

BULETINUL INSTITUTULUI POLITEHNIC DIN IAȘI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Volumul 64 (68), Numărul 2, 2018
Secția
ELECTROTEHNICĂ. ENERGETICĂ. ELECTRONICĂ

PLC APPLICATION FOR BRUSHLESS MOTOR POSITIONING

BY

MIHAI RAȚĂ*, **GABRIELA RAȚĂ**, **ADRIAN GRAUR** and
CIPRIAN AFANASOV

Ștefan cel Mare University of Suceava
Faculty of Electrical Engineering and Computer Science

Received: April 30, 2018

Accepted for publication: June 28, 2018

Abstract. Often at lab applications, the teachers use only PLC simulator software, because the hardware equipment is expensive. This paper presents a solution that allows students to study both the hardware and software parts of application, in the laboratory works. The hardware part of solution consists in a brushless motor, powered by a high performance drive – Sinamics S120, from Siemens, which is controlled with a S7-1516 3PN/DP. The software application supposes to make a position control of the brushless motor (with 20 bit resolution absolute encoder) with PLC and HMI. Because in position control applications it is difficult to realize a mechanical device used by the students to observe if the motor executes the target position, in this paper the authors propose a solution that solves this problem.

Key words: PLC; industrial automation; industrial communications; electrical engineering education.

1. Introduction

Now the PLC (Programmable Logic Controller) is used in any factory and before 1968 didn't even exist. Mr Morley (the undisputed father of the

*Corresponding author: *e-mail*: mihair@eed.usv.ro

PLC) purposely, had to make the PLC easy to understand and program for the technicians and maintenance electricians of the day (*History of the PLC*). These technicians and maintenance electricians were already very used to relay schematics and wiring, which was and is a skilled position to hold. Today all PLCs have the main programming language Ladder Diagram. So, the electrical engineer must know how to use the PLC in automation application. When the students learn to use the PLC in the automation application it is very important for them to have at the laboratory experimental stands in order to provide an experience closer to the real world applications (Haba, 2010). This is one of the reasons why the authors develop the solution presented in this paper.

2. The Proposed Solution

If it need to realise an experimental application that shows how to control the position of motor, it is very difficult to make a mechanical equipment so students to observe if the motor shaft is rotated with a good precision to the target position. This is other reason why the authors develop the solution presented in this paper, in order to solve this problem. On the motor shaft is mounted a laser pointer. The laser beam can be projected at different heights on a vertical ruler, depending of the motor shaft angular position. The height of the laser beam projection depends, also, on the distance between the ruler and the motor. Fig. 1 illustrates, schematically, the operation principle of the proposed solution.

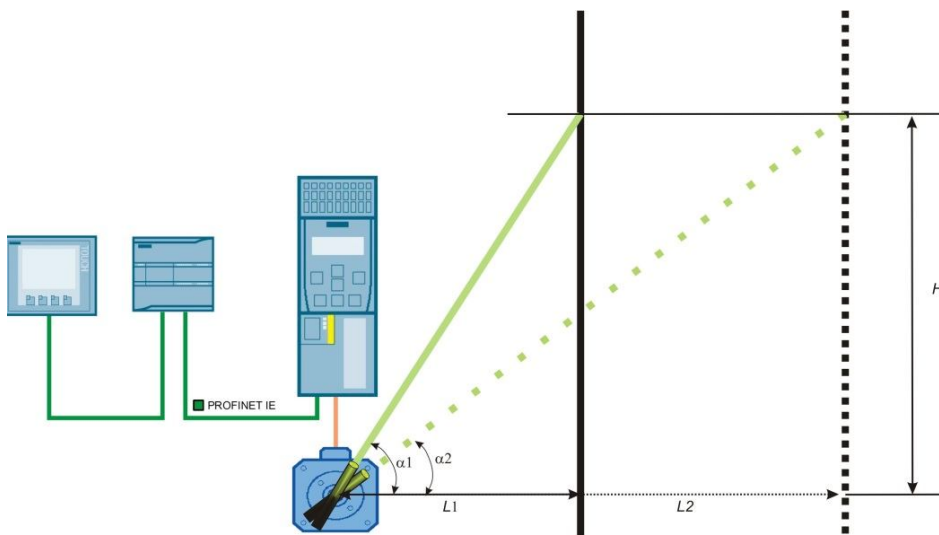


Fig. 1 – Principle operation of the proposed solution.

