USING SA/RT METHOD AND SCADA FOR THE ANALYSIS AND THE SUPERVISION OF AN HYDROGEN CIRCUIT

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Abstract: *The aim of this paper is to present an application of structured analysis and real time (SA/RT) method on a control-command application and a supervisory control and data acquisition systems (SCADA). Then, the architecture of the SCADA system in a thermal power plant (TPP) is presented. An example of a control-command application of the supervision of the hydrogen circuit in a TPP in Tunisia is presented and analyzed using the SA/RT formalism. Finally, this functional and operational analysis enables us to facilitate the different steps of the specification, programming and the configuration of a tabular in a SCADA system.*
Key words: *SCADA; System analysis; Hydrogen circuit; SA/RT method.*

1. Introduction

Supervisory Control and Data Acquisition (SCADA) systems are industrial control systems which deploy several technologies that enable industries (manufacturing, water, power, transportation and many more) to monitor, gather and process data which are presented in a friendly form to human operator [1-2]. These systems offer functionalities such as synoptic diagrams, historical reports, alarms, trends, recipes and communication of relevant information to management levels.

SCADA systems have a hierarchical structure and in such systems there are effectively five levels [3]:

- Field level apparatus and control devices;
- RTUs (Remote Terminal Units) and PLCs (Programmable Logic Controllers) microprocessor controlled electronic devices which are an interface between objects in the physical world and SCADA systems;
- Communications media unit transmits and receives data between the master unit and the remote unit. The Communications Media can be a cable, wireless media, satellite or radio;
- The master stations, operator screens and displays. This level includes devices which collect the required process data for return to the Master SCADA Unit. These devices are installed where the process is being monitored;
- The commercial data processing computer system (Master SCADA Unit). This computer is the main control unit centrally located for use under the operator's control.

The objective of this paper is to show the importance of the use of structured analysis and real time for system specification. The next section briefly presents the architecture of a SCADA system in a thermal power plant (TPP). Finally, we present and discuss a case study of the SA-RT analysis of a hydrogen circuit in a TPP.

2. Architecture of SCADA system

One of the effective tools in power network automation is the SCADA system [4]. In fact, the different equipments, including SCADA system, have been installed in many companies over the world in order to modernize their power system distribution networks [5-8].

In this part, we present an example of the architecture of a SCADA system in a TPP in Tunisia. So, we present on the one hand, the different steps of programming in a SCADA environment and on the other hand, the configuration of the tabular of a control-command application.

Figure 1 illustrates the architecture of a SCADA system of a TPP. This system is composed of the following elements [9-11]:

- A plate of the terminal block;
- FBM (Field Bus Module);
- FCM (Field Bus Communication Module);
- CP60 (Control process);
- DNBT (Dual Node Bus base_T interface);
- AW (Work Station Processor);
- WP (Application Work Station).
- Among software of the SCADA system, we mention:
- SYS MON: System monitor that supervises the good working of all the facilities of the system.
- FOXVIEW: Interfacing operator to visualize the tabular with a slim rod to activate the main functions of the SCADA system.
- FOX DRAW: Creator of tabular.
- FOX SELECT: Software permitting to reach the various elements of the hierarchy of the CP60.
- ICC (Integrated Control Configuration): Software permitting to create and to configure programs residing in the CP60.
- AIM HISTORIAN: Software permitting 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.

