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Rehabilitation of an Old Traditional Elevator Based on PLC Techniques

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***Abstract**: This paper describes the rehabilitation and developing of an old didactic traditional elevator available in the laboratory. The authors tried to merge the programmable logic controller (PLC) with the elevator's traditional electric circuit for developing its control circuitry. The PLC employed in this research is Simatic (s7-200), it was used to replace the old control system of the elevator which had high faults that were due to its complex wiring and numerous mechanical contacts which were able to burn out or could result in bad contacts. The obtained results were satisfactory because the merging procedure between the traditional and the modern systems is successfully implemented; personnel safety is improved and electromechanical problems were decreased .*

Key words: *Elevator, PLC, Sensors, Control systems.*

إعادة تأهيل مصعد قديم باستخدام تقنيات المتحكم المنطقي القابل للبرمجة

حسان ثابت حسان، ابراهيم سلمان جميل، اسماعيل عبد الجبار حسن

الخلاصة: يوّضح هذا البحث إعادة تأهيل مصعد تعليمي قديم باستخدام متحكّم منطقي قابل للبرمجة PLC)) من نوع s7-200 حيث قام الباحثون بدمج المتحكّم المنطقي القابل للبرمجة مع الدوائر الكهربائية التقليدية الأساسية للمصعد لغرض تطوير نظام السيطرة الخاص به. لقد تمّ استخدام المتحكّم المنطقي القابل للبرمجة لتطوير نظام التحكّم الكهربائي القديم الخاص بهذا المصعد، حيث كان نظام التحكّم الكهرومغناطيسي القديم معقّد كهربائيا ويعاني من مشاكل ميكانيكية ناتجة عن تراكم الأتربة على المتحسسات الكهروميكانيكية وبين الملامسات الخاصة بالمناولات والمرحّلات في دائرتي السيطرة والقدرة لهذا المصعد. لقد كانت نتائج هذا العمل جيدة لأن عملية الدمج بين النظم التقليدية والحديثة قد تم تنفيذها بنجاح كما تم تحسين نظام سلامة المستخدمين, وانخفضت المشاكل الكهروميكانيكية.

الكلمات الدالة : المصاعد، المتحكم المنطقي القابل للبرمجة، المتحسسات، أنظمة تحكّم .

1. INTRODUCION

The drawbacks of the classical elevator system are [1]:

- High failure rates of the control system are due to complex wiring of its circuits, numerous contacts, the ability of electrical contacts to burn out which could result in bad contacts.
- Complex and modern control functions were very difficult to be achieved by electrical wiring based on traditional methods.
- Due to having large inertia, the electromechanical components are too slow and the control system will have low precision.

The rehabilitation and development of the old elevator improves the quality of elevator's system, develops the maintenance and the repair tools of elevator's operation compared to classical system and therefore facilitates the work compared to previous period and increases the reliability of the elevator. The developments made to overcome the disadvantages of classical elevators are [1], [2]:

1. The classical relays and IC boards are replaced by a PLC in order to make the control methods of the machines of the elevator easy and cheap.
2. The integration of monitoring software can be done by the use of a PLC for easy and efficient troubleshooting and maintenance.
3. Students can learn more skills such as detecting the required input and output elements of the system, connecting the input and output units to the PLC, writing any PLC program, making changes on the program, making the selection of appropriate sensors, operating and testing of the whole system, understanding the error messages and solving system faults.
4. Elevator control with PLC is an important issue of Electrical and Electronic Engineering education and it is becoming a requirement for intelligent building applications.

The original electric control circuit design of this didactic elevator was created by Elettronica Venita (EV) in 1977 [3], an Italian company for producing didactic instruments, so all red numbers on the schematic diagrams in this paper are referred to the connections of the original diagram shown in appendix-1.

Related works

Although the sources of the related works are very scarce in the internet and the global references; KONE, an international manufacturer of elevators, issued a handbook of how to modernize existing lifts [4] [5]. A Chinese company issued a presentation about the modernizing old lifts [6]; finally a European company also issued a paper about improving safety and accessibility of existing elevators]7].

2. PROPOSED SYSTEM CONSTRUCTION

2.1 Hardware Task

To design a control system for an elevator, it must be divided into several parts; each part is responsible of its particular task which is tested and implemented independently and then combined with other parts. The elevator control system that is based on PLC techniques is classified into three main parts [1][8]. First part is the floors and their sensors, second part is the PLC and the third part is the elevator with its motor and the cabin. The diagram of this type of control system is shown in figure (1).

