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Analysis and supervision of the water extraction of a thermal power plant

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The aim of this paper is to analysis the water treatment process in a thermal power plant (TPP). In fact, we present an application of a supervisory control and data acquisition (SCADA) system. Thus, an example of a SCADA system of the center of RADES in Tunisia was presented. Our contribution in this work consists in the analysis of the water loss in the TPP on the one hand and the supervision of the water extraction circuit using the SCADA system, on the other hand.

Key words: Water extraction, water loss; thermal power plant, supervisory control and data acquisition (SCADA).

INTRODUCTION

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 based on renewable energies or fossil energies. With regards 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 to produce electricity in order to satisfy needs of its customers. Among electricity production centers of the STEG, we mention the center of RADES (near to Tunis, Tunisia) (Annual Report, 2012). It is one of the most important centers of the point of view the power installed (700 MWS). It has been inaugurated in 30 of May, 1986. It is about a thermal power plant (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 in order to avoid the maximum loss of production, it is extremely important to master all aspects having linked to the security and the profitability of the highest level.

In fact, the electricity production in a TPP is based on a set of energies transformations using water as support of energy. This water must have a noble quality in order to guarantee the installation security and to improve production groups' performances. It is therefore necessary to apply a rigorous water treatment and a control of its quality (Vitaly, 2008).

The process of the electricity production in the TPP of RADES is essentially based on the water distributed by the SONEDE (National Water Distribution Utility of

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Tunisia). This water generally contains dissolved mineral salts and organic matters. The presence of these elements can generate problems bound to the furring, the corrosion and the different facilities contamination notably the furnace, the steam-powered turbine and water or steam circuits (Kagiannas et al., 2003; Ecob et al., 1995).

In order to assure the required quality of water in the water-steam cycle of the TPP, the water treatment process is necessary. Indeed, water passes by the filtration chain then introduced in the inverse osmosis station and thereafter in the demineralization station (Changling and Boon-Teck, 2006). In fact, the water of the SONEDE used in the TPP of RADES is unfit to the feeding of furnaces. It contains matters suspended and in various solutions in nature and in quantity of salts and gases dissolved. The matter suspended is constituted of the sand, of colloidal clays, insoluble mineral salts and of organic matters (products of animal and plant deterioration). These bodies give a certain coloration to water (turbidity) that requires a clarification treatment. This undesirable foulness can drive to the serious damages. Among which we mention notably corrosion and furring (or encrustations). In order to avoid these problems, it is necessary to:

(i) Eliminate gases (CO_2, O_2, N_2) of the water by the physical degassing or the chemical degassing by the injection of the oxygen reduction as N_2H_4…
(ii) Use of the destitute water of mineral salts for example water done demineralization with a conductivity ($\sigma < 0.2$ µS/cm) and a content in silica $SiO_2 < 30$ ppb.
(iii) Work with a sufficiently basic pH ($8.5 < pH < 9.5$).

The objective of this paper is to identify the water loss in a TPP and to control the water extraction circuit using a SCADA system. An example of a SCADA system of the TPP of RADES is presented.

PRESENTATION OF AN EXAMPLE OF A SCADA SYSTEM

The supervisory control and data acquisition (SCADA) term refers to a system that collects data coming from different sensors of an industrial or other process, these sensors can beings installed in the same site or distant (several Km), the introverted data are treated by a unit called processor power station (CPU, PCU, PC...), results are sent in real time to the Men / Machine interfacing that can be a computer with its peripherals (Baily and Wright, 2003).

The SCADA system assures the surveillance and the control of electric, mechanical or electronic equipment equipping all or a part of the network (Munro, 2008). 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 (Carke et al., 2003; Horng, 2002). The intended role to the SCADA system is to collect data instantaneously of their sites and to transform them in numeric signals by following to send them through the network of communication toward the main and secondary stations (Wiles, 2008). This centralized supervision allows operators, since the control room of the TPP, to control facilities in their domain of exploitation and the different types of incidents (Ozdemir and Karaoc, 2006; Warcuse et al., 1997; Gergely et al., 2010). 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 (Annual Report, 2012). It avoids so the overcharge of the node network bus. Figure 1 shows an overall view of the TPP of RADES using a SCADA system. The SCADA system of the TPP of RADES orders and classifies all data for (Lakhoua, 2009a) (Lakhoua, 2009b) (Lakhoua, 2010a):

(i) Instantaneous impression.
(ii) Visualization on screen using data tables and tabular diagrams.
(iii) Registration of instantaneous exchanges of numeric and analogical data.
(iv) Instantaneous calculation for example corrections of gas debits, direct middle specific consumption, middle values.
(v) Storage of the analogical information of the process.
(vi) Calculation of outputs and losses of the process.
(vii) Surveillance of the SOE signals (entrances rapid contact 1ms)
(viii) Interfacing interactive Men / Machine for the surveillance of the system and the conduct of processes (tabular, curves view of alarm) (Figure 2).

