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Modification of Electro - Pneumatic Elevator System depending on the air pressure and flow rate determinations

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Abstract-The paper presents Determination of pressures and flow for an Electro-pneumatic elevator system controlled by PLC to achieve the requirements modifications for improve presence model. The controller used for the prototype was implemented in Ladder logic on a PLC. The PLC used for this work is (LS\GLOFA-G7M-DR20A) series with (8) input and (12) output and the expansion modal (G7E-DR10A) series with (6) input and (4) output and become (14) input and (16) output. The PLC is programmed with Ladder diagram. This develop of a new elevator system is expected to be effective at ideal design in low-rise internal buildings when this elevator type are used.

Key Words: *Pneumatic, electro-pneumatic, Elevator, PLC, ladder.*

تعديل منظومة المصعد الكهرو-هوائي بالأعتماد على حسابات الضغط ومعدل الجريان

حاتم كريم، فكرت عبد الكريم ، سيف الدين طه

الخلاصة:البحث يمثل حسابات الضغط والجريان لمنظومة المصعد الكهرو هوائي والمسيطر عليه بواسطة المبرمج القابل اللبرمجه لغرض اجراء التعيلات المطلوبة لتحسين نموذج موجود .المسيطر للنموذج المستخدم نفذ بمنطق المخطط السلمي وبلستخدام الـ PLC .المسيطر المستخدم في هذا العمل تمثل بـالـ PLC (LS\GLOFA-G7M-DR20A) بمحموع مدخلات (٨) ومخرجات (١٢) و الـ expansion modal (G7E-DR10A) بمجموع مدخلات (٦) ومخرجات (٤) فكان عدد المدخلات الكلية (١٤) وعدد المخرجات الكلية (١٦).وتمت برمجة الـ PLC بلغة المخطط السلمي .هذا التطوير لمنظومة المصعد الجديد يتوقع لها فاعلية كبيرة وتاثير مهم على وضع التصميم الصحيح عند استخدام هذا المصعد في البنايات ذات الارتفاعات المنخفضه.

I. INTRODUCTION:

Electro-pneumatics [1] knows as pneumatic components controlling by electrical impulses. It uses all electronic components like micro-controller, sensors, relays, electronic switches, transformers. Electro-pneumatics is now commonly used in many thinks. They are also used extensively in production and packaging systems. Its control depends on electrical control systems operating pneumatic power systems. In this, solenoid valves are used the electrical and pneumatic systems. Limit switches and proximity sensors are used as feedback elements. The greatest advantage of electro-pneumatics is the integration of various types of PLC for control.

Pneumatics [2] is section of science which accord with the study of gases especially air, its properties and application at pressure higher (compressed) or lower (vacuum) than atmospheric. Has no need for return piping, whereas, the pneumatic can be easily connected to an air supply. the air is released to atmosphere. It is un-acceptor for burning.

The automation systems [3] that deals upon electro-pneumatic technology are mainly consist of three types of elements: actuators, sensors and control elements PLC, becomes main tool for control elements which is used to execute the logic of the system. Inputs like proximate and switches and outputs like the direct control valves PLC made simulating the system as needed. This causes saving time, reducing mistakes, and increasing complexity by using the same elements. Under the American requirements and safety regulations [4], the pneumatic elevator is operated by turbines fitted at the cylinder top (hoist way) creating a low pressure above the cabin (car), causing the car to move upwards by the force of nature: the ambient atmospheric pressure.

The first pneumatic vacuum elevator (revolutionary technology) [5] is now available for indoor and outdoor household and commercial usage around the world. Outstanding features include: one day installation, no pit nor infrastructure required, 12 volt circuits, no energy consumption during descent and low when ascending, panoramic visibility, highest safety during power outages, low maintenance with no lubrication required. The authors in Ref.[6] used the Supervisory Control and Data Acquisition (SCADA) to supervise and control the working of the elevator. The response on the fault occurred could be taken within no time by interfacing PLC and SCADA with the elevator system.

The only research work in the literature talk about implementing an electro-pneumatic elevator controlled by a PLC was worked by the researchers in Ref.[7]. He designed and constructed Electro-pneumatic model with the possibility of being controlled by a mobile phone; the model for remote control of PLC by means of Short Message System (SMS) was projected for the application of Electro-pneumatic elevator as in Ref.[8] explained about an elevator operation which uses an AC motor to drive the elevator cabin. The elevator was fully automated using PLC. The researcher in Ref. [9] designed a roped elevator prototype, which uses a linear induction motor (LIM) as a traction machine. This design established a new concept for elevators through a new construction technique and assembly of the system with counterweight

The proposed elevator can be named by electro-pneumatic elevator. This elevator may be operated by an actuator (with fitted cabin (car) slotted on it) creating a high pressure under or over the cabin, causing the car to move upwards and downwards, respectively.

