the testing station is shown in Figure 3-2.

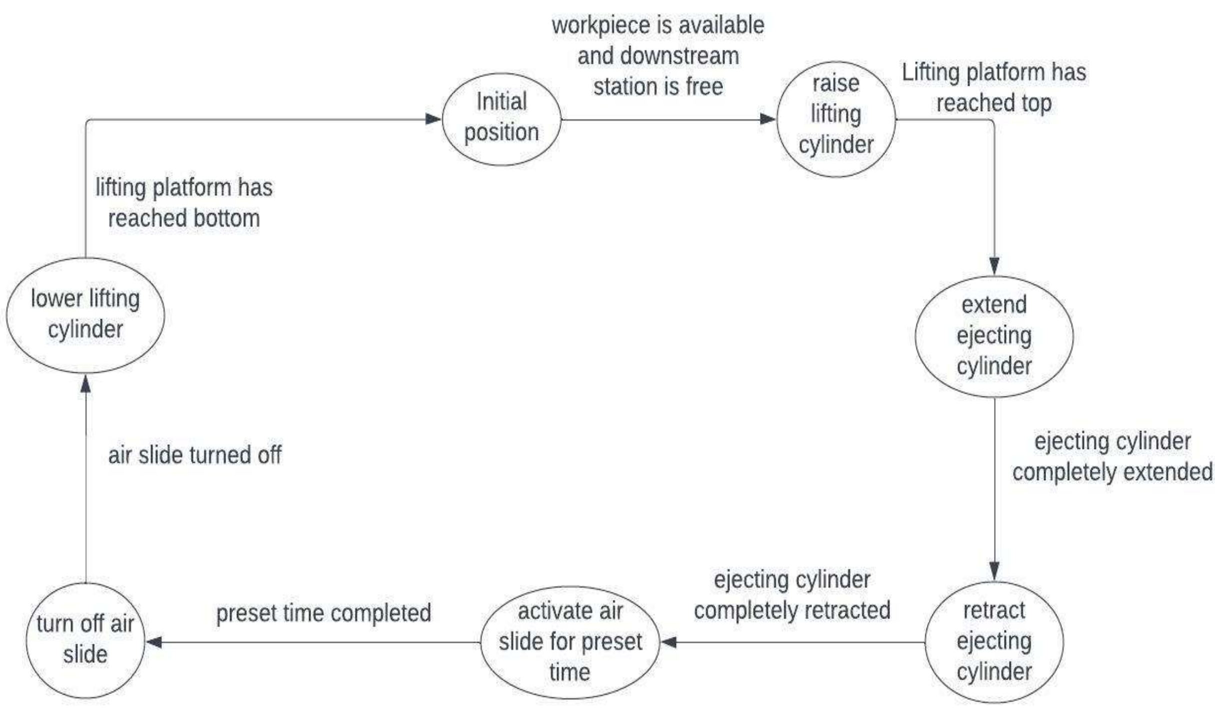


Figure 3-2: State Diagram for Testing Station

3.3 Processing Station

The Processing Station consists of a rotary index table where workpieces undergo proofing, stamping, and drilling processes. Subsequently, the processed workpiece is transferred to the Sorting Station.

3.3.1 Input and Output Definitions for Processing Station

The input sensors/buttons and output actuators involved in the operations of the Processing Station, along with their descriptions, are detailed in Table 3.3.

Table 3.3: Input and Output Definitions for Processing Station

Name	Data Type	Logical Address	Comment
drilling_unit_motor_on	Bool	%Q0.0	when 1, drill turns on. Stops when 0
indexing_table_motor_on	Bool	%Q0.1	when 1, it keeps on rotating. Stops when 0 Note: even when randomly stopped, the holes align
lower_drilling_unit	Bool	%Q0.2	when 1, lowers the drilling unit up
raise_drilling_unit	Bool	%Q0.3	when 1, raises the drilling unit up
fixing_workpiece(horizontal)	Bool	%Q0.4	when 1, the horizontal stamper on the drill unit stamps the workpiece. It remains in that ejected postn until made to 0
proofing_workpiece(vertical)	Bool	%Q0.5	when 1, the vertical stamper on the checking unit moves downward to proof. Make it 0 to take back to initial position.
push_out_workpiece	Bool	%Q0.6	when 1, the slanted pusher at the end ejects the work piece to downstream. It remains in that position. So, make it 0 afterwards.
station_occupied	Bool	%Q0.7	set this at 1 when stationn is occupied. Its purpose is to feed the information to upstream station that the station is not empty
sensor_workpiece_available_at_start_of_rtry_table	Bool	%I0.0	1 when workpiece is at initial postn of rotatory table (it means the workpiece is available to start processing at
sensor_workpiece_at_drilling_unit	Bool	%I0.1	1 when workpiece reaches drilling unit; else 0
sensor_workpiece_at_checking_unit	Bool	%I0.2	1 when workpiece is at checking unit; Else 0
sensor_drill_in_upper_postn	Bool	%I0.3	1 when drill is at upper postn
sensor_drilll_in_lower_postn	Bool	%I0.4	1 when drill is at lower postn
sensor_indexing_table_positioned	Bool	%I0.5	when rotating table is stopped and aligned then 1. Else 0. When table is continuously moving, it becomes 1 for few milisecond. But then becomes 0.
downstream_stn_free	Bool	%I0.7	1 when downstream stn is free. This i/p comes from the o/p of next station
start_button_stn3_physical	Bool	%I1.0	to start
stop_button_stn3 (NC)_physical	Bool	%I1.1	to stop
reset_button_stn3_physical	Bool	%I1.3	resets the station; clears internal values and brings everything to their default position

3.3.2 Processing Station State Diagram

The state diagram developed for the Processing Station is shown in Figure 3-3.

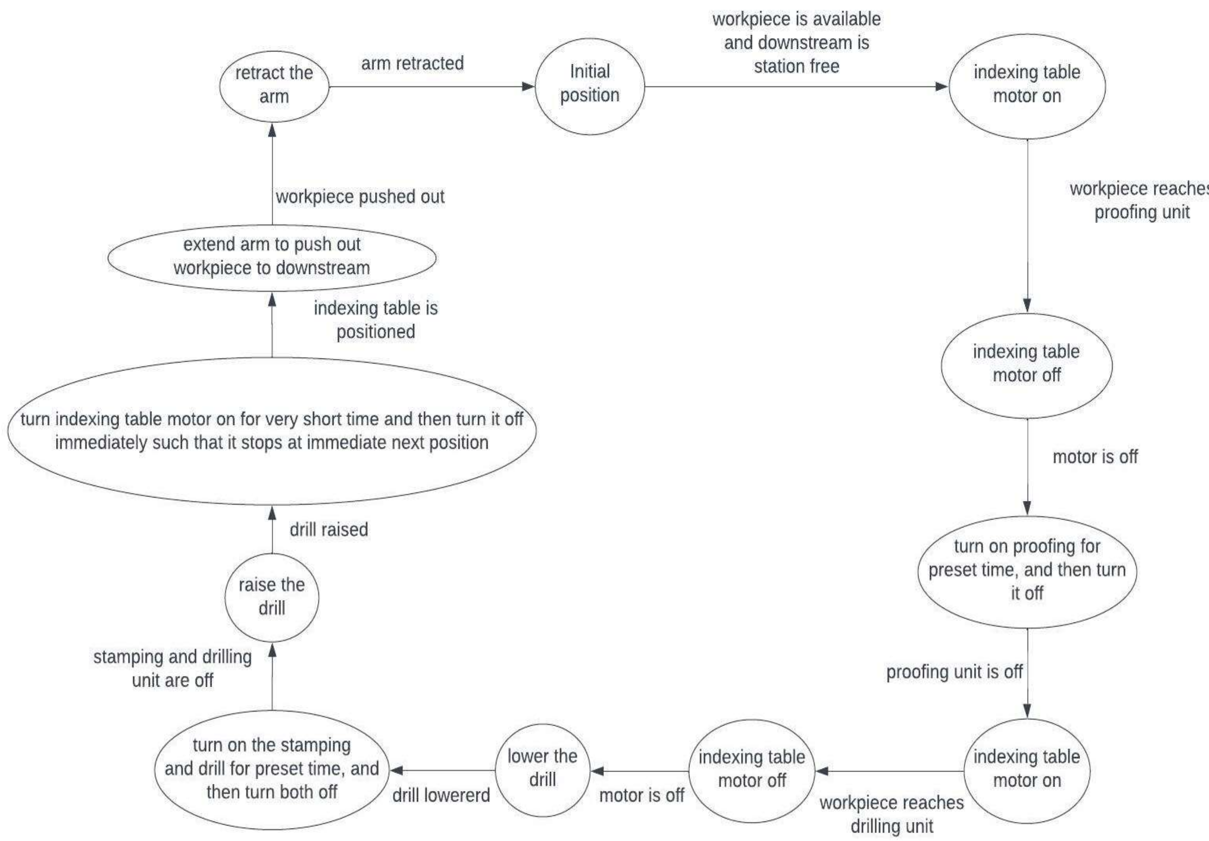


Figure 3-3: State Diagram for Processing Station

3.4 Sorting Station

The final station, Sorting Station, receives workpieces from the Processing Station and categorizes them based on type (red, black, or metallic). The sorted workpieces are collected on respective slides, concluding the project's manufacturing process.

3.4.1 Input and Output Definitions for Sorting Station

The input sensors/buttons and output actuators involved in the operations of the Sorting Station, along with their descriptions, are detailed in Table 3.4.

Table 3.4: Input and Output Definitions for Sorting Station

Name	Data Type	Logical Address	Comment
belt_motor_on	Bool	%Q0.0	When 1, the conveyer turns on and keep on running.
extend_switch1 (First one from start)	Bool	%Q0.1	When 1, the first arm extends and sends the workpiece down the first conveyer. When 0, it
extend_switch2 (Second one from start)	Bool	%Q0.2	When 1, the second arm extends and sends the workpiece down the second conveyer. When 0, it retracts
retract_stopper(otherwise_always_extended)	Bool	%Q0.3	When 0, the stopper is extended and it blocks entry to the conveyer. When 1, stopper is retracted and workpiece can be sent into the
station_occupied	Bool	%Q0.7	1 when station is occupied. This is used to provide information to upstream station that whether this station is
sensor_workpiece_available	Bool	%I0.0	When 1, it indicates the workpiece has entered the conveyer. This sensor is located at the very beginning of conveyer.Changes back to 0 when the workpiece passes that point
sensor_metallic_workpiece	Bool	%I0.1	It ss 1 when metallic piece passes through. But immediately goes back to 0 as piece passes that point (it happens quickly since conveyer
sensor_workpiece_not_black	Bool	%I0.2	It is 1 when non-black (either red or metal) piece passes through. But immediately goes back to 0 as piece passes that point (it happens quickly since conveyer will be
sensor_slide_full	Bool	%I0.3	1 when either of the 3 slides are completely full. Else 0.
sensor_switch1_retracted	Bool	%I0.4	1 when when 1st arm in conveyer is retracted.
sensor_switch1_extended	Bool	%I0.5	1 when when 1st arm in conveyer is extended.
sensor_switch2_retracted	Bool	%I0.6	1 when when 2nd arm in conveyer is
sensor_switch2_extended	Bool	%I0.7	1 when when 2nd arm in conveyer is extnded. Else 0
start_button_stn4_physical	Bool	%I1.0	to start
stop_button_stn4 (NC)_physical	Bool	%I1.1	to start
reset_button_stn4_physical	Bool	%I1.3	resets the station; clears internal values and brings everything to their default position

3.4.2 Sorting Station State Diagram

The state diagram developed for the Sorting Station is shown in Figure 3-4.

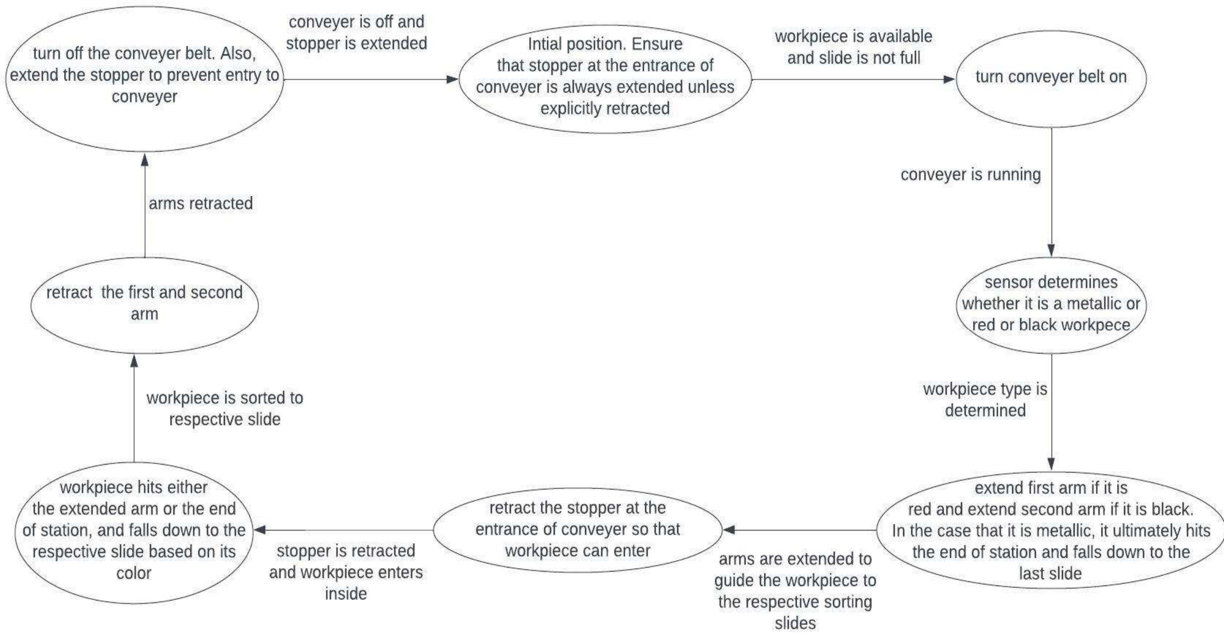


Figure 3-4: State Diagram for Sorting Station

Chapter 4

Interconnection of the Four MPS Stations

The four stations are independently controlled by separate PLCs. These PLCs are interconnected through a static switch forming a network. The stations are assigned the following IP addresses:

i. Distributing Station (192.168.0.10)
ii. Testing Station (192.168.0.11)
iii. Processing Station (192.168.0.12)
iv. Sorting Station (192.168.0.13)

Refer to Figure 4-1 for a graphical representation of the interconnected system network.

