SYSTEMIC ANALYSIS OF A SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM

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Abstract: *This paper tries to present firstly the functionality of a supervisory system for complex processes, and secondly the concepts of a supervisory control and data acquisition (SCADA) system. Our contribution consists on applying a systemic analysis method OOPP (Objective Oriented Project Planning) on a SCADA system of a thermal power plant (TPP).The paper briefly discusses the functions of a SCADA system and some advantages of the application of the OOPP method for the analysis of a human centered supervisory system. Then the basic principles of the OOPP method applied on the SCADA system are presented. Finally, an application of supervision of the signals of the chemical analysis in a TPP is presented.*

Key words: SCADA; Systemic analysis, OOPP method; thermal power plant.

1. 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. 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 systemic analysis methods such as OOPP (Objective Oriented Project Planning) for the design of supervisory systems. An example of a SCADA system of a thermal power plant (TPP) 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 OOPP in the design steps are developed. In Section 3, after presenting concepts of OOPP, this method is applied to a SCADA system of a TPP. The last section presents a discussion about the advantages and inconveniences of systemic analysis methods.

2. Functionality of a supervisory system

Supervision consists of commanding a process and supervising its working [1]. 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.

A supervisory system has to give to the human operator [2-4]:

- 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.

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 [3-6]. The information synthesis system manages the presentation of information via any support (synoptic, console, panel, etc.) to the human operator.

3. Review on 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 [6-10].

We present in this part some applications of SCADA systems that have been presented in various researches.

Researcher, Poon H.L. [11], has tried to make a survey of the current development of data acquisition technology. The various practical considerations in applying Data Acquisition Systems are summarized, and some feasible areas of advanced applications are investigated.

Researchers, Ozdemir E. & al. [12], 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.

Researcher, Horng J.H. [13], 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. [14], 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 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. [15], 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. [16], 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.

Researchers, Ralstona P.A.S., & al. [17], 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. Presented in broad terms is probability risk analysis which includes methods such as FTA, ETA, and FEMA. The authors have concluded with a general discussion of two recent methods 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. [18], 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. The design and installation of the automation system, which includes the software and hardware, is simple and easily accessible. The system has reduced the labor cost, and has increased the labor productivity of the operation due to the remote supervision of the process.

4. Presentation of the OOPP method

In this part, we present the participative methods literature and particularly the systemic method OOPP used in this research.

4.1 Participative methods literature

There are many methods that have been used to enhance participation in Information System (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), Structured Analysis and Design Technique (SADT) and OOPP.

The objective of the Delphi method 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.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 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 (Quality Function Deployment) [20].

The SADT and OOPP methods 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 [21-22]. It enables capturing of proposed system's functions and data flows among the functions. The OOPP method is used to enhance participation in IS planning and requirements analysis [23]. It has become the standard for the International Development Project Design.

4.2 OOPP method

The OOPP method which is also referred to as Logical Framework Approach (LFA) is a structured meeting process. This approach is based on four essential steps: Problem Analysis, Objectives Analysis, Alternatives Analysis and Activities Planning. It seeks to identify the major current problems using cause-effect analysis and search for the best strategy to alleviate those identified problems [23-24].

The first step of "Problem Analysis" seeks to get consensus on the detailed aspects of the problem. The first procedure in problem analysis is brainstorming. All participants are invited to write their problem ideas on small cards. The participants may write as many cards as they wish. The participants group the cards or look for cause-effect relationship between the themes on the cards by arranging the cards to form a problem tree (Fig.1).

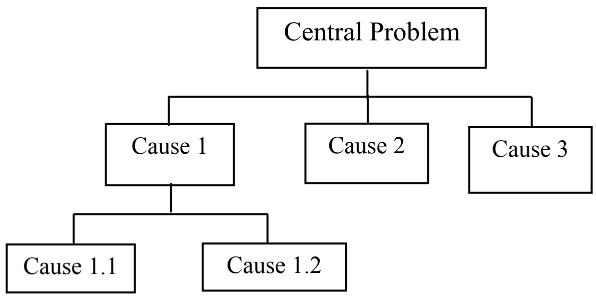

Fig. 1. Problem tree of the OOPP method

In the step of "Objectives Analysis" the problem statements are converted into objective statements and if possible into an objective tree (Fig.2). Just as the problem tree shows cause-effect relationships, the objective tree shows means-end relationships. The means-end relationships show the means by which the project can achieve the desired ends or future desirable conditions [21].

The objective tree usually shows the large number of possible strategies or means-end links that could contribute to a solution to the problem. Since there will be a limit to the resources that can be applied to the project, it is necessary for the participants to examine these alternatives and select the most promising strategy. This step is called "Alternatives Analysis". After selection of the decision criteria, these are applied in order to select one or more means-end chains to become the set of objectives that will form the project strategy.

