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PLC AS A DRIVER FOR STEPPER MOTOR CONTROL

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ABSTRACT: The paper is presenting a simple and cheaper solution for programming and controlling of stepper motor in unipolar connexion by using a Programmable Logic Controller (PLC). The stepper motors are using for driving mechatronic and robotic systems. There are many and specialized drivers for power and control designed by a lot of firms. On the other hand Programmable Logic Controllers have proven to be viable alternatives to driving machine tools, of industrial systems and Robots. PLC is well-suited for industrial environment. The paper highlights the simplicity and ease of configuration control and programming of the stepper motor by using a PLC. The paper proposes a method of programming and controlling.

1. INTRODUCTION

In the last decade the use of stepper motors for precision control in manufacturing, printing, robotics, and many other related areas has increased dramatically. Looking into a dot matrix or ink jet printer one finds at least two stepper motors. One for rotating the platen and one for print head positioning. Stepper motors are used anywhere precise positioning is required [1]. Many off-the-shelf options exist for controlling stepper motors. These range from stand-alone or PC based single axis controllers to complex multi-axial control versions. While offering many excellent features, most systems available are expensive. Prices start in the middle hundreds and rise into the thousands of dollars from there. Stepping motors can be viewed as electric motors without commutators. Typically, all windings in the motor are part of the stator, and the rotor is either a permanent magnet or, in the case of variable reluctance motors, a toothed block of some magnetically soft material. All of the commutation must be handled externally by the motor controller, and typically, the motors and controllers are designed so that the motor may be held in any fixed position as well as being rotated one way or the other. Most steppers, as they are also known, can be stepped at audio frequencies, allowing them to spin quite quickly, and with an appropriate controller, they may be started and stopped "on a dime" at controlled orientations. For some applications, there is a choice between using servomotors and stepping motors. Both types of motors offer similar opportunities for precise positioning, but they differ in a number of ways. Servomotors require analog feedback control systems of some type. Stepping motors come in two varieties, permanent magnet and variable reluctance (there are also hybrid motors, which are indistinguishable from permanent magnet motors from the controller's point of view). Variable reluctance motors usually have three (sometimes four) windings, with a common return, while permanent magnet motors usually have two independent windings, with or without center taps. Center-tapped windings are used in unipolar permanent magnet motors. Stepping motors come in a wide range of angular resolution. The coarsest motors typically turn 90 degrees per step, while high resolution permanent magnet motors are commonly able to handle 1.8 or even 0.72 degrees per step. With an appropriate controller, most permanent magnet and hybrid motors can be run in half-steps, and some controllers can handle smaller fractional steps or microsteps. [6].

2. Basic Stepping Motor Control

Typical controllers for unipolar stepping motors are based on switches; a control unit, is responsible for providing the control signals to open and close the switches at the appropriate times in order to spin the motors. The control unit is commonly a computer or programmable interface controller, with software directly generating the outputs needed to control the switches. As with drive circuitry for variable reluctance motors, we must deal with the inductive kick produced when each of these switches is turned off. Again, we may shunt the inductive kick using diodes, but now, 4 diodes are required. The extra diodes are required because the motor winding is not two independent inductors, it is a single center-tapped inductor with the center tap at a fixed voltage. When one end of the motor winding is pulled down, the other end will fly up, and visa versa. When a switch opens, the inductive kickback will drive that end of the motor winding to the positive supply, where it is clamped by the diode. The opposite end will fly downward, and if it was not floating at the supply voltage at the time, it will fall below ground, reversing the voltage across the switch at that end. Some switches are immune to such reversals, but others can be seriously damaged. A capacitor may also be used to limit the kickback voltage. The rules for sizing the capacitor are the same as the rules for sizing the capacitor, but the effect of resonance is quite different! With a permanent magnet motor, if the capacitor is driven at or near the resonant frequency, the torque will increase to as much as twice the low-speed torque. The mechanical resonant frequency depends on the torque, so if the mechanical resonant frequency is anywhere near the electrical resonance, it will be shifted by the electrical resonance [6].

