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Structured Analysis and Modeling of a Supervisory Control and Data Acquisition in a Thermal Power Plant

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ABSTRACT

This paper introduce the need for the structured analysis and the modeling of control-command applications in a thermal power plant (TPP) using a supervisory control and data acquisition system (SCADA). Then, the architecture of a SCADA system in a TPP is presented. A significant example of a control-command application in a TPP in Tunisia is presented. It is concerning the water-steam cycle of the TPP which is composed by two stations: the inverse osmosis station and the demineralization station. In fact, an application of the analysis and the modeling methods in a TPP, generally used in industry, on the basis of the Grafcet and SA-RT formalism is presented. In fact, different modules are represented and described: Context Diagram, Data Flows Diagram, Control Flows Diagram, State Transition Diagram, Timing Specifications and Requirements Dictionary. Finally, this functional and operational analysis allows us to help the different steps of the specification, the programming and the configuration of a new tabular in a SCADA system.

Keywords: *SCADA, Grafcet, SA-RT method, water-steam cycle, thermal power plant.*

1. INTRODUCTION

Supervisory control and data acquisition systems (SCADA) have become popular to occur the efficient monitoring and control of distributed remote equipments. In fact, the SCADA system habitually consists of the following subsystems [1-3]:

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

SCADA systems can be found in risky infrastructures for example power grid systems and power plants, gas, oil and water distribution systems, structure monitoring, production systems for food, cars, ships and other products.

In industrial plants, the supervision systems implemented in SCADA software, must assume, at least, the next three main tasks: monitoring, control and fault tolerance [4-6].

In fact, the common control actions are performed automatically by RTU or by programmable logic controllers (PLC) [6-10]. Multitude control functions are habitually limited to basic overriding or supervisory level intervention. For instance, a PLC can control the flow of water cooling through element of an industrial process, but the SCADA system can allow operators to change the set points for the flow, and permit 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

The aim of this paper is to clarify benefit of the use of the structured analysis and the modeling based on the two methods Grafcet and structured analysis and real time (SA-RT) for system specification. The next section briefly presents SCADA system in a thermal power plant (TPP) and an example of a control-command application. Finally, a case study of the Grafcet modeling and SA-RT analysis of a water-steam cycle in a TPP using a SCADA system is presented and discussed.

2. ARCHITECTURE OF A SCADA

A SCADA system of a TPP (Figure 1) is constituted of the following elements [7-8]:

- A plate of bornier;
- Field Bus Module (FBM) ;
- Field Bus Communication Module (FCM) ;
- Control process (CP60) ;
- Dual Node Bus base T interface (DNBT) ;
- Work Station Processor (AW) ;
- Application Work Station (WP).

In a TPP, there are different tools used by the SCADA system, for instance:

- SYS MON: system monitor that supervises the high-quality working of all the facilities of the system.
- FOX DRAW: creator of tabular.
- FOXVIEW: interfacing operator to visualize the tabular with a slim rod to activate the main functions of the SCADA system.
- FOX SELECT: software permitting to reach the various elements of the hierarchy of the data base of the CP60.

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- Integrated Control Configuration (ICC): software permitting to produce and to configure programs residing in the CP60.
- AIM HISTORIAN: software permits to collect, to organize and to protect data for storage, it also permits to configure features of points to archive, as messages partners to events.

