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# Multiobjective and multiattribute decision making in a fuzzy environment and their power engineering applications

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ABSTRACT

This work presents and generalizes our experience in the use of fuzzy set theory, including its combination with another branch of mathematics of uncertainty, in developing general approaches and methods for optimization and decision making with considering the uncertainty and multicriteria factors in problems of the design, planning, operation, and control of complex systems. Two major classes of situations that require the use of a multicriteria approach are identified. In accordance with this, two general classes of models related to multiobjective ($\langle X, F\rangle$ models) and multiattribute ($\langle X, R\rangle$ models) problems, respectively, are considered. Methods for their analysis based on the use of the Bellman–Zadeh approach to decision making in a fuzzy environment and fuzzy preference modeling techniques, respectively, are considered. Although, the use of $\langle X, F\rangle$ and $\langle X, R\rangle$ models is of an independent character, they also serve as parts of a general scheme for multicriteria decision making under conditions of uncertainty. This scheme is associated with the use of a generalization of the classic approach to considering the uncertainty of information to multicriteria problems, based on analyzing special aggregations of payoff matrices. The authors' experience in the use of the results indicated above for solving diverse classes of power system planning and operation problems is described. This experience convincingly demonstrates diverse advantages of applying fuzzy mathematics in optimization and decision making problems of power engineering.



## 1. Introduction

Various kinds of uncertainty [20,27,57] are commonly encountered in optimization and decision making problems related to the design, planning, operation, and control of complex systems. This situation is to be considered as natural and unavoidable. Considering this, it should be noted that the incorporation of the uncertainty factor in building mathematical models serves as a vehicle for increasing their adequacy and, as a result, the credibility and factual efficiency of decisions based on their analysis. As an adequate means for this incorporation can serve the use of fuzzy set theory [51,65]. Its utilization in

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problems of an optimization character offers advantages of both the fundamental nature (the possibility of validly obtaining more effective, less “cautious” solutions as well as considering simultaneously different manifestations of the uncertainty factor [20,50]) and the computational character [21,50].

The authors of [17,57] classify internal uncertainties (related to decision maker (DM) values and judgments) and external uncertainties (defined by environmental conditions lying beyond the control of the DM). This paper deals with both types of uncertainty in problems of a multicriteria character, which are associated with so-called uncertainty of goals [50]. Some researches in the field of operational research and systems analysis agree that, from the general point of view, this type of uncertainty is the most difficult to overcome because "we simply do not know what we want". In reality, this type of uncertainty cannot be effectively captured only on the basis of applying formal models, as sometimes the unique information sources are the individuals who make decisions.

It is possible to identify two major classes of situations [21,50] which require the use of a multicriteria approach:

- The first class is associated with problems whose solution consequences cannot be estimated with the use of a single criterion: these problems are associated with the analysis of models which include economic as well as physical indices (when alternatives cannot be reduced to comparable form) and also by the need to consider indices whose cost estimations are difficult or impossible (for example, many power engineering problems are to be considered on the basis of criteria of technological, economical, ecological, and social character);
- The second class is related to problems that may be solved on the basis of a single criterion (or several criteria). However, if the uncertainty of information does not permit one to derivate unique solutions, it is possible to reduce these problems to multicriteria decision making by applying additional criteria, including those of a qualitative character, whose utilization is based on knowledge, experience, and intuition of involved experts.

Taking this into account, it is necessary to distinguish two types of criteria: objectives and attributes. In such a manner, multicriteria decision making problems can be classified into two wide classes [33,34]:

- Multiobjective decision making;
- Multiattribute decision making.

Generally, multiobjective decision making is known as the continuous type of multicriteria decision making and its main characteristics are that the DM needs to achieve multiple objectives while these objectives are non-commensurable and conflict with each other. A multiobjective decision making model includes a vector of decision variables, objective functions that describe the objectives, and constraints. The DM attempts to maximize or minimize the objective functions.

At the same time, multiattribute decision making is related to making preference decision (that is, comparison, choice, prioritization, and/or ordering) over the available alternatives that are characterized by multiple, usually conflicting, attributes. The main peculiarity of multiattribute decision making problems is that there are usually a limited number of predetermined alternatives, which are associated with a level of achieving the attributes. Based on the attributes, the final decision is to be made.

According to this classification, two classes of models, corresponding to two classes of situations, which require the use of a multicriteria approach indicated above, may be constructed: $\langle X, F\rangle$ models (as multiobjective models) and $\langle X, R\rangle$ models (as multiattribute models). The present work briefly describes these models as well as methods of their analysis, based on applying the Bellman–Zadeh approach to decision making in a fuzzy environment and on utilizing techniques of fuzzy preference modeling, respectively. The joint consideration of $\langle X, F\rangle$ models and $\langle X, R\rangle$ models is justified, first of all, from the substantial point of view. In particular, in any type of our activities, for example, in planning (strategic, innovation, new business, research and development planning) always two fundamental questions arise: "what to do?" and "how to do?". The answers to the first fundamental question can be elaborated by constructing and analyzing $\langle X, R\rangle$ models. At the same time, the construction and analysis of $\langle X, F\rangle$ models helps in answering the second fundamental question.

Moreover, the analysis of $\langle X, F\rangle$ models and $\langle X, R\rangle$ models serves as parts of a general scheme for multicriteria decision making under conditions of uncertainty, discussed below. This scheme is associated with a generalization of the classic approach to considering the uncertainty of information to multicriteria problems, based on analyzing special aggregations of payoff matrices. Its important feature is to use available quantitative information to the highest degree to reduce decision uncertainty regions. If the problem resolving capacity related to quantitative information processing does not allow one to obtain unique solutions, the general scheme assumes the use of qualitative information based on knowledge, experience, and intuition of experts involved in the decision making process.

The authors' experience in the use of the indicated results for solving wide classes of problems of power system planning and operation is described. This experience convincingly demonstrates the advantages of applying fuzzy mathematics, including its combination with another branch of mathematics of uncertainty, to solve problems of power engineering from different points of view.

Taking the above into account, the rest of the paper is organized as follows. Section 2 is dedicated to the analysis of $\langle X, F\rangle$ models, including models of multiobjective allocation of resources. The issues related to setting up and solving multiattribute problems within the framework of $\langle X, R\rangle$ models are considered in Section 3. The general scheme of multicriteria decision making under conditions of uncertainty which integrates the analysis of $\langle X, F\rangle$ models and $\langle X, R\rangle$ models with a generalization of the classic approach to considering the uncertainty of information to multicriteria problems is a subject of