PLC programming to optimize water flow in secondary cooling zone

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Abstract. In the paper was made PLC programming, with which an adaptive system was implemented, was used the Simatic Manager Step 7 software, which is specific to the chosen PLC Simatic S7-300. Input data, computation relationships and correlations between the different sizes were retrieved and processed from the database of the two human operators, commanding the opening of the valve automatically. With this software, it was possible to eliminate the human factor in controlling parameters specific to the continuous casting secondary cooling zone.

1. Introduction

Secondary cooling zone is the most important part of the continuous casting. It is considered to be a very important part of a continuous casting and has the role of ensuring the quality of the material, the material surface shape and has to ensure a homogeneous cooling and a uniform repartition of the water on the materials surface [1-5].

In this paper, a solution is proposed for controlling and optimizing the cooling water flow from the secondary cooling zone of the continuous casting using a PLC (programmable logic controller) SIEMENS S7 300. Starting from the actual structure of a driving system for a plant modern continuous casting, an effective solution is proposed which allows real-time modification of the water flow distribution on the three secondary cooling zones. The proposed system was tested and validated in experimental determinations on a laboratory stand. The programming language is STEP7, a language that is used to configure the components to assign parameters and, last but not least, to program it [6], [7].

2. Structure of the system

Figure 1 shows the PLC system control interface, it is the first welcome screen that displays system components and base readings. In order for the WinCC application to communicate with the programmable machine and other elements of the automated system (servers, databases, automation systems and auxiliary SCADA), certain drivers must be installed and some protocols configured. The communication between the SCADA-WinCC server and the programmable machine is based on the TCP / IP Ethernet base using the CP373 communication module [1], [7], [8].

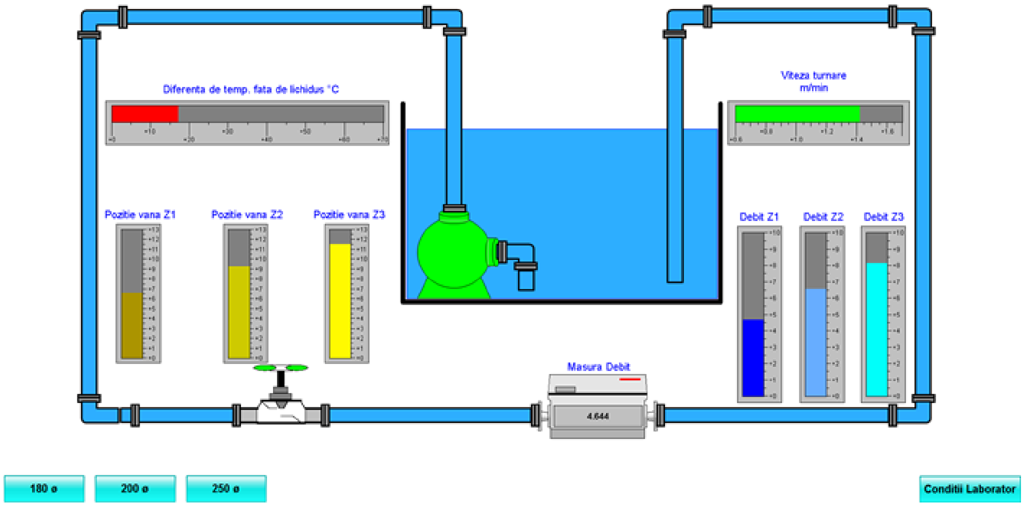

Figure 1. PLC system control interface

In Figure 2 is the SIEMENS PLC configuration and the experimental stand. The cooling water pipe has a flow-meter that generates a PLC-readable current signal at the terminals and displayed in the SCADA interface. By simulating the inlet temperature with the potentiometer (in the continuous casting process, the potentiometer will be replaced by a temperature sensor) the programmable controller will command the closing or opening of the solenoid which will increase or decrease the water flow in the cooling circuit and, implicitly, control the temperature [7], [9].

Figure 2. SIEMENS PLC configuration and the experimental stand

3. PLC programming

At this stage, three important directions have been pursued with regard to the optimization of water flow to cool the steel from the secondary casting area: PLC programming; optimizing the system through additional use of fuzzy rules.

