AUTOMATION OF REFRIGERATION SYSTEM WITH PLC AND LABVIEW, AN ACADEMY INDUSTRY COOPERATION CASE STUDY

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Abstract - The paper describes a new automation system developed to control and monitor a refrigeration system used for industrial experimental tests. The equipment owner it is a certificated laboratory for experimental tests in thermodynamics, aeronautics and vibrations. One of the laboratory activities is the products and equipment certification. During the certification process, the ambience temperature is a factor that needs to be controlled. The paper presents the SCADA system developed to monitor and control the water temperature of a refrigeration system used in the climate chambers. The system was successfully tested and is currently in operation in a shaker's temperature control. The project it was developed in cooperation between academia and industry. It is a case study that demonstrates the potentialities of knowledge transfer between both actors.

Keywords: Automation, Thermodynamics, Chiller, LabVIEW, PLC, SCADA

1. Introduction

The Triple Helix concept has been used as an operational strategy for regional development and to promote the economy based on the knowledge. It was intended as a model of interaction between Government, Academia and Industry, (The three actors of Triple Helix), that has the objective to transfer knowledge and technology from universities to business and societies. The interaction model needs to be dynamic and adaptable to industry specifications, or technologies and geographic regions. A lot of work was developed and published to discuss the Triple Helix concepts [1][2][3]. The objective of this paper it is not to discuss the Triple Helix model, but a case study that presents the collaboration between university and industry, and the transfer knowledge and technology. The project developed and presented here is a technological example of cooperation and involvement of the actors to develop a technological system with practical applicability. Both institutions, university and industry benefits from the project.

In the most traditional industrial automation systems it was supposed that the operator was responsible for monitoring and control the processes. With the increase complexity of industrial processes, appears the necessity for a remote controlling and monitoring. It facilitates the operator functions and their efficiency. Furthermore, the aggregation of feedback data, gives to supervisors the ability to monitor trends, forecast requirements, and optimize procedures. The SCADA (Supervisory Control and Data Acquisition) systems were created for supervision, control and data acquisition in order to improve the automation systems efficiency.

The SCADA systems architecture enables the sensors and actuators located in remote locations can be connected with an intranet or internet network. Typically, the connection is established across Remote Terminal Units (RTU) that enable the digitization of signals from sensors or establish the communications with actuators. The Human Machine Interfaces (HMI) are also very important in SCADA systems for the interaction between operator and system in order to allow access to databases, manipulate variables, analyze trends, monitor and control the system. The use of SCADA systems in the industry is indispensable nowadays and in particular when the automation systems are complex.

In the bibliography there are much work developed for the implementation of SCADA systems in the industry and projects developed from the universities to industry [4] [5]. In [6] the authors present the development and implementation of a framework of Intranet-SCADA using LabVIEW based data acquisition and management for a reservoirs system. In [7] are presented the State-of-the-Art of SCADA system architecture and the simulation in a real-time process, in this case a boiling system.

The refrigeration system implemented in this work is a LabVIEW based intranet SCADA system, to provide smart controlling and data acquisition using the company private network. The system was developed in order to provide temperature control of a cooling fluid circuit with the increasing of electrical efficiency. The cooled equipment is a high capacity shaker (105 kN) and a climatic chamber, both equipments shown in Figure 1. With this shaker are performed dynamic tests (random, sine, SOR, ROR, SROR, classic shock, SRS shock) and modal analyses with or without climatic environment (-45ºC to 150ºC).

All the experiments with water temperature control performed by the system described in this paper.

The remaining structure of the paper is organized as follows: The second section describes the materials and methods. The third section describes the experimental results, and the paper is finished with a fourth section about conclusions and future work.

Figure 1: Shaker (red equipment) and climatic chamber, over the shaker.

2. Material and Methods

The project goal consists in the creation and implementation of a SCADA system to monitor and control the water temperature of the refrigeration system. The refrigeration system is composed by a chiller, a water deposit and also by three equipments which are: shaker, climate chamber and vacuum chamber. Each equipment as also the chiller, has water pumps.

