Quality Approach as Applied on a Photovoltaic Water Pumping System

Ben Jouida H.
National Higher Engineering School of Tunis (ENSIT),
University of Tunis,
U.R: LSDE_C3S, Tunisia
haythem_benjouida@yahoo.fr

Lakhoua M.N.
National School of Engineering of Carthage (ENICarthage), University of Carthage,
U.R: SMS, Tunisia
MohamedNajeh.Lakhoua@ieee.org

Gharbi R.
National Higher Engineering School of Tunis (ENSIT),
University of Tunis,
U.R: LSDE_C3S, Tunisia
rached_gharbifr@yahoo.fr

***Abstract*— The search for quality has become a key point for the competition thanks to its importance of supply over demand. Thus, obtaining the quality of services and products usually goes by the establishment of a quality assurance system and quality tools at both the design and the realization of product level. Also, the quality has always been efficient tool for the industry organizations to meet customer needs. In fact, the main researchers' objective is to find formal methods, to analyze and model the industrial processes and to facilitate their control.**

In this paper, we provide an operational and structured vision through the integration of the Six Sigma decision making method to analyze and identify relevant parameters which allow operation in a context of total quality. Improvement solutions are also proposed for the operating manner of the production system.

Keywords— ***Quality approach, Six Sigma, photovoltaic system, systems analysis***

I. Introduction

Quality has always been a major goal since the customer requirements has increased along with the rise of the competition [1]. For this purpose, ISO 9000: 2000 defined, in this context, the quality as being "the ability of a set of inherent characteristics fulfills requirements" [2]. Regarding the NF X 50 -120 the Quality is defined as "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs" [3] [4].

The Quality is considered as an integrated business processes with other processes such as the production and maintenance [5].

The American Production and Inventory Control Society proposed a definition of quality from different points of view**:**

- The quality "product" approach is based on the product attributes
- The quality "user" approach is the employability
- The quality "production" approach is the needs' conformity
- The quality "value" approach is the degree of excellence at an acceptable price [6].

In addition, the Quality includes several aspects depending on the needs, the requirements and the according to various aspects [7], [8], [9]. In practice, the different aspects of quality can be in two forms:

- External quality corresponding to the customers' satisfaction. It provides products or services that meet customer expectations and improves the market company's share.
- Internal quality corresponding to the improvement of the internal workings of the company. Its purpose is to implement ways to best describe the organization, to identify and to limit malfunctions. The main objective of the internal quality is to control and to improve the quality of the product. This internal quality generally goes through a step of identification and formalization of internal processes carried out through a participatory system analysis approach [10] [11].

Thus, it appears that the term Quality cannot be defined in one aspect. It is a point of view concerning all activities which relate to the product, the production processes, the organizational structures and the customer. Moreover, a reflection on the quality aspect must take into account, the relevant parameters of the different interacting processes in a productive system.

The aim of quality management is the development of the verification technologies, the product quality and the specification of the quality standard achieved, mainly, in terms of economic objectives. The goal of maintaining quality is closely depends on its ability to diagnose problem areas as well as problem prevention strategies [12] [13].

The aim of this paper is to develop an operational and structured vision through the integration of the Six Sigma decision making method to analyze and identify relevant parameters which allow operation in a context of total quality. Improvement solutions are also proposed for the operating manner of the production system. A case study of a photovoltaic water pumping system is proposed.

II. Tools for resolution of quality problems

Our research interests in the problems related to energy production systems with a photovoltaic system.

Several types of quality problems were introduced in the literature:

- The problems of special cause, which are sudden and unpredictable instability that causes a decrease in the level of performance and prevents the return to this level.
- The problems of common causes, which are the steady level of performance, the highest expected level of performance.

Thus, a quality tool is a coherent set of practical measures implemented in the company to improve the performance of one or more characteristics of product or service.

