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IMPLEMENTATION OF AN AUTOMATED SYSTEM FOR THE CHEMICAL REACTION MICRO-PLANT MODULE, SUPERVISED BY SCADA SYSTEM

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ABSTRACT

The purpose of this research work is to provide control techniques, implementation of sensors, programmable logic controllers, pumps and actuators in general; that allow to repower the didactic module of electricity generation through the use of a PEM fuel cell. Once the process was analyzed in its different stages such as: distilled water level, chemical powder dosing and mixing reaction tank; it was possible to incorporate in each subprocess the elements according to each requirement such as ultrasonic sensors for level, particle sensors per million, placement of solenoid valves for water flow passage, mechanical actuators for chemical powder dosing and all this is controlled by a low-end PLC. And for a correct monitoring of the process, a SCADA system is implemented with all the variables incorporated in the process. As a final result, the automation of the module makes it have a better performance; and the use of control techniques such as the PID implemented for the PEM pile, means that it always has a correct and continuous flow of pressure.

KEYWORDS: PEM fuel cell, PID control, SCADA, solenoid valves, sensors.

1 INTRODUCTION

The search for energies that are generated by replacing diesel and coal, has led several countries to look for renewable energies using wind, solar radiation, the movement of waves, use of the heat of magma and countless energies that can be obtained from nature. The didactic module in which we work generates electrical energy in low proportions using a mixture with distilled water and a reactive chemical that, when mixed produce a reaction, this mixture is sent to a hydrogen generator, which recirculates the prepared mixture and gradually extracts the hydrogen to enter a PEM type fuel cell that is responsible for generating direct current electricity of approximately 12VDC. This voltage can be converted to alternating current by means of an inverter.

The approach of this work is based on the automation of the existing process that is located in the chemical reaction micro-plant. The dosage of the chemical with water was exposed to a certain temperature in another tank and then placed in the chemical tank, this process was carried out to generate a chemical reaction before it was mixed with the water found in the mixing tank. The entry of water and chemical mixture was executed with a manual key and it was not possible to visualize any of the variables in the process such as: the level of water in the tanks, number of particles per million of hydrogen produced and consumed by the PEM pile.

By means of a SCADA system, the construction and implementation of tanks, sensors, actuators and PLCs it is possible to monitor the entire process in real mode. In turn, a batch system doses the amount of chemical powder required.

It is important to implement some type of traditional control, to ensure that the PEM fuel cell is always powered by hydrogen, despite the drops produced by electricity consumption. The control techniques studied are based on the Proportional, integral and derivative PID controller.

General objective

Implement an automated system for the chemical reaction micro-plant module, supervised by a SCADA system.

2 METHODOLOGY

Methodology is techniques or procedures to address a problem in an orderly and efficient manner, the research methods used are:

Experimental

Technique: Observation/Modeling and analysis of statistical data is carried out. Research by the level of knowledge is considered:

Application: Because it helps to better understand the principles of this case.

Quantitative: Because the information on results is taken to support what is sustained.

Fig. 1 shows an automatic system for the entry of distilled water into the filters, the entry of the chemical necessary for the mixture, an agitator to obtain a homogeneous mixture and the supply of the fuel cell for the generation of electricity.

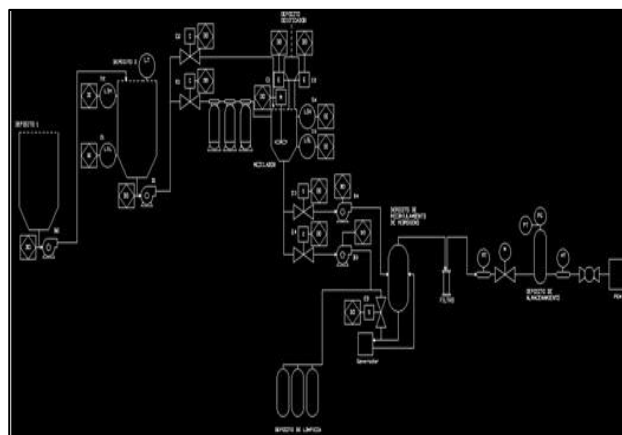


Fig. 1 Proposed solution

It is also proposed to place a closed control loop for the pressure that is generated at the exit of the process and in turn to the fuel cell, for this a PID control is necessary.