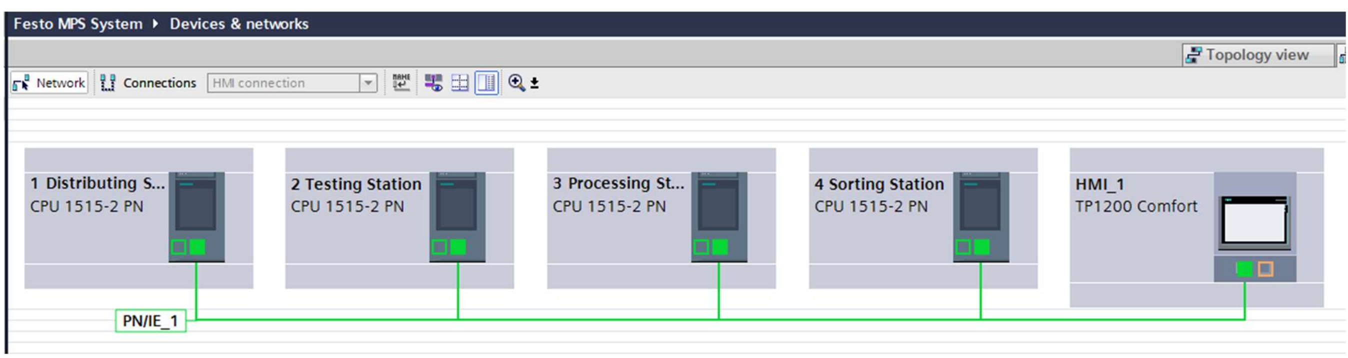


Figure 4-1: Network View of the Interconnected System

Chapter 5

Human-Machine Interface (HMI) Development

Figure 5-1 shows the HMI screen developed for the project. While physical buttons at each station can control individual operations, the HMI offers a more straightforward method for simultaneously starting, halting, and resetting all four stations.

Figure 5-1: Developed HMI Screen

This interface provides visual cues regarding the active status of the stations, along with real-time information on the availability of downstream stations. In the event of a system-wide interruption due to an unknown circumstance, the HMI aids in identifying potential bottlenecks, especially those caused by occupied downstream stations incapable of accepting new workpieces. This feature enables efficient troubleshooting and resolution to maintain the system's optimal functionality.

Chapter 6

Results and Discussion

The PLC program was developed successfully, controlling the sequence of actions in all four stations simultaneously. The program underwent testing, and it was observed that all four stations were coordinated. If there are no other external faults, the sequence continues continuously unless the stack magazine in the Distributing Station is empty or the slide in the Sorting Station becomes full.

This project demonstrated the significance of state diagrams in navigating complex processes. Each station featured intricate sequences with conditions governing transitions between steps. Using state diagrams made it easier to break down the process into clear steps, helping to understand the conditions needed for progress. This method greatly simplified the development of ladder logic.

Chapter 7

Conclusion

The Festo MPS project served as a valuable exercise in comprehending the intricacies of industrial manufacturing environments with sequential operations. The experience gained in programming these operations provided valuable insights and served as effective preparation for real-world scenarios in educational settings. The project showcased the practical application of theoretical concepts, emphasizing the importance of meticulous planning and logical sequencing in industrial automation programming.

References

1. FESTO. (2015). Distributing Station Manual.
2. Evans, W. (n.d.). Hybrid Lab Ch. 28 – Festo. Hybrid PLC Mechatronics. https://hybridplc.org/wp-content/uploads/labs28_S.pdf

Appendix A

PLC Program for Distributing Station

The PLC program that governs the distributing station has been developed on its corresponding S7-1500 PLC. The ladder logic program corresponding to the distributing station is given on the following page.

Festo MPS System / 1 Distributing Station [CPU 1515-2 PN] / Program blocks

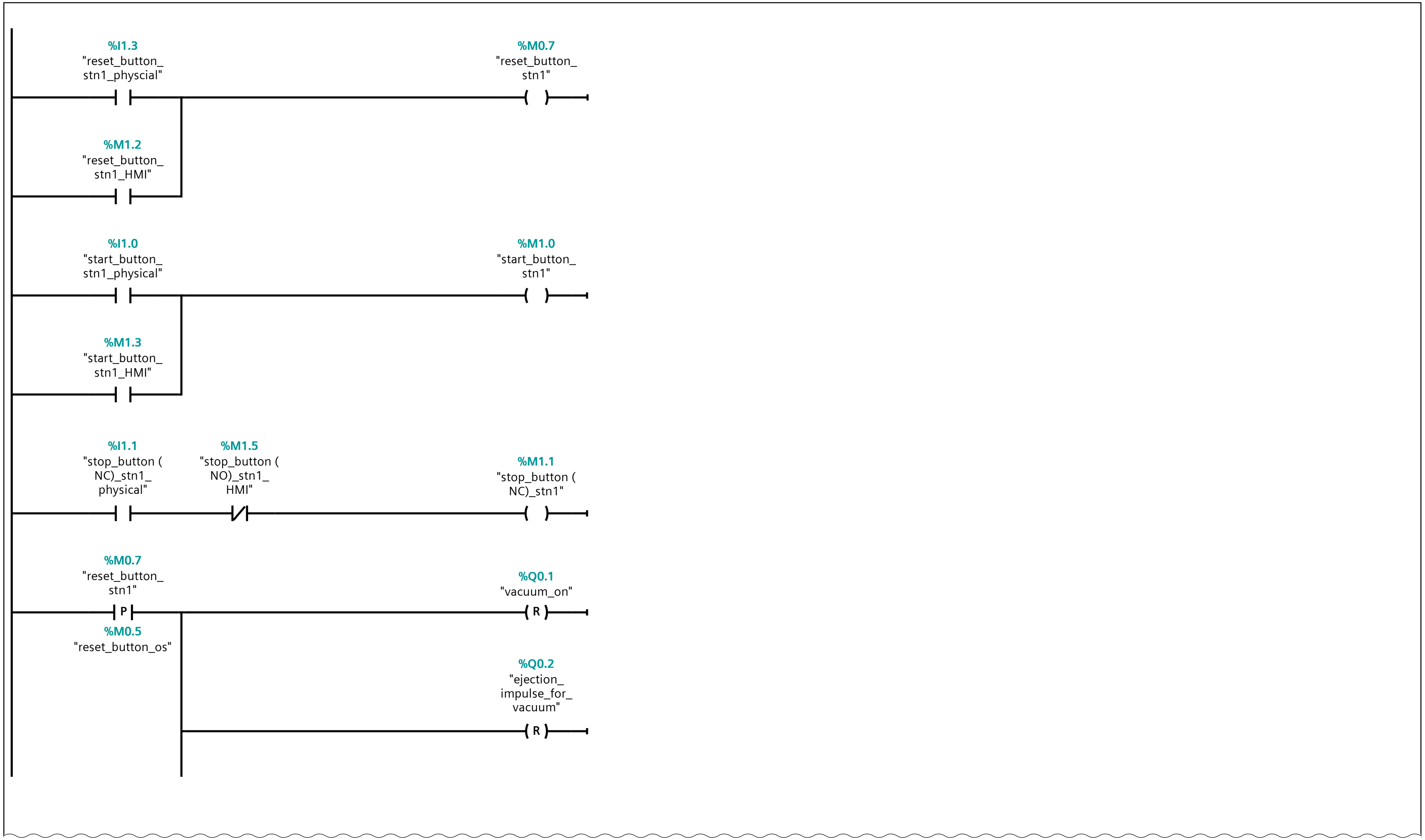
Main [OB1]

Main Properties							
General							
Name	Main	**Number**	1	**Type**	OB	**Language**	LAD
Numbering	Automatic						
Information							
Title	"Main Program Sweep (Cycle)"	**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Main		
Name	**Data type**	**Default value**
▼ Input		
Initial_Call	Bool	
Remanence	Bool	
▼ Temp		
flag_for_one_last_step_after_stack_empty	Int	
Constant		

Network 1:

Network 1: (1.1 / 7.1)



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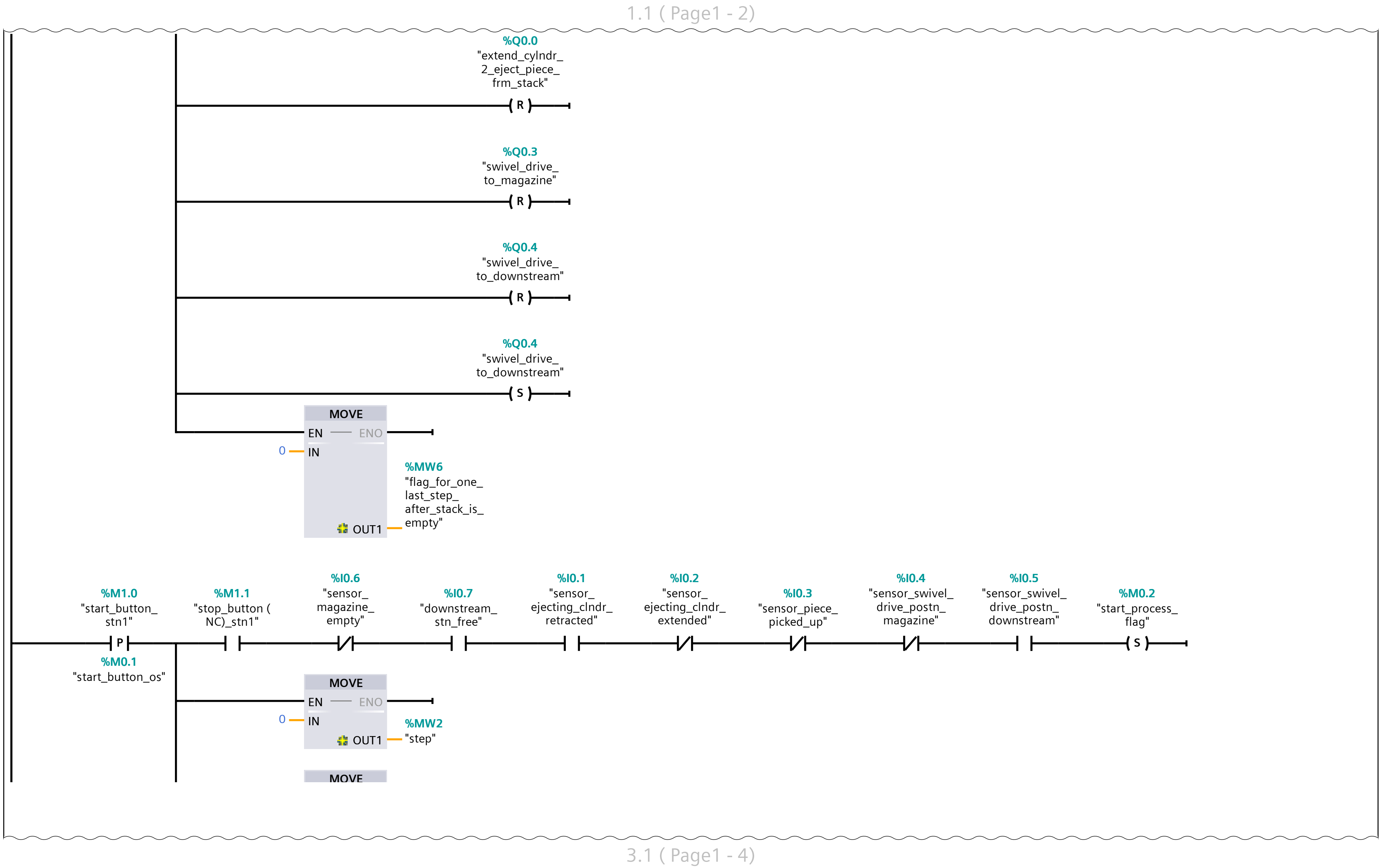
Network 1: (2.1 / 7.1)



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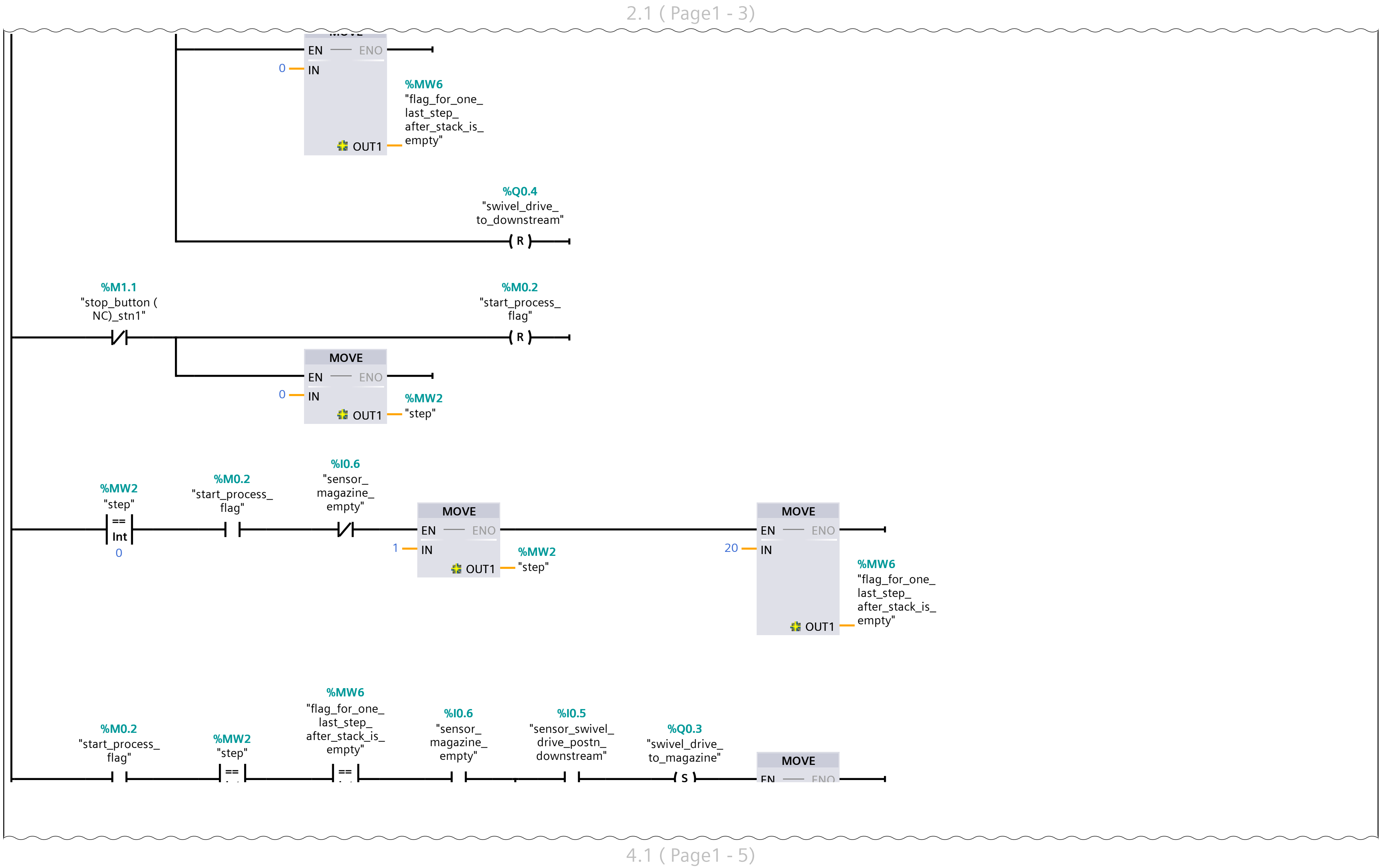

