Application of Functional Analysis on a SCADA System of a Thermal Power Plant

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***Abstract*—The aim of this paper is to present firstly the functionality of a supervisory system for complex processes, and secondly to present the concepts of SCADA (supervisory control and data acquisition) systems. A functional analysis technique SADT (Structured Analysis and Design Technique) has been applied on an example of a SCADA system of a thermal power plant. This technique allows a functional description of a SCADA system. The paper briefly discusses the functions of a SCADA system and some advantages of the application of functional analysis for the design of a human centered supervisory system. Then the basic principles of the SADT technique applied on the SCADA system are presented. Finally, the different results obtained from the SADT technique are discussed.**

***Index Terms*—Supervisory systems, SCADA, Functional Analysis, SADT, Thermal power plant**

I. Introduction

Today, the supervision of production systems is more and more complex to perform, not only because of the number of variables always more numerous to monitor but also because of the numerous interrelations existing between them, very difficult to interpret when the process is highly automated.

The challenge of the future years is based on the design of support systems which let an active part to the supervisory operators by supplying tools and information allowing them to understand the running of production equipment. Indeed, the traditional supervisory systems present many already known problems. First, whereas sometimes the operator is saturated by an information overload, some other times the information under load does not permit them to update their mental model of the supervised process.

Moreover, the supervisory operator has a tendency to wait for the alarm to act, instead of trying to foresee or anticipate abnormal states of the system. So, to avoid these perverse effects and to make operator's work more active, the design of future supervisory systems has to be human centered in order to optimize Man-Machine interactions.

It seems in fact important to supply the means to this operator to perform his own evaluation of the process state. To reach this objective, Functional Analysis seems to be a promising research method [1]. In fact, allowing the running of the production equipment to be understood, these techniques permit designers to determine the good information to display through the supervisory interfaces dedicated to each kind of supervisory task (monitoring, diagnosis, action, etc.). In addition, Functional Analysis techniques could be a good help to design support systems such as alarm filtering systems.

By means of a significant example, the objective of this paper is to show interests of the use of Functional Analysis techniques such as SADT (Structured Analysis and Design Technique) for the design of supervisory systems. An example of a SCADA system of a thermal power plant is presented. The next section briefly describes the characteristics of a SCADA system and the problems linked to its design. Next, the interests of using SADT in the design steps are developed. In Section 3, after presenting concepts of SADT, this technique is applied to a SCADA system of a thermal power plant. The last section presents a discussion about the advantages and inconveniences of the Functional Analysis technique used.

II. Functionality of a Supervisory System

Supervision consists of commanding a process and supervising its working [2]. 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.

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.

A supervised system is composed of the following parts:

- The Man-Machine Interfaces (MMI), displaying information thanks to the information synthesis system.
- The supervisory tools, supplying services thanks to the automatic supervisory system and the decision support systems.
- The control/command part, interface between the MMI, the supervisory tools and the process.
- The process is also called production system or operative part, performing the physical work on the input product flow.

According to recommendations proposed by Vittet J. [3], a supervisory system has to give to the human operator:

- A global view of the installation and its operation. The operator must access this pertinent information, without much reasoning.
- Information concerning the evolution of the process state.
- Information which permits results of operator's actions to be controlled quickly.
- The means to drive away into the different levels of process abstraction.
- Good alarms; i.e. well defined, well commented and specific to the different running modes.

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According to the point of view proposed by Lambert M. [4], an automatic supervisory system is a traditional supervisory system, that is to say, a system which provides a hierarchical list of alarms generated by a simple comparison with regard to thresholds. The information synthesis system manages the presentation of information via any support (synoptic, console, panel, etc.) to the human operator.

III. Presentation of SCADA systems

SCADA is the acronym for "supervisory control and data acquisition." SCADA systems are widely used in industry for supervisory control and data acquisition of industrial processes. The process can be industrial, infrastructure or facility [5-6-7-8]. We present in this paragraph a review of SCADA systems on the one hand and some applications of SCADA systems that have been presented in various researches, on the other hand.

A. Review of SCADA systems

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, 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.
- 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 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.

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.

B. Some researches of SCADA systems

Researcher, Poon H.L. [9], has tried to make a survey of the current development of data acquisition technology. The various practical considerations in applying Data Acquisition Systems (DAS) are summarized, and some feasible areas of advanced applications are investigated.

Researchers, Ozdemir E. & al. [10], have used a Java-enabled mobile as a client in a sample SCADA application in order to display and supervise the position of a sample prototype crane. The wireless communication between the mobile phone and the SCADA server is performed by means of a base station via general packet radio service GPRS and wireless application protocol WAP. Test results have indicated that the mobile phone based SCADA integration using the GPRS or WAP transfer scheme could enhance the performance of the crane in a day without causing an increase in the response times of SCADA functions. The operator can visualize and modify the plant parameters using his mobile phone, without reaching the site. In this way maintenance costs are reduced and productivity is increased.

Researcher, Horng J.H. [11], has presented a SCADA of DC motor with implementation of fuzzy logic controller (FLC) on neural network (NN). He has successfully avoided complex data processing of fuzzy logic in the proposed scheme. After designed a FLC for controlling the motor speed, a NN is trained to learn the input-output relationship of FLC. The tasks of sampling and acquiring the input signals, process of the input data, and output of the voltage are commanded by using LabVIEW. Finally, the experimental results are provided to confirm the performance and effectiveness of the proposed control approach.

Researcher, Aydogmus Z. [12], has presented a SCADA control via PLC for a fluid level control system with fuzzy controller. For this purpose, a liquid level control set and PLC have been assembled together. The PLC used in this work has no fuzzy module or software. The required fuzzy program algorithms are written by the author. Sugeno type fuzzy algorithm has been used in this study. A SCADA system has been composed for monitoring of water level in tank and position of the actuator valve. The main objective of this work is to present an implementation setup has been realized with no fuzzy logic controller module/software in this study.

