Study of the Automation of the Overhead Crane of the SHITURU Factory of GÉCAMINES

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Abstract: ***Basically, whether in the storage depots and in the sector industry or in the construction sector, the regularity of the handling operations of the loads can be carried out using devices such as overhead cranes and cranes. Devices are really paramount. Our study relates to the traveling crane of the Gécamines of shituru which is in the town of Likasi. This during the operating system and the control a device of the Gécamines shituru overhead crane are archaic and poses risks of agent insecurity. This study aims to improve the functioning of the crane thanks to a replacement of manual devices (manual switches of control) by sensors which will be connected to an API to allow good control automatic control of the overhead crane and thus improve the operating system and guarantee the worker safety.***

Keywords: overhead crane, automatic control

1. General Introduction

1.1. Theoretical aspects of the research

In recent years the world has undergone a change following an evolution in the use of new technologies in industry. In the case of handling heavy parts it is often difficult for an operator to handle or move certain objects so easily; the crane for this purpose, it is currently used in companies, because it allows to carry out tasks such as: loading, unloading and storage operations of manufactured products. We found that at Gécamines bridge operators (those in charge of operating an overhead crane) are exposed to the risk of electrocution with the power lines of the overhead cranes in a hall during their climb to the cabin of control, since the control of the overhead crane is done manually. This difficulty requires improvement, the results of which will be presented in this research entitled: "**Study of the automation of the overhead crane at the Gécamines SHITURU plant**".

How can the overhead crane operate automatically to avoid accidents and guarantee the safety of workers? This is the research question of this study. We think that by this question we will have to make an improvement in the control of the traveling crane of Gécamines which until then was still done mechanically (manually).

To achieve this, we plan to develop a command and control system that will control the overhead crane using an API (industrial programmable logic controller). The various manual devices used in the current system will be replaced by other automatic devices which will ensure automatic control of the crane and for this purpose avoid the risk of electrocution (accidents) in order to ensure good continuity of the production.

This study is interesting insofar as it will improve the safety of the workers of this company by automating the overhead crane of Gécamines Shituru which today is carried out manually.

2. Definitions of Concepts

2.1 Overhead cranes

2.1.1 Definition and structure

Cranes are robust and versatile devices that operate in Cartesian space. They move on parallel raceways, their hook gripping tool or other lifting accessory) is suspended by means of cables from a lifting mechanism (winch or hoist) capable of moving on a bridge perpendicular to the bearing of the device. The frame of overhead traveling cranes can be made according to the case: Sections, Latticework, boxes, Mechanically-welded structure, Mixed.

2.1.2 Types of overhead cranes

An overhead crane can be of the single girder, double girder, overhead crane with rotary, four-girder or multi-girder overhead crane and can take on various configurations.

Rotary type overhead crane

Mono girder type overhead crane

Figure 1.1: Different types of overhead cranes

a) **The double-girder overhead crane**: is designed for handling operations with a lifting capacity of up to 60 tons or more and a span of 45 meters with the advantage of not having a lifting limit.
b) **The single girder overhead crane**: has a load capacity of up to 10 tons and can reach spans of 36 meters max.
c) **Four-girder bridge crane**: Used in the production of pipes, this bridge can lift sleepers 65 m long. To prevent oscillation of the sleepers, a telescope system is provided between the main beams and the sleeper.
d) **Rotating traveling crane**: Traveling crane capable of rotating 360.

2.1.3 Constituent elements of the overhead crane

The main elements of the overhead crane are:

a) **Framework:** This is the set of framework comprising in particular the following elements: main beam and box spring.
b) **Carriage:** this is the assembly from which the gripping device is suspended, it contains the following elements: running roller; drum; lifting motor; steering motor; mitten.
c) **Runway**: it consists of two rails fixed to the building, on which the bridge rolls.

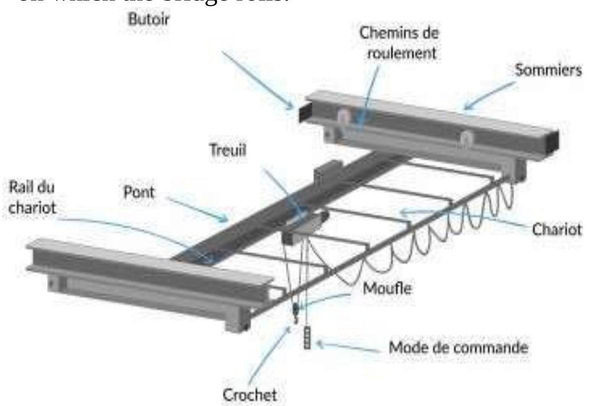

Figure 1.2: Descriptive elements of an overhead crane

2.2 Descriptive elements of an overhead crane

2.2.1 Operation of overhead cranes

A traveling crane, whatever its type, must move loads from one point to another in minimal time by performing three possible movements

a) Steering movement: the steering movement due to the movement of the chariot along the transverse axis along the axis (OX).
b) Raising movement: that is to say the movement of the load attachment mechanism along the vertical axis by actuation of the winch; along the axis (OY).
c) Translation movement: Axis of the rolling tracks which corresponds to an overall movement of the bridge along the axis (OZ).

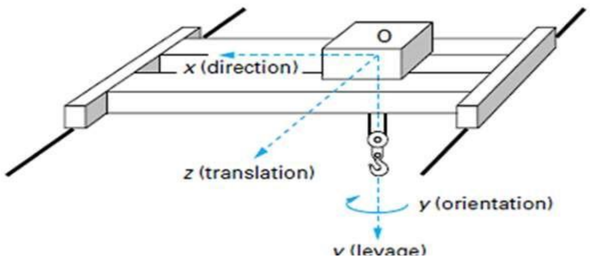

Figure 1.3: Different movement of an overhead crane

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These three movements are ensured by three electric motors coupled to reducers to provide strong torques, and to increase the safety and efficiency of these devices, they are also equipped with braking systems.

This device must be controlled by a qualified operator (bridge operator, overhead crane driver) using a remote control or from a driver's cab fixed to the bridge for better visibility in large overhead cranes.

2.2.3. Automated production systems (SAP)

2.3.1 Automatism and automation

Automation is a machine whose operation does not require human intervention. It is a machine which, by means of mechanical, pneumatic, hydraulic or electrical devices, is capable of acts imitating those of animated bodies. Automation allows the company to improve its competitiveness (product costs, quality, adaptability to demand). Its purpose is to associate the means of production and the means of automatic control which make it possible to ensure the reproducibility of the result in the most autonomous way possible (more or less independent of human intervention).