All the automation process will be made through FATEK FBs-20MC Programmable Logic Controller (PLC). Two input modules FBs-RTD6 are coupled on the PLC, they are responsible for the readings of the resistance temperature detector (RTD) Pt-100 probes which will be placed on the input and output water pipe of each water pump and also on the water deposit. One Ethernet module FBs-55CE is also coupled on the PLC, for establish communication between the PLC and the network of the laboratory, providing the access to all computers.

The communication will be established via Facon Open Platform Communications (OPC) server, which will be in charge to receive and send the data from the PLC to the user or vice versa.

The Human Machine Interface (HMI) will be made through an application in LabVIEW. The application will show the temperatures in the system, will inform the user if the water pumps are armed through the electrical panel, will give the possibility to arm or disarm the water pumps depending of the software mode that has been chosen. The user will be able to define the maximum temperatures of each water pump. The LabVIEW will also contain one visual alarm that appears if any of the temperatures is reached.

The functional block diagram of process is shown in Figure 2.

The *WinProladder* software was used to make the PLC program. Here we have to secure that it can run in three different modes:

1-Forced physical functioning, i.e. whenever any of the water pumps is armed or disarmed manually through the electrical panel. When the rotary switch position is ON, close one PLC input relay that informs the program that the physical mode is working and disables the possibility of control through the software, the water pump, only giving the possibility of monitoring.

2-Software functioning in manual mode, i.e. using the recourse of the PLC the user can arm or disarm the water pumps through the LabVIEW application.

3-Software functioning in automatic mode, i.e. using the recourse of the PLC the user can only arm or disarm the three equipments water pumps. The chiller water pump is automatically armed and disarmed through the combination of *setpoint* and *hysteresis temperature*, defined by the user. Figure 3 illustrates the functioning of the chilled water pump when the software works in automatic mode. The chart shows the temperature temporal evolution and the water pump actuation, according the *setpoints*. The flowchart of Figure 4 helps to understand the three operating modes and how the system works.

As a security measure there will be have not only a visual alarm but also a sound alarm and as previously referred the alarm only appears if any of the temperatures set by the user is reached.

The only way to be disabled is through an inverse timer defined by the user to disarm it temporally while the time doesn't reach the end. The inverse timer can be set through a pressure button or through the LabVIEW application.

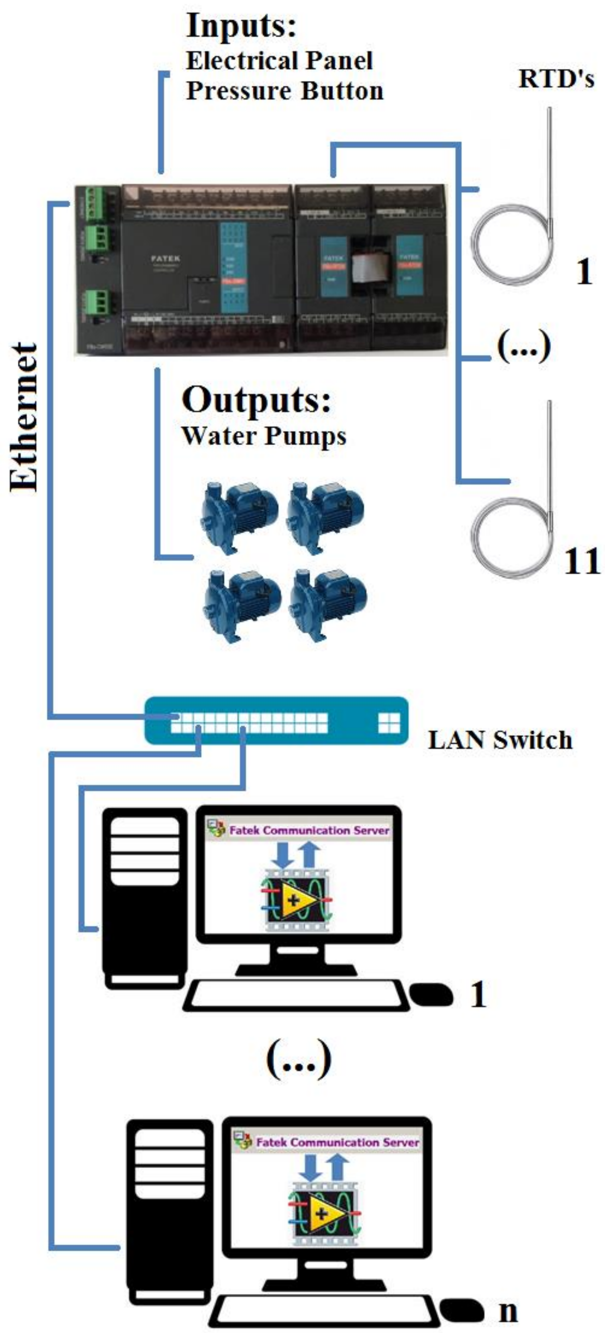

Figure 2: Functional block diagram of the process.