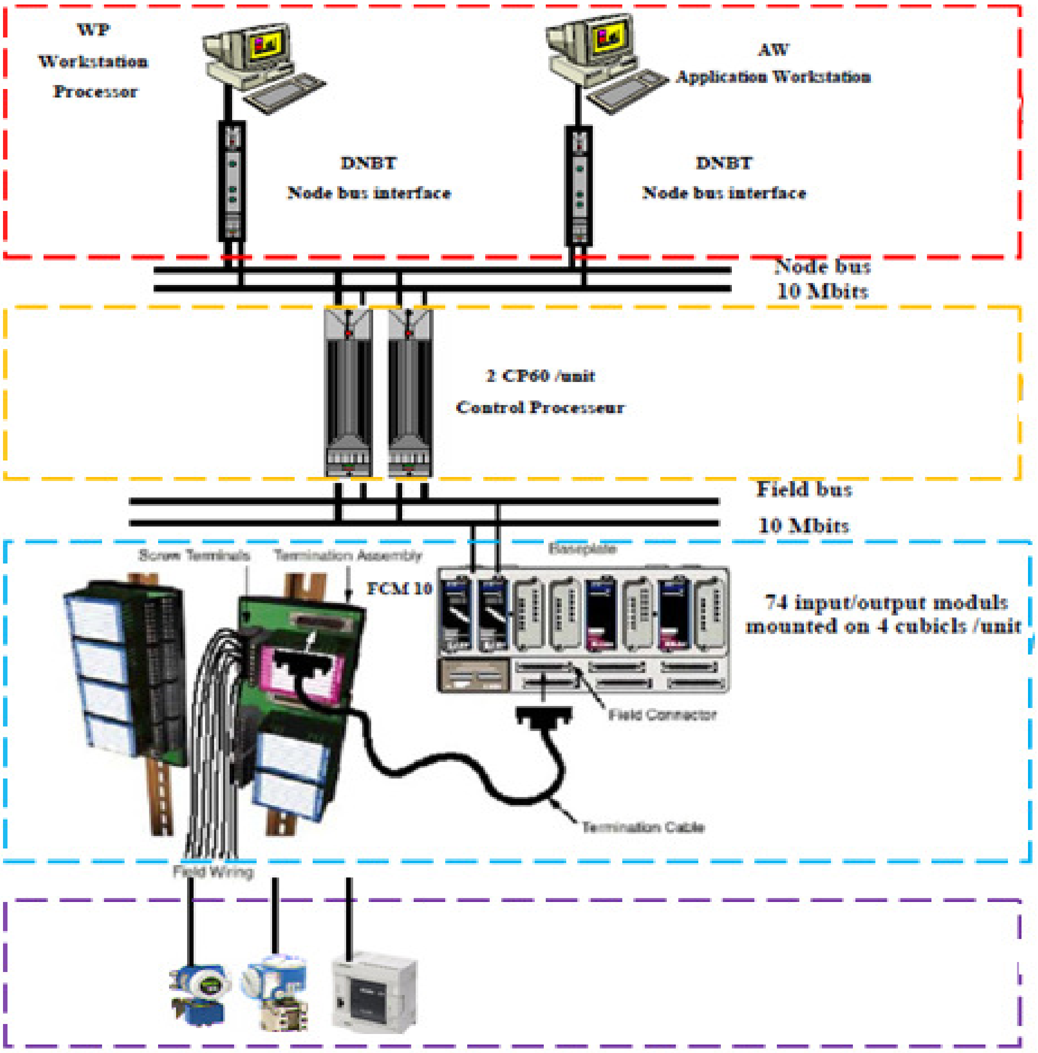

Fig. 1. Architecture of the SCADA system of a TPP.

3. Presentation of the SA/RT method

The SA/RT (Structured Analysis for Real-Time Systems) method was defined in the mid 80's by two research teams: Ward and Mellor [12], Hatley and Pirbhai [13]. Their works, carried out separately, propose real-time extensions of DeMarco's structured analysis. The extensions concern the addition of the control functionalities describing the dynamics of the system and the corresponding data processing [14].

The basic idea of this graphical method consists in putting in evidence inside data flow diagrams elements dedicated to the control view. A data flow diagram (DFD) provides a processes (activities) net drawing. A DFD expresses a representation means to depict inter-processes exchanges, in order to enlighten the control or data flows sent or received by each process when an execution is performed. Consequently, such a diagram shows a special activity whose role is to pilot the set of other activities. This control activity study is therefore tackled to describe the effective control logic [15].

Figure 2 shows the representation principles of the functional, the behavioral and the informational view of a system by means of the SA/RT method.

