HARDWARE CONFIGURATION OF THE CONTROL SYSTEM FOR THE CONTROLLED HYDRIDING INSTALLATION

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Abstract

This paper presents the automation solutions for the controlled hydriding process through modern means of acquisition and control. The hydriding of zirconium consists in the direct interaction between pure hydrogen and metal / metallic alloy. The control of the hydriding process is achieved by introducing specific quantities of hydrogen. The proposed hardware configuration addresses possibilities of interconnection of process equipment and automation instrumentation with PLC (Programmable Logic Controller) type hardware modules. Solutions were proposed for the integration of new-generation, intelligent type instrumentation, facilitating an easier interfacing with the equipment in the process. Safe technologies for information transmission in industrial environments were also proposed.

Keywords: *Controlled hydriding, Programmable logic controller, Smart instrumentation*

Introduction

Complex technological processes require the control of a significant number of variables and the solution of communication problems induced by the distribution of equipment.

In many cases, the nuclear power plant (NPP) control is achieved by a group of control programs and hardware logic that monitors and adjusts the parameters, to ensure the NPP safe operation.

At the technological level, a shared bidirectional communication environment is used to interconnect in parallel the automation equipment (sensors, execution elements), control or configuration and maintenance equipment.

The transmitted information is formed by measured or command signals, as well as information regarding the status and operation mode of the interconnected equipment. The implemented communication protocols must to efficiently manage the high data traffic and to allow the addition of new components without stopping the operation of the system.

The way to measure and control the controlled hydriding process is to introduce known quantities of hydrogen. The controlled hydriding of U-Zr-Er alloys (in form of baguettes) is carried out under certain conditions of pressure and temperature [1].

The determination of the hydrogen amount in the hydrided baguettes is done by the difference between the hydrided baguettes mass and the metal baguettes mass.

The hydride composition (hydrogen/zirconium ratio) depends both on the hydrogen pressure and the temperature at which the hydriding treatment is performed. There are well-defined relationships between hydrogen content, working temperature and hydrogen pressure.

The aim of the paper is the automation of a controlled hydriding installation using programmable logic controllers.

In order to automate the controlled hydriding installation, besides the technological equipment (furnace, vacuum pump and buffer vessel), two automatic measurement and control systems, one for the temperature and one for the hydrogen intake, were added.

Moreover, the automatic measurement and control systems, in addition to sensors and execution elements, contain programmable logic controllers (PLC) and their related input / output modules for the automation of the controlled hydriding installation.

The paper contains a brief presentation of the controlled hydriding process, including a description of the automatic measurement and control systems related to the process. The proposed hardware solution for the controlled hydriding installation is further detailed, and some conclusions are highlighted.

Description of the controlled hydriding process

The method generally used to hydriding of zirconium, as well as the Zr-U-Er ternary alloy, consists in the direct interaction between pure hydrogen and the metal.

The composition of the hydride (hydrogen/zirconium ratio) depends on the hydrogen pressure and the temperature at which the hydriding treatment is performed. For this reason, the rate at which the required hydrogen is supplied has a major importance on the baguettes quality [1, 2].

The hydriding process is strongly influenced by the purity of hydrogen, the main impurities being water, oxygen and nitrogen. The water and oxygen lead to the appearance of an oxide layer on the baguette surface, while nitrogen causes the appearance of a nitride layer, impermeable to hydrogen. Their presence is manifested by a low reaction rate or process failure due to the oxidation or nitridation of the metal surface.

The same effect can be induced by organic impurities (oils, fats) on the metal surface.

In order to carry out the controlled hydriding process, an installation was designed, including: controlled hydriding furnace, vacuum pump, buffer vessel with constant volume, two automatic measurement and control systems, one for the temperature and one for the hydrogen precinct (Fig. 1).

The automatic measurement and control systems (for temperature and hydrogen intake) consist of thermocouples, absolute pressure transducer, vacuum sensor, solenoid valves (SV), pneumatic solenoid valve and differential pressure transducer.