The quality tools have sometimes been referred as the following seven quality tools: survey sheet, Pareto chart, cause-effect diagram, graphs and histograms, control charts, brainstorming, QQOQCP. These are the resources used in the improvement actions.

In literature, multiple researchers focus on the integration of the quality management with the production management. Kim and Gershwin [14] have developed a continuous model which studies the interaction of quality and productivity.

The quality management concept appears, under the impulse of researchers that announced as the quality of management promoters finds that many organizational aspects hinder the quality. Wanting to solve the quality problem, by specifying checks at the production level, is not enough. We need to rethink the organization of the design and the production so as to reduce the number and the cost of controls and to introduce the concept of the quality in the related production services.

Six Sigma is a methodology, first appeared in 1990 by Motorola. It is used by companies to improve the quality and the efficiency of their processes. The Six Sigma method is based on the MSP and is often used to provide the organization with measurable and effective action, to reduce quality's costs and losses. The method is based on five steps, which contract in the "DMAIC": Define, Measure, Analyze, Improve and Control [15] [16] [17].

- **Define:** This step consists in identifying the maximum of problems and then ranked them by priority order. The problem is then defined in time and space, this using the QQOQCP quality method to identify customers' need and to clarify objectives**.**
- **Measure:** This step leads to search and collect the relevant data for a well-defined process and measure existing results. In this step, the measure must be justified by the quality diagram method ISHIKAWA or 6 M and Pareto method. Also this step leads to a description of the current situation and especially the description of the encountered problems**.**
- **Analysis:** This step allows the use of analytical and statistical tools in order to identify the causes of problems. At this stage of development of the method, we must understand the issues in order to formulate, using the FMEA risk analysis method or mastering effects or quality brainstorming tool, the solutions that bridge the gap between the current situation and customers' objectives**.**
- **Improve:** This step allows the identification and implementation of solutions, to prevent problems, using tools such as GANTT, histograms and graphs. This particular phase may be important in some specific cases in several stages. In order to take the time to test and validate the most appropriate solutions.
- **Control:** This step consists in controlling or monitoring to ensure the performance of data process, to control the gap between the initial data and the obtained results (quality, cost, time...) and to analyze the obtained improvements. This assessment also allows, if necessary, the adjust of the solution according to the unanticipated effects. Results must be communicated and documented using a communication plan, advertising and visual management**.**

The establishment of a Six Sigma approach enhances the improvement of the product quality and the customer services. Indeed, the main objective of Six Sigma is to increase the profitability by reducing waste while protecting the customer's interest [18] [19]. It is also a statistical measure of the process performance to determine, with great accuracy, the quality of products or services.

The concept of quality is closely linked to that of variability. Some even define the non-quality as a variability regarding an expected reference. The fight against the variability is one of the basic concepts of Six Sigma [20].

The variability in any process is indispensable. It fact, totally compliant products does not exists. However, it is possible to control this variability and to reduce it to the maximum [21] [22].

For this, it must first fix the desirable value and limits the acceptable variation for this average value (the tolerance interval). Then, it is necessary to evaluate the process capability in order to provide an average value of products close to the desired value. This is the standard deviation "σ" that measures the dispersion of products around the average value.

III. The Need for system Modeling

System modeling is essential for understanding and analyzing the phenomena involved in the industrial systems. The conduct of such systems is also based on the use of systems analysis models [23] [24]. These models must account for the structure and behavior of the system and allow the analysis of its qualitative and quantitative properties [25] [26] [27].

The SADT was developed by Ross in 1977 [28] [29]. It allows the analyze step in a graphically and structured way. To do so, the system functions are put in boxes and their connections are represented by arrows [30] [31] [32]. It consists in decomposing the system into subsystem and examining the processes by identifying the activities, their input and output elements, and the controls.

The construction of an SADT model starts with the most general and abstract description of the system. This description, contained in a single module, can be divided into sub modules; each representing a component of the original box. This process may then be iterated until the desired degree of detail is obtained. Each sub-modules or modules-son does not add or subtract from the context of the father module [33] [34] [35].