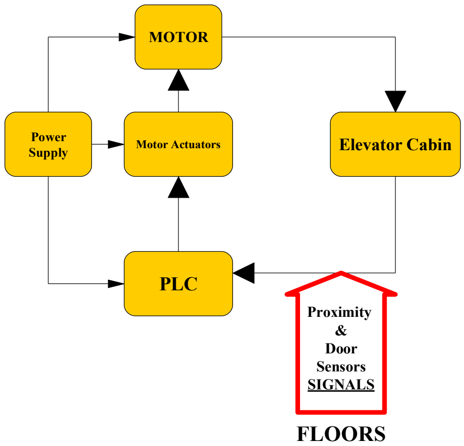

Fig. 1 Block diagram of an Elevator control system

The control system based on PLC techniques is accomplished by realizing six major components: PLC, AC motor and its actuators, push buttons, level sensors, display unit and elevator's cabin. Positioning level sensors are used to determine the elevator's position and the requesting push buttons are used as inputs by users. The number of each floor will be displayed on the display units as outputs. The PLC evaluates the user's request by the push button signal and the elevator's position by the level sensors to drive the elevator's motor up or down. The schematics of the control system of old elevator consist of three groups of sensors [3]; each group consists of a number of sensors and switches connected in series, which were considered as AND gates in the new design as shown in figure (2).

As compared with the electric circuit of Appendix-1; part(a) of figure (2) shows two types of mechanical sensors which were swapped with new versions of sensors to reduce maintenance problems and improve security sensation, sensors ES and EI were swapped with two inductive proximity sensors [9], [10] and sensors of type CP were swapped with photo sensors [10], [11]. In part (b) of figure (2) only sensors of type CPC were swapped with reed switch sensors [11]. No changes were applied to part (c) due to their complicated mechanical system used for opening and closing the doors of the elevator. The symbols of figure (2) are given in table (1).

Figures (3) and (4) show the three groups of sensors as they are connected in different control scheme

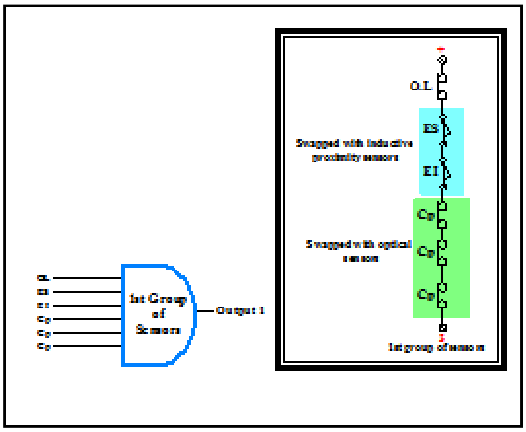

Fig. 2 Part (a) Group No. 1 of Sensors

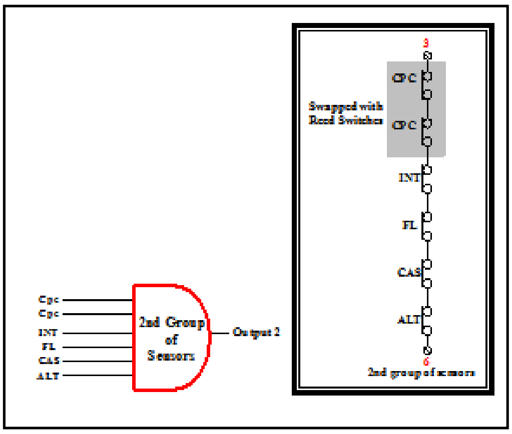

Fig. 2 Part (b) Group No. 2 of Sensors

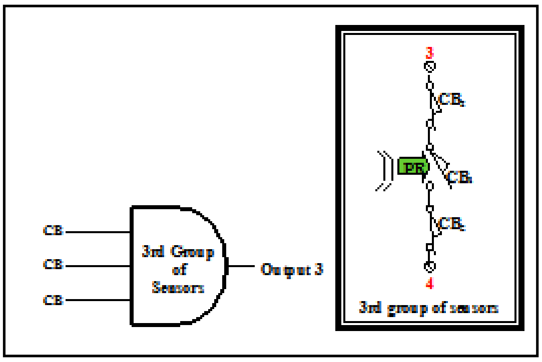

Fig. 2 Part (c) Group No. 3 of Sensors

Table (1) The Symbols of Fig. **2**

OL	Thermal Overload Relay & its relative contacts
ES	Upper extra- run contact
EI	Lower extra- run contact
CP	Preliminary approaching Contact
CPC	Cabin door Contacts
INT	Cabin top switch (for maintenance safety purposes(
FL	Slack rope contact

