7 Programmable Logic Controllers (PLC)

by

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7.1 Introduction

The textile processes are often characterized by their complexity. Therefore specific control systems are necessary to supervise and rule the operations of the production activities. Additionally, since the various production steps are in sequential order, they require synchronization and control of the interconnection between the various phases of the production lines. The automation systems receive signals from the sensing and measuring devices, they process them and they generate commands to activate correspondingly the actuators, which in turn change the operation conditions of the machines.

According to the initial approach the control systems were realized through electronic circuits. The inputs of them received the signals of the sensing devices located on the machines and their output was driven the actuators. The decisions were made according to logical correlations between the values of the inputs, which were realized by the design details of the electronic system. Often this method of construction of a control system is known as wired logic approach. As it is expected, the logic relationships between the inputs and the outputs could not be changed easily since they require the hardware change of the electronic systems. Practically a new system should be designed in order to obtain the new characteristics demanded by the user.

A later alternative to the wired logic systems became possible after the spread of the use of the microcomputer systems in the industry. Industrial computer systems with specific characteristics have been designed to serve as general purpose control systems. The inputs of that systems can receive the signals of the sensing devices and the outputs can drive small loads or they can activate relays to drive heavier loads. The control logic i.e. the logical correlation of the inputs and the outputs ir realized through the applications software of the microcomputer system. This category of the industrial control systems are known widely as programmable logic systems (PLC's). The use of the PLC's has been spread rapidly and they have supported highly the automatization of the textile processes. The processes can be automated by the use of the PLC's without any need of extremely specialized electronic engineers as it was necessary for the design of the wired logic systems. The implementation of the PLC's presupposes two major actions: a. the selection of the suitable PLC among the existing models in the market or the selection of a specific configuration in the case of modular systems and b. the development of the application software according to the control logic to be realized. Often the software is developed using a symbolic graphics language, so that the elimination of the need of highly skilled programming personnel to be achieved.

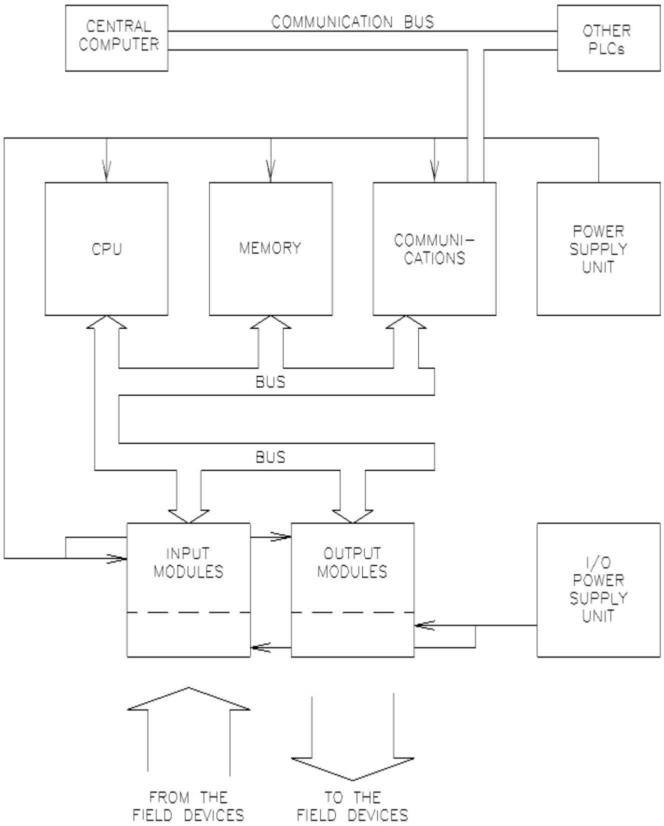

Figure 7.1: PLC's block diagram and its interconnections.

7.2 PLC characteristics

From the structural point of view, the PLC's form two major categories: the compact and the modular systems. The two types are used in applications with considerable different requirements and they are not competitive to each other.

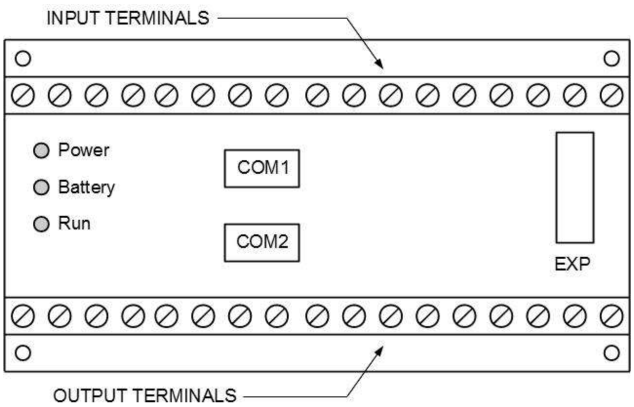

Figure 7.2: Typical outline of a compact PLC.

