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Full Length Research Paper

SCADA applications in thermal power plants

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This paper presents the applications of a supervisory control and data acquisition (SCADA) system in thermal power plants (TPPs). In fact, a supervisory system must take into account the physiological and cognitive features of the supervisory operator. The paper briefly discusses on the one hand the different steps of the application of a SCADA system and the difficulties to manage and on the other hand it presents three examples of the application of a SCADA system in a TPP in Tunisia and the instrumentations and the measurements used. The first application is related to a counting system of the natural gas, the second one is related to the supervision of pumps vibrations and the third one is related to the supervision of heavy fuel oil.

Key words: SCADA, supervision, control, data acquisition, thermal power plant.

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 (Baily and Wright, 2003).

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 (Carke et al., 2003).

Supervisory control and data acquisition systems (SCADA) 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 (Warcuse et al., 1997) (Wiles, 2008).

The SCADA system usually consists of the following subsystems (Ozdemir and Karacor, 2006):

(1) A Man-Machine Interface (MMI) is the apparatus which presents process data to a human operator, and through this, the human operator, monitors and controls the process.
(2) A supervisory system, acquiring data on the process and sending commands to the process.
(3) Remote Terminal Units (RTUs) connecting to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system.
(4) 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 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 (Horng, 2002).

With the advances of electronic and software technologies, the SCADA systems are widely used in industrial plant automation. It provides an efficient tool to monitor and control equipment in manufacturing processes on-line.

Abbreviations: TPP, thermal power plants; **SCADA,** supervisory control and data acquisition.

The SCADA automation system always includes several functions, e.g., signal sensing, control, human machine interface, management, and networking (Munro, 2008; Gergely et al., 2009).

The objective of this paper is to show interests of the use of a SCADA system for thermal power plants (TPPs). Some examples of the application of a SCADA system are presented. The different steps of the applications of the SCADA system are developed and the different instrumentations are presented.

Presentation of a SCADA system

The different generation sources in the Tunisian electrical system are: hydroelectric, co-generation, renewable (biomass, solar and wind), natural gas thermal power and others including diesel, oil and coal. The decision to invest in power generation projects, especially in natural gas thermal power generation, involves a series of issues and challenges (World Energy Council, 2009). In fact, the real need for thermal power capacity is determined by the combination of energy supply and demand curves (Jerbi et al., 2009).

The Société Tunisienne de l'Electricite et du Gaz (S.T.E.G) is a vertically integrated monopoly for power and gas. It is responsible for power transmission and distribution and gas distribution. The monopoly of the power generation has been abolished, and the first IPP is a reality. The transmission and distribution losses of the Tunisian electricity grid are about 12% of the power generated (Annual Report, 2008; Bouchoucha et al., 2006; Khadraoui and Elleuch, 2008).

During the last few years, the S.T.E.G has evolved in a difficult international conjuncture characterized by the increasing of the hydrocarbon's prices. In spite of this economic situation, the S.T.E.G has deployed many efforts in different domains of its activity that enabled it to record some remarkable results. This is why the growth of 4.8% of the national production of electricity in 2007 enabled to the S.T.E.G to answer to the country evolution demand under the best conditions of continuity and security (Electricity and Gas Revue, 2008).

Among the units of electricity production of the S.T.E.G, the Centre de Production de l'Electricité de Radès (C.P.E.R) that produce the 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. In fact, a thermal power plant (TPP) is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser. The greatest variation in the design of TPPs is due to the different fuel sources. Some prefer to use the term energy center because such facilities convert forms of heat energy into electrical energy.

In TPPs, mechanical power is produced by a heat engine which transforms thermal energy, often from combustion of a fuel, into rotational energy. Most TPPs produce steam, and these are sometimes called steam power plants (Vitaly, 2008). TPPs are classified by the type of fuel and the type of prime mover installed.

The electric efficiency of a conventional TPP, considered as saleable energy produced at the plant busbars compared with the heating value of the fuel consumed, is typically 33 to 48% efficient, limited as all heat engines are by the laws of thermodynamics [9]. The rest of the energy must leave the plant in the form of heat (Kagiannas et al., 2003) (Changling and Boon-Teck, 2006).