CAS	Safety Apparatus Contact
ALT	Cabin internal emergency push button
CB	Block Contact (Floor doors(
PR	Retractile shoe

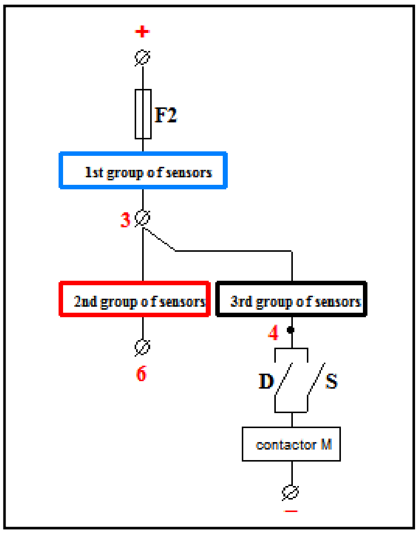

Fig. 3 Electrical Connections of Sensors in the Electromechanical Elevator Circuit

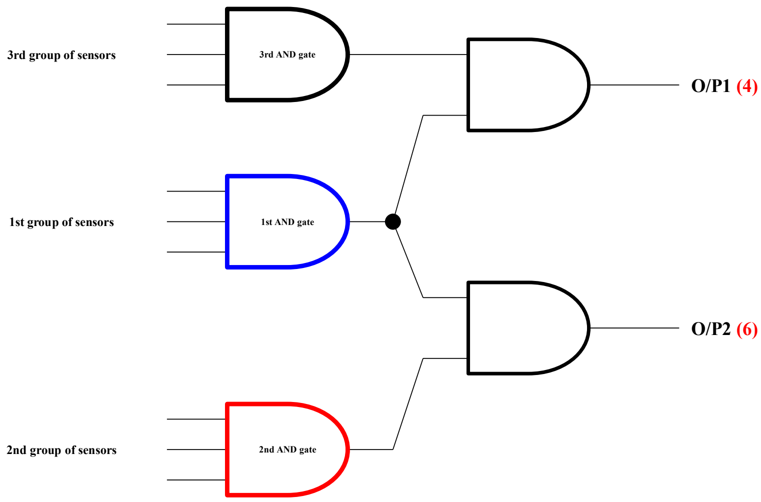

Fig. 4 Logical Connections of Sensors in the PLC Elevator Circuit

In order to analyze the rehabilitation operation of the elevator, it is important to concentrate on the following points in Appendix-1:

A. *The components which are eliminated from the old electromechanical system of the elevator*:

1. The Pilot relay (P) with its relative contact – Figures (5) and (8)
2. The relays (R1, R2 and R3) with their relative contacts, each one of these auxiliary relays is responsible of calling its own floor - Figures (6), (7) and (8)
3. Some of the contacts which belong to contactors D, S & M – Figures (3), (5), (6) and (7)
4. The off delay timer (RR) with its relative contacts – Figures (6), (8) and (10)

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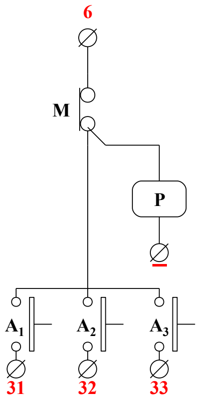

Fig. 5 Cabin push-buttons

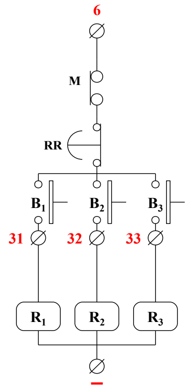

Fig. 6 Floors push-buttons

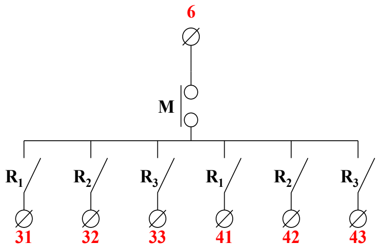

Fig. 7 NO Contacts of R1, R2 & R3

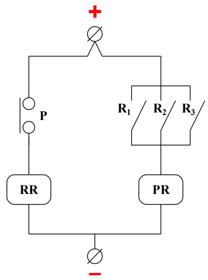

Fig. 8 RR & PR relays

B. *The power supply and the alarm electric circuits of the* elevator:

The power supply of the control circuit and the alarm circuit of the original design are shown on figure (9). They are replaced by a multiple outputs power supply as in figure (15):