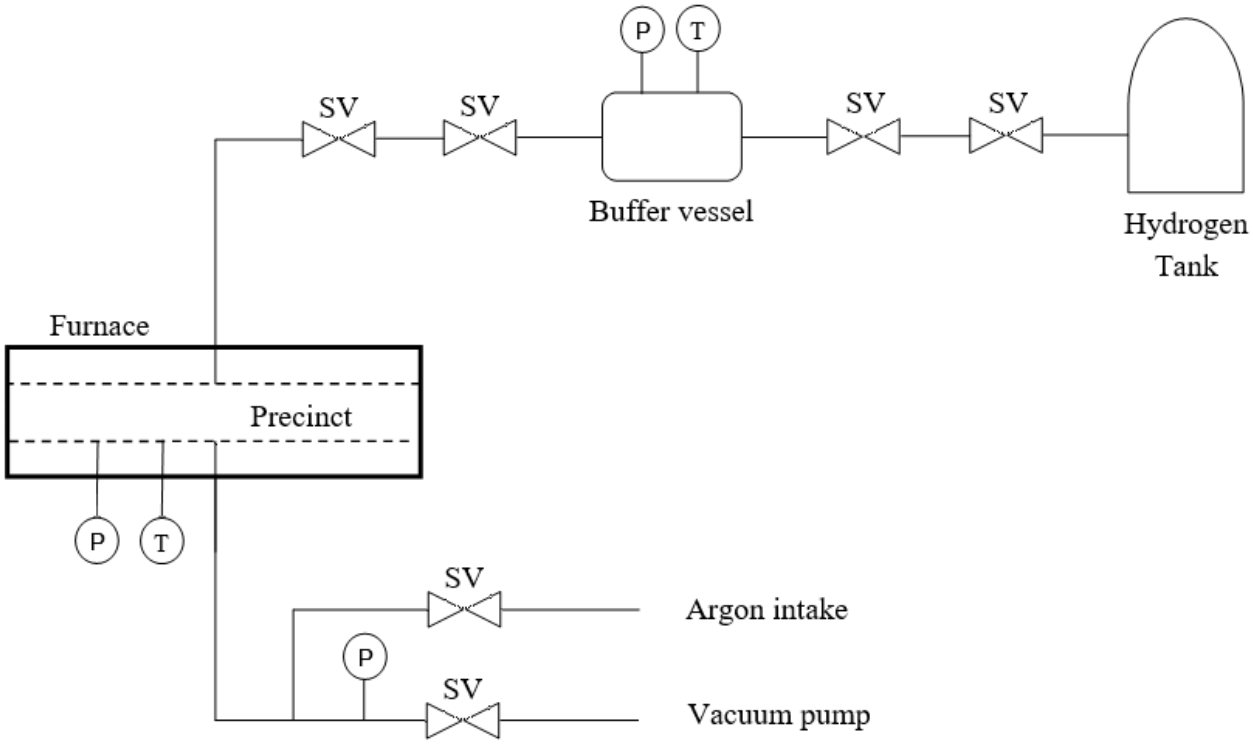


Fig. 1. The controlled hydriding installation

In the active area of the precinct, the metal baguette support system (metal support and metal tubes) is introduced. Steel tubes are used as a support for baguettes. The enclosure is connected to the vacuum pump, the automatic hydrogen intake system and has a water-cooled area.

Hardware configuration of the control system related to the controlled hydriding installation

Knowing the technological process of controlled hydriding and the components of the two automatic measurement and control systems (one for the temperature and one for the hydrogen intake), the interconnection possibilities of the important process equipment are specified in order to establish an optimal hardware configuration, namely: hydriding furnace, vacuum pump, absolute and differential pressure transducers, valves and thermocouple.

The controlled hydriding furnace is a tubular furnace, with uniformly heated zones, equipped with a controller that allows the furnace temperature control, data recording and bidirectional communication with a Siemens PLC [3-5] through an Ethernet communication port. The communication between the two devices will be realized through an industrial Ethernet switch, using Modbus TCP communication protocol. Also, the furnace is provided with the possibility of configuring three user thresholds (operator, supervisor and engineer).

Since the furnace is provided with a precinct, for a more accurate control of the inside temperature, an additional thermocouple type R with compensation and plug (identical to those installed in the oven) will be used, connected to the thermocouple input on its input/output panel.