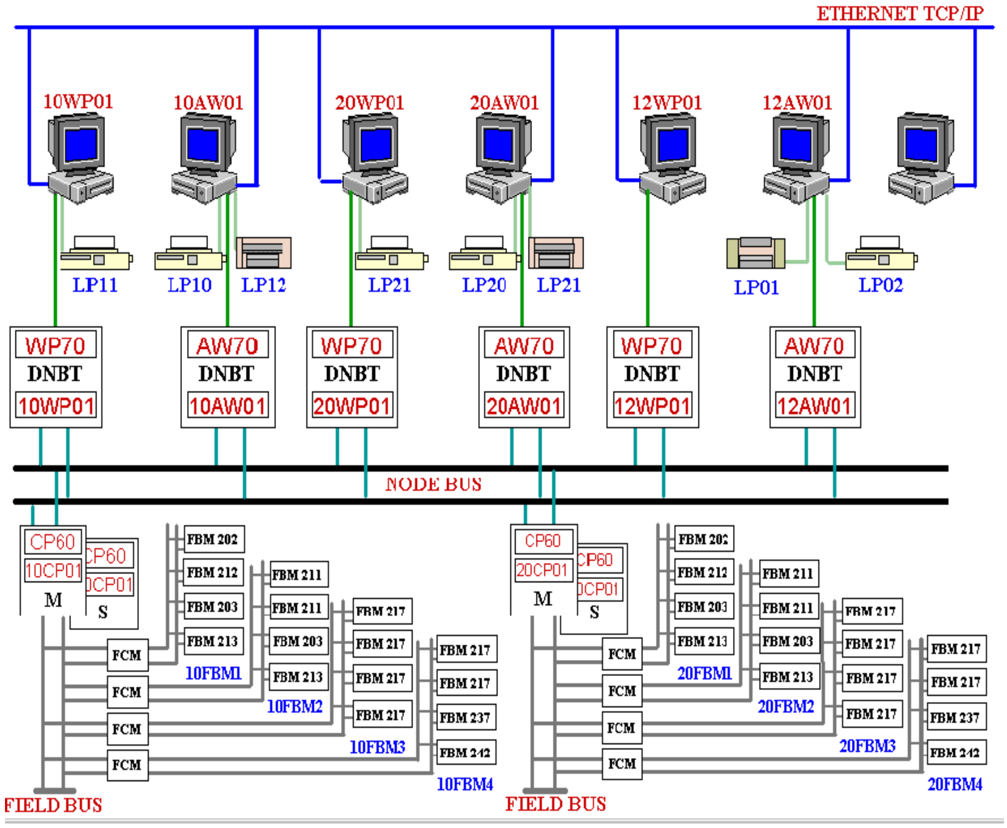

Figure 1- Architecture of the SCADA system.

3. PRESENTATION OF THE GRAFCET AND THE SA-RT METHOD

There are many graphical methods in general used in industry. Two of the most significant methods are SA-RT and Statecharts.

The first method is SA-RT which is a short name for Structured Analysis Method with extensions for Real Time [9]. The model is represented like a hierarchical set of diagrams that includes data and control transformations (processes). In fact, the control transformations are specified using State Transition diagrams, and the events are represented by control flows.

The second method is Statecharts which is a paradigm for specification of real time systems based on graphical and state. The system is represented like a set of hierarchical states as an alternative of processes. Every state can be decomposed into sub states and so on. The Statecharts notation is more condensed than the SA-RT notation and has been formally defined [10-11].

As a result, SA-RT is a complex method for system analysis and design. This is one of the most often used design method in technical and real-time oriented applications adopted by various Case-Tools [12]. It is a graphical, hierarchical and implementation autonomous method for top-down development.

SA-RT method enables us to know an entrance and an exit of data in an algorithm or a computer program [13]. It is divided in three modules: Context Diagram (CD), Data Flows Diagram (DFD) and Control Flows Diagram (DFC). Each module includes in its graphic interpretation special symbols.

Grafcet is a mode of representation and analysis of an automatism, particularly well adapted to the systems with sequential evolution that is decomposable into stages. It is diverted from the mathematical model of the Petri Nets. Its name is the acronym at the same time of "functional graph of command stages/transitions" and of "graph of the group AFCET (French Association for the economic and technical cybernetics)" [14-15].

In fact, the Grafcet is a graphical representation which translates, without ambiguity, the evolution of the cycle of a sequential automatism. This diagram allows describing the behavior expected from the automatism by imposing a rigorous approach, so avoiding the incoherence in the functioning [16-17].