Since the efficiency of the plant is fundamentally limited by the ratio of the absolute temperatures of the steam at turbine input and output, efficiency improvements require use of higher temperature, and therefore higher pressure, steam.

Most of the TPPs operational controls are automatic. However, at times, manual intervention may be required. Thus, the plant is provided with monitors and alarm systems that alert the plant operators when certain operating paracounters are seriously deviating from their normal range.

Figure 1 presents the architecture of the SCADA system. The stations belong to a superior network Ethernet (10 Mb/s). Principally, this network enables to exchange files between the stations (Lakhoua, 2009a). It enables to avoid the overload of the Node bus network. In fact, the SCADA system is composed by modules that exchange information thanks to the communication network. It exist three levels in the SCADA system: acquisition; treatment anMen/ Machine Interface.

(1) I/A: Intelligent / Automation,
(2) FBM: Field bus modules,
(3) FCM: Field Bus Communication Module,
(4) AW: Application work station,
(5) WP: Work station Processor,
(4) CP60: Control Process60,
(5) DNBT: Dual Node bus.

Supervision of the natural gas

Natural gas is the fastest growing primary energy source in the world. It is the more used one of fuels in the TPPs because it is more manageable, own that coal or the heavy fuel-oil; on the other hand it presents dangers and the bigger explosion risks. The exploitation of the natural gas requires a structure, of equipments, of instruments and an automatic control (Eugenio and Berzosa, 2007; Hamedi et al., 2009).

The TPP of the C.P.E.R is nourished in natural gas from the Tunisian network of distribution. In fact, the gas undergoes several operations of preparation before being introduced in the steam generator, it must be filtered, rehash, relaxed and counted.