As is exemplified in Fig. 1, if the ruler is placed from the motor at $L1$ distance and if it is desire the laser beam to be projected at height H , the motor

shaft must be rotated with $\alpha 1$ angle. The target angular position is given by the equation:

$$\alpha 1 = a \tan \left(\frac{H}{L1} \right). \quad (1)$$

If the ruler is moved at the other distance by the motor, $L2$, and if the laser beam should be projected at the same height H on the ruler, the motor shaft angular position must be adjusted at a new angle value $\alpha 2$.

For this application, the authors use the following equipment (Rata *et al.*, 2016):

a) *Permanent-magnet synchronous motor* model 1FK7-HI (1.5kW) connected with high resolution absolute encoder single turn 20 bit with DRIVE-CLiQ interface (encoder AS20DQI).

b) *High performance drive* – Sinamics S120, realized in a modular platform control that can be used in every application from flow control (such as pumps, fans and compressors) to highly-complex motion control (such as milling, turning and machining). The Control Unit used is CU320-2 PN that can control up to 12 drives in V/f control mode, or up to 6 drives in Servo or Vector control mode. The control unit CU320-2 PN is connected with a power module PM340 using the CU adapter CUA31 via the DRIVE-CLiQ communication interface.

c) *PLC S7-1500* (CPU1516-3PN/DP) has three communication interfaces (two interfaces for PROFINET and one for PROFIBUS DP master). In addition this model of PLC has integrated the following main technical properties: *web server* (that permits to access the CPU usually for diagnostic purposes), *technology* (integrated closed-loop control functionality, motion control which supports speed-controlled axes, positioning axes, synchronous axes and external encoders), *system diagnostics* (the alarms are displayed on a PC, HMI device, Web server or the integrated display), *security* (Know-how protection, Copy protection).

d) *HMI* model KTP700 Basic with PROFINET interface.

The PLC and HMI are programmed in TIA Portal software (*Step 7 Basic V13 SP1*, 2014) and Sinamics S120 is programmed in Drive Starter (*Sinamics S120*, 2014). For SINAMICS S120, one of several telegram types can be selected for cyclic data exchange with PLC. For this application *Siemens telegram 390, PZD-2/2* for Control Unit and *Standard telegram 3, PZD-5/9; Servo* for Drive (configured in Servo control mode) are selected. The PLC, HMI and Sinamics S120 are connected in a PROFINET network, as it is illustrated in Fig. 2 (*Sinamics S120*, 2014).

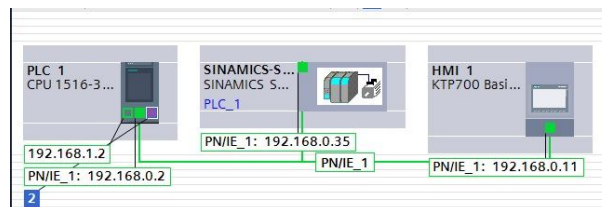


Fig. 2 – Print screen of *Devices & networks* window in TIA Portal.

One of the reasons why the authors chose this PLC is the integrated motion control instructions that reduce the effort to develop a software application used in motor position control. Two sequences of software application are presented in Fig. 3. Sequence, illustrated in Fig. 3 *a*, realizes the calculation of the target position for the motor shaft, necessary to rotate the laser beam such that, the projection of laser beam on the ruler (placed at the $L1$ distance from the motor) be at desired height H .

After calculation of the motor target position it is necessary to realize a positioning control of the motor. Fig. 3 *b* illustrates the *MC_MoveAbsolute* instruction used to make the motor shaft motion to an absolute position. The positioning control is executed with positive edge of the *Execute* input, if instruction is enabled on input *EN* and the target position (calculated in the sequence illustrated in Fig. 3 *a*) is prescribed at input *Position*.

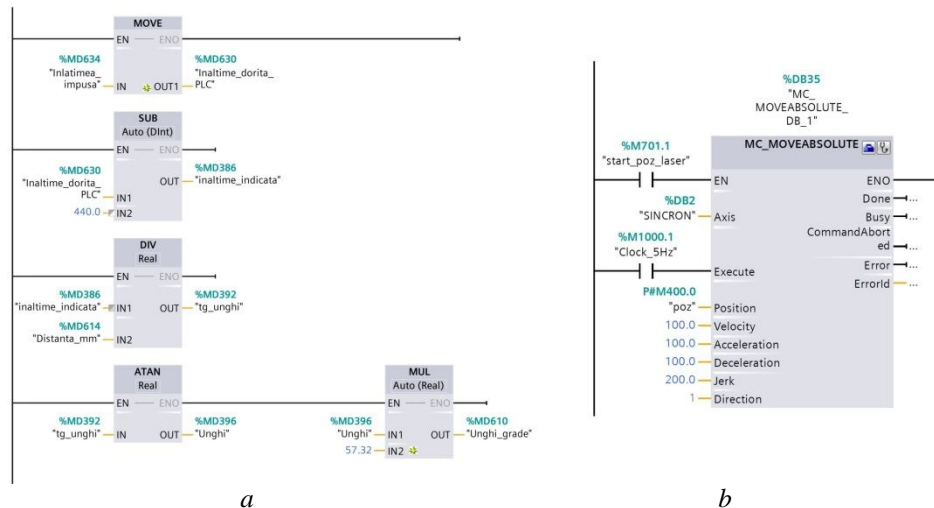


Fig. 3 – Sequences of the software application.