The SCADA system of RADES is equipped of three communication networks (Lakhoua, 2010b):

(i) Field bus, 5 Mbits, permitting to do exchanges of the numeric data of the entrance card / exits (FBM) toward the central system (CP) via modules of communication (FCM);
(ii) Node bus, 10 Mbits, permitting to do exchanges of the numeric data of the central system (CP) via modules of communication (DNBT) toward the Men/Machine interfacing (workstations);
(iii) Ethernet TCP/IP, 100 Mbits, permitting to do exchanges of files between workstations of the Men/Machine interfacing. It avoids so the overcharge of the Nodebus network.

PRESENTATION OF THE INVERSE OSMOSIS AND THE DEMINERALIZATION STATIONS

Considering that the water of the SONEDE contains an

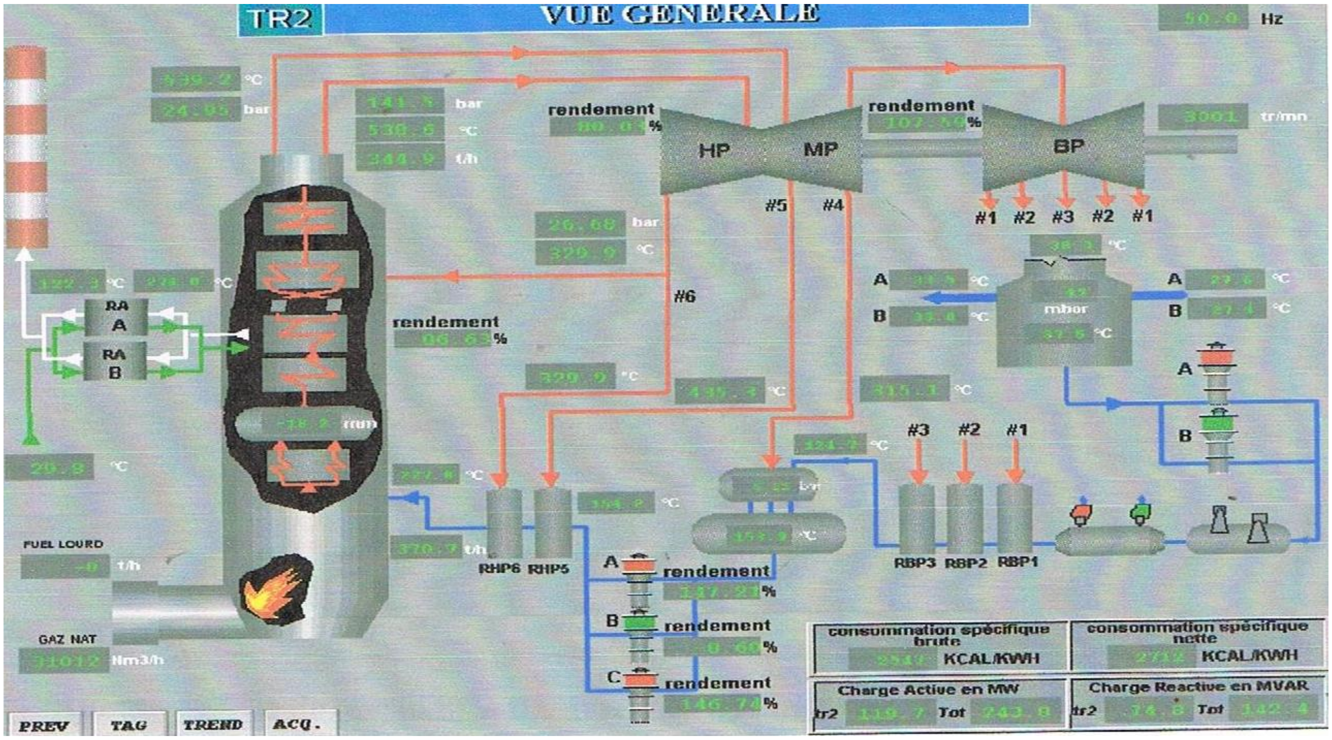

Figure 1. Overall view of the TPP of Radès with SCADA.