4. EXAMPLE OF THE WATER STEAM CYCLE IN A TPP

In this paragraph, an example of a control-command application in a TPP is presented. The example is the water-steam cycle.

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Considering that the water contains an important rate in dissolved salts and in matter suspended, it is necessary 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 particularly membrane calmative.

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

The control of the water quality is a main task to maintain the efficiency and the sure and continuous working of the power station. To guarantee the best water quality at the level of the water steam circuit, the TPP of Radès (Figure 2) is constituted by an inverse osmosis station that permits to eliminate the majority of salts dissolved in the raw water before being treated in a demineralization station [18]. This stage serves to minimize risks of failing by corrosion of the turbine or the loss of the efficiency and the power.

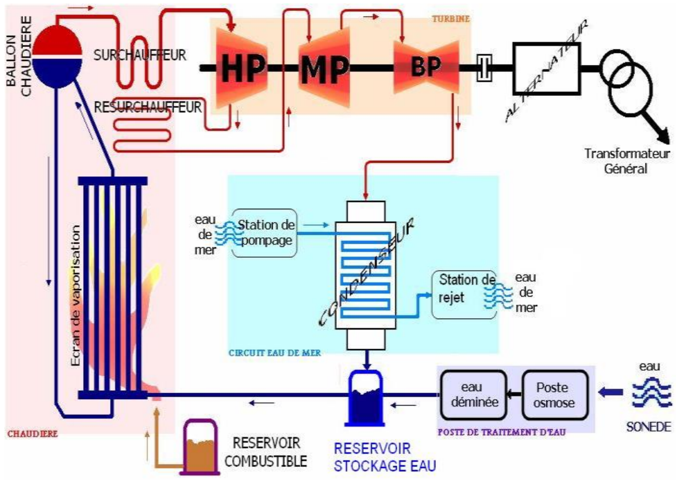

Figure 2- Thermal Power Plant (TPP).

The basic principle of the ion exchange consists in diminishing ions (remaining salts that are lower to 8%) in solution in water is to recuperate ion of value, either to eliminate a harmful or bothersome ion for the ulterior utilization of water (Figure 3).

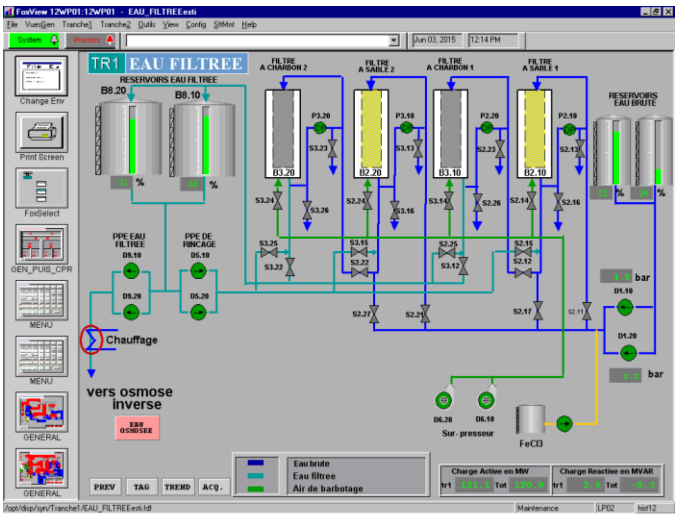

Figure 3- Display of the filtered water

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 (Figure 4).

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.

