Development of a Modern Learning Environment for Education in Mechatronics and Industrial Automation

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Abstract

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Development of a Modern Learning Environment for Education in Mechatronics and Industrial Automation

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Abstract: Mechatronic systems represent the interaction in real automation applications of the mechanical systems and the electronic control. Modular mechatronic systems implementation results not only in the improvement of the system abilities but also in savings of time to market because of the possibility to select, wire and adjust fewer components. The usage of programmable logic controllers (PLC) for the core of the modular system has been accepted as a general approach in the industry automation. The goal of the presented research is to develop a reliable electronic system and proper assignments for practice in the mechatronic field including real components – PLCs, motors, motor drives and sensors. The practical implementation of the laboratory set-up is explained. Some software examples are presented.

Keywords: PLC, STEM, digital control, motion control, embedded systems.

1. INTRODUCTION

Mechatronic systems represent the synergy of the mechanical engineering and the electronics resulting in precise control of actuators and drives. They enable the interaction in real automation applications of the mechanical systems and the electronic control. This is the only way to involve the power of the fluids in the accurate positioning integrating the hydraulics and pneumatics with the electronics. The development of the mechatronics as a major engineering field illustrates the advantages of the integration of the embedded microprocessor control in the machines functionality. This development aims at the introduction of the modern information and communication technologies and the artificial intelligence in the new generations of machines, devices and systems.

Digital communications improve the electromagnetic compatibility because of the higher noise immunity of the digital circuits than that of the analog ones which leads to minimizing the system faults. The performance of the Internet of Things concept representing the ability of the components to communicate with each other opens up entirely new fields of activity. This permits widening of self-diagnostic, self-testing and the complete introduction of self-regulating systems which will lead to autonomous production. All mentioned above matters are specific features of the paradigm Industry 4.0. The integration of networked, distributed and smart systems in the industrial automation is an unstoppable trend because of the constant increase of the technical and economic requirements.

The embedded systems introduction has led to integration of new functions into the field devices - communications, self-calibration and adaptation. They allow the improvement of the functionality of the mechanical systems especially in motion control enabling higher accuracy of the speed and positioning. Modular mechatronic systems allow function integration which leads to increase the complex system adaptability and standardization. This results not only in the improvement of the system abilities but also in savings of time to market because of the possibility to select, wire and adjust fewer components.

To choose the proper modules for the complex system design is a challenging engineering task where a care must be taken not only about the technical characteristics of the modules but about other factors as reliability, sustainability, time to market and prices. In this context the usage of programmable logic controllers (PLC) for the core of the modular system has been accepted as a general approach in the industry automation [Hughes, T. A (2000)], [Zhang, Peng (2008)], [Jack, H. (2008)]. To involve PLCs in the automation systems skilful hardware and software engineers with knowledge and experience are needed. They will be able to develop flexible and reliable automation systems in order to overcome the challenges of the fourth industrial revolution.

Obtaining basic theoretical knowledge and practical skills for starting a career in the industry is among the main requests of the employers to the faculties in the STEM field. The engineering faculties face the task to organize an attractive and modern education in the field providing relevant subjects, assignments, manuals and laboratory tools.

The goal of the presented research is to develop a reliable electronic system and proper assignments for practice in the mechatronic field including real components – PLCs, motors, motor drives and sensors. Creating conditions for studying and practicing PLC programming will enable the students to master the basics of the automation software development. This paper is organized as follows: section 2 highlights the application of the simulation in the learning process. The

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proposed laboratory set-up and corresponding educational tasks are described in section 3. The conclusions and the future work are presented in the last section.

2. SIMULATION AS A BASIC APPROACH IN STEM EDUCATION

The purpose of the learning process is to convince the students in their abilities obtained in the classes. They have to understand the benefits of the studied matters and to be motivated to continue the learning because the STEM field is changing rapidly. The obtained abilities in controlling scaled models of real industrial objects give the students self-confidence and motivation to extend their knowledge. The learning process has to be organized with proper examples in order to increase smoothly the level of difficulty. Obtaining sustainable results is expected by mastering the knowledge step by step using the learning by doing approach.

In order to give the graduates relevant knowledge and skills in the technology and engineering field the Faculty of Electronic Engineering and Technologies at Technical University of Sofia included in the last semester of the Bachelor in electronics curriculum a new course entitled "Automated control in the industry" with two hours laboratory work per week. It is intended to prepare the students to begin a successful career in the STEM field. In the laboratory work is emphasized on the PLC programming training. For this purpose a proper hardware is ensured which allows different basic tasks from the industrial automation and mechatronics to be solved using the learning by doing approach.