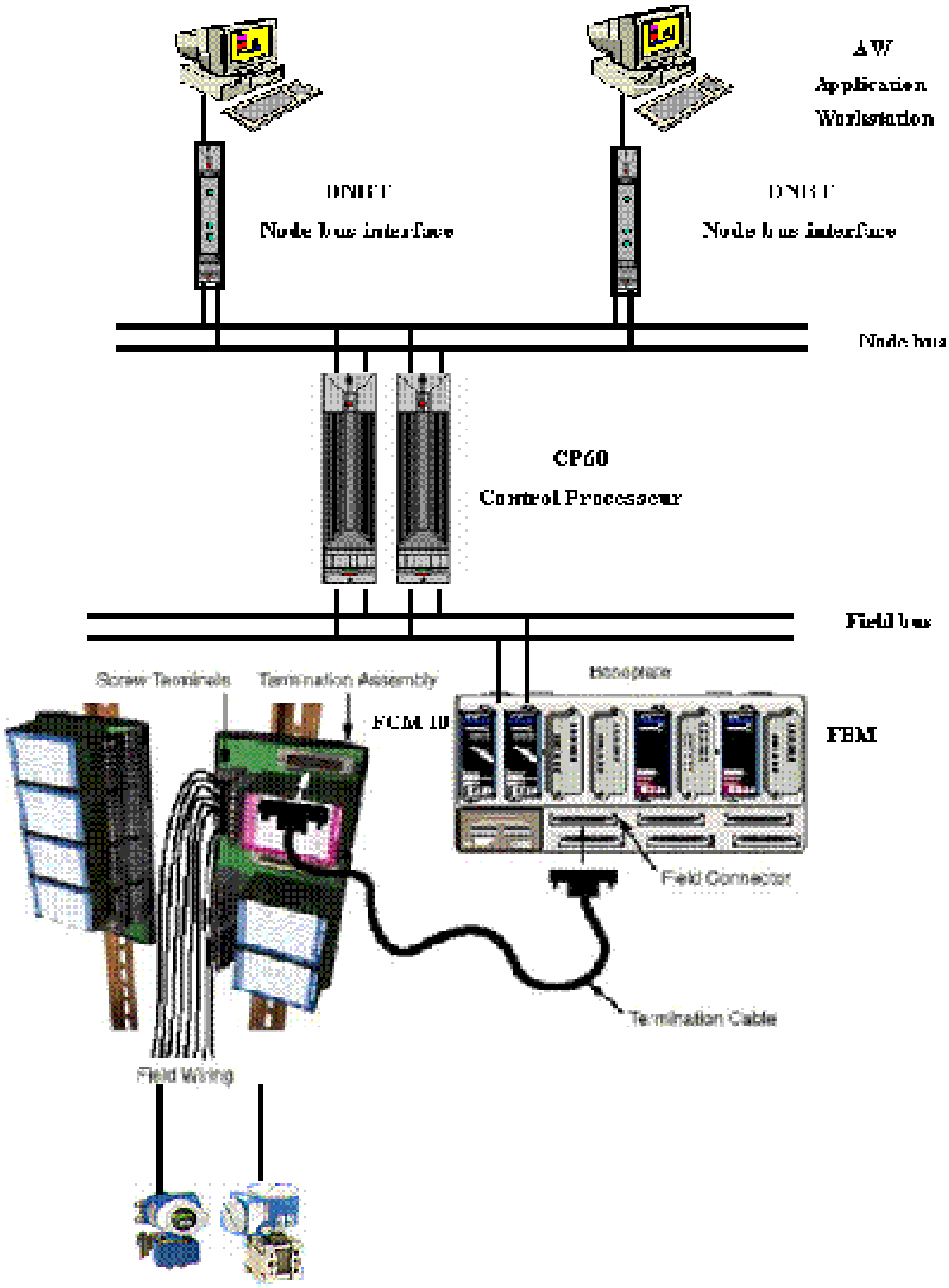

Figure 1. Architecture of a SCADA system.

In this paragraph, the different stages of interfacing and configuration of a natural gas counting system to the SCADA system of the C.P.E.R are (Lakhoua, 2009b; Lakhoua, 2009c):

(1) The branching of the counters gas lighter to the SCADA system;
(2) The programming of the general counting of the gas lighter;
(3) The configuration of a new tabular circuit of the natural gas containing the new information.

We choose the input/output map, the programming and the necessary block. This operation is achieved by the standard algorithms called blocks provided by Foxboro. The proposed solution is to make the counting of impulses by the SCADA system and to program blocks of hourly and daily numbering. These impulses are given