The compact PLC's physically are located in a single box with connecting strips for the input and the output signals. The case of the PLC is suitable for industrial use. The compact PLC's have a standard number and kind of inputs and outputs per specific model and constructor. As a rule, they can not be changed i.e. the user can not add or remove inputs and outputs. Thus it is essential to select the proper PLC by forecasting the possible future needs, in order to avoid change of the PLC due to lack of inputs or outputs in a next development phase of after a necessary change. Newer and sophisticated architectures permit the cascade connection of more that one PLC, allowing the development of higher capacity systems based on compact units. The compact PLC's are relatively of low prices and they are available in various configurations concerning the inputs and the outputs number available to the user. Typical number of inputs and outputs characteristic for compact PLC's is up to 20. Apart of the control inputs and outputs the compact PLC's are equipped with communication lines, power inputs etc. The software development can be made through specific consoles of from personal computers equipped with the necessary development software. The final version of the application code is downloaded to the compact PLC using the communication ports existing for this specific operation.

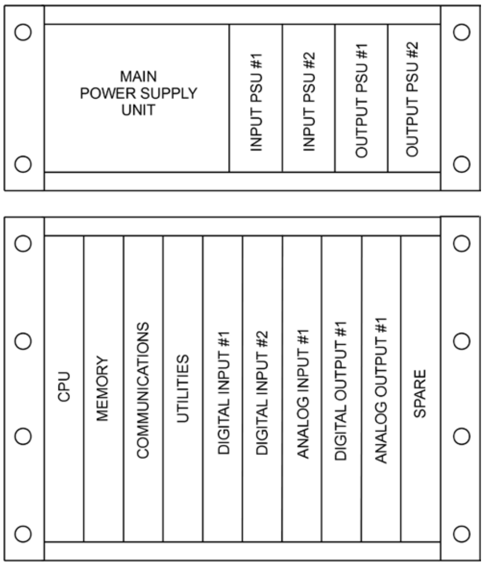

Figure 7.3: Typical outline of a modular PLC.

The modular PLC's are made to support the necessary expansion needs of the application. They consist of various modules of different kinds. They are placed on industrial racks and the correct selection of the type of the modules concerning their kind and their capacity results in the desired configuration. The initial configuration can be changed by removing and adding modules, of course within usually wide limits. Typically the number of the inputs and the outputs can be in the range of many decades or hundreds. The modular systems are usually more expensive than the compact ones and they are suitable for applications of higher complexity. The user selects the number of the inputs modules taking in account the type and the number of the inputs available in each specific module. In the same sense the output modules are selected and the final configuration will be available for the programming phase. In addition to the control input and outputs modules, there are available communications, power etc. modules.

7.3 Input and output characteristics

The inputs and the outputs can be of different kind designed to serve different needs of the users. However in order to support the industrial components and systems compatibility, the inputs and the outputs are standardized and a certain palette of them is being used in the industrial applications.

The inputs can be digital or analog. The digital inputs are simpler and they can receive signals corresponding to the logical levels "0" and "1". The analog inputs are more sophisticated and they can receive signals which are varying within certain limits. The analog input receives the signal, it conditions it and finally it samples it for the conversion of its amplitude in a digital word. This numerical value series generates the digital form of the signal to be used by the PLC. The analog inputs can receive either voltage or current signals. The typical standardized variation ranges for the voltage signals is 0–5 V and 0–10 V. For the electrical current signals is 0–20 and 4–20 mA. For the outputs of the PLC the categorization is the same as in the case of inputs.

The developer must take the output characteristics of the sensing devices and the input characteristics of the actuators in order to conclude to the final architecture of the PLC system and to define the exact number and kind of the single inputs and outputs or the respective number of the input and output modules.

7.4 Software development

The typical programming can be made using the graphical programming language known widely as "Ladder", due to the characteristic ladder-like structure of the programming graphics. However it is possible to use typical programming assembly or higher level languages coding tools as well. Every PLC is equipped with a certain firmware, a kind of simple operational system allowing the up- and downloading of the applications software, the start and stop of the operation etc.