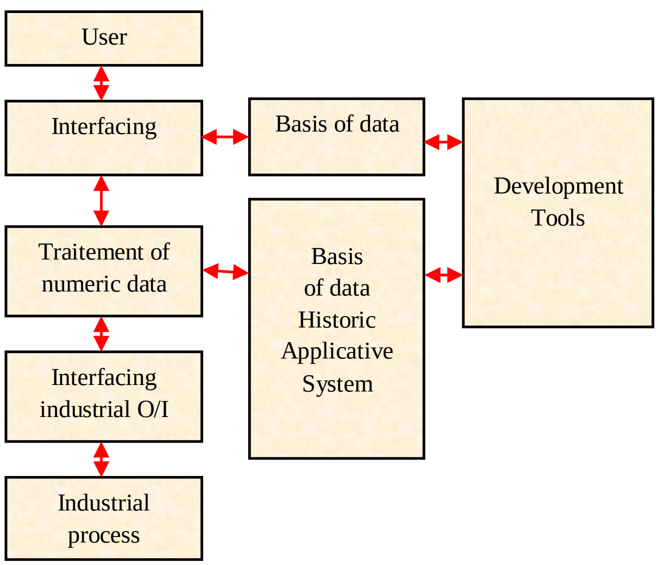

Figure 2. Principle of a SCADA system.

elevated rate in dissolved salts and in matter suspended, it is indispensable to adopt a stage of pretreatment to assure the good working of the inverse osmosis installation and to protect modules against risks of usuries, corrosion and especially membrane calmative (Tarja et al., 2006).

The pretreatment is constituted of two filtration chains each including a sand filter and an active coal filter. Thereafter, we present the two stations of the TPP: inverse osmosis and demineralization.

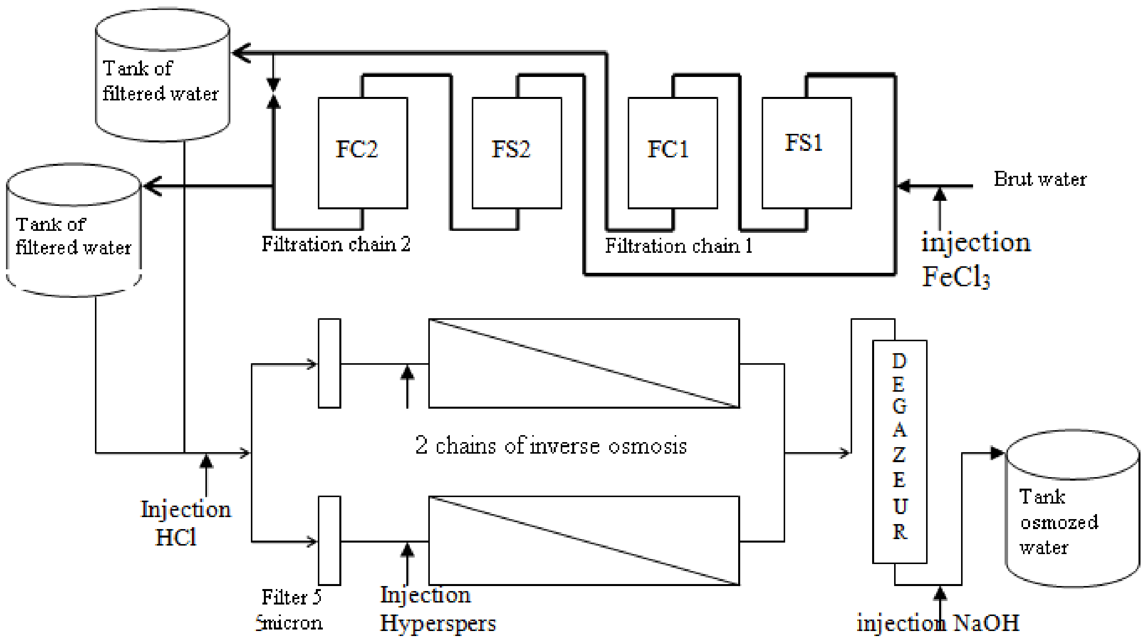

Figure 3. Functional diagram of the inverse osmosis station of the TPP of RADES. FS1: Sand filter of the filtration chain 1. FC1: Active coals filter of the filtration chain 1. FS2: Sand filter of the filtration chain 2. FC2: Active coals filter of the filtration chain 2.