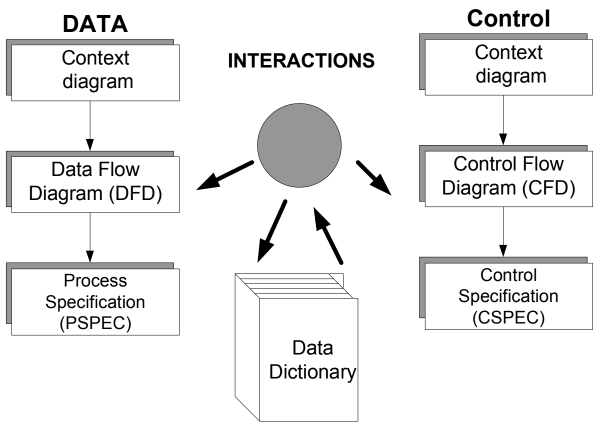

Fig. 2. SA/RT elements structure [15].

The functional view of SA/RT method is modeled by means of the structured analysis tools. The graphic components of the model are data flows, data storages and processes. They are organized by means of specific construction rules into diagrams named Data Flow Diagrams (DFD). The first DFD is the context diagram. It gives the only system representation inside which are visualized the model borders. They define the limit between the system and its environment. The model is organized as a hierarchy of DFD, whose context diagram represents the highest level [14]. Each DFD expresses a refinement of one immediate ancestor DFD such that the decomposed process is called father process of one of its son processes. At the bottom of the branching, the leaves identify atomic processes. Also called primitive, those processes cannot be described through DFD; we have to resort to another representation mode. This ultimate step of the functional modeling corresponds to the process specification (PSPEC) which is mainly done using textual languages.

Informational aspect of the SA/RT method: The data and the events occurring at all the model stages are defined in a dictionary. As for the complex data storage, the WM approach predicts a modeling by means of Entity/Association diagrams used for modeling sizeable and complex data such as databases [14].

The behavioral view of SA/RT: this aspect of the studied system is supported by tools which are able to take into account events needed to manage correct process execution. A control model is derived for each DFD drawn and supplies the control logic to be applied to their related sub-processes. So the control logic hierarchy is established upon the DFDs one. Each control unit specification is realized using automaton, or state transition table or array [15].

SA-RT is the specification models that have been widely used in real-time system and software engineering applications. It is a generic method addressing both system analysis and the design of real-time and complex systems [16-17].

SA/RT diagrams deal with two views of the considered system: a static view, the structural description, and a dynamic view, the behavioral description. In SA/RT standards (though slightly different), the structural description is done by data flow diagrams (DFD) and the behavioral description is done by the control flow diagram (CFD) coupled with state transition diagrams (and/or process activation tables). For SA/RT specifications other tools are also used (including process specifications, data dictionary...) which are mainly textual tools.

4. Case study of hydrogen circuit

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.

Hydrogen is an odorless, colorless, very light gas (more that air) and composed of two atoms of hydrogen. It possesses a high gravimetric energizing power: 120 MJ/kgs compared to oil (45MJ/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 H2), 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.

The purity of hydrogen H2 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 H2 intern to form an exploding the mixture. It is necessary to renew a certain volume of H2 lodged in the alternator by another volume coming from bottles H2.

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 (Fig.3) permitted the increase of the strength of the alternator and an efficient utilization of the hydrogen pressure.

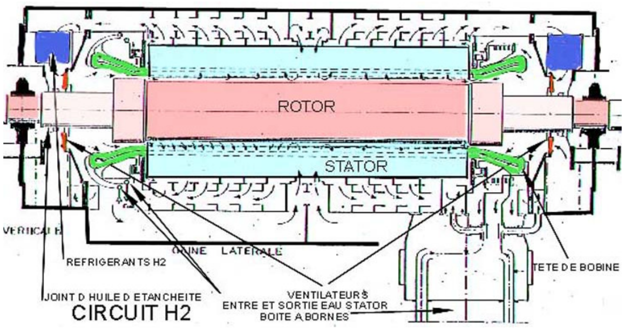

Fig. 3. Cooling by hydrogen of an alternator.

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.