Researcher, Munro K. [13], has developed the idea that SCADA systems are being rapidly integrated with corporate networks but the ramifications of a SCADA breach are far more worrying than disruption to production.

Researchers, Patel M. & al. [13], have presented a SCADA system that allows communication with, and controlling the output of, various I/O devices in the renewable energy systems and components test facility RESLab. This SCADA system differs from traditional SCADA systems in that it supports a continuously changing operating environment depending on the test to be performed. The SCADA System is based on the concept of having one Master I/O Server and multiple client computer systems. The authors have described the main features and advantages of this dynamic SCADA system, the connections of various field devices to the master I/O server, the device servers, and numerous software features used in the system.

Researchers, Ralstona P.A.S., & al. [15], have provided a broad overview of cyber security and risk assessment for SCADA and DCS, have introduced the main industry organizations and government groups working in this area, and have given a comprehensive review of the literature to date. Major concepts related to the risk assessment methods are introduced with references cited for more detail. Included are risk assessment methods such as HHM, IIM, and RFRM which have been applied successfully to SCADA systems with many interdependencies and have highlighted the need for quantifiable metrics. Presented in broad terms is probability risk analysis (PRA) which includes methods such as FTA, ETA, and FEMA. The authors have concluded with a general discussion of two recent methods (one based on compromise graphs and one on augmented vulnerability trees) that quantitatively determine the probability of an attack, the impact of the attack, and the reduction in risk associated with a particular countermeasure.

Researchers, Avlonitis S.A. & al. [16], have presented the structure and the installation of a flexible and low cost SCADA system. An ordinary PC with the appropriate interface and software operates the system. The system was installed to an old desalination plant in parallel with the existing old type conventional automation system, which is using relays, timers, etc. The automation system allows remote control and supervision of the plant at reasonable low cost. On the other hand, the system can be used for additional safety measures for the RO plant. The analysis of the data which are collected could be used for the prediction of possible breakdowns of the RO plant. The design and installation of the automation system, which includes the software and hardware, is simple and easily accessible. The operation of the system is simple and user-friendly and can be altered with very little knowledge in programming. The installation of the system has been proved quite useful in preventive maintenance, taking into account the peculiarity of this particular reverse osmosis plant. The system has reduced the labor cost, and has increased the labor productivity of the operation due to the remote supervision of the process.

IV. Methodology of Analysis of a SCADA System

A. Participative methods literature

There are many methods that have been used to enhance participation in IS planning and requirements analysis. We review some methods here because we think they are fairly representative of the general kinds of methods in use. The methods include Delphi, focus groups, multiple criteria decision-making (MCDM), total quality management (TQM), and SADT.

The objective of the Delphi method [17] is to acquire and aggregate knowledge from multiple experts so that participants can find a consensus solution to a problem.

A second distinct method is focus groups (or focused group interviews) [18]. This method relies on team or group dynamics to generate as many ideas as possible. Focus groups have been used for decades by marketing researchers to understand customer product preferences

MCDM [19] views requirements gathering and analysis as a problem requiring individual interviews. Analysts using MCDM focus primarily on analysis of the collected data to reveal users' requirements, rather than on resolving or negotiating ambiguities. The objective is to find an optimal solution for the problem of conflicting values and objectives, where the problem is modelled as a set of quantitative values requiring optimization.

TQM [20] is a way to include the customer in development process, to improve product quality. In a TQM project, data gathering for customers needs, requirements elicitation may be done with QFD.

The SADT method represent attempts to apply the concept of focus groups specifically to information systems planning, eliciting data from groups of stakeholders or organizational teams. SADT is characterized by the use of predetermined roles for group/team members and the use of graphically structured diagrams. It enables capturing of proposed system's functions and data flows among the functions [21-22-23].

B. SADT method

SADT [21-22-23], which was designed by Ross in the 1970s, was originally destined for software engineering but rapidly other areas of application were found, such as aeronautic, production management, etc.

SADT is a standard tool used in designing computer integrated manufacturing systems, including flexible manufacturing systems [22]. Although SADT does not need any specific supporting tools, several computer programs implementing SADT methodology have been developed. One of them is Design: IDEF, which implements IDEF0 method. SADT: IDEF0 represents activity oriented modelling approach (Figure.1). IDEF0 representation of a manufacturing system consists of an ordered set of boxes representing activities performed by the system. The activity may be a decision-making, information conversion, or material conversion activity. The inputs are those items which are transformed by the activity; the output is the result of the activity. The conditions and rules describing the manner in which the activity is performed are represented by control arrows. The mechanism represents resources (machines, computers, operators, etc.) used when performing the activity.

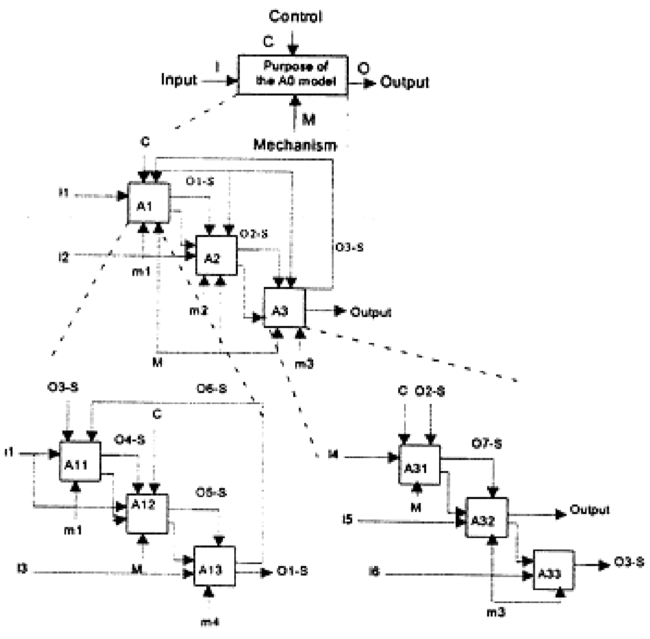

Figure 1. Top-down, modular and hierarchical decomposition of SADT method.