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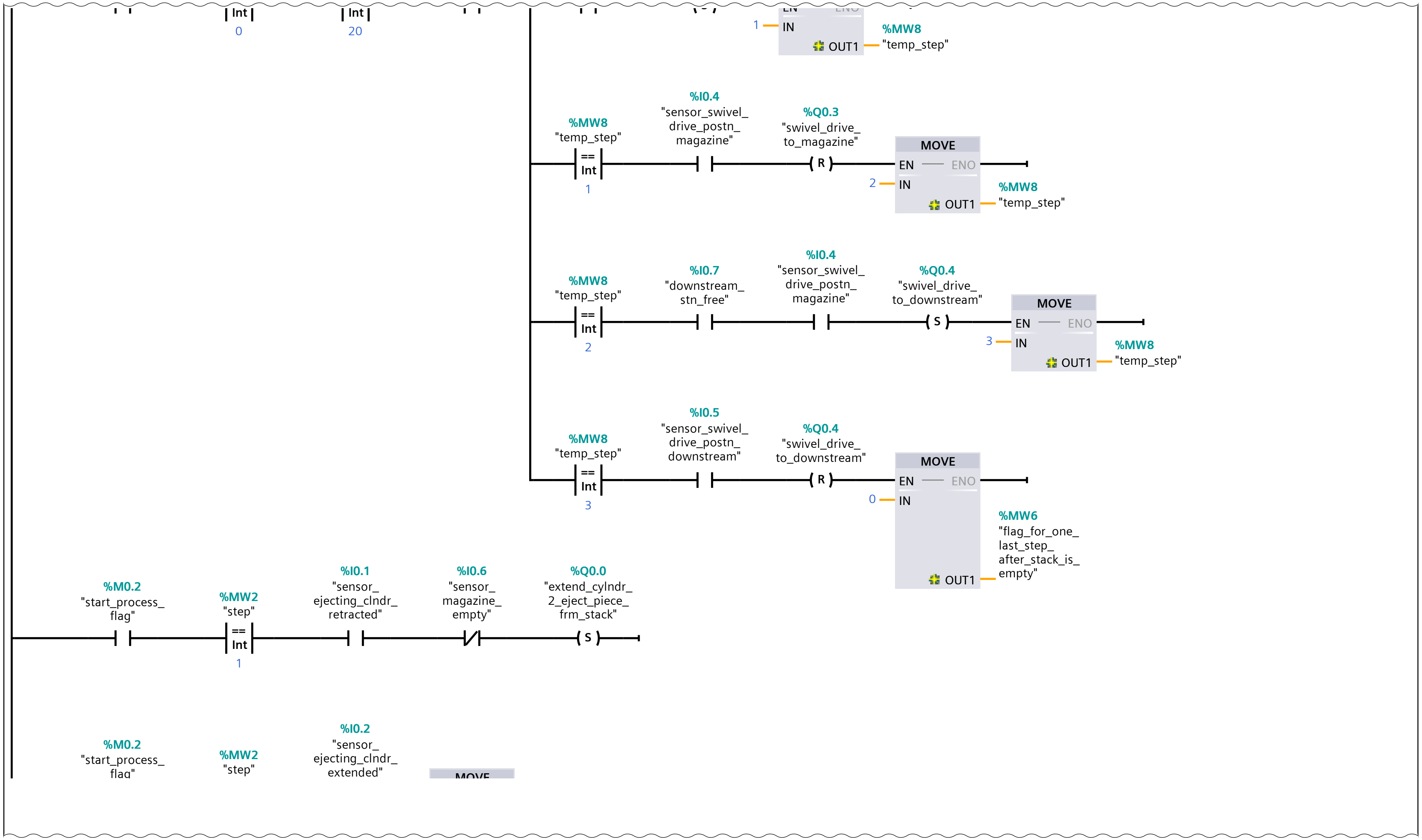

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Network 1: (5.1 / 7.1)

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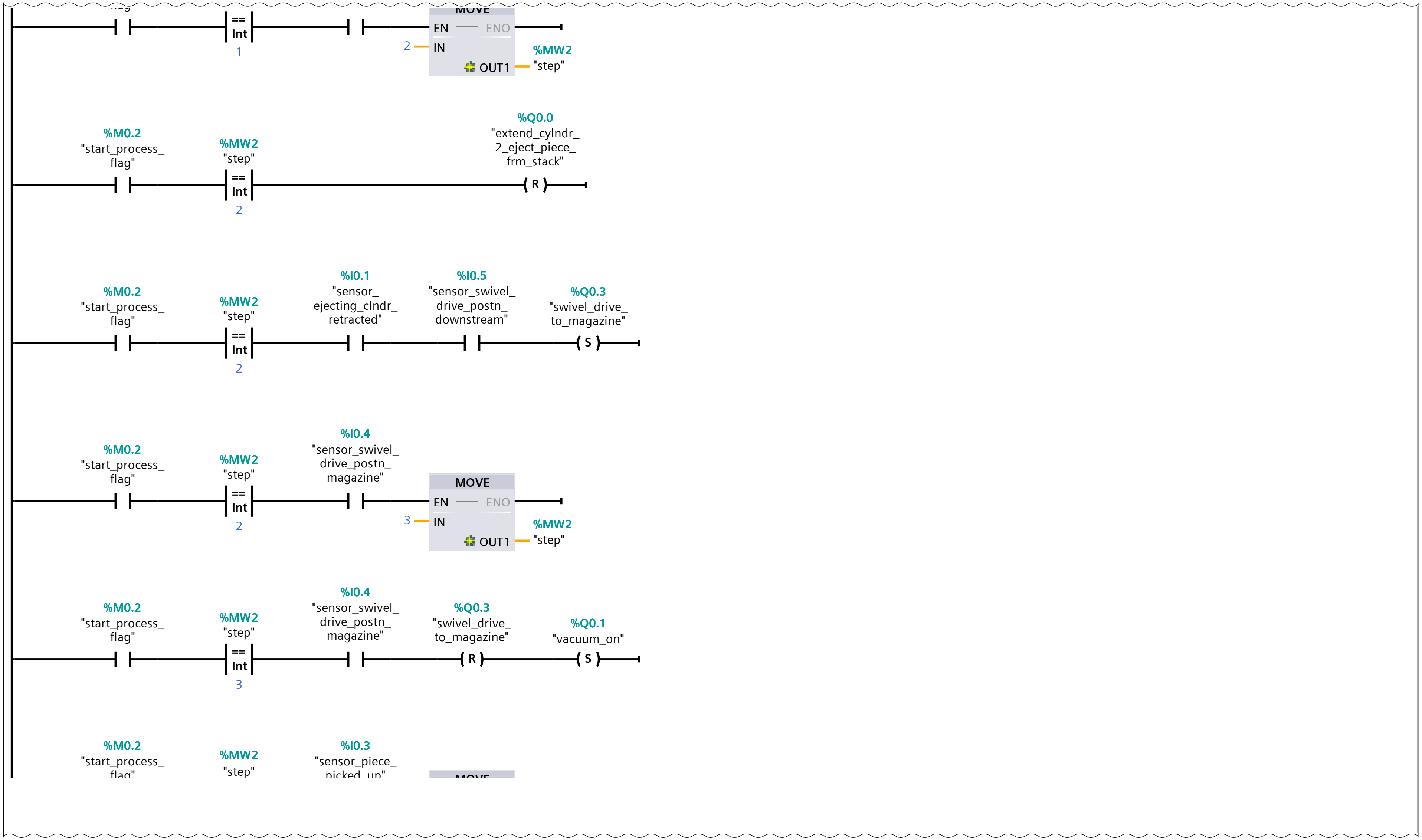

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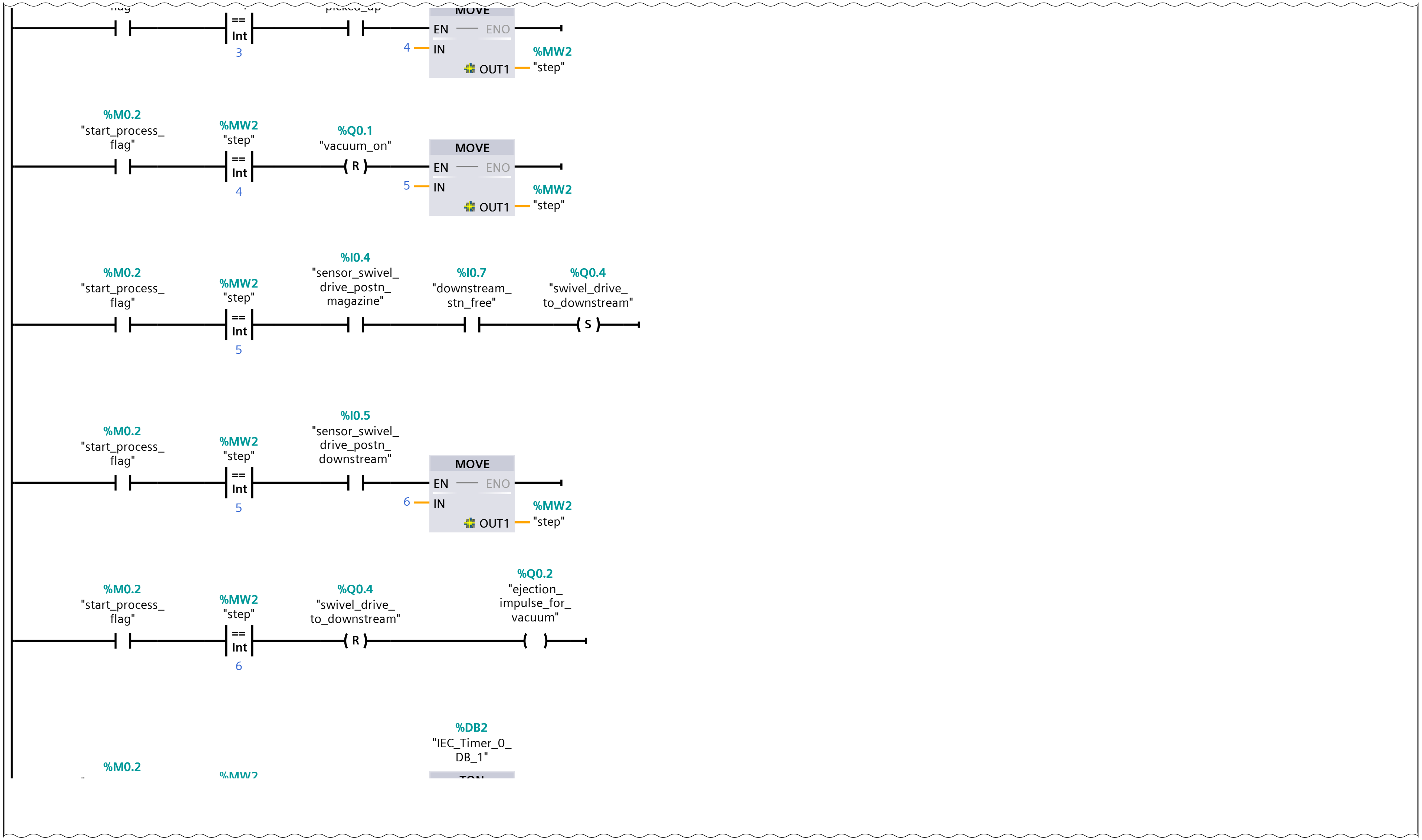
Network 1: (6.1 / 7.1)

5.1 (Page1 - 6)