2.3.2 Automated system

An automated system is said to be automated if it always performs the same work cycle after receiving instructions from an operator. It allows: to increase productivity: to manufacture the maximum number of products during the minimum time, to improve production flexibility: this consists in manufacturing the maximum number of varieties of products, with the same equipment, to improve working conditions work by eliminating the most arduous tasks and increasing safety.

2.3.2.1. Description of an automated system

It includes an operational part (PO) and a control part (PC) which dialogue together. The PO brings together all the technical operators who ensure and control the production of the useful effects for which the automated system was designed. It is the PO that acts directly on the work material to bring it its added value. The CP is the set of information processing means which ensures the control and coordination of the tasks (of the succession of actions of the PO, in place of the operator and from pre-established programs. Information exchanges between the CP and the PO are of two types:

- Sending orders to the control signals to the PO pre-actuators,
- Receipt of reports from the CP via information input devices (sensors).

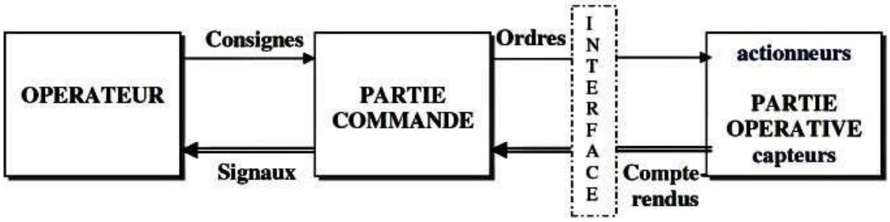


Figure 1.4: The parts of an automated system

The structure of an SAP reveals elements of informational links between the CP and the PO, namely:

a) The pre-actuators: They receive low energy signals sent by the CP and transform them into physical quantities capable of obtaining the desired effect from the actuators located on the PO. The pre-actuators can be contactors, distributors. [9].

Frequency converter Contactor

Figure 1.5: Pre – actuators

b) Sensors: These are tools that transform a physical quantity (force, speed, pressure position, flow rate, intensity, etc.) into a logic or analog signal carrying information that can be used by the PC. The role of the sensors therefore consists of capturing PO status information and transform into a transportable signal (energy flow) and understandable by the PC.

Position sensor Smoke sensor

Figure 1.6: Sensors

c) The actuators: Their role is to carry out these orders. They transform pneumatic (compressed air), hydraulic (pressurized oil) or electrical energy into mechanical energy. They come in different forms like:

- Motors: hydraulic, pneumatic, electric,
- cylinders: linear (1 or 2 rods) rotating, rodless.

d) The interface: In order for orders and information to be able to circulate between the control and operational parts, the connection cables are sometimes insufficient. It is then necessary to place an interface between the control and operational part (this interface is an electronic circuit which makes it possible to translate the orders and the information between the two parts).

3. Methodological Aspects of the Research

3.1 Data collection techniques.

a) Documentary technique.

Researchers analyze a phenomenon with the help of certain documentation. This technique will allow us to consult various documents on cranes, automation, and collect the data necessary for our study.

b) The interview

It is an interview between the observer and his subject, this interview aims to organize a relationship of verbal communication between the investigators and the respondents. This approach allowed us to collect information concerning our research topic from the actors involved in this object of study transform into a transportable signal (energy flow) and understandable by the PC. We arranged interviews with mister Gui, papa Dona and other factory workers.

c) Direct observation.

This first-rate technique in methodological research will allow us to get in touch with the study environment in order to collect the necessary data.

3.2 Presentation of the field of study.

3.2.1. The SHITURU factory of the general quarries and mines (Gécamines).

Gécamines, or General Company of Quarries and Mines GCM, is a commercial company under private law, 100% owned by the State of the Democratic Republic of Congo, it was created in 1967, it concentrates its activities around prospecting, research and exploitation of mineral reserves in the former province of Katanga.

The SHITURU factories are located in the province of Haut-Katanga precisely in the town of Likasi, in the group between 120km from Lubumbashi and 180km from Kolwezi the commune of shituru and the commune of panda as well as the SNCC camp, it is specialized in the manufacture of copper as well as cobalt.

3.2.2. Structure of the Gécamines overhead crane.

The overhead crane used at Gécamines and of the twin-girder type, equipped with a control cabin fixed to the end of the bridge beam, it has a lifting capacity of up to 16 tonnes max and a range of 30 meters wide, 40 m long and 10 m high. The overhead crane power supply network is 3*550V AC-50HZ, the contactor coil voltage is 240V AC.

3.2.2.1. Equipment used on the Gécamines crane in SHITURU

a) Motor

The motors used for the various movements of the crane are carried out by wound rotor motors which are equipped with a braking system, they are generally called brake motors.

b) Crane power supply

The crane is powered via pantographs which allows the current to be transferred from the line to the control cabin, the transfer of the electric current is done via a sliding contact between the copper and the coal.

3.2.2.2. Electrical diagrams of the Shituru overhead crane.

It is composed of three parts:

- First part the bridge.
- Second part the hoist.
- Third part the trolley.

a) Diagram of the bridge (translation).

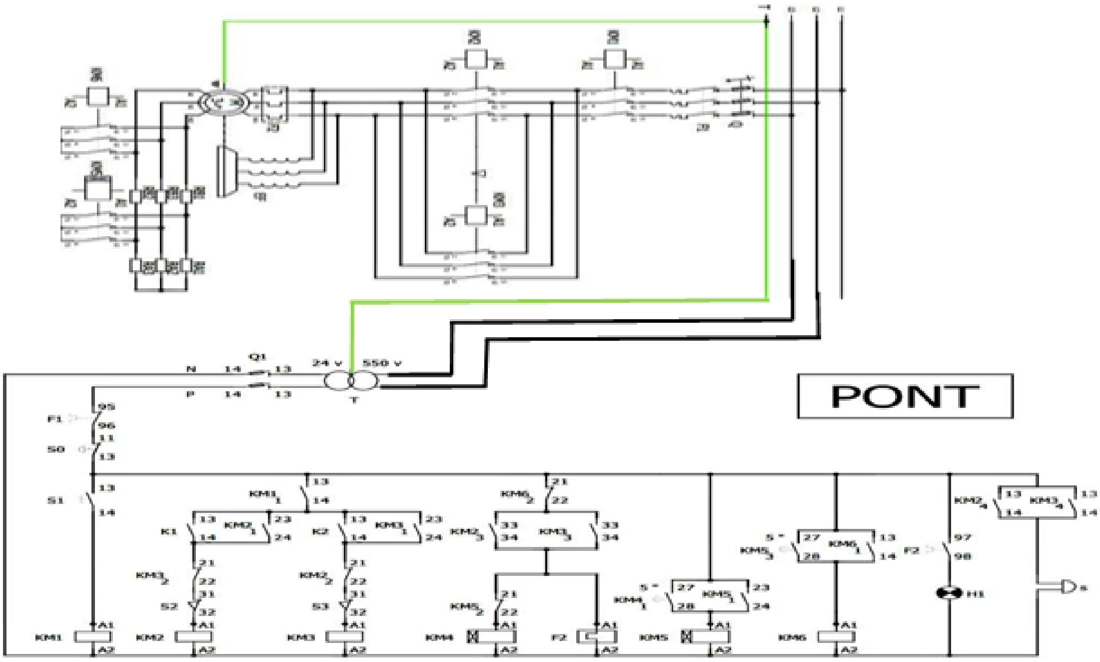


Figure 1.7: Bridge control and power electrical diagram (translation)

