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Decision making under uncertainty in energy systems: State of the art

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ABSTRACT

The energy system studies include a wide range of issues from short term (e.g. real-time, hourly, daily and weekly operating decisions) to long term horizons (e.g. planning or policy making). The decision making chain is fed by input parameters which are usually subject to uncertainties. The art of dealing with uncertainties has been developed in various directions and has recently become a focal point of interest. In this paper, a new standard classification of uncertainty modeling techniques for decision making process is proposed. These methods are introduced and compared along with demonstrating their strengths and weaknesses. The promising lines of future researches are explored in the shadow of a comprehensive overview of the past and present applications. The possibility of using the novel concept of Z-numbers is introduced for the first time.

Contents

1. Introduction

The uncertainty handling has been one of the main concerns of the decision makers (including governors, engineers, managers, and scientists) for many years [1]. Most of the decisions to be made by energy sector decision makers are subject to a significant level of

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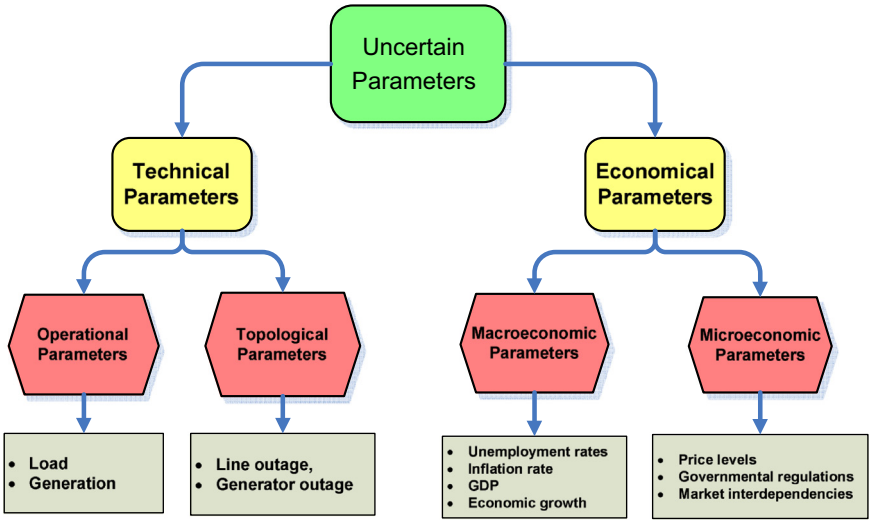

Fig. 1. General classification of uncertain parameters in energy system studies.

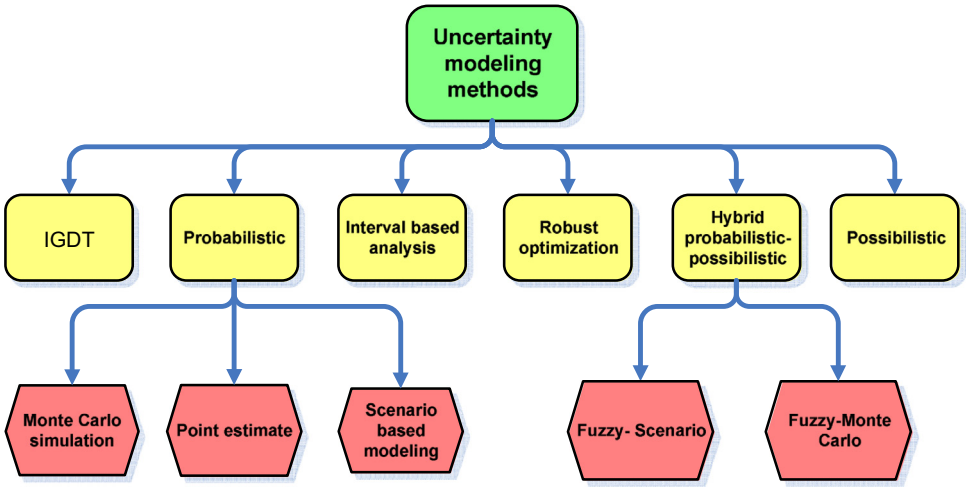

Fig. 2. Uncertainty modeling tools.

data uncertainty [2]. The uncertain parameters in power system studies can be generally classified into two different categories including (see Fig. 1):

- Technical parameters: These parameters are generally categorized in two main classes, namely topological parameters and operational parameters. The topological parameters are those related to network topologies like failure or forced outage of lines, generators or metering devices, etc. The operational parameters are tied with operating decisions like demand or generation values in power systems.
- Economical parameters: The parameters which affect the economical indices fall in this category. Microeconomics investigates the decisions of smaller business sectors like aggregators, domestic or industrial consumers while macroeconomics focuses on the entire power system industry. For example, uncertainty in fuel supply, costs of production, business taxes, labor and raw materials are analyzed in microeconomics. On the other hand, the issues like regulation or deregulation, environmental policies, economic growth, unemployment rates, gross domestic product (GDP) and interest rates are analyzed in macroeconomics. All of these parameters are subject to uncertainties and should be correctly addressed in economical studies.

There are various uncertainty handling methods developed for dealing with the aforementioned uncertain parameters as depicted in Fig. 2. The main difference between these methods is in line with the different techniques used for describing the uncertainty of input parameters. For example, fuzzy method uses membership functions for describing an uncertain parameter while the stochastic methods use probability density function. The similarity of them is that all of them try to quantify the effect of input parameters on model's outputs. These methods and the way the uncertainty is handled by them are described as follows:

- Probabilistic approach: One of the earliest works in stochastic programming was done by Dantzig in 1955 [3]. It is assumed that the input parameters of the model are random variables with a known probability density function (PDF).
- Possibilistic approach: The fuzzy arithmetic was introduced by Lotfi A. Zadeh in 1965 [4]. The input parameters of the model are described using the membership function (MF) of input parameters.
- Hybrid possibilistic–probabilistic approaches: Both random and possibilistic parameters are present in the model.
- Information gap decision theory: It was first proposed by Yakov Ben-Haim [5] in 1980. In this method, no PDF or membership function is available for input parameters. It is based on the