The turbo-alternator group of the center of RADES is cooled internally by gas hydrogen. As the shows the diagram of circuit (Fig.4), 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.

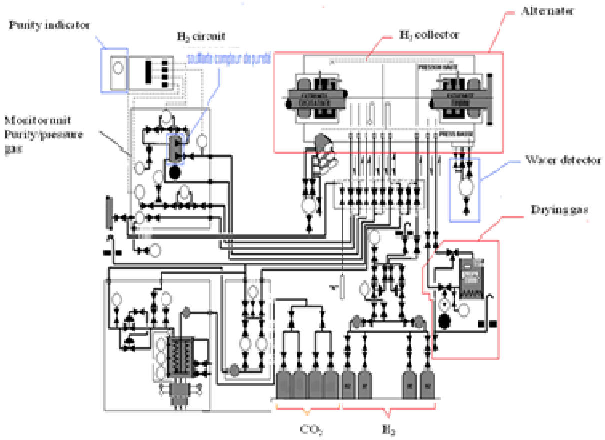

Fig. 4. Circuit of the hydrogen gas of the TPP.

The pressure of hydrogen gas 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, hydrogen gas is provided with the help of the superior hose of distribution of the alternator.

The purity of hydrogen gas 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 hydrogen gas in order to maintain the pressure of the internal gas to a value wanted of 1 to 8 Abs bars.

Hydrogen gas 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, hydrogen gas 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.

5. Results of the SA/RT analysis

In this paragraph, we present the results of the SA-RT analysis of a control-command application using a functional and operational method.

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. Then, the case study of the hydrogen circuit of the TPP is analyzed according to the SA-RT formalism presented [18-20].

After modeling of the hydrogen circuit of the TPP using the SA/RT method, we establish four diagrams as follows:

- Context diagram of the hydrogen circuit;
- Control flow diagram of the hydrogen circuit;
- State-transition diagram of the hydrogen circuit.

Figure 5 represents the context diagram of the SA-RT model of the hydrogen circuit. In fact, the context diagram is constituted of one functional process « To supervise the hydrogen circuit 0 » and 12 terminators.

The context diagram defines perfectly the interface between the designer and the client, that is, to provide or generate data in order to display these data on the tabular of the hydrogen circuit.

The data flow diagram of the SA/RT model constitutes the first decomposition of the process presented in the context diagram. Then, we can break down the initial functional process of the application of control in six basic elements: To acquire signals, To convert signals A/N, To treat signals, To convert signals N/A, To command, To display alarms.

