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MODELLING AND DESIGN OF QUALITY MANAGEMENT SYSTEM BASED ON SADT AND PETRI NET TOOLS

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Abstract: *This paper deals with designing efficient quality management systems (QMS). The aim is to assure that the resources and the activities performed inside this system are coherent with given objectives. Firstly we build a functional model of the QMS using the SADT tool. This model respects the PDCA principle. Then we derive a Petri net model which takes into account the dynamic behavior of the QMS. By applying Petri net analyzing techniques we can identify properties like of the QMS like deadlock free. This approach is applied for designing the QMS of the maintenance service in a power plant.*

Key words: *quality management systems, PDCA principle, SADT model, Petri nets, maintenance service.*

1. INTRODUCTION

The quality became currently a management tool and an essential criterion in enterprises especially for trade. There are a strong links between quality and productivity, because the use of quality as a management tool helps companies to increase their productivity. We are interested to quality management system in enterprise because each enterprise must have permanently the improving concern of its productivity and its competitiveness. Our opinion that the system of management of quality is an essential element to create this dynamic of progress in enterprise. Moreover, the increasing concurrence due to globalization forced most of the companies enterprises to adopt a quality management system in order to maintain or increase the confidence of the clients. A quality management system contains: quality planning, quality control, correct operation of system quality assurance and a program of improvement of quality 0.

In the thesis 0, the author considers that the quality management system includes the quality assurance, the improvement of quality, the statistical quality control and the unit control. But the standard ISO 9000 version 2000 defines of the quality management as the activities or actions allowing to pilot and control an organization by quality 0. Further, this version (ISO 9000:2000) denote the eight fundamental principles relating to the quality management 0 as following: Customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making and mutually beneficial supplier relationships. The objective of quality management system is to realize the quality planning, quality control, quality assurance and quality improvement 0. A lot of research work has been done concerning the quality management systems in enterprise, but few results are dealing with the implementation of a QMS in a company. We were particularly interested in the approach presented in 0. The author proposed a method to implement a quality management system, this method is summarized by: analyzing of the enterprise with the aspect process, and analyzing of the obtained model by using the concept of risk, and then converting these risks in a formal method in term of costs, time and performance. This problem is also addressed in 0 which we proposed a method to implement the quality management system, this method consist of ten steps and we used the process approach to realize our quality management system.

In this article, we present an approach to model and design an efficient QMS. The aim of this approach is to detect eventual deadlocks in the functioning of the QMS and assure that the resources allocated and the activities per-formed are coherent with given objectives. We consider that the QMS is a discrete event system (DES). The dynamic behavior of such a system is driven by the occurrence of the events according to some conditions. In a QMS, the events are related to activities while the allocated resources give the conditions for the execution of the events.

The first step of this approach consists in building the SADT model of the QMS according to the PDCA principle. The SADT model provides a functional representation of the QMS. Some advantages of this representation are highlighted in Section 2. However, the SADT model can not represent the dynamic behavior of a system. Therefore, starting form the SADT model we build a Petri net model which provides an intuitive representation of the relation between activities and resources, while taking into account the structure of the QMS. Using Petri net specific analysis techniques we can analyze properties of the QMS behavior, like deadlock free. A deadlock may be generated by a bad allocation of the shared resources between different activities. This approach is applied for designing a QMS of a power plant under the control of the government. In this paper we focus our attention on the maintenance department.

In The structure of the paper is the following. In the next sections we present an approach for modeling and design of QMS based on these tools. This approach is applied to design the QMS of the maintenance department in section 3. Finally, we give some conclusion remarks.

2. ASSOCIATION SADT – PETRI NETS

2.1. Existing methods

For the study of the dynamic aspects of our model SADT we must make another model as Petri nets, but we consider always our model SADT. Estraillier and Kordon declared that the recent studies have led to two main research areas 0:

- Extension of Petri nets in order to add some hierarchical or structuring capabilities,
- Association of Petri nets with another formalism that brings its structuring capabilities.

Several methods have been proposed in the literature to associate SADT and Petri Net models. We will indicate some methods among them:

The method of Jensen 0 is based on augmenting the SADT model of a system with behavioral information describing the input/output relations by means of channel expressions and guards. A set of formal rules is given, to automatically translate the augmented SADT into colored Petri nets that can be simulated on a dedicated simulator.

