Energy Policy 37 (2009) 5752–5763

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

A hierarchical decision making model for the prioritization of distributed generation technologies: A case study for Iran

Ali Zangeneh [a,*], Shahram Jadid [a], Ashkan Rahimi-Kian [b]

[a] Center of Excellence for Power System Operation and Automation, Department of Electrical Engineering, Iran University of Science and Technology, Tehran, Iran
[b] CIPCE, School of ECE, College of Engineering, University of Tehran, Tehran, Iran

ARTICLE INFO

Article history:
Received 7 October 2008
Accepted 18 August 2009
Available online 16 September 2009

Keywords:
Distributed generation technologies
Analytical hierarchy process (AHP)
Iran

ABSTRACT

The purpose of this paper is to present an assessment and evaluation model for the prioritization of distributed generation (DG) technologies, both conventional and renewable, to meet the increasing load due to the growth rate in Iran, while considering the issue of sustainable development. The proposed hierarchical decision making strategy is presented from the viewpoint of either the distribution company (DisCo) or the independent power producer (IPP) as a private entity. Nowadays, DG is a broadly-used term that covers various technologies; however, it is difficult to find a unique DG technology that takes into account multiple considerations, such as economic, technical, and environmental attributes. For this purpose, a multi-attribute decision making (MADM) approach is used to assess the alternatives for DG technology with respect to their economic, technical and environmental attributes. In addition, a regional primary energy attribute is also included in the hierarchy to express the potential of various kinds of energy resources in the regions under study. The obtained priority of DG technologies help decision maker in each region how allocate their total investment budget to the various technologies. From the performed analysis, it is observed that gas turbines are almost the best technologies for investing in various regions of Iran. At the end of the decision making process, a sensitivity analysis is performed based on the state regulations to indicate how the variations of the attributes' weights influence the DG alternatives' priority. This proposed analytical framework is implemented in seven parts of Iran with different climatic conditions and energy resources.

1. Introduction

Energy has been recognized as one of the most essential and crucial inputs for social and economic development. Nowadays, the huge demand for energy to facilitate economic growth and social development is largely met with fossil fuels. However, the current energy system is not sustainable due to its significant negative effects on the well-being of humans and ecosystems (GSPM, 2002).

Sustainable development has been defined in many ways, including development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). It calls for a long-term energy policy that puts increasing emphasis on the use of renewable sources of energy, the demand as well as supply-side management, and the optimization of the efficiency of the generation, distribution and use of energy. Energy consumption is rapidly increasing in developing countries, which affects global climate change and global and regional energy management (Urban et al., 2007). Among the various kinds of energy carriers, electricity has a special role in helping to attain social and economic development. Electricity consumption in Iran, as a developing country, is intensively growing not only due to increasing social welfare, but also because of low energy prices that lead to inefficient usage. The growth rate of electricity sold to the household sector in Iran was determined to be 7.2% during the period from 1991 to 2005. Although government and legislators must apply policies such as those that actualize the price of energy by removing energy subsidies or institute demand-side management activities (e.g., peak shaving, peak shifting, etc.) to reduce energy consumption patterns (Karbassi et al., 2007), they also have to consider plans for increasing the capacity of energy production for the country. However, it is important to note that the government sector may not be able to expand electricity generation for all sectors and regions efficiently. A greater scope for the participation of private entities in electricity generation and more competition should be encouraged in this field. One of the favorable grounds for the privatization of electrical generation from the viewpoint of investors is to invest in distributed generation (DG) due to its low investment cost and financial risk. In recent years, the regulatory part of the ministry of energy (MOE) has encouraged investors and companies to invest in distributed generation units

* Corresponding author. Tel.: +98 21 77491223; fax: +98 21 77491242.
E-mail addresses: zangeneh@iust.ac.ir (A. Zangeneh), jadid@iust.ac.ir (S. Jadid).