3. PLC architecture and operation

The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls. PLCs have been gaining popularity in the domain of factories and will probably remain predominant for some time to come. Most of this is due to the advantages they offer: cost effective for controlling complex and flexible systems, where PLCs can be reapplied to control other systems quickly and easily, computational abilities allow more sophisticated control, trouble shooting aids make programming easier and reduce downtime, reliable components make these likely to operate for years before failure. A Programmable Logic Controller is a specialized computer, designed to be used for industrial control [4]. Programmable Logic Controllers are sometimes called programmable controllers (PC) but are more commonly called PLCs. Ladder logic is the main programming method used for PLCs. As mentioned before, ladder logic has been developed to mimic relay logic. The decision to use the relay logic diagrams was a strategic one. By selecting ladder logic as the main programming method, the amount of retraining needed for engineers and technicians was greatly reduced. The first PLCs were programmed with a technique that was based on relay logic wiring schematics. This eliminated the need to teach the electricians, technicians and engineers how to program a computer - but, this method has stuck and it is the most common technique for programming PLCs today [3]. There are other methods for programming PLCs. One of the earliest techniques involved mnemonic instructions. These instructions can be derived directly from the ladder logic diagrams and entered into the PLC through a simple programming terminal. Sequential Function Charts (SFCs) have been developed to accommodate the programming of more advanced systems. These are similar to flowcharts, but much more powerful. Structured Text programming has been developed as a more modern programming language. It is quite similar to languages such as BASIC.

The architecture of a PLC's CPU is basically the same as that of a general purpose computer; however, some important characteristics set them apart. First, unlike computers, PLCs are specifically designed to survive the harsh conditions of the industrial environment. A well-designed PLC can be placed in an area with substantial amounts of electrical noise, electromagnetic interference, mechanical vibration, and non-condensing humidity [5]. A second distinction of PLCs is that their hardware and software are designed for easy use by plant electricians and technicians.

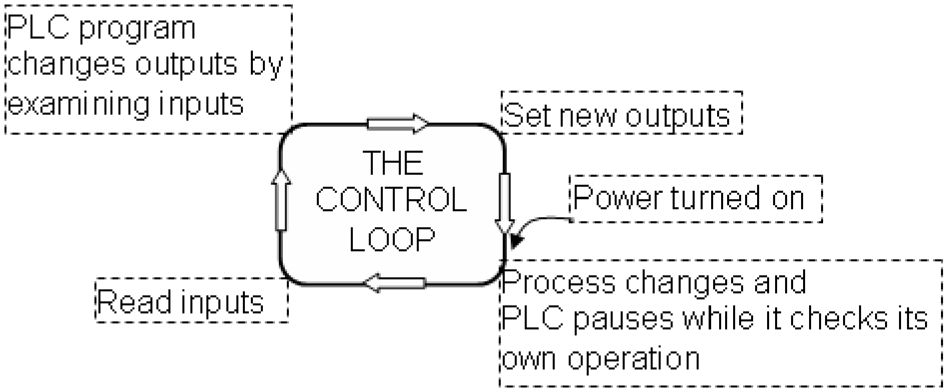

Fig. 1. Program execution

The hardware interfaces for connecting field devices are actually part of the PLC itself and are easily connected. The modular and self-diagnosing interface circuits are able to pinpoint malfunctions and, moreover, are easily removed and replaced. Also, the software programming uses conventional relay ladder symbols, or other easily learned languages, which are familiar to plant personnel. Whereas computers are complex computing machines capable of executing several programs or tasks simultaneously and in any order, the standard PLC executes a single program in an orderly, sequential fashion from first to last instruction, (Fig. 1). Bear in mind, however, that PLCs as a system continue to become more intelligent. Complex PLC systems now provide multiprocessor and multitasking capabilities, where one PLC may control several programs in a single CPU enclosure with several processors. The personal computer and the PLC possess similar CPU architecture; however, they distinctively differ in the way they connect field devices. While new, rugged, industrial personal computers can sometimes sustain midrange industrial environments, their interconnection to field devices still presents difficulties. The personal computer is, however, being used as the programming device of choice for PLCs in the market, where PLC manufacturers and third-party PLC support developers come up with programming and documentation systems for their PLC product lines. Some control software manufacturers, however, utilize PCs as CPU hardware to implement a PLC-like environment. The language they use is based on the International Electrotechnical Commission (IEC) 1131-3 standard, which is a graphic representation language (sequential function charts) that includes ladder diagrams, functional blocks, instruction lists, and structured text. These software manufacturers generally do not provide I/O hardware interfaces; but with the use of internal PC communication cards, these systems can communicate with other PLC manufacturers' I/O hardware modules [5].

