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THE METHOD FOR REMOTE CONTROL OF A MECHATRONIC SYSTEM, BASED ON A BLUETOOTH MODULE

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ABSTRACT

The paper presents a mechatronic system programmed and controlled by a PLC. The mechanical structure consists of a Dc motor and pneumatic actuators. The Control from short distance is necessary in many industrial applications.The paper presents a case study based on a mechatronic system controlled using a bluetooth.

KEYWORDS: mechatronic system, remote control, PLC

1. INTRODUCTION

New technologies that rely on machinery incorporate cutting-edge achievements in fields like computer science, electronics, mechanical tool which transforms the car into a mechatronic product.

The control of the mechatronic systems, industrial (flexible lines of production) is often implemented with the help of PLC controllers and it includes regulators whose feedback loop can control precise movements through the program and on the system sensorial together into execution.

Pneumatic actuators are used in industries with fire, explosive atmospheres, danger of contamination and in all industries where you can perform automated production lines with high productivity.

Linear motion in mechatronic systems is preferably pneumatic for advantages such as high speed, acceleration and simple control. Regarding oscillation or rotation the highest efficiency is obtained by the use of electric motors.

Based on information received from sensors and transducers, PLC is processed and the appropriate response is sent to the actuators that implement actions on the mechanical system. Their ties between energy and information flow in mechatronic systems are monitored and controlled in closed control loops thus avoiding the unintentional operation of the system.

The advantages of electric motors lead to further integration in mechatronic structures. These advantages of electric motors can include: driving without noise, simple and efficient energy supply, good dynamic, repeatability and precise positioning.

1.1. Pneumatic actuators

In pneumatics, air is Used to convey energy and signals. Air is a gaseous mixture comprising:

- Approximately 78 Vol.% Nitrogen
- Approximately 21 Vol.% Oxygen.

The rest is hydrogen, neon, helium, argon, carbon dioxide, krypton and xenon.

Pneumatic actuators use pressurized air and are used in environments with explosion, risk of contamination and the advantages offered by these terms. Air can be compressed and tends to expand. These properties are described by Boyle’s Law: the volume of a simple of gas is inversely proportional to the pressure applied to the gas if the temperature is kept constant, or the product of the volume and pressure of a fixed quantity of an ideal gas is constant, given constant temperature.

Pneumatic actuators are usually of the linear motor type, motor rotary gripper or distributor. Pneumatic actuators can not be used in precise positioning applications due to the compressibility of air and temperature variations depending on volume.

Specific problems arising from pneumatic low efficiency are related to positioning, speed control, braking. Structurally a pneumatic system is an assembly of pneumatic and mechanical elements through the means of execution, which makes a series of moves by a predetermined algorithm. Seen from another angle, this system is the description of a pneumatically driven production line.

A new trend in proportional pneumatic actuators are pneumatic actuators that rely on analog control techniques and equipment or PWM signals. This direction of development is strongly driven by the achievements of computer technology so they can meet the demands on response time, precise control.

In mechatronic systems hybrid actuators (Pneumohydraulic) are also used where compressed air is used to generate movement and hydraulic circuit is used for positioning or speed control acceleration, etc.

1.2. DC motors

DC motors still remain topical even if 90% of application uses AC motors [5]. Depending on the connection mode of excitation winding, continuous current motors are classified as:

a) Separate field excitation motor- stator and rotor windings are connected to different voltage sources (Fig.1).

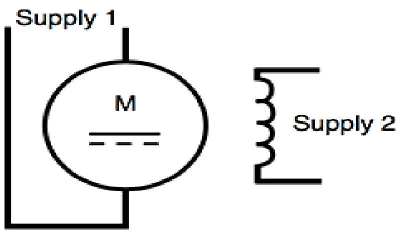

Fig. 1. Separate excitation

b) Series wound motor- the field coil is connected in series to the armature coil, hence its name (Fig.2).

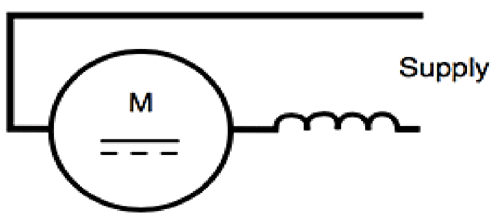

Fig. 2. Series excitation

c) Parallel excitation- the coils are connected in parallel or supplied via two sources with different voltages (Fig.3).

