APPLICATION OF A SCADA SYSTEM ON A HYDROGEN STATION

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Abstract: *After a presentation of the architecture of a supervisory control and data acquisition system (SCADA), we present an application of a SCADA system on a hydrogen station of a thermal power plant (TPP). Thus, the cooling techniques by hydrogen of an alternator and the description of the hydrogen circuit of a TPP have been presented. Our contribution in this work consists in integrating a module for the calculation of hydrogen flights to a SCADA system.*

Key words: *SCADA, hydrogen station, calculation of flights, thermal power plant, security.*

1. Introduction

Supervision consists of commanding a process and supervising its working. To achieve this goal, the supervisory system of a process must collect, supervise and record important sources of data linked to the process, to detect the possible loss of functions and alert the human operator [1] [2].

The main objective of a supervisory system is to give the means to the human operator to control and to command a highly automated process. So, the supervision of industrial processes includes a set of tasks aimed at controlling a process and supervising its operation [3] [4].

SCADA (supervisory control and data acquisition) systems are widely used in industry for supervisory control and data acquisition of industrial processes. The process can be industrial, infrastructure or facility.

SCADA system is used to observe and supervise the shop floor equipments in various industrial automation applications. SCADA software, working on DOS and UNIX operating systems used in the 1980s, was an alarm-based program, which has a fairly simple visual interface.

The SCADA system usually consists of the following subsystems:

- A Man-Machine Interface (MMI) is the apparatus which presents process data to a human operator. Through this, the human operator, monitors and controls the process.
- A supervisory system, acquiring data on the process and sending commands to the process.
- Remote Terminal Units (RTUs) connecting to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system.
- Communication infrastructure connecting the supervisory system to the RTUs.

In fact, most control actions are performed automatically by RTU or by programmable logic controllers (PLC). Host control functions are usually restricted to basic overriding or supervisory level intervention. For example, a PLC may control the flow of cooling water through the part of an industrial process, but the SCADA system may allow operators to change the set points for the flow, and enable alarm conditions, such as loss of flow and high temperature, to be displayed and recorded. The feedback control loop passes through the RTU or PLC, while the SCADA system monitors the overall performance of the loop [5] [6] [7].

With the advances of electronic and software technologies, the supervisory control and data acquisition systems are widely used in industrial plant automation. It provides an efficient tool to monitor and control equipment in manufacturing processes on-line. The SCADA automation system always includes several functions, e.g., signal sensing, control, human machine interface, management, and networking [8] [9] [10].

The objective of this paper is to show interests of the use of a SCADA system in a hydrogen station of a thermal power plant (TPP). An example of a SCADA system of a TPP is presented. Next, the interests of the application of the SCADA system are developed. The last section presents a discussion about some advantages of the application presented.

2. Context of the enterprise

Every day, we use the electric energy without even to be conscious of it. The electric energy serves in all domains including those where we think that it is not used (central heating of gas, thermal motor-driven vehicles...). Means of production of this energy are very various; we classify them today depending on whether they are to basis of renewable energies or fossil energies. With regard to these last, reserves not being inexhaustible, we tries to replace them by the renewable energies that have for main advantage to be less polluting.

The Tunisian Society of Electricity and Gas (STEG) is a society whose main function is produce electricity in order to satisfy needs of its customers [11] [12].

Among centers of electricity production, we mention the one of RADES that is one of the most important centers of the STEG of the point of view power installed (700 MWS). It has been inaugurated May 30, 1986. It is about a TPP producing electricity while using dry water steam to drag the alternator in rotation, this steam is generated in a furnace that transforms the chemical energy of the fuel (natural gas, heavy fuel-oil) in calorific energy.

By reason of the complex requirements and to avoid to the maximum losses of production, it is extremely important to master all aspects having milked to the security and the profitability of the highest level.

The center of RADES is equipped of a SCADA network. Stations belong to a network superior Ethernet (10 Mb/s). Mainly this network permits to do exchanges of files between the various stations. It avoids so the overcharge of the node network bus.

The SCADA system assures the surveillance and the control of electric, mechanical or electronic equipment equipping all or a part of the network. It also allows operators to command and to control all facilities of the power station, as well as to offer all necessary information to the good conduct of a stage data of the power station.

