Power customer satisfaction and profitability analysis using multi-criteria decision making methods

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ABSTRACT

Nowadays, the consumer demands for electrical energy are increasingly growing, because this energy is present in all fields of human activity. Any company producing and distributing electric power sets two main objectives, namely: customer satisfaction and profit making. The aim of this paper is to investigate appropriate tools (multi-criteria decision making methods) aiding decision makers to achieve these goals. The criteria adopted revolve around quality of service and include: cost, reliability, availability, maintainability and power quality. However, the alternatives are technical and organizational measures often taken in planning and operation phases of electrical power systems. Three methods are used, namely: the analytic hierarchy process (AHP), the cost benefit analysis (CBA) and the economic criteria inspired from game theory (ECIGT). The first method highlights the impact of the experts' views in the formalism of the final decision of the manager and it is viewed as a transparent decision process. As for the ECIGT, it provides several scenarios to define a strategy according to the decision maker's behavior. One of its important finding resides in the possibility of evaluating the reactions of the customers towards the decisions taken by the system manager. Consequently, it allows the analysis of the enterprise profitability. However, the CBA method is efficiently integrated into these two complex methods decision making. The application developed in this paper shows that RAM (reliability, availability and maintainability) criteria are significant stakes in the performance of a business and are an important asset for new projects justification.

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1. Introduction

Distributors of electrical energy are often working to meet a balance between the requirements' satisfaction of the end users of the power system and the containment of the generated costs. This issue requires the knowledge of useful criteria aiding to lead to an appropriate management without prejudicial constraints. In several cases, the decisions taken by managers are resulted from the ultimate reflections of a group of experts who associates weights to the importance of both suitable criteria and suggested alternatives. In both competitive and monopoly markets, customer satisfaction is a prerequisite and a critical business objective. In a liberal environment, the customer has free choice to provide the best services and in this case the non-competitive company risks losing much of the market, consequently it reduces its profitability. In the case of a monopoly market, the consumer dissatisfaction can lead to a conflict of interest which undoubtedly will have adverse consequences for both parties. This paradigm is addressed in the context of multi-criteria decision making. The aim of this paper is to investigate mechanisms leading to simultaneously analyse customer satisfaction and enterprise profitability in both monopoly and liberal environments. It provides decision makers with scientific tools aiding them to choose the best alternative from one sample to meet the fixed goals, objectives, desires values and so. Compared to this issue, three multi-criteria decision making methods are introduced, insuring the development of mathematical models taking into account the psychological side of both decision makers and customers, namely: the analytic hierarchy process (AHP), the cost benefit analysis (CBA) and the economic criteria inspired from game theory (ECIGT). The AHP method is a transparent process that remains very useful for a company insuring a public service. It is also a measurement theory that prioritizes the hierarchy and consistency of judgmental data provided by a group of decision makers. As for the ECIGT approach, it presents a certain virtue, like the ability to simulate different possible states of the manager (optimistic, pessimistic, prudent or gambler) and allows to understand the reactions of consumers (not satisfied, satisfied or quite satisfied) in relation to the attitude of the decision maker.

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This method is widely used in the resolution of problems posed in an uncertain future. The third proposed method; CBA is an appropriate tool for costs assessment and efficiently integrated into AHP and ECIGT decision making methods cited above. To achieve the objectives set, five criteria were selected namely: the cost, the reliability, the availability and the maintainability of the network, as well as the power quality. These criteria highlight, with a high fidelity and in a simultaneous manner, the consumer's and the company's interests. The consumer seeks a product with both high availability and quality encompassed in terms of quality of service. However, the enterprise privileges profitability, which is heavily reliant to the cost of the services, to the system reliability and to the applicability of the needed maintenance actions, which in turn should be performed easily and leading to efficient results. A general decision making process can be divided into eight steps such as: problem definition, requirements determination, goals establishment, alternatives identification, criteria definition, decisions making tool selection, alternatives against criteria evaluation and finally solutions against problem statement validation. The developments expressed in the present paper follow these requirements where steps order is quite respected, considering a part of the distribution network of Bejaia city (Algeria) as a practical case. After analyzing the current state of the network which is considered poor in terms of quality of service, decision-makers had to take technical and organizational measures to improve the supply of electric energy. Experts' opinions and consumers' reactions were supported with great interest to avoid inconvenience leading to conflicts. For purposes of simulations, a software program was developed to implement the mathematical models developed for each method. The obtained results provide decision-makers with a range of choices enabling them to target a well-defined goal and take appropriate actions according to the means of the power supply company. The rest of the paper is organized as follows: Section 2 sets the decision methodology overview. Section 3 develops briefly the three used multi-criteria decision making methods, easily applicable to electric power system. The criteria and the alternatives useful in the case study application are presented in Section 4. The description of the system under study is dressed in Section 5; however, Section 6 is devoted to the application and where the results are discussed. Finally, the conclusions of the research are presented in Section 7.