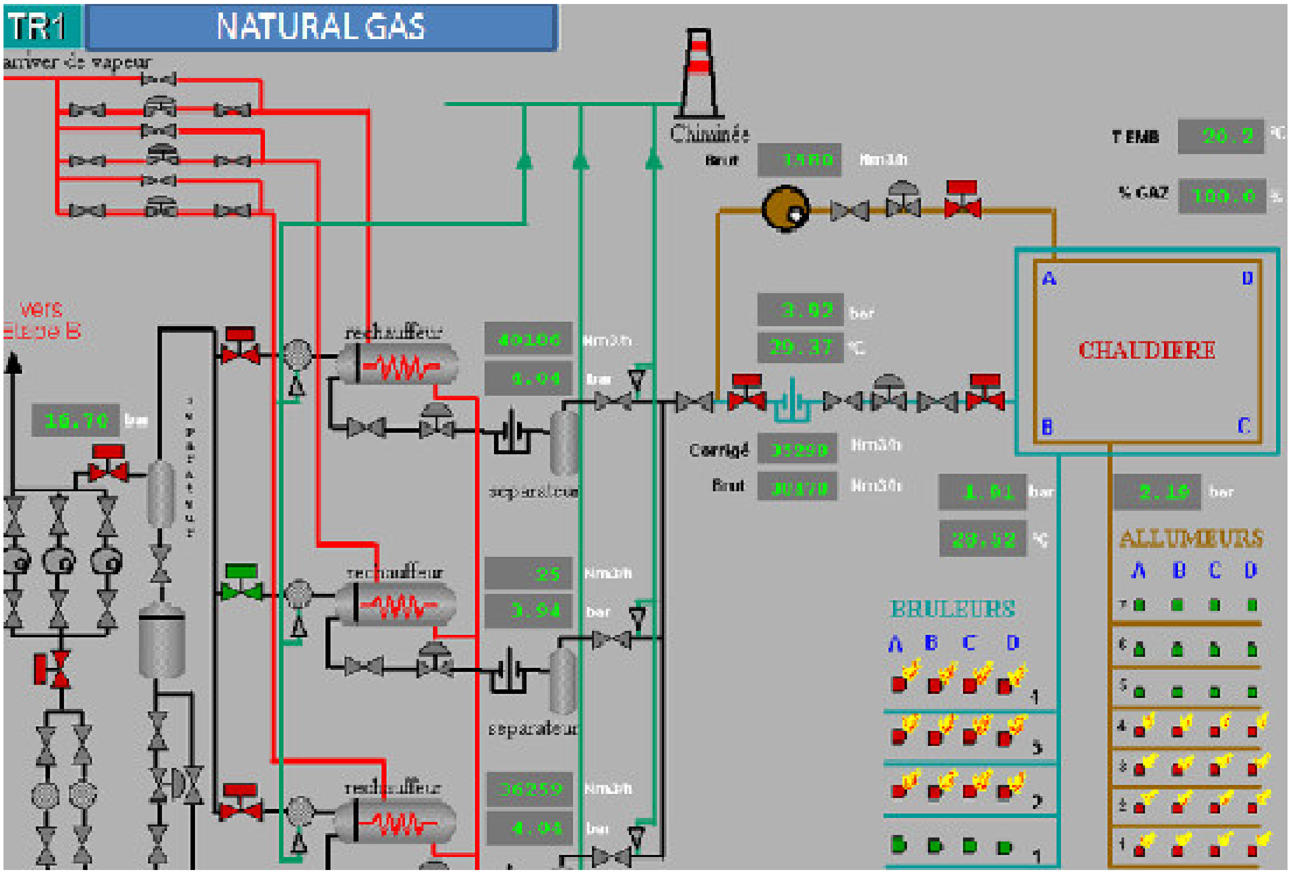

Figure 2. Display of the natural gas of the TPP.

out by the generator of meter impulses to turbine.

The meter to turbine of gas lighters is installed 7.5 ms of the steam at the level, the distance between this one and the SCADA system is appraised to 160 m, the work of branching are done during the minor revision of the power station.

After these works of branching, we programmed the different blocks of counting of the volume gas lighters. An algorithm of numbering of the volume of natural gas has been adopted. Indeed, the AIN block permit the reading of the raw value (0 to 65535 points) a way of entrance of a module FBM217 that achieves then on a read data of conditioning functions (characterization, stake to the ladder, limitation), of filtering and alarm.

The ACCUM block achieves the integration and delivers to OUT exit a quantity. The block COST permits to pilot one of exits all or nothing of a module of FBM E/S in fashion bistable or pulsionnel. Finally, the block MATH permits to achieve some arithmetic operations in definite chain in a program.

For the stage of configuration, we used the ICC (Integrated Control Configuration) software. This last enables us to create and to configure programs residing in the CP60.

For the stage of different block programming (AIN, ACCUM...), we identified the label, the compound and the address of the signal.

The interfacing consists in improving the counters and to conceive a new tabular of the circuit natural gas containing the new counters of gas lighters by using of Fox Draw software.

We preceded the following manner: creation of the meter gas lighter; test of meter working; configuration of the different alarm display; configuration of the meter overlay and test of the meter overlay.

A new display was elaborated using the FoxDraw software containing the new counters of the natural gas of the TPP (Figure 2).

Supervision of pumps vibrations

Surveillance systems of vibration are often equipped of measure chains for other complementary parameters, as the axial position, the crankiness, the differential dilation, the dynamic pressure, the speed of rotation and the temperature (Piroddi et al., 2006).

Among the new systems of measures, we mention notably IDS (system of icing detection) and AGMS (system of measure of the bore between the rotor and the stator) that complete a system of vibration surveillance efficiently, but that are also usable as of the autonomous specific systems (Vibro-Meter, 1990).

The MMS system (System of Machine Surveillance) is the synthesis of the long experience of Vibro-Meter in the domain of the surveillance of machines and its expertise to master technologies of vanguard as for the manufacture of the electronic of surveillance.

The instrument of the vibration control measures the vibration all the time when machines (turbine of power plant, big dimension compressor, pump, blower…) are in service. When the supervised vibration reached the amplitude of vibration, that is adjusted in advance, the instrument gives out an exit of point of alarm contact to give a warning to the working of the machine or gives out an instruction to stop the working of the machine, avoiding so the danger and accidents before they occur.

The mechanical vibration that is developed in a machine is controlled by a sensor of vibration and is converted in electric signal and this signal is introduced in an amplifier of vibration. In this amplifier, a signal that is proportional to the speed of vibration and supervised by an instrument of vibration control, and convert in a signal that is proportional to the displacement of the vibration, and this last is to its tower convert in a tension to continuous current, that is given back like signal to an indicator and a signal to the circuit of alarm.