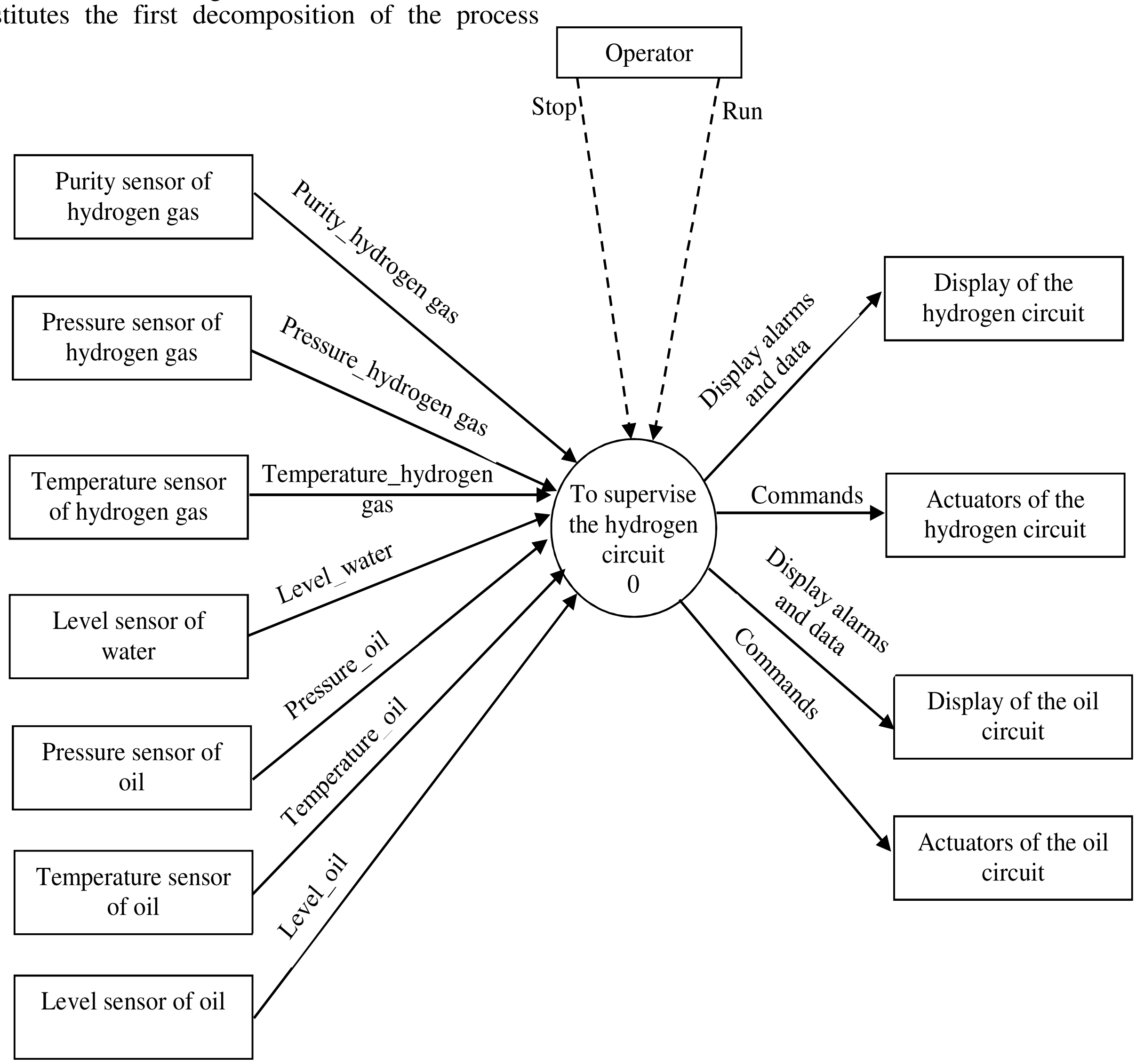

Fig. 5. Context diagram of the SA/RT model of the hydrogen circuit.

Figure 6 shows the Control flow diagram of the SA/RT model that includes the control aspect to the data flow diagram elaborated.

In fact, the implementation of the process of monitoring at the level of preliminary diagram can express the execution or the sequence of the functional processes.

Figure 7 shows the state-transition diagram of the SA/RT model of the Hydrogen circuit.