The boxes called ICOM's input-control-output-mechanisms are hierarchically decomposed. At the top of the hierarchy, the overall purpose of the system is shown, which is then decomposed into components-subactivities. The decomposition process continues until there is sufficient detail to serve the purpose of the model builder. SADT: IDEF0 models ensure consistency of the overall modelled system at each level of the decomposition. Unfortunately, they are static, i.e. they exclusively represent system activities and their interrelationships, but they do not show directly logical and time dependencies between them. SADT defines an activation as the way a function operates when it is 'triggered' by the arrival of some of its controls and inputs to generate some of its outputs. Thus, for any particular activation, not all possible controls and inputs are used and not all possible outputs are produced. Activation rules are made up of a box number, a unique activation identifier, preconditions and postconditions [23].

Preconditions and postconditions describe what is required for and what results from the activation. Both preconditions and postconditions are logical expressions of ICOM codes, where each ICOM code identifies a single control, input, output, or mechanism arrow for that particular box. When an ICOM arrow does not participate in activation, it is simply omitted from the precondition. Similarly, when some of the outputs of a box are produced during activation, the ICOM codes for those outputs not generated are omitted from the postcondition. A precondition expresses the required presence (or absence) of any of the objects associated with the inputs, controls, outputs, or mechanisms involved in the activity. A post condition indicates presence (or absence) after the activity has occurred

For SADT diagrams or function boxes, we will consider two events to be representing the activation states of the activities. The first event represents the instant when the activity is triggered off, and the second event represents the ending instant.

This method has got several advantages:

- Large field of applications such as automation, software developments, management systems and so on.
- Facility and universality of the basic concepts.
- Existence of a set of procedures, advises and guidelines

We present, in an in exhaustive manner, some studies of the SADT method with an industrial character that have been presented in various researches:

Researchers, Santarek K. & al. [24], have described an approach to manufacturing systems design that allows automatic generation of controller logic from a high level system design specification. The high level system design specification was developed using SADT method and Design:IDEF software package. The interface is based on a number of transformation rules from an IDEF0 specification into a Petri net. A standard qualitative analysis and simulation of the Petri net is used to determine if the manufacturing system will operate in the desired manner.

Researchers, Benard V. & al. [25], have developed and proposed the Safe-SADT method. This method allows the explicit formalization of functional interactions; the identification of the characteristic values affecting the dependability of complex systems, the quantification of the reliability, availability, maintainability, and safety (RAMS) parameters of the system's operational architecture, and validation of that operational architecture in terms of the dependability objectives, and constraints set down in the functional requirement specifications (FRS).

Researchers, Lauras, M. & al. [26], have proposed an approach based on enterprise modelling tools (GRAI, SADT/IDEFO) that allows integrating the best practices defined by these methods. Besides the indicators following through the results and determinants, three types of indicators are introduced to analyse the performance: the facility viewpoint measures, the appropriateness of the resources available with the determinants of the activity. The ambition viewpoint evaluates with the determinants the feasibility of the aims assigned to the activity. The reality viewpoint measures the impact of determinants on the results of the activity.

V. Presentation of a SCADA System of a Thermal Power Plant

During the last few years, the Société Tunisienne de l'Electricité et du Gaz (S.T.E.G) has evolved in a difficult international conjuncture characterized by the increasing of the hydrocarbon's prices [27]. 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 [28-29-30].

Among the production units of electricity of the S.T.E.G, we present an example of a thermal power plant that consists on a system producing 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 is a power plant (Figure.2) 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 thermal power plants 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 thermal power plants, mechanical power is produced by a heat engine which transforms thermal energy, often from combustion of a fuel, into rotational energy. Most thermal power plants produce steam, and these are sometimes called steam power plants. Thermal power plants are classified by the type of fuel and the type of prime mover installed.