1. A 24VDC supply for the control circuit.
2. A 5VDC supply for alarm circuit (with a backup battery and its charging system).
3. A 5VDC supply for signaling circuit as shown in figure (10).

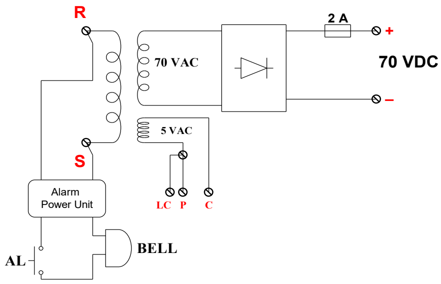

Fig. 9 Electrical Power Supply of the Elevator

C. The signaling circuit:

1. The "ENGAGED" lamps are connected directly to the output of the PLC and controlled by it via the contact (RR) which belongs to its OFF delay timer.
2. The "PRESENT" lamps are connected directly to the outputs of the PLC and controlled by it via limit switches which were swapped with inductive proximity sensors and connected directly to the inputs of the PLC.
3. The lamp inside the cabin is permanently ON.

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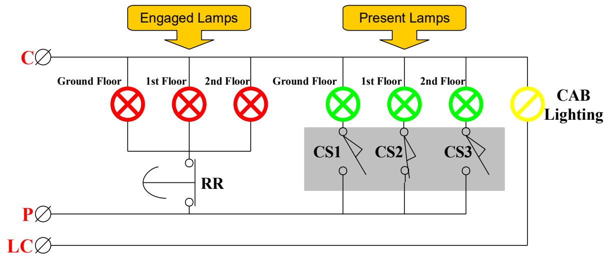

Fig. 10 The Signaling Circuit

D. *The collection of the intermediate floor (1st floor):*

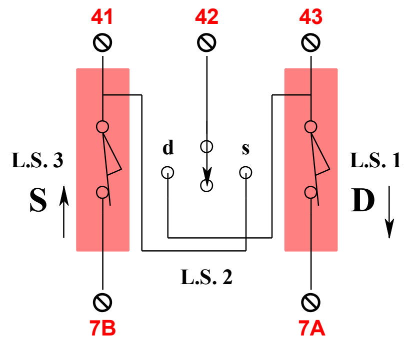

Fig. 11 The Reverse

Figure (11) and table (2) show the designed control system in the intermediate floor and how it controls the whole operation of the elevator. Figure (11) shows the electric connections of the limit switches at this floor. In the new design; the limit switch LS2 is kept unchanged because of its complicated mechanism whereas the limit switches LS1 and LS3 are swapped with two Inductive proximity sensors with normally closed contacts NC. Table (2) is a truth table of the operation mentioned above, where:

(1) – Is a closed Contact.
(0) – Is an opened Contact.

As shown in table (2), four operations were taking place in this truth table; they were described in detail here and interpreted in the PLC control program, as shown in figure (19).

Table (2) The Truth Table of the Operation

	2nd Floor	1st Floor		Ground Floor	
		L .S 2			
	L .S 3 (S)↑	d	s	L .S 1 (D)↓	
Starting point	1	0	0	1	1
Moving downward to Ground Floor	1	0	1	1	2
Reaching Ground Floor	1	0	1	0	
Moving upward to 1st Floor	1	0	1	1	3
Reaching 1st Floor	1	0	0	1	
Moving upward to 2nd Floor	1	1	0	1	
Reaching 2nd Floor	0	1	0	1	
Moving downward to 1st Floor	1	1	0	1	4
Reaching 1st Floor	1	0	0	1	

- Operation #1, the cabin is stopped at 1_{st} floor (*Starting Point*).
- Operation #2, the cabin starts moving from 1st floor to ground floor (*Descending*),
  L.S2 changes to (s).
  L.S1 will open at cabin's arrival in ground floor.
- Operation#3, the cabin starts moving from ground floor to 2nd floor (*Ascending*),
  L.S1 closes.
  L.S2 opens when approaching 1st floor and changes (d) when leaving 1st floor to 2nd floor
  L.S3 opens when cabin's reaches 2nd floor.
- Operation#4, the cabin starts moving from 2nd floor to1st floor,
  L.S3 closes.
  L.S2 opens when reaching1st floor

E. The maintenance circuit:

When the switch (INT) in figure (2-b) is opened; all the circuits in figures (5, 6, 7, 11) will be isolated and enables the maintenance circuit which can move the cabin upward or downward by push-buttons shown in figure (12).