3.1. PLC programming

We used the "SIMATIC Manager Step 7" software that is specific to the chosen PLC, namely SIMAITC S7-300. Input data, computation relationships and correlations between the different sizes were retrieved and processed from the database of the two human operators, the command of opening the valve automatically. With this software, it was possible to eliminate the human factor in controlling parameters specific to the continuous casting secondary cooling zone.

The actual achievement of the program consisted of three stages: schematic representation of the real rack; creation of functional blocks; establishing logical and operational functions within functional blocks.

Before the actual start of programming, the hardware configuration of the project must be set. This is done both for the programming environment to communicate successfully with the equipment being programmed, but also to set certain details such as: addresses, interfaces, input card types, communication module setting, Profibus bus setting, setting extension modules, input / output cards and their addresses, etc. To make the hardware configuration, you should follow the following steps, Figure 3: open the "Hardware" object in the project folder. In the application that opens, the devices that make up the station to be programmed must be selected from the Siemens library. These components must be ordered according to the actual arrangement in the racks and according to the actual connections. Also, these devices must be set up.

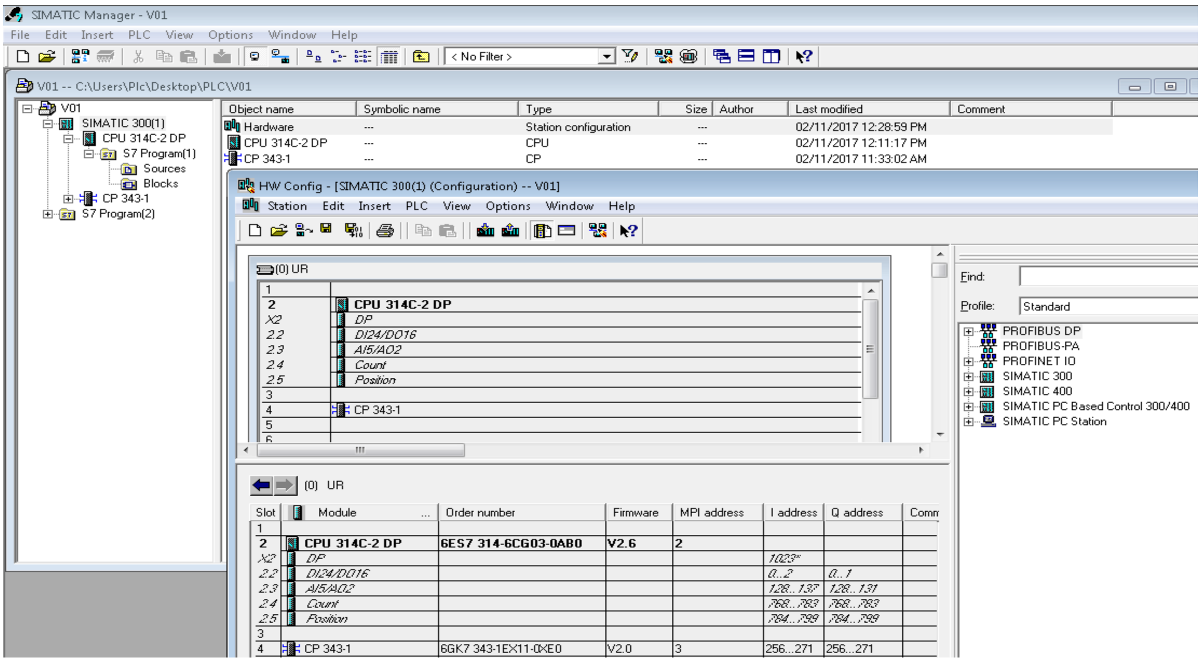

Figure 3. Hardware configuration

The "Hardware" object in the project file includes a SIMATIC 300 CPU 314C-2 DP model, which has both analogue and digital inputs of 40 and 40. The advantage of this SIMATIC S7 processor 300 is given by incorporating the optimal number of analog inputs and outputs required for this project. An important device for communication between the PLC and the PC is the CP 343-1 interface, mounted on the rack on the right side of the SIMATIC S7-300 processor [10].

The first functional block is created automatically at the start of a new project with the default name OB1. This first functional block has the role of initializing the project-specific parameters (variables).

In function block FC2, Function Block Diagram (FBD) functions are used to calculate the analog signal needed to control the Danfoss AB-QM DN10-250 automatic flow controller motor.

The first OB1 functional block comprises the following logical and operational functions: starting pump in automatic mode; analog input valve position reading; flow input reading; potentiometer reading; display the valve command; running the FC2 functional block.

