Diagnostic and Maintenance Education Course for PLC Based Automatic Machines

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Abstract: - The fast science and technology development make possible the fourth industrial revolution, which changes the production processes towards more autonomous functioning with more intelligent automatic control systems that communicate with other such systems without or with little need of a human operators. The mass automation of production processes is taking over the low qualification jobs from the labor market, while at the same time new work positions appear that require certain skills and expertise in the automation field. The requirements towards many low-qualification work positions grow and such employees working with some type of automation machines already need to possess basic knowledge about the way they are being controlled in order to diagnose and deal with problems occurring with them. Nowadays, production companies, at least in Bulgaria, find it difficult to hire personnel with broader knowledge and skills required for the everyday maintenance of their automated machines and production lines. We have understood what combination of experiences they need to possess and have updated our PLC course with the necessary knowledge. The aim of this paper is to present this additional qualification course which gives to students, with electrical background, the necessary diagnostic and maintenance knowledge and expertise needed for such a work position.

Key-Words: - PLC, Education, Maintenance, Automation, Controller, Programming

1 Introduction

Nowadays, we live in a swift and dynamically changing world, where technology develops fast [1]. The science and industry tend to miniaturize, electronize and automate everything around us. The fourth industrial revolution is going to transform people's lives, together with the requirements towards their abilities. Some work positions are supposed to disappear while others will come to live. The requirements towards the labor force are changing in all spheres of life [2,3]. This has already happened before, with the oncoming of computers, which we accept as something usual nowadays, but opposed to the near past, now everyone is required to have some level of computer and software work experience in order to be competitive on the labor market. The mass miniaturization of all electronics, recently allowed the appearance of smart phones, which are some type of small sized computers. With the appearance of these new devices the requirements towards the personnel have grown again, because now for many work positions the employers require from people to be able to work with those novel communication devices for different reasons.

The fourth industrial revolution slowly but surely transforms the industry, towards fully automated production processes and machines. This leads to loss of many low qualification work positions, but at the same time new ones appear which require more experience and knowledge about the way the automatic equipment works and broader knowledge in more than one sphere [2,3]. There are already companies in Bulgaria, looking for maintenance personnel with broader experience in the electrical, electronics, automation and communication fields and it seems that they have problems finding it. In this case they are pushed to hire people with some knowledge in the field and to pay for their qualification in order they to be able to do their work in a proper manner and in order the company to be able to continue its unimpeded development. The solution of this problem could be a proper education course that gives to students all necessary knowledge required for such work positions. We have led talks with representatives of production companies located in Ruse city and came to the conclusion what basic knowledge the maintenance personnel must possess in order to be able to handle its everyday work tasks. The aim of this paper is to

present a qualification course which gives to students, with electrical background, the necessary knowledge and expertise needed for such a work position.

University of Ruse owns laboratory with Siemens industrial automation equipment and leads a Programing Logic Controllers (PLCs) education course to students studying in the field of electronics. Based on the new understanding we have acquired, we understood that our course is incomplete and we have managed to improve it by adding the missing knowledge. Siemens are leader of the European automation market nowadays and one of the top 10 industrial automation companies in the world and for that reason the course have been developed for the Siemens series PLCs and software, but it could easily be modified for the equipment of another industrial automation producer [4,5].

The aim of this paper is to present the basic skills and knowledge that students should acquire from such education course in order for them to be able to take on an automatics maintenance work position.

The course is appropriate for students in the automation, electronics, electrical, industrial communication and computer science fields or for other fields where students possess some electrical background.

2 Objectives and Methodology

The main objectives of the education course are to provide to students all necessary knowledge in a practical manner, which means that they must work to find the solutions of different problems and in such a manner to acquire real understanding about this matter, and real experience in the field that they could apply directly in their future work.

The methodology is to make students work on and explain the different practical problems and solutions. The problem based learning process is important for their development and future work success [6,7]. When people try to explain something and if they couldn't, then they actually understand what exactly they don't know about it.

The lectures and exercises are led in an active form, more like a conversation between equal members of a work team. The active education makes students think, develops their intelligence and allows them to better understand the studied material [8,9]. Students are being asked different questions all the time before the solution of certain problem is given to them. In such a way, they are being stimulated to think and work in team together towards the correct answers or solution. Rarely any answers are given directly to them, but more likely they are being stimulated through many consecutive questions to come to the conclusions themselves. They are given common practical tasks to solve with real automation equipment which will bring them the necessary experience. They need to manually work with the studied equipment in order to develop the necessary operating skills [10].