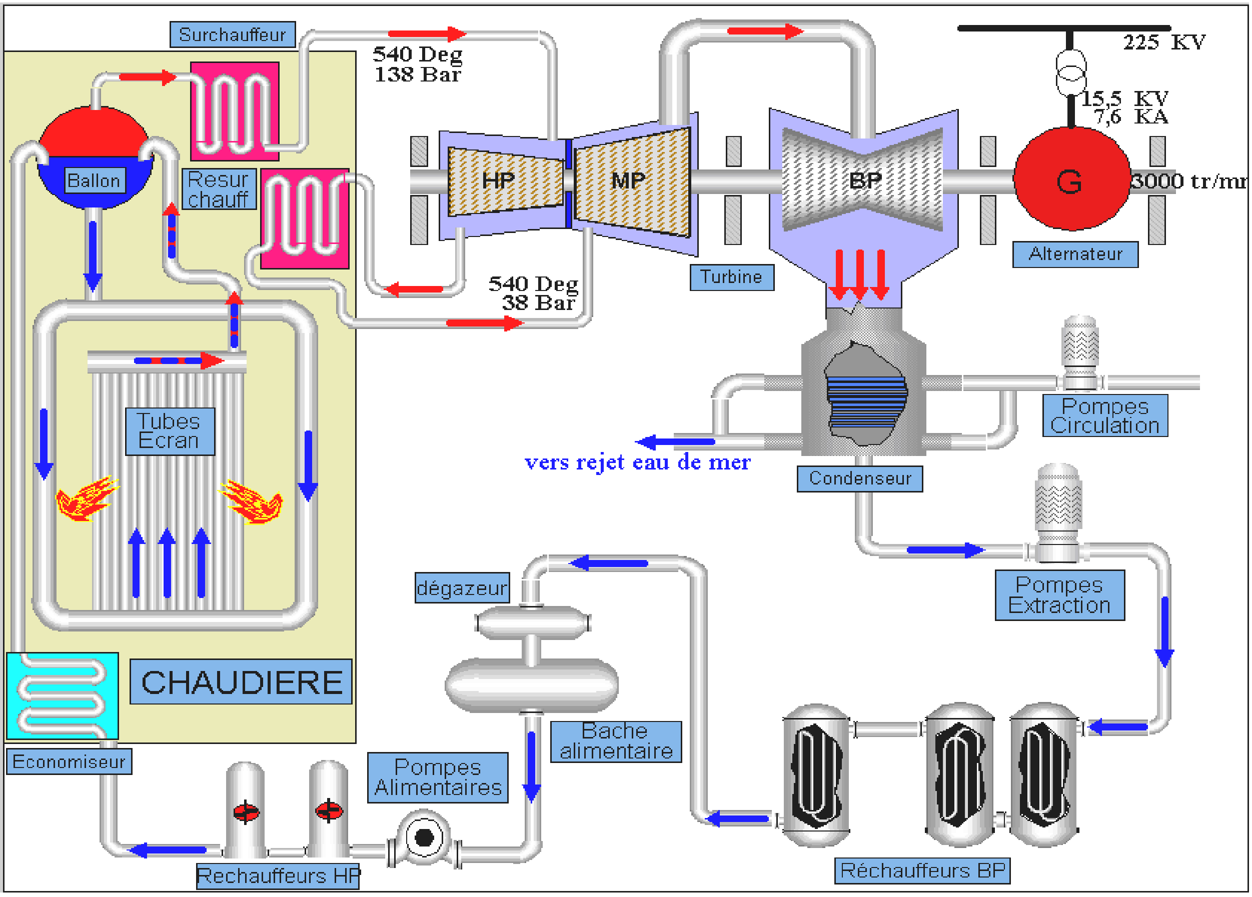

Figure 2. Functionality of a thermal power plant.

The electric efficiency of a conventional thermal power plant, 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. The rest of the energy must leave the plant in the form of heat [31-32-33].

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.

This overheated steam drags the HP rotor (high pressure) of the turbine in rotation and relaxes to the exit of the HP body of the turbine, so it comes back again in the furnace to be until 540°C after, it will be sent back to the MP body (average pressure) then to the BP body (bass pressure) of the turbine.

During these steps, the calorific energy is transformed in available mechanical energy on the tree of the turbine. Thus, this mechanical energy will be transmitted to the alternator, being a generator of alternating current, in the goal to produce the electric energy with a tension of 15.5KV.

After the condensation, water will be transmitted thanks to pumps of extraction in the station of BP to be warmed progressively before being sent back to the furnace through the intermediary of the food pumps. This warms progressive of water has for goal to increase the output of the furnace and to avoid all thermal constraints on its partitions. And this station of water is composed of a certain number of intersections that is nourished in steam of the three bodies of the turbine. Finally, the cycle reproduces indefinitely since steam and water circulate in a closed circuit.

Most of the thermal power plants 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 parameters are seriously deviating from their normal range.

An example of a SCADA system of a thermal power plant is presented (Figure 3). The stations belong to a superior network Ethernet (10 Mb/s). Principally, this network enables to exchange files between the stations. 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 (Figure.3). It exist three levels in the SCADA system: acquisition; treatment and Men/Machine Interface.