Modern control systems are code driven and the verification of the software is a very important and responsible task. There have to be created conditions close to the real ones in order to test the software operation. All possible cases have to be executed before the implementation of the system in the field. In simple and not risky applications the test might be performed by running the software on the machine and observing its operation. Unfortunately this is not allowed in complex systems. Then the simulation is the only approach for testing the developed software without the actual machine.

Modelling and simulation are often used approaches in the scientific and application projects. In many fields of the industry is impossible to adjust the hardware and the software of the automated system in real conditions by security and safety reasons. So, their operation is verified onto a model of the industrial object and after possible settings the system is implemented in the real conditions.

Simulation and modelling have wide application in operators training in heavy industries like electric power production, chemical manufacture, machine building and etc. where interruption and accident regimes creation for the purpose of training are impermissible. In greater extent these approaches are used in the education in STEM field because of the following reasons:

• They allow a numerous physical laboratory set-ups dedicated to different tasks of automation to be ensured;
• They support design of new laboratory assignments with different degrees of difficulty in accordance with the students' level of knowledge;
• They provide safety conditions for the students.

Consequently the need of simulators arises. It is important their input and output parameters to completely match those of the simulated objects.

Developing a simulator for use in the learning process in PLC programming is based on an accurate specification of the electrical and functional characteristics of the input and output circuits of the standard industrial controllers.

3. LEARNING ENVIRONMENT IMPLEMENTATION

The environment is based on the PLC of Siemens Simatic S7-1200 CPU 1214C DC/DC/DC with on-board 14 digital inputs and 10 digital outputs, and 2 analog inputs. The input and output ranges for the digital ports are 24 Vdc and +10V for the analog inputs [Siemens AG]. In order to make the simulator applicable in work with another PLCs like Simatic S7-200, Simatic S7-300, and VIPA, its abilities has to be extended. For this reason the number of the digital inputs and outputs has to be increased and the ability to set negative analog voltage up to -10V has to be provided. The block diagram of the simulator is shown in Fig. 1.

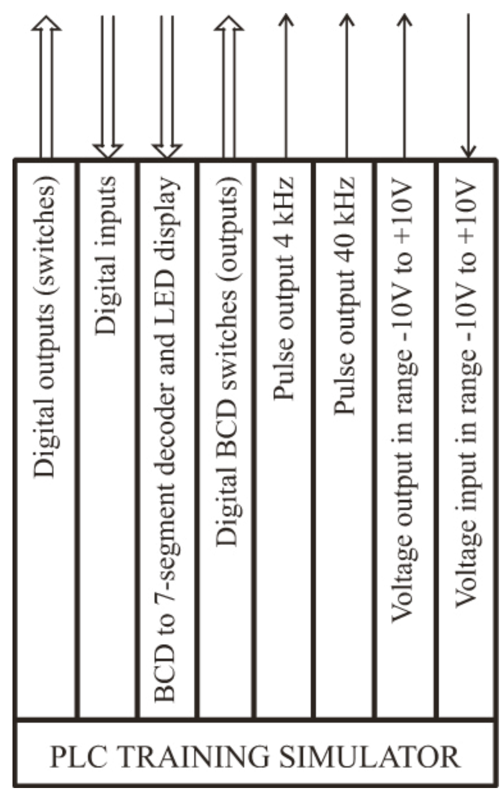


Fig. 1. PLC training simulator – block diagram.

The simulator contains 16 digital inputs, 16 digital outputs, 1 analog input, and 1 analog output for general purposes. For testing hardware and software counters there are provided two pulse outputs with fixed frequencies of 4 kHz and 40 kHz and amplitude 24V. Also there are intended BCD switches possible to set numbers in the range from –999 to 999. To display BCD numbers in the same range four 7-segment indicators are provided. The analog input and output range is from -10Vdc to +10Vdc and both voltages are measured and displayed.

3.1 Laboratory workplace configuration

The laboratory training workplace depicted in Fig. 2 consists of the described above simulator – 1 [P. Yakimov et al. (2019)], PLC Simatic S7-1200 – 2, PC - 3, smart AC variable speed drive model Commander SKA1200037 – 4 [Control Techniques], AC induction motor – 5 and reducer - 6 [Motovario], and incremental rotary encoder – 7 [Sensata Technologies].