The instrument of vibration measure used in this application is constituted by a sensor of vibration (Model U1-FH) and an instrument of vibration control (Model AVR-148). In fact, the sensor of vibration is similar to the con-struction of a loudspeaker to permanent magnet. The sensor is attached to the machine on the one hand with screws and on the other hand to connect to the system of registration with the special cables (Lakhoua, 2010).

With sensors of Vibro-Meter, we measure in general most the critical parameters in the surveillance of machines, but particularly what concerns vibrations. In this domain, Vibro-Meter proposes a vast range of sensors, of conditioners of the signal as well as an effective signal transmission.

To achieve a complete surveillance monitor, we always associate a treatment module UVC 691 with a surveillance module with a high performance PLD 772.

Most modules of Vibro-Meter provide unipolar signals in the range of 0 to 10 V DC. However, the PLD 772 can accept some bipolar signals in the range of 0 to ±10 V DC. In fashion of programming of the PLD 772, it is possi-ble to define the calibration of the display and all parameters of alarm. While equipping the PLD 772 of an interfac-ing RS-485, the module is capable to the digital communication. Thus, a surveillance system can make part of a cabled network. A computer detains the main computer role. All other modules PLDS 772 in racks are some secondary stations. Such a link between a surveillance system and a main computer is in measure to do programming functions from afar and of data transfer.

Figure 3 presents the new display of the pumping process elaborated using the FoxDraw software.

Supervision of heavy fuel oil

Problem approached in this application is related to the detection of the level of the tanks of heavy fuel oil by a floating level sensor and the absence of indication of the level on the SCADA system in the control room of the TPP.

In fact, the tanks have thermal exchangers with a hot steam for liquid heating. These tanks are protected against oxidation of metallic bodies thanks to a specific painting. The objective of this application is to replace the ancient level sensor. New solution must be installed in an easy way and without having too much change of tanks and the slightest contact with liquid. That's why we opted for installing the new sensor in the upper level of the tank in form of tubing with bridle which is used in case of the gauging or installation of equipment.

Three solutions were studied: the first one consists in a level sensor to diver. This sensor is a submerged cylinder the height of which is equal at least to the maximum height of fuel oil in the tank. The diver is hanging in a dynamometric sensor who thinks subjected to a force function of the height of the liquid (Schoenwald and McCullouch, 1993; Menon and Hariharan, 1979).

The second solution consists in using an ultrasonic level sensor. The principle is based on the program of an ultrasound wave reflected on the surface of fuel oil. It picks up echo and it measure the course time. The course time is independent of the fluid and the pressure. It is nevertheless necessary to respect a "dead zone" specific to the sensor.

The third solution consists in the use of an electromagnetic level sensor. This one is constituted of a hanging counterpoise at the end of a cable. A motor allows unwinding this cable up to getting that counterpoise gets into contact with a liquid. At this instant, the tension of the cable loosens operating a commutator which reverses the rotation sense of the motor. During the descent of the sensor head, impulsions are generated in regular spaces. The counting of impulsions allows us to have the level.

The solution proposed consists in using an ultrasound level sensor (PULSAR dB 25). This solution is simpler than the diver and the sensor head (Lakhoua, 2009d).

The advantage of this solution: no contact with liquid, therefore no wear of damage. In fact, the ultrasonic and sonic instruments of measure of level both work while using the basic principle of the sound waves to determine the level of fluid. The expanse of frequency of ultrasonic method is ~20-200 kHz.