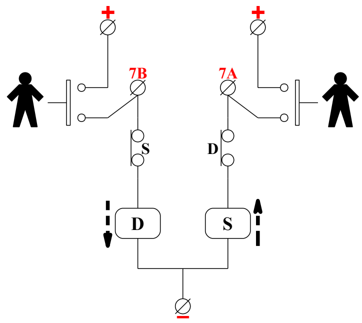

Fig. 12 Original Maintenance Circuit

F. The power supply circuit:

This power circuit is kept unchanged as in the original design as shown in figure (13). It consists of a reversing circuit of the elevator's three phase induction motor using three power contactors:

- Start contactor (M).
- Up contactor (S).
- Down contactor (D).

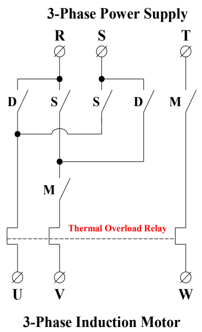

Fig.13 Power Circuit of the elevator

G. *Final wiring connections of the PLC:*

The final connections of the sensors, push-buttons, switches, contactors and lamps are shown in figure (14); and they are described in tables (3-a) and (3-b):

Table (3-a) Inputs

No. of Inputs	Designation
1	OL
2,3,4	INT and maintenance push-buttons
5	CAS (Operates when the cabin exceeds the speed limit or in case of falling(
6	ALT (mushroom type NO push-button(
7,8	)ES and EI) inductive proximity sensors with normally closed contacts NC
9,10,11	A1, A2, A3 (Push-buttons inside the cabin(
12,13,14	B1, B2, B3 (Push-buttons of the floors(
15,16,17,18	LS1, LS2 (the reverser) and LS3
19,20,21	CB1, CB2, CB3
22,23,24	CP1, CP2 CP3
25,26	CPC1, CPC2
27	FL (Stops the motor in case of breaking of one rope or more(
28	Alarm push-button (AL(
29,30,31	CS1, CS2, CS3 (Lock contacts for pilot light (PRESENT(

Table (3-b) Outputs

No. of Outputs	Designation
1,2,3	Main power contactors
4	Retractile shoe
5,6,7	"Present" indication lamps; which are controlled by inductive proximity sensors with normally open contacts NO (one lamp for each floor)
8	"Engaged" indication lamp controlled by the OFF delay timer (RR), in fact it is a combination of three lamps connected in parallel (one lamp for each floor)
9	Internal lamp of the cabin
10	Alarm

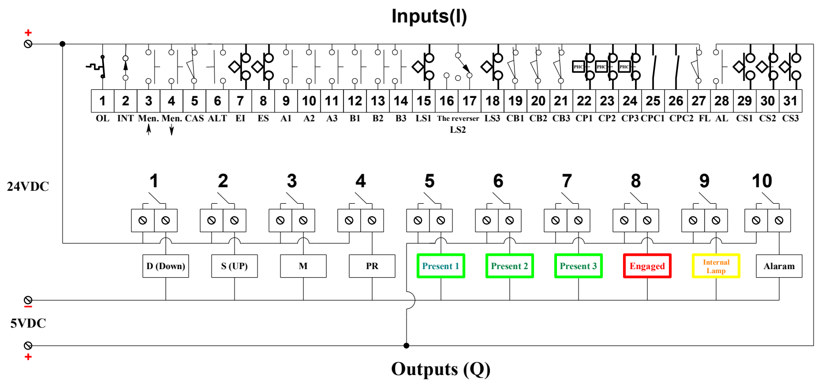

Fig. 14 The External Electrical Connections of the PLC

H. PLC Specifications:

The s7-200 PLC used in this research has the following specifications [8]