A diagram of the control loop is shown in Fig. 2.

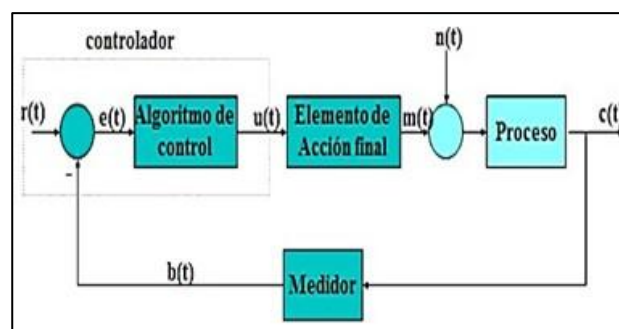


Fig. 2 Control Loop. In original language: Spanish

Theoretical foundation

Fuel Cell

It is a device that has as a mechanism to transform the chemical energy of hydrogen into electrical energy omitting the combustion step, this makes it an efficient process since it avoids the exploitation of hydrocarbons, as can be seen in figure 3, it is made up of an electrolyte and two electrodes (an anode and a cathode) on the sides.

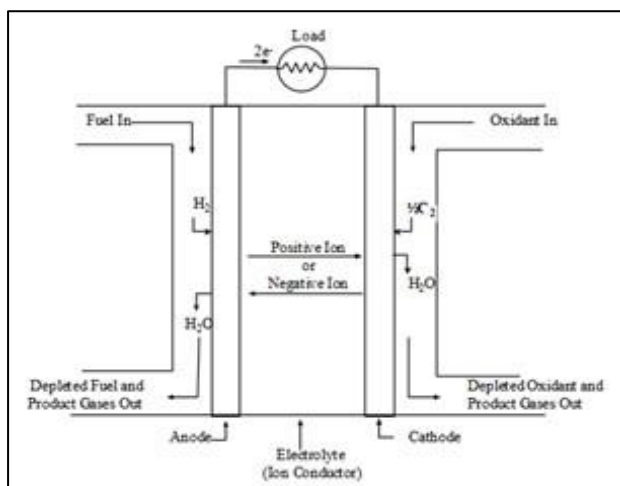


Fig. 3 Fuel Cell

Fuel Cell Operation

An electrochemical reaction is generated in the electrodes by introducing a fuel (hydrogen) into the anode and an oxidant (oxygen) into the cathode. Hydrogen oxidation and oxygen reduction are performed, which produces a displacement of electrons from the anode to the cathode, by means of an electrolyte, resulting in the generation of electrical energy. See Fig. 4

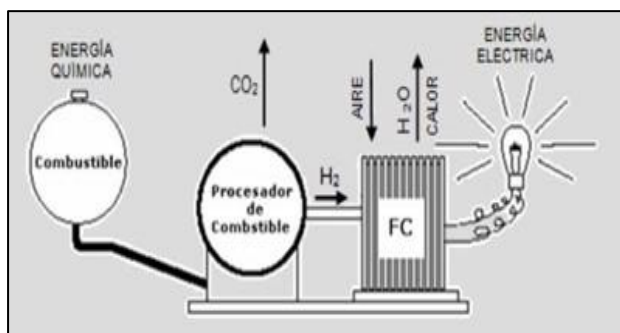


Fig. 4 Diagram of operation of a Fuel Cell. In original language: Spanish

Classification of Fuel Cells

They are classified according to the type of electrolyte, its power capacity, temperature and performance.

Proton Exchange Membrane (PEM) Fuel Cell

The electrolyte used by this type of battery is made up of an impermeable polymeric membrane that separates the gases produced at the anode and cathode.

It works at low temperatures between 80°C and 95°C, it has a quick response at its outlet to have a continuous supply according to the energy consumption to which it is exposed.