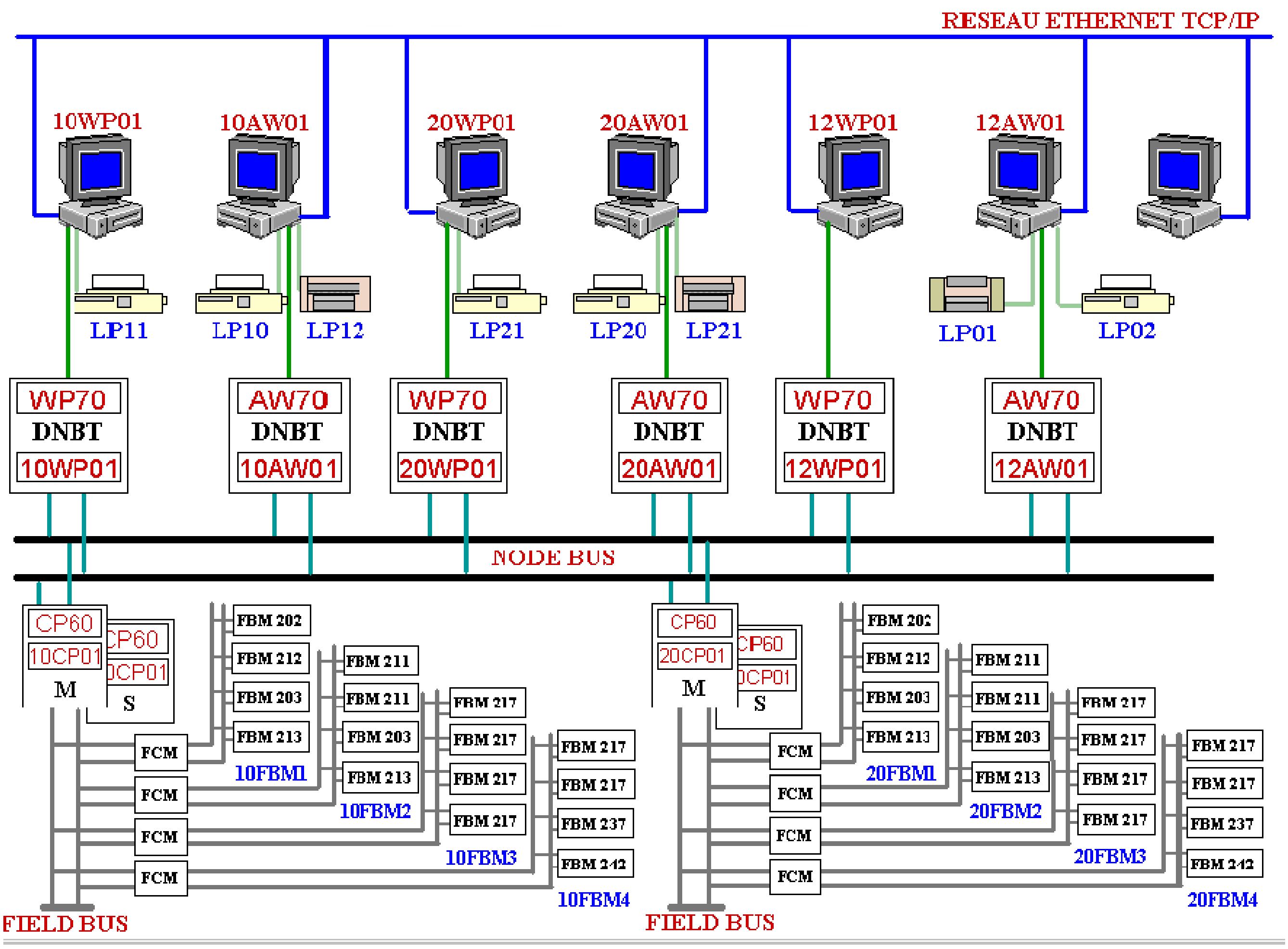

Figure 3. Architecture of a SCADA system.

Legend:

I/A: Intelligent / Automation

FBM: Field bus modules

FCM: Field Bus Communication Module

AW: Application work station

WP: Work station Processor

CP60: Control Process60

DNBT: Dual Node bus 10Base-T Interface

VI. Application of SADT method

Based on the description of the SCADA system, a corresponding SADT model of actigrams type has been built. An important point must be noticed: the point of view of the analysis is that of a person without concrete experience on the SCADA system, i.e. only through a bookish knowledge, whose objective is the use of the final models for the design of supervisory displays (monitoring, diagnosis displays, etc.). In fact, application of Functional Analysis technique must permit in this case:

- to determine the functions of the system;
- to put in evidence the different modes of running;
- to split up the system into sub-systems;
- to determine pertinent variables.

So, this SADT model is composed exclusively of actigrams (Figures 4-8). It starts with the main function 'To supervise the signals of a thermal power plant' (Figure.4). Then, this function is broken into sub-functions and this process is developed until the last decomposition level has been reached (levels A1, A2 and A3).

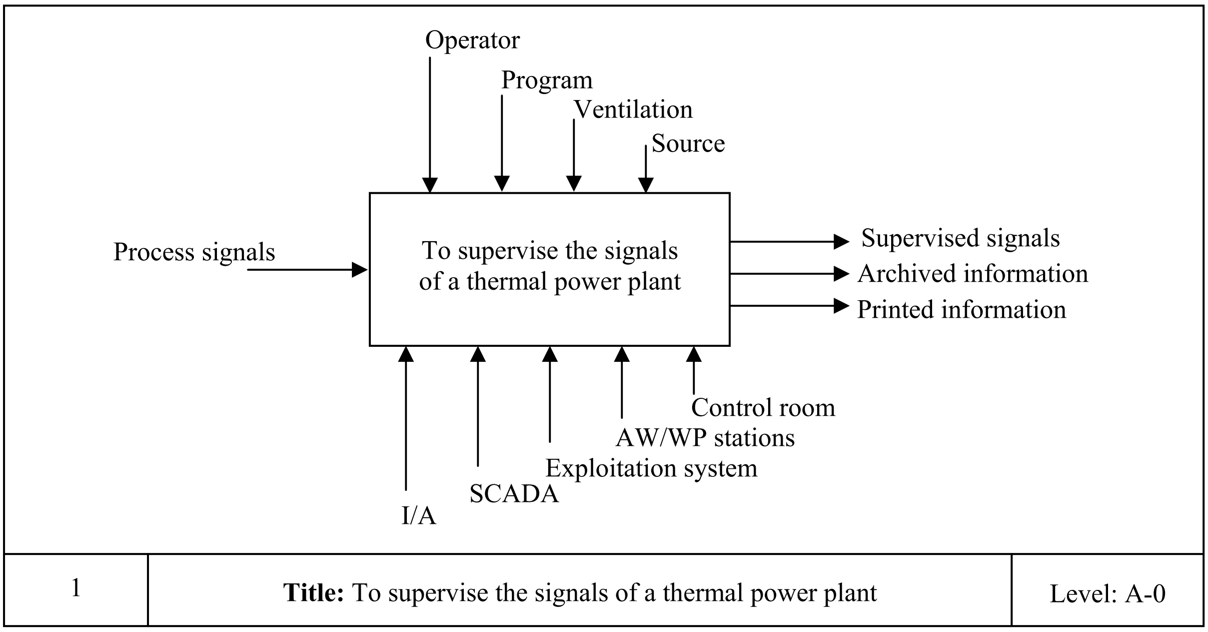

Figure 4. A-0 level of the SADT model.