The control of the water quality is an important task to maintain the efficiency and the sure and continuous working of the power station (Yubin et al., 2002). To guarantee the best water quality at the level of the water steam circuit, the TPP of RADES arranges an inverse osmosis station that permits to eliminate the majority of salts dissolved in the raw water before being treated in a demineralization station (Figure 3). This stage serves to minimize risks of failing by corrosion of the turbine or the loss of the efficiency and the power (Electricity and Gas Revue, 2011). The bold lines present the water circuit in the two filtration chains and the light lines present the water circuit in the two inverse osmosis chains. The basic principle of the ion exchange consists in withdrawing ions (remaining salts that are lower to 8%) in solution in water is to recover an ion of value, either to eliminate a harmful or bothersome ion for the ulterior utilization of water (Firoozshahi and Mengyang, 2010). The exchange of ions is a process which ions with a certain load contents in a solution are eliminated of this solution, and replaced in the same way by an equivalent quantity of other ions load gave out by the strong but the opposite load ions are not affected. In the demineralization chain, osmosis water passes by the following stages:

(i) A weak cationic exchanger (CF1);
(ii) A strong cationic exchanger (CF2);
(iii) A weak anionic exchanger (AF1);
(iv) A degasser;
(v) A strong anionic exchanger (AF2);
(vi) A strong cationic exchanger (CF3);
(vii) A strong anionic exchanger (AF3).

After the demineralization, the water must have a lower conductivity of 0.2 µS/cm, a pH between 6.5 and 7.5; silica < 30 ppb. Figure 4 shows the water treatment cycle in the demineralization station.

RESULTS OF THE IDENTIFICATION OF THE WATER LOSS AND THE SCADA APPLICATION

Demineralized water is distributed to the two production plants A and B, the laboratory and the unloading of the fuel station. Consumption of the latter two is negligible compared to the amount consumed by the process of generation of electricity (Figure 5). Demineralized water is distributed to the four stations of the TPP using two tanks. For each station, demineralized water is used primarily for the extra three following circuits:

(i) The water-steam circuit;
(ii) The water cooling circuit of the bodies of various rotating machinery (Noria circuit);
(iii) The secondary steam circuit used primarily for the fuel heating.