4. Application

The paper presents a simple method for stepper motor driving and control. For experiments may be used any types of unipolar or bipolar stepper motors, (fig. 2).The power of stepper motor implies the value of courant from coils. Drivers based on switching with Darlington transistors are dedicated for specified type of motor.

Using PLC with outputs based on relays permits to control more intensity of courant from motor coils. The problem can be frequency of switching power on coils of motor. There are more practical applications with speed of rotation no very high. For example positioning, indexing, movements with slow speed and precision etc., can be based on PLC with relays outputs. Supply of coils and value of courant intensity depends of power source. The value of coils intensity courant depends of electrical resistance of coils. Resistance of coils depends of power of stepper motor. The power supply of stepper motors system become very important. Experiments are based on different types of stepper motors with connexions in unipolar and bipolar method. Depending of stepper motor type, the number of wires may be four, five or more.

Fig. 2. Some types of stepper motors

4.1. Hardware configuration

The PLC used for application is Moeller Easy 512 DC RC and programming is possible in diagram DIN IEC based on relays wiring as electrical diagram or in Ladder diagram. Output Q01 as normal open relay contact offers supply for the first coil, L1 from stepper motor. The next outputs of PLC, Q02, Q03 and Q04 offers supply for next motor coils: L2, L3 and L4 as is shown in (fig. 3). Power supply is provided by external source 24 DC Voltage with protection. To the digital inputs will have start and stop buttons. The elements connected to the PLC as digital outputs will be: L1, L2, L3 and L4, coils of stepper motor. The program for experiments was created in EASY-SOFT 6 PRO and verified on CoDeSys v2.3 and in V4.0 Step7 MicroWIN. The first variant was created in Ladder diagram, verified in SIMULATION modus on EASY SOFT 6 PRO using a personal computer and special cables .between computer and PLC. Independence display of PLC permits to verify simple programs and correct them from PLC buttons if is necessary.

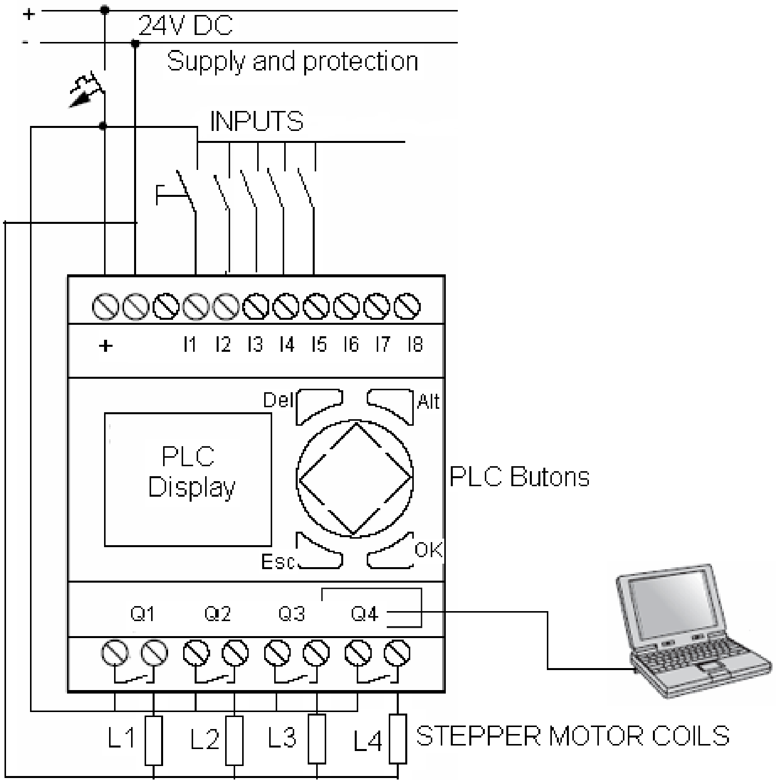

Fig. 3. Hardware configuration

4.2. Program structure

The Program for control of movement in a single sense, consist of nine instructions which are divided in four networks. The network 1 shows instructions for start command

and control of time for energize coil L1 (Q0.1 from (fig. 4) is the same output Q1 from figure 8). Operand T4 is necessary for replaying the rotation cycles after passing all networks.