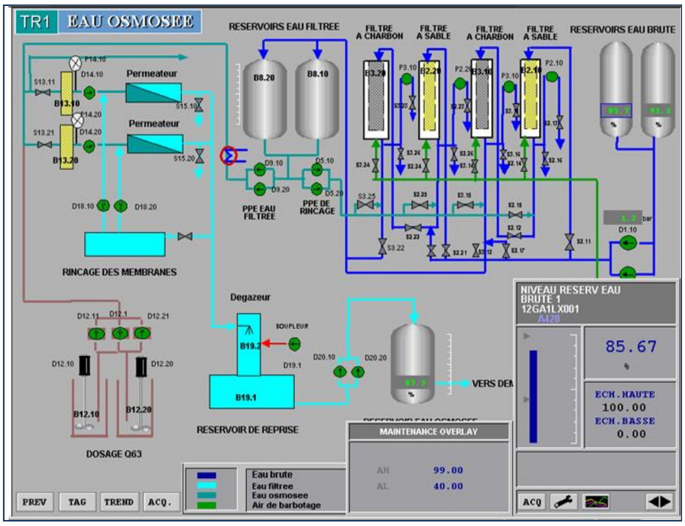

Figure 4- Display of the chemical analysis parameters.

In order to remedy to the nonattendance of indication, of follow-up and of storage of the chemical characteristics of the water of the boiler, it is essential to achieve an interfacing between the chemical sensors (pH and conductivity meters) and the surveillance stations of the control room.

In fact, the interfacing of the signals of the pH and the conductivity of the ball furnace is guaranteed by a data configuration of both analogical and numeric signals and requires a unique code for every entrance which must be programmed in the data base system.

5. RESULTS OF THE ANALYSIS AND MODELING

In this paragraph, the results of the analysis of the water-steam cycle by means of the Grafcet and a functional and operational SA-RT method are presented.

Compared to the results given by other methods such as SADT (Structured Analysis Design Technique), the SA-RT method allows a functional as well as a temporal analysis of a control-command application [19-21].

The automation of the post of production of water osmosis for an industrial programmable automaton Siemens S7-300 requires the modeling of the post. To reproduce at best the functioning of the post, we shall use a sequential model of representation which is the Grafcet. This technique is a clear, strict language.

In fact, The Grafcet is a graphic tool of definition for the sequential automatism, in all or nothing. It is also used in many combinatorial cases, where there is a sequence to be respected and where the state of the sensors is enough for solving the problem.

5.1- GRAFCET modeling

The starting up of the system is made by the support on the putting on button in the case of normal functioning. The support on one of the two stop buttons (urgency "AU" or system "AS"), interrupts the functioning of the system and causes the road marking of an alarm in the case of an emergency shutdown.

The Grafcet of figure 5, describing the general functioning of our system consists of several macro-stages.

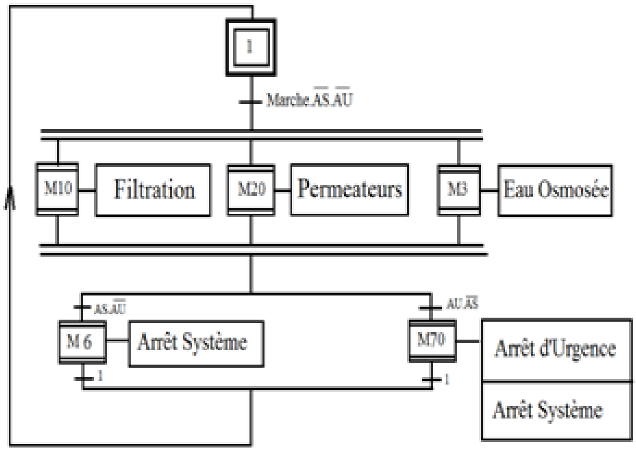

Figure 5- Grafcet of the general functioning of the system.

The cycle of filtration (Figure 6) includes the production which is the passage of the water, coming from the tank of raw water, by the sand filter of each of both chains, then by the coal-based filters active. This cycle includes in particular the rinsing of the filters which starts during the saturation of one of the filters and the road marking of an alarm pressure in case of obstinacy of the saturation after the cycle of rinsing.