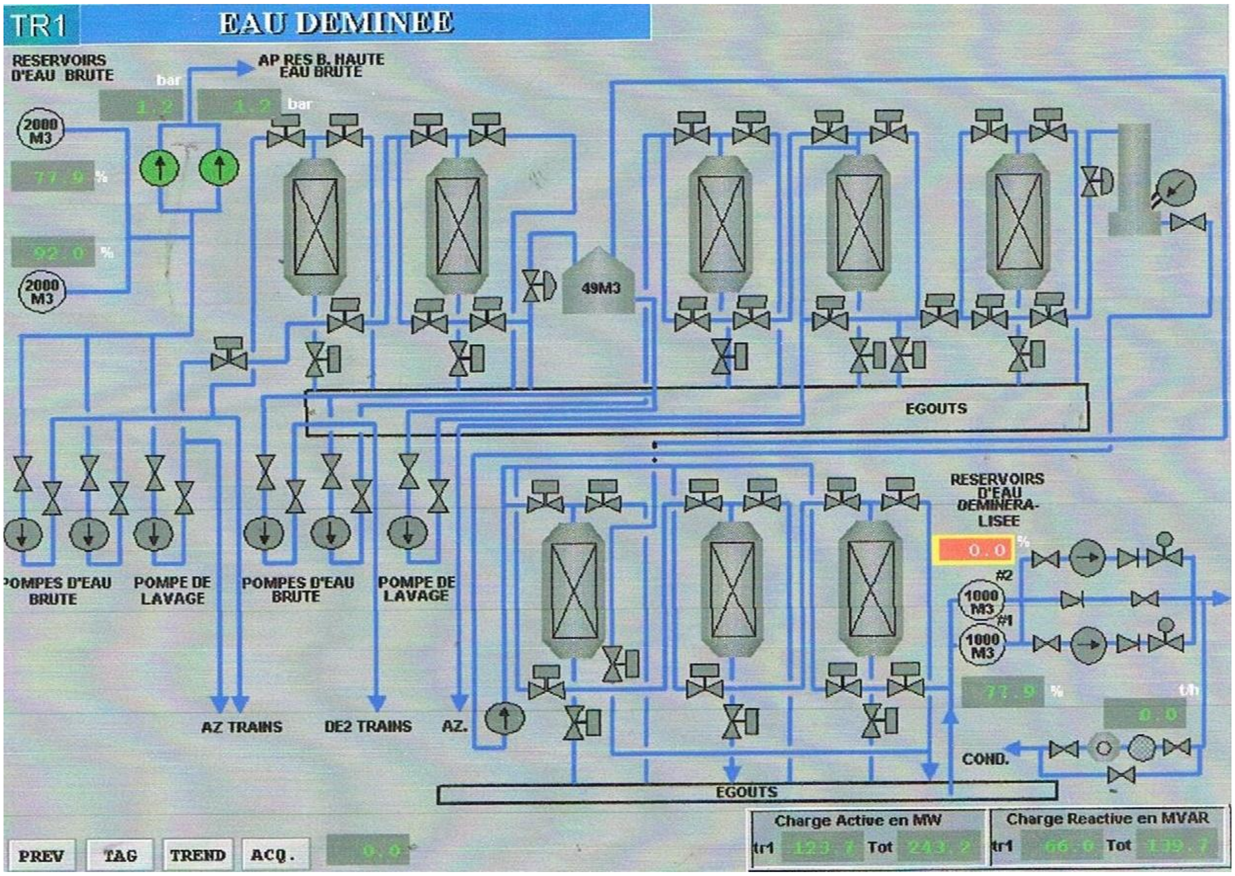

Figure 4. Demineralization station of the TPP of RADES.

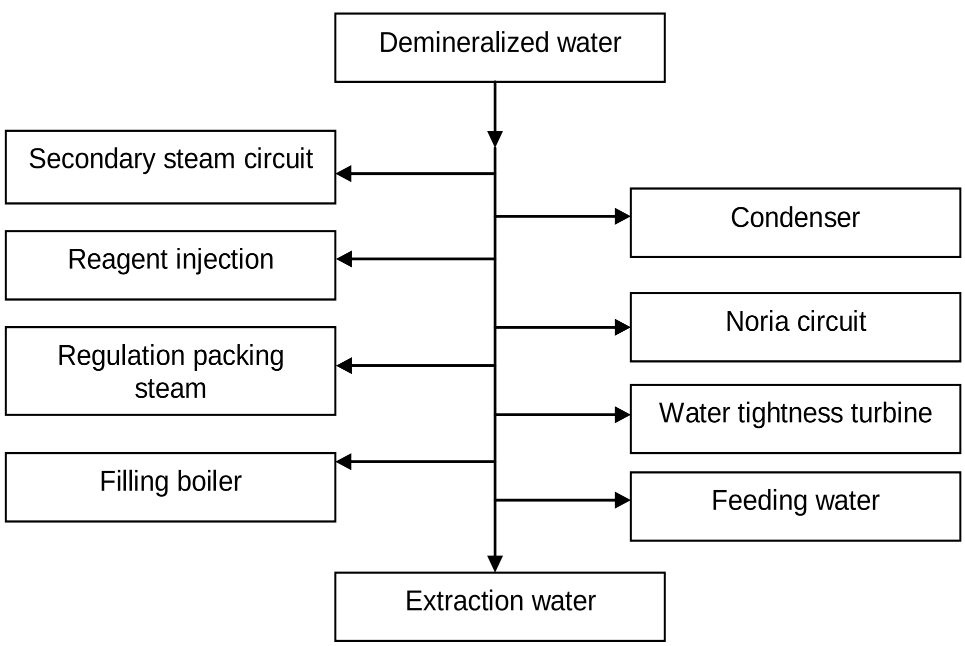

Figure 5. Demineralization station of the TPP.