PROGRAM COMMENTS

Network 1 START and activating of first coil and timer

I0.0 initiates stepper cicle

```
LD    I0.0
LD    Q0.1
AN    T1
OLD
O     T4
=     Q0.1
TON   T1, 200
```

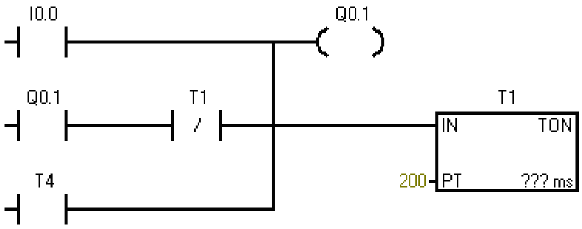

Fig. 4. Network 1

The second network shows instructions for energizing output Q0.2 and default coil L2. Monitoring of timing for L2 energize is realized by timer T2, (fig. 5).

Network 2 Supply of the second coil from stepper motor

Coil Q0.2 is acttiv during T2 is activ

```
LD    T1
LD    Q0.2
AN    T2
OLD
=     Q0.2
TON   T2, 200
```

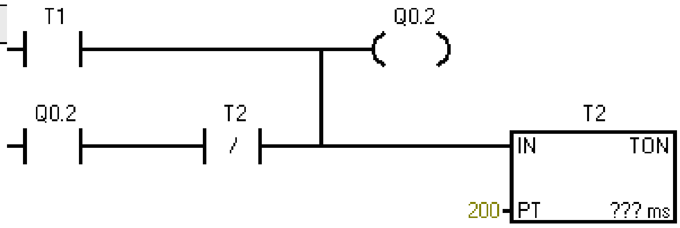

Fig. 5. Network 2

The third network contains instructions which provide energizing of output Q0.3 and default coil L3, figure 11. The timer T3 will stop supply of L3 will start supply of coil L4, network 4, (fig. 6), (fig.7).

Network 3 Supply of the third coil from stepper motor

Coil Q0.3 is acttiv during T3 is activ

```
LD    T2
LD    Q0.3
AN    T3
OLD
=     Q0.3
TON   T3, 200
```

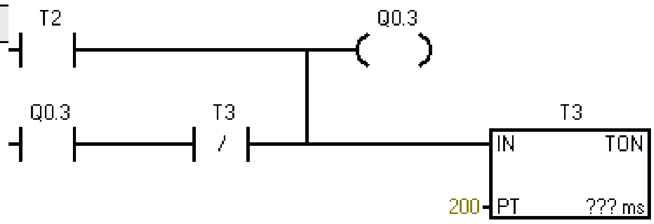

Fig. 6. Network 3

Network 4 Supply of the fourth coil from stepper motor

Coil Q0.4 is acttiv during T4 is activ

```
LD    T3
LD    Q0.4
AN    T4
OLD
=     Q0.4
TON   T4, 200
```

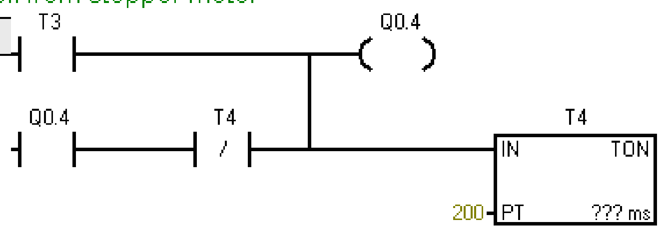

Fig. 7. Network 4

The program for movement in a sense of stepper motor in unipolar coils connections is presented as function block diagram, in (fig. 8).

