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Semi-virtual Plant for the Modelling, Control and Supervision of batch-processes. An example of a greenhouse irrigation system

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Abstract: In this work, a hardware-software architecture for control engineering education is proposed and a case of study regarding a greenhouse irrigation virtual process has been implemented. This specific process is especially useful for subjects related to industrial automation, since it is characterized by mixed dynamics (continuous/discrete) and can be controlled by a Programmable Logic Controller (PLC). In such a case, there is no need to access to the real process that is not always available for practical exercises. Moreover, the developed scheme eliminates the maintenance costs related to real process, being a very important advantage for academic institutions. The developed architecture for the industrial process simulation uses Labview, OPC, MODBUS, SolidWorks and Schneider Modicon M340 PLC for the control of virtual processes. The developed example is applied to the greenhouse fertirrigation control that enables the agricultural engineering students to design the irrigation control system. The control strategy is implemented on the PLC which interacts with the virtual process by carrying out the necessary actions in order to control the appropriate variables of the process.

Keywords: virtual plant, engineering education, greenhouse, irrigation control

1. INTRODUCTION

Nowadays, the introduction of automatic control techniques for agricultural sector in production and postharvest processes is experiencing a considerable growth. Obviously, the greenhouse production stage is the most important one, and thus, a significant effort should be made to improve both the quantity and quality of the fruit. Moreover, crop growth is mainly determined by environmental climatic variables and by the amount of water and fertilizers that are applied through the irrigation system; thus the growth of the crop can be controlled by manipulating these variables. For this reason, the use of greenhouses is ideal for growing crops since these variables can be controlled to achieve an optimal growth and development of plants. The growing demands for quality and variety of products at increasingly competitive prices, are determining the use of different technologies to both increase the performance and to accelerate the production cycle. Once the optimum conditions for growth and development of plants are determined, the next step consists on the design and implementation of control systems able to get the maximal potential of the crop growth. The process automation and the use of appropriate controllers represent the first step, that enables the execution of such a complex tasks (Rodríguez and Berenguel, 2004).

PLCs are normally used to build automation systems which are applied to processes characterized by a sequential evolution. This is mainly due to PLCs' modular architecture based on microprocessors or microcontrollers which can be programmed to control the selected variables in real time. Additionally, they are designed to deal with industrial environments providing standardized peripherals (Porras and Montanero, 1994; Schneider Electric, 2015). In agricultural sector, there are numerous processes that exhibit sequential (discrete) or mixed dynamics (continuous and discrete) that must be controlled. For example, in the fertirrigation system is not only necessary to keep certain variables controlled (eg. supply tank levels), but also it is necessary to perform an ordered sequence for valve opening, engine ignition, activation of mixers, etc. Therefore, the fertirrigation control systems are essential tools to deliver water and fertilizers to the crop

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in the required amount and frequency. Hence, the use of them is optimized, avoiding stressful situations that can adversely affect production. This feature enables high levels of efficiency in water use, fertilizer and energy. In consequence, its main objective is to reduce productions costs and water consumption. Initially, irrigation control systems consist of simple timers, but equipments have evolved into more complex systems based on computers that control fertirrigation based on environmental changes and on the crop development stage. The selection of the appropriate automation level for each case should be made as a function of technical and economic criteria determined by individual preferences of the farmer. The lowest level of automation consists of valve opening and closing, that can be extended by including control of other factors to consider finally the control of the whole system. In any case, it will be required to have at the disposal of qualified staff and to provide adequate technical services.

Taking into account the aforementioned aspects, the knowledge of this kind of control systems is essential in agricultural engineering education. Hence, it is vitally important that students can design the irrigation control system and implement it into the PLCs that are widely available at the automation labs of the University of Almería. The problems arise at the practical evaluation of developed control strategy since real industrial plants are not usually available for students training purposes. Additionally, the application of the proposed architecture suppresses the plant maintenance costs and increases the understanding process since each student can perform as many tests as needed in order to check the influence of different control system parameters (Rodríguez et al., 2013). In this work the hardware-software architecture (based on Labview, OPC, MODBUS, SolidWorks and Schneider Modicon M340 PLC) introduced in Rodríguez et al. (2013) has been extended to batch-processes. In addition, the developed scheme is implemented to the fertirrigation control system in order to show its efficacy. The objective of this development is to replace the manual trainers used to simulate process evolution with a dynamic graphical virtual environment to improve the education experience.

This paper is organized as follows: Section 2 shows an introduction to the educational framework in which the work presented in this paper is used. Section 3 includes a description of the main changes proposed to adapt the hardware-software architecture presented in Rodríguez et al. (2015) to processes with a mixed nature. Section 4 is devoted to discuss the main results. More specifically, a practical case of study about a greenhouse irrigation system is widely analysed. Finally, in Section 5 the main conclusions and future works are summarized.

2. EDUCATION IN AUTOMATION AND BATCH-PROCESSES

The province of Almería presents the highest worldwide greenhouses concentration (more than 35000 hectares). For that reason, the Agricultural Engineering Degree offered by the University of Almería is one of the most representative degrees at this university supported by a wide teaching and research experience within this field. The main objective of this degree is the academic training of engineers with a large theoretical and practical knowledge about intensive crops, the use of new technologies in agricultural production and the sustainable development of rural communities.

On the other hand, the tools and methodologies for advanced process control have been developed in order to maximize process capacity, yield and product quality, to save energy and raw materials reducing, at the same time, process variations and human intervention. Often, business and production requirements require to carefully evaluate automation decisions and finding better ways to solve problems. A system of Advanced Process Control allows you to develop batch control applications and to provide a flexible production environment. Thus, at the University of Almería different subjects focused on the automation of this kind of processes are taught. These subjects have the following objectives:

- Exposing the concept of automatic control system distinguishing between continuous and discontinuous control, as well as the choice of each one of them depending on the type of control problem.
- Explaining the concept of continuous controllers tuning, describing some of the basic techniques for carrying out this process, and the implementation of PID controllers.
- Studying the main characteristics and types of sequential controllers, considering the external and internal architecture of a PLC and its operating principles.
- Explaining the IEC1131-3 Standard, so objects, blocks and programming languages for PLCs.

Finally, students will be able to perform the basic steps needed to complete the design of "batch" type processes control applied to different industrial environments. The development of the above objectives will allow students to:

- Be aware of the need of industry automation.
- Focus on skills from the point of view of new technologies.
- Apply the learned concepts and techniques to real systems.
- Compare different systems by studying their advantages and disadvantages. Therefore, the possibility of select an appropriate system as a function of the characteristics of the industrial process.

As an example, the subject of "Automation and Process Control" (Agricultural Engineering degree) is divided into two main content blocks, see Table 1. More specifically, Block I is dedicated to *Agrifood Process Control* and the second block is about *Agrifood Process Automation*. In addition, both of them are composed by theoretical lessons and a laboratory practice, with a total duration of 3 ECTS credits each of them.

More concretely, in order to complement the theoretical concepts learnt by students, an agricultural process automation problem is assigned to each work-group. This problem is composed by both continuous and sequential processes which can be modelled and controlled through the available resources at the University of Almería.