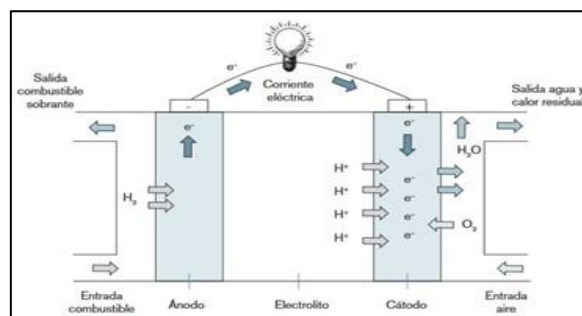


Fig. 5 Fuel Cell (PEM). In original language: Spanish

They use an alkali or a mixture of water with KOH as an electrolyte, allowing rapid electrochemical reactions to be obtained, for which an efficiency of 70% is obtained.

They can work in high temperatures of 100°C to 250°C and in low temperatures of approximately 23°C to 70°C.

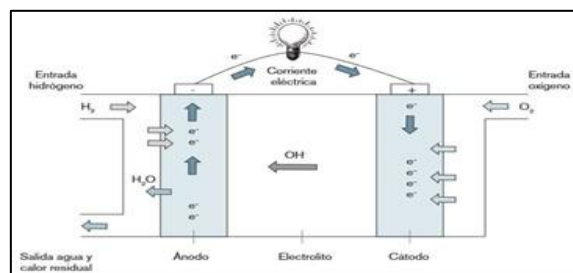


Fig. 6 Alkaline Fuel Cell (AFC). In original language: Spanish

Phosphoric Acid Battery (PACF)

It uses phosphoric acid as an electrolyte, which is a disadvantage when working at low temperatures as the electrolyte loses its conductivity properties.

Therefore, this type of battery works in high temperatures from 150°C to 220°C.

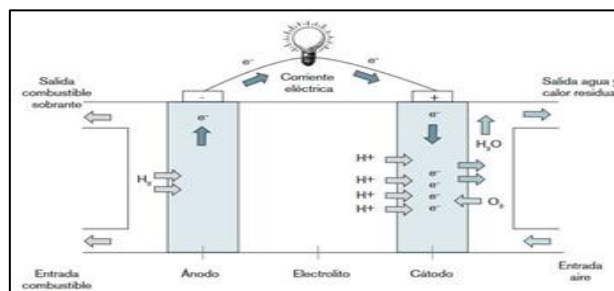


Fig. 7 Phosphoric Acid Stack (PACF). In original language: Spanish

Molten Carbonate Pile (MCFC)

This type of battery uses a polymer membrane as an electrolyte, reaches an efficiency of 40% and works at a temperature of 50°C to 100°C.

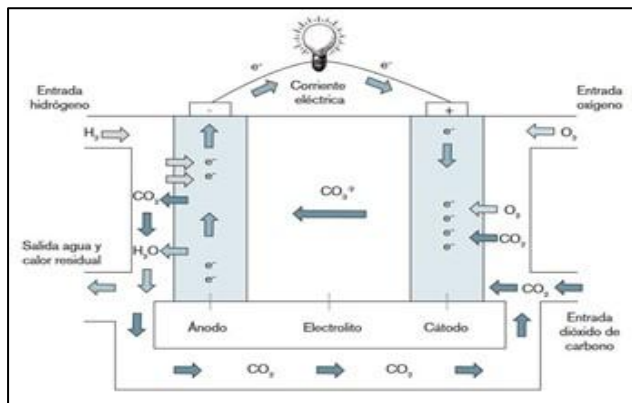


Fig. 8 Molten Carbonate Pile (MCFC). In original language: Spanish

Solid Oxide Pile (SOFC)

It uses zirconium or calcium as an electrolyte, therefore, there is 50% efficiency. It works at temperatures of 1000°C thus helping the conductivity of the electrolyte.