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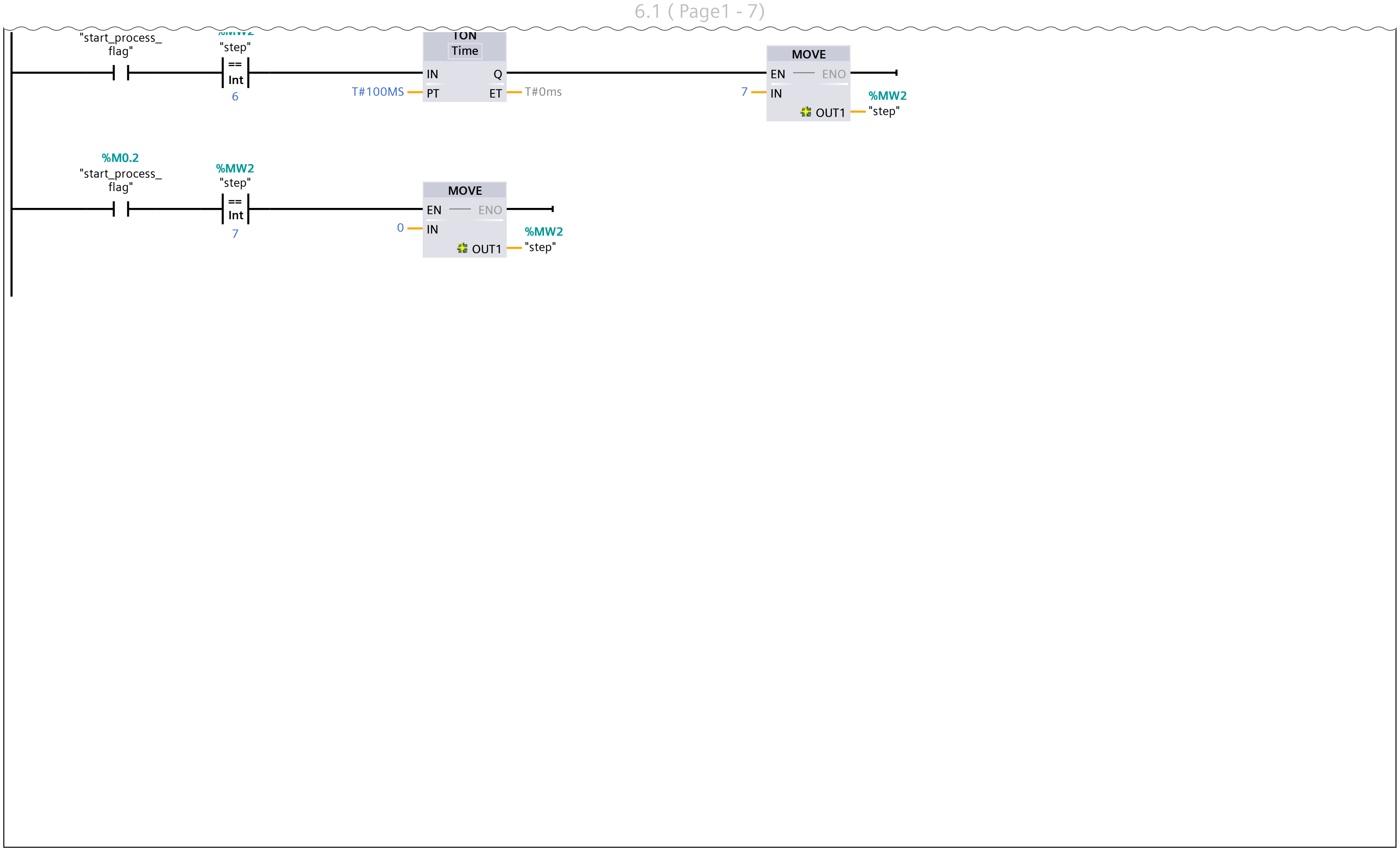


Appendix B

PLC Program for Testing Station

The PLC program that governs the testing station has been developed on its corresponding S7-1500 PLC. The ladder logic program corresponding to the testing station is given on the following page.

Festo MPS System / 2 Testing Station [CPU 1515-2 PN] / Program blocks

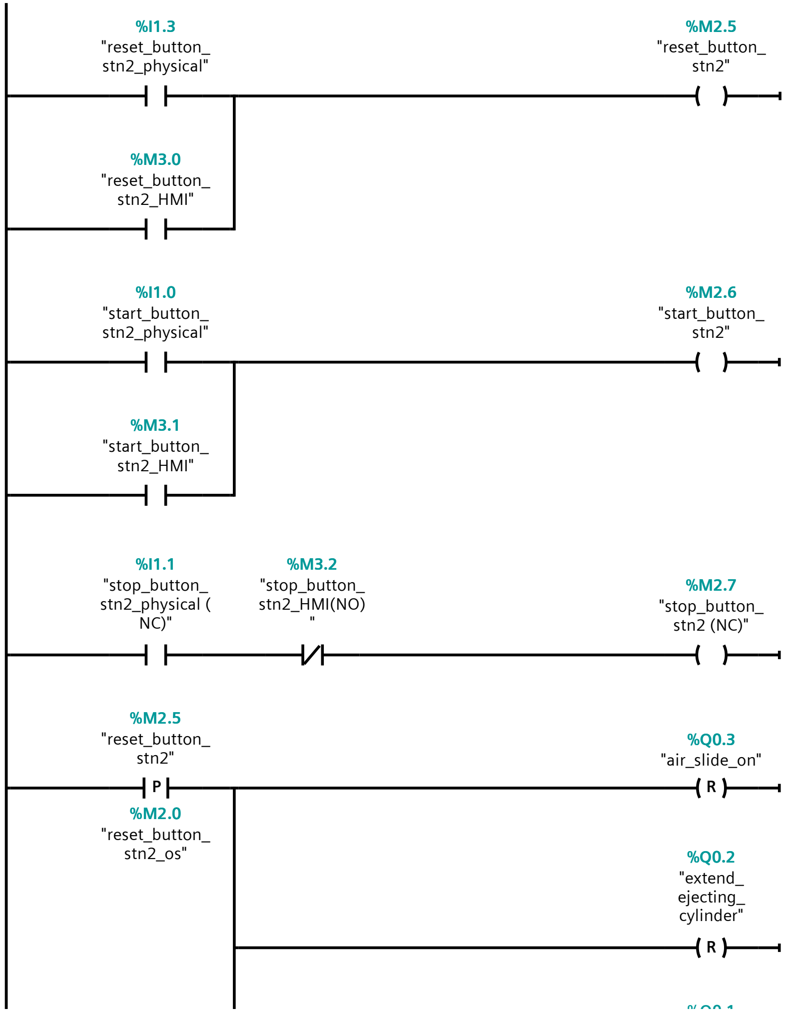
Main [OB1]

Main Properties							
General							
Name	Main	**Number**	1	**Type**	OB	**Language**	LAD
Numbering	Automatic						
Information							
Title	"Main Program Sweep (Cy-cle)"	**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Main		
Name	**Data type**	**Default value**
▼ Input		
Initial_Call	Bool	
Remanence	Bool	
Temp		
Constant		

Network 1:

Network 1: (1.1 / 6.1)



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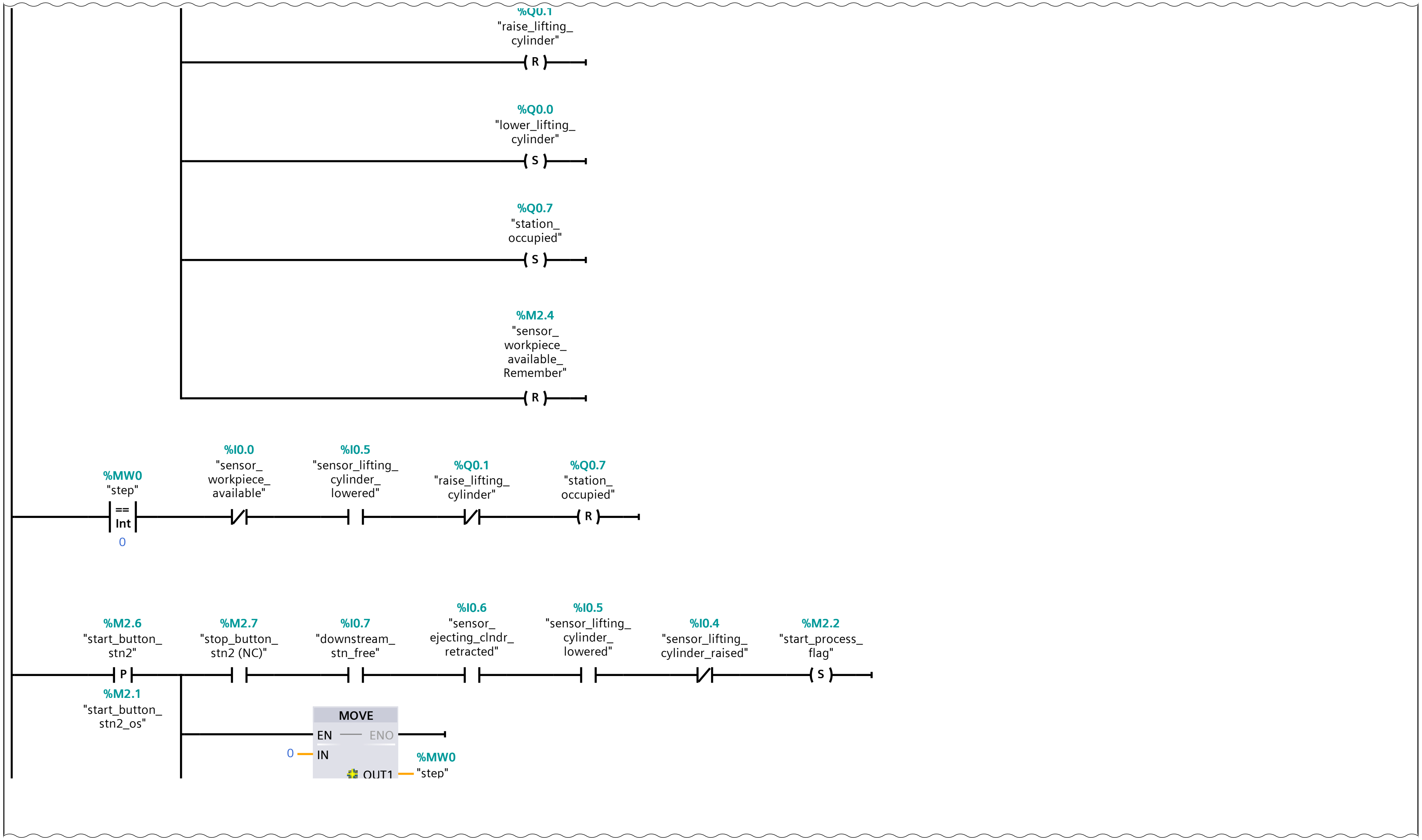

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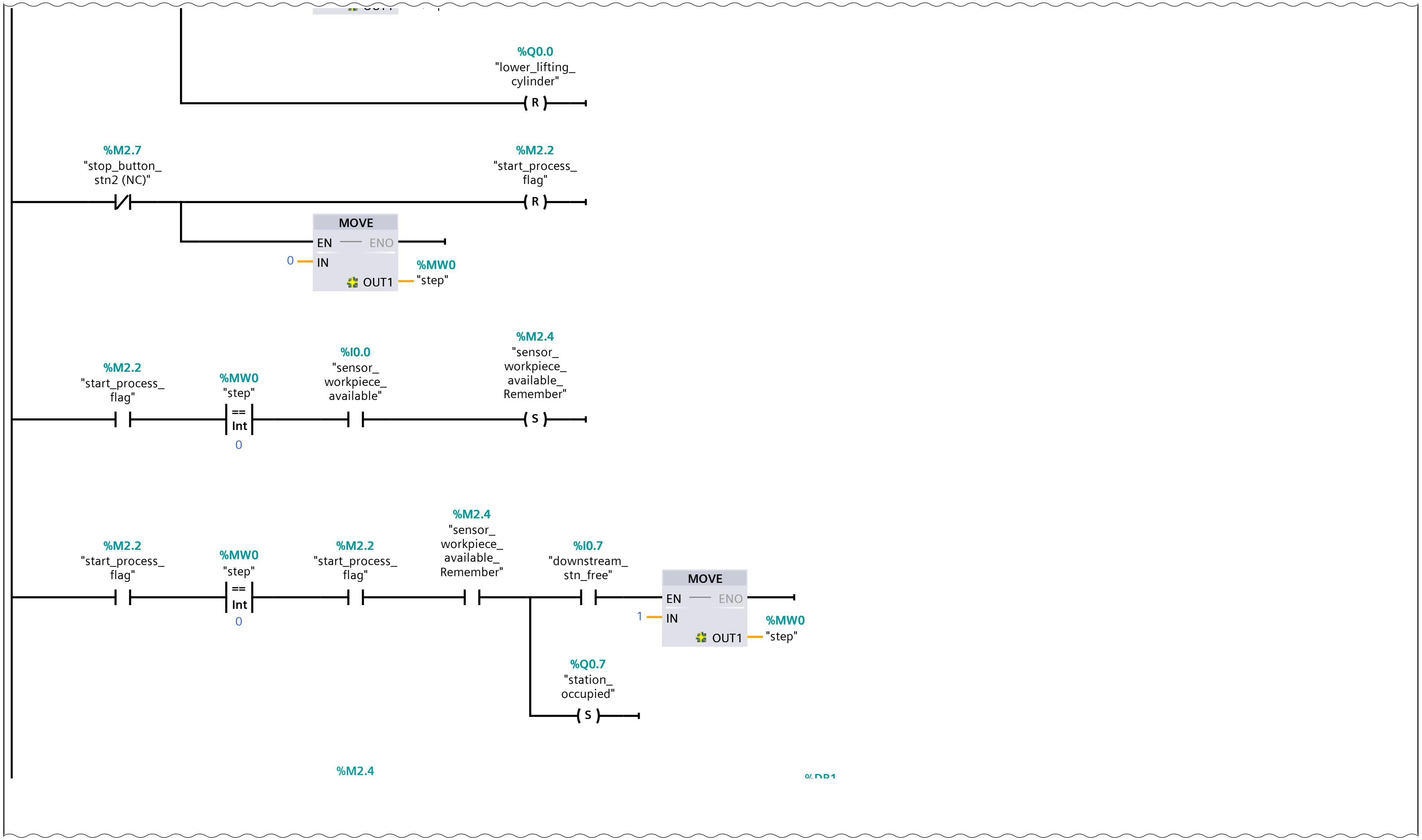
2.1 (Page1 - 3)



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Network 1: (4.1 / 6.1)