The electrical signals are transmitted to the PLC over wires, which are connected to the inputs of the device. For a digital input the corresponding logical level is stored in a variable, able to be used by the program. The variables have standard format per PLC constructor. A typical format is "I1.2" corresponding to the second input of the first input module. The respective format exists for the outputs i.e "O2.3" declaring the third output of the second output module.

The values of the signals are represented and values of variables and they are used by the application software of the PLC in order to perform the control procedure. The application software realizes the logic of the correlations between the inputs and the outputs of the system i.e. the control algorithm. Any kind of change on the control algorithm can be made only by changing the application software of the PLC, without any hardware changing.

7.5 Operation of the PLC

The PLC is located in a suitable electrical box for the protection of it and of the cables and connectors. After the downloading to it of the final form of the application software, the PLC is ready for its industrial operation. The execution of the software starts by the dedication of specific values to the input variables according to the level of the signals connected on them. The execution of the control software uses the initial values of the variables. They remain constant even if the value of the signal changes during the execution of the control software. Any new value of the input will pass in the respective variable only after the end of the current control cycle and before the execution of the next control cycle. As it is obvious the fast response of the system to external changes, depends directly to the short duration of the control cycle of the software. The longer and complex the control software, the longer the execution time of the code and thus there will be a delay of the reaction of the system to the external changes.

7.6 A case study

A characteristic example of the use of PLC's has been selected in order to give the practical aspects of their implementation. The scenario of the application is as follows:

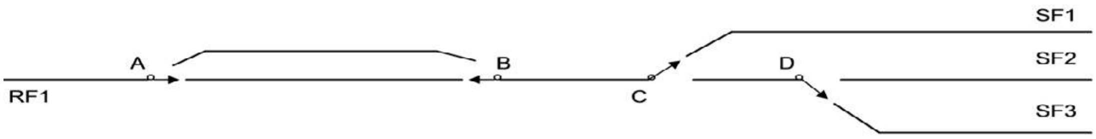

Figure 7.4: The bobbins transportation layout between roving and spinning frames.

In a spinning mill the transfer of the bobbins from the roving frame (RF1) to the ring spinning frame (SF) is automated. It is considered that a roving frame feeds three ring spinning frames (SF1, SF2 and SF3). The bobbins are transferred hanged on trains, which move on rails. On the branching of the rails there are remote controlled shunts. They take the proper positions so that the train will find the right path. The topology of the installation is as follows. There are four trains on the rails.

Upon the loading of the full bobbins on the ring spinning frame, the empty ones are transferred on the train. The ring spinning frame sends a train replacement request signal. The shunts take a proper position, so that the empty bobbin train will travel to the bypass rail between A and B. It stays there for a while. The shunts take a position which permits the full bobbin train to travel to the ring spinning frame. Then the shunts change their position again, so that the empty bobbin train waiting in the bypass rail will arrive in the roving frame rail.

Figure 7.5: The SIMATIC-S7 PLC of Siemens.

In order to give a realistic solution on the above technical implementation, a PLC of Siemens has been selected. The SIMATIC-S7 is widely used and it has a very good technical support. From the family of SIMATIC-S7 the CPU 224 is used. We suppose that the input signals are connected to the SIMATIC-S7, the CPU evaluates their values, applies the combinational and sequential logic rules and finally activates the corresponding outputs. The outputs of the PLC drive the respective actuators for the control of the installation.

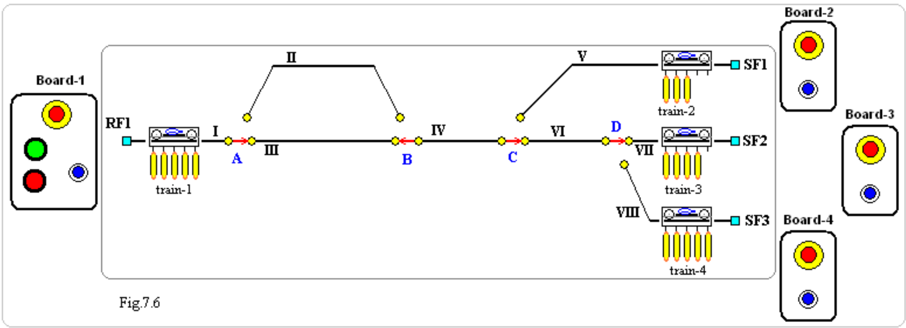

Figure 7.6: The operation buttons activate the inputs of the PLC.