The intended role to the SCADA system is to collect data instantaneously of their sites and to transform them in numeric signals and by following to send them through the network of communication toward the main and secondary stations (Fig.1).

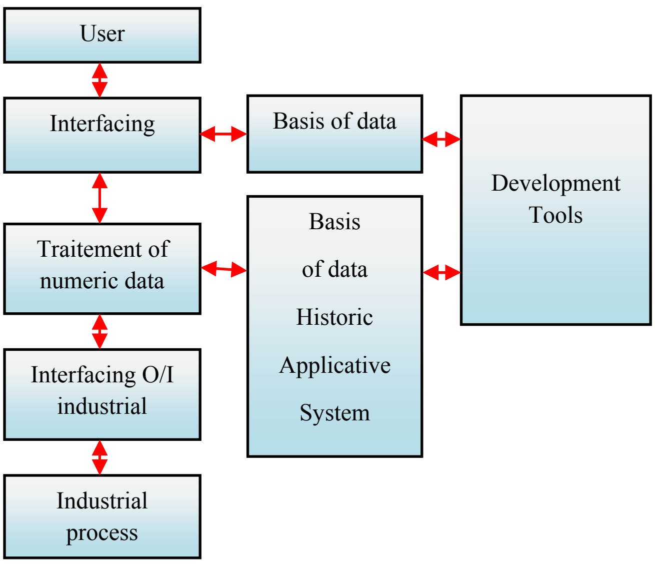

Fig.1. Principle of a SCADA system

3. Presentation of the hydrogen circuit of a TPP

In this part, we present a description of the hydrogen circuit of a TPP. This is why we present on the one hand the gas hydrogen and on the other hand the technique of interior cooling of an alternator.

3.1 Presentation of hydrogen

Hydrogen is an odorless, colorless, very light gas (more that air) and composed of two atoms of hydrogen (Tab.1). It possesses a high gravimetric energizing power: 120 MJ/kgs compared to oil (45 MJ/kgs), to the methanol (20 MJ/kgs) and to the natural gas (50 MJ/kgs). However it is as the lightest gas (2,016g/mol H_2), of where a weak volumetric power: 10,8MJ/m3 facing the methanol (16 MJ/m3), natural gas (39,77 MJ/m3). It puts a real problem of storage and transport: that it is for the utilization of hydrogen in a vehicle or for the transport in pipeline, in truck, it is the volumetric density that imports. The volumetric energizing density of H2 is not interesting that to the state liquid tablet either (700 bars).

The fact that a mixture of hydrogen and air is an exploding mixture on a large range of proportions, the machine and the procedure of utilization specified is conceived so that no exploding mixture can occur in the normal conditions of working.

TABLE I
CHARACTERISTICS OF HYDROGEN AND AIR

Characteristic	Air	Hydrogen
Density	1.00	0.07
Thermal conductivity	1.00	7.00
Coefficient transmission of heat of surfaces to gas	1.00	1.35
Specific heat	1.00	0.98
Combustion of support	Yes	No
Agent oxidizing	Yes	No

The aforesaid unforeseen conditions cannot present themselves that during the replacement. However the pressure of gas being nearly equal to the air pressure in this condition, the intensity of explosion can take place doesn't pass to the more of 7bar.

We can mention parameters that we must respect them to avoid all unexpected risk:

- Hydrogen and air must not be mixed ever.
- The dioxide of carbon must be used like intermediate gas at the time of the replacement of air by hydrogen or the opposite.
- At the time of the replacement of gas, the alternator must be opened to the atmosphere so that no pressure not passing 0.1 to 0.2bar can be developed.

The purity of hydrogen H_2 in an alternator is always maintained superior to 95% until 98% and when it decreases to 90% an alarm is given out to the panel of the local cupboard as well as the room of control. Preventing gas H_2 intern to form an exploding the mixture. It is necessary to renew a certain volume of H_2 lodged in the alternator by another volume coming from bottles H_2.

3.2 Interior cooling of the alternator

The cooling by hydrogen has been adopted for turbo-alternators in 1926. This technique has been used for the interior cooling of drivers while doing circulating of the fluid in their conducts, putting the fluid in contact with materials in which the heat is produced.