The case of the installation-operation is an experimental site in a research environment. It is a water pumping installation, which is fed through photovoltaic panels.

The photovoltaic installation produces the energy required to operate the pomp. The water flow is depended on the level of sunshine. Moreover, the rational exploitation of this installation helps control power consumption, minimize costs and benefit from free energy.

This installation is composed of solar panel, a conversion system, a control and regulating system, a pump and a water circuit from the bore to the storage tank. Figure 1illustrates the structure configuration of the installation.

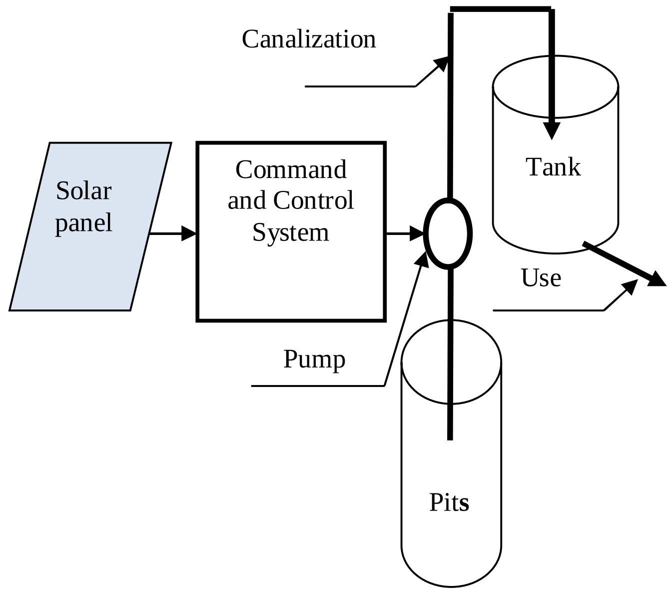


Fig. 1. Photovoltaic water pumping system

The modeling of the water pumping system by the SADT method allows to understand how the system works and to identify relevant parameters that require measurement and evaluation. Thus, we represent the actigrams A-0 and A0 (Fig.2). Moreover, measures have been taken including the average solar energy per day, per year and the corresponding water flow.