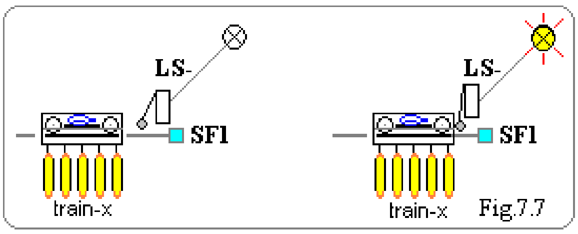

Figure 7.7: The arrived train activates the limit switch which in turn acts on the input of the PLC.

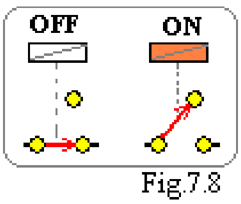

Figure 7.8: The shunts are activated by the outputs of the PLC through solenoids.

In the previous figures the interfaces of the inputs and the outputs of the PLC for the current application are indicated. The transportation system equipped with the input/output (I/O) signaling devices (switches and actuators) is given in the Figure 7.9.

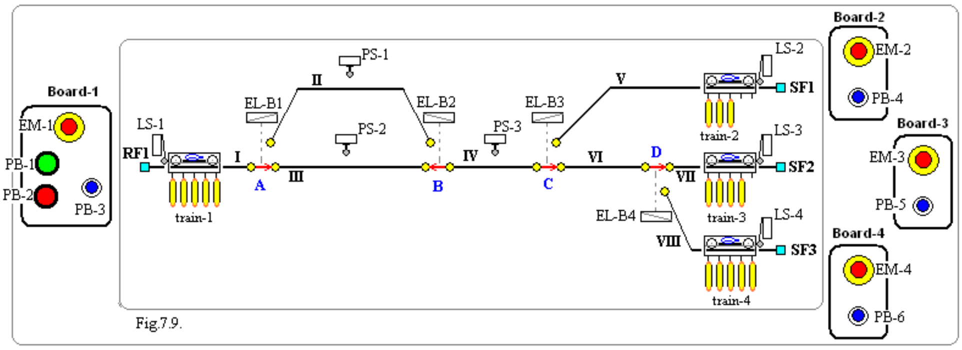

Figure 7.9: The outline of the installation with the I/O devices.

The input switches and the actuators are mapped on the inputs and outputs of the PLC, as in the following table 7.1. It is worth to mention that the physical signal caused by the pressing of the emergency switches is allocated on the input I0.0. In the software of the PLC, the emergency signal will be handled as the value of the input I0.0 (1 or 0, true of false etc).

Inputs			Outputs		
Mnemonic	*Description*	*Inputs PLC*	*Mnemonic*	*Description*	*Outputs PLC*
EMS	Emergency Stop	I0.0	*D-1*	Direction Train-1	Q0.0
PB-1	Start System	I0.1	*M-1*	Electromotor Train_1	Q0.1
PB-2	Stop System	I0.2	*D-2*	Direction Train-2	Q0.2
PB-3	Train on area RF1 ready.	I0.3	*M-2*	Electromotor Train_2	Q0.3
PB-4	Button Call from area 1	I0.4	*D-3*	Direction Train-3	Q0.4
PB-5	Button Call from area 2	I0.5	*M-3*	Electromotor Train_3	Q0.5
PB-6	Button Call from area 3	I0.6	*D-4*	Direction Train-4	Q0.6
LS-1	Limit Switch Area 1 (RF1)	I0.7	*M-4*	Electromotor Train_4	Q0.7
LS-2	Limit Switch Area 2 (SF1)	I1.0	*EL-B1*	Electromagnet of Shunt-1	Q1.0
LS-3	Limit Switch Area 3 (SF2)	I1.1	*EL-B2*	Electromagnet of Shunt-2	Q1.1
LS-4	Limit Switch Area 4 (SF3)	I1.2	*EL-B3*	Electromagnet of Shunt-3	Q2.0
PS-1	Pressure Switch Line-AB	I.1.3	*EL-B4*	Electromagnet of Shunt-4	Q2.1
PS-2	Pressure Switch Line-AB′	I1.4			
PS-3	Pressure Switch Line-CD	I1.5			

Table 7.1: Mapping table of the I/O signals on the inputs and outputs of the PLC.

After the hardware connections of the input and output devices to the PLC, the next step is the software development. The code can be written in the classic way, based on programming script or in a graphics based programming language, the ladder.