For application parametrization, a HMI was used. In addition, a small animation can be realized. In TIA Portal software (Totally Integrated Automation Portal) the animation can be realised more easily than in other software. In Fig. 4 is presented an example for horizontal movement of the ruler. After setting the start position and the target position, the tag variable with a range of variation must be chosen.

Another reason why the authors chose this PLC is trace measurements integrated that permit to analyse and save the variation in time of any variable.

In Fig. 6 it is illustrated the print screen of trace measurements for one case, when are displayed: the height of projected laser beam on ruler (H), the distance between motor and ruler (L), the calculated position of motor shaft in degree and the motor target position for *MC_MoveAbsolute* instruction.

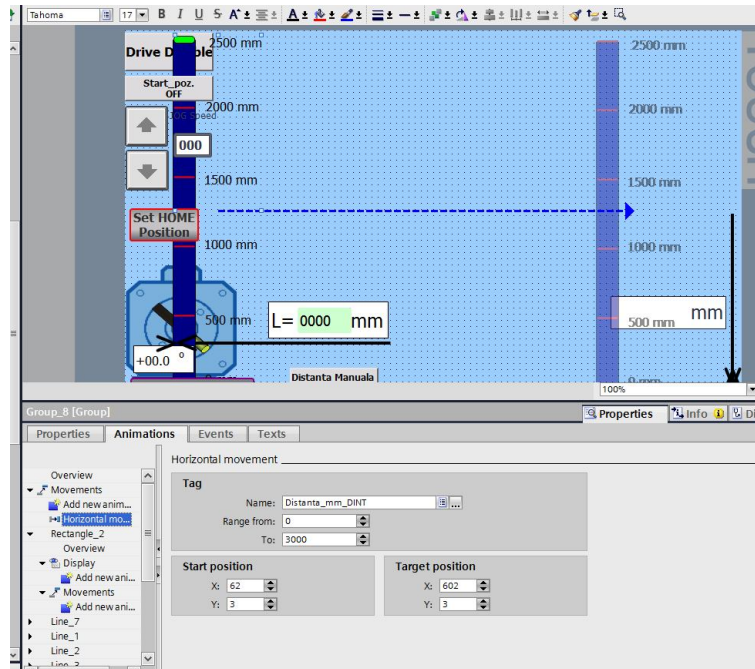


Fig. 4 – Animation on HMI with TIA Portal.

The HMI screen has buttons for manual rotate (clockwise or counter clockwise) of the motor shaft (using *MC_MoveJog* instruction) necessary for positioning of the laser beam to the HOME position on ruler ($H = 0$ mm). When this position is reached, the *Set HOME Position* button must be pressed, for the home position activation. After the end of this operation, the desired height H can be prescribed and we can see how the projected laser beam on the ruler is stop on same height with target.

3. Experimental Results

Experimental tests were performed, based on the setup illustrated in Fig. 5. The distance between the motor and the ruler is measured with an ultrasonic sensor UM30-14113 (from Sick) capable to measure distance in range 35,..., 3,400 mm and the measured distance value is displayed on HMI. The ruler has the height of 2,500 mm.

Another reason why the authors chose this PLC is trace measurements integrated that permit to analyse and save the variation in time of any variable.

In Fig. 6 it is illustrated the print screen of trace measurements for one case, when are displayed: the height of projected laser beam on ruler (H), the distance between motor and ruler (L), the calculated position of motor shaft in degree and the motor target position for *MC_MoveAbsolute* instruction.