Power Supply: 220VAC
CPU Model: 224
Digital Inputs: 14/24VDC
Digital Outputs: 10/ Relay
Extension Input Module (SM1221): 16 Digital Inputs/24 VDC
Extension Input / Output Module (SM1223): 8 Digital Inputs/24 VDC
8 Digital Outputs/ Relay

2.2 Software Design:

The elevator's control system can be considered as a typical real time system because of the random nature of the destination, call time and locations of the passengers. The software used in designing the control program is Step7-MicroWIN32 which is an engineering software developed by Siemens Energy and Automation Inc. [12]. The Ladder language (LAD) [10] is chosen to be used in programming this task because it has the following features:

1. The ladder logic is easy for educational purposes and is popular around the world.
2. The ladder logic uses the same components that are used in a line diagram format of a hard-wired control [10], [12].

The PLC used in this research is Simatic s7-200 (CPU 224) [12] and its power supply configuration is (AC/DC/RELAY) with input extension modules (EM221) [12], there are 31 input ports and10 output ports used in the system.

Figure (15) describes the 1st section of the control program simulation; each group of sensors is presented, for simplicity, as a normally closed contact (NC).

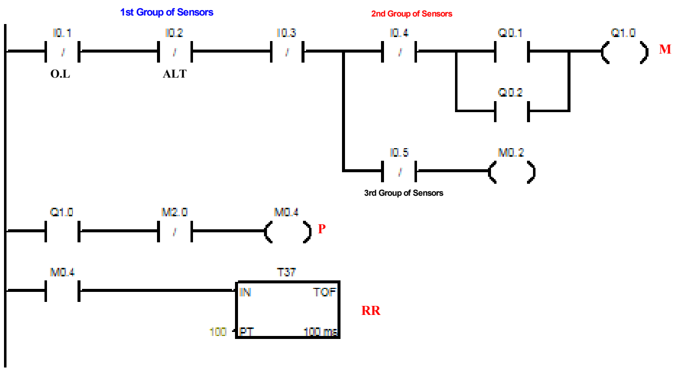

Fig. 15 First Section of the Control Program

Figures (16) and (17) show a section of the program which controls the relation between the cabin's and the floors' requesting push-buttons and the retractile shoe for safety purposes by locking the doors of all the floors during the elevator's movement and allows the only door of the floor at which the cabin is landed to be opened .

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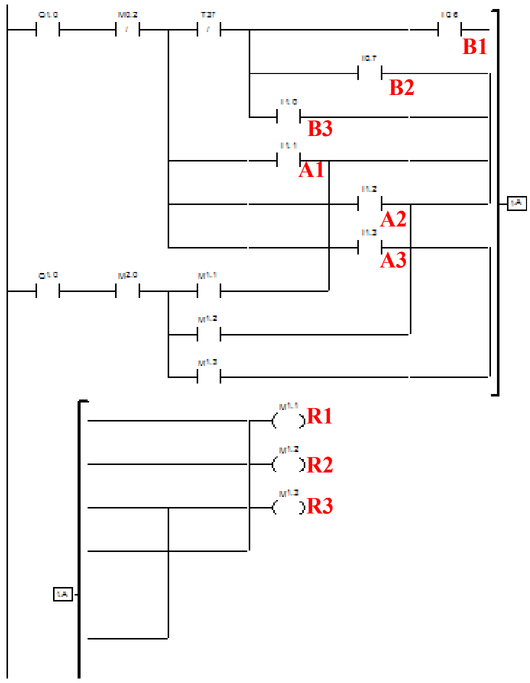

Fig. 16 The Cabin and Floors Requesting Part of the Program

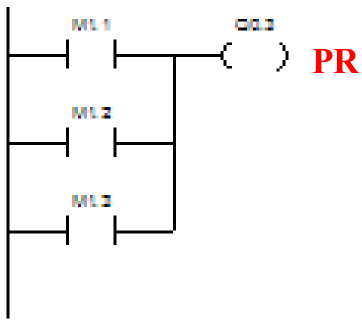

Fig. 17 The Retractile Shoe Control

Figure (18) shows the segment of the program that controls the signaling circuits of the elevator as an interactive system with human beings and the alarm circuit in case of emergency.