Another method proposed by Jafari and Boucher 0 is based on the use of a number of transformation rules to generate Petri nets logic form SADT. Here the authors focus on describing the distinction between conflict and con-currency is not specified in the model SADT.

The method proposed by Liang and Hong 0 considered the manufacturing systems as a series of transformation from a functional hierarchy representing the material flow, a controllable hierarchy by designing information flows that control the material flow, a dynamic hierarchy which is constructed as a hierarchy of Petri nets and a commanding hierarchy to an optional secured hierarchy. This technique provides a systematic method to treat the manufacturing systems.

The method proposed by Zaytoon and Villermain-Lecolier 0 is based on the annotation of SADT arrows and on local mapping rules that map an SADT model into a corresponding Petri net by assembling subnets corresponding to the elements of SADT. The possibility of automatically mapping the execution and analysis results obtained at Petri net level back to corresponding SADT elements is guaranteed by the properties of the mapping rules used in this method. Since each element (set of contiguous elements) at Petri net level corresponds to a single element at the SADT level.

The method proposed by Santarek and Buseif 0 considered that there are 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.

The authors modeled flexible manufacturing systems by SADT model, their objective is to realize software package, moreover, to make dynamics (because the SADT model is a static model), the authors transformed SADT model towards Petri nets.

Consequently, the authors proposed a rule of transformation to make the simulation of their software interfaces.

2.2. Proposed method

The pervious approaches are applicable to the systems of production. They aim to present the succession of the activities, as well as the shared resources. In the method of Jafari and Boucher, the authors are interested to model the parallel activities or in conflict. They considered only the case of the activities which have a single input and output. But in our case, we have several inputs and outputs. In more, the conflict between the activities. However, in quality management systems, there are specific resources to each activity for example the method of Santarek and Buseif models only the shared resources and also the method of Zaytoon and Villermain-Lecolier which proposed a method applicable in the case of system of production automated. Moreover, certain resources are consumed by the execution of the activity (for example: financial resources, certain material resources), we can say that the pervious approaches didn’t discuss this case.

The approach that we propose for the construction of the Petri net from a SADT model is based on the pervious approaches, but by exceeding all the limits of these approaches, and with taken into account the specific aspects of the quality management systems. The first step consists in analyzing the hierarchical organization and the functions of the enterprise. Then we construct the model SADT. After having built the SADT model we must assure the coherence with the hierarchical organization of the enterprise. This step provides useful information for constructing the associated Petri net, which is describing the relationship between the activities and for understanding of dynamic behavior of the QMS. Then we build the Petri net by using the rules given in Fig. 1.

3. APPLICATION

In this section, we will present our model of enterprise, SADT model and the Petri nets of service maintenance of our model of enterprise.

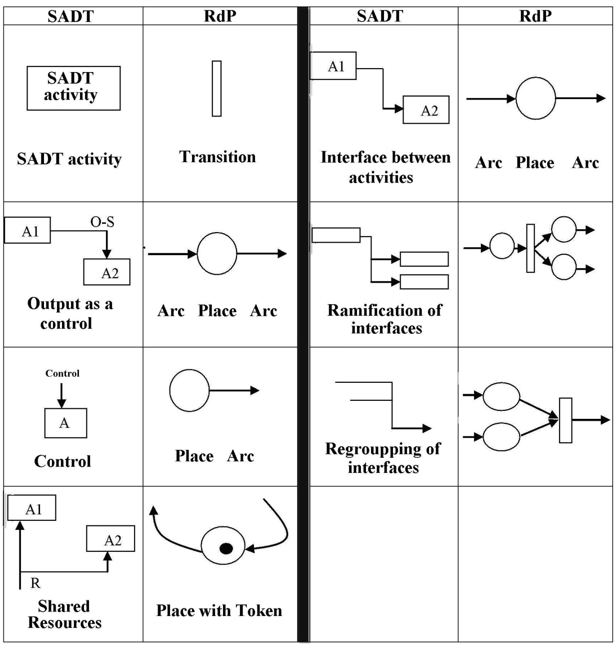

Fig. 1. Rules to realize Petri nets.