Thus, using this thermocouple and two controllers for the terminal ends of the heated zone (edge), through the cascade control function of the controller, it will be possible to control, with greater accuracy, the temperature from furnace enclosure.

The heating elements temperature is measured separately by built-in thermocouples. The temperature controller reads all the thermocouples and calculates the amount of power needed to reach the setpoint.

According to the process technological requirements, a vacuum pump will be used to create a vacuum in the furnace. The turbo pump is provided with an integrated controller, with the role of a frequency converter.

The vacuum pump is connected to the Siemens PLC, to achieve functional control, through the serial communication port. The controller (inverter) identifies the presence of the grid and transforms the single-phase AC power supply into a three-phase, medium-frequency output, necessary for powering the pump motor.

The Siemens PLC is equipped with an RS232 communication module for controlling the vacuum pump through the serial communication protocol. For a more accurate control of the vacuum from the furnace enclosure, an external sensor will be used with the possibility of connecting to the turbo molecular vacuum pump.

Maintaining the vacuum in the furnace will be achieved by installing a pneumatic solenoid valve between the vacuum pump and the furnace. The command of the pneumatic solenoid valve is realized through a digital output of the Siemens PLC. The solenoid valve position will be identified by means of two position indicators connected to two digital inputs of the Siemens PLC.

The admission of hydrogen, according to the technological process, implies the need of an automatic system for measurement and control.

From the technological flow point of view, the installation consists of a hydrogen tank, two solenoid isolation valves between the tank and the buffer vessel, followed by two isolation solenoid valves between the buffer vessel and the enclosure of the controlled hydriding furnace.

The automatic hydrogen intake measurement and control system consists, in addition to solenoid valves, of two sensors, one temperature and one differential pressure transducer for measuring process parameters, in the buffer vessel and an absolute pressure transducer for measuring the pressure from enclosure of the furnace.

The data acquisition in the PLC, from the absolute and differential pressure transducers, is carried out by means of the analog input module, configured in current for a unified signal 4 ÷ 20mA. Two analog inputs will be used to read process pressures and use them in the control strategy.

Regarding the temperature in the buffer vessel, the process parameters are processed by the CPU, through the analog input module, configured in current. The signal from the thermocouple to the analog input module can be transmitted by converting the signal from the thermocouple into a unified 4 ÷ 20mA signal.

As previously mentioned, four electro-valves controlled by the outputs of the Siemens PLC are used to control the hydrogen intake. Also, in the same way, an electro-valve is used for argon supply at atmospheric pressure.

The process parameters monitoring and control will be possible in two ways, by using an HMI (Human Machine Interface), which communicates with the PLC through a switch, and through a central PC (Personal Computer), according to Fig. 2.

The presented solution was based on the use of a CPU (Central Processing Unit) with integrated relay outputs, with dry contact (2A each output), necessary to actuate the five solenoid valves and the pneumatic solenoid valve.

The voltage supply, necessary for the operation of the automation equipment, is provided by two voltage sources. Thus, one source provides power to the CPU, RS232 communication module, analog input module, HMI, switch, and the second source provides power to five solenoid valves and one pneumatic solenoid valve.

