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Risk and Balance in Wind Energy

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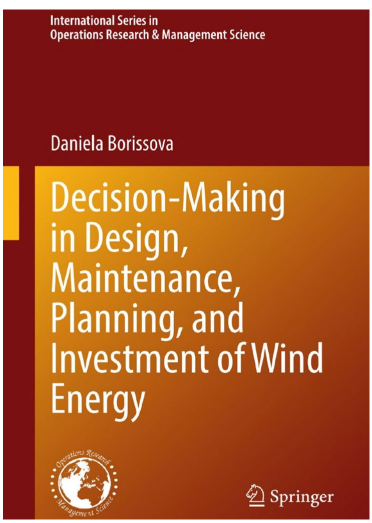

In 2024, the monograph "*Decision-making in the design, maintenance, planning and investment of wind energy*" was published by Springer Cham as part of the series of books: International Series in Operations Research & Management Science, which encompasses various areas of operations research and management science including telecommunications, health care, capital budgeting and finance, economics, marketing, public policy, military operations research, humanitarian relief and disaster mitigation, service operations, transportation systems, etc.

This monograph examines current issues in the renewable energy sector from an operations research point of view and advances in information and communication technologies. It consists of 6 chapters and begins with an introduction to the formulation of optimization models and methods for solving them.

Chapter 1 describes not only the decision-making process but also offers a classification of multi-criteria decision problems. Special attention is paid to the process of formulating optimization models and their refinement represented by several main stages, as shown in Fig. 1.

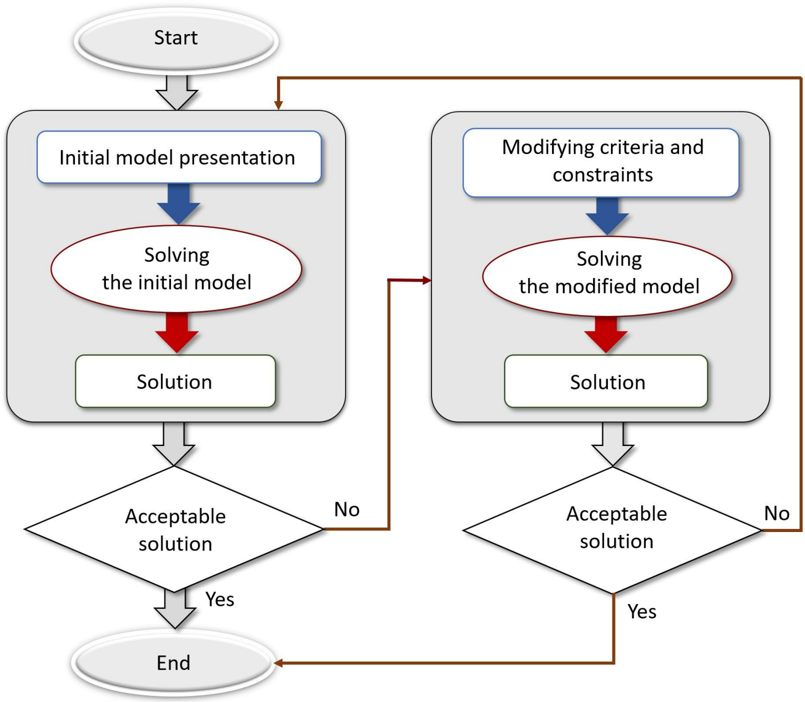

Fig. 1. Stages in the modelling process [1]

Optimization models can be seen as an effective tool in supporting decision-making based on the appropriate models that lead to reasonable solutions to various problems in many fields. This chapter includes 99 references.