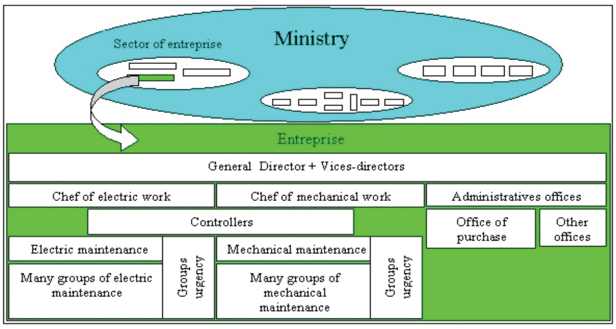

Fig. 2. Architect of service maintenance of power plant.

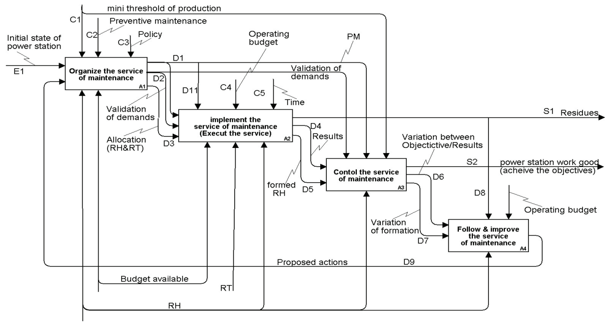

Fig. 3. Diagram A0 of SADT model of service maintenance of power plant.

3.1. Description of our model

The presented study in this article relates to a power plant under the control of the ministry for energy. We will focus on the services maintenance of our power plant. The hierarchical organization of this plant is given in Fig. 2.

The objective of service maintenance in a power plant is to ensure the correct operation of components in the power plant: boilers, pumps, the valves, etc. This service must realize all the preventive and corrective maintenance actions. The data necessary to start two types of maintenance (Preventive and corrective maintenance) is sent by the monitoring system (Controllers). The service maintenance has as resources: human resources and technical resources. Human resources are represented by the operators of maintenance, and the technical resources are represented by the equipment and materials necessary to realize the maintenance. This enterprise is under the control of government (Ministry of energy) *i.e.* the operating budget and min threshold of production (production of electricity) are determined by the ministry.

3.2. SADT model

We created five diagrams of the model SADT of service maintenance in power plant. We will present the diagram A0 and the diagram A2, but others diagrams will only describe them.

The diagram A0 models the principal activities of the ser-vice of maintenance. This diagram contains four activities which present the organization of the service of maintenance (A1), the implement of the service of maintenance concerning the execution of the service (A2), the control of the service of maintenance (A3) and the follow up and the improvement of the service of maintenance (A4). This diagram showed in Fig. 3.

Moreover, the diagram A1 can be to have three boxes, plan the actions of maintenance (A11), define and allocate human and technical resources (A12) and define the expense (A13). This diagram starts when we determine the initial state of the power plant which indicates all current information of the power plant (quantity, situation in the preventive maintenance, state of the components... etc.), the program of maintenance will be achieved, while taking of account the preventive maintenance and the mini threshold of production, at the same time, we send information to begin the activity, to define and allocate human and technical resources, by considering that the program of maintenance is already defined, as well as the mini threshold of production. In this step, we go out with allocation of human and technical resources, demand of purchase for the missing components and the demand for formation to improve human resources. On the other hand, for implementing these demands, it is necessary to define the expenses.

The diagram A2 explains the implementation of the service of maintenance (execute), it contains four boxes. By using the program of maintenance like an indicator of input, the mini threshold of production like an indicator of control, the result will be the realization of maintenance, in other words, a new state of the power plant. We go out with the working tools and the tools broken which will enter the activity to check working tools. Moreover, the result of this activity is residues and checked and repaired tools which will be used in next maintenance. However, we execute the activity of implementation the formations of human re-sources, by using the allocation of resource and the validation of demands for formation to evaluate human resources, but we should not forget the operating budget of the power plant as control, the result of this activity will be formed human resources which will be used to evaluate the quality of work. Finally the last activity is the implementation of the purchases, in this activity the input will be the demands for purchase, the result will be technical resources. The controls are the operating budget and the delay of purchase. This diagram showed in Fig. 4.