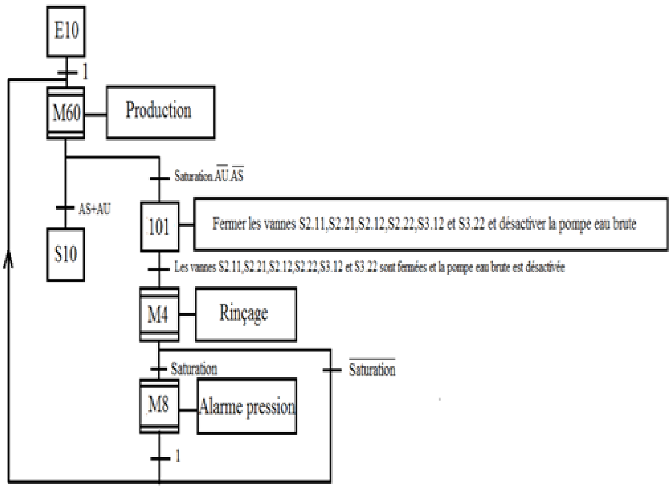

Figure 6- Macro-stage Filtration.

The cycle permeateurs (Figure 7) includes the production of the permeat, which is the passage of the water filtered through the filters of safety (5µ) then by the floors of permeateurs, rinsing of permeateurs in case of saturation and the road marking of an alarm pressure in case of obstinacy of the saturation after the cycle of rinsing.

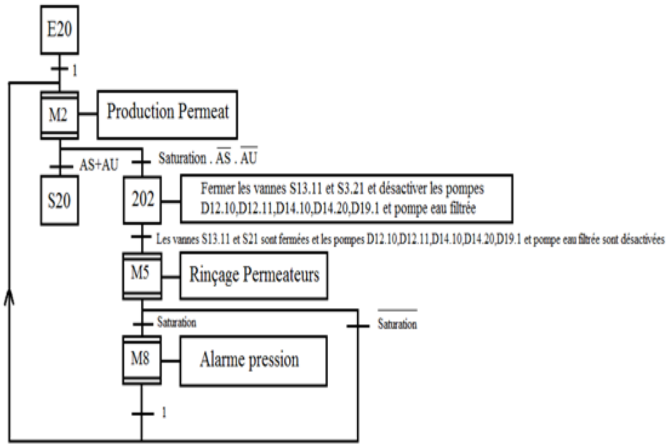

Figure 7- Macro-stage permeateurs.

The cycle osmosis water (Figure 8) contains the production of the water osmosis, which is the passage of the water coming from permeateurs by the degasser where it is going to undergo a degassing of the CO_2. This degased water will then be stored in the intermediate cover then inhaled by pumps water osmosis and finally stored in the water tank osmosis.

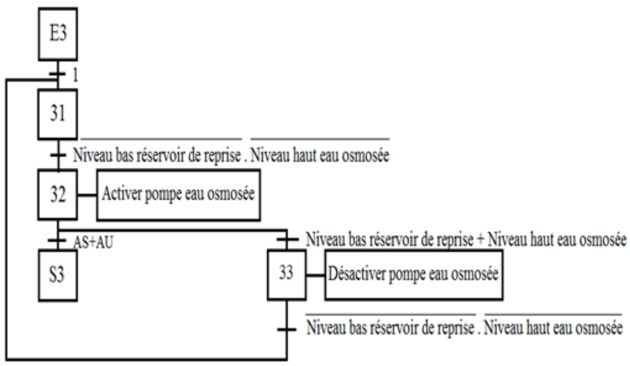

Figure 8- Macro-stage osmosis water.

5.2- SA/RT Analysis

Following modeling of the control-command application with the SA-RT method, the Control flow diagram of the water-steam cycle (Figure 9) and the State-transition diagram of the water-steam cycle (Figure 10) are presented.

The potential uses for the SA-RT model are the design of a monitoring display and a diagnosis display. For the design of a monitoring display, the preliminary data flow diagram of the SA-RT model supplies a comprehensive view of the system. Indeed, information relative to all processes represented through this stage should appear in a monitoring display .