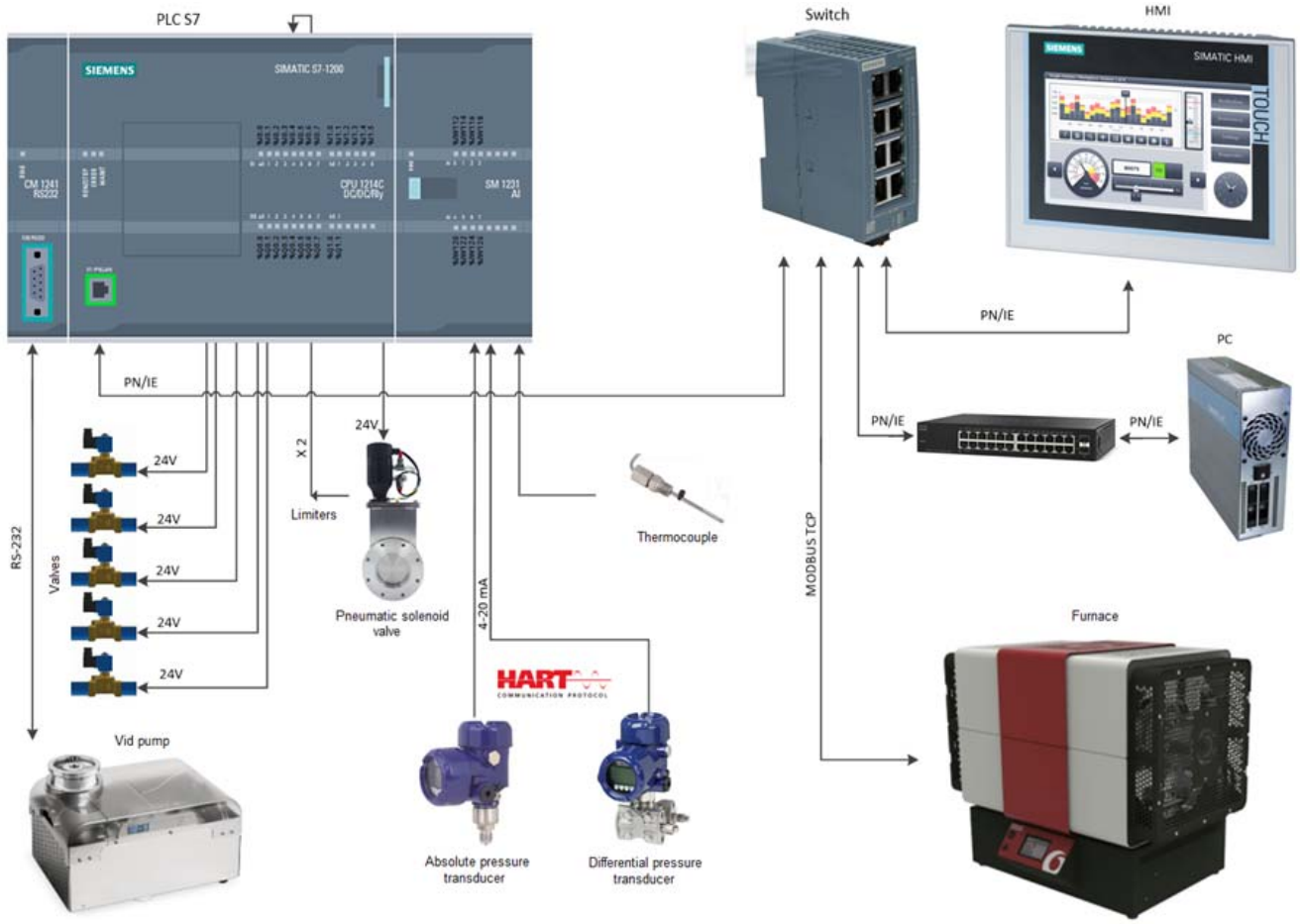


Fig. 2. Hardware configuration for the controlled hydriding installation

The proposed hardware configuration is an optimal solution, both from the point of view of compatibility between the process equipment and the automation modules, as well as from the point of view of software implementation of all the process requirements.

The final configuration was also made by analyzing several interconnection possibilities and will be implemented at the Institute of Nuclear Research Pitesti, as a result of a modernization process of the controlled hydriding installation.

Conclusions

Through this work, automation solutions were proposed for the controlled hydriding installation, using programmable logic controllers.

Based on the controlled hydriding process and the hardware configurations of the process equipment, the possibilities of their interconnection with the automation hardware modules were identified.

The solutions proposed include using of new generation instrumentation and, where necessary, of intelligent type for an easier interface with the rest of the equipment and to provide secure protocols for the information transmission in industrial environments.

It was taken into account that some data from the sensors must be transmitted at longer distances, which are not safe for certain standard information transmission protocols.

The optimized hardware configuration for the controlled hydriding furnace automation was presented, proposing possibilities of interconnection of the process equipment and the automation instrumentation with the PLC type hardware modules.

When realized the hardware configuration by using PLC-type modules, the possibility of software implementation of all the specified process requirements was taken into account.

The hardware configuration proposed in this paper is a preliminary step for the development of the application in order to optimize the operation of the installation through modern means of data acquisition and control.

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