The principle of the interior cooling permitted the increase of the strength of the alternator and an efficient utilization of the hydrogen pressure.

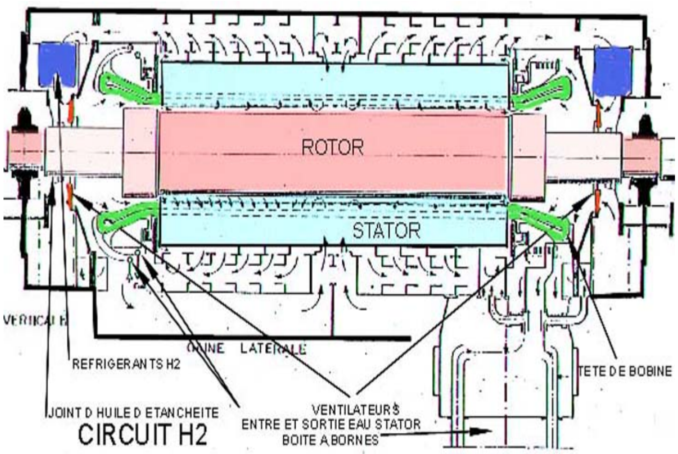

Fig.2. Cooling by hydrogen of an alternator

The cooling by hydrogen present the following advantages:

- Losses by ventilation are reduced thanks to the weak density of hydrogen.
- A strength increased by unit volume of material under tension is assured by reason of the high thermal conductivity and the big transmission coefficient of hydrogen heat.
- The maintenance cost is reduced being given that the circuit of gas retraining is entirely insulated to dusts and humidity.
- The noise of air rubbing is reduced thanks to the weak density of gas and to the circuit closed of ventilation.

3.3 General description of a hydrogen circuit

The turbo-alternator group of the center of RADES is cooled internally by gas hydrogen. As the shows the diagram of circuit (Fig.3), the device of gas control is composed by the following elements:

- A spray of carbon dioxide
- A device of gas hydrogen feeding
- A drier of gas
- A unit of surveillance of gas pressure / purity
- Command valves
- A meter of purity.

The pressure of gas hydrogen inside the alternator is maintained to a face value of 3 to ABS 6 bars, thanks to a regulator of pressure gone up on the collector of feeding in hydrogen.

In the same way, the purity of hydrogen in the alternator is always maintained to more of 95% and, when it descends to 90%, an alarm is given out, preventing the internal gas to compose an exploding mixture. The gas of carbon dioxide is used fluid how of sweep to fill to either hunt the hydrogen of the alternator in order to avoid that hydrogen and air won't be mixed in a critical condition.

At the time of replenishment of the alternator by hydrogen, the dioxide of carbon is used to hunt the air of the alternator. The valve of safety is adjusted to an ABS 6 bar pressure so that, when an anomaly occurs in the circuit of gas of carbon dioxide, the pressure of the bottle is exercised on all tubings.

The CO_2 being heavier than air, it is provided in the alternator through the lower distribution hose. It is then necessary to measure the purity of gas to the top of the alternator: the lower hose leads to the valve of command in the post office of distribution that is opened opportunely and closed.

In the same way, the puff of the meter of the purity is starting up in the alternator with the spray in start. When the purity of carbon dioxide gotten on the meter of purity is besides 75%, the feeding is stopped and hydrogen is by following introduces to its room.

By reason of its relatively weak weight in relation to the CO_2, gas hydrogen is provided with the help of the superior hose of distribution of the alternator.

The purity of gas hydrogen must be measured to the bottom of the alternator that is for it the valve of command is opened appropriately and closed. A regulator of pressure is installed between the hose of gas feeding and the station of gas hydrogen in order to maintain the pressure of the internal gas to a value wanted of 1 to 8 Abs bars.