- Q1: Fuse holder disconnector.
- K1: first direction on switch.
- K2: second reverse direction switch.
- KM1: main contactor.
- KM2: first run contactor.
- KM3: second reverse direction contactor.

KM4: timed contactor for the first rotor resistance elimination time.

- KM5: timed contactor second rotor resistance elimination time.
- KM6: third stage rotor resistance elimination contactor.
- F1, F2: thermal overload relays.
- S0: Stop push button.
- S1: Power on push button.
- S2: first direction limit switch.
- S3: second direction limit switch.
- S: buzzer.
- H1: motor fault.
- EF: electric brake with shaft locked at standstill
- M: Three-phase asynchronous motor with wound rotor.

b) Diagram of the carriage (direction)

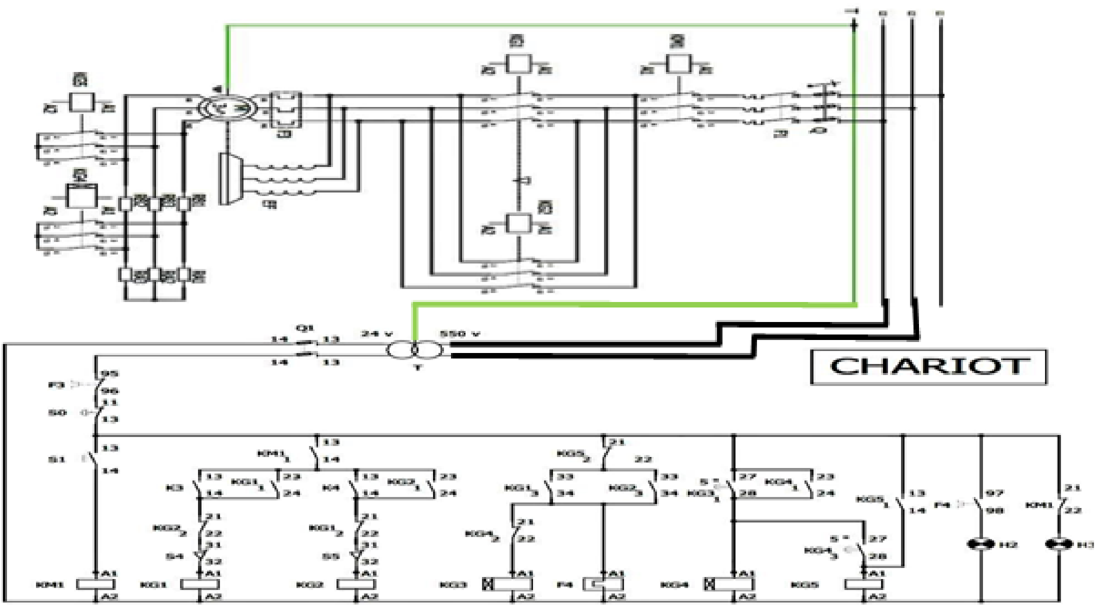


Figure 1.8: Truck control and power electrical diagram (steering)

- K3: first direction on switch.
- K4: second reverse direction switch.
- KM1: main contactor.
- KG1: first run contactor.
- KG2: second reverse direction contactor.
- KG3: timed contactor for the first rotor resistance elimination time.
- KG4: timed contactor for second rotor resistance elimination time.
- KG5: third stage rotor resistance elimination contactor.
- F3, F4: thermal overload relays.
- S0: Stop push button.
- S1: Power on push button.
- S4: first direction limit switch.
- S5: second direction limit switch.
- H2: motor fault.
- H3: Presence under voltage.
- EF: electric brake with shaft locked at standstill
- M: Three-phase asynchronous motor with wound rotor.

c) Drawing of the winch (breeding)

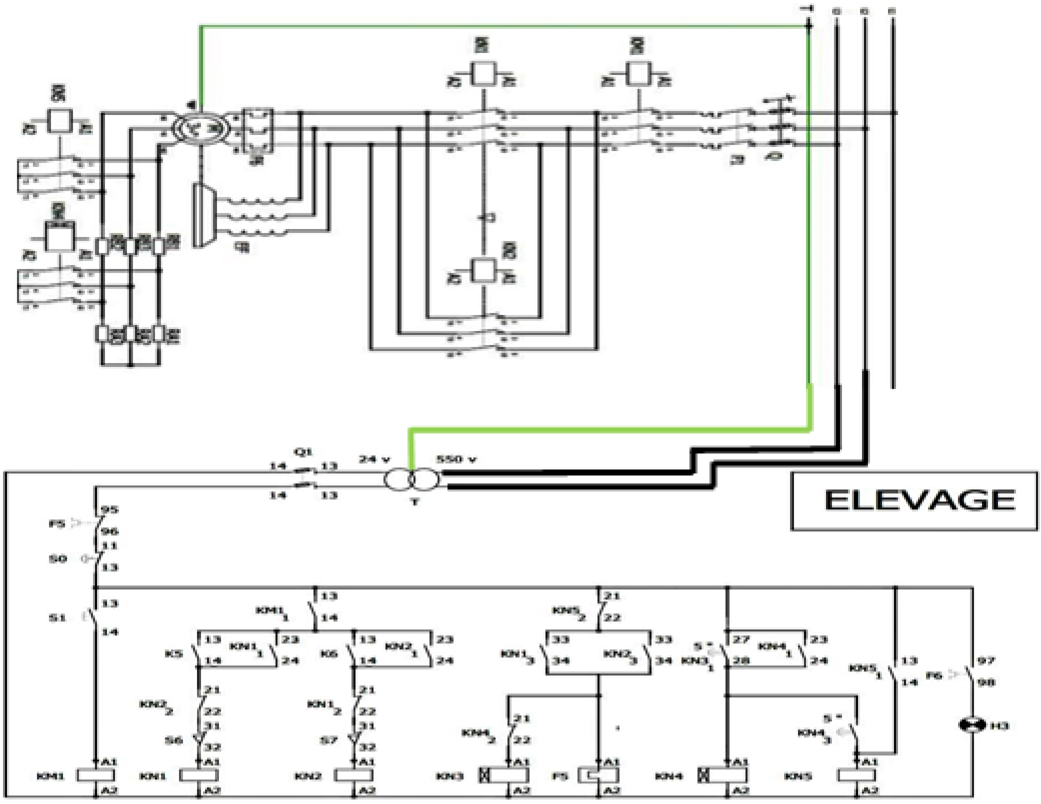


Figure 1.9: Electric winch control and power diagram (breeding)