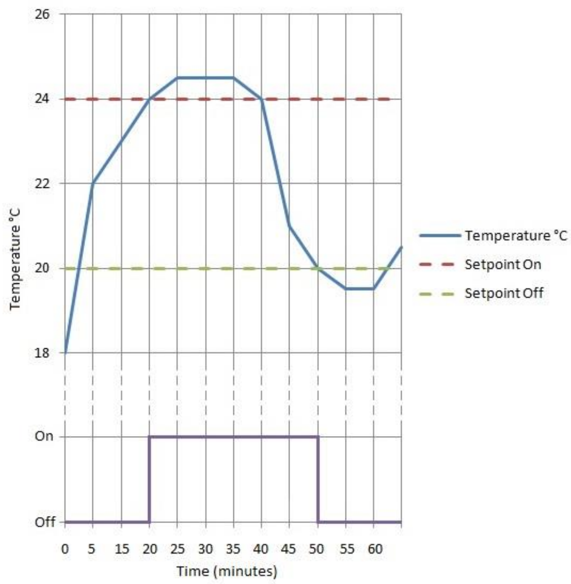

Figure 3: Chiller water pump control with the system in automatic mode.

3. Experimental Results

As referred, in LabVIEW application the user has two modes that can be select through radio buttons, which let the user have only one mode selected, automatically deactivating the other mode and their properties.

When the software functioning in manual mode is selected the user have full control of the water pumps, the user can arm or disarm each water pumps separately through *boolean* buttons, when they are armed the light turns ON, and he also have control on setting the maximum temperatures of each water pump as the inverse timer too.

When the software functioning in automatic mode is selected, it disables and fades the *boolean* button of chiller water pump, showing to the user that the option of manually control the chiller water pump is not available anymore and this option proceeds to reply only the *setpoint* and *hysteresis temperature*. If are any water pump is physically running through the electric panel, it also disables and fades the water pump *boolean* button and activates the indicator LED.

When the chiller water pump output water is above of the combination of *setpoint* and *hysteresis temperature*, the water pump automatically gets armed and its button assumes the red color and starts to blink. The alarm is only available for the equipment water pumps.

The alarm timer can always be defined, but with the particularity that it only accepts the time when the button is pressed, even if there is a value inserted on the numeric control, the timer display shows the remaining time. When the alarm is active, the visual alarm starts to blink assuming the red color.

The application has also the possibility to stop all pumps no matter which mode is running.

The screenshot of LabVIEW front panel, developed in this project, is shown on the Figure 5.