The courses are led with the help of a wall setup which we have available in our Siemens automation laboratory, Fig. 1.

The setup is equipped with Siemens S300 and S200 PLC stations, different types of ET200 peripheries, computers, an industrial switch and human machine interface devices (HMIs), some of them connected to Profibus network and others to Profinet network.

Fig.1 Available Siemens automation setup

3 Basic Skills Required for the Everyday Automation System Maintenance Work Position

The automation maintenance personnel should possess general knowledge about the PLCs structure, way of work and its possibilities to control machines and processes. They should be able to solve simple programming tasks so they need to understand the most often used Ladder programing language, the program structure and how to use the simulator and other available functions in order to correct their programs. All of this material is already covered in our entry level PLC course which has already been described in detail in another paper. Besides this experience, the future automation maintenance personnel should be able to diagnose any occurring problems with the automation system, such with defective sensors, cables, PLC Input Output (IO) modules, or network communication

problems. This means that they need to attend a practical “Diagnostic course”.

Once the problem is found the maintenance should be able to replace in a safe manner the defective components and to reconfigure the new ones with all necessary parameters and adjustments. So they need to attend a “Hardware maintenance course”.

At some point they will need to be able to do simple upgrades of the automation equipment, so they must have knowledge about the way of work of the different industrial networks running on the different plant levels. They should be experienced in network configuration and topology creation, so they will need to attend “Network configuration and topology creation course”.

We have optimized and extended the material studied in our basic PLC course and now it includes diagnostics, hardware maintenance and network configuration training. This is possible because for the maintenance work position, all of the mentioned courses should be led on a basic level, because they are supposed to just maintain and adjust the work of basic automation equipment without creating whole new automation systems, but they should be able to do their work in a safe manner, so safety of the production process and personnel is the primary concern. Professional automation companies with real automation experts are taking care of more difficult upgrade tasks or are helping in case of general failure of the automation system. The problem of the production companies is that the usage of such services on a daily level is too expensive for them and it takes time for the experts to come, and time is money. They need maintenance personnel on the spot so they can react immediately on the daily simple problems.

4 Diagnostic Course

At this class students learn the diagnostics capabilities of given PLC and they work on real problems in order to achieve the necessary experience in the field. The diagnostics course consists of five sub-modules.

4.1 Diagnostics Based on Front PLC Panel Indicator Lights

At this class, students learn the meaning of the different colors and the lighting modes of the front controller panel led lights, Fig. 2. The lighting modes could be, off, steady on, or flashing with certain speed and all of them have different meanings. Students are being given tables with the meanings of the different modes and colors and then some problems are generated and they are being asked to find what might have caused this indication to appear. The class includes also diagnostics of digital inputs and outputs based on the corresponding led lights.

Fig. 2 Diagnostic lights of PLC S7 315F

4.2 Diagnostics via the Diagnostic Buffer of a Controller

Students are being explained how to reach the diagnostic buffer and what types of messages are being displayed there. Then some problems are generated and they are being asked to find what is the reason for the generation of the corresponding messages.

4.3 Diagnostics of Analog Sensors

The different types of analog sensor interfaces and standard signals are presented to students. Sensors could be with 2, 3 or 4 wires and they are being connected in different manner to the PLC analog modules based on the standard signals used by the producers which could be voltage or current. Students are explained that if needed they could actually measure with a multimeter the signal given by certain analog sensor or analog output in order to verify if it is working properly. For this class a potentiometer setup has been created that simulates the function of an analog input sensor, which they could connect to given analog input. It is explained that Industrial equipment producers have created analog modules with steady unconfigurable interfaces, older ones with configurable interfaces with mechanical switch and newer ones with electronic configuration of the separate analog pins which is done through the software and the

programing station. They are being shown how they can reconfigure such a module.

4.4 Diagnostics via Variable Tables

At this point students learn how to create and use variable tables in order to check in real time the current readings of certain analog or digital sensors, analog outputs and program variables.

The created potentiometer setup simulating an analog input is used for analog input readings. A led diode has been connected to an analog output in order the analog output control to be visualized through the light the led emits. The students are asked through the variable table to send certain digital value to the corresponding analog output which is being converted to voltage that corresponds to certain intensity of light emitting. This setup helps them to better understand how exactly the analog conversion and control occur and to visualize the final result, which brings them good practical experience about this matter.

