Electrical Power and Energy Systems 54 (2014) 221–225

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

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

An efficiency oriented model of electricity market in transition period

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ARTICLE INFO

Article history:
Received 28 February 2013
Received in revised form 28 June 2013
Accepted 13 July 2013

Keywords:
Electricity market
Virtual generation right
Generation efficiency
Transition period
Financial tool
Developing country

ABSTRACT

Generation efficiency is a key factor to save energy and reduce emissions. Many countries have resorted to the market liberalization for higher efficiency. The reformers usually expect the price could guide the efficiency through the competition between the generators. But the market will not get matured enough in a short time, especially in developing countries. In this efficiency oriented model, the security constraint economic dispatch (SCED) is adopted to achieve the physical efficiency, and virtual generation right (VGR) is proposed as the coordinated financial tool to adjust the performance of the generators to be aligned with the efficiency. The simulation demonstrates a typical case with modified 39-bus New England system. The result confirms the feasibility of the model.

1. Introduction

Based on the consideration of security and reliability, electric industry worked in vertically integrated environment in the past. Since the nineties, market liberalization has been the main trend around the world. It is generally accepted that the competition could improve the efficiency and absorb external investments. The western countries have led the liberalization around the world. Most of them have passed the difficult transition period and continue after the wholesale market to open the trades on transmission, distribution or demand. Meanwhile, some developing countries which started the liberalization years ago have slowed down their steps or have gotten into troubles about some problems. It is usually amazing that the European countries and the USA have achieved these tasks so quickly and well though they once have also been puzzled by some transition problems [1]. In fact, no market can simply copy the mode from other countries, or even from other regions of the same country. The differences of energy resources, network structure, utility ownerships, economic policies and some other factors will force every market to explore a unique way for its own development of electricity market. However, the exploration is much more serious in developing countries where the state-owned industries still make up the main part of their economy. There is rarely experience for them to run large markets with liberalized price and fair competition. Plenty of analyses and considerations have to be made for electricity market in developing countries, like the choices about market structure in [2,3]. The transition period in these countries may last for more than ten years.

Accompanying the market liberalization, another critical problem faced by electric industry is the energy saving and emission reduction. Though renewable energy sources have developed quickly in these years, thermal generators still take the main responsibility of generation. In 2010, the capacity of the thermal generators was about 70% of the total capacity in China, and more than 1000 million tons of coal have been consumed by them. The measurement of how efficiently the fuel is transformed into electricity is typically defined as the heat rate (Btu/kW h) which means the quantity of heat content to generate 1 kW h [4]. Multiplied by the fuel price ($/Btu) as the market basis, the efficiency is more generally evaluated for independent generators or the aggregation of them by the fuel cost per kilowatt-hour ($/kW h). There are significant differences between the efficiencies of the generators. To generate an equal amount of electricity, the fuel cost of an inefficient one could be double of the fuel cost of an efficient one. It means much more fuel will be consumed to satisfy the demand. When almost every country is trying to reduce the fuel cost and emissions in these years as required by Kyoto protocol, this is a serious environmental, political, and economic problem. Combining the goals of market liberalization and efficiency improvement, developing countries usually become stressful to undergo the long transition period.

In fact, the efficiency improvement and the liberalization should be naturally coordinated and intimately related from

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http://dx.doi.org/10.1016/j.ijepes.2013.07.022

long-term view. Some western countries have figured the prospective future about the generation efficiency under market mechanism and keep working on this [5]. However, the following reformers are usually frustrated by this in the transition period. They may choose to retreat back to the traditional centralized mode, or find the compromise between complete market mechanism and the traditional mode. In our opinion, once the generators have been separated from the grid or privatized, the fundamental market structure has been formed up and the vertical regulation has been broken. No matter which way is selected for the next step, there is little chance to escape from price and return back to the past. What the reformers should do is finding effective models to buffer the negative impact. In this paper, the transition model is proposed based on the situation in China. Moreover, it is also hoped the model could inspire other countries with similar difficulties.

The rest of the paper is organized as follows: Section 2 introduces the coordinated financial tool as a new conception in the model. Section III describes the proposed model with 3 subsections. Section 4 includes the market simulation and the data analysis. Section 5 is devoted to the conclusions.

2. Coordinated financial tool

A