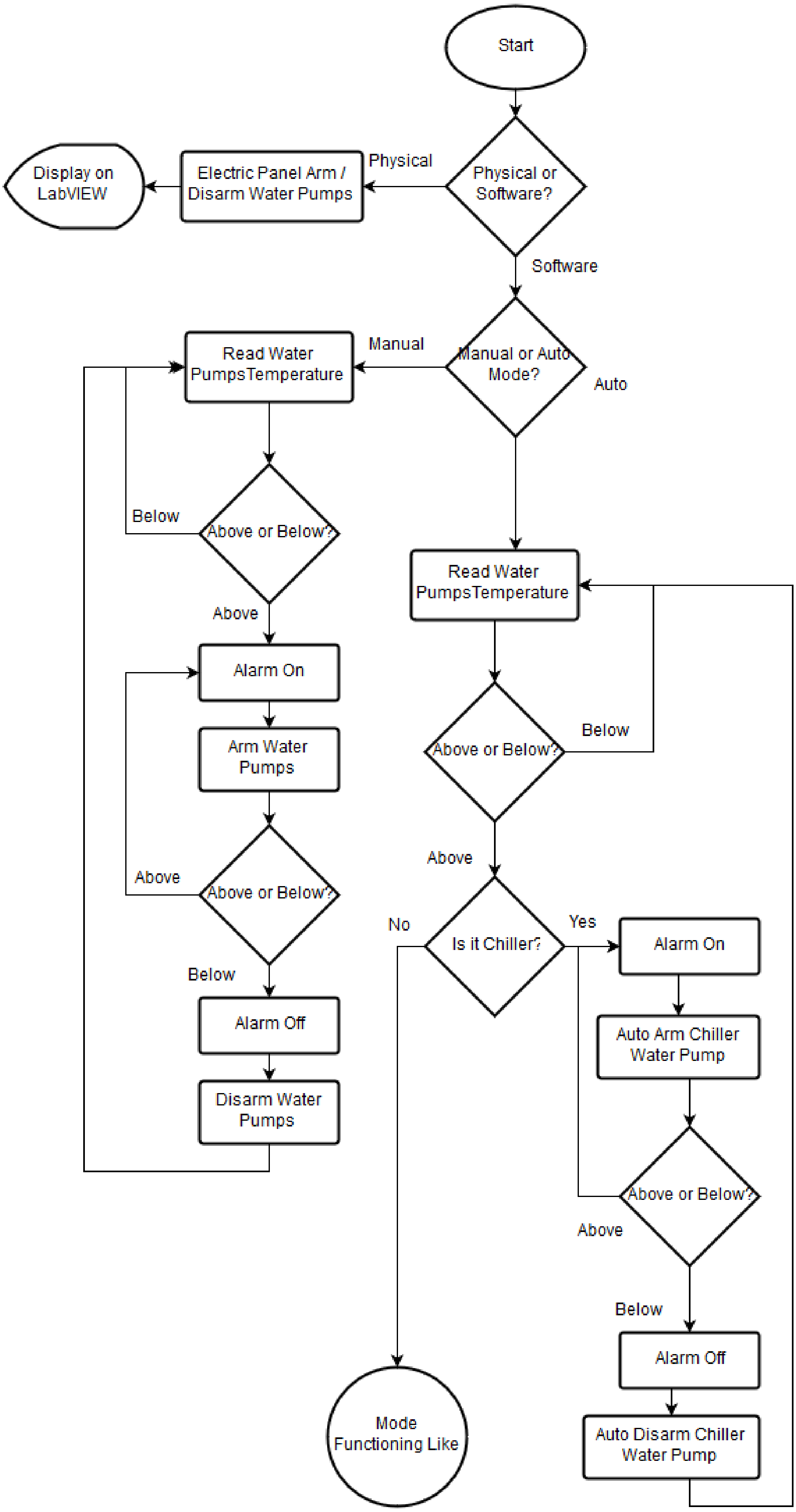

Figure 4: Flowchart of the automation system

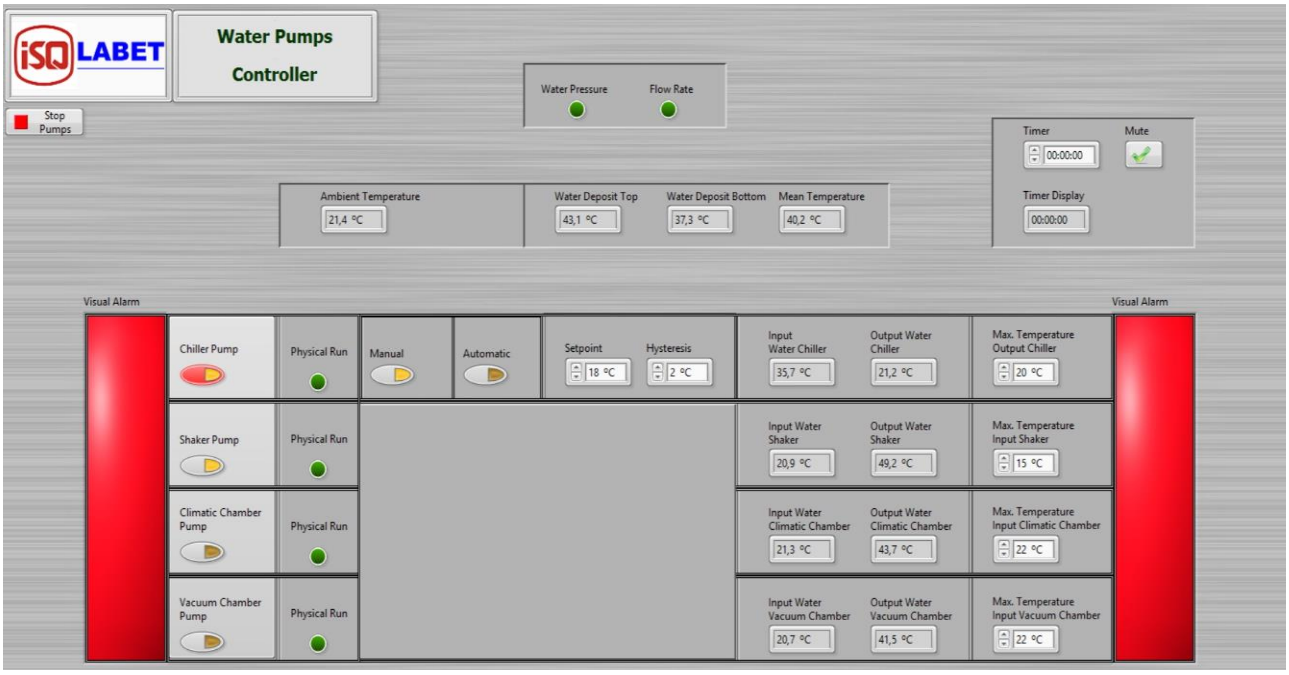

Figure 5: Screenshot of LabVIEW front panel working on software automatic mode, showing the alarm activated by the shaker water pump.

4. Conclusions and Future Work

In the paper it is described an automation project developed within the academy for industry application. It is a successful example of contribution between academia and industry that shows the importance to develop applied projects in order to transfer know-how from universities to the industry but also to understand what are the industry problems and how they can be solved based on technological knowledge.

It was developed a LabVIEW-based SCADA system to monitor and control a refrigeration system used in the control temperature in experimental tests.

As all the control program is running on the PLC, if any faults occur on the network or on the computers that are running the application, the system secures the integrity of the refrigeration system. The functionality is ensured by the PLC that reads the temperature values and activates the sound alarm based on the *setpoint* that has been set before the failure.

For future work it will be also implemented two other major factors that can disarm the chiller water pump. It will be considered the circuit water pressure and water flow rate in order to improve the integrity of the system.

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5. References