The FC2 functional block with the algorithm through logic and operational functions performs the simulation of the temperature difference in the continuous casting process of the steel by means of the potentiometer and the opening of the valve flap.

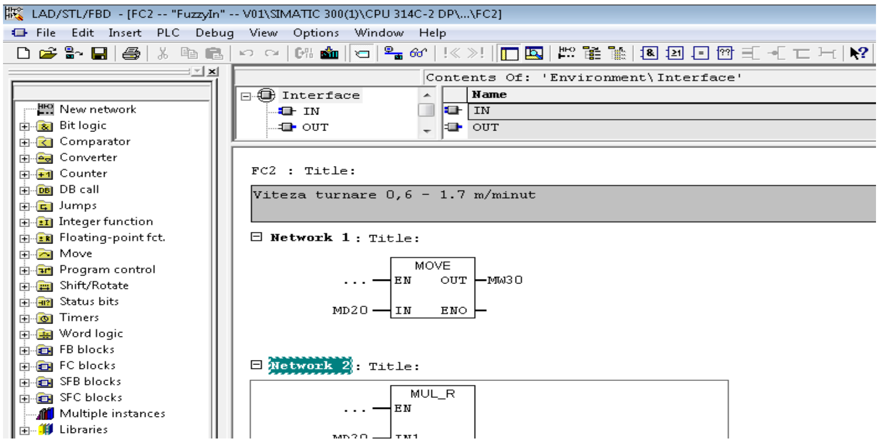

Figure 4. The FC2 functional block

3.2. Optimize the system by using additional fuzzy rules

Fuzzy logic allows the treatment of vague variables whose values can continually vary across any defined numerical range, making decisions based on the position of the indicator in the numerical range and predefined rules. The applicability of fuzzy logic is varied, the metallurgical field being one in which fuzzy systems are increasingly used.

Methods based on fuzzy logic do not have very strictly defined algorithms, and they appeal largely to the experience of the specialist in the field. For the issue in question, a database was built from information gathered from technology experts and was actualised with information from the mathematical model of the solidification process [11]. The above program was designed to simulate the current state of cooling water flow regulation, replacing the human factor. To optimize the system, it was proposed to use additional Fuzzy rules to real-time correlation of the three parameters, temperature-speed-flow. In Figure 5, following the physical sense of the technological process of obtaining steadily cast steel [12], the following rules were imposed that correlate the process parameters in real time. The program connection with the PLC is made directly from the FuzzyControl ++ application, Figure 6. From this point on, the PLC further uses the imposed Fuzzy rules, optimizing the flow control system.