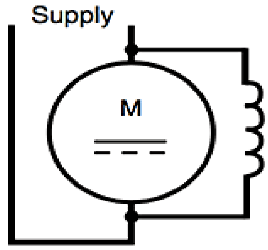

Fig. 3. Parallel excitation

d) Compound wound motor- this type of connection combines the qualities of the series and parallel excitation motor (Fig.4).

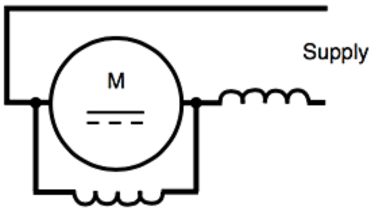

Fig. 4. Mixed excitation

DC motors work on the principal, when a current carrying conductor is placed in a magnetic field. If the direction of the current in the wire is reversed, the direction of rotation is also reversed. When the magnetic field and electric field interact they produce a mechanical force, and based on that the working principle of DC motor is established. The direction of rotation of this motor is given by Fleming's left hand rule.

Permanent and transient operating modes are determined by the equations:

Supply voltage:

$$U_A = R_A I_A + L_A \frac{diA}{dt} - E \qquad (1)$$

Emf:

$$E = -Ke\varnothing n \qquad (2)$$

Electromagnetic torque:

$$M = K\varnothing I \qquad (3)$$

Torque ecuations:

$$M - M_{r\varepsilon} = J \frac{d\,\Omega}{dt} \qquad (4)$$

Excitation magnetic flux:

$$\varnothing = f(I, ie) \qquad (5)$$

where:

$M_{r\varepsilon} = M_r + M_m + M_{fe}$ - represent the total resistant torque.

In stationary operation, equations become:

$$U_A = R_A I_A - E \qquad (6)$$
$$M = M_{r\varepsilon}$$

By eliminating the variable E, the first two equations (1) and (2) give the speed-current characteristic equation.

$$n = \frac{U_A - R_A I_A}{Ke\,\Phi} = \frac{U_A}{Ke\,\Phi}\left(1 - \frac{R_A I_A}{U_A}\right) \qquad (7)$$

Substituting the appropriate torque, the current through the speed-torque characteristic equation results.

$$n = \frac{U_A}{Ke\,\Phi} - \frac{R_A}{KeK\,\Phi^2} M \qquad (8)$$

1.3. PLC as controller and Bluetooth control

Modern mechatronic systems rely on some modern principles such as: flexibility, modularity, communication, fault tolerance.

Currently the crossing point between top results in technology is mechatronics. This congruence of such different technological branches explains the complexity of the processes in terms of both architecture and electro-sensory system and control [2]. In this context, it is obvious the complexity of the mechatronic systems, especially the driving system.

PLC (Programmable Logic Controller) is a digital computer used for automation of industrial processes. It is an example of a real-time output result to be produced in response to input conditions within a bounded time. Unlike a general purpose computer, PLC is designed for multiple inputs and outputs, extended temperature range, immunity to electrical noise, vibration resistance.

It is important to understand the principle because, depending on that, programmers structure the control logic. This iterative process is known as the "sweep cycle" and the time required to achieve it is known as the time of scanning (Fig.5).

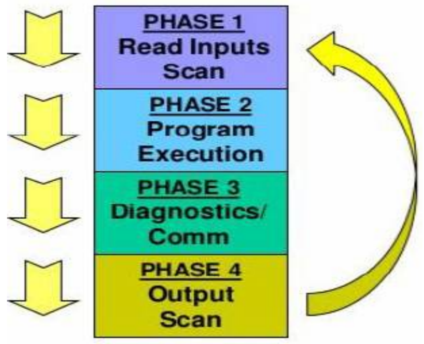

Fig. 5. A scan cycle’s mode of operation

Input and output terminals allow interconnection with the receiving or transmitting of signals to it.

Now that we know how the flow of information reaches the controller we can see how it can be used. The inputs can be digital, analogue and communication protocols with intelligent sensors.

The digital or analog outputs can control actuators that can work in a proportional mode. I/O Digital (discrete) the interface is used to connect devices that transmit or receive signals boolean and I/O analogical (numeric) the interface allows transmission and reception of signals on more bits and it is the digital representation of an analog quantity.