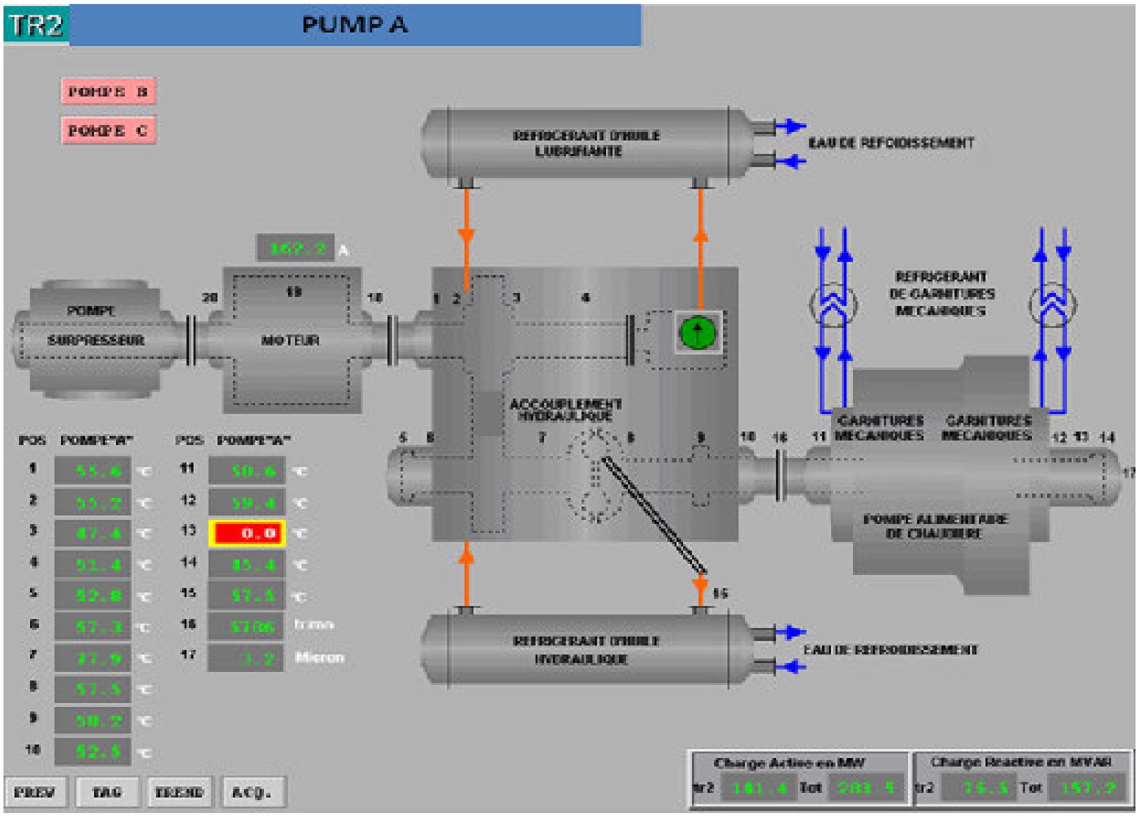

Figure 3. Display of the pump A of the TPP.

A crystal piezoelectric located in the transducer converts electrical impulsions into sound energy circulating in the form of waves in chosen frequency and it in constant speed in a given middle. The sound waves issued by packets, go back to the transducer in form of echoes.

The instrument measures the time necessary for the packet to attain the surface, be reflected and to come back. This time is proportional to distance between the transducer and the surface and can be used to determine the level of fluid in the tank.

By applying an alternating current to a piezoelectric crystal, crystal constricts and decompresses alternately and issues a sound.

In the sounding line of ultrasound scan, the glow of piezoelectric crystal is accomplished by an electrical impulsion, like a bell which they hit. Crystal enters resonance then and issues ultrasounds on which frequency depends of the thickness of crystal. Frequency is well brought up all the more as crystal is slim. Figure 4 presents the new display of the circuit of heavy fuel oil tanks of the TPP.

Conclusion

The SCADA system is used for monitoring and controlling industrial processes from remote areas. It allows an operator to make a set point changes on remote controllers, to open/close valves/switches, to monitor alarms and to gather instrument information from a local process to a widely distributed process, such as oil/gas fields, pipeline systems, or hydroelectric generating systems. In the context of SCADA, it refers to the response of the control system to changes in the process and makes them similar to real-time control system in the virtual environment.

In this paper, an example of a SCADA system in a TPP is studied and some applications are presented. First, we presented the supervision of a counting system of the natural gas of a TPP. This application was permitting the branching of counters of the natural gas to a SCADA system of the TPP in the one hand, and requires the programming and the configuration of the counting system, on the other hand.

Second, we presented the supervision of a system of vibratory surveillance in a TPP. This application enables us the creating and the maintaining dynamics of updating the pumping process displays.