In Ref. [10] the authors focused on using Siemens LOGO PLC loaded by software LOGO Soft Comfort V7.0. To control the circuit and building the elevator model based on DC Motor to control the up and down movement of the elevator car. Pandian et al. [11] Presented in their work two methods for controlling pressure. In the first method, the pressure is measured in one chamber and the pressure in another chamber is observed. In this case, a choked flow condition is assumed by the authors. In addition, mass flow rate is assumed to be known while deriving the error equation. Both of these assumptions are restrictive since at a low pressure difference, the flow rate is not choked. Also, the mass flow rate is a function of pressure whose value is to be estimated. In the second method, the same assumptions of the first method were used. In this method, the difference between the estimated and actual pressure in one chamber is treated as a disturbance and the pressure in another chamber is observed using a sliding-mode observer design.A.M Al Ibrahim and D.R.Otis [12] found in their studies that the charging and discharging processes of air inside an actuating cylinder were studied experimentally for a work cycle which raised and lowered a mass .the processes were found to be reproducible and complex .the measured temperature and pressure histories were discussed, and the effect of the supply pressure and the mass load were examined .the effect of the piston seal static friction was quite clear on the temperature and pressure histories . Nominal values for Reynold and Grashof numbers were computed.

The current work, focuses on using pneumatic components and electrical components to build prototype model of an Electro-pneumatic elevator consisting of three (floors) in about (160 cm*40 cm*70 cm) and the travel length (125 cm) controlled by using PLC. The PLC is programmed with Ladder language. The used plc is (LS\GLOFA-G7M-DR20A) series with (8) input and (12) output and the expansion modal (G7E-DR10A) series with (6) input and (4) output .Total will become (14) input and (16) output. . It is programmed with a Ladder language (GMWIN 4.0), and during its construction, many theoretic knowledge from various fields were applied.

II. MODEL CONSTRUCTION:

Elevator laboratory model that was built for the purpose of comparing it with real lift. It is in fact made up of electrical materials and pneumatic represented as follows:

The compressor , pneumatic cylinders ,valves, power supply , PLC**,** connectors, proximate switch, wires, hoses, distributors, pressure gauges, external switch cabin, internal switch cabin, light number, buzzer, all of this components were listed in tables(A-1)and(A-2)and (A-3):-

TABLE (A-1) PNEUMATIC COMPONENTS

Pneumatic component	**Name of company**	**specifications**
Air compressor	ROLLS COMPANY	Direct- driven air compressor with (1-8) bar
cylinder	Festo company	125 cm length double acting cylinder
solenoids	Bosh company	Normally close (NC) DC24 v , 50 HZ

TABLE (A-2) ELECTRICAL COMPONENTS

Electrical	**Name of company**	**Specification**
PLC	LS/GLOFA-G7M-DR20A	12 inputs and 8 outputs programmed in ladder language (GMWIN4.0)
Expansion modal	G7E-DR10A	6inputs and 4 out puts programmed in ladder language (GMWIN4.0)
Power supply	Anlixun company	s-120-24/p 110 v AC 1.6A ,50/60 HZ DC (5A) ,230v AC 0.8 A
Compressed Air flow	T-CDI-5200-10 S.	Input power: 250 mA at 24 v DC, output resistance: 600 Ohms max.
Proximate switch	ABB company	4mm inductive

TABLE (A-3) MECHANICAL SPECIFICATION OF THE ELEVATOR SYSTEM

Elevator cabin		**Elevator frame**	
Length	19 cm	Length	160 cm
depth	13 cm	Width	40 cm
Width	17.5 cm	depth	70cm
Cabin Material	wood	Travel distance	125 cm
WOOD thickness	8 mm	Frame material	PVC Rigid
Cabin Weight	0.5kg	PVC density	1300kg/m^3
Load Wight	5kg	Maximum Velocity	0,05 m/sec