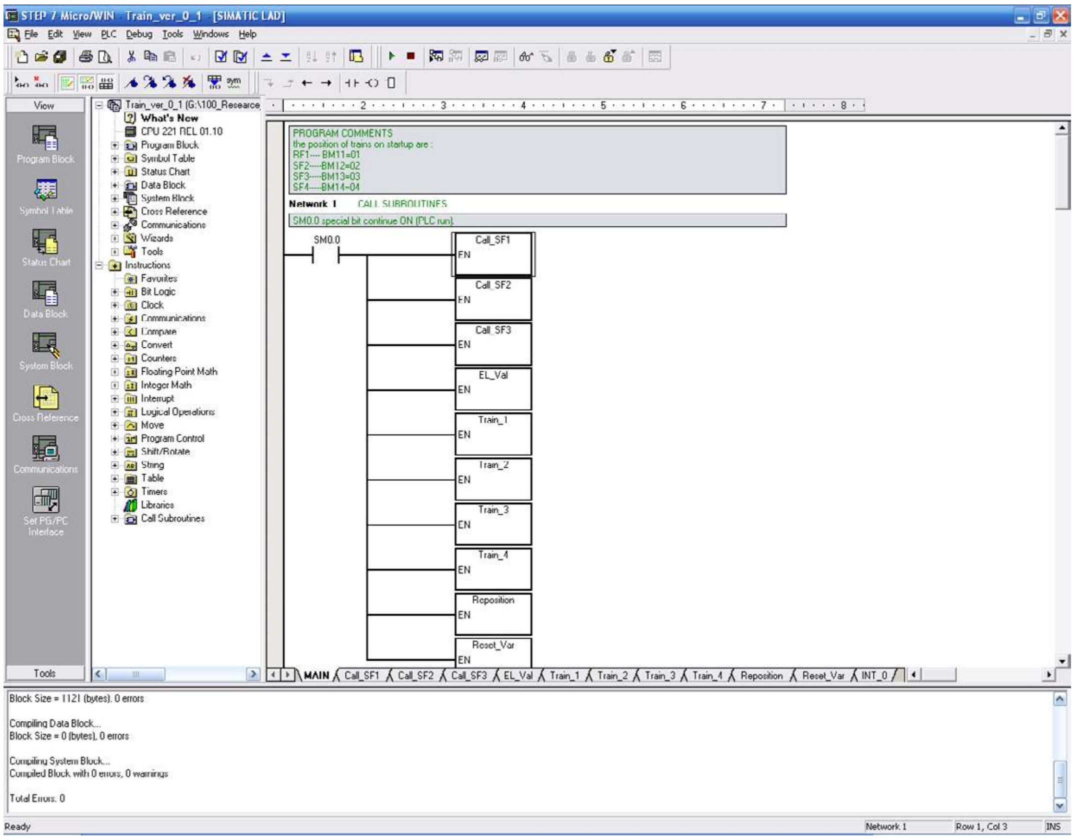

Figure 7.10: The V4.0 STEP 7 MicroWIN programming environment.

The programming environment used for the software development is the V4.0 STEP 7 MicroWIN of Siemens. It allows fast and reliable programming supporting the visual realization of the code.

