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What are the right policies for electricity supply in Middle East? A regional dynamic integrated electricity model for the province of Yazd in Iran

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ABSTRACT

Energy planning techniques are essential tools in the management of new complex energy systems. Among different techniques, System Dynamics is an appropriate technique for the simulation of complex energy systems and the analysis of their dynamism. In this paper, a regional dynamic integrated electricity model (RDIEM) is developed for a regulated electricity supply system in order to analyze the results of different scenarios and policies and find the right policies for the electricity generation. The results of model are validated with a real case in the province of Yazd in Iran. The results show that the balanced growth and the environment-oriented policies have the best results among different policies. Although the application is related to the Iranian case, the implications are much wider, especially in the Middle East.

Contents

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1. Introduction

The importance of electricity in the new world together with the uncertainties in its future demands has made electricity planning to be a main concern for the electricity consumers and producers in different countries. In recent years, there have been various attempts in the field of energy planning which have led to some novel and valuable models. Depending on their approach to the energy planning problem, these models can be categorized in the following four groups:

- Econometric models: these models are mainly generated based on the econometric techniques. They are long-term or mid-term models with a low level of details having a top-down approach in the analysis of the energy systems. One of the main econometric models is E3MME [1]. The fact that these models do not consider enough details as well as the existing dynamism of energy systems implies that the results of these models do not have enough degree of accuracy.
- Energy equilibrium models: these models, with mid-term or long-term horizon and an almost low level of details, are created based on the equilibrium equations and the game theory principles. The most popular models in this category are ENPEP and SGM [1]. These models have a top-down approach in the analysis of the energy systems. Likewise, the main drawbacks of these models are also the lack of accuracy and the low level of details. In comparison with the econometric models, the equilibrium models consider the dynamism of the energy system to some extent.
- Optimization models: these models, which are created based on the mathematical programming, are short-term or mid-term models with a high level of details. On the contrary to the above-mentioned models, these models have a bottom-up approach. Some of the main optimization models are MARKAL, MESSAGE and EFOM [1–3]. In addition to these well-known and comprehensive models, there are some other optimization models which have had regional applications (for example see [4]). Even though these models have a high level of details, they do not have enough flexibility in dealing with different variables and in the analysis of the dynamisms of the energy systems.
- Simulation-based models: these models are based on the model-based simulation principles. In most cases, these models are short-term or mid-term with the highest amounts of details and a bottom-up approach. These models are the best models in considering the dynamisms of the systems and they have also an acceptable level of accuracy and flexibility in system analysis. As a result of these advantages, the simulation-based models are the most popular models in energy planning. LEAP [5], TIMES [6] and MIDAS [7] are some of the most popular simulation-based models in energy planning. Moreover, there are also some regional energy plans based on the simulation models (e.g. [8]).

Even though, the popular simulation-based models have an acceptable capability to handle the energy systems, they do not have enough flexibility in the number of variables and analyzing the dynamics of the more complex energy systems, especially in the developing countries.

System Dynamics, which is also a simulation-based technique, studies the interactive relationships between variables and makes a good understanding of the considered system. Because of the complexity of energy systems in the developing countries (due to the impact of economic, social, and political factors), SD is an appropriate approach to make a realistic local energy model. While SD has the advantages of the simulation-based models, it also has a great flexibility in facing the complexity of energy systems.

A review of literature showed that the previous applications of SD in electricity energy planning were not inclusive enough as they have not considered all the related subsystems and variables. In other words, these researches have focused on the analysis of some parts of the system such as regulating, price, tariff and demand.

On the other hands, Middle East is one of the main important parts of the world corresponding to the energy issues. The existence of abundant sources of fossil energies with a significant potential in a wide range of renewable energies make it the most effective part of the world in energy market. These valuable potentials have been accompanied with some substantial obstacles in the economical and governmental structure of the Middle East countries, such as oil-based economics, the pale role of private sector in economics and the wide range of subsidies, especially in energy sector. These obstacles with the wide sources of fossil energy in Middle East caused a reluctancy between Middle East countries to invest in renewable sources of energy. The combination of these issues in addition to the environmental problems, make a complex situation for energy planners.

In this study, the system dynamics approach was applied to analyze the Iranian electricity supply system and propose the suitable policies for the role of private sector, the portfolio of energy, the required amount of demand side management programs and research and development programs. For this purpose, a regional dynamic integrated electricity model was developed (RDIEM) and the effectiveness of the model in handling the dynamism of the system and analyzing different scenarios and policies is validated with a real case in the province of Yazd in Iran. The results of the model are evaluated based on different economical, technical and environmental indices.

The rest of the paper is organized as follows: in Section 2, the related publications are reviewed. A brief review on the structure of electricity energy system in Iran is represented in Section 3. Section 4 introduces the main structure of the proposed SD model. In Section 5, the validation of the proposed model and the results of policy analysis are argued. Finally, the concluding remarks are represented in Section 6.

2. Literature review

System Dynamics which was pioneered by Forrester [9] is valued as a strategic tool to analyze the effects of different policies