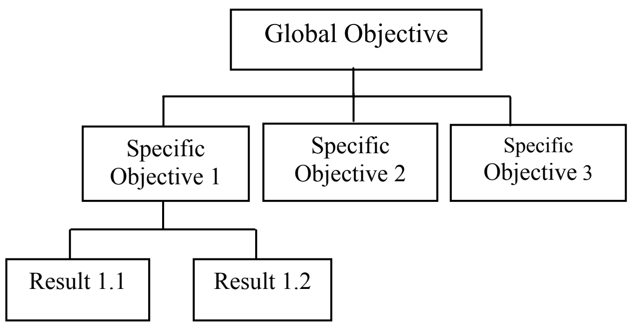

Fig. 2. Objective tree of the OOPP method

After defining the objectives and specifying how they will be measured (Objectively Verifiable Indicators: OVIs) and where and how that information will be found (Means of Verification: MOVs) we get to the detailed planning phase: "Activities Planning". We determine what activities are required to achieve each objective. It is tempting to say; always start at the situation analysis stage, and from there determine who are the stakeholders.

We present some studies of the OOPP method in Information System planning that have been presented in various researches:

Researchers, P. Gu & al. [25] have presented an object-oriented approach to the development of a generative process planning system. The system consists of three functional modules: object-oriented product model module, object-oriented manufacturing facility model module, and object-oriented process planner.

Researcher, Peter S. Hill [26] has question the appropriateness of highly structured strategic planning approaches in situations of complexity and change, using the Cambodian-German Health Project as a case study. He has demonstrated the limitations of these planning processes in complex situations of high uncertainty, with little reliable information and a rapidly changing environment.

Researchers, Peffers K. & al. [27], have used information theory to justify the use of a method to help managers better understand what new IT (Information Technology) applications and features will be most valued by users and why and apply this method in a case study involving the development of financial service applications for mobile devices.

5. Case study of a SCADA system of a TPP

Among the units of electricity production of the Tunisian Society of Electricity and Gas (S.T.E.G) [28], we present an example of a thermal power plant (TPP).

In fact, a TPP is a power plant in which the prime mover is steam driven (Fig.3). Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser. The greatest variation in the design of TPPs is due to the different fuel sources. Some prefer to use the term energy center because such facilities convert forms of heat energy into electrical energy [29-30].

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

The electric efficiency of a conventional TPP, considered as saleable energy produced at the plant busbars compared with the heating value of the fuel consumed, is typically 33 to 48% efficient, limited as all heat engines are by the laws of thermodynamics. The rest of the energy must leave the plant in the form of heat.

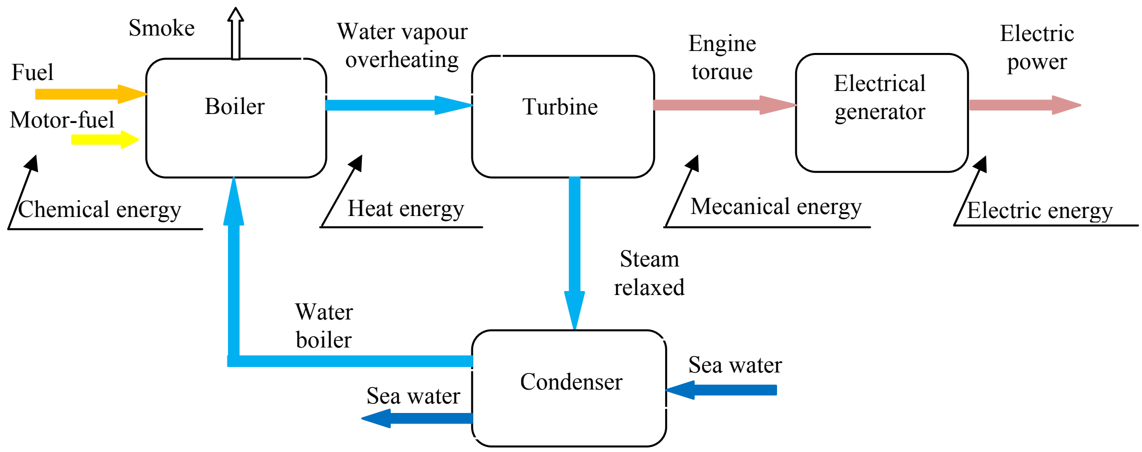

Fig. 3. Functionality of a thermal power plant

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

Figure 4 present the architecture of a SCADA system of a TPP.

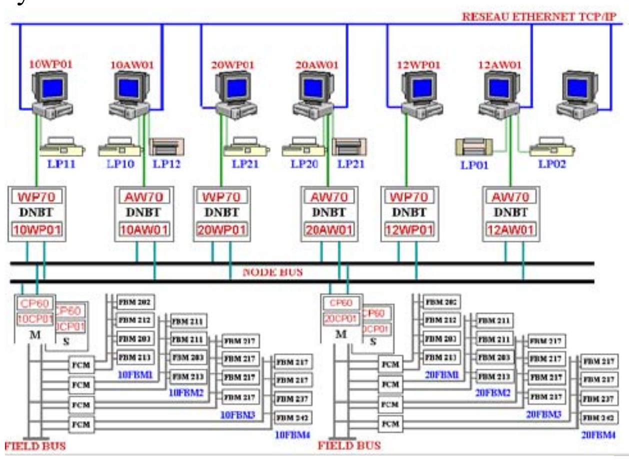

Fig. 4. Architecture of a SCADA system

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

The stations belong to a superior network Ethernet (10Mb/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 using the communication network. It exist three levels in the SCADA system: acquisition; treatment and Men/Machine Interface.

