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Dynamic analysis of various investment incentives and regional capacity assignment in Iranian electricity market

Masoud Hasani-Marzooni [a], Seyed Hamid Hosseini [b,*]

[a] Electricity Economics and Management Group, Niroo Research Institute (NRI), Tehran, Iran
[b] Center of Excellence in Power System Management and Control, Department of Electrical Engineering, Sharif University of Technology, Tehran, P. O. Box: 11155-9363, Iran

HIGHLIGHTS

- ► System dynamics-based modeling of capacity investment in Iranian electricity market.
- ► Assessment of regulating policies effects on the generation capacity investment.
- ► Feasibility study of implementing the regional capacity assignment in Iran.

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ABSTRACT

This paper develops a system dynamics model to analyze the impacts of different kinds of capacity payment as investment incentive mechanisms in Iranian electricity market. Since it is aimed that the incurred capital and operating costs of generation technologies be recovered in Iranian electricity pool, the noncompetitive capacity payment mechanism has been introduced for this purpose in order to encourage new investments in electric power generation system. In the current mechanism, the capacity payments are designated to the generating units in the whole country electricity market. An annual base value of capacity payment is proposed based on recovering the capital cost of a benchmark generation technology. This value is altered according to the operational reserve in the day-ahead electricity market. This supporting policy is simulated and analyzed in the proposed dynamic framework in order to track the trend of new investments in the Iranian electricity market. The feasibility study of implementing the regional capacity assignment is the main focus of this paper. Different possible regulating policies such as floating rates for capacity payment and electricity price cap, the multiple capacity payments to various technologies, and the regional electricity market with territorial capacity allocation are examined in order to investigate the consequences and performances of different decisions and policies in the capacity investment of Iranian electricity market.

1. Introduction

Several electric power systems around the world have been going through the process of restructuring in order to introduce commercial incentives in the expansion of electric power supply chain including generation, transmission, and distribution. At the same time, unbundling of generation, transmission, and distribution has been arisen in addition to deregulation and privatization of power systems. The main objectives of these reforms are to increase the competition and thereby, the economic efficiency in the electric power system operation and planning. The strategies of utilities are also shifted from cost minimization to profit maximization since the decentralized decisions have been made for both the power system operation and the capacity investment. Besides, the energy and environmental policies have added complexity to this framework.

Due to these reforms, some complementary modeling approaches have been developed in order to analyze the electric power system operation and planning (Dyner and Larsen, 2001). In addition to the traditional and classic optimization methods in which the equilibrium state is generally assumed and the equilibrium operating points are achieved, simulation-based methods have been employed to analyze the operation and planning of electric power systems (Ventosa et al., 2005). The dynamic nature of the technical and economical systems arisen from combination of electric power systems and electricity markets, time delays of systems, and stochastic uncertainty of parameters can be well

* Corresponding author. Tel.: +98 912 2079440; fax: +98 21 66023261.
E-mail addresses: mhasani@nri.ac.ir (M. Hasani-Marzooni), hosseini@sharif.edu (S.H. Hosseini).

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List of Symbols

Demand_t	Daily peak demand (in MW)
AvCap_t	Total available capacities in each day (in MW)
Reserve_t	Operational reserve in each day (in %)
W_t	Weighting factor in each day (unitless)
K	Auxiliary factor (unitless)
CPF_t	Capacity payment factor in each day (unitless)
BVCP	Base value of capacity payment (89 Rials/kW)
CP_t	Daily capacity payment (in Rials)

addressed in the time simulation method. System dynamics modeling (Sterman, 2000) has been extensively used in order to analyze and examine the investment trend and the consequences of imposing different regulated policies in the electricity market considering the dynamic behaviors of market players and time delays such as permission acquiring time and construction time.

The system dynamics concept has been utilized firstly in UK in order to analyze the dynamic aspects of the UK former electricity market (Bunn and Larsen, 1992; Bunn et al., 1993; Gary and Larsen, 2000). Ford also used system dynamics model to study the dynamics of new power plants construction and their boom and bust cycling nature in the west US market as well as the causes leading to the critical situation in the California electricity market (Ford, 1999, 2001). The method was also used by some researchers in Scandinavian countries in order to analyze the Nord-pool electricity market (Vogstad et al., 2002; Botterud et al., 2002; Vogstad, 2004). The privatization and deregulation processes of electricity markets considering the dynamic natures in Colombia (Dyner and Bunn, 1997), Germany (Jäger et al., 2009), Switzerland (Ochoa, 2007), Korea (Park et al., 2007), Pakistan (Qudrat-Ullah and Karakul, 2007), and Turkey (Kilanc and Or, 2008) have been studied using system dynamics method.