4.5 Step by Step Program Diagnostics and Simulation

In order for students to be able to find certain program errors, the way of work of the program simulator is explained to them with the help of some simple examples. The step by step program check is shown in more detail in this class.

5 Network Topology Configuration and Diagnostic Course

At this module they learn that there are different network levels in the automation systems over which are running different networks based on the different requirements. Our setup consists only of Siemens industrial equipment which is connected in two types of networks Profibus and Profinet. Students learn the differences between both networks and what type of configuration they need to do if they have to add a new network device or to replace an old one.

A Siemens micro memory card (MMC) is shown to students and it is explained to them that it stores the name and IP address of the corresponding Profinet device to which it belongs. The configuration differences between older series devices with MMC and newer ones without a MMC are explained. The sequence in which the devices are connected and to which port also matters in industrial networks, Fig. 3. They have an exercise where they have to create with the help of the Siemens software certain network topology created on the wall setup. They are being shown how to find available network devices with the help of the "Accessible Nodes" instrument. Then they are being given simple network configuration and diagnostic exercises, where they should write a new name and IP address with the help of the "Edit Ethernet Node" instrument to certain device or to figure out certain simple network problem. They are required to connect to a network available automation devices and to configure Network addresses with the help of the "Network Configuration" instrument.

The address configuration of older and newer Profibus devices is underlined, which could be mechanical with the help of dip switches located on the front panel of the device or software. They are requested to adjust the Profibus network speed and to change network addresses of some available devices. The Profibus network termination is explained together with problems related to it and such problems are also demonstrated with examples created on the available wall setup.

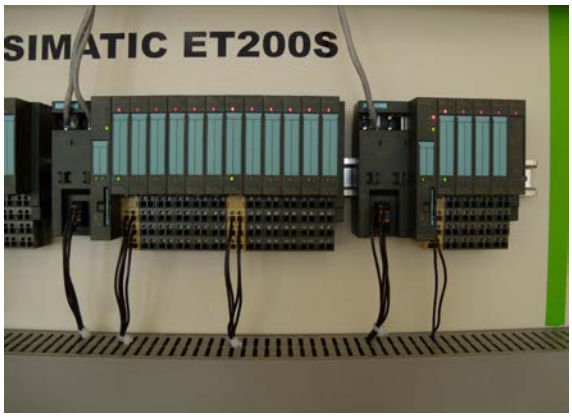

Fig. 3 Unconfigured automation devices

6 Hardware Maintenance Course

It is important the defective modules to be found, but it is as well needed the maintenance personnel to be able to actually replace them in an effective manner and without braking them or changing the hardware configuration if it is not needed. At this class students are allowed to practically disconnect and replace automation modules and slots with new ones, in a safe way, and to reconfigure the new ones if they are different. In our laboratory we have got S300 series Siemens modules and ET200S series peripheral modules and there are specifics concerning their replacement. We remove the terminals of specific modules and explain that with

this future they don't need to disconnect the wires, because if they do they risk to make a fatal mistake during the rewiring. We show to students the device keys on the back which prevent them from connecting the wrong module to certain slot. The specific process of slot removal of ET200S is presented. The difference between hot swappable modules and not hot swappable ones is explained. We allow students to actually disconnect modules and change their slot positions, to adjust the slot key if they have to replace certain module with a different one and to reconfigure the hardware configuration after that, Fig. 3.

7 Conclusions

The course is practically oriented and intends to give to student real understanding and useful practical experience. Lectures go together with the exercises so in such a way students could see, touch and do their own experiments if there is something unclear. All lectures, exercises and problems are being presented in manner which stimulates them to think and in order for them to answer the different questions, they should have an actual understanding. The exam is a solution of certain practical problem. To their questions we usually answer with questions which pushes them towards the solution but don't give them the answer right away.

The course has already been led to groups of students studding the electronics specialty and they find it interesting, meaningful and helpful, and usually work with diligence and desire. It gives them the necessary knowledge, understanding and experience to solve comparatively simple automation problems and to apply for lower level work positions in the automation field, one of which being the maintenance one.

The Problem based active approach develops students' intelligence and makes them work with diligence and desire, which improves their expertise. In parallel, they are being stimulated to work in team which is important in today's complicated industrial world. The course is practically oriented, necessary and required for the current and future trouble-free industrial development, for which are needed many high-quality workers with broad specializations.

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