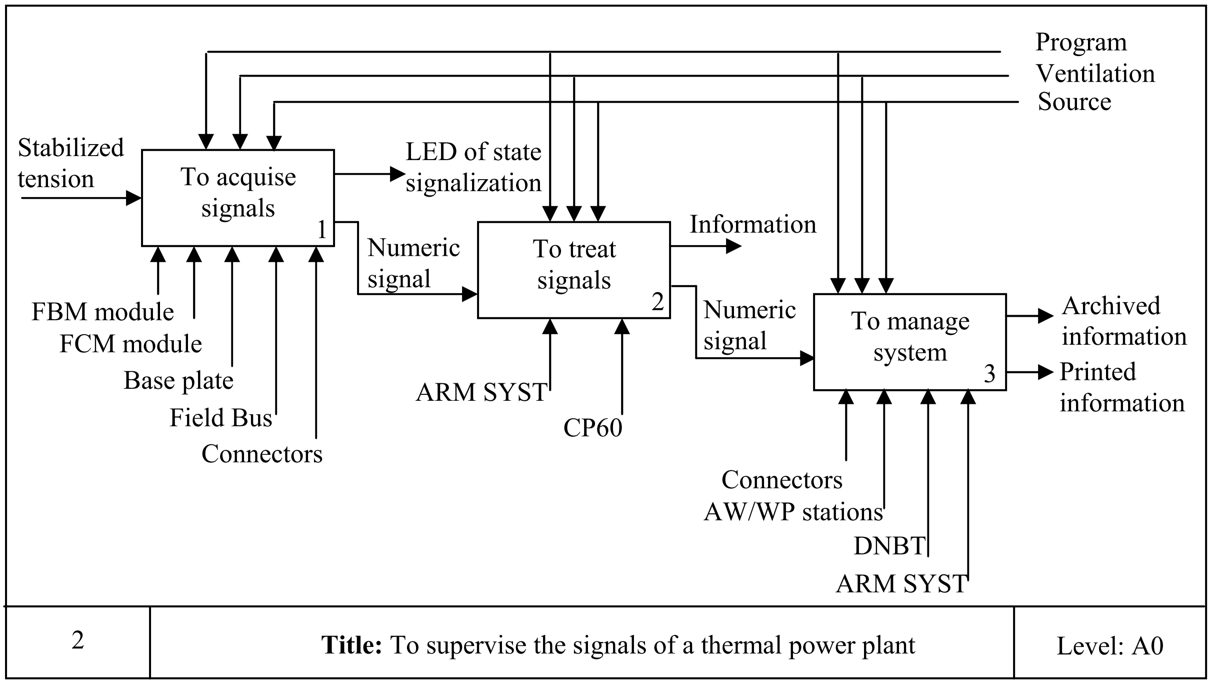

Figure 5. A0 level of the SADT model.

Recall that the techniques such as SADT are semi-formal. By consequence, for the same subject, different correct models can be built without having to know with certitude which model is the good or, at least, the best. In fact, this kind of model allows lets users sufficient freedom in its construction and so the subjective factor introduces a supplementary dimension for its validation. That is why the validation step on the whole necessitates the confrontation of different points of views.

As to the SADT technique, users can follow rules or recommendations to the level of the coherency of the model, such as distinction between the different types of interfaces, numeration of boxes and diagrams, minimal and maximal numbers of boxes by diagram, etc. One intends, by coherency application of the heritage rule i.e. when data are placed at a N decomposition level, it is explicitly or implicitly present at the inferior levels. However, a complementary mean to check coherency of actigrams is a confrontation between actigrams and datagrams, which is not possible in our case.

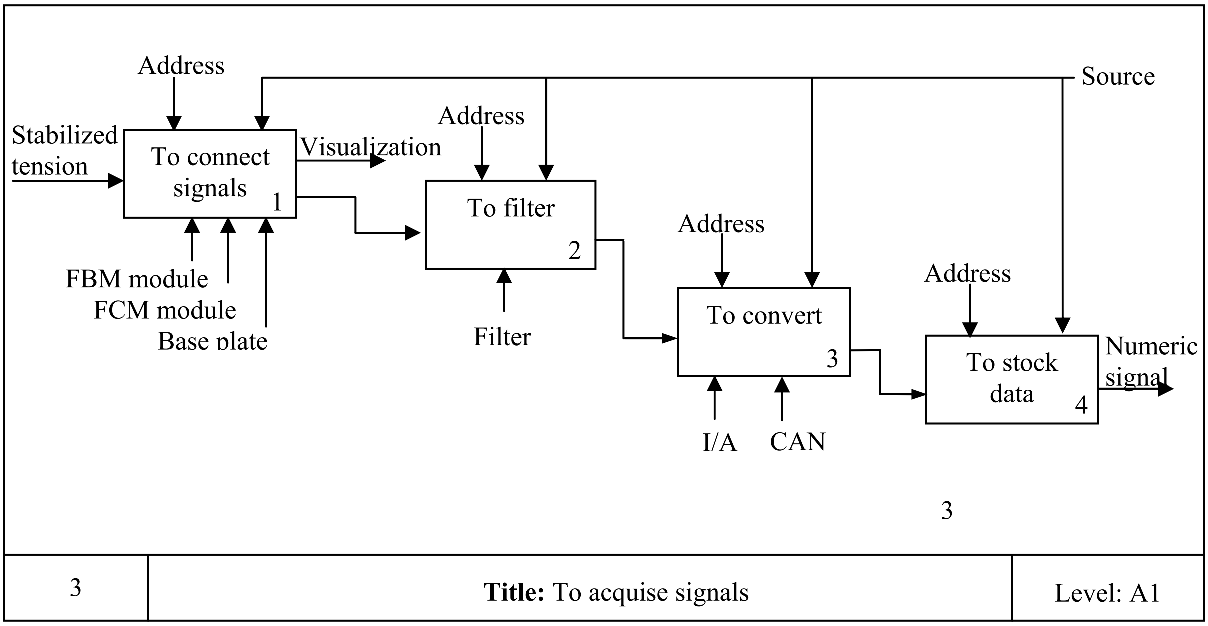

Figure 6. A1 level of the SADT model.