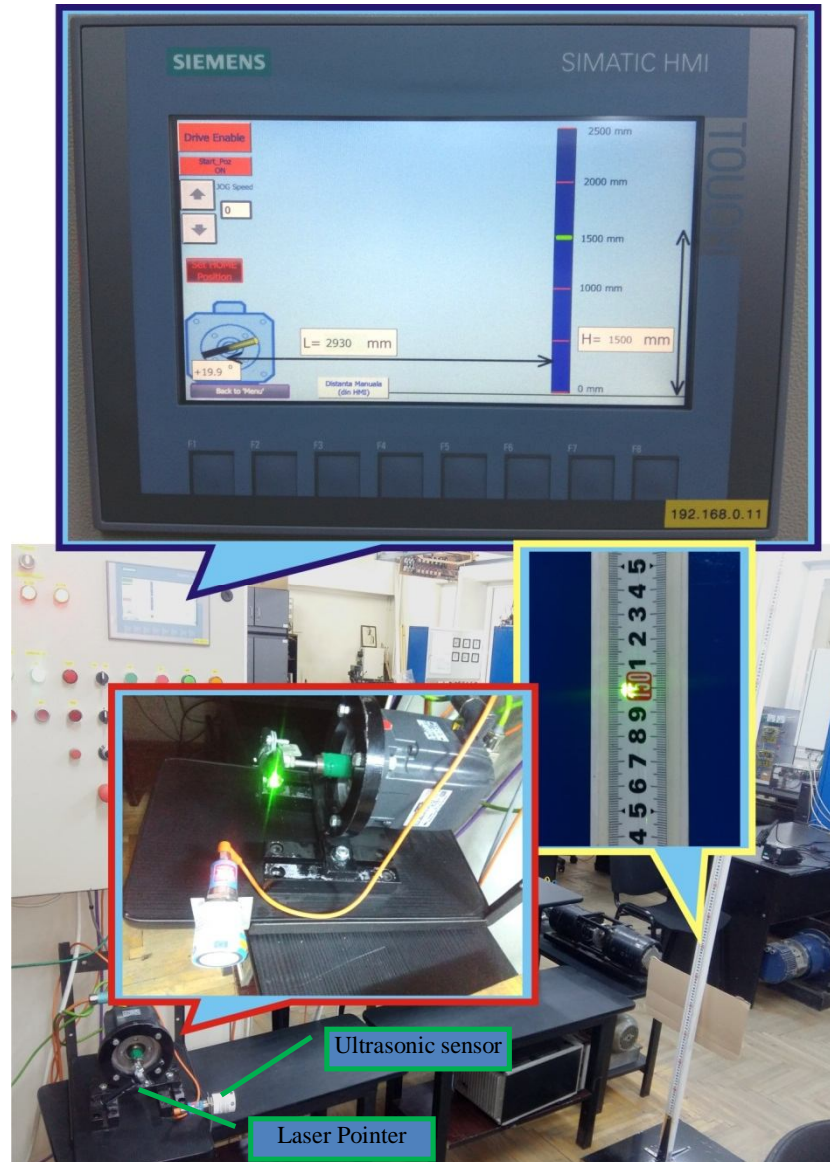


Fig. 5 – The experimental arrangements.

These signals are recorded in two situations. In first case the height H is variable (using HMI, for H it is prescribed one of these values: 0, 500, 1,500 and 2,500 mm) and the distance L is maintained constant and we can observe how the motor target position is adjusted, such that the projected laser beam on ruler is at desired height. In second case the height H is maintained constant and

the distance L is variable. The changing of the distance L is obtained by moving the ruler at different distances to the motor and we can observe that the motor target position is automatically adjusted, such that the laser beam at the same point on the board is projected.