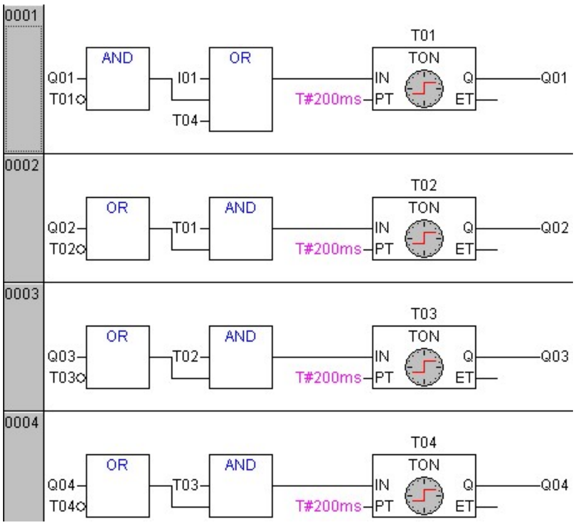

Fig. 8. Program in function block

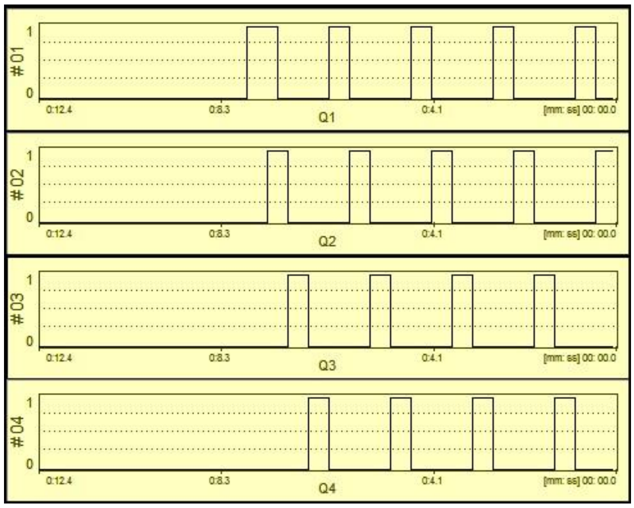

Fig. 9. Status of PLC outputs

The internal oscilloscope from
software is running in simulation modus. Simulation cycle time can be set between 30 and 3000 milliseconds. For the simulation here being presented one used a simulation cycle time of 200 milliseconds. For each 200 milliseconds the program in ladder is executed cyclical. A diagram of status of coils switching is presented in (fig. 9). It shows pulse sequence, after the first pulse on Q1 follow the pulse for Q2 and so on.

5. CONCLUDING REMARKS

Programming and controlling movements of a stepper motor is possible by using a PLC. The power of stepper motor depends of outputs module from PLC. When PLC contains relays on outputs it is possible to supply coils of stepper motor at different value of voltage and courant. A disadvantage of using PLC based on relays outputs, as a driver for stepper motor may be high limit of frequency for coils switching. The PLC used for experiments has cycle time between 30 and 3000 milliseconds. It follows that range of speed at stepper motor shaft can have large limits. The solution presented in paper may be used for driving mechanical or mechatronic structures. The value of switching frequency must be chosen depending of types of PLC.

References

[1] Paul J. Wilder,1 James D. McBrayer,2 and Kenneth A. A Simple Multi-Axis Stepper Motor Controller Using a PC Parallel Port. Woechan3.

[2] Bogdan, L. Analog control and programming of a RPP robot with a PLC, Proceedings of the International Conference on Manufacturing Systems – ICMaS, Vol. 4, 2009, ISSN 1842-3183, University POLITEHNICA of Bucharest, Romania. p.85.

[3] Bogdan, L. Programming and controlling of RPP robot by using a PLC, Annals of Scientific Papers „INT ORADEA-2010 , Fascicle of Management and Technological Engineering, VOLUME IX (XIX), 2010, ISSN 1583 - 0691, CNCSIS "Clasa B+", p 2.4.

[4] Bryan, L.,A., Bryan, E., A. (1997). Programmable Controllers, Theory and Implementation. Second Edition. An Industrial Text Company Publication, Atlanta, Georgia, USA.

[5] Hugh, Jack, Automating Manufacturing Systems with PLCs, Version 4.7, (2005) http://claymore.engineer.gvsu.edu/~jackh/books.html, accessed: 2009-02-10.

[6] http://www.cs.uiowa.edu/~jones/step/types.html (1 of 8)2003-12-3 16:59:51

[7] ***Easy500, Easy700, Control Relay-User Manual, 1st published 2004, edition date 05/04, © Moeller GmbH, 53105 Bonn.