- K5: decent switch.
- K6: switch mounted.
- KM1: main contactor.
- KN1: first run contactor.
- KN2: reverse second direction contactor.
- KN3: timed contactor for the first rotor resistance elimination time.
- KN4: timed contactor second rotor resistance elimination time.
- KN5: third stage rotor resistance elimination contactor.
- F5, F6: thermal overload relays.
- S0: Stop push button.
- S1: Power on push button.
- S6: first direction limit switch.
- S7: second direction limit switch.
- H4: Presence under voltage.
- EF: electric brake with shaft locked at standstill
- M: Three-phase asynchronous motor with wound rotor.

3.2.2.2. Operation of the traveling crane at the Gécamines SHITURU plant.

The crane operator receives the order to move a load x from point A to point B, the crane operator closes the fuse holder disconnector, he pulses S1 and powers up the overhead crane, the crane operator operates on K1 or K2 (forward or reverse) depending on where the load is located, it moves the bridge to the load, it maneuvers on K3 or K4 (forward or reverse) it moves the trolley according to the direction in which the load is located, he detects the load, he maneuvers on K5 the hook is lowered towards the load, an agent connects the load to the hook, that the connection is made correctly the crane operator maneuvers on K6 the load is lifted, the crane operator maneuvers again on K1 or K2 (forward or reverse) he moves the crane according to the place where the load must land, the crane operator maneuvers on K3 or K4 (forward or reverse) he moves the trolley according to the direction where he must deposit the load, after the detection the crane operator maneuvers on K5 he carries out the decent of the load to the desired place, another agent unties the load from the hook, of which this good he maneuvers on K6 and brings it up the hook. If it happens that there is still a load to lift from point A to point B, the crane operator will perform the same cycle. The traveling crane is stopped by pressing S0.

3.2.2.3 Grafcet level 1.

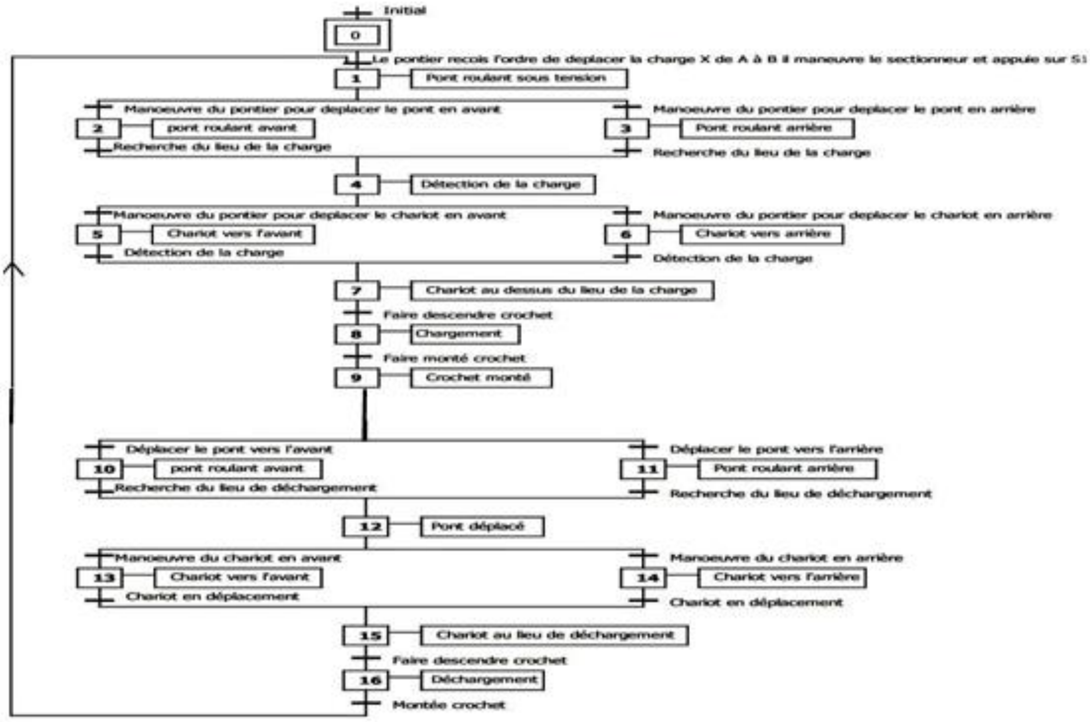


Figure 1.11: Level 1Grafcet of the overhead crane operating system.