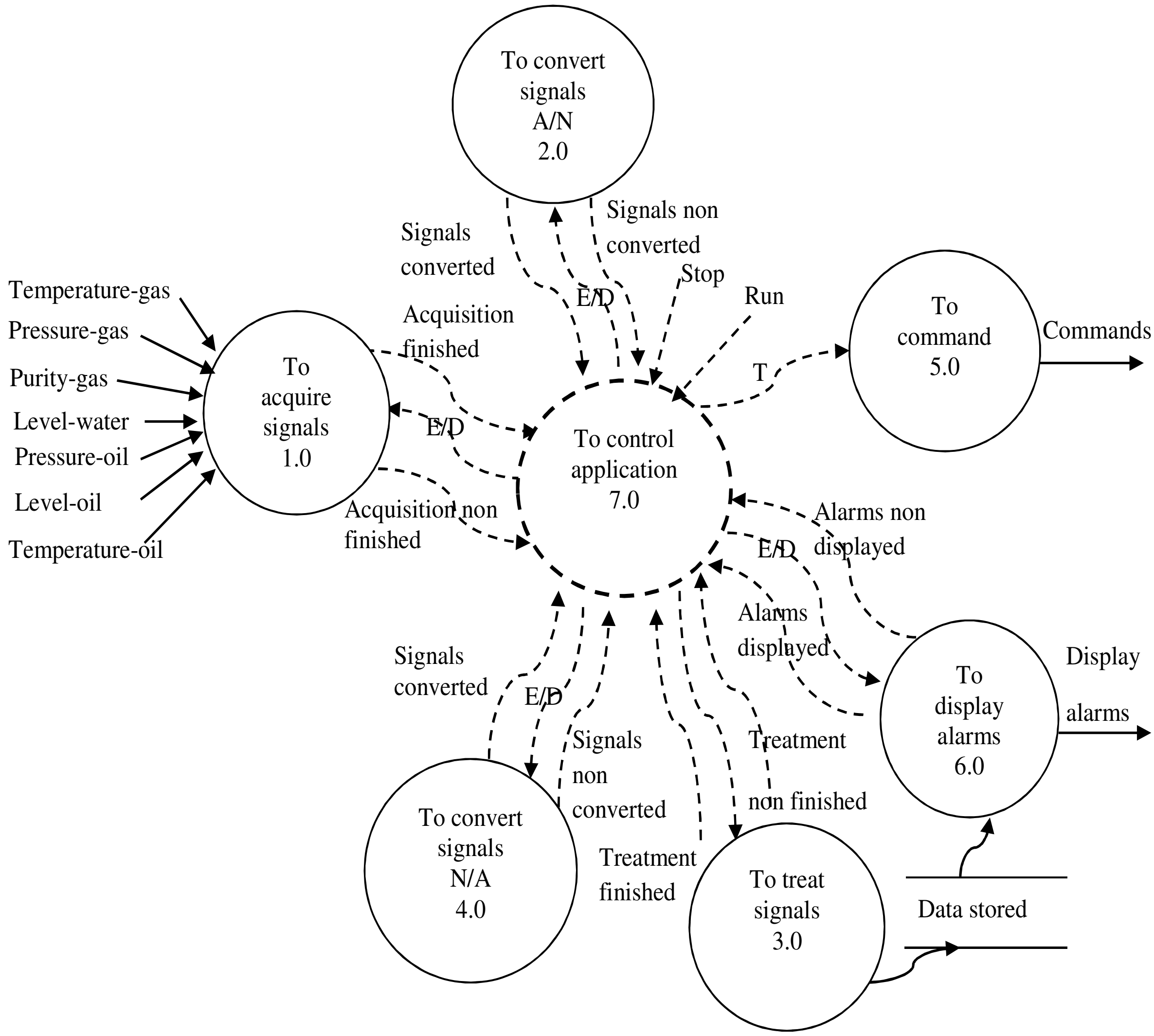

Fig.6. Control Flows Diagram of the SA/RT model of the hydrogen circuit.

The possible 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 global view of the system. Indeed, information relative to each process represented through this level should appear in a monitoring display [21-25].

For the design of hierarchical diagnosis display, each data flows diagram of the SA/RT model constitutes a vision at a given abstraction level. So, each of these data flows diagrams gives a less or more detailed vision. In function of the objectives defined by the designer for each display, a particular data flows diagram can supply the required information.

Finally, this application of the functional analysis technique on the SCADA system of a thermal power plant shows briefly the interests of the SA/RT method in the design of supervisory systems. In fact, many diagrams using the SA/RT are presented and described.

5. Conclusions

In this paper, we presented on the one hand, the functionality of a SCADA system and on the other hand, an analysis of a control-command application using the SA/RT method. The example was the hydrogen circuit of thermal power plant. In fact, it is very important to use software of the SCADA system for the programming and the configuration of the tabular in a SCADA environment.

The SA/RT analysis will allow an easy stage of a parametric modeling and implementation through the development of a control algorithm helping in the design of a supervising and monitoring system of the hydrogen circuit.

Staring from this case study of the architecture of a SCADA system discussed in this paper, work is in progress to develop a functional analysis and real time for the various applications of control-command in a thermal power plant.