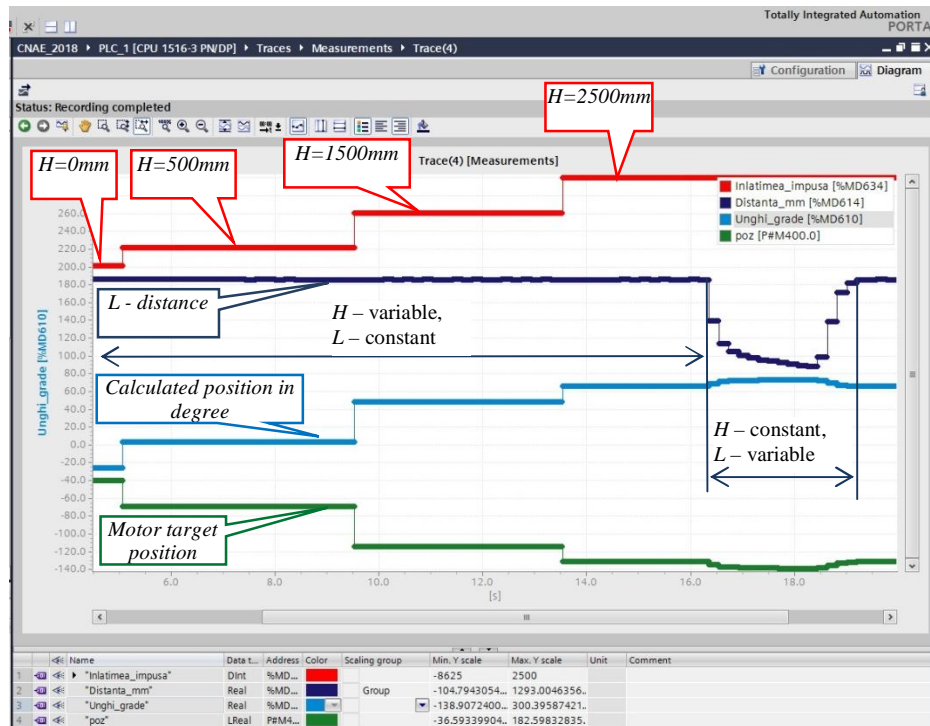


Fig. 6 – Trace Measurements in TIA Portal.

The solution, proposed in this paper by the authors, uses an ultrasonic sensor for measure the distance between the motor and the ruler. But this sensor can be omitted and the ruler could be placed at any distance by the motor. This distance must be measured with precision.

The higher distance, increases the precision of measuring the real position of the motor shaft. If this distance is 4,000 mm, for 1 mm displacement of the laser beam projected on the ruler it is necessary to rotate the motor shaft by 0.0143 degree. This corresponds to a precision higher than 15 bits for motor shaft real position measurement.

4. Conclusions

In this paper, a solution with brushless motor in position control application controlled by PLC has been proposed. When the students have labs with position control it is very important for them to have possibility to observe

what motion executes the motor. But a mechanical device that offers this feature is very expensive. The solution presented in this paper solves this problem with low cost, easy to realize and consists in mounting a laser pointer on the motor shaft, whose beam is projected on a vertical ruler. By measuring the displacement of the laser beam on the ruler it is possible to determine with which angle the motor shaft has rotated.

If it is used a PLC (in this paper the authors use S7-1516 3PN/DP) with powerful instructions integrated then it is easy for the students to make a software application with motor position control.

Acknowledgements. This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0776 / No. 36 PCCDI / 15.03.2018, within PNCDI III.

REFERENCES

- Haba C.-G., *Extending the Use of PLC Simulator Software in Student Laboratory Works*, Advances in Electrical and Computer Engineering, **10**, 1, 84-89 (2010).
- Rață M., Rață G., *A Solution for Study of Positioning Control of Two Axes*, Proceedings of the 2016 Internat. Conf. and Exposition on Electrical and Power Engineering (EPE 2016), 2016, Iași, Romania, 648-652.
- Zaky M., Shaban S., Fetouh T., *Adaptive and Robust Sliding Mode Position Control of IPMSM Drives*, Advances in Electrical and Computer Engineering, **17**, 1, 61-68 (2017).
- * * *History of the PLC*, <https://library.automationdirect.com/history-of-the-plc/>
- * * *Sinamics S120 – Getting Started, April 2014*, https://support.industry.siemens.com/cs/document/99742202/sinamics-s120-getting-started?dti=0&lc=en-za_
- * * *Step 7 Basic V13 SP1 – System Manual, December 2014*, https://support.industry.siemens.com/cs/attachments/109054417/STEP_7_Basic_V13_1_enUS_en-US.pdf.

APLICAȚIE CU PLC PENTRU CONTROLUL POZIȚIEI UNUI MOTOR BRUSHLESS

(Rezumat)

Deseori în aplicațiile practice de laborator profesorul utilizează doar simularea funcționării programului realizat întrucât un stand experimental este destul de costisitor. În acest articol autorii prezintă o soluție care le oferă studenților atât posibilitatea realizării unei aplicații software pentru PLC, cât și observarea efectului programului asupra echipamentului fizic. Standul experimental utilizează un motor brushless alimentat de la un convertor de frecvență pentru acționări special de tip S120 (produs de firma Siemens) conectat într-o rețea industrială PROFINET cu un automat programabil de tip S7-1516 3PN/DP și un HMI (KTP600). Aplicația software presupune poziționarea unui motor brushless ce are conectat la arbore un sensor de poziție cu rezoluția maximă de 20 biți. În această situație este dificilă realizarea unui echipament care să permită măsurarea unghiului cu care se rotește axul motorului atunci când

primește o comandă de poziționare. Soluția propusă în acest articol rezolvă acest neajuns și constă în montarea unui pointer laser pe arborele motorului, a cărui rază se proiectează pe o riglă gradată, în poziție verticală, care se află la o anumită distanță de motor. Prin măsurarea deplasării razei laser pe riglă se poate determina cu ce unghi s-a rotit arborele motorului.