3.2.2.4. Grafcet level 2.

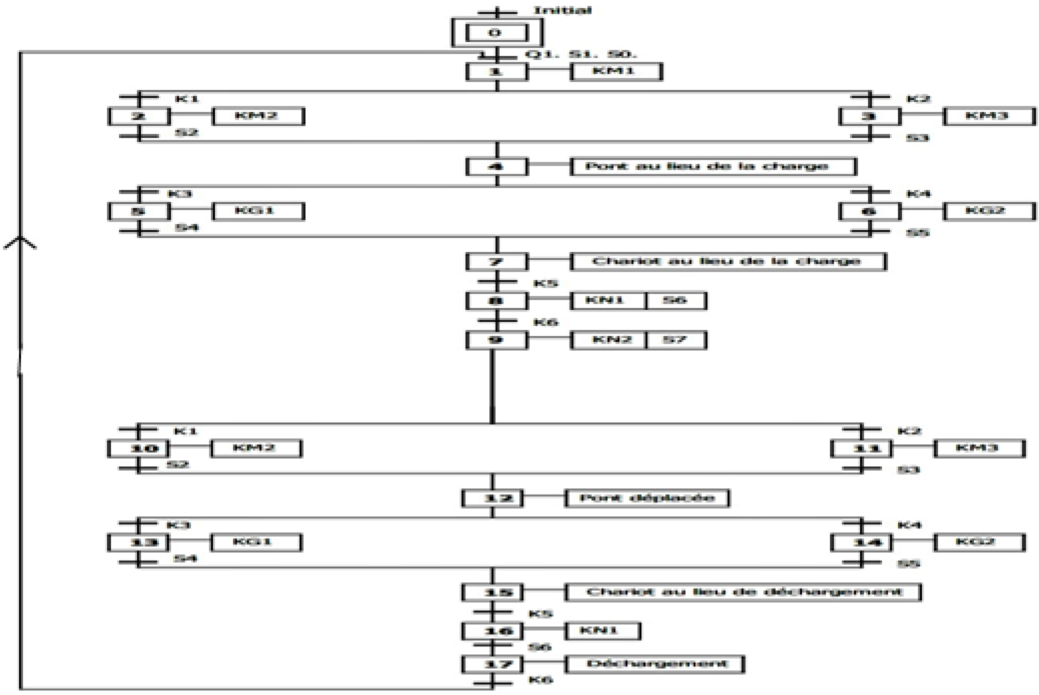


Figure 1.11: Level 2 Grafcet of the overhead crane operating system.

4. Implementation of the automation of the overhead crane of the SHITURU factory

4.1 Industrial programmable logic controllers (PLC)

A Programmable Logic Controller is an electronic machine, programmable by non-IT personnel and intended to control automatic processes in an industrial environment and in real time. The programmable automaton receives information relating to the state of the system and then controls the pre-actuators according to the program written in its memory. Generally programmable logic controllers have a cyclic.

Figure 1.12: Siemens industrial programmable logic controller.

4.1.1. Constitution of the API

The intelligent part of the automaton resides in the central processing unit (CPU), it is broken down into several elements which are:

a) **The microprocessor:** First, the microprocessor is mainly used for information processing, it performs logic functions such as binary addition, upcounting, downcounting and other integrated functions such as timing, calculation etc then, it is connected to the other elements such as the memory and the I/O interface through parallel links called buses to convey the information in binary form.
b) **Inputs**: Inputs are used to receive external data, more precisely they receive information through sensors or system push buttons.
c) **The outputs**: Are used for the transmission of data to the outside, in addition to make the relay between the screen and the printer. For more details, these outputs receive
d) the information dictated by the microprocessor and stored in memory, they are refreshed as the program runs.
e) **Memory:** It is designed to receive, manage and store information from the various sectors of the system which are the programming terminal (PC or console) and the processor, which manages and executes the program. It also receives information from the sensors.
f) **Power supply**: All current PLCs are equipped with a 240 V 50/60 Hz, 24 V DC power supply. The inputs are 24 V DC and grounding must also be provided. [12].

4.2 Development of Grafcet for the new crane control system.

4.2.1. Specifications for the new Gécamines overhead crane control system.

An operator pulses S1 and powers up the crane. An SD detector detects a load sends the information to the PLC, and the PLC activates the VH1 alarm for 10 seconds and commands the bridge forward to the place where the load is located. Two load detection sensors F1 and F2 (front or rear load) signal to the PLC in which direction the load is located, after detection of the load the information is transmitted to the PLC and controls the truck according to the direction of load.

Two load position sensor F3 or F4 (position of the front or rear load), sends the information to the PLC, and lowers the hook until it reaches the end of course sensor SF1, agents bind the load on the hook for 30 seconds, after the time the API raises the hook until it waits for the SF2 limit switch. The PLC controls the bridge backwards until it reaches the place where the load is to be deposited.

Two load location detection sensors F5 and F6 (front or rear load location) after detection it sends the information to the PLC and controls the truck (forward or backward) to where must land the load, two load location position sensor F7 and F8 (front or rear load location position sensor), after detecting the position it sends the information to the PLC and decent the hook until reaching the SF1 limit switch.

Agents untie the load from the hook for 20 seconds, after 20 seconds the hook goes up until it reaches the SF2 limit switch. If the SD detectors still detect a load the cycle can start again, but if the SD load detectors detect no load the bridge automatically stops.

4.2.2. Layout of handling facility

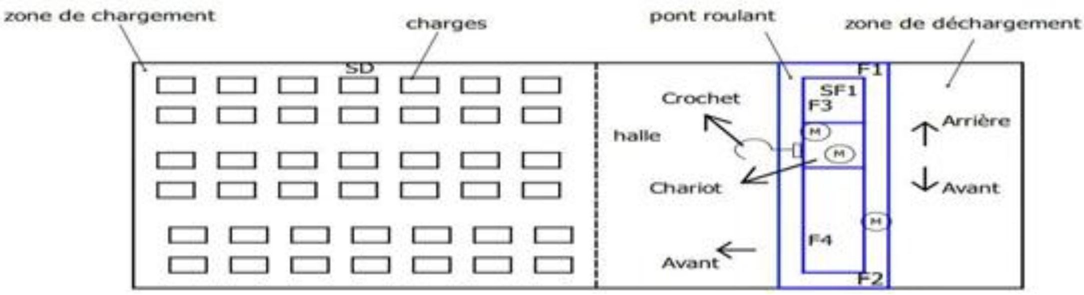


Figure 1.13: Layout of handling facility

4.2.3. List of system devices

- DCY: Start button.
- KM1: Main contactor.
- KM2: Bridge running first direction contactor.
- KM3: Rear axle second direction contactor.
- KG1: Truck run first direction contactor.
- KG2: Truck rear second direction contactor.
- KN1: First direction contactor fitted (breeding).
- KN2: Second direction lowering contactor (breeding).
- S1: Push button
- VH1: Alarm
- F1: Detection of front loads.
- F2: Detection of rear loads.
- F3: Front load position.
- F4: Rear load position.
- SF1: Limit switch mounted
- SF2: Decent limit switch sensor.
- F5: Front load location detection sensor.
- F6: Rear load location detection sensor.
- F7: Front load location position sensor.
- F8: Rear load location position sensor.
- SD: Load detectors

4.2.4. Replacement table of devices from the old system to the new control system.

Old system symbol Function New system symbol Function
K1: front axle switch SD: front axle load detector
K2: rear axle switch SD: rear axle load location sensor
K3: front carriage switch F1: detection of front carriage front loads
K4: rear carriage switch F2: detection of rear carriage rear loads
K5: Drop hook switch F3, F7: Hook drop front load position sensors
K6: hook mounted switch F4, F8: hook mounted rear load position sensors