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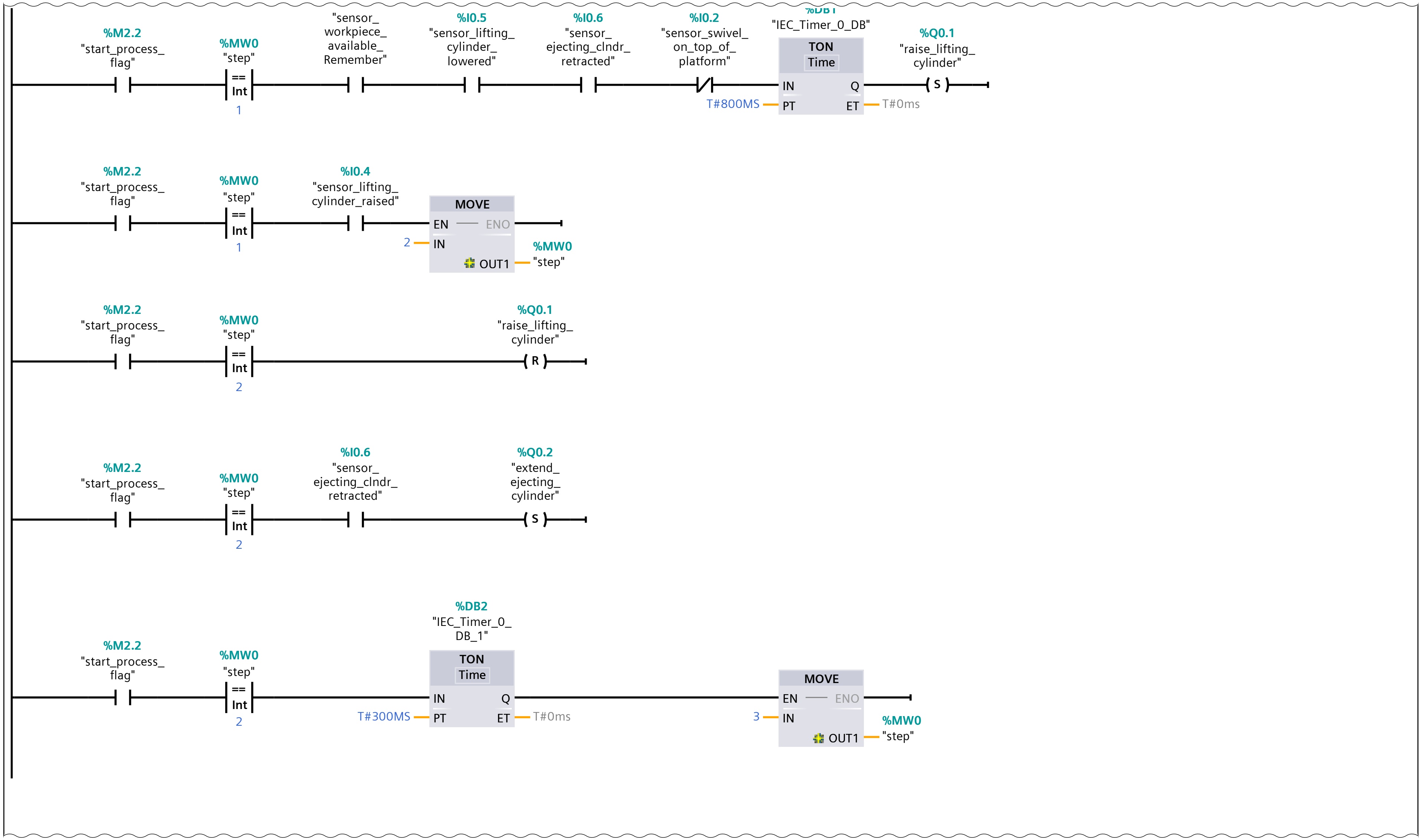

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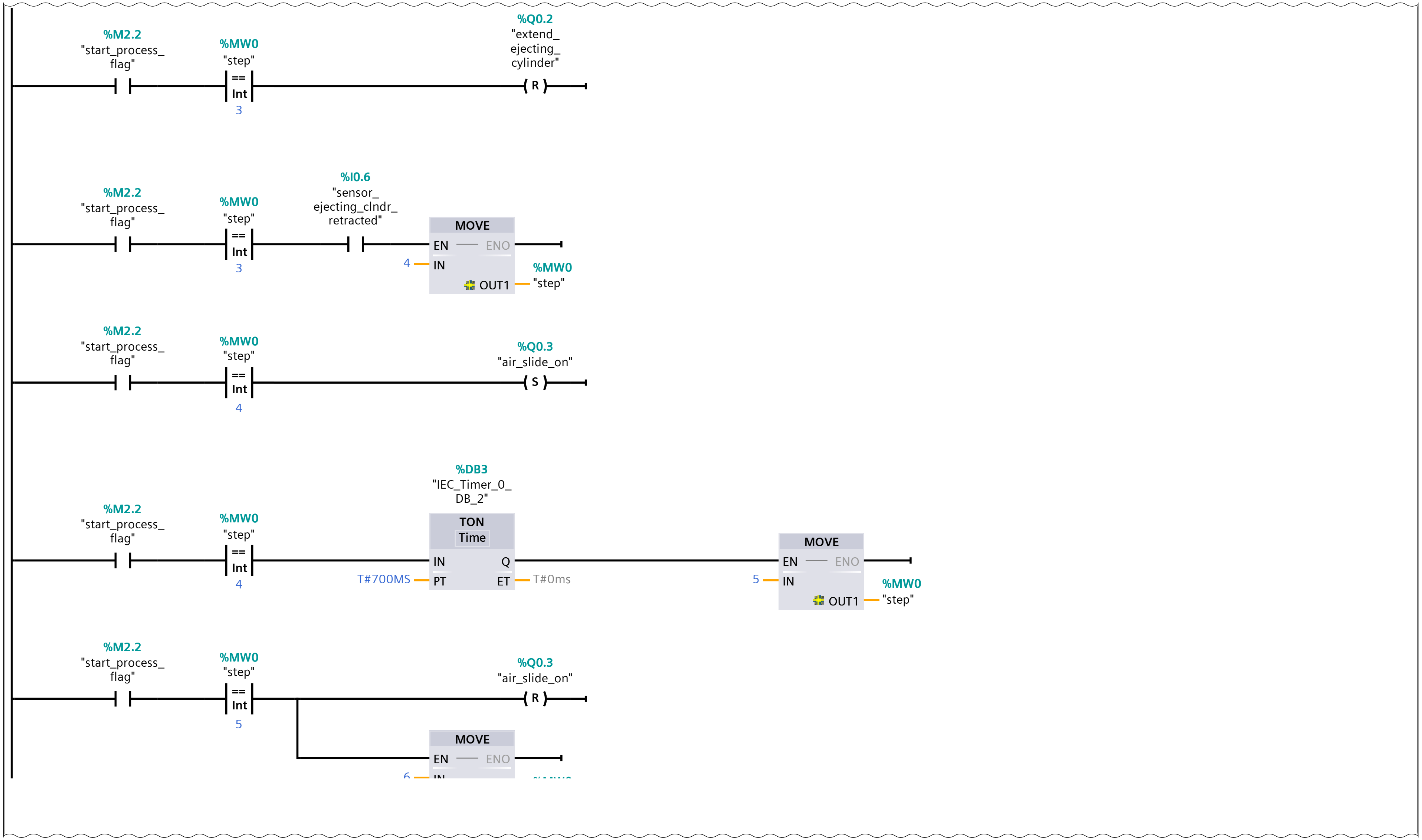

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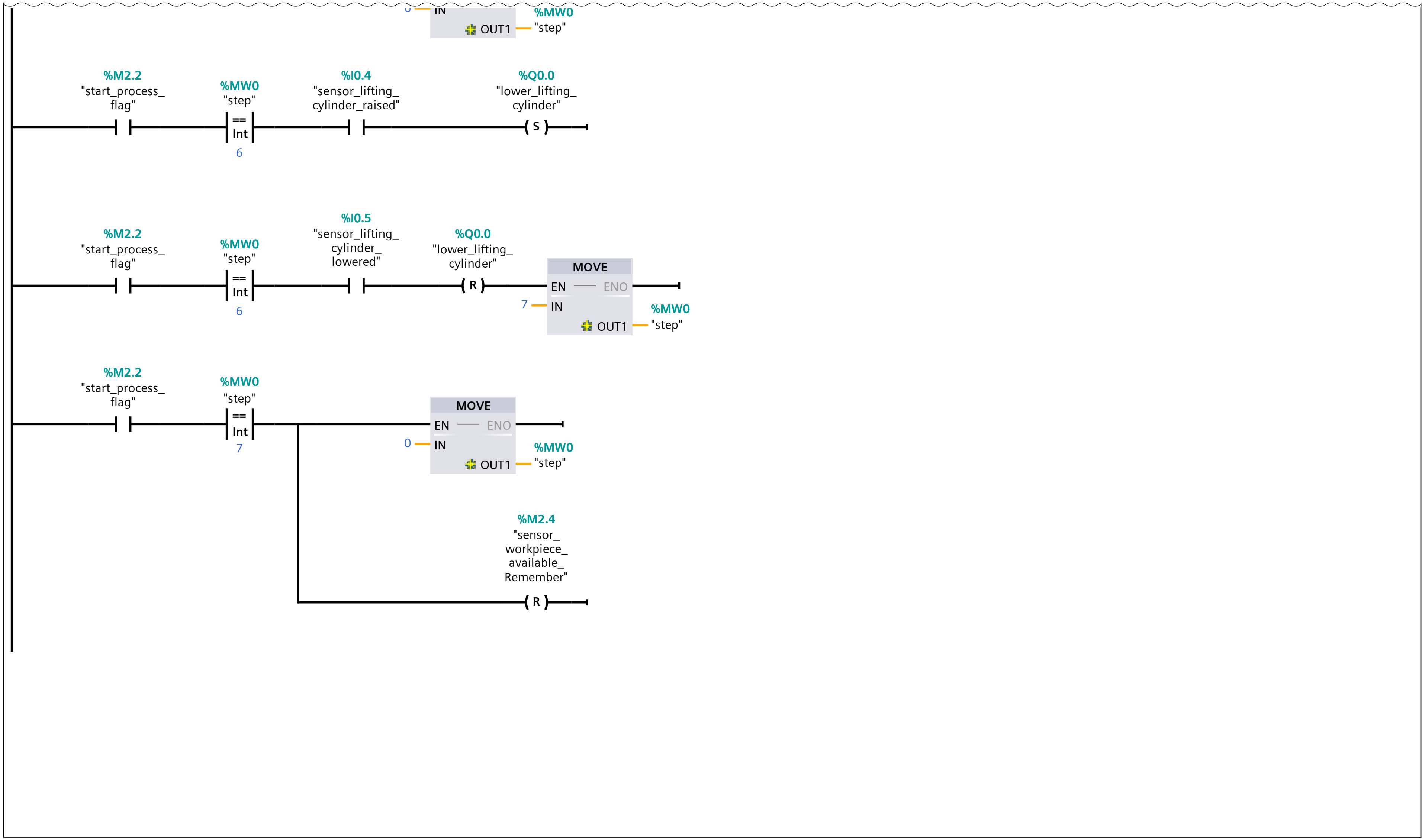
Network 1: (6.1 / 6.1)

5.1 (Page1 - 6)



Appendix C

PLC Program for Processing Station

The PLC program that governs the processing station has been developed on its corresponding S7-1500 PLC. The ladder logic program corresponding to the processing station is given on the following page.

Festo MPS System / 3 Processing Station [CPU 1515-2 PN] / Program blocks

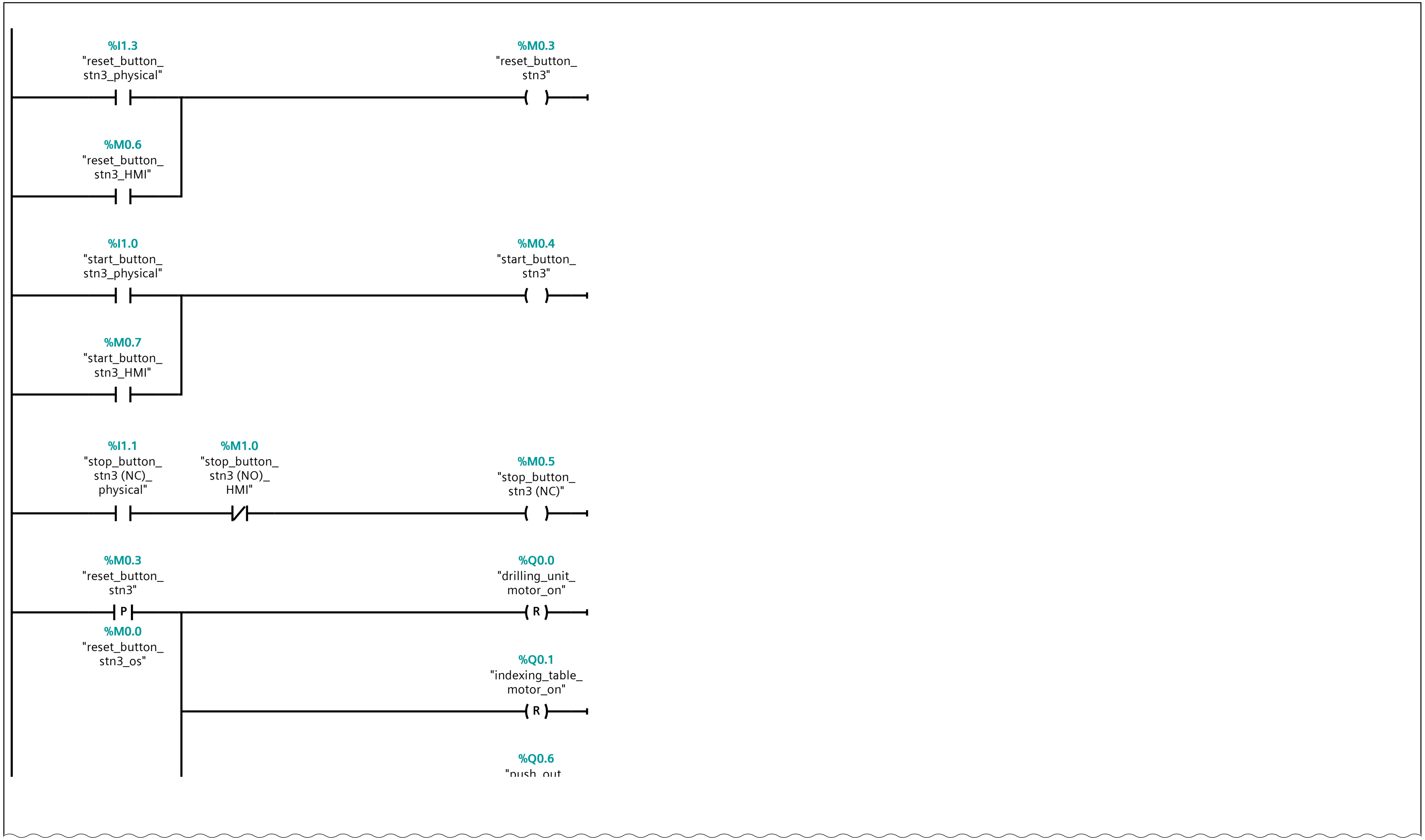
Main [OB1]