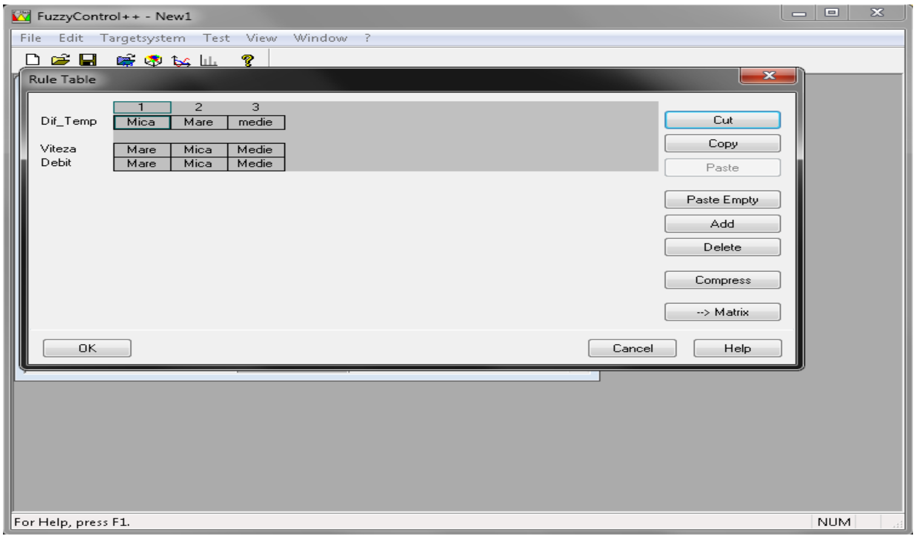

Figure 5. Fuzzy rules

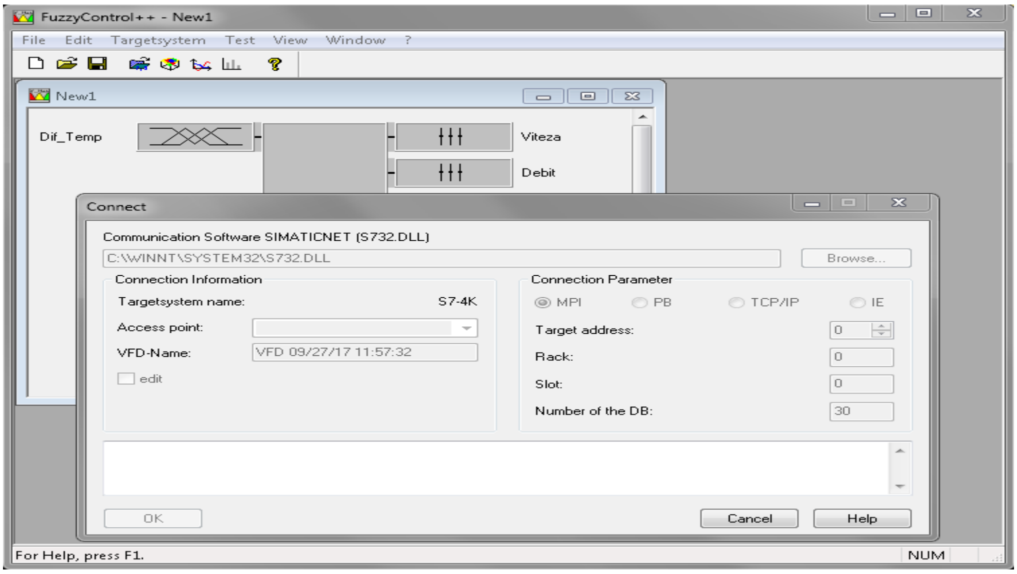

Figure 6. PLC conexion

4. Experimental results

In the following figures, you can see the charts with the main parameters for viewing both the classic method and the improved fuzzy rule method. Thus, if the classic control is chosen, the user can see the graphs shown in Figure 8. By choosing the fuzzy control on the screen, the graphs in Figure 9 appear. Both windows include four graphs showing the time variation of the following parameters: the temperature difference to the liquid; casting speed; the position of the valve on all cooling zones; the flow rate in the three zones. We can see that fuzzy method is better because the control of each zone is more better and faster.