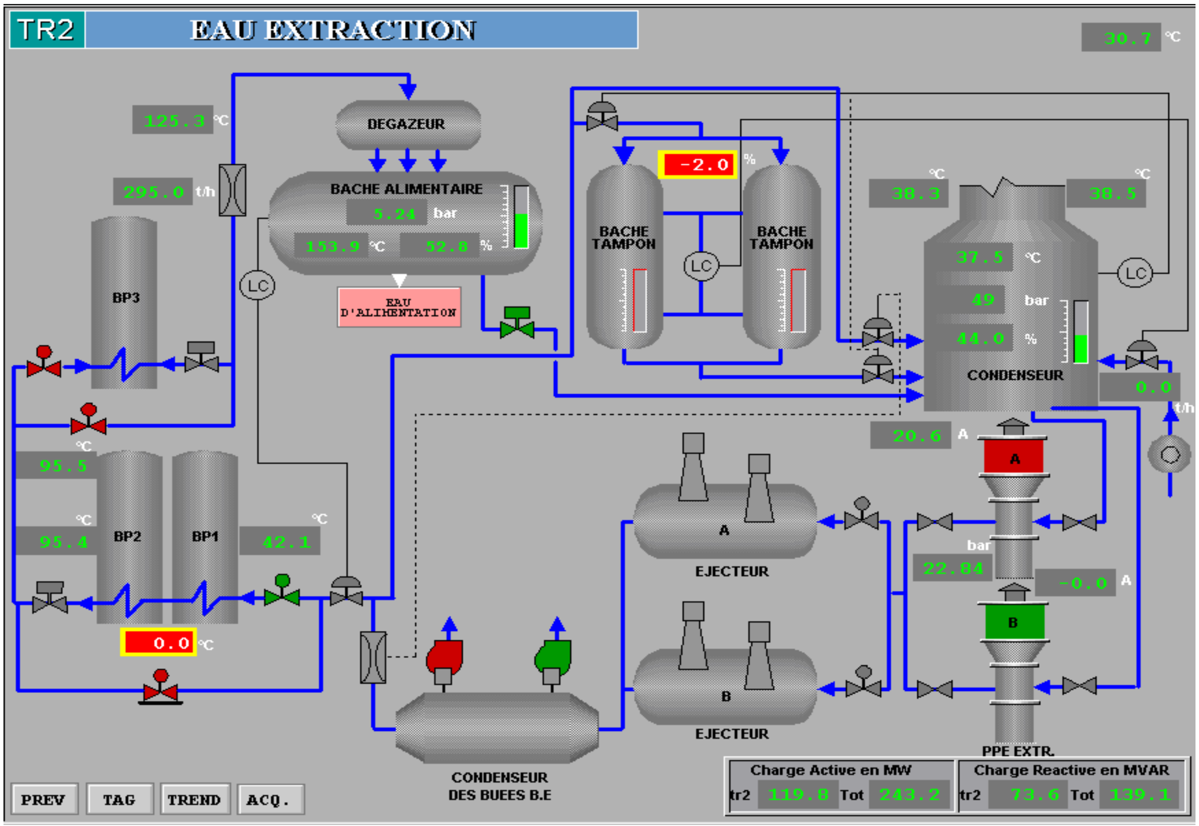

Figure 6. Display of the water extraction circuit of the TPP.

The ongoing purges are formed by the boiler purges which are necessary to maintain the quality of condenser water steam cycle. The ongoing purges volume varies between 50 and 70 m^3/day for one station. Sampling purges are carried out automatically by on line continuously analyses of the water of the boiler parameters (pH, conductivity...). The volume of these purges varies between 3 and 5 m^3/day for one station. The staple purges occur after judgments or in case of anomalies that require draining of the boiler or other bodies (ball boiler, covering food...). The sampling purges of the plant A allow extra Noria circuits of the two stations. The make-up of the water steam circuit varies between 70 and 80 m^3/day for one station.

In this application, we have installed an ultrasonic flow meter in the make-up water circuit and an electromagnetic flow meter in the osmosis position. Flow converted to the level of the ultrasonic flow meter will be issued as an electric signal 4 to 20 mA, towards the electronic room to treat by the input (UA 374 and UT 375) modules. Then, it will be forwarded to the ordinary and finally visualized in the control room. Figure 6 shows the display of the circuit of the water extraction of the TPP.

This application is declined in six stages:

Stage 1: Choosing the site of the signal (FBM module) that treats the deminiralized water.
Stage 2: Programming the AIN block for the supervision of the ultrasonic flow meter signals.
Stage 3: Testing the AIN block by injection of current.
Stage 4: Passing the cable between the electronic room and the SCADA room.
Stage 5: Programming three ACCUM blocks and two COUT blocks.
Stage 6: Improving the existing tabular of the water extraction circuit.

CONCLUSION

SCADA systems are used to control and monitor physical processes, examples of which are transmission of electricity, transportation of gas and oil in pipelines, water distribution, traffic lights, and other systems used as the basis of modern society. In this paper, we presented an identification of the water loss in a thermal power plant and an application of the SCADA system on the water extraction circuit. Moreover, we proved the importance on using a SCADA system for sustainable development in the supervision of the thermal power plants. Also the paper outlines the general concepts and required equipments for the supervision of such power plants. Some applications of SCADA system implementation in electrical companies over the world have been presented.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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