4.2.5 Level 1 Grafcet of the new system

Table 1.1: Replacement of devices from the old system to the new system

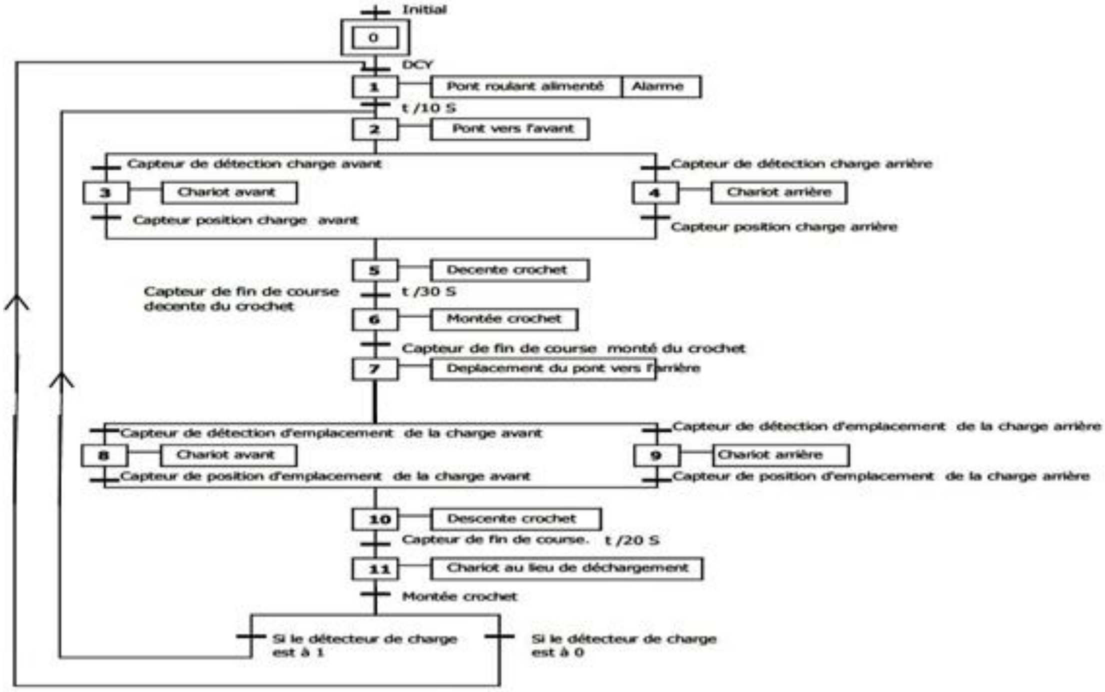


Figure 1.14. Level 1 Grafcet of the new system

4.2.6 Grafcet level 2 of the new system

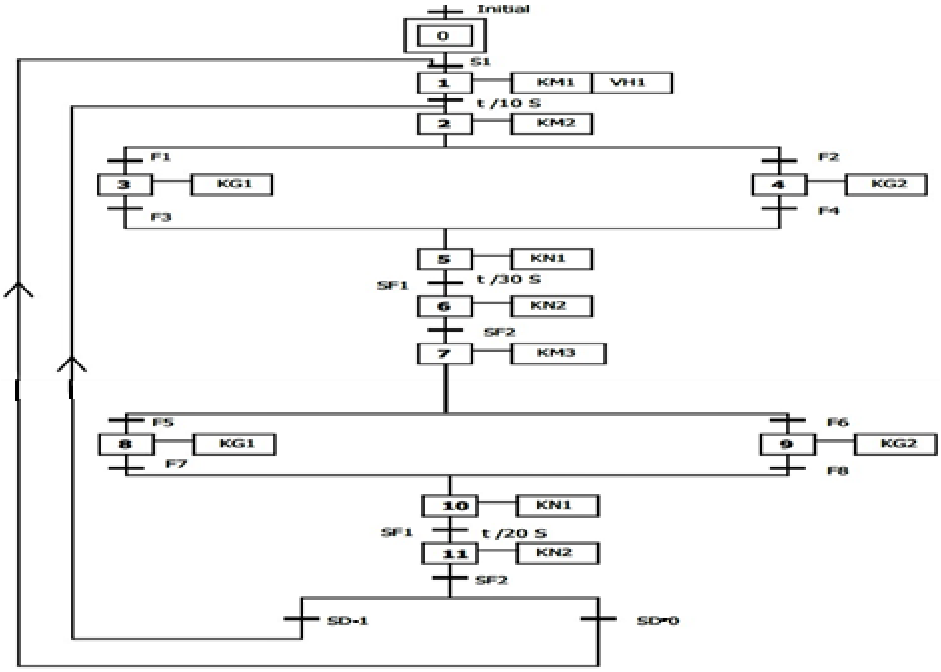


Figure 1.15: Grafcet level 2 of the new system.

4.2.7 System device addressing

API inputs API outputs
S1: E0.0 KM1: A0.0
VH1: E0.1 KM2: A0.1
DSY: E0.3 KG1: A0.3
F2: E0.4 KG2: A0.4
F3: E0.5 KN1: A0.5
F4: E0.6 KN2: A0.6
SF1: E0.7 M1: A0.7
SF2: E1.0 M2: A1.0
F5: E1.1 M3: A1.1
F6: E1.2
F7: E1.4
F8: E1.4
SD: E1.5