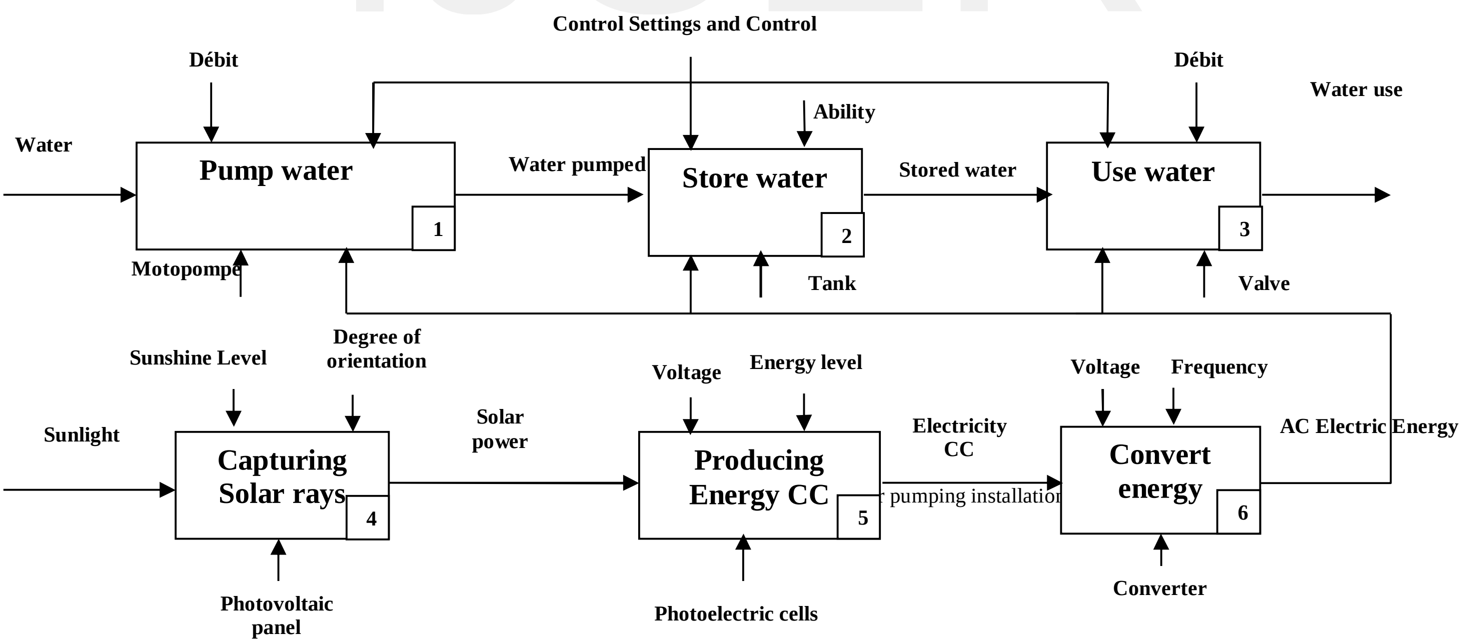


Fig. 2. Actigram A-0 of the SADT model

IV. Results of the Quality Approach

The power of the photovoltaic pump is dependent on sunlight, as the volume of water collected varies from one season to another. The figure 3 shows the rate of sunshine for the first day of October 2014 and the curve of the figure 4 shows the flow of water corresponding to the same sampling instants of sunshine and for the same day. Table 1 shows the average solar energy per month depending on the amount of water volumes collected per month.

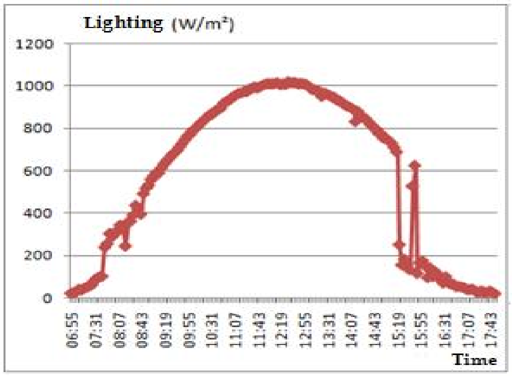


Fig.3. The rate of sunshine (01/10/2014)

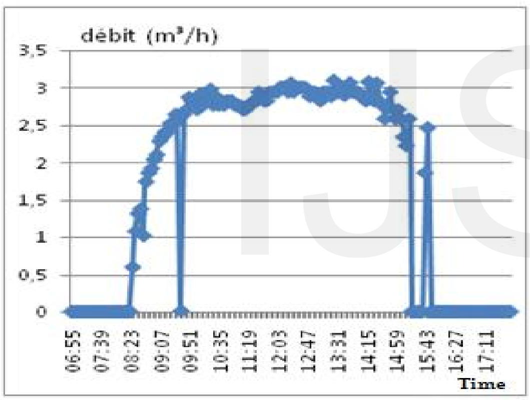


Fig. 4. The water flow (01/10/2014)

TABLE I. Water withdrawals per month depending on solar energy (2014)

Month	Average solar energy in kW/m²/day	Total amount of water in m³ / month
January	3,731	497,96
February	4,554	507,028
Mars	5,245	508,337
April	5,693	644,311
May	6,927	747,212
June	6,965	632,816
July	7,197	606,559
August	7,292	654,721
September	6,699	351,265
October	5,435	473,547
November	4,31	442,814
December	3,731	476,249

The figure 6 shows the curve of the average energy during the first month of the year 2014.