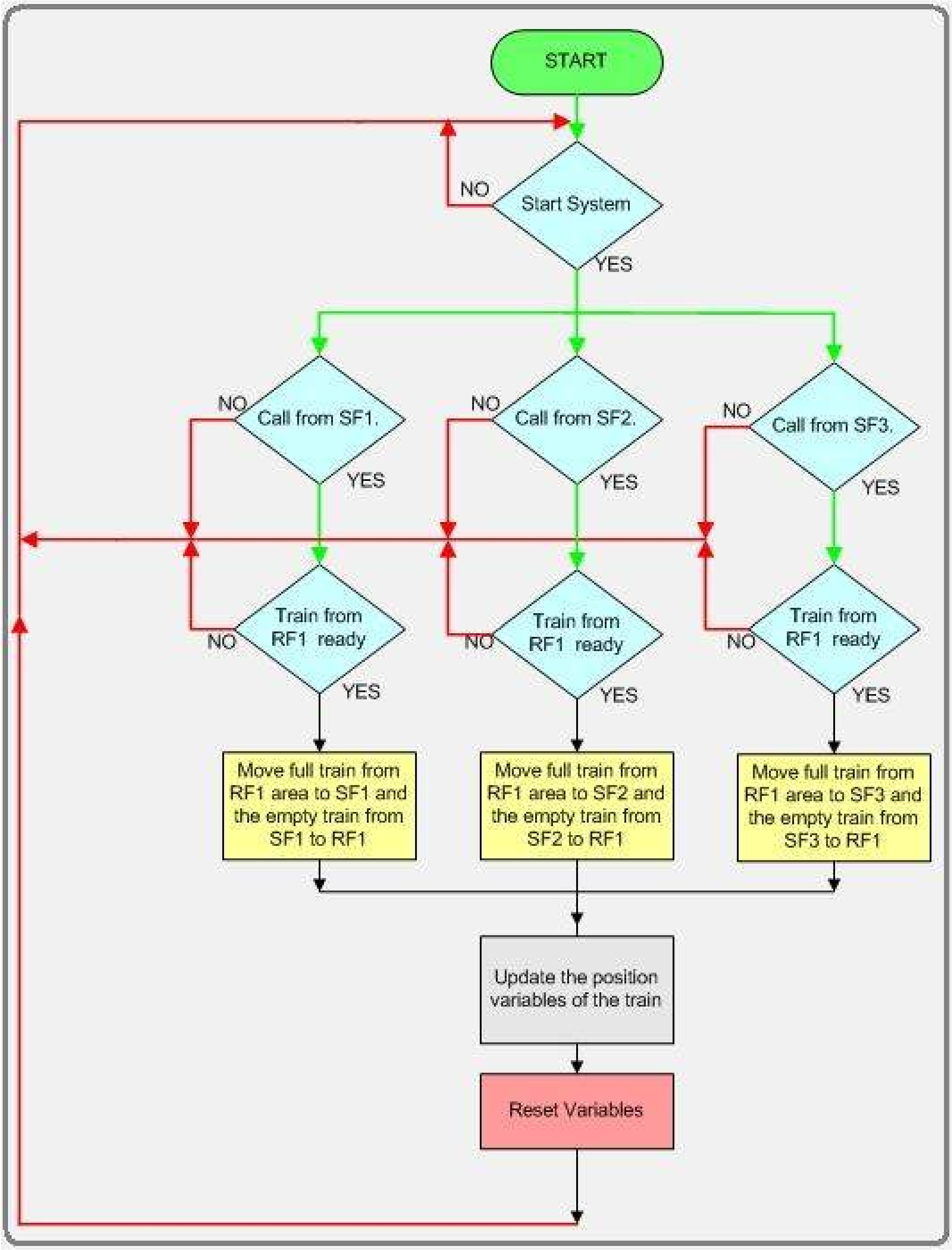

Figure 7.11: The block diagram of the application software.

The software is structured and it consists of the main part and the subroutines. In the main part exist the initialization, the start and stop procedures. Also the call wait stage is characteristic of the operation of the main part. The CallSF subroutine is managing the transportation of the train to the spinning frame and the return of the empty train to the roving frame. It acts on the shunts and receives signals from the limit switches and intermediate variables. The subroutines TrainX rules the motion of the trains taking in account their positions and the requested actions. Some other routines like Reset_Var, Re_position and El_Val are supporting parts. Figure 7.11 gives the total structure of the application software in the form of a block diagram.