Chapter 2 refers to decision-making in planning and investing in wind energy. The life cycle of the wind farm is presented in five consecutive stages namely site assessment; planning and design; construction and commissioning; operation and maintenance; and decommissioning, which are subject to this chapter. A groups of technical, economic, and environmental indicators are discussed and used as criteria in a model for the assessment and selection of wind site locations. Some pros and cons in location selection for onshore and offshore wind farm buildings are presented. In this regard, a model for ranking economies with investment purposes based on a multicriteria optimization model is proposed. In addition, decision-making problems for supplier selection can be found. A generalized approach to support business group decision-making by three different strategies for selection or ranking is formulated. Furthermore, a decision-making model for personnel ranking, taking into account the availability of hard and soft skills, is also presented [2]. It is also shown how personnel skills can be assessed by using a variety of tests with different levels of complexity. This chapter ends with 83 references.

Chapter 3 addresses the problems of decision-making in wind farm design. A wind farm layout design concept is presented, which is used in the formulation of single- and multi-criteria optimization models for selecting the type, number and placement of wind turbines [3, 4]. Based on the same concept, a two-stage algorithm for wind farm layout design through multi-objective combinatorial optimization is proposed. It integrates multi-attribute decision-making techniques and multi-objective decision-making techniques in the selection and performance evaluation of the selected wind turbine. For a wind site with the presence of forbidden zones for the deployment of wind turbines, two additional models are offered, taking into account the availability of areas with a regular geometric shape and an irregular shape. In addition to these models, a model for the optimal layout of a wind farm design considering the location of the common connection point is proposed [5]. This chapter ends with a description of some criteria concerning hybrid wind-solar power plants used in combinatorial optimization model for the selection of such site. This chapter includes 62 references.

Chapter 4 is related to decision-making models in the one dimensional (1D) cutting of blanks for wind turbine manufacturing and processing planning of details. This chapter starts with a description of the wind turbine life cycle represented by several stages including supply of raw material; supplier selection and transportation; production of blanks, elements, and assembly; wind turbine operation; demolishing; and recycling. To minimize waste, a proposed combinatorial optimization model for 1D cutting problems is discussed [6]. Then, for the cut blanks, an optimization model is formulated for job shop scheduling on multiple machines [7]. Based on the processed details it is shown how to make a product configuration design via group decision-making and combinatorial optimization. For the purposes of production and assembly of the final product, there is also an optimization model for determining the personnel schedule in an open shop environment with various criteria such as determination of operators' number to achieve minimum staff idle; determination of operators' number providing minimum processing time or simultaneously determination of minimum staff idle and minimum staff number. There are 57 references to this chapter.

Chapter 5 deals with the decision-making problems related to structural health monitoring and predictive maintenance of wind turbines. For the goal, single- and multi-objective optimization models aiming to determine the optimal number and placement of sensors for structural health monitoring purposes are presented [8]. In addition, a predictive maintenance strategy for repairing or replacing the machine as a whole is proposed, which relies on two types of cost-benefit evaluations used in formulated optimization models [9]. All of these activities and models could be integrated in into intelligent e-maintenance decision support systems. Also, it is possible to incorporate the proposed group decision-making approach for evaluation and choice under uncertainty conditions [10]. The number of references in this chapter is 48.

From the theoretical and practical point of view, special attention deserves **Chapter 6**, which deals with the economic aspects and social impact of wind energy. It starts with some positive and negative impacts of wind energy. When building a wind energy project, an accurate not only technical, but also economic assessment is needed to achieve the profitability of the project. It is therefore important to define the costs of wind energy from a macro perspective and to highlight the differences in the cost composition of different types of wind farms and the applicability of different economic analysis methods and evaluation metrics [11]. Some of the economic indicators for the assessment of investments in wind energy projects are shown in Fig. 2.