For the design of hierarchical diagnosis display, each data flows diagram of the SA-RT model constitutes an image at a given abstraction stage. So, each of these data flows diagrams gives a less or more detailed vision. In fact, the designer defines the objectives for each display and can provide the necessary information by a particular data flows diagram can provide [22-23].

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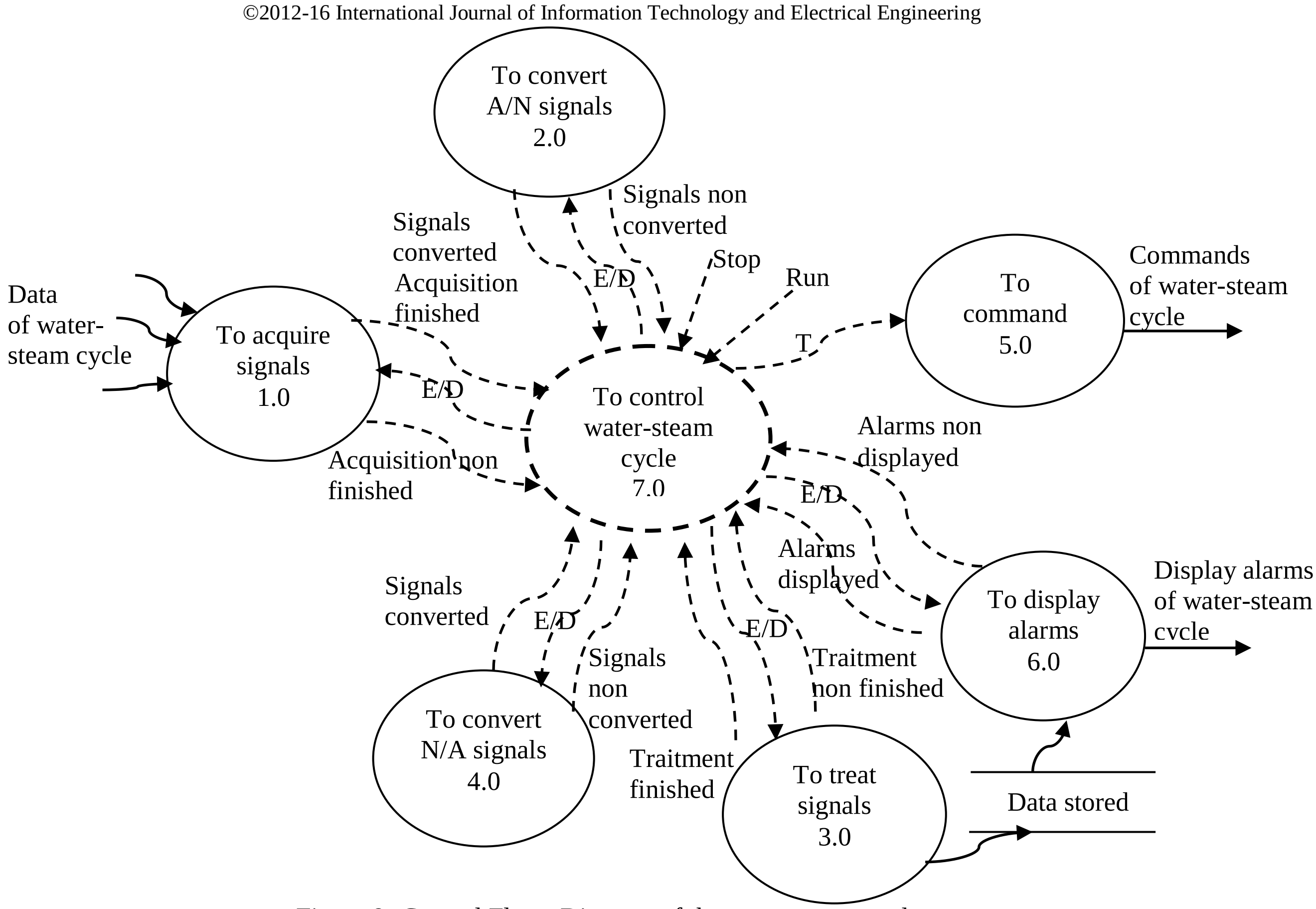

Figure 9- Control Flows Diagram of the water-steam cycle.