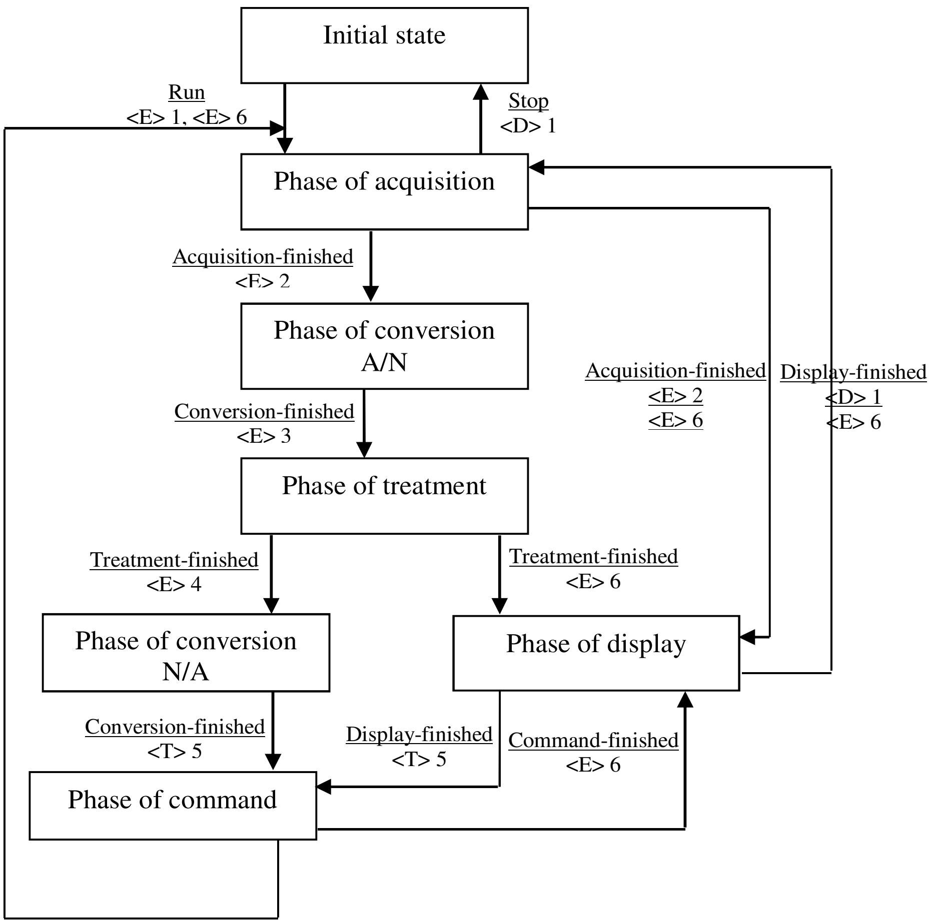

Fig. 7. State /Transition diagram of the SA/RT model of the hydrogen circuit.