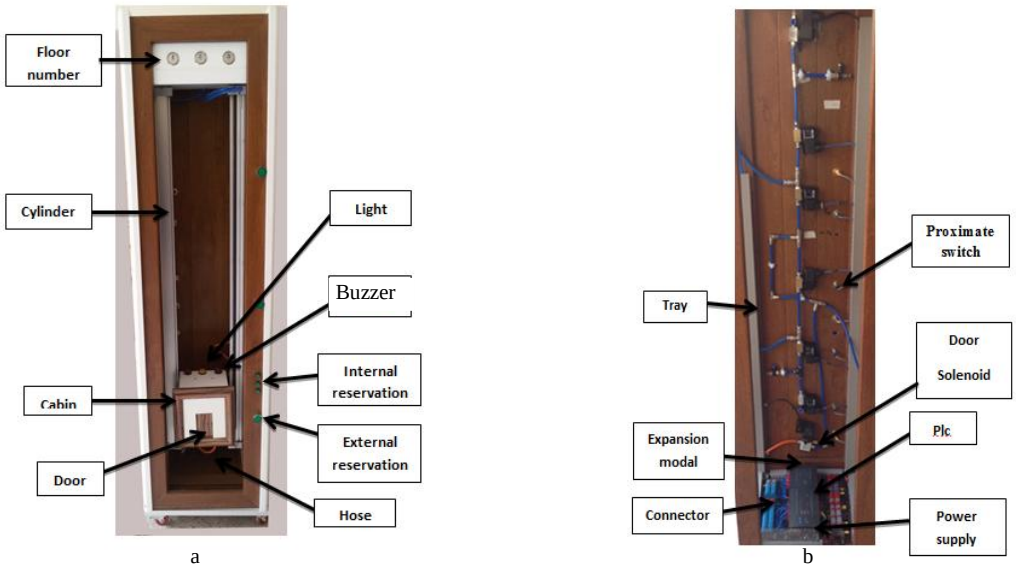

Fig.1: Elevator system (a-front view, b-back view)

III. ELECTRO-PNEUMATIC COMPONENTS:

The electrical connection for the elevator parts can be shown in the back side of the prototype elevator model shown in the Fig. (1-b). These parts can be listed as below:-

A. The solenoid:-

Each cylinder used in the elevator system contains (2) holes (Input & output) ,one is to push the air from down to up and the other one is to push the air from up to down and in order to control the air in a specific point should be used the solenoids. In this model, a solenoid type (2/2) normally closed (NC) has been used. The role of these solenoids is to be closed and opened in two directions. In our actual design, could be controlled the ascending of the air through solenoids (SV3 &SV5), but regarding the descending of the air, could be controlled it by using a solenoid (SV2 & SV4). Also and in order to accelerate the cabin movement between floors, solenoid (SV6) has been used for ascending and Solenoid (SV1) for descending and according to the drawing in figure (2)

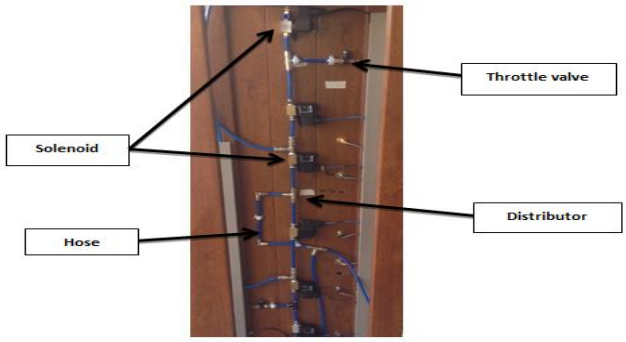

Fig.2: The solenoid

B. The Air Compressor:

The uses of compressor are to give a pressure range of (1-8bar) to the system of this device. It must be taken in the consideration to use the most suitable air compressor being with minimum size and lower noise and give the perfect rated pressure required for the proposed elevator model.