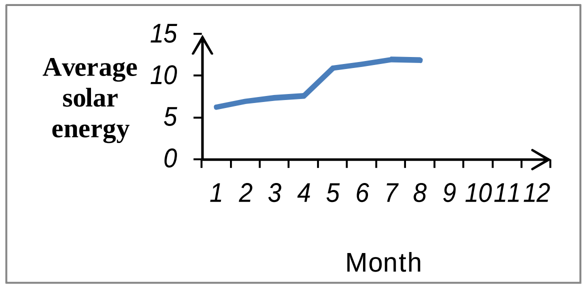


Fig. 5. Average solar energy

The table 2 shows how to verify the defects and quality level according to Sigma method in decentered in process.

TABLE II. Faults and Sigma level of quality in-center process

Cp	Cpk	Sigma Quality Level	Criterion
0.5	0	1.5	**Bad**
0.6	0.1	1.8	
0.7	0.2	2.1	
0.8	0.3	2.4	
0.9	0.4	2.7	
1	0.5	3	
1.1	0.6	3.3	
1.2	0.7	3.6	
1.3	0.8	3.9	**Limited**
1.4	0.9	4.2	
1.5	1	4.5	
1.6	1.1	4.8	
1.7	1.2	5.1	
1.8	1.3	5.4	
1.9	1.4	5.7	
2	1.5	6	**Excellent**

The principle of normality test verifies the differences between a perfect theoretical distribution of a normal distribution and a real distribution (points). If the probability is greater than 0.05, it is considered that the law follows a normal distribution.

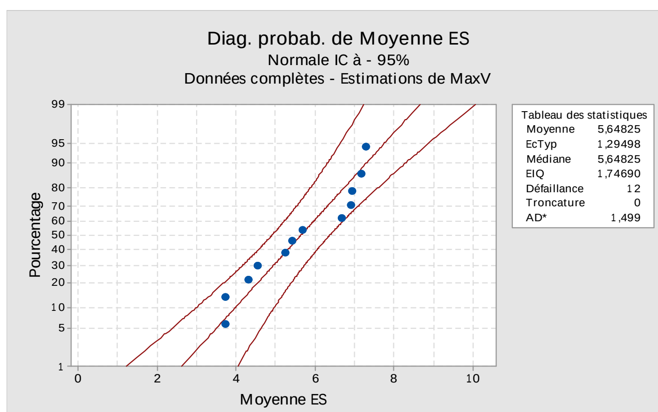
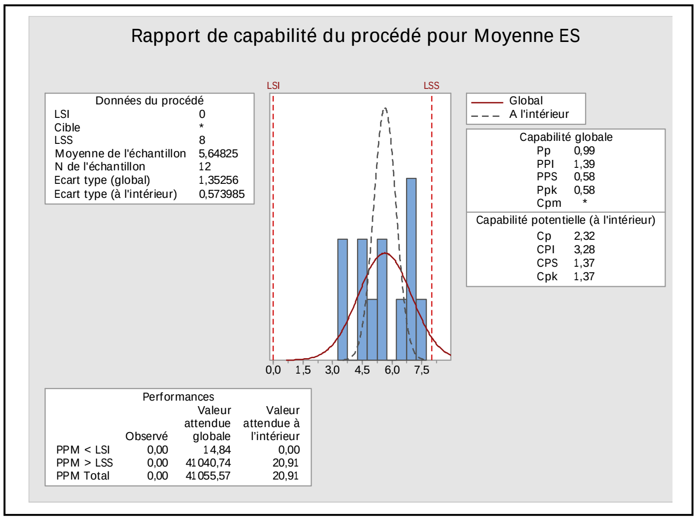


Fig. 6. Diagram of probability of the average of solar energy

The obtained probability P = 1.29 is greater than 0.05. Thus, our measurements are normally distributed.

For the capability curve of the process, it should be noted that the law is normal in our case.