Programming methods of PLC are contained in IEC 61131 and they are the following:

LD- Ladder Diagram – is the main programming method for PLC’s. Ladder logic has been developed to mimic relay logic (Fig.6). The first PLC was programmed with a technique that was based on relay logic wiring schematics and this eliminated the need to teach the electricians, technicians and engineers how to program.

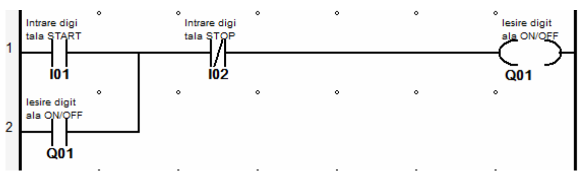

Fig. 6. Example of a program in LD language

FBD- is another graphical programming language. The main concept is the data flow that starts from inputs and passes in block(s) and it generates the output (Fig7).

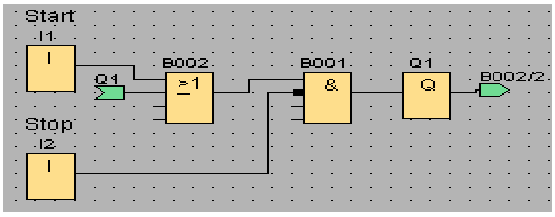

Fig .7. Example Program in FBD language

ST- Programming has been developed as a more modern programming language. It is quite similar to languages such as BASIC and Pascal. For example see below the loop For in ST language:

```
FOR I:=1TO 80 BY 2 DO
IF ARR[I] =70
THEN J:=I;
EXIT;
END_IF;
END_FOR;
```

IL- Instruction list method of programing is close to assembler. It is an old language, hard to maintain, hard to read for externals, hard to handle in larger projects, no programing structure.

SFC- Sequential Function Chart is used like a sketching language to describe the height level states of a mechatronic system (Fig.8). It is a graphical height level language.
It is very useful to put together in a flow chart form the other PLC programming elements, such as function blocks (FB) or structured text (ST).

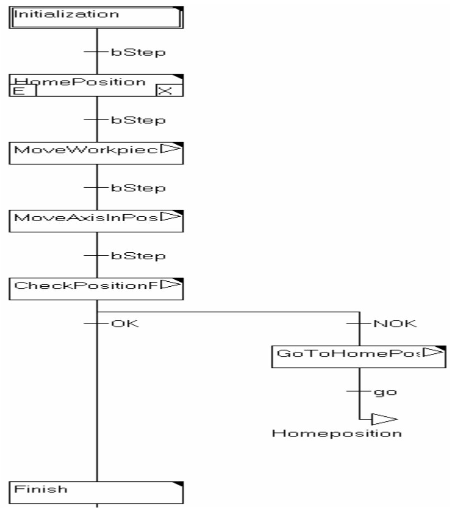

Fig. 8. Example of SFC programming language

Also standard defines programming methods and basic data types. Wireless communication interface via Bluetooth protocol can transfer data between devices spatially limited.

For low-cost implementation of a transmission system we can connect a Bluetooth interface directly to an existing controller. The operating frequency ranges from 2.4 GHz to 2.48Hz and the synchronization protocol is based on a master-slave structure.

2. CASE STUDY

The experimental structure of a mechatronic system controlled by Bluetooth was designed and manufactured as part of, the authors graduation thesis (Fig.9). The system relies on kinematic structure with movements in the Cartesian system for transfering part of the process to another.

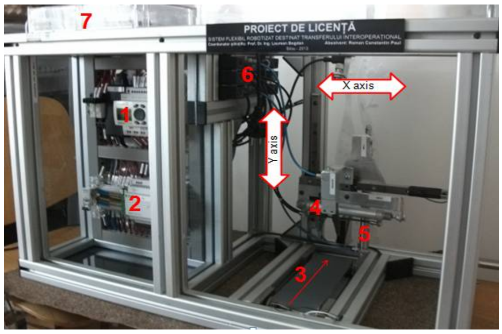

Fig. 9. Mechatronic system for interoperable transfer

The main components of the mechatronic system that is presented:

1. PLC controller, it is a part of the decision system.
2. Power supply 230Vac to 24Vdc, it powers the control and sensory system.
3. Conveyor
4. Pneumatic cylinder axis X
5. Pneumatic cylinder axis Y
6. Solenoid valve for control cylinders
7. Integrated Bluetooth command.