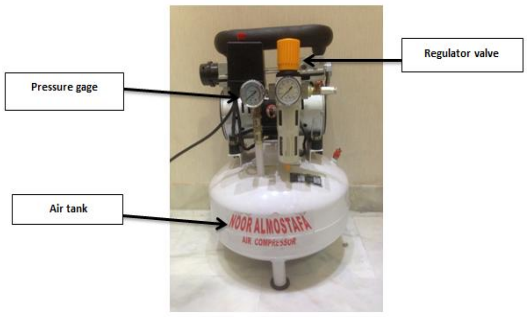

Fig.3. The mute air compressor

IV. Programmable Logic Controller (PLC):

PLC is considered as the controller in this model .It can be easily programed it to do the requested job through the computer device .The PLC used in this project is (LS/GLOFA-G7M-DR20A) & The Expansion Modal (G7E-DR10A) Series. The operator program used in the current model is (GM WIN 4.0) in ladder language

V. Creeping:

In order to have an exact stop in each floor , a proximate switch can be used in a technical way with an equal dimensions for each floor. After number of attempts to get the right stop in a specific time in each move from floor to floor as its shown in figure (4). a proximate switch has been used above the first floor about 10 cm height and called it down arrive floor one (Down AF1).The same thing with the third floor where a proximate switch has been used about 10 cm under the floor and call it this time up arrive floor 3 (Up AF3). Regarding the second floor in this prototype , above and under the floor also 10 cm height a proximate switch has been used and called it down arrive floor two & up arrive floor two (Down AF2) & (Up AF2).

The role of theses proximate switches is to send a sign while the cabin passes in up and down direction. The sign will be send to the PLC informing the arrival of the cabin up and down .PLC will operate the solenoids in both cases .If the ascendance of the cabin is correct and normal , the following solenoids will be operated :

(SV3& SV5 & SV6).When the cabin will reach to the proximate switch dedicated to the creeping, the PLC will put off the solenoid (SV6), which will lead to slow down the speed of the cabin and the air will flow out from the throttle valve which it controlled manually. As a result, the elevator will stop in front of the requested floor exactly. In the normal descending case, the solenoids (SV1&SV2&SV4) will be operated . When the cabin will reach to the proximate switch dedicated to the creeping, the PLC will shut down the solenoids (SV1), which is leading to repeat

the same steps of the slowdown of the cabin in the ascending case and it will stop exactly in the requested Floor. The electro- pneumatic elevator doesn't need to a separate brakes system, because there is no free fall at any reason and definitely. In all cases that demands brakes, there is a smooth and calm descend by air vacuum operation in cylinders and according to the load that exist in the cabin. Adding, the existence of another cylinder and piston in this project, it can work in case of any failure in the original cylinder and piston.

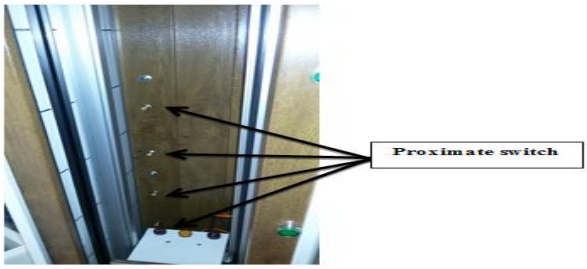

Fig.4. Creep proximate switch

VI. PNEUMATIC SCHEMATIC DIAGRAM

From the first sight to this device, it can be seen the connection of the elevators parts very clearly in the back side. All item used for this project can be shown in figure (1-b), also schematic wiring in figure (5).

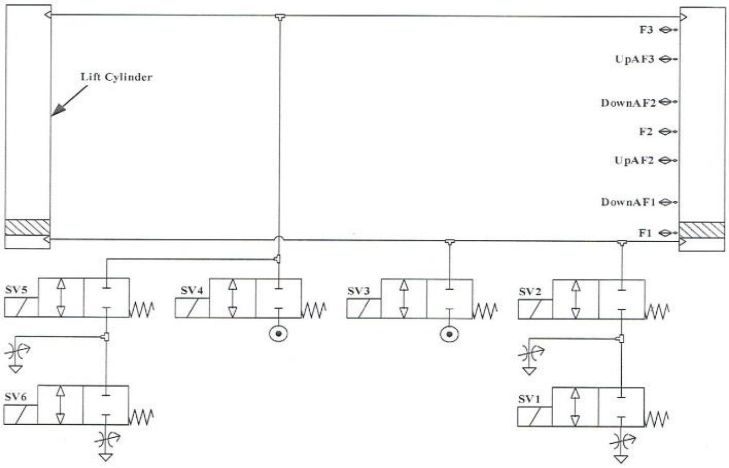

Fig.5: The Wiring Schematic Diagram

VII. SOFTWARE PROCESS OF THE ELEVATOR SYSTEM:

The software process in this model depends on the sensing of the floors through the proximate switch which it in charge to send the sign to the PLC. The PLC will operate the solenoids in both directions (Up& Down).Ladder program has been implemented in this system with another sub-program as shown in the figure (6- a) & (6-b).