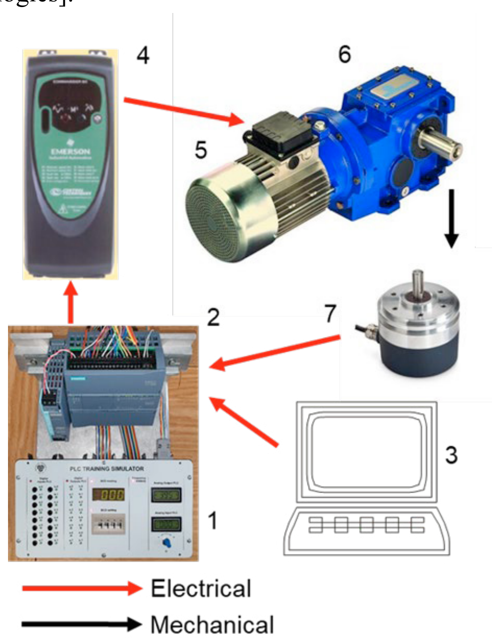


Fig. 2. Laboratory training workplace.

The configuration of the working place allows PLC software development and testing using real industrial devices. There are highlighted the electrical and mechanical connections in the laboratory set-up for practicing loop control of AC induction motor. The PLC executes its program and produces analog voltage in the 0-10V range which is accepted by the variable speed drive in order to control the motor speed in the range 0-1200 RPM. It is set by using the BCD switches of the simulator in the range 0-120 followed by a multiplication by 10. After the reducer the speed is measured by the use of the encoder which is mechanically coupled to the shaft of the reducer and its outputs are connected to the inputs of the PLC. It is possible with the same set-up the more difficult task for positioning to be executed. The direction of the rotation is controlled by the PLC in accordance with the input information set by the simulator.

3.2 Typical code examples

STEP 7 programming environment of Siemens is installed on the PC. It allows software development using the following standard programming languages: LAD (ladder logic) - a graphical programming language, FBD (Function Block Diagram) - a programming language that is based on the graphical logic symbols used in Boolean algebra, and SCL (structured control language) - a text-based, high-level programming language. The environment provides a user-friendly conditions for development, editing, and monitoring the operation of the user's application. After the editing the code is uploaded to the PLC memory and executed.

The workplace enables laboratory assignments involving practically all modules of the PLC - digital inputs and outputs, analog inputs and outputs, counters, communications and etc. The code example in Fig. 3 uses LAD and it is intended to control the motor rotation direction and start/stop. It will give the students skills in logic functions realization and their application in the real industrial control.

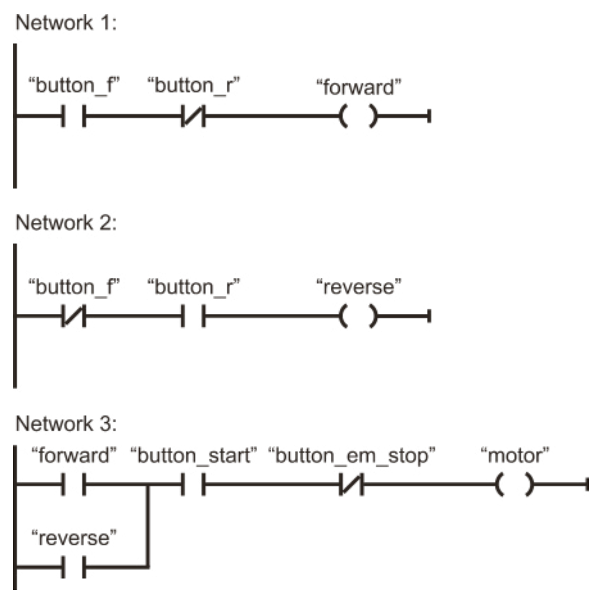


Fig. 3. Start/stop and direction control of Commander SKA1200037 using four inputs of the PLC.

The smart AC variable speed drive model Commander SKA1200037 has two digital inputs for control the direction – "forward" and "reverse", and one digital input for enable the drive – "motor". The program uses four inputs of the PLC – "button_f", "button_r", "button_start" and "button_em_stop". These inputs are connected to digital outputs of the simulator. Networks 1 and 2 control the direction and realizing XOR to prevent setting equal values on the corresponding inputs of the drive. The logic outputs "forward" and "reverse" are included in the Network 3 which realizes the start/stop control. The start is inhibited when the direction is not chosen. The "button_em_stop" input stops the drive in emergency cases. This solution is trivial and it is to provoke the students' curiosity to minimize the number of inputs. In Fig. 4 is shown another solution where only one digital input "button_dir" is used for determining the direction instead of the two ones from the previous example. The action of the logic is identical but the goal is to remind the students that they have to search optimal solutions of the logic functions in terms of number of inputs.