The movement is actuated by a motor for conveying transfer and for gripping or moving the product to another station we use pneumatic actuators. The system is controlled by a PLC-based motion checking program implemented previously with information from the internal and external sensory system. Internal information which is given by the sensors refers to the position sensors of pneumatic axes and the state for power plant conditions. The external sensory system refers to the control of the process itself and to the state of the upstream and downstream stations of the transfer system.

2.1. Mechanical parts of the mechatronic system

The kinematic structural scheme (Fig.10), determines the movement possibilities of the mechatronic systems.

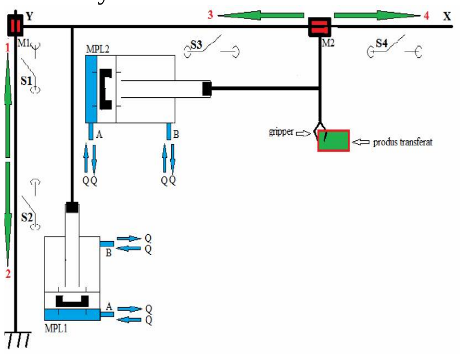

Fig. 10. Kinematic structure

2.1.1. Cinematic aspects

The spatial kinematic structure provides the movement mechanical hand in a Cartesian coordinate system A, X, Y, Z = 0. Translational couplers which perform the linear motion 1-2 or 3-4 are performed using two pneumatic axes. The drive component utilizes pneumatic and electric actuators (cc engine). The movement of the object in space is caught by the gripping system from one point to another by varying the 6 coordinates which determine the position of a body in space [1].

The advantage of the kinematic structure built as shown is that during movement the manipulated piece retains its orientation. The kinematics analysis is done according to the number of degrees of freedom, type of movements and their sequence.

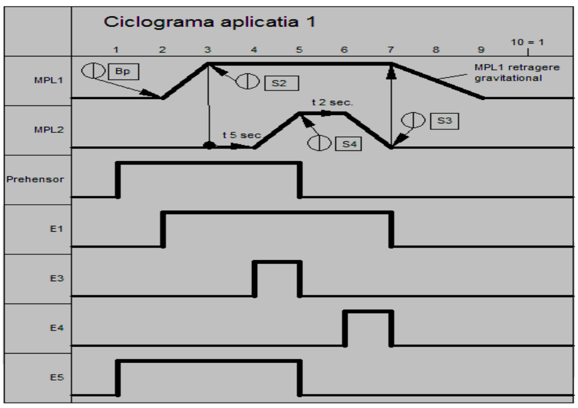

Fig. 11. Motion condition for Application 1

The cyclogram (Fig. 11) is used to show the process for automation programmers and for calculating the simultaneity factor which can be used for calculating the power needs on every step of the process upon which it can resize the electrical equipment cabinet (Fig. 12).

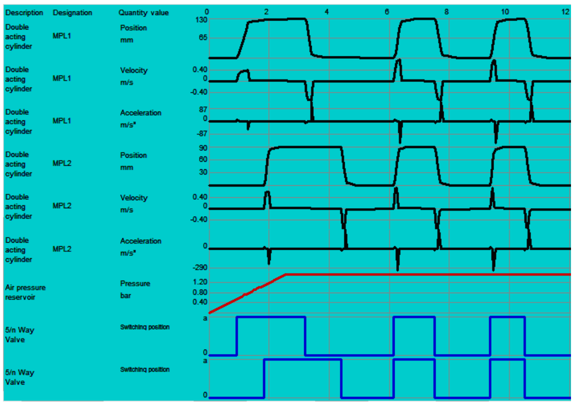

Fig. 12. Catch oscilloscope pneumatic axis parameters

From the chart, we can see that parameters such as acceleration, position and speed depend on pressure and flow. The frictional resistance of the cylinder needs to be taken into account when calculating the effective force, speed and acceleration. Under normal operating conditions (pressure range 4 to 8 bar) the frictional force can be assumed to be around 10% of the theoretical cylinder force [6].

The following formula can be used to calculate the effective piston force:

Double acting cylinder (with 2 piston rods where A1=A2):

$$F_{eff} = A1 \cdot p1 - F_F \qquad (9)$$

F_F -frictional force (approx 10% depends on manufacturer).

3. HARDWARE CONFIGURATION AND PROGRAMMING

The brain of the system will be a PLC (N1) and for remote control a Bluetooth integrated system (N2) will be used.