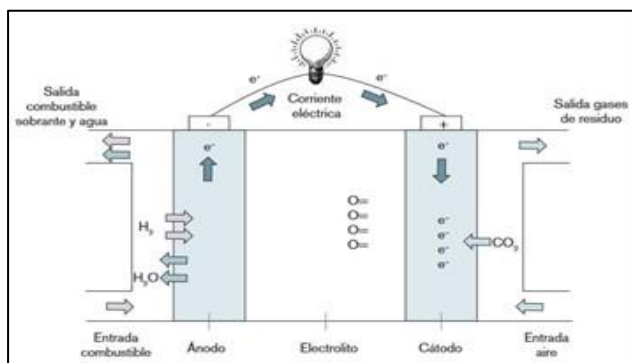


Fig. 9 Solid Oxide Pile (SOFC). In original language: Spanish

Hydrogen Generator

Hydrogen Generation by Electrolysis

Electrolysis consists of separating the chemical composition of water into two gases: hydrogen and oxygen.

In a cell with water, two electrodes are introduced to which a current is applied, these electrodes are separated by an electrolyte that helps in the conductivity of the electrons, in this way hydrogen is generated in the cathode and in the oxygen anode.

SCADA systems.

Scada (Supervisory Control And Acquisition or control with data supervision) is a software that has the function of remotely monitoring and supervising industrial processes through an interface that allows communication between the system and the user.

The main characteristics of a SCADA are the following:

- Collection and storage of data on the information received.
- Graphic and animated design of process variables and their monitoring by alarms.
- Execution of control actions to modify the evolution of the process, through the connected outputs.
- Connectivity to other applications and databases.
- Supervision, to observe the evolution of the control variables from a monitor.
- Database.
- Presentation, graphical representation of the data.

A SCADA system has been created to monitor from a single point, the different processes of one or more plants. [20]

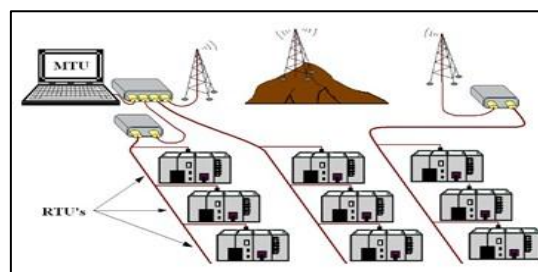


Fig. 10 Components of a SCADA system

PID Controller

PID controllers allow control of the processes normally found in industries to be obtained through a closed-loop system and is composed of three actions: proportional (P), integral (I) and derivative (D).

These actions can be derived into P, PI, PD, and PID controls

The proportional action P handles an adjustable gain K_p , which is proportional to the signal obtained in the process.

In the PI control, through the integral action, it allows to observe in the graph a signal of increasing or decreasing control that seeks to cancel the error.

In the PD control, by means of the derivative action, it allows you to observe the response time of the controlled variable to the desired value.

The PID control uses all three actions to stabilize the system, thus being the most used in industrial processes.

Closed control loop

Closed control loop systems consist of entering an input signal to the PID controller or system, which based on the output signal stabilizes the system to the desired value.

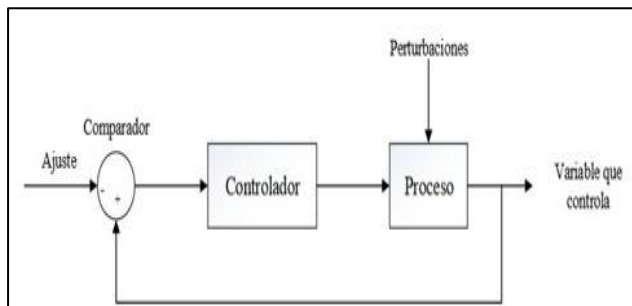


Fig. 11 Closed Loop Control System. In original language: Spanish

3 METHODOLOGICAL FRAMEWORK

Background

The chemical reaction micro-plant was designed to be operated manually. To carry out the operation of the panel, the water was entered into the main tank manually until its maximum level was obtained, and then the pump was activated that allowed the water to pass through the filtering stage and reach the Mixing Tank. The chemical substance had to be prepared later in an individual container and heated manually, once this process was carried out it was entered into the Premix Tank and then valve 1 was opened and this chemical substance fell into the mixing tank. Once this stage was completed, valve 2 was opened so that the mixture of purified water and chemical water reached the hydrogen generator and finally obtained electrical energy.

4 RESULTS

The values obtained manually using the Ziegler-Nichols method were improved to obtain better stability in the motorized valve, when working with small pressures it tended to be destabilized.