A general system dynamics model focusing on the formulation of the mathematical framework has been presented in (Olsina et al., 2006). The capacity payment has been also added in the mathematical framework (Assili et al., 2008). An extensive simulation-based model considering some complementary capacity mechanisms such as capacity payment, capacity market, hybrid capacity mechanism and comparison between them has been proposed in (Hasani-Marzooni and Hosseini, 2011a). The stochastic nature of renewable energy recourses such as wind power technology has been also considered in the simulation-based model (Hasani-Marzooni and Hosseini, 2011b). The system dynamics modeling have been employed to assess the regulating policy of incentive mechanisms for renewable energy resources such as the green certificates market (Ford et al., 2007; Hasani-Marzooni and Hosseini, 2012a) and also to analyze the adoption of different strategies of market players in this framework (Hasani-Marzooni and Hosseini, 2012b) as well as the short-term market power assessment in a long-term dynamic modeling of capacity investment (Hasani-Marzooni and Hosseini, 2012c).

In this paper, a simulation-based model using the system dynamics methodology will be proposed for the Iranian electricity market. In the previous works (Ford et al., 2007; Hasani-Marzooni and Hosseini, 2011a, 2011b, 2012a), the electricity market implementation and capacity assignment was considered globally for the whole power system. In this study, the previous works are extended in order to consider the alternative of regional capacity assignment in the regional electricity market implementation. In such framework, the effects of electricity supply and demand in each region and also, the effects of electricity power exchange among the regions, on the regional electricity market prices and the regional generation capacity expansion are studied. Also, in this paper, the effects of the transmission expansion planning on the capacity development of the tie-lines between the regions, in the long-term assessment, are considered in the case of regional generation capacity assignment. The regulatory policies and the market player behaviors in accordance with the Iranian electricity market framework have been included in the presented model for both the whole country electricity market and the regional electricity market simulation cases. Some scenarios concerning the possible regulatory changes (e.g., the electricity price cap and the capacity payment) are examined in order to analyze the market performance related to the capacity investment and also to provide insights into the possible consequences of different decisions made either by the market players or by the regulatory commission. Since the penetration factor of renewable energies in Iranian electricity market is not high, the related effects may be trivial. But in order to keep the generality of the model in considering the parameters affecting the electricity market price, the stochastic nature of renewable energy was included in the proposed model of Iranian electricity market.

The rest of the paper is organized as follows. In Section 2, a short description of Iranian electric power system and electricity market is presented. The regional partitioning of Iranian electric power grid in order to implement the regional capacity assignment is referred in Section 3. Section 4 introduces the system dynamics model. Section 5 describes the proposed methodology. In Section 6, simulations of Iranian electricity market with different regulating scenarios using the proposed model will be carried out and the results will be analyzed. Finally, conclusions are outlined in Section 7.

2. Iranian electric power grid and electricity market

Iran has a highly developed integrated power grid, including generating plants, bulk power transmission network with 400 and 230 kV transmission lines with the length of more than 18,000 miles and 132 and 63 kV sub-transmission networks. The 400 kV transmission lines in Iranian bulk power transmission network are depicted in Fig. 1. As shown in this figure, the electric power system in the whole country is partitioned into five regions. The regional partitioning of Iranian electric power grid is the result of comprehensive studies made by SIEMENS Company (SIEMENS, 2006) in which the whole electric power grid has been divided into five regions with the related tie-lines depicted in Fig. 1. The regions were selected based on the dynamic stability analysis in the transmission system of Iran. Important tie-lines of 400 kV are shown in Fig. 1.

The regions in Fig. 1 are north region (Region 1 including six electric companies), west region (Region 2 including four electric companies), south-east region (Region 3 including three electric companies), north-east region (Region 4 including one electric company), and south region (Region 5 including two electric companies).

Several interconnections exist to transit electricity with all neighboring countries including Iraq, Turkey, Armenia, Azerbaijan, Turkmenistan, Afghanistan, and Pakistan. Iran has the largest installed capacity amongst the systems in the Middle East. The installed capacities of different generation technologies and the generation mixes in 2009 are tabulated in Table 1. The electricity peak demand was 37878 MW in 2009. An average annual growth rate of about 7% in electrical peak demand of 2010 has been