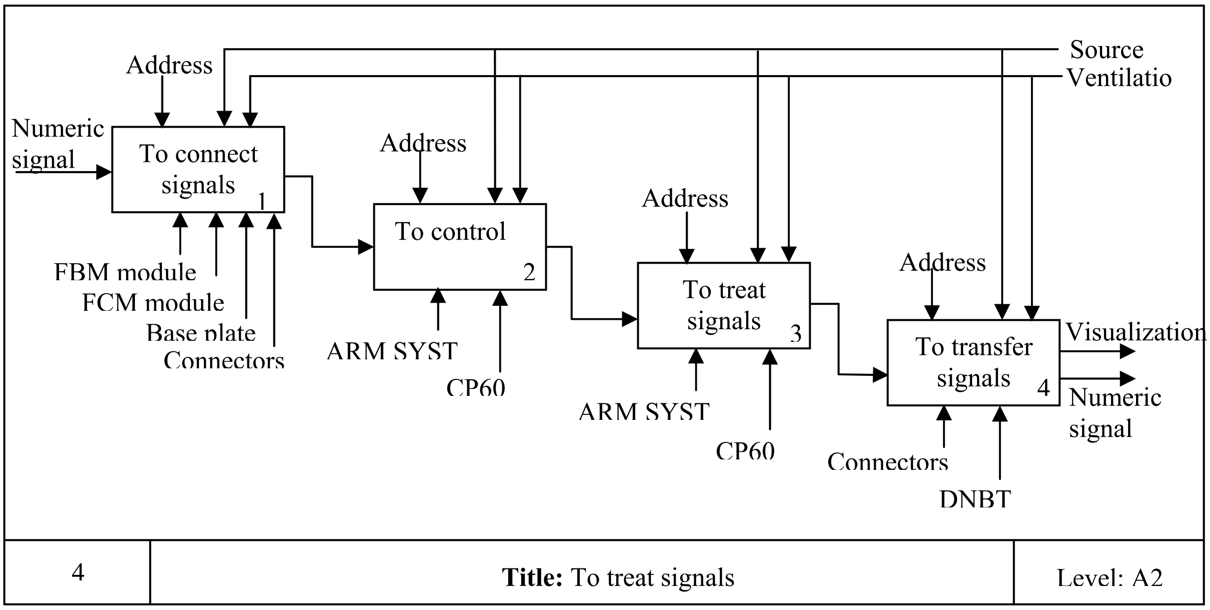

Figure 7. A2 level of the SADT model.

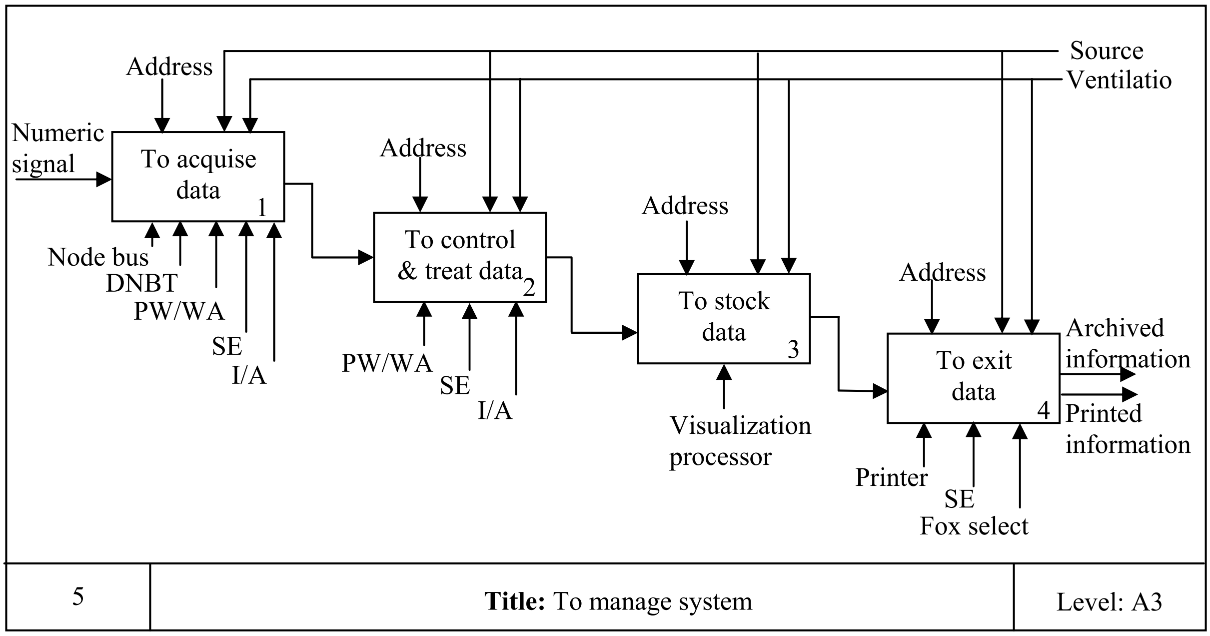

Figure 8. A3 level of the SADT model.

For the SADT box, there is the function (verb to infinitive) and around this box, the associated data are specified of which the nature (input, output, control or mechanism) appears directly.

The possible uses for the SADT model are the design of a monitoring display and a diagnosis display. For the design of a monitoring display, the A0 level of this model (Figure.4) supplies a global view of the system. Indeed, information relative to each function represented through this level should appear in a monitoring display.

For the design of hierarchical diagnosis displays, each actigram of the SADT model constitutes a vision at a given abstraction level. So, each of these actigrams gives a less or more detailed vision. In function of the objectives defined by the designer for each display, a particular actigram can supply the required information.

Finally, this application of Functional Analysis technique on the thermal power plant shows briefly the interests of the SADT method in the design of supervisory systems.

VII. Conclusion

In this paper, we presented the main functions and characteristics of supervisory systems for highly automated processes through a general description. In fact, in the design of a supervisory system, the difficulty lies in the capacity to represent both the process faithfully and to provide for the designers usable information. In fact, a supervisory system must take into account the physiological and cognitive features of the supervisory operator because an inadequacy between the supplied information and the operator’s information requirement is dangerous. So, to be more efficient, the design of a supervisory system should be human centered.