Inputs of PLC (Fig. 13) will monitor the sensors and actuating outputs according to programmed logic. On the inputs of the PLC, it is connected and integrated the system for remote control [3]. These inputs can be read in analogic signal and this means that we can control the direction and speed of movements. The integrated Bluetooth command may provide an analog signal output of 0 to 5Volts. PlC is equipped with a 0- 10Volts analog input. The analog signal is converted into a numerical value with an ADC (Analog to Digital Converter) with a resolution of 10 bits which can encode the input signal on 1023 different levels [4].

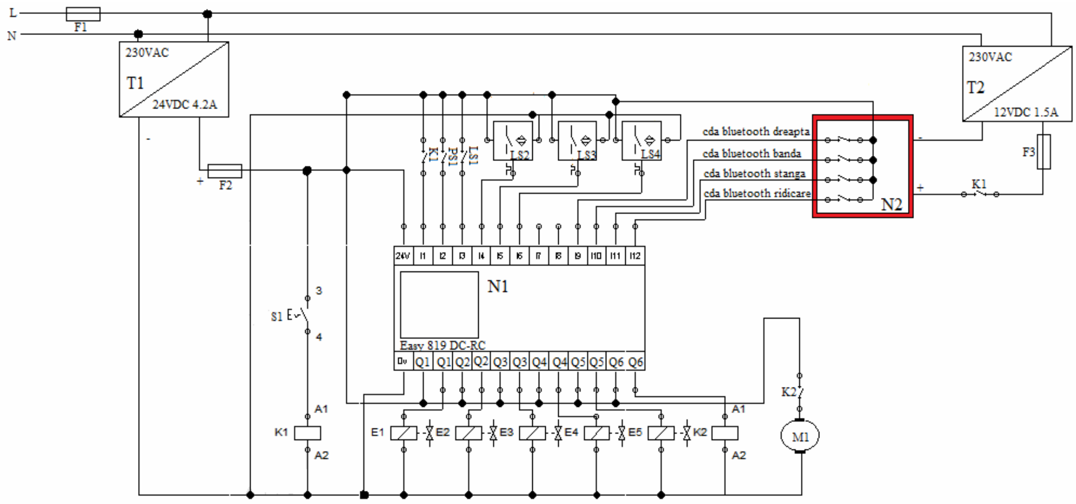

Fig. 13. Hardware configuration

The execution of the program is cyclical as shown in Fig.13. The loop execution of the program is synthesized in the flowchart diagram shown in Fig. 14.

When programming a complex system without visual aid we have difficulty conceiving the mental algorithm while achieving conversion into program code. Programmers design functions or algorithms based on graphics and then they make the program based on these graphical supports. One such example is the flow diagram.

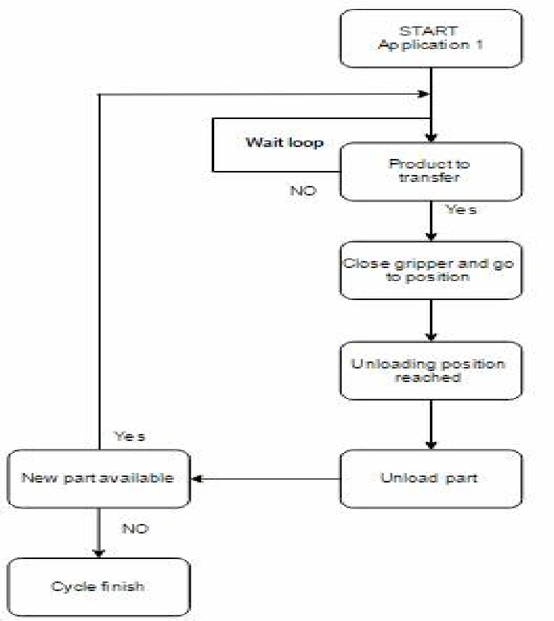

Fig. 14. Flowchart of the program

4. CONCLUSIONS

There are many applications that require a remote control due to process conditions. To support theoretical considerations a mechatronic system is described in the case study, which is controlled based on PLC.

PLC’s and embedded controllers are complementary technologies and, when applied strategically, they will both provide reliable solutions to control task.

Many problems that may occur can not be identified and solved only starting from experimental observations.

Control is programmed to the desired movement sequence considering that any perturbation does not affect movement. For application where tight control is required we can use a closed loop control. PLC characteristics allow operation of facilities to a high degree of flexibility, which makes them indispensable in any automated process.

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