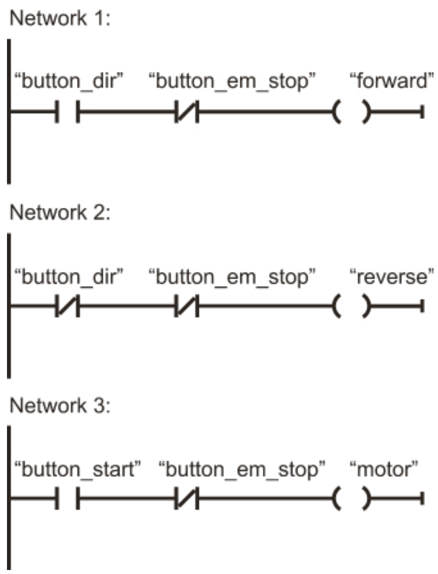
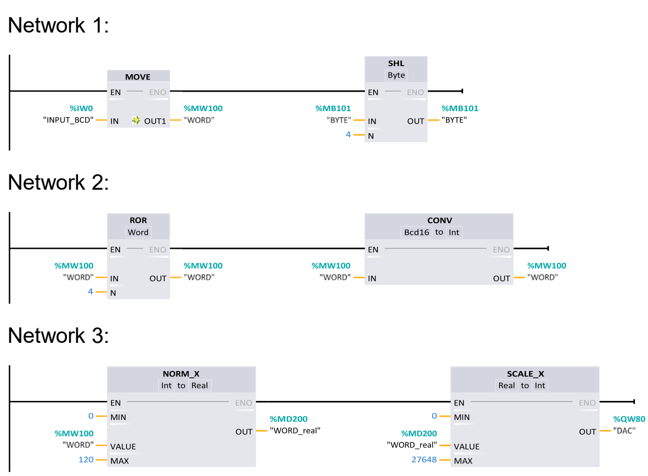


Fig. 4. Start/stop and direction control of Commander SKA1200037 using three inputs of the PLC.

The next example represents the generation of the output voltage in the range 0-10V in accordance with the set rotation speed in the range 0-1200 RPM. The code executes reading a BCD number in the range 0-120, its conversion to integer, the mapping and loading the calculated result to the analog output. The code is presented in Fig. 5 and demonstrates the usage of box instructions.



The BCD switches of the simulator are connected to the input points of the PLC as follows: the lowest digit - to the digital inputs from DI b0 to DI b3; the medium digit is connected to digital inputs from DI a0 to DI a3; the highest digit is connected to digital inputs from DI a4 to DI a7. The first two networks of the program realize the BCD to integer conversion. The Network 1 is intended to position the BCD numbers in consecutive half bytes according to their weight and in Network 2 the BCD word is converted to an integer. In the input scan the states of the input points are stored in two bytes in the Process Image Inputs memory on addresses IW0 and IW1. In the logic scan this information is moved as a word to the Bit memory (M) on address MW100. The next two instructions shift and rotate the bits in order to set the half bytes consecutively in the lowest 12 positions of the word clearing the highest 4 bits. After that the BCD word is converted to integer. The range of integers representing the rated voltage range is 0-27648. To convert values that are in engineering units to an analog output value is needed first to normalize the value in engineering units to a value between 0.0 and 1.0, and then to scale the obtained value between 0 and 27648. For this purpose STEP 7 provides the NORM_X and SCALE_X instructions which are used in Network 3. In this way the BCD input in the range 0-120 representing the engineering value rotation speed in the range 0-1200RPM is converted to an analog voltage in the range 0-10V which will be supplied to the drive and the AC motor will rotate with the corresponding speed.

4. CONCLUSIONS

The paper considers the main objectives of the development of a learning environment for practicing in the field of mechatronics and industrial automation. It consists of a modern hardware and software and allows for studying step by step the PLC software by using the learning by doing approach. The usage of real industrial devices provides education in conditions close to the reality. The possibilities of the configured workplace give a flexibility in the development of cases for studying the different instructions of the standard programming languages LAD, FBD and SCL. It is expected that this will lead to a successful education in the STEM field which will allow the graduate engineers to acquire sustainable theoretical knowledge and practical skills for the start of their career in the industrial automation.

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REFERENCES

Hughes, T. A (2000). Programmable controllers, Third Edition. ISA – The Instrumentation, Systems, and Automation Society, 334 p.

Jack, H. (2008). Automating manufacturing systems with PLC-s, (Version 5.1, March 21, 2008), Copyright (c) 1993-2008 Hugh Jack (jackh@gvsu.edu).