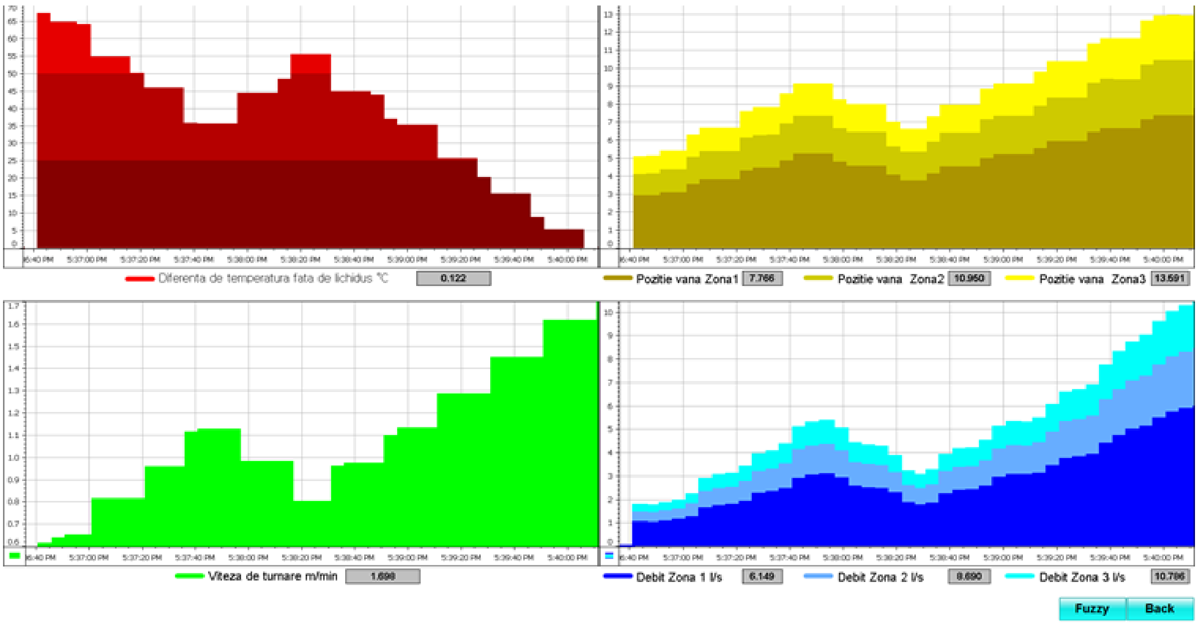

Figure 7. Classic method - SCADA interface

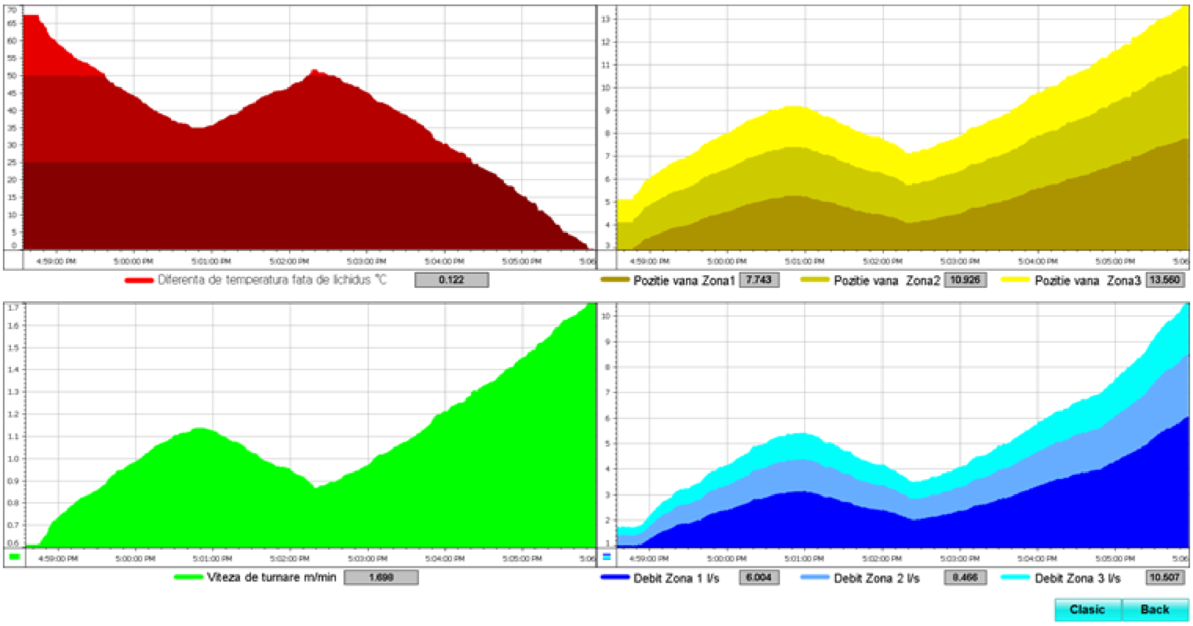

Figure 8. Fuzzy method - SCADA interface

Taking into account the results obtained the next step was to check the functionality of the system in the continuous casting process. In order to obtain the temperature values experimental measurements were carried out on the continuous casting process within S.C. Arcelor Mittal S.A. Hunedoara. The Continuous Casting Plant within the "Continuous Casting" section of the S.C. Arcelor Mittal S.A. Hunedoara is conceived and manufactured by Mannesmann and comprises five yarns for pipe billets with diameter ϕ 180 mm, ϕ 200 mm, ϕ 250 mm, ϕ 270 mm, ϕ 310 mm or blanks for re-dimensioning with dimensions 240x270 mm, 310x280 mm. They confirmed the results of the simulations.

5. Conclusions

In this paper, a solution for controlling and optimizing the cooling water flow from the continuous casting secondary cooling zone is proposed using a SIEMENS S7 300 PLC (programmable logic controller). Was made PLC programming, with which an adaptive system was implemented, was used the Simatic Manager Step 7 software, which is specific to the chosen PLC Simatic S7-300.

Input data, computation relationships and correlations between the different sizes were retrieved and processed from the database of the two human operators, commanding the opening of the valve automatically. The laboratory results were confirmed with real measurement.

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