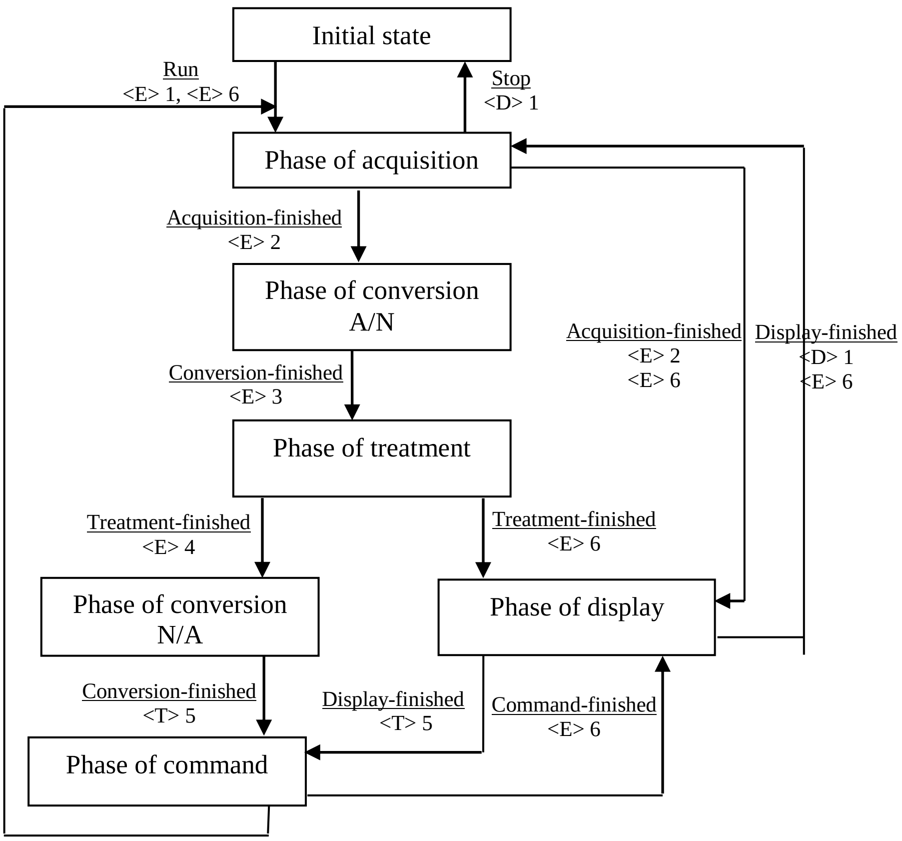

Figure 10- State-transition diagram of the water-steam cycle.

5. CONCLUSION

In this paper, the functionality of a SCADA system is presented on the one hand, and a control-command application using the SA-RT method is analyzed, on the other hand. In fact, it is very important to use a specification technique for the analysis and software of the SCADA system for the programming and the configuration of the displays in a SCADA environment.

The Grafcet modeling and the SA-RT analysis will allow an easy stage of a parametric modeling and implementation during the development of a control algorithm serving in the design of a supervising and monitoring system of the thermal power plant.

Finally, this application of the functional analysis techniques on the SCADA system of a thermal power plant shows the interests of the Grafcet language and the SA-RT method in the design of supervisory systems.

Staring from this case study of the SCADA system of the thermal power plant discussed in this paper, work is in progress to develop a functional analysis on the basis of a specification technique and real time for the various control-command applications in a thermal power plant and to perform the different displays used for the supervision system.

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