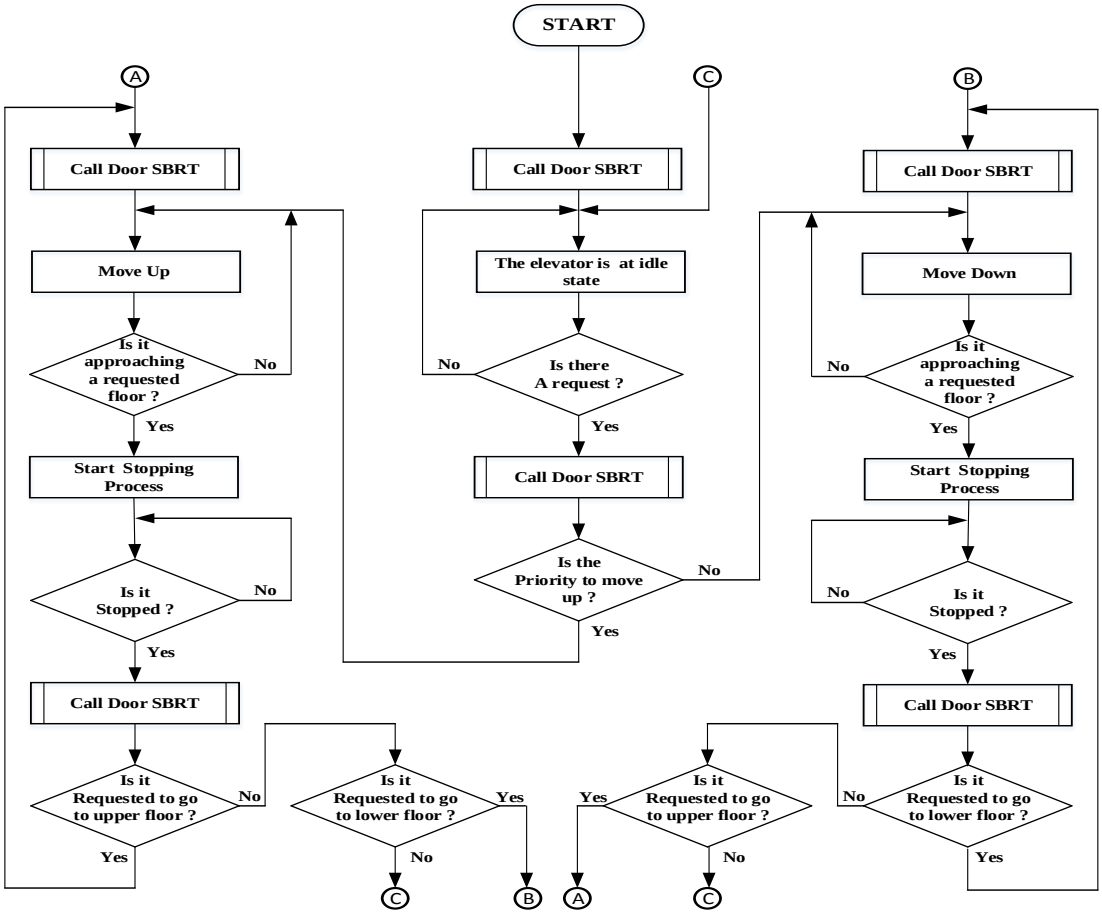

Fig. 6-a: Elevator control algorithm flowchart

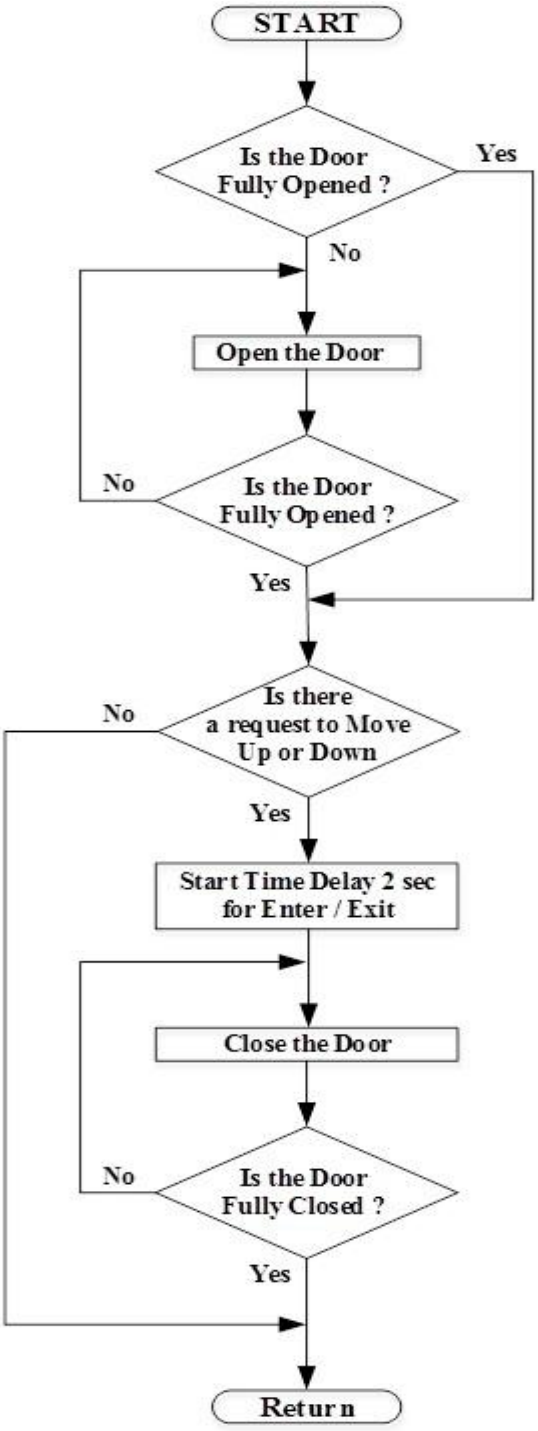

Fig. (6-b): Door Subroutine Flowchart

VIII. RESULTS AND DISCUSSION:

In this experiment it was used the Data Acquisition System (DAQ OR DAS) for the purpose of drawing the pressure and flow waves by connecting (PC) to measure the flow device and then connect the sensors pressure to the airway in the input and output of the cylinders and by computer through (DAS) and using MATLAB program has been drawing waves of the state no load and the case of a 5 kg load, as shown in Figure tying experience (7). The

red line represents the pressure curve in the room (A) shown in Figure (8) , when the cabin rise from the first floor to the second floor , the pressure starts from time (4 seconds) until it reach to the (2.8 bar) . After that the pressure will be stable of time (4 seconds) to the time (13 seconds) and then starts to go down due to the process of creeping generated as a result of proximate switch from time (13 seconds) to the time (19 seconds), a time of reaching to the second floor. The time in the beginning of the curve due to the operation of the program, the elevator's structure, and filling time the room (B) for the purpose of raising piston to the highest. The blue curve represents the pressure in the room (B) the descending of the pressure when the cabin moved from the first floor to the second floor and starting to get off from the time (4 seconds) to the time (13 seconds) ,at the