Main Properties							
General							
Name	Main	**Number**	1	**Type**	OB	**Language**	LAD
Numbering	Automatic						
Information							
Title	"Main Program Sweep (Cy-cle)"	**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Main		
Name	**Data type**	**Default value**
▼ Input		
Initial_Call	Bool	
Remanence	Bool	
Temp		
Constant		

Network 1:

Network 1: (1.1 / 7.1)



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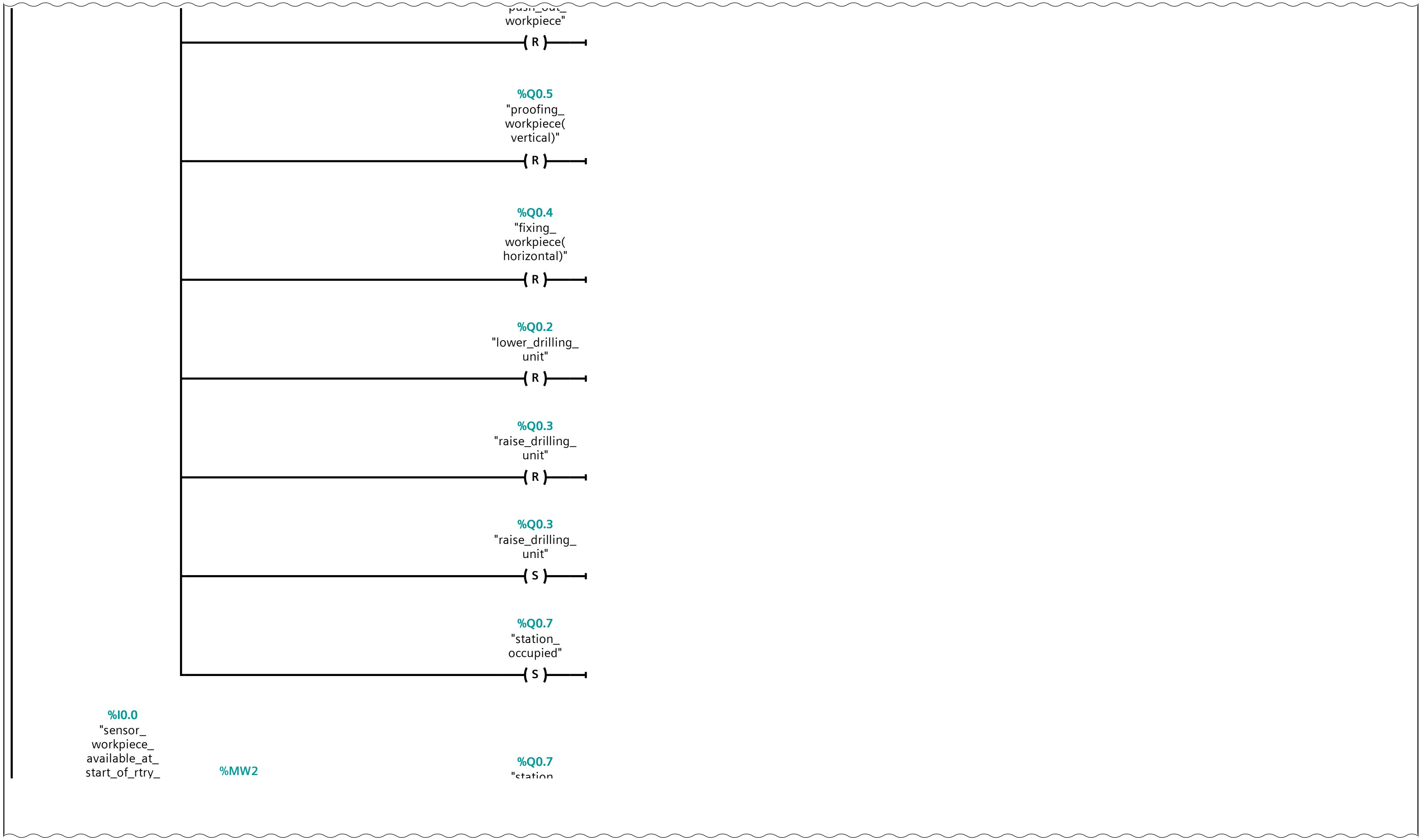

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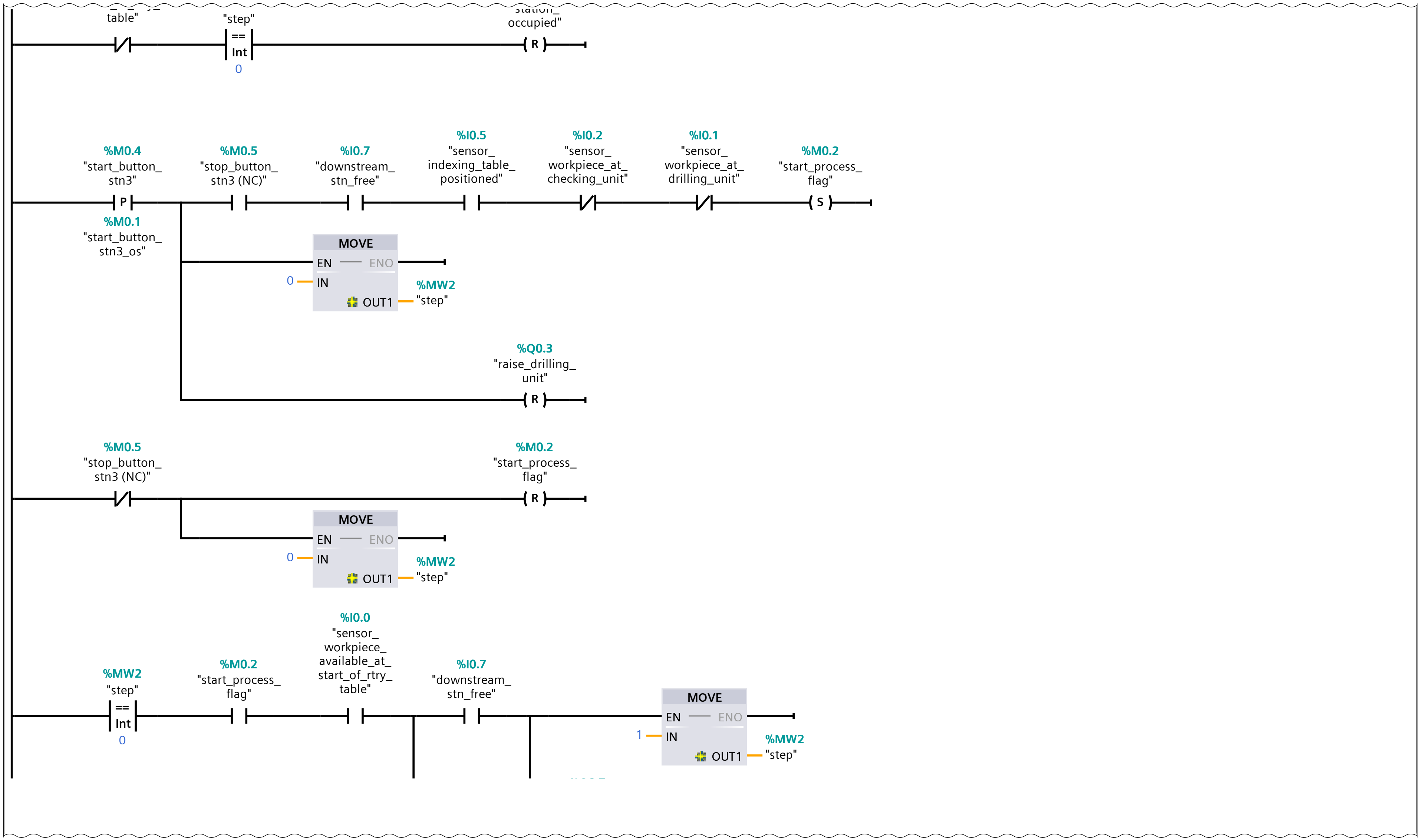

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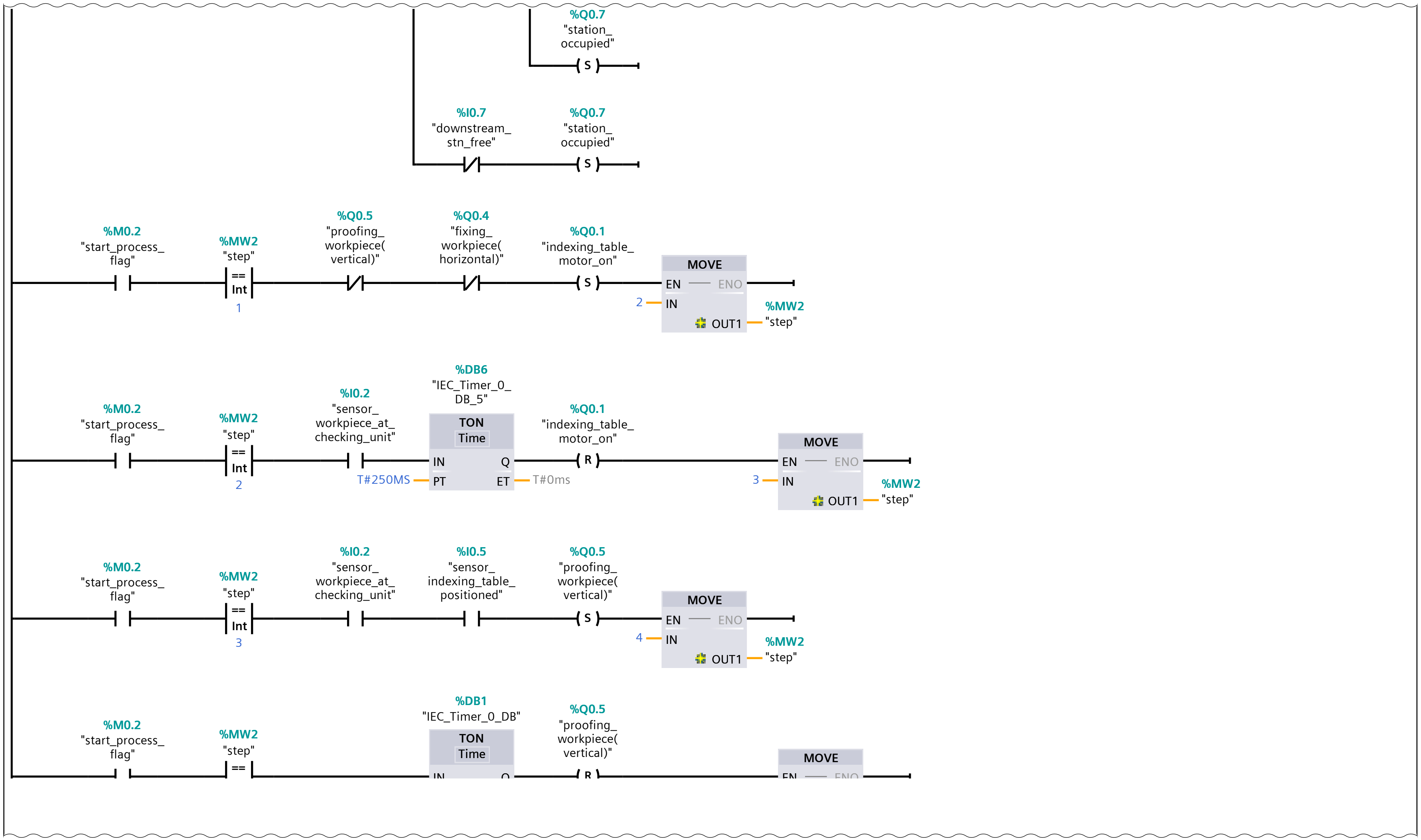
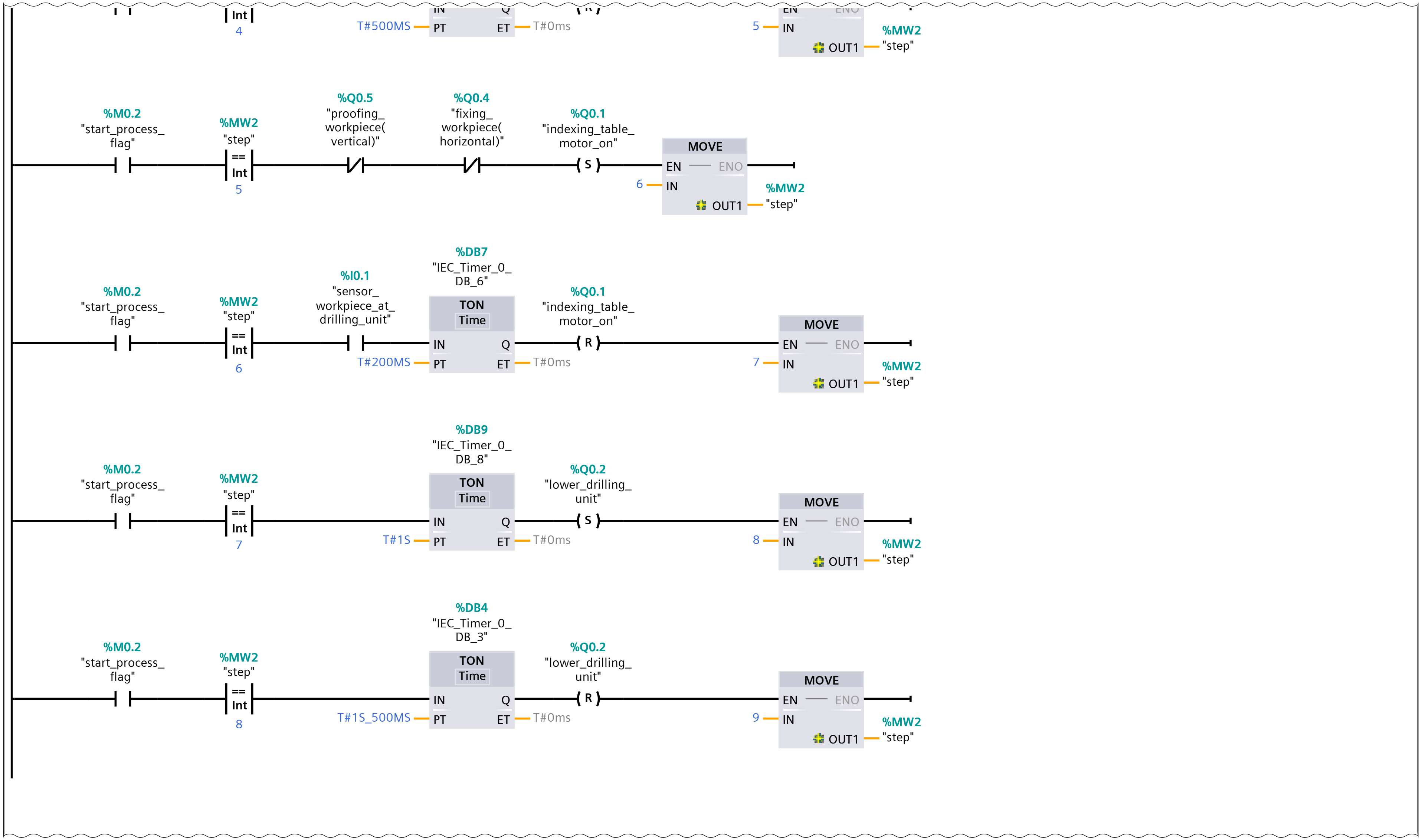
3.1 (Page1 - 4)