5.1 Application of the OOPP method

Based on the description of the SCADA system, a corresponding OOPP model 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 of a TPP, 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.).

TABLE: OOPP ANALYSIS OF A SCADA SYSTEM

N°	Code	Designation
1	GO	Supervision of the signals of a thermal power plant
2	SO1	Acquisition of the signals of a thermal power plant
3	R1.1	Connection of the signals
4	A1.1.1	To use the FBM module
5	A1.1.2	To use the FCM module
6	A1.1.3	To use the Base plate
7	A1.1.4	To use connectors
8	R1.2	Filtration of the signals
9	R1.3	Conversion of the signals
10	R1.4	Storage of data
11	SO2	Treatment of the signals
12	R2.1	Connection of the signals
13	R2.2	Control of the signals
14	A2.2.1	To use the ARM SYST
15	A2.2.2	To use the CP60
16	R2.3	Treatment of the signals
17	A2.3.1	To use the ARM SYST
18	A2.3.2	To use the CP60
19	R2.4	Transfer of the signals
20	A2.4.1	To use the DNBT

21	A2.4.2	To use connectors
22	SO3	Management of the system
23	R3.1	Acquisition of data
24	A3.1.1	To use the Node bus
25	A3.1.2	To use the DNBT
26	A3.1.3	To use the PW/WA
27	A3.1.4	To use the SE
28	A3.1.4	To use the I/A
29	R3.2	Control & treatment of data
30	A3.2.1	To use the PW/WA
31	A3.2.2	To use the SE
32	A3.2.3	To use the I/A
33	R3.3	Storage of data
34	R3.4	Exit of data
35	A3.4.1	To use the printer
36	A3.4.2	To use the SE
37	A3.4.3	To use the Fox select

The application of a systemic analysis method 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.

The application of the systemic analysis on the SCADA system of a TPP shows briefly the interests of the OOPP method in the design of supervisory systems.

5.2 Experimentation whitin the TPP

According to the systemic analysis of the SCADA system presented above, we realized an application of supervision in order to master functionalities of the system.

In this part, we present experimentation within a TPP in order to solve an industrial problem. It is about the problem of absence of indication of the chemical features of the water of the furnace (pH and conductivity) of room of control of the TPP. Indeed, the follow-up and the storage of these chemical features is not assured currently.

The different stages of this application are the following:

- Choice of the site of the signal (FBM module).
- Programming of the AIN block (Analogical Input) for the supervision of the signal pH ball furnace.
- Programming of the CIN block (digital Input) for the supervision of the signal conductivity ball furnace.
- Test by injection of current for standardization of the AIN block and test of the alarm by short circuit for the CIN entrance
- Passage of the cable between the room of sampling and the SCADA room.
- Branching of the analogical signal (module 10FBM215) and the numeric signal (module 10FBM325).
- Creation of a new tabular for the general vision of the room of sampling of the TPP.

All these different stages have been achieved according to the gait of the analysis presented by the OOPP method.

The result of this experimentation consists in the realization of a new tabular for the room of sampling (Fig. 5). It contains an applicable indication of the pH as well as the conductivity.

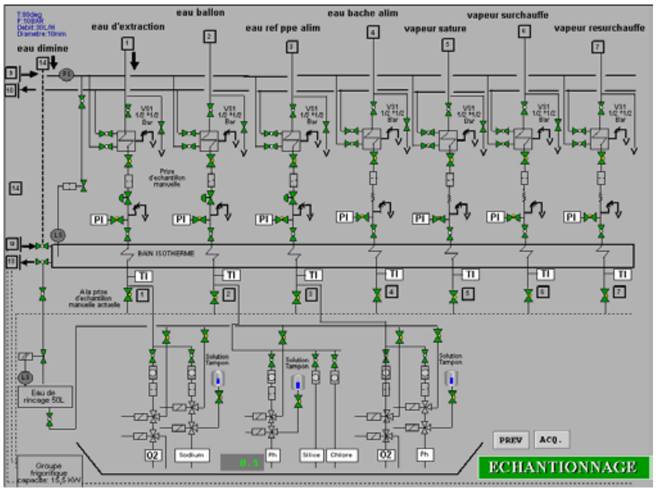

Fig. 5. New tabular for the room of sampling

6. Conclusion

In this paper, we presented the main functions and characteristics of supervisory systems for highly automated processes through a general description.

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, systemic analysis seems to be a promising way because the major advantage of these kinds of methods 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 OOPP method on a SCADA system of a TPP 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 systemic analysis methods 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.).

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