pressure (0.8 bar)the creeping process started , where the pressure will reduce to(0.6 bar) at the time (17 seconds) and then start to climb to be stable at pressure (0.8 bar) at the time (19 seconds), and this is the arrival time of the cabin to the second floor (the required floor) . Regarding the flow process, it had been noted that it starts from the time (zero) until reaching the time (4 seconds) where it begins to climb for the purpose of filling the room (B) under the piston to reach (40 liters per minute) and then almost stabilized in time (6 seconds) until reaching the time (13 seconds) and here begins the process of creeping where flowing begins to rise until it reaches the maximum level (90 liters per minute) at the time (22 seconds) , the process of vacuum through the throtle valve to stabilized later on in time (25 seconds). Than the above ,it had been noted that the pressure in the room (A) is less than the pressure in the room (B) at the beginning of the first round and in the case of ascending . Due to the lack of flow in the room (A) The flow will be exclusively to the room (B) only, and vice versa in the case of descending. As note in the creeping case, pressures act will be in reverse because of the balancing between the two rooms (A & B) in terms of pressure

Fig.7. The experimental setup

Fig.8. Cylinder and piston representation

To illustrate, the first case of a transmission elevator from the first floor to the second floor was taken , in both cases, as shown in Figure below (9- a) and (9 - b**)**