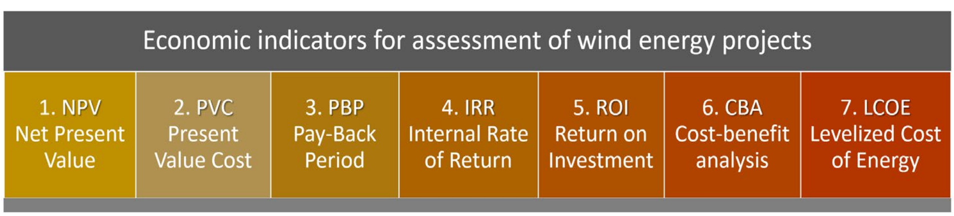

Fig. 2. Economic indicators for assessment of wind energy projects investments

Net Present Value (NPV) depends on the annual cash flow estimate, which takes into account all the variables related to the initial capital investment, operation and maintenance costs and decommissioning costs. Present Value Cost (PVC) considers the total cost during the whole life cycle of the wind farm involving the impact of economic factors in the form of interest rates and inflation rates. PBP (Pay-Back Period) is another measure that expresses the time, required for cash flow to be equal to the investment and may be used for preliminary evaluation of high-risk projects in times of uncertainty. It is possible by comparing the total ROI (Return on Investment) of the particular project with the average ROI for the industry, the profitability of the project investment can be estimated. Cost-benefit analysis (CBA) as a major economic and financial tool for evaluating net benefit can remove market distortions and indicate those actions with the lowest social cost or the highest net social benefit. Internal Rate of Return (IRR) is an indicator of the profitability prospects of a potential investment, i.e. this is the discount rate that makes the net present value of all cash flows from a particular project equal to zero. The Levelized Cost of Energy (LCOE) model as an economic model determines the expected cost of energy from an unbuilt power plant as it expresses the measure of the average net present cost of electricity generation for a specific system over its lifetime. All of these indicators could be used to determine the profitability of wind power plants.

Another important aspect of wind energy development, besides sustainability, is the opportunity for economic growth and job creation. It is shown that the total employment rate is easily the result of the sum of stable and temporary jobs. In this regard, an original measure of the quality of working conditions [12] based on the OECD (Organization for Economic Cooperation and Development) quality of work framework is described [13].

A special section is devoted to the types of risks associated with wind energy projects. These are summarized into five groups development and construction risks; economic risks; political risks; social risks; and cyber-attack risks. None of them could be missed as they all concern different aspects of the realization of wind power plant projects. They have to be identified, carefully analyzed, then properly treated, monitored, and finally reviewed.

It is interesting to mention the existence of two type formulated indexes related to energy consumption balance index formed by various combinations of conventional and renewable sources; and index of relative share of wind energy consumption among the other renewable sources [14]. According to published data [15], two cases are discussed. In the first case, a combination of conventional energy sources and a variety of renewable sources (gas, nuclear, hydro, wind, solar, etc.) are considered, with nuclear energy considered as a renewable energy source. In the second case, gas and nuclear energy are considered as conventional energy sources. It was found that the combination of energy sources in the first case shows the lowest values for Europe in the years studied, from which it is concluded that Europe uses the most renewable energy resources. The reverse of this finding is true for higher-middle-income countries. In the second stratum, where gas and nuclear sources are considered as conventional sources, the highest use of renewable energy is observed for the EU and lower middle income countries have the least use of renewable energy. The conclusion is that regardless of whether gas and nuclear energy are defined as renewable or conventional, there is a clear trend in favor of renewables. The second indicator of the consumption of the specific type of renewable energy could be used to determine the dynamics between the used sources of renewable energy. A trend of sustainable wind energy consumption in the EU among other renewable energy sources has been observed.

The distribution of energy consumption from different sources in Bulgaria follows EU trends, and wind energy consumption shows steady growth. This chapter ends with 65 references.

Today and in the future, risk and balance are key issues in wind power that seek its decisions. Prof. D. Borisova's monograph is an anticipatory step into the future, as the progress of technology requires the making of increasingly complex decisions taking into account various objective and subjective factors. The monograph describes various models, part of the operations research to specific real-life problems related to wind energy. Properly formulated optimization models have been shown to lead to finding the best solutions to complex problems.

I recommend that these models become available not only to operations research professionals and students, but also to wind energy managers. Here they will find a valuable resource for addressing the real-world challenges of making sustainable progress in wind energy.

Finally, I would like to thank the publisher Springer for their very good judgment in terms of the substantive monograph and proven professionalism in selecting the manuscripts for publication.

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