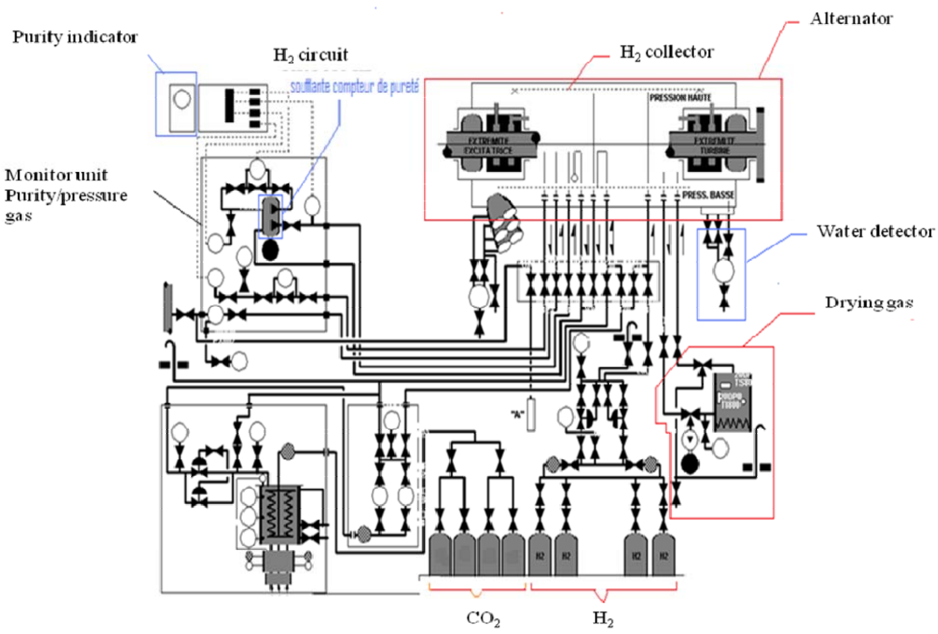

Fig.3. Circuit of the gas hydrogen of the TPP

Gas hydrogen is introduced in the alternator while manipulating the regulator of pressure or the regulator. When the purity of hydrogen measured is 95% or more on the meter, its feeding is stopped, the regulator of pressure is adjusted foreseen at the level and the pressure of the alternator is increased. Thus, gas hydrogen is introduced in the envelope, giving back the ready alternator to the working. The diagram of circuit of the system of gas control represents the position of every floodgate during the working.

Otherwise, the drier of gas, composed of a full reservoir of alumina activated (absorbing agent), of a heating device, of a puff, of a thermometer…, is installed between the circuit high pressure and the circuit bass pressure of the alternator so that gas crosses the drier all along the working of the alternator.

The absorbing agent is capable to absorb 1 kg of water thereabouts. When he reaches its limit of saturation, the drier is isolated of the alternator to dry the saturated agent to the hot air. To this effect, a puff and heating device are foreseen. Otherwise, a thermostat equips the drier in the goal of its protection against overheats it.

The drought of the absorbing agent can be appraised according to its color. Of other way, alumina activated to the dry state appears in bruise, on the other hand it appears blank grayish to the humid state.

4. Integration of a module for the calculation of hydrogen flights

In this part, we present on the one hand, the programming of the general numbering, timetable and daily of the gas hydrogen consumption and on the other hand, the configuration of a new tabular circuit gas hydrogen containing the new information.

In this work, the SCADA system assures the interfacing between the debit meters of hydrogen and stations of surveillance in the control room of the TPP. This interfacing is assured by different modules and interfacings that transform the signal of exit of the debit meter that is an analogical signal (4-20mA) in a numeric signal. Among these interfacings, we mention some: FBMS modules, FCMS modules, CP60, DNBT, AWS and WPS stations [14-17].

This is why we studied the choice of the I/O, stages of programming and the necessary block choice. This last operation is achieved by standard algorithms called blocks provided by the Foxboro software.

4.1 Position of the problem

The center of RADES arranges a regulator of pressure that assures the feeding of H_2. When the uncommunicative gas in the alternator and the pressure is increased the regulator in will be stopped. The calculation of hydrogen flights makes himself by hand therefore we cannot have an exact value on these flights. This value is not displayed on the SCADA system [13].

The daily taking of values of numberings of flights of hydrogen consumption decreases the precision of calculation of the output of every slice.

4.2 Proposed solution

To remedy these problems we propose a solution of automatic reading of the value of the gas hydrogen flight. The proposed solution is to make the calculation of flights by the SCADA system and to program blocks of the daily calculation. This solution is automatic and cyclic where the period of the time is stationary.