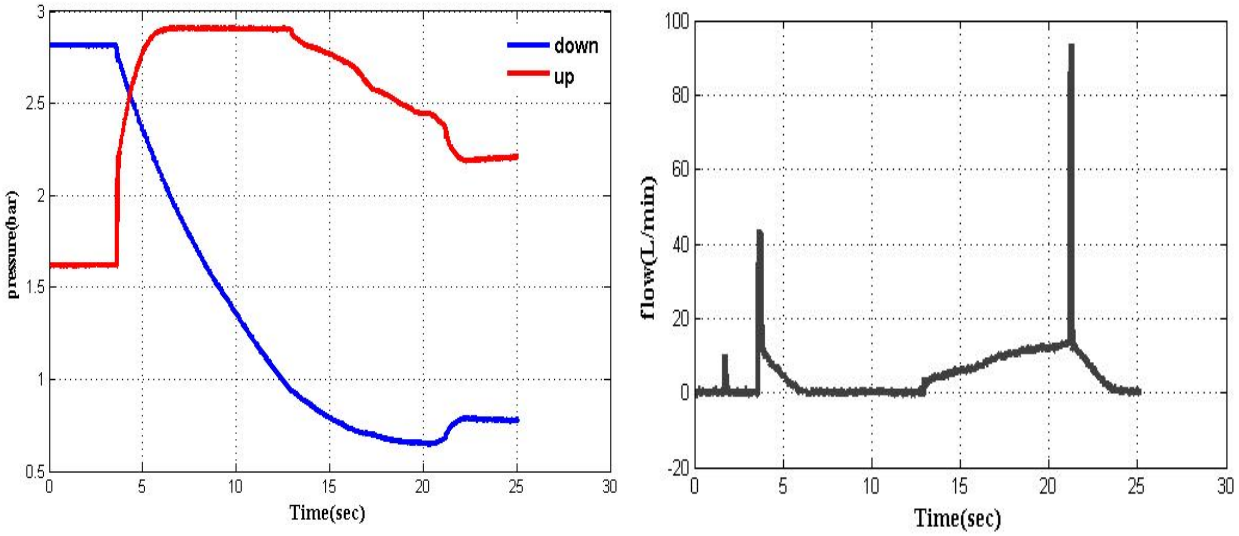

Fig. (9-a) Pressure and flow for no load case when elevator move from floor 1 to floor 2

In Figure **(**7-a**)** the load imposed here is only for the weight of the cabin, which is about (0.5 kg), according to the specifications listed in the table (A-3).

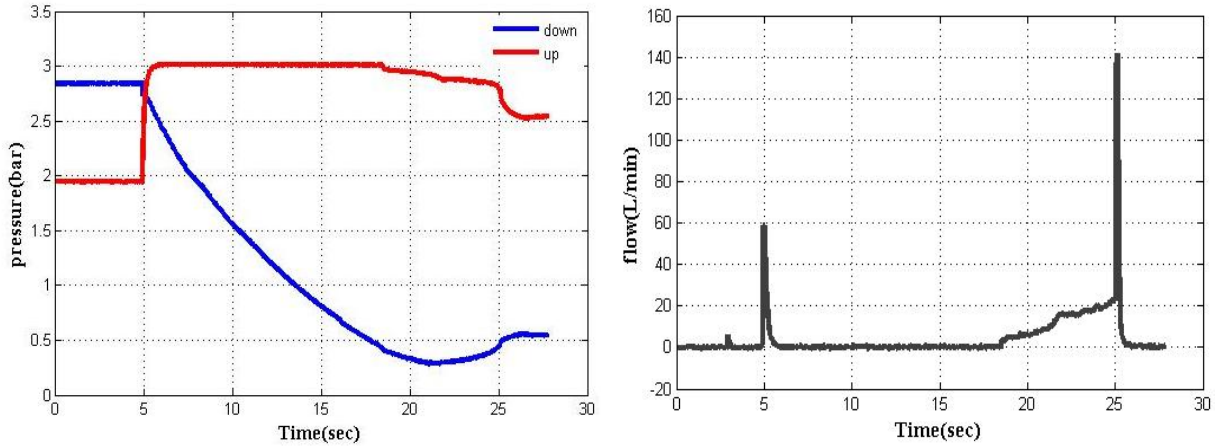

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Figure (9-b) Pressure and flow for load 5kg case when elevator move from floor 1 to floor 2

In Figure (9-b) when the load is (5kg), the curves of pressure and flow in the case of cabin movement from the first floor to the second floor compared with the previous figures in terms of the pressure ,the pressure begins inversely move of time (5 seconds) and the fact that movement here is upward of cabin where (3 bar) and the downward is (0.5 bar) ,either flow (under piston) will reach at this time to (60 liters per minute) then the process of creeping begins and the process of unloading the air also to reach at (140 liters per minute) , then the cabin will stabilize at the time (25 second), and this is the time to reach to the desired floor.