2. Decision methodology overview

Electric utilities need to provide energy delivery services at the lowest cost. The customer satisfaction has become a critical business objective. Combined to the enterprise profitability, it is directly related to reliability, availability and maintainability of the network, as well as to the power quality. The association of these criteria to the strategies developed by the company to attain the fixed objectives and goals constitute the multi-criteria decision making paradigm. To analyse customer satisfaction and enterprise profitability, three methods are developed, namely: the analytic hierarchy process (AHP), the cost benefit analysis (CBA) and the economic criteria inspired from game theory (ECIGT). Regarding customer's wants treatment on manufacturer products, Yang [1] relates reliability to customer satisfaction and presents reliability and quality techniques as important parameters for improving customer satisfaction. Considering Kano model, the author described the relationships between customer satisfaction and customers' wants. Bollen et al. [2] have introduced the customer dissatisfaction index (CDI) defined as the probability that the supply for a given customer is of insufficient reliability. Elliot and Serna [3] stated that utilities are facing new challenges to managing customer satisfaction. They have discussed key elements summarized as follows: the first order drivers are service, price and reliability and

the second perception drivers are customer responsiveness, company reputation, and outage frequency and duration. Once the managers understand these drivers, the next step is to assess opportunities for improvement. To evaluate the satisfaction of users of the electric power, in a recent publication, Guo and Niu [4] developed a method based on decision tree, where the analysis is conducted by choosing 20 customer questionnaires. To highlight the importance of the AHP method, a review of a total of 150 AHP application papers is provided by Omkarprasad and Sushil [5] as an informative summary kit for researchers and practitioners. However, AHP has recently been applied to solve problems concerning electric power systems. It has been used by Negim et al. [6] as an expert system to identify the vulnerability of special protection schemes (SPS), and by Malik and Sumaoy [7] for impact evaluation and logical prioritization of demand side resources to planning criteria. ANP and AHP processes were jointly used by Chen et al. [8] for the strategic selection of a feeder management system applied to the power industry in china. The development with practical application given in the present paper has proven that AHP method makes the selection process very transparent with a great benefit to a company assuring public services. The approximated values of weights representing the degrees of importance of criteria and alternatives are validated by the results obtained using the CBA method. To investigate the behaviors of the decision-makers in an uncertain future and to highlight the reactions of the customers, we have introduced some economic criteria inspired from game theory. According to this issue, Voropai and Ivanova [9,10] have conducted some investigations in relation to both game theory and the problem of expansion planning of power systems. It is stated that if the power supply company invests in the installation, the investment project may call for a multi-criteria assessment. For an independent investor, one should allow for an incentive for the behavior of the other concerned subjects and the problem can be associated with the game statement. The AHP, the CBA and the ECIGT methods were adopted in the present paper because customer satisfaction refers to customers' mental state after comparing the products and services received with their expectations.

3. Decision making tools

3.1. Analytic hierarchy process

The decision method decomposes a complex multi-criteria decision problem into a hierarchy. AHP is also a measurement theory that prioritizes the hierarchy and consistency of judgmental data provided by a group of decision makers. AHP incorporates the evaluations of all decision makers into a final decision, without having to elicit their utility functions on subjective and objective criteria, by pair-wise comparisons of the alternatives. Five selection criteria C_j (for $j = 1–5$) are considered to be relevant and are respectively: the cost, the reliability, the availability, the maintainability and the power quality. Four alternatives are selected denoted by A_i (for $i = 1–4$) highlighting technical and organizational measures taken during planning and operation phases of the power system. Steps to general use of the AHP method are summarized in Ref. [11] and its application to power customer satisfaction and enterprise profitability is described as follows:

(1) Model the problem as a hierarchy containing the decision goal (customer satisfaction and enterprise profitability), the alternatives (technical and organizational measures) for reaching it, and the criteria for evaluating the alternatives (cost, reliability indices, and power quality).

(2) Establish priorities among the elements of the hierarchy by making a series of judgments based on pair-wise comparisons of the elements.