Zhang, Peng (2008). Industrial control technology: a handbook for engineers and researchers. William Andrew Inc., Norwich, NY, USA, ISBN: 978-0-8155-1571-5.

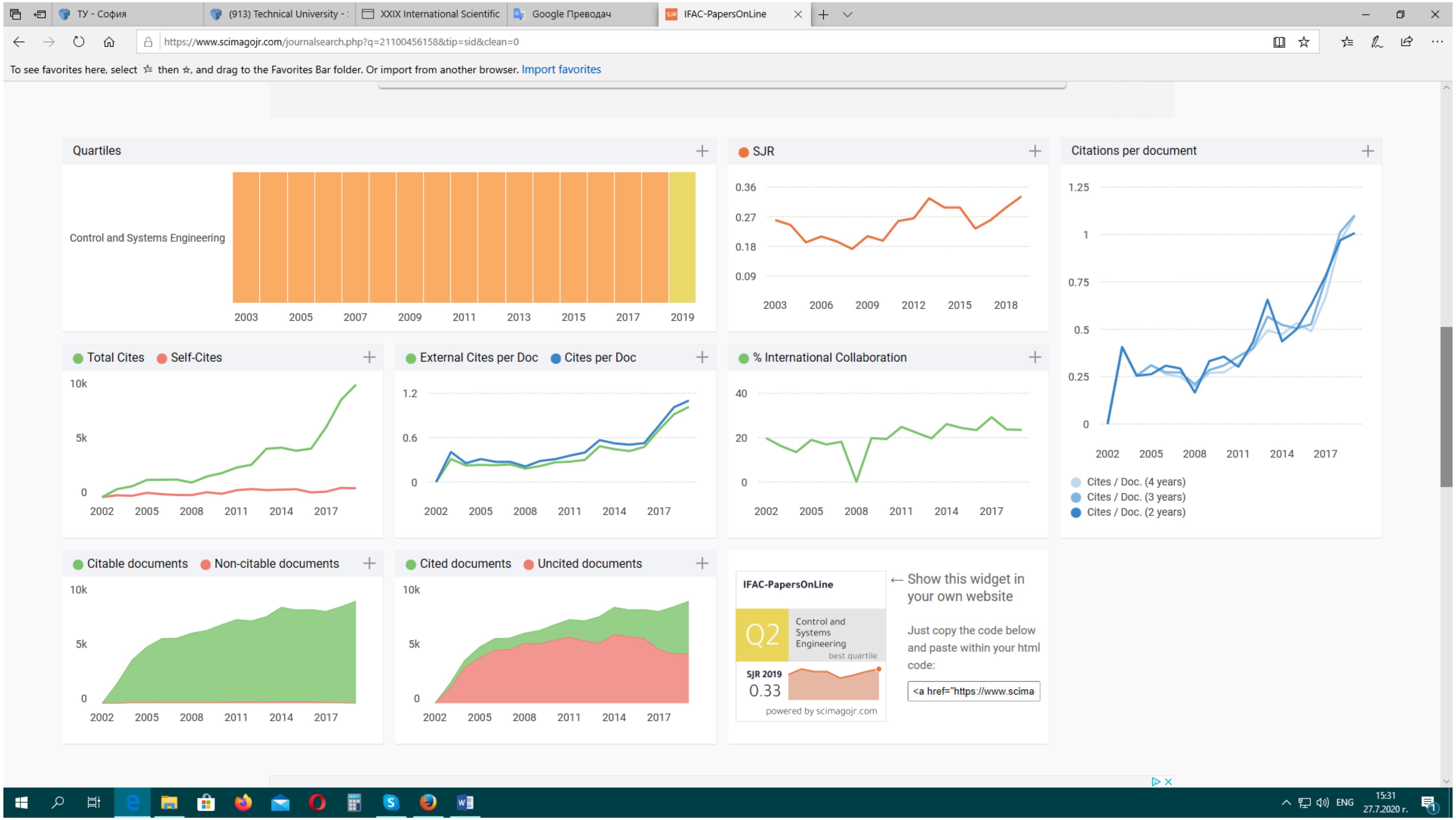
P. Yakimov et al. (2019). "Development of hardware and software methods and tools for a successful PLC training," presented at the X National Conference with International Participation "Electronica 2019", May 16 - 17, 2019, Sofia, Bulgaria.

Control Techniques, https:// www.controltechniques.com.

Motovario, https://www.motovario.com.

Sensata Technologies, https://www.sensata.com.

Siemens AG, S7-1200 Programmable controller. System Manual. V4.2, 09/2016, A5E02486680-AK.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