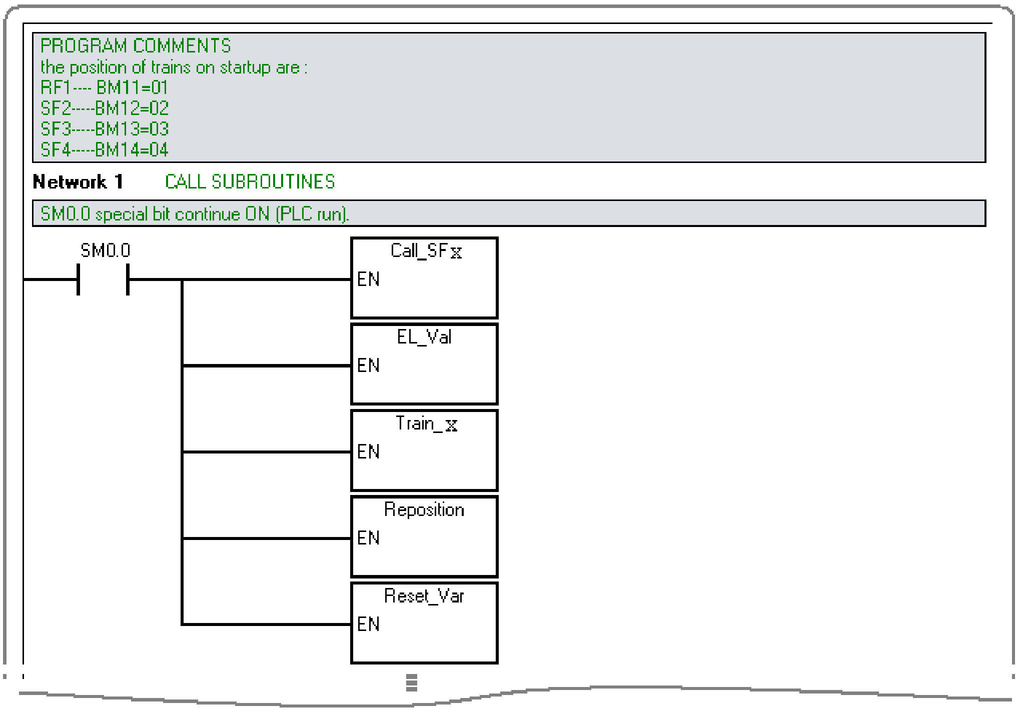

Figure 7.12: The main part of the program (In real there are 3 different Call_SFX and four Train_X routines).

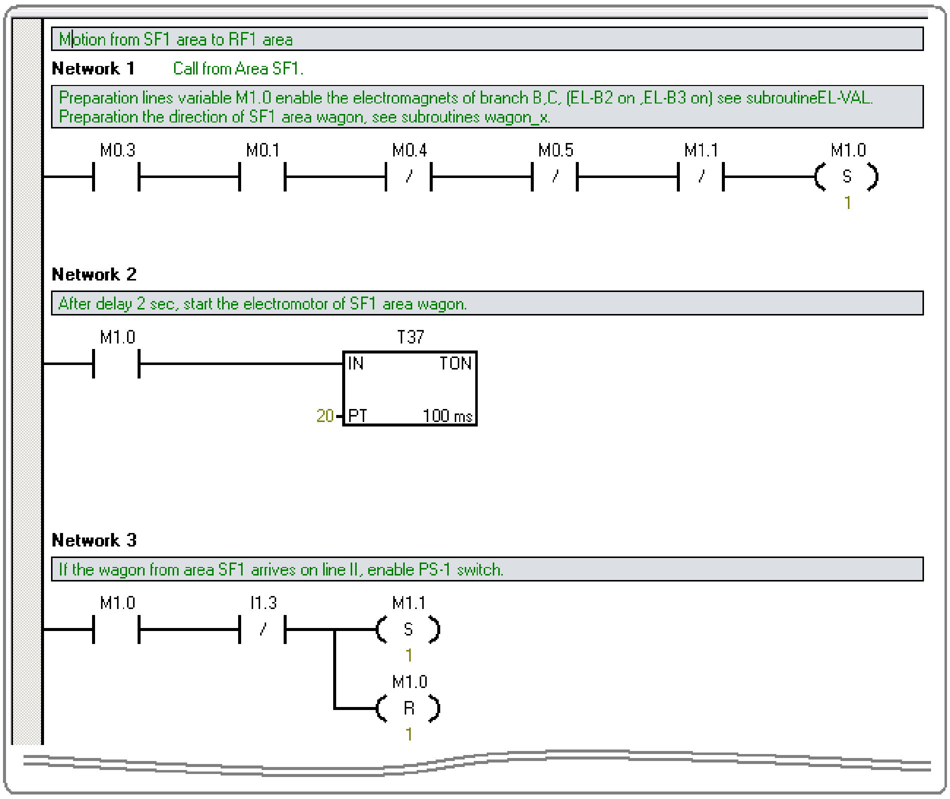

Figure 7.13: The first part of the Call_SFX subroutine. It continues in the same sense for the various parts of the route.