The proposed solution is represented as follows:

- To read the present values of the pressure and the temperature of hydrogen.
- To trigger a temporal meter of one hour or 24 hours.
- To read values of the pressure and the temperature of hydrogen after a period chosen T.
- To apply the formula used below for the calculation of the gas hydrogen flight:

$$L = 0.4S \times \left(\frac{P1 + B1}{273 + t1} - \frac{P2 + B2}{273 + t2}\right) \times \frac{24}{T}$$

  L: value of flight (m^3/jour)
  S: volume of the alternator (m^3)
  P_1, P_2: pressure of hydrogen (HG mm)
  B_1, B_2: air pressure (HG mm)
  t_1, t_2: middle temperature of hydrogen (°C) between the value of the entrance refrigerating and the exit refrigerating
  t = (t entr refr + t exit_refr$_1$ + t exit_refr) / 3
  T: lasted of test (H)

- To display the final result.
- To return in the beginning.

A second manual solution consists in reading the present values of the temperature and the pressure. We define a period of calculation and we reach the historic of the SCADA system and to take the previous values and to apply the formula. The problem that imposes is himself here that this solution is not efficient and the found values are not still precise.

4.3 Realization of the solution

In order to achieve the retained solution permitting to integrate a module for the calculation of hydrogen flights, we proceeded to the following three stages: programming of blocks, configuration and conception of the tabular.

The algorithmic of treatment is based on the concepts of block and diagram (or compound). Indeed, a block is a software entity that achieves a specific function more less complex (stake to the ladder, conversion, filtering, calculation, test of alarms, etc.) definite by its algorithm.

The CALC block permits to achieve some logical and arithmetic operations in chain to the manner of a programmable calculate.

The AIN block does the reading of the raw value (0 to 65535 points) a way of entrance of a module FBM217 achieves then on a read data of conditioning functions (characterization, stake to the ladder, limitation), of filtering and alarm.

The SIGSEL block arranges eight analogical entrances (INP1 to INP8) and deliver to its exit (OUT) a value based on those of its entrances and the criteria of selection kept (maximal value, minimal value, middle value or median value).

For example, figure 4 presents the introduction of parameters of the SIGSEL block for the calculation of the middle temperature of hydrogen in the alternator.

For the configuration stage, we used the ICC software (Integrated Control Configuration). This software permits the creation and configuration of the resident program in the CP60.

Figure 5 presents the configuration of the display of the alarm of the signal.

For the conception stage of the tabular, we used the FoxDraw software. This software possesses a library of components permitting to represent the various elements of an industrial installation (Fig.6).