Thus obtaining a better graph with a more stable motorized valve without voltage peaks and a better response time.

A stable pressure was also observed, the system works with a maximum pressure of 15PSI and a minimum pressure of 8 PSI.

To verify the stability of the system, several tests were carried out with different Setpoints, obtaining optimal results.

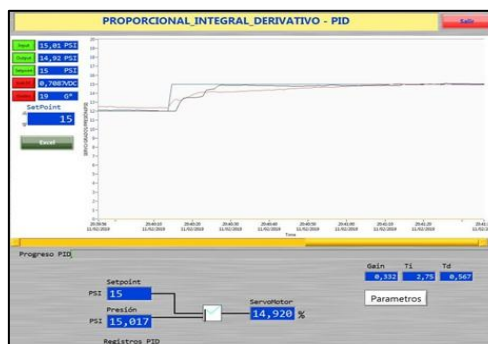


Fig. 13 Setpoint from 12 PSI to 15 PSI. In original language: Spanish

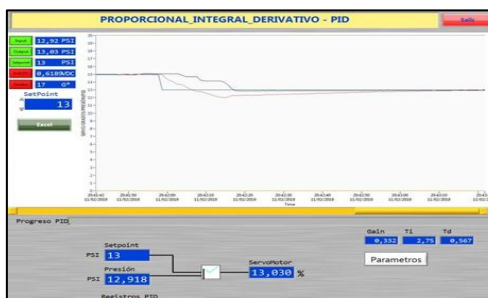


Fig. 14 Setpoint from 15 PSI to 13 PSI. In original language: Spanish

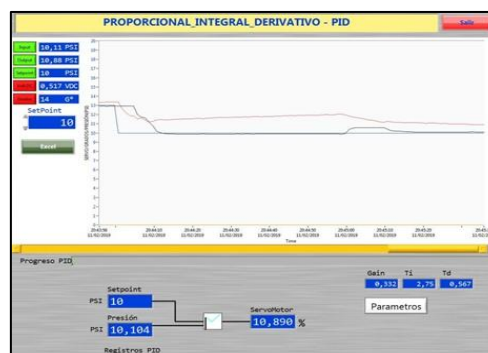


Fig. 15 Setpoint from 13 PSI to 10 PSI. In original language: Spanish

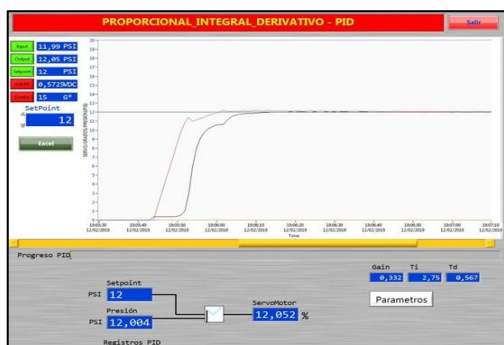


Fig. 12 Improved PID system. In original language: Spanish

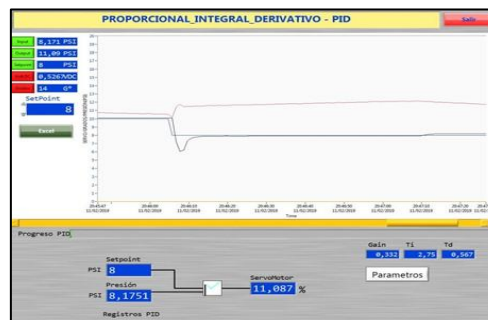


Fig. 16 Setpoint from 10 PSI to 8 PSI. In original language: Spanish

To change the parameters of our PID in the SCADA system we click on the "Parameters" button, enter

username and password.