The parameters presented in the graph are calculated using the Minitab:

- **Cpk** = 1.37 > 1.33 This means that our process is able for this area.
- **Cp** = 2.32 > 1.8 This means that our process is able for this area.
- Standard deviation **σ** = 1 .3

Our process is capable and well controlled. Consequently, the quality level Sigma = 5.4. Therefore, the need for solar energy is almost excellent.

The principle of normality test verifies the differences between a perfect theoretical distribution of a normal distribution and a real distribution (points). To do this, one calculates the probability and if it is greater than 0.05, it is considered that the law follows a normal distribution.

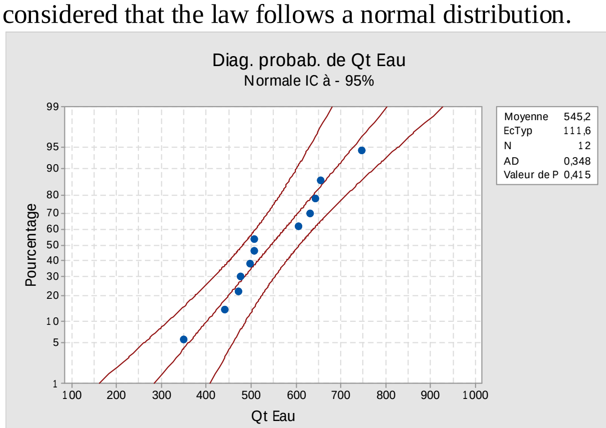


Fig.8. Diagram of probability of the water supply diagram of the report of the process capability for the average of solar energy

This gives the probability **P** = 0.415> 0.05 and our actions follow a normal distribution.

For the capability curve of the process, it should be noted that the law is normal in our case.

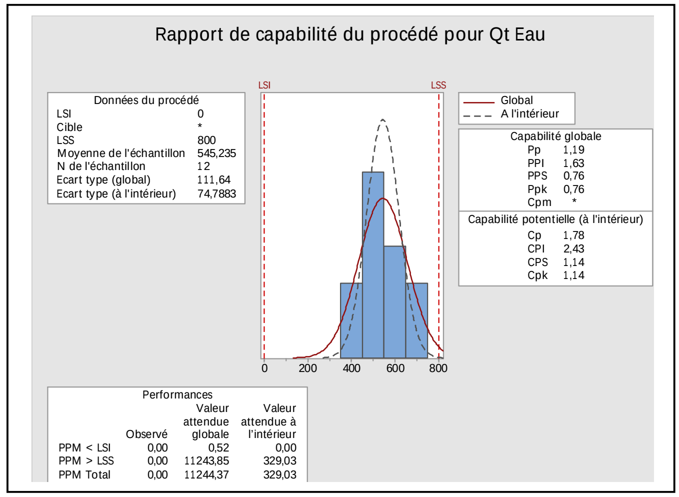


Fig.9. Diagramme du rapport de capabilité du procédé pour la moyenne de l'énergie solaire

The parameters shows in the graph are calculated by the Minitab:

- **Cpk** = 1.14 > 1.1 This means that our process is able for this area.
- **Cp** = 1.78 > 1.6 This means that our process is able for this area.
- Deviation **σ** = 111.64.

Our process is capable and well controlled, and the quality level of Sigma 4.8. Therefore, the need for water is almost excellent.

V. Conclusion

In this paper, the need for system modeling of a photovoltaic water pumping system for understanding its operation and exploitation with consistency and in a correct manner was presented. In fact, the methods used for the description of this system are characterized by their graph formalism which is necessary for the description of the system operating modes studied and identified sub systems and knowledge of its internal and external functions.

The analysis through Six Sigma has shown that the system is operated in a rational way, but it can be reinforced by an additional storage unit for more capacity. In addition the use of water may be used in non-sunny periods, particularly during the night. We advocate the use of this pumping system for private and public gardens and for the green zones.

Staring from this case study of the application of the structured analysis and Six Sigma of a photovoltaic water pumping system discussed in this paper, work is in progress to develop a general methodology of analysis and modeling for different industrial systems.

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