However, the diagram A3 contains two boxes, The first box (A31) is the control of the actions of maintenance, we take into account the new state of the power plant or the maintenance carried out as an input data, the difference between the achieved objectives and the obtained results as indicator of result and the program of maintenance as an indicator of control. In more, the second box (A32) is the quality control of formation of human resources; consequently, the result of this activity will be the difference between the formations obtained and the envisaged formations. We mustn't forget the controls: the validation

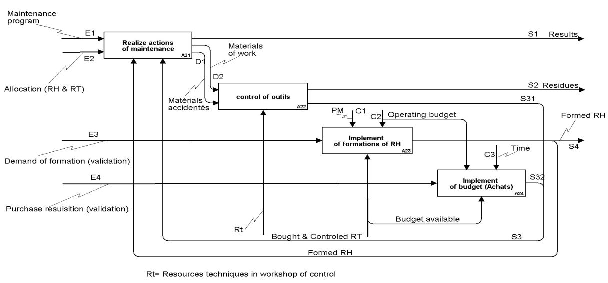

Fig. 4. Diagram A2 of SADT model of service maintenance of power plant.

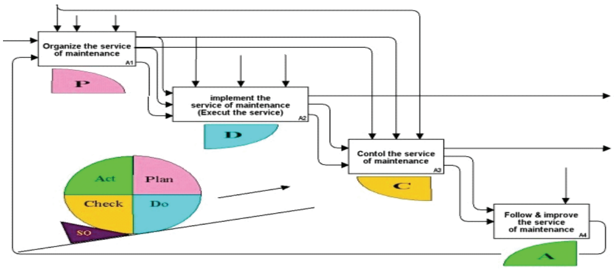

Fig. 5. SADT model and PDCA principle.

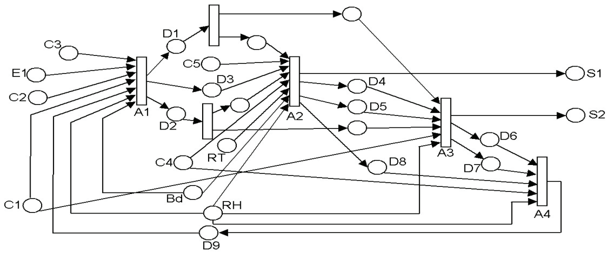

Fig. 6. Petri net equivalent of diagram A0.

of the required formations and the programs of maintenance. Finally, the diagram A4 explains the activities of follow up and of improvement of the service of maintenance, consequently the result will be the corrective suggested actions.

We confirm that our model SADT are designed in accord with the PDCA principle (Deming cycle), *i.e.* the major of 14 points of Deming are verified, this is shown in Fig. 5.

3.3. Petri nets

We should be said that model SADT is a static model, *i.e.* it can not be used to represent a dynamic behavior. Consequently to study the dynamic aspect it is necessary to use some other tool such as temporal SADT or Petri nets. Now, the Fig. 6 summarizes the application of our method for deriving Petri net from the SADT model. The Petri net model of the QMS designed for the Maintenance Department is obtained by combining the Petri nets corresponding to each SADT diagram.

Using reachability analysis techniques specific to Petri nets, we can check the existence of deadlocks. Moreover, by analyzing the average marking of given places we can evaluate if the resources allocated for some task are sufficient or if there is a waste.

4. CONCLUSION

In this article, we present an approach to model and design an efficient QMS. The aim of this approach is to detect eventual deadlocks in the functioning of the QMS and assure that the resources allocated and the activities performed are coherent with given objectives. In this approach, we proposed to associate the tools SADT and Petri net.

Firstly we build a functional model of the QMS using the SADT tool. This model respects the PDCA principle. Then we derive a Petri net model which takes into account the dynamic behavior of the QMS. Our future research work focuses on developing a performance evaluation approach for decision making in QMS.

Table 1

Signification of abbreviation on the Fig. 6

Abbreviation	Significations of abbreviation
E1	Initial state of power plant
C1	Min threshold of production
C2	Preventive maintenance
C3	Policy
C4	Operating budget
C5	Time (delay)
D1	Program of maintenance
D2	Validation of demands
D3	Allocation (RH & RT)
D4	Results
D5	Formed human resource
D6	Variation between Objective/Results
D7	Variation (difference) of formation
D8	Residues
D9	Corrective & proposed actions
S1	Rapport concerning the Residues
S2	Indicator (achieve the objectives)

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