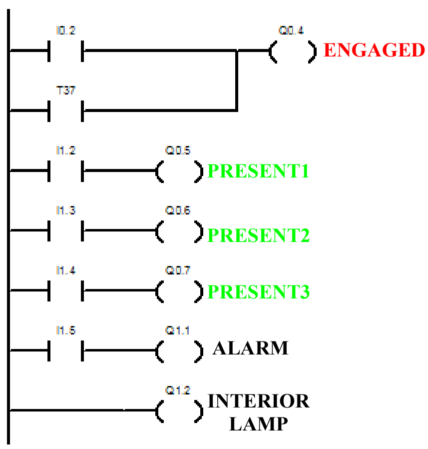

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Fig. 18 The Signaling Section of the Program

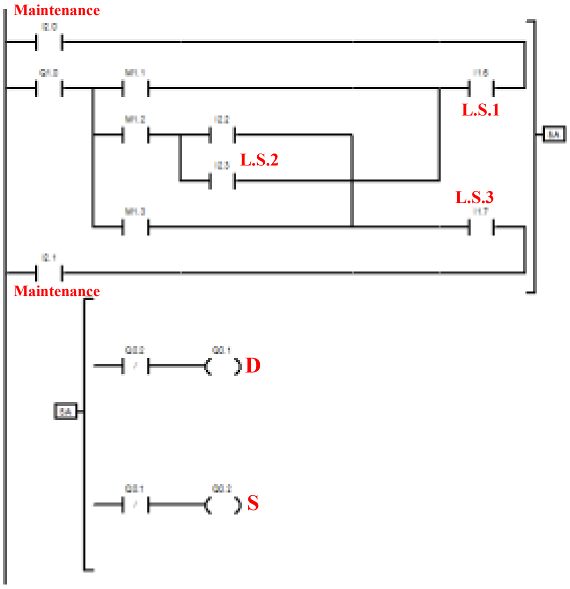

Fig. 19 The Maintenance and the Reverser Section of the Program

3. EXPERIMENTAL RESULTS

After interfacing of PLC with elevator, the trials of the setup were done and the setup successfully worked as per the designed and developed control system. About 42% of the traditional old control system was replaced with new control items.

When pressing push button A1 or B1 of the ground floor; the motor will run until the cabin reaches the required position and activates the sensor to stop the motor, but if the cabin is in the required floor; the motor will not be operated. Also by pressing push button A3 or B3 of the second floor; the motor will run either in the forward or in the reversed direction depending on its position, when the cabin reaches the required position; a sensor will be activated and stops the motor. The motor of the elevator will not run if the cabin is in the required floor as mentioned before; subsequently this concept works for other floors too. Apart from the PLC program in this paper; the flowchart in figure (20) epitomizes the basic operation of any conventional elevator.

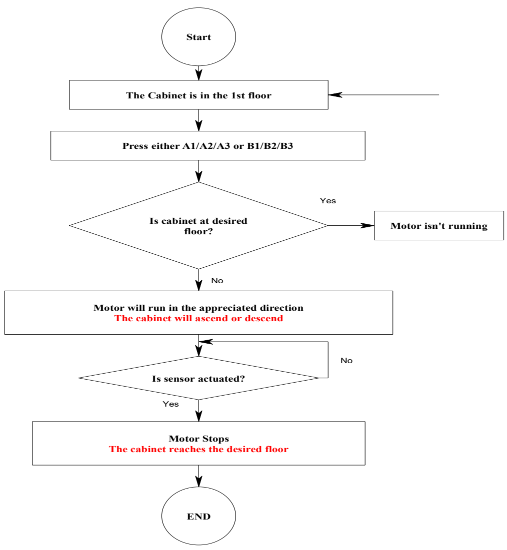

Fig. 20 The Epitomized Flowchart of an Elevator

Figure (21) shows the didactic elevator after rehabilitation with the new controlling unit.

Fig. 21 The Didactic Elevator after Rehabilitation

Figure (22) shows the didactic elevator and its internal components during the rehabilitation operation.

Fig. 22 The Didactic Elevator during Rehabilitation

4. Conclusion

In this paper, the authors' target was to concentrate on the merging of the (PLC) with classical control circuitry of the old elevator. The authors succeeded in designing and developing a PLC based control system for this didactic elevator.

The following conclusions can be drawn from this work:

- Micro PLCs can be integrated with an elevator.
- The traditional control system of the elevator has been improved by implementing PLC. It is noticed that the PLC based control system for an elevator operates better than a traditional electromechanical control system. This paper gives the basic structure, control principle and realization method of the PLC control system in detail. It also presents the key aspects of the programming of the ladder diagram system. The system has simple auxiliary circuits and the tests performed showed that the reliability and the performance of the elevator has enhanced.