IX. CONCLUSIONS:

A new PLC based pneumatic-elevator system has been proposed and successfully implemented as a prototype model after taking in our consideration the structure dimensions and the suitable tools for this model . The current model is totally working with three floors. Electro-pneumatic elevator is a development for a new idea which is a derivative and developed for pneumatic (vacuum) elevator when the vacuum air idea [5] replaced by pressure

(compressed) air idea. Electro-pneumatic elevator can carry a person from floor to another floor without cables, pulleys or counter weight. It's mounted on any finished floor eliminating the concept of a pit excavation and an engine room.

It is observed that, the PLC based controller for electro-pneumatic elevator works well and achieve a quiet with more signals (for development requirement), smooth and efficient ride without any noticeable jerky motion.

The industries and other business establishment will be greatly benefited from this type of control system especially for domestic appliances. However, before pressing this type of control system for commercial use, the in depth study, experimentation and validation are required. This development of elevator system is expected to be most effective in low-floor residential buildings such as indoor and outdoor household, commercial usage around the world.

The current system prototype model can be used as teaching tool in learning enhancement for the undergraduate's students in the electrical and electro-mechanical engineering departments in the Universities. It note that the behavior of the pressure and flow varies according to the existing situation where the pressure at the beginning and end of the round and when arriving to the creeping status, will have some values of different weights which must be taken into account in the final design.

REFERENCES:

[1] G. Prede and D. Scholz, "Electro-pneumatic", Text Book TP 201 2005-Festo.
[2] F. Ebel, Fundamentals of Pneumatics, Denkendorf, Text Book TP 101 2000-Festo.
[3] F. Ebel, S. Idler, G. Prede and D. Scholz, "Fundamentals of Automation Technology", technical book, Denkendorf, Germany, 2008-Festo.
[4] Daytona Elevator, Pneumatic Vacuum Elevators, Report, www.daytonaelevator.com.
[5] A-Mid American Elevator Company, Inc., Report, North Wolcott Avenue Chicago, Illinois, email: sales@mid-americanelevator.com.
[6] Sehgal, Saru, and VikasAcharya. "Effect of PLC and SCADA in boosting the working of elevator system."Electrical, Electronics and Computer Science (SCEECS), 2014 IEEE Students' Conference on. IEEE, 2014
[7] P. MATOUŠEK, "Model of Electro-pneumatic Elevator with the Possibility of Control by Mobile Phone", Annals of Faculty Engineering Hunedoara-International Journal of Engineering, Fascicule 3, July-Sept, Tome III, 2010, pp. 67-72.
[8] Osama, M. and Abdul-Azim, O., "Implementation and performance analysis of an elevator electric motor drive system", IEEE Power System Conference, 12th International Middle-East, Bhopal, India, 12-15 March 2008.
[9] T. R. Fernandes Neto, R. S. T. Pontes, "Design of an Elevator Prototype Propelled by a Linear Induction Motor", University of Ceará, Induction Motor Drives research papers, http://www.engpaper.com/induction-motor-drive.htm.
[10] Singh, G., Agarwal, A., Jarial, R.K.and Agarwal, V., "PLC controlled elevator system", IEEE Students Conference on Engineering and Systems (SCES), 12-14 April, 2013, pp. 1-5.
[11] Pandian, S. R., Takemura, F., Hayakawa, Y., and Kawamura, S., "Pressure Observer-Controller Design for Pneumatic Cylinder Actuators", *IEEE/ ASME Transactions on Mechatronics*, Vol 7, no. 4, pp 490-499.
[12] A.M Al-Ibrahim & D.R. Otis "Transient Air Temperature and Pressure measurements During the Charging and Discharging Processes of an actuating Pneumatic Cylinder ".Technical Paper Series N92-16.1 National Fluid Power Association 3333 N.Mayfair Road .Milwaukee,WI 53222-3219 .414-778-3344.
[13] Dr.Jamal Abdul Kareem ,Dr.Hatam K. and ,Athraa S. "implementation of an electro – pneumatic prototype elevator controlled by PLC "eng.&Tech.Journal.Vol.33.Part (A).N0.8.2015