[1] Etzkowitz, Henry. The triple helix: university-industry-government innovation in action. Routledge, 2010.

[2] Farinha, Luís; Ferreira, João; Gouveia, Borges; Networks of innovation and competitiveness: a triple helix case study, Journal of the Knowledge Economy, 1-17, 2014, Springer US.

[3] Carlos Eduardo Lopes da Silva, Ramon Baptista Narcizo, Rodolfo Cardoso, The Proximity between Academy, Industry and Government: Towards a More Sustainable Development of a Brazilian Oil Region, Procedia - Social and Behavioral Sciences, Volume 52, 2012, Pages 100-109, ISSN 1877-0428.

[4] P. Panchal, A. Patel and J. Barve, "PI control of level control system using PLC and LabVIEW based SCADA," Industrial Instrumentation and Control (ICIC), 2015 International Conference on, Pune, 2015, pp. 1196-1201.

[5] S. G. Hegde, S. R. Desai, D. R. Gajanan, S. B. Kowligi and Sachin RC, "Implementation of SCADA in industries using wireless technologies," Industrial Instrumentation and Control (ICIC), 2015 International Conference on, Pune, 2015, pp. 143-148.

[6] M. N. Ashraf, S. A. B. Khalid, M. S. Ahmed and A. Munir, "Implementation of Intranet-SCADA Using LabVIEW Based Data Acquisition and Management," Computing, Engineering and Information, 2009. ICC '09. International Conference on, Fullerton, CA, 2009, pp. 244-249.

[7] M. Endi, Y. Z. Elhalwagy and A. hashad, "Three-layer PLC/SCADA system Architecture in process automation and data monitoring," Computer and Automation Engineering (ICCAE), 2010 The 2nd International Conference on, Singapore, 2010, pp. 774-779.