Finally, we presented the supervision of heavy fuel-oil tanks of a TPP. This application allows us to assure the connection between the ultrasound sensor and the post of surveillance in the control room of the TPP. However, the paper discusses the need to monitor the process and

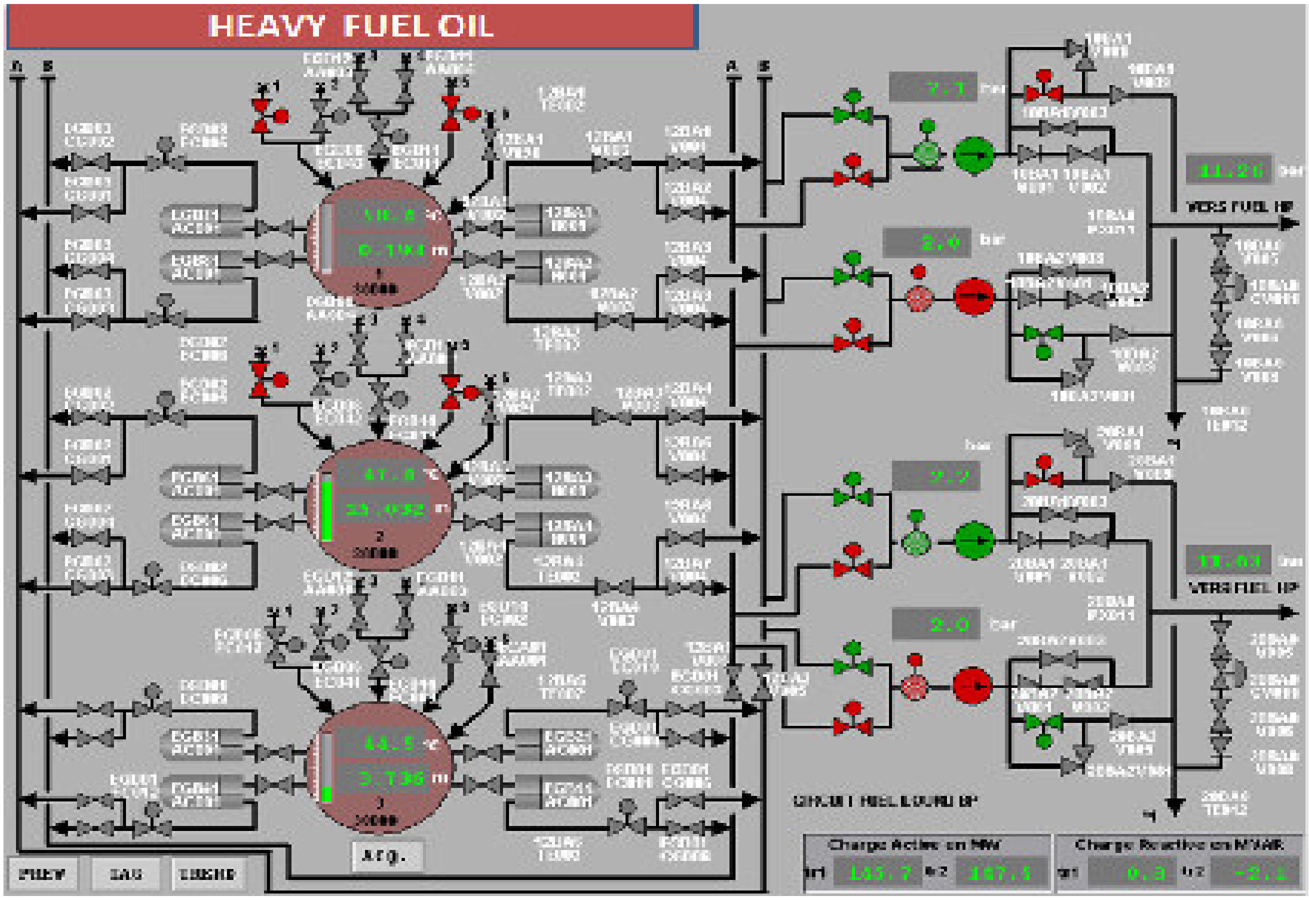

Figure 4. Display of the circuit of heavy fuel oil of the TPP.

possibly control the operation of TPPs from virtually anywhere.

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