To reach this objective, Functional Analysis techniques seem to be a promising way because the major advantage of these kinds of techniques is due to the concept of function and abstraction hierarchy which are familiar to the human operator. These techniques permit the complexity of a system to be overcome. In this paper, the application of SADT method on a real system, a SCADA system of a thermal power plant generates a source of useful information for the design of a supervisory system (monitoring and diagnosis displays, definition of alarms, etc.). So, research into the application of Functional Analysis techniques for the design of a human centered supervisory system must be intensified in order to solve several difficulties and to improve their efficiency (tools to build the model, tools to check the validity of the model, etc.).

References

[1] Vernez D., Vuille F., Method to assess and optimise dependability of complex macro-systems: Application to a railway signalling system, Safety Science, Volume 47, Issue 3, March 2009, p.382-394
[2] Millot P., Supervision des procédés automatisés et ergonomie, Paris, France, Hermès, 1988.
[3] Vittet J. Eléments pour une conception intégrée des salles de contrôle, Phd dissertation, Université Scientifique et Médicale de Grenoble, Grenoble, France, 1981.
[4] Lambert M., Riera B., MartelG., Application of functional analysis techniques to supervisory systems, Reliability Engineering and System Safety 64, 1999, p.209–224.
[5] Warcuse J., Menz B., Payne J. R., Servers in SCADA applications, IEEE Trans. Ind. Appl. 9 -2, 1997, p.1295-1334.
[6] Bailey D., Wright E., Practical SCADA for Industry, Elsevier, 2003.
[7] Clarke G., Reynders D., Wright E., Practical Modern SCADA Protocols, Elsevier, 2003
[8] Wiles J., Techno Security's Guide to Securing SCADA: A Comprehensive Handbook On Protecting The Critical Infrastructure, Elsevier, 2008.
[9] Poon H.L., Applications of Data Acquisition Systems, Computers in Industry 13, 1989, p.49-59.
[10] Ozdemir E., Karacor M., Mobile phone based SCADA for industrial automation, ISA Transactions, Volume 45, Number 1, January 2006, p.67-75.
[11] Horng J.H., SCADA system of DC motor with implementation of fuzzy logic controller on neural network, Advances in Engineering Software 33, 2002, p.361-364.
[12] Aydogmus Z., Implementation of a fuzzy-based level control using SCADA, Expert Systems with Applications, article in press, 2008.
[13] Munro K., SCADA - A critical situation, Network Security, Volume 2008, Issue 1, January 2008, p.4-6.
[14] Patel M., Cole G. R., Pryor T. L., Wilmota N. A., Development of a novel SCADA system for laboratory testing, ISA Transactions 43, 2004, p.477-490.
[15] Ralstona P.A.S., Grahamb J.H., Hiebb J.L., Cyber security risk assessment for SCADA and DCS networks, ISA Transactions 46, 2007, p. 583-594.
[16] Avlonitis S.A., Pappas M., Moutesidis K., Avlonitis D., Kouroumbas K., Vlachakis N., PC based SCADA system and additional safety measures for small desalination plants, Desalination 165, 2004, p.165-176.
[17] Roth R.M., Wood W.C.I., Delphi A., approach to acquiring knowledge from single and multiple experts, Conference on Trends and Directions in Expert Systems, 1990.
[18] Parent M., Gallupe R.B., Salisbury W.D., Handelman J.M., Knowledge creation in focus groups: can group technologies help? Information & Management 38 (1), 2000, p.47-58.
[19] Jain H.K., Tanniru M.R., Fazlollahi B., MCDM approach for generating and evaluating alternatives in requirement analysis, Information Systems Research 2 (3), 1991, p.223-239.
[20] Stylianou A.C., Kumar R.L., Khouja M.J., A Total Quality Management-based systems development process, The DATA BASE for Advances in Information Systems 28 (3), 1997, p.59-71.
[21] Schoman K., Ross D.T., Structured analysis for requirements definition, IEEE Transaction on Software Engineering 3 (1), 1977, p.6-15.
[22] Marca DA., McGowan CL., SADT: structured analysis and design technique, New York: McGraw-Hill Book Co., Inc., 1988.
[23] Strohmeier A., Buchs D., Génie logiciel : principes, méthodes et techniques, Presses polytechniques et universitaires Romandes, Lausane 1996.
[24] Santarek K., Buseif I.M., Modelling and design of flexible manufacturing systems using SADT and Petri nets tools, Journal of Materials Processing Technology, Vol. 76, Issues 1-3, 1998, p.212-218.
[25] Benard V., Cauffriez L., Renaux D., The Safe-SADT method for aiding designers to choose and improve dependable architectures for complex automated systems, Reliability Engineering & System Safety, Vol. 93, Issue 2, 2008, p.179-196.
[26] Lauras, M., Lamothe, J., Pingaud, H., Une méthode orientée processus pour le pilotage par la performance des systèmes industriels, Journal Européen des Systèmes Automatisés, 41(1), 2007, p.71-100.
[27] Rapport Annuel de la S.T.E.G 2007, Société Tunisienne de l’Electricité et du Gaz (S.T.E.G), Juillet 2008.
[28] Kagiannas A.G., Askounis D., Anagnostopoulos K., Psarras J., Energy policy assessment of the Euro-Mediterranean cooperation, Energy Conversion and Management 44, 2003, p.2665-2686.
[29] European Commission, External Relations Directorate-General. The EU relation with Tunisia, 2001. http://europa.eu.int/comm/external_relations/tunisia/intro/index.htm.
[30] World Energy Council, Energy Info Centre. Tunisia, 2001. http://www.worldenergy.org/wec-geis/edc/countries/Tunisia.asp.
[31] Prisyazhniuk V.A., Alternative trends in development of thermal power plants, Applied Thermal Engineering 28, 2008, p.190-194.
[32] A. Franco, C. Casarosa, On some perspectives for increasing the efficiency of combined cycle power plants, Applied Thermal Engineering 22 (13), 2003, p.1501-1518.
[33] Ozturk H.K., Yilanci A., Atalay O., Past, present and future status of electricity in Turkey and the share of energy sources, Renewable and Sustainable Energy Reviews 11, 2007, p.183-209.