4.2.8 PLC programming in STEP 7-V5

Table 1.2: List of API inputs and outputs

4.2.9. API Setup

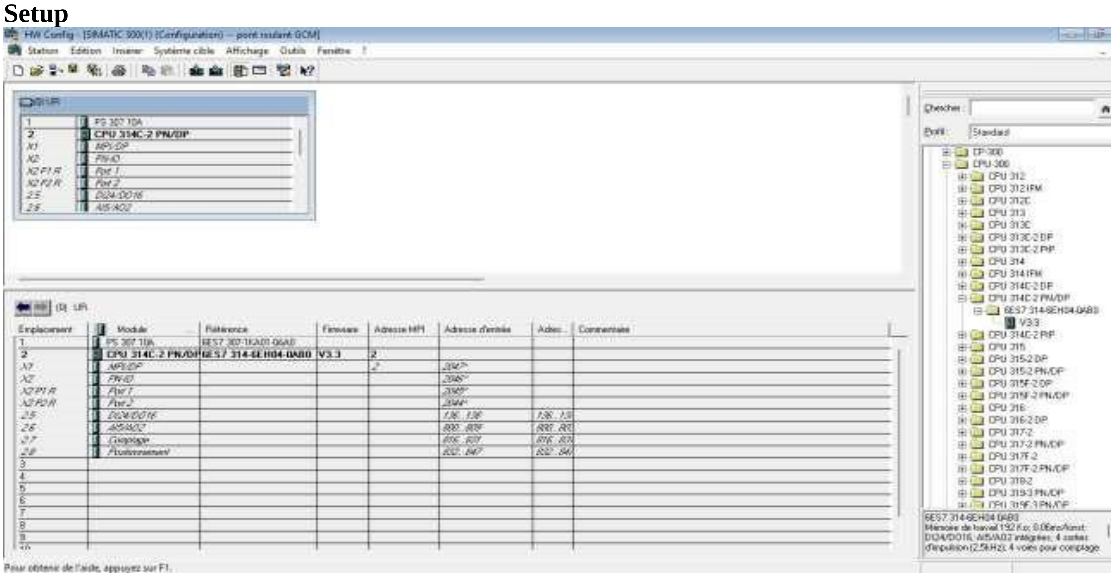
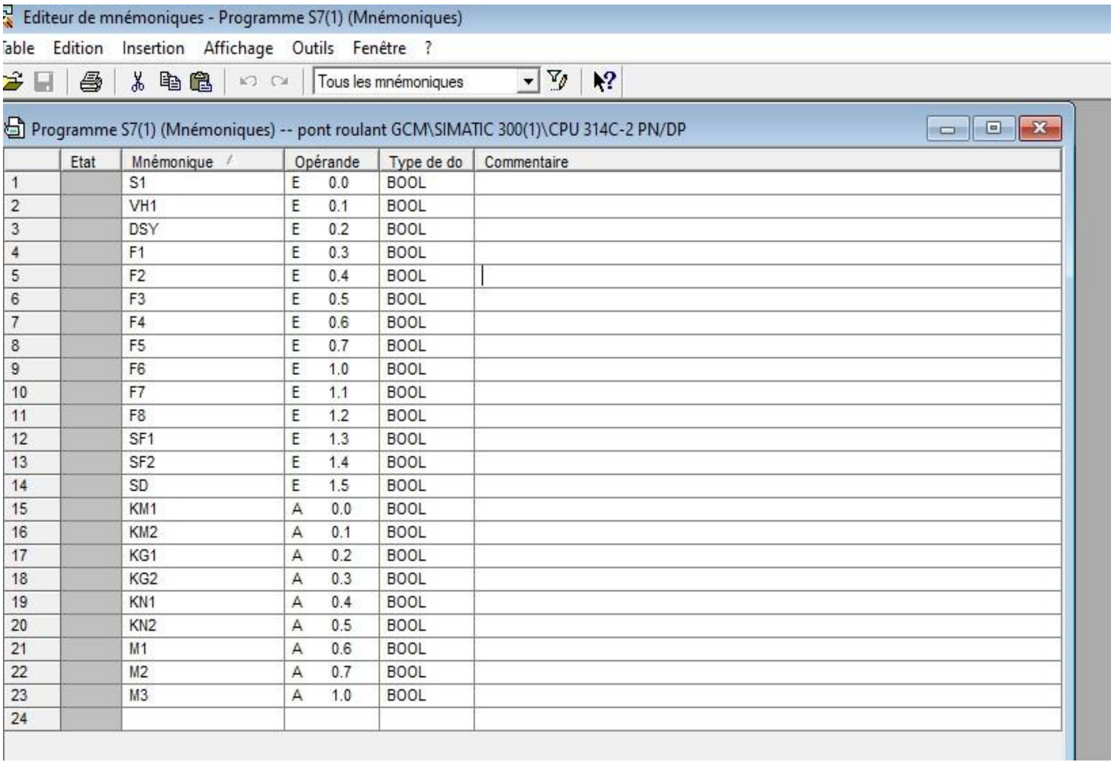


Figure 1.16: Configuring the PLC in STEP 7-V5

4.2.10. Mnemonic table



Editeur de mnémoniques - Programme S7(1) (Mnémoniques)

Programme S7(1) (Mnémoniques) -- pont roulant GCM\SIMATIC 300(1)\CPU 314C-2 PN/DP

	Etat	Mnémonique	Opérande		Type de do	Commentaire
1		S1	E	0.0	BOOL	
2		VH1	E	0.1	BOOL	
3		DSY	E	0.2	BOOL	
4		F1	E	0.3	BOOL	
5		F2	E	0.4	BOOL	
6		F3	E	0.5	BOOL	
7		F4	E	0.6	BOOL	
8		F5	E	0.7	BOOL	
9		F6	E	1.0	BOOL	
10		F7	E	1.1	BOOL	
11		F8	E	1.2	BOOL	
12		SF1	E	1.3	BOOL	
13		SF2	E	1.4	BOOL	
14		SD	E	1.5	BOOL	
15		KM1	A	0.0	BOOL	
16		KM2	A	0.1	BOOL	
17		KG1	A	0.2	BOOL	
18		KG2	A	0.3	BOOL	
19		KN1	A	0.4	BOOL	
20		KN2	A	0.5	BOOL	
21		M1	A	0.6	BOOL	
22		M2	A	0.7	BOOL	
23		M3	A	1.0	BOOL	
24						

Figure 1.17: Mnemonic table.