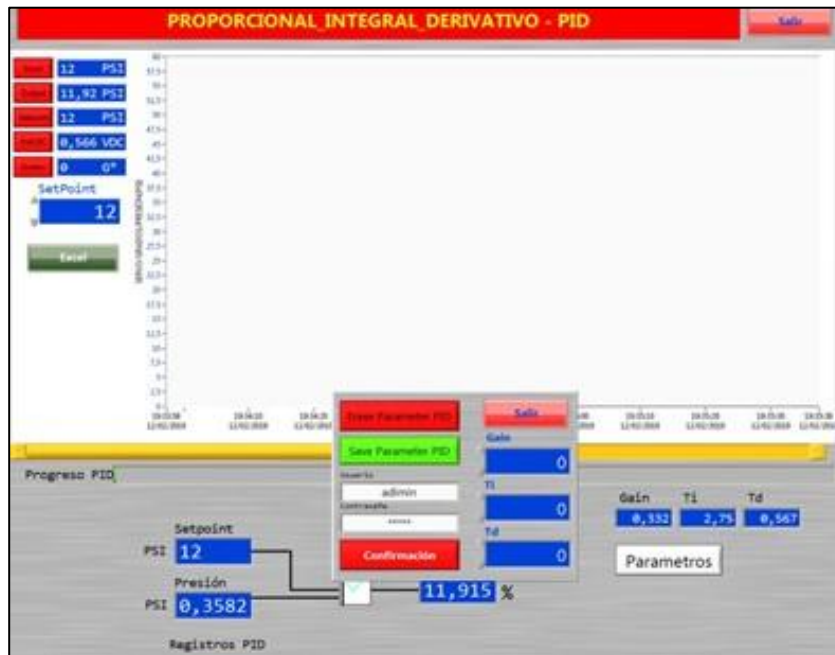


Fig. 17 PID - Username and password. In original language: Spanish

Through the Labview program, the values of the signals during the execution of the system were obtained, also called "Historical", to obtain this table

we will click on the "Excel" button to generate the file. We can also see the table on the SCADA screen.

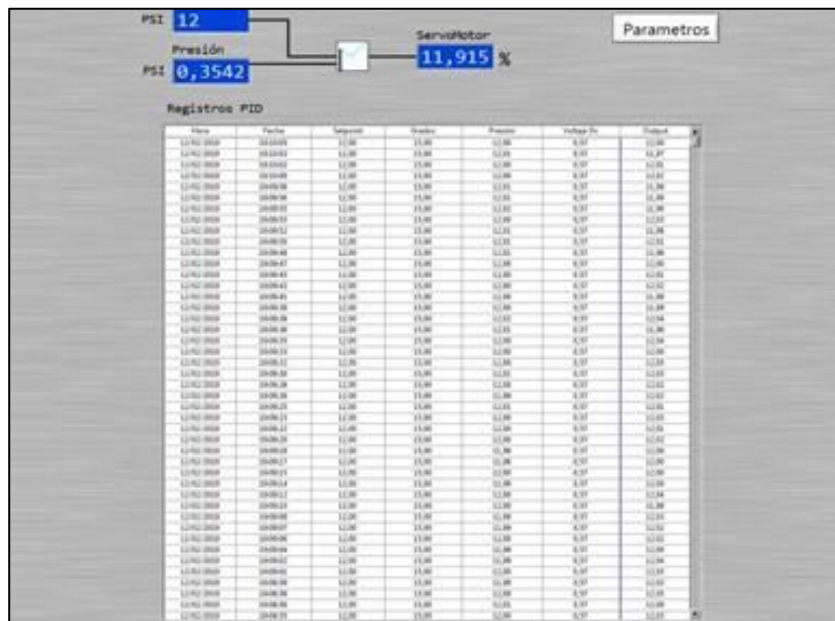


Fig. 18 Table of Historical. In original language: Spanish

5 CONCLUSIONS

It is possible to show in the previous chapters that the process goes from being manual to a continuous and automatic process, implementing water pumps and mechanical actuators for the correct dosing of the

chemical powder for the generation of hydrogen. The control for hydrogen consumption was established by theoretical techniques such as Ziegler and Nichols that provide a starting point for the PID controller to be able to refine it through various tests.

For these tests, compressed air is used to verify the correct operation of the PID controller, since the hydrogen generation system is not enabled and is developed by another group of thesis students. Despite the automation and implementation of a PID controller, implementing the SCADA system provides the user with comprehensive supervision of the entire process, through screens strategically

placed on each element of sensors and actuators that allow each of the variables used to be seen in real time.

In the execution of the project, it has been possible to put into practice all the knowledge acquired throughout the university career, thus achieving each of the objectives established in the project.

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