References

1. Portilla N. B., Queiroz M.H., Cury J.E.: Integration of supervisory control with SCADA system for a flexible manufacturing cell. In: Proceedings of the 12th IEEE International Conference on Industrial Informatics, 2014, pp.261-266.
2. Marciniak P., Kulesza Z., Napieralski A., Kotas R.: Scripting languages for simulations in modern SCADA systems. In: Proceedings of the 17th International Conference Mixed Design of Integrated Circuits and Systems, 2010, pp. 613-618.
3. Bailey D., Wright E.: Practical SCADA for Industry, Elsevier, 2003.
4. Patel M., Cole G.R., Pryor T.L. and Wilmota N.A.: Development of a novel SCADA system for laboratory testing, ISA Transactions 43, pp 477-490, 2004.
5. Marchat H. : La gestion de projet par étapes - Portefeuille de projets, Editions d'Organisation, 2009.
6. Lakhoua M.N.: Application of Functional Analysis on a SCADA system of a Thermal Power Plant, Advances in Electrical and Computer Engineering, Issue No2, vol. 9, 2009.
7. Lakhoua M.N.: Application of Functional Analysis Techniques and Supervision of Thermal Power Plants, Thermal Power Plants, Mohammad Rasul (Ed.), ISBN: 978-953-307-952-3, InTech, 2012.
8. Lakhoua M.N.: SCADA applications in thermal power plants, International Journal of Physical Sciences, vol.5, N°7, pp 1175-1182, 2010.
9. Lakhoua M.N: Application of functional analysis for the design of supervisory systems: case study of heavy fuel-oil tanks, International Transactions on Systems Science and Applications, vol.5, N°1, June, pp. 21-33, 2009.
10. Lakhoua M.N: Surveillance of pumps vibrations using a SCADA, Control Engineering and Applied Informatics, vol.12, N°1, 2010.
11. Lakhoua M.N.: Systemic analysis of a supervisory control and data acquisition system, Journal of Electrical Engineering, (www.jee.ro), vol.11, N°1, 2011.
12. Ward P. and Mellor S.: Structured Development for Real-Time Systems, Yourdon Press, 1985.
13. Hatley D. and Pirbhai I.: Strategies for Real-Time system Specifications (SA-RT), Masson, Paris. France, 1991.
14. Ben Ahmed S., Moalla M. , Courvoisier M.: Towards a design methodology for flexible manufacturing systems command combining SA-RT and object Petri nets. In: Proceedings of the IEEE Symposium on Emerging Technologies and Factory Automation ETFA'95, 1995, Vol.1,pp. 83-94.
15. Marty J.C., Sartor M.: A specification method combining statecharts, activity-charts, and SART concepts in FMS study. In: Proceedings of the 20th IEEE International Conference on Industrial Electronics, Control and Instrumentation IECON'94, 1994, Vol. 2, pp.1147-1152.
16. Hastono P., Huss S.A.: Automatic Generation of Executable models from Structured Approach Real-Time Specifications. In: Proceeding of the 25th IEEE International Real-Time Systems Symposium (RTSS), 2004.
17. Benzina A., Paludetto M., Delatour J.: About the suitability of Petri nets for describing, validating and evaluating SA-RT specifications. In: Proceedings of the 4th IEEE In ternational Computer Science Conference and 4th Asia

Pacific Software Engineering Conference, 1997, pp. 249-258.
18. Gergely E.I., Popenţiu-Vladicescu Fl., Madsen H., Mang G.E., Nagy Z.T. and Spoială D.: A Procedure for PLC Programs Validation, SOFA2009, Romania, 2009, pp. 169-174.
19. Husi G., Szász C. and Hasimoto H.: Application of reconfigurable hardware technology in the development and implementation of building automation systems, Environmental Engineering and Management Journal, 13: (11) 2014, pp. 2899-2905.
20. Gergely E.I., Popenţiu-Vladicescu Fl., Madsen H., Mang G.E., Nagy Z.T., Spoială D.: A Procedure for PLC Programs Validation, Proceedings of the 3rd International Workshop on Soft Computing Applications SOFA 2009, pp. 169-174, July 29 – August 1, Szeged, Hungary – Arad Romania, 2009.
21. Lakhoua M.N.: Structured Analysis and Supervision Applied on Heavy Fuel Oil Tanks, Journal of Computer Science and Control Systems (JCSCS), vol.9, N°1, May 2016.
22. Glaa R. and Lakhoua M.N.: Methodology of Analysis and Design of a SCADA System, CISTEM, IEEE, 3-6 Nov. 2014, Tunisia.
23. Lakhoua M.N., Glaa R., Ben Hamouda M., El Amraoui L.: Contributions to the Analysis and the Supervision of a Thermal Power Plant, International Journal of Advanced Computer Science and Applications, 2016, Vol.7, N°1.
24. Ben Salem J., Lakhoua M.N., El Amraoui L., Analysis of a Braking System on the Basis of Structured Analysis Methods, International Journal of Advanced Computer Science and Applications, Vol.7, N°1, 2016
25. Lakhoua M.N., Ben Hamouda M., Glaa R., El Amraoui L.: Structured Analysis and Modeling of a Supervisory Control And Data Acquisition in a Thermal Power Plant, International Journal of Information Technology and Electrical Engineering, February 2016, Vol.5, Issue 1.