4.2.11 Programming in S7-GRAPH of the crane control system in the function block FB1.

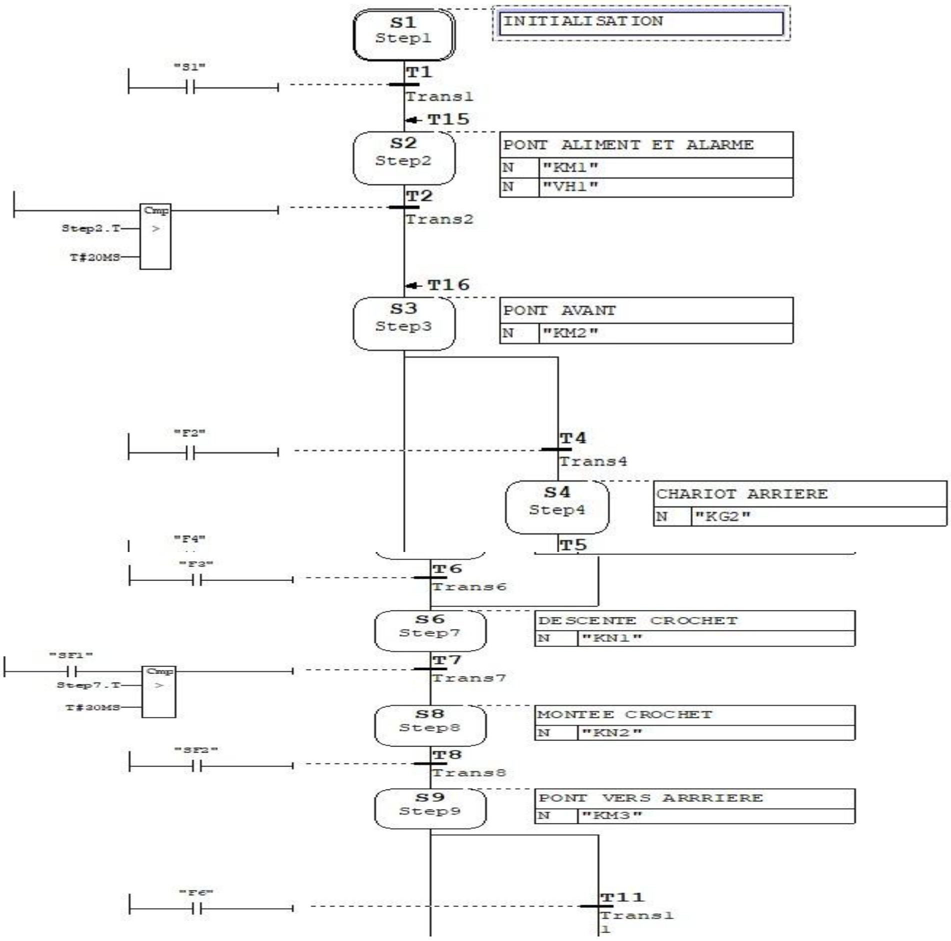


Figure 1.18: Grafcet of the crane control in S-7 GRAPH language.1.

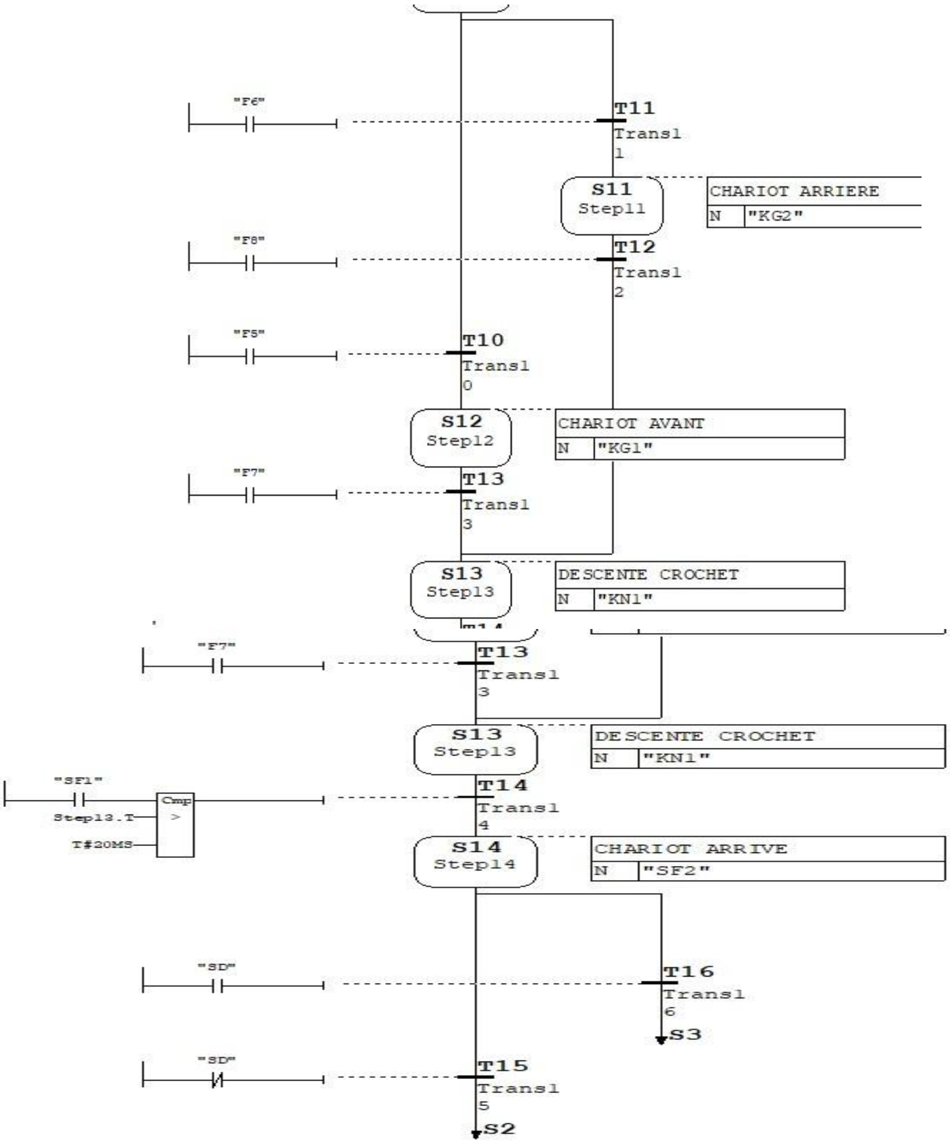


Figure 1.19: Grafcet of the crane control in S-7 GRAPH language.2.

4.2.12. Loading the FB1 block into OB1 and configuring the emergency stop

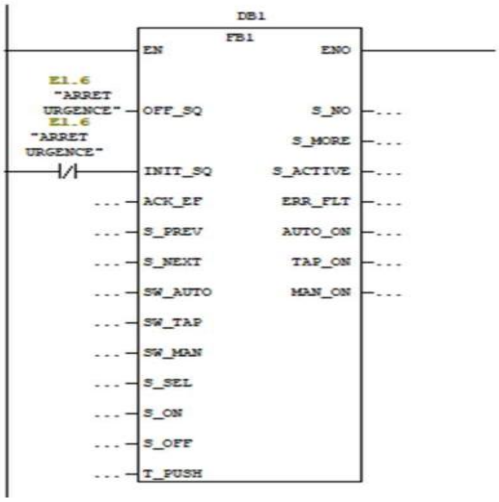


Figure 1.20: Change of block FB1 to organization block OB1.

5. General Conclusion

This study aimed at automating the overhead crane of Gécamines de SHITURU. To achieve our goal, we have implemented an automated system that will control the control of the overhead crane at the SHITURU factory using an industrial programmable logic controller A. P. I. The industrial programmable logic controller is today the most common constituent for achieving automation, it is found in practically all sectors of industrial. We first started by understanding the operation of the old Gécamines overhead crane system to draw up a specification. Subsequently we brought out a grafcet which shows the operation of the old operation of the overhead crane. We have improved and replaced the manual devices with sensors and actuators necessary for the operation of the new system. Finally, bring out a new grafcet from the overhead crane which then allowed us to proceed with the programming of the API.

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