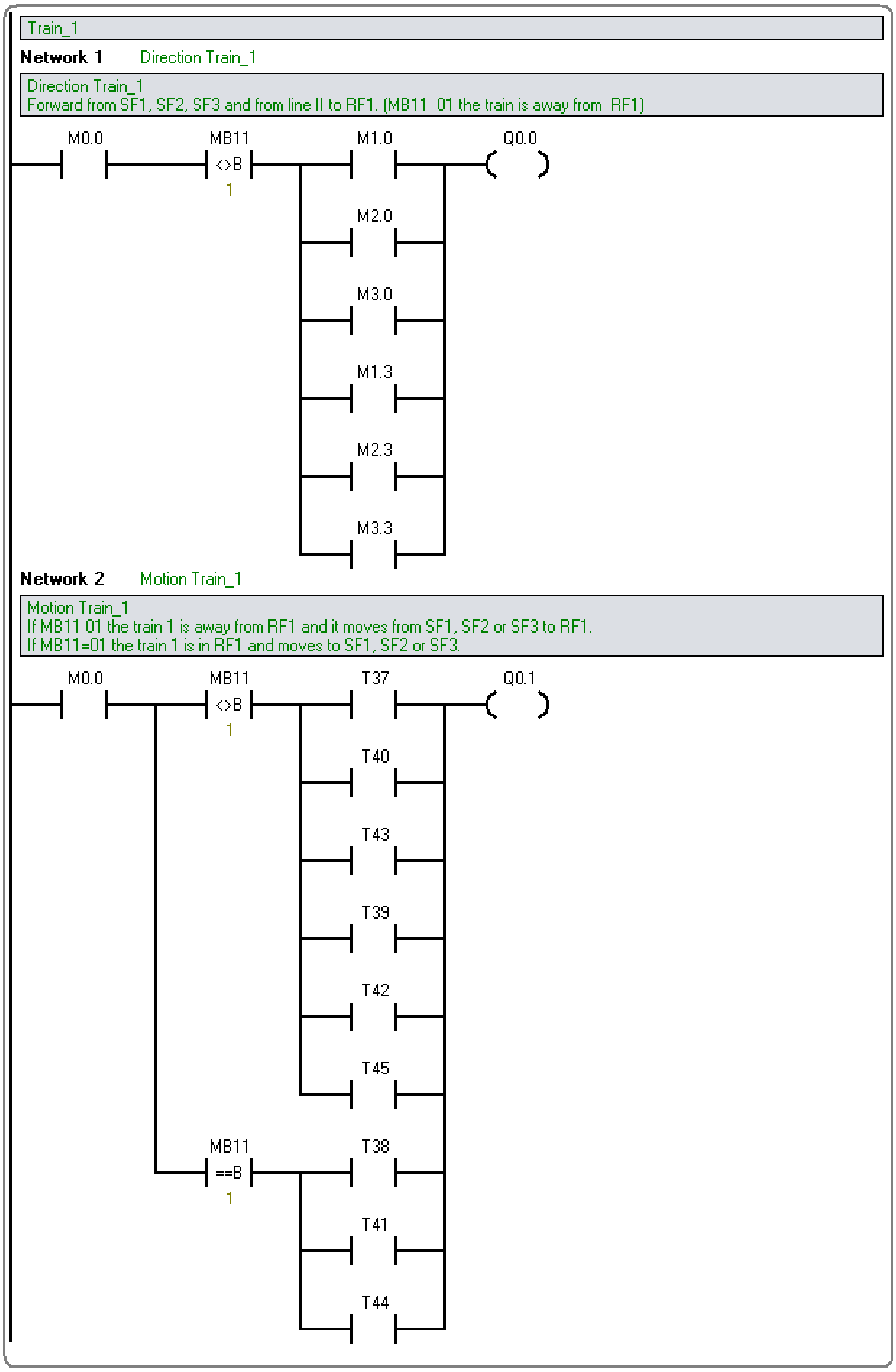

Figure 7.14: The Train_1 subroutine. The rest derives by the cyclic rotation of the indices.

The above figures present the structure and partly the realization of the application software code for the development of a bobbin transportation system between the roving frame and the spinning frames. There are many similar applications in the textile production processes. Thus this example is indicative and characteristic for the wide field of use of the Programmable Logic controllers in the textile industry. If a reader wants to access the full code of the present case study, he/she is kindly invited to contact the authors.

As it is shown, the use of the Programmable Logic Controllers gives a satisfactory solution to many technical problems and applications of the textile processes. The hardware wiring is not complicated and the software programming can be successfully performed by the user or by any other skilled person. The PLC's can be replaced without essential difficulty in the case of a damage or malfunction. The use of the PLC's has been widely spread all over the world and it is a de facto technological standard for the automatization of the operation of production machines, transportation systems, testing instruments etc.

7.7 Acknowledments

The publication of the pictures related to the SIMATIC-S7 has been possible only after the kind permission of the producing company Siemens. Obviously, any other kind of use is not permitted (indicative cases: copy, reproduction, publication etc), without the explicit permission of Siemens.

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7.8 References

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