In this study, real time controlling and monitoring of a three floored elevator prototype based on PLC is realized. This paper discusses the whole circuitry and the development of the ladder program, which has been implemented by using s7-200 from Siemens. The input and output ports for the forward and reverse rotation of the elevator's motor, the opening and closing of the doors; the different types of sensors presented in each floor and at the ends of both the door opening and closing have been discussed in the paper and interpreted in the program.

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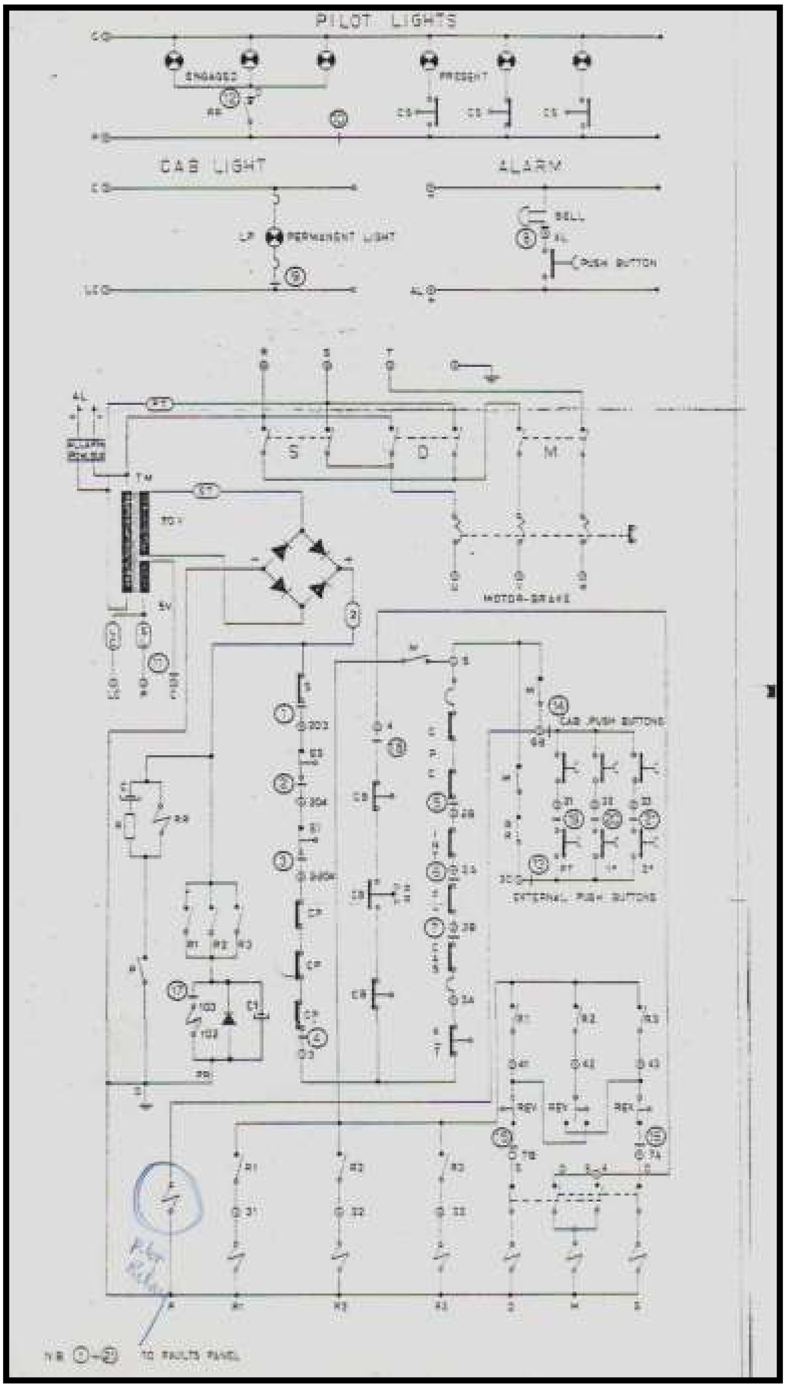

Appendix (1): Original Circuit Diagram of the Elevator
Courtesy of Elettronica Venita Co., Italy