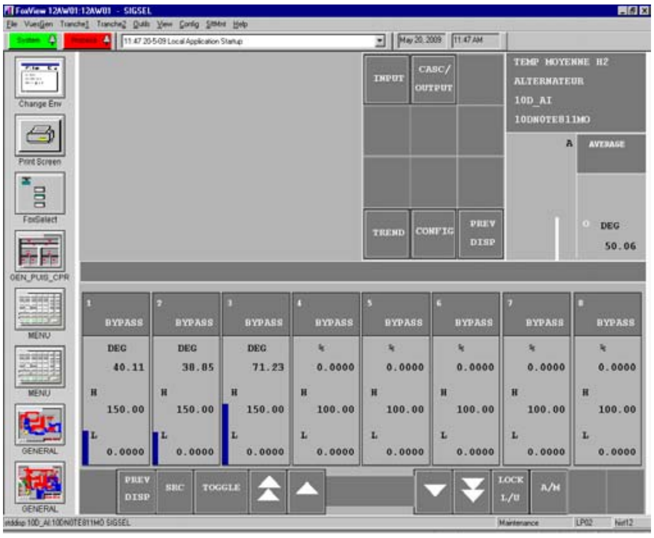

Fig.4. Middle temperature H_2

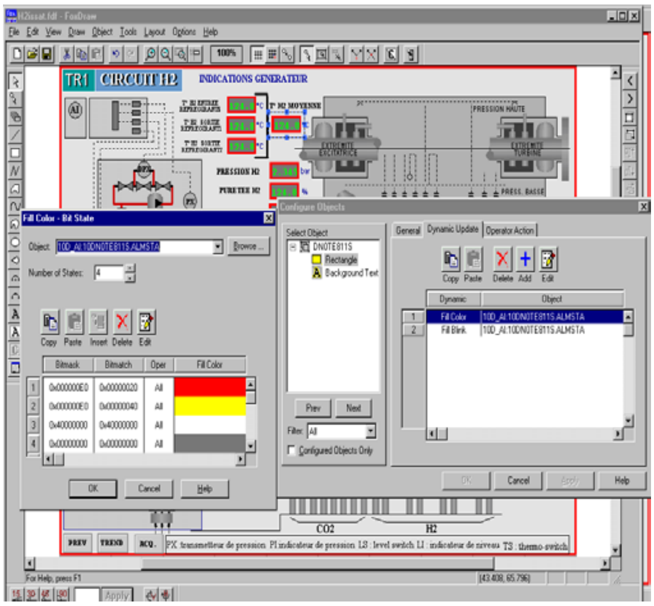

Fig.5. Configuration of the display of the alarm of the signal

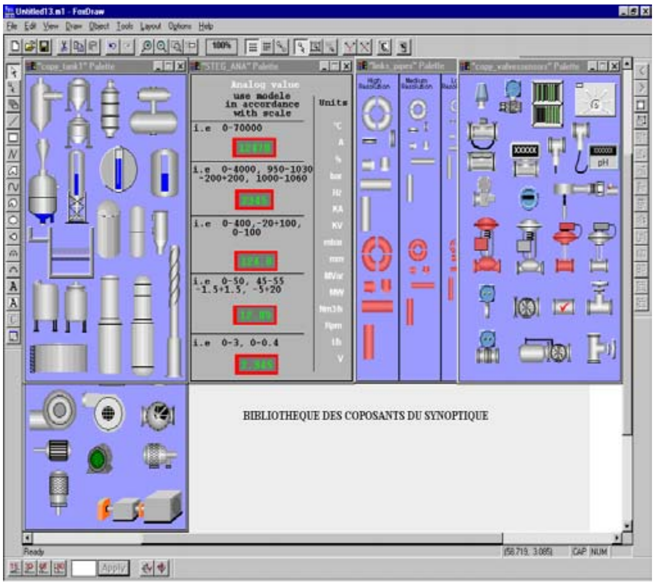

Fig.6. Library of components of the FoxDraw software

Figure 7 presents the new tabular elaborate of the Hydrogen circuit containing the new modifications.

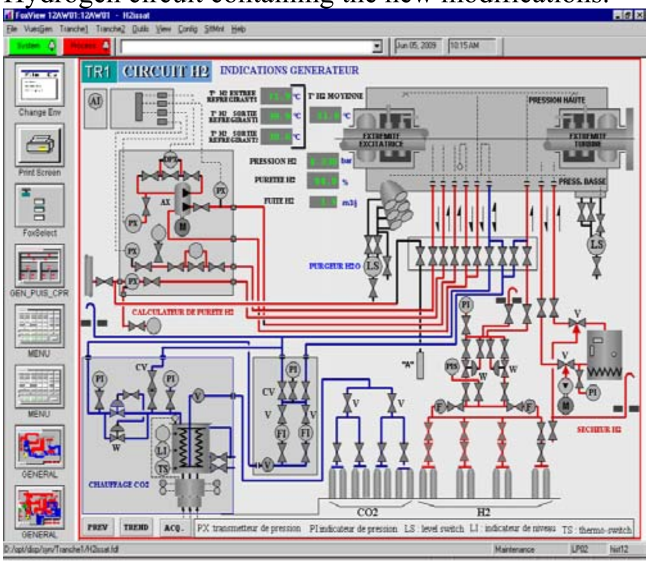

Fig.7. New tabular of the hydrogen circuit

5. Conclusion

In this paper, we presented on the one hand the architecture of a SCADA system and on the other hand an application of a SACDA system on the hydrogen station of a thermal power plant.

The application of the SCADA system consists in integrating a module for the calculation of hydrogen flights in the alternator. The proposed solution was permit to elaborate a new tabular for the hydrogen circuit containing the new modifications.

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