0301-4215/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2009.08.045

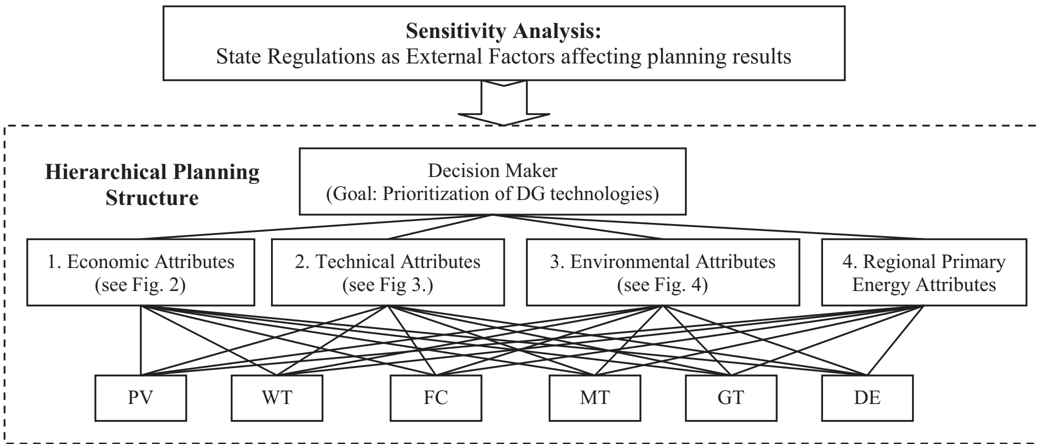

Fig. 1. Proposed hierarchical decision making structure to prioritize DG technologies.

to harness this increasing demand. It is one of the new strategies of the MOE for restructuring and moving toward privatization.

The importance of DG is now being increasingly accepted and realized by power system engineers (El-Khattam et al., 2004). Nowadays, DG is a feasible alternative for developing new capacity, especially in competitive electricity markets, from an economic, technical and environmental point of view. The IEA (2002) lists five major factors that contribute to this new interest in DG, i.e., developments in distributed generation technologies, constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity, the liberalization of the electricity market, and concerns about climate change.

DG is a broad concept that includes various technologies. Although diesel/gas reciprocating engines and gas turbines encompass most of the DG capacity being installed, there is not a unique DG technology that considers its different attributes such as economic, operational, environmental, etc. The aim of this work is to present a comparative assessment aimed at determining the interest for various distributed generation technologies based on their various characteristics and also to assess the opportunity and potential for domestic energy sources. In this paper, a hierarchical decision making framework based on multi-criteria decision making (MCDM) methods is presented to prioritize the distributed generation technologies according to criteria such as their economic, operational and environmental attributes. Each criterion is divided into several sub-criteria, and the decision making process is applied using an analytical hierarchy process (AHP) to help decision makers and private investors in the development of DGs. A sensitivity process is performed to assess the importance of state regulations on final decisions. This study is performed in seven regions of Iran with various potentials of primary energy resources.

This paper is set out as follows: Section 2 describes the outline of the proposed decision making structure. In Section 3, the evaluation attributes of the hierarchial structure are introduced. The AHP approach is briefly explained in Section 4 and finally, the simulation results for some specific regions of Iran are presented in Section 5.

2. Proposed strategic framework

Strategic planning and management of natural resources has been identified as an important factor in the economic and social development of the countries in Asia and the Pacific (GSPM, 2002). The relationships between energy, the environment and sustainable development present a difficult paradox to the governments of the Asian and Pacific region due to the huge demand of energy for facilitating economic growth and social development that is largely met with fossil fuels.

Strategic planning is a multi-criteria decision making process which considers several issues. The proposed strategy is a hierarchical decision making structure that uses AHP to prioritize preferences for DG technologies according to various criteria. The hierarchical structure is shown in three levels in Fig. 1. After introducing the goal in the first level, the attributes are divided into four main categories in the second level, namely: economic attributes, technical attributes, environmental attributes and regional primary energy resources. The first three attributes of this level consist of some sub-attributes that are concealed in Fig. 1 to avoid complexity in the diagram. These attributes and their sub-attributes are explained in detail in Section 3. The strategy is designed in such a manner so that it deals with probable challenges, both current and future, in an integrated approach. The DG technologies that are considered as alternatives in this comparative assessment are: photovoltaics (PV), wind turbines (WT), fuel cells (FC), micro turbines (MT), gas turbines (GT) and diesel reciprocal engines (DE). This analysis is performed in several regions of Iran according to their potential of conventional and renewable energy resources. The comparative assessment of all the individual technologies with all of the possible options can provide an executive summary to the decision maker how allocate their total investment budget to various technologies.

To simulate a real decision making framework, a block named external factors is included in Fig. 1 in order to assess how these factors can influence the results of final decisions. The block consists of state or government regulations. Government regulations include policy legislations such as the promotion of renewable technologies by giving subsidies or the enactment of severe power quality conditions. This block is used to perform a sensitivity analysis and to determine how the weights of attributes and sub-attributes influence the alternative hierarchies with respect to uncertainties and state regulations.

3. Evaluation attributes

As shown in Fig. 1, the hierarchical decision making structure consists of four attributes. These attributes along with their sub-attributes are explained in detail in the following section.

3.1. Economic attributes

The economic attributes (shown in Fig. 2) are divided into two main categories: cost and market. Cost attributes include both fixed and variable costs, i.e., investment and operating costs. The investment cost is a critical evaluation parameter for electricity