5.1 (Page1 - 6)

Network 1: (5.1 / 7.1)

4.1 (Page1 - 5)

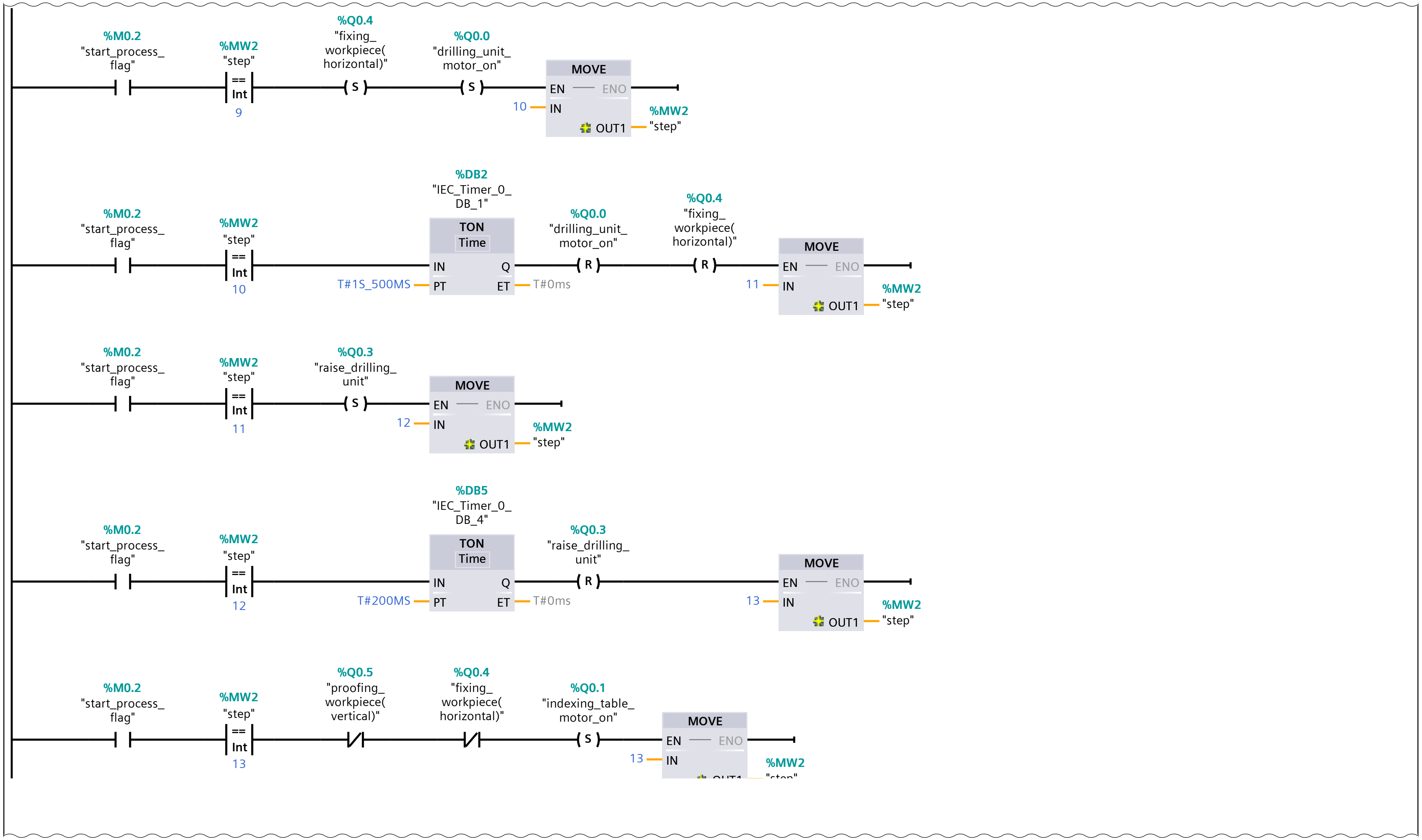


6.1 (Page1 - 7)

Totally Integrated
Automation Portal

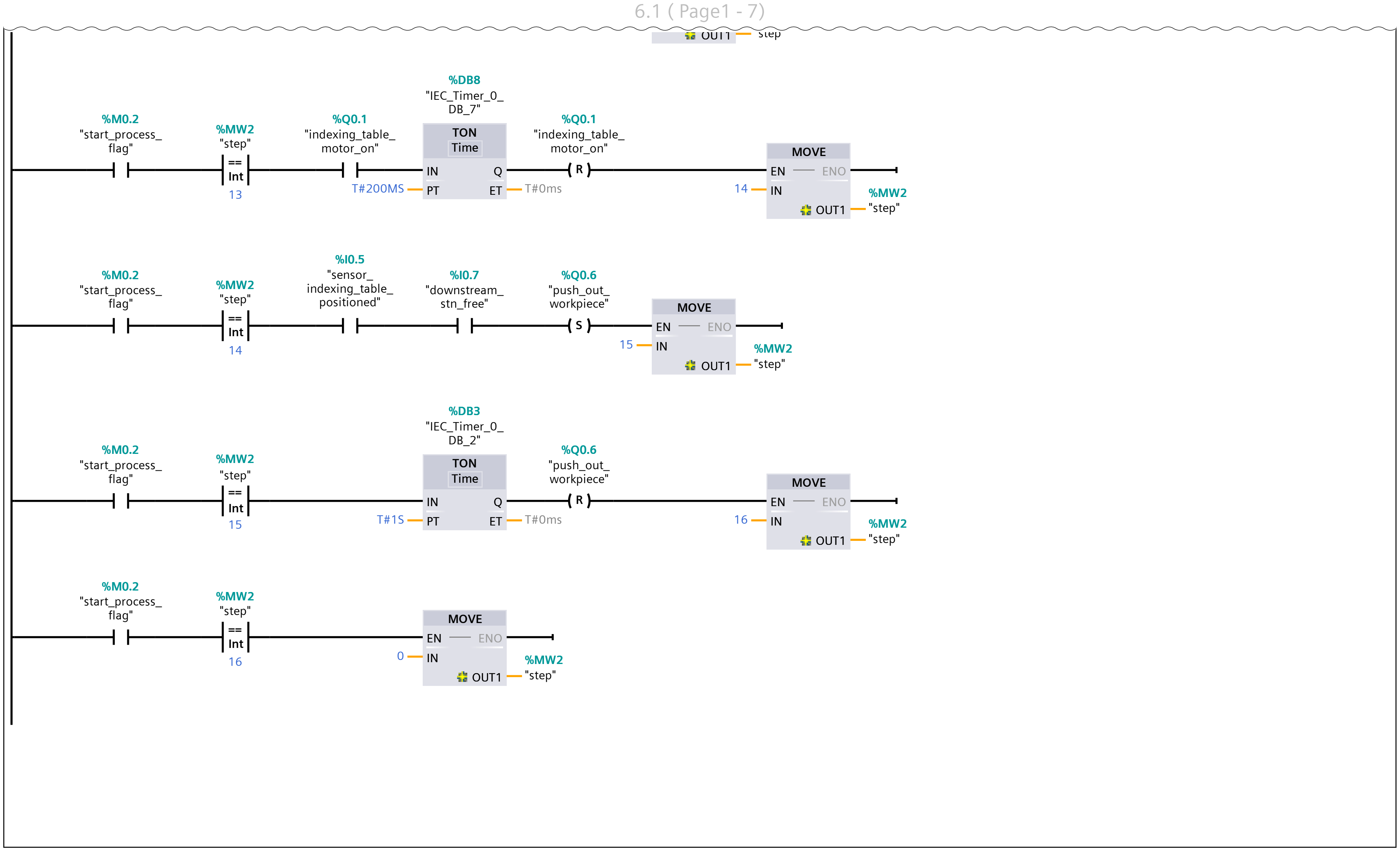
Network 1: (6.1 / 7.1)

5.1 (Page1 - 6)



7.1 (Page1 - 8)

Network 1: (7.1 / 7.1)



Appendix D

PLC Program for Sorting Station

The PLC program that governs the sorting station has been developed on its corresponding S7-1500 PLC. The ladder logic program corresponding to the sorting station is given on the following page.

Festo MPS System / 4 Sorting Station [CPU 1515-2 PN] / Program blocks

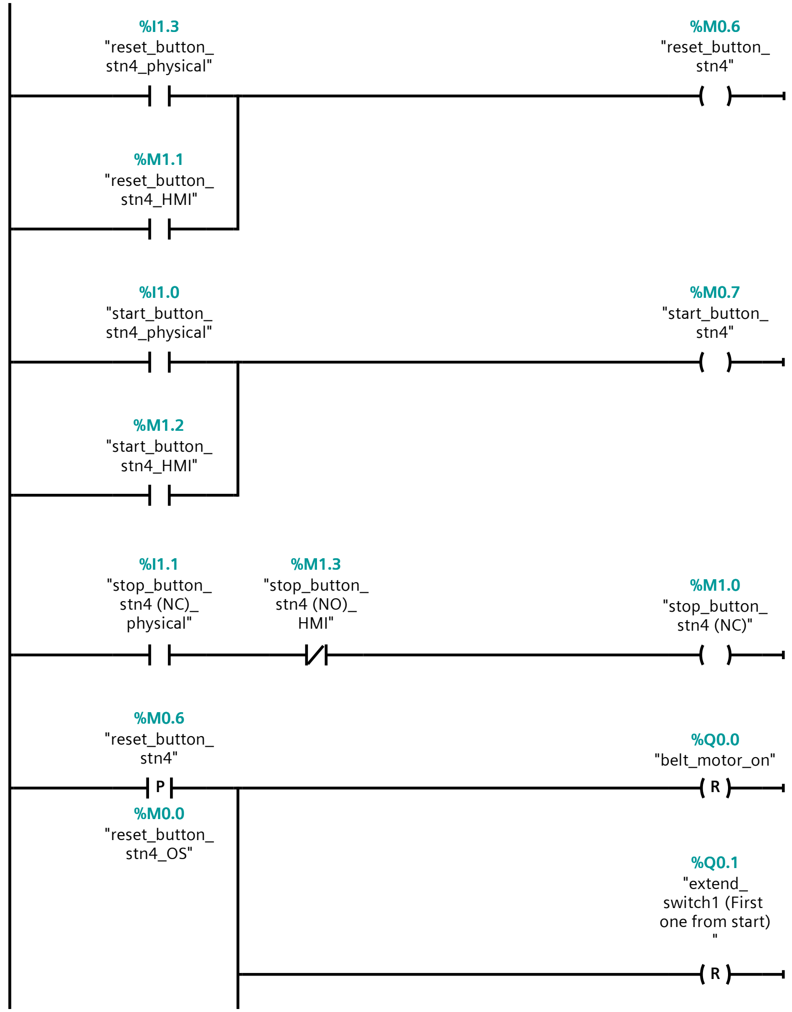
Main [OB1]

Main Properties							
General							
Name	Main	**Number**	1	**Type**	OB	**Language**	LAD
Numbering	Automatic						
Information							
Title	"Main Program Sweep (Cycle)"	**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Main		
Name	**Data type**	**Default value**
▼ Input		
Initial_Call	Bool	
Remanence	Bool	
Temp		
Constant		

Network 1:

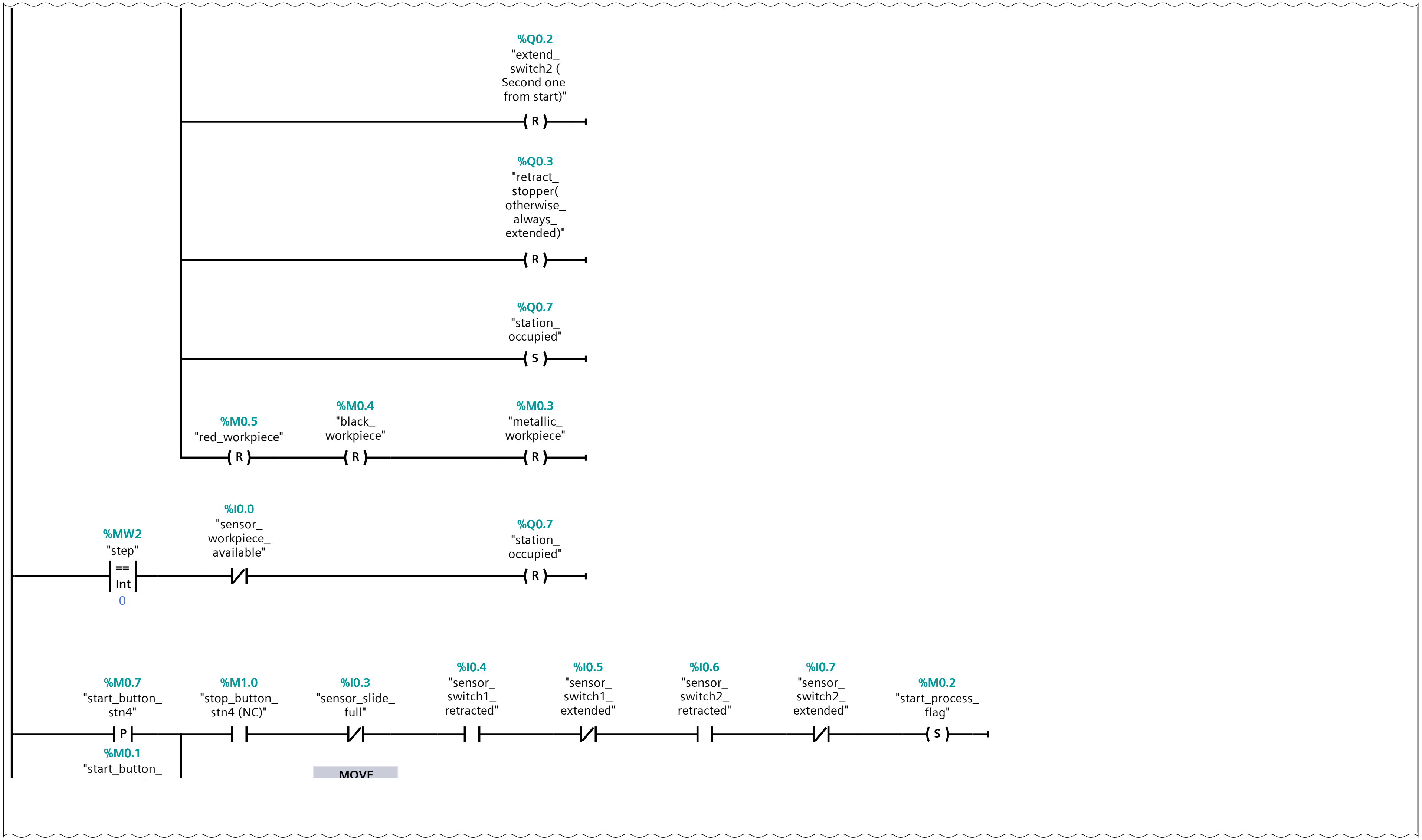
Network 1: (1.1 / 6.1)



2.1 (Page1 - 3)

Network 1: (2.1 / 6.1)

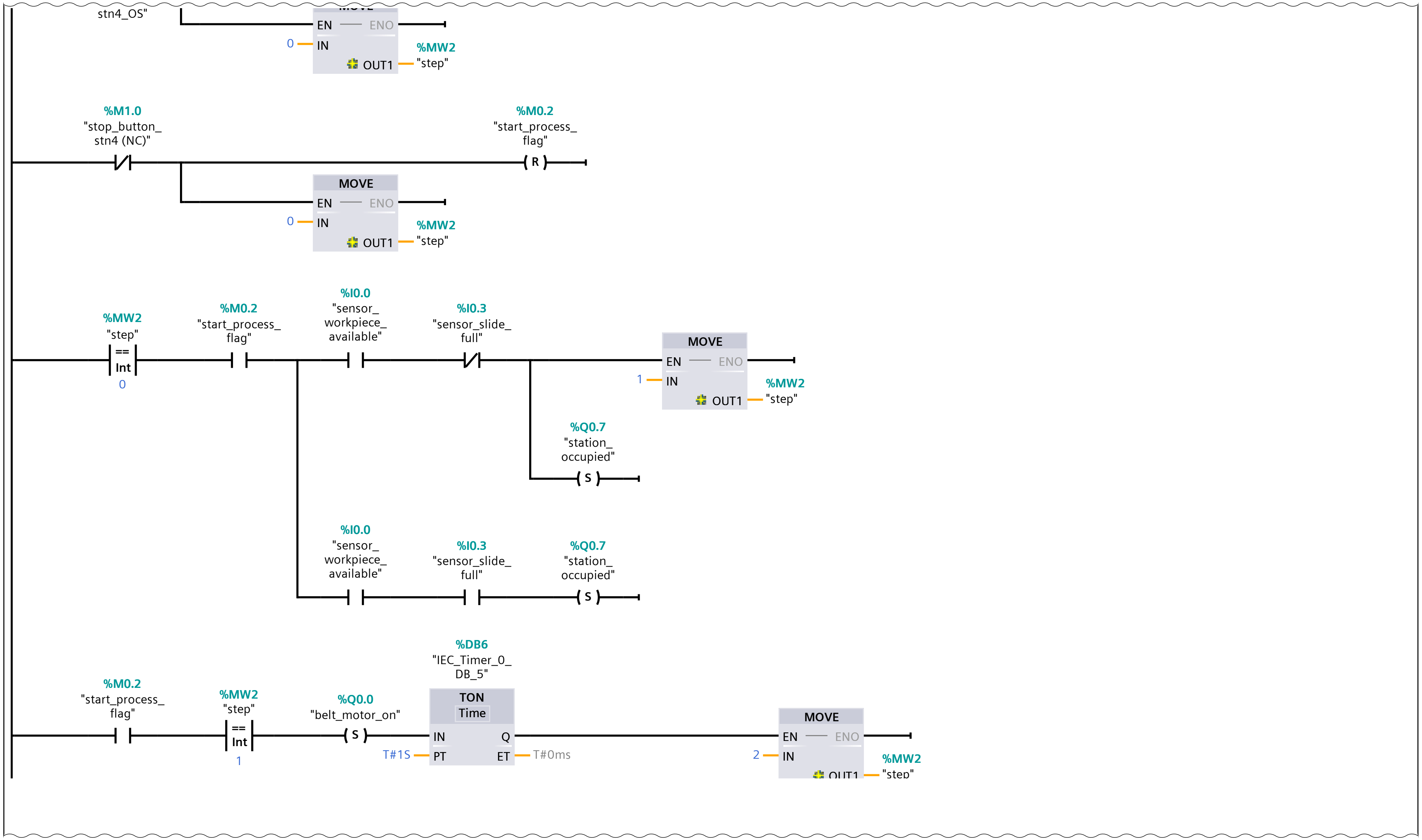
1.1 (Page1 - 2)



3.1 (Page1 - 4)

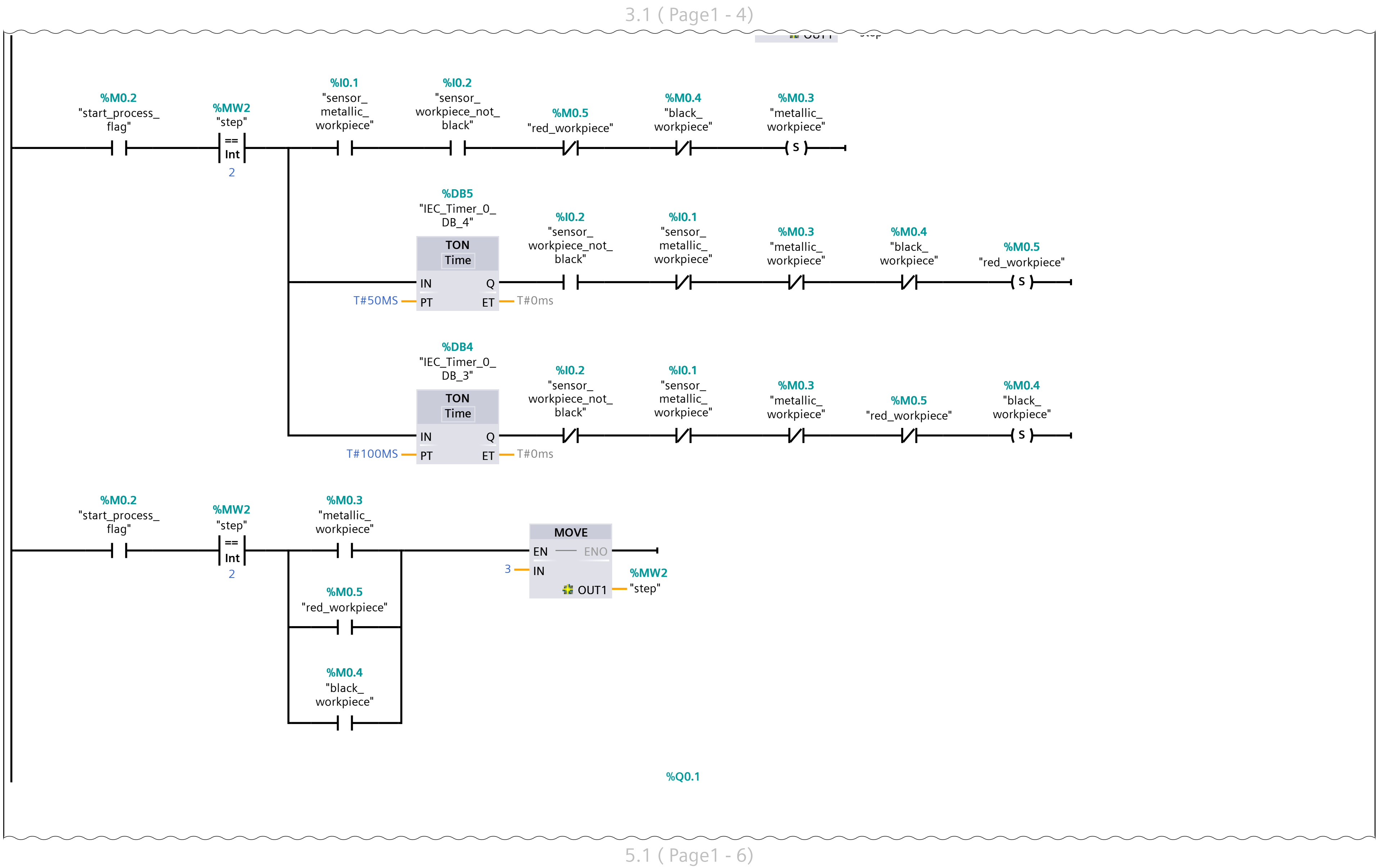
Network 1: (3.1 / 6.1)

2.1 (Page1 - 3)



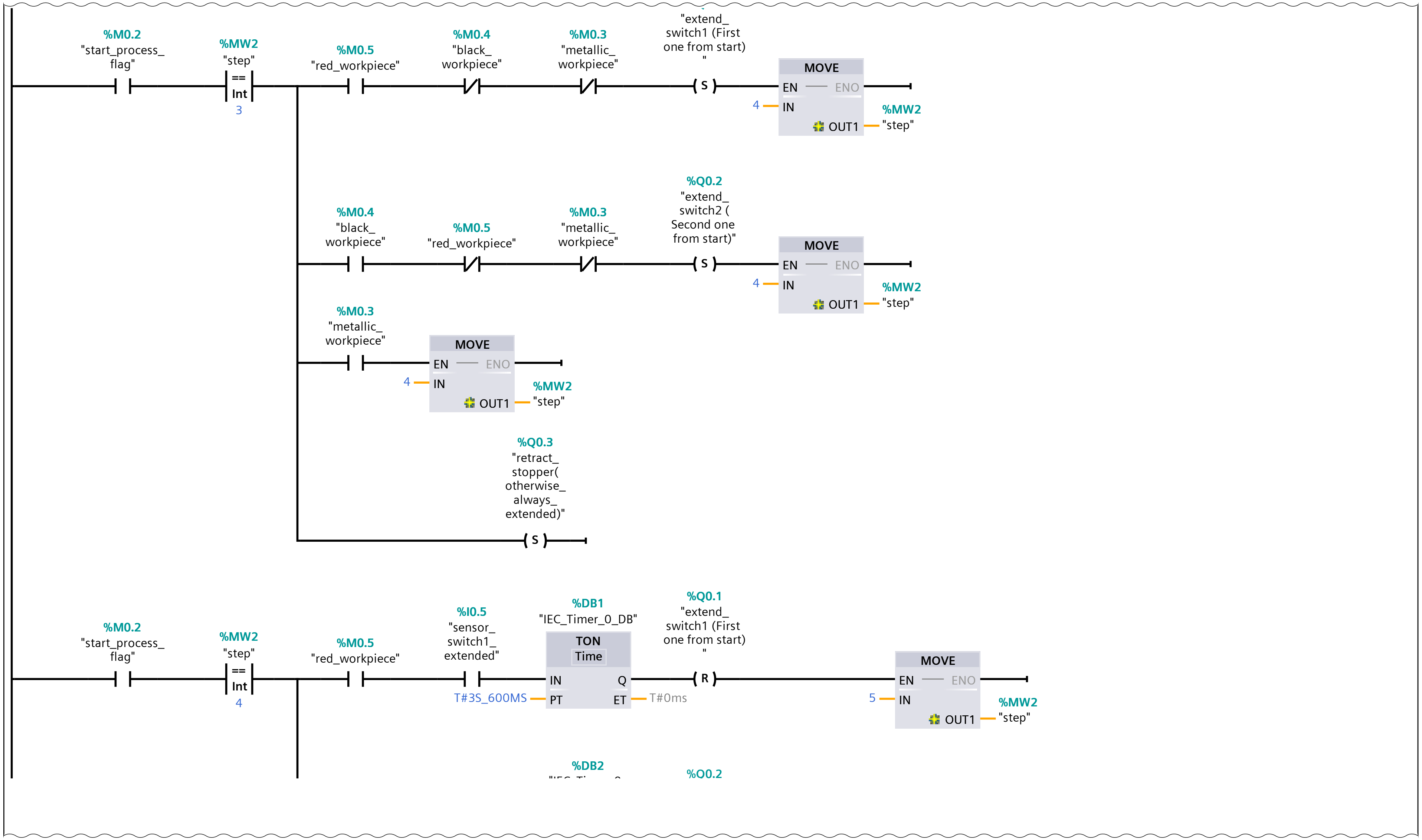
4.1 (Page1 - 5)

Network 1: (4.1 / 6.1)



Network 1: (5.1 / 6.1)

4.1 (Page1 - 5)



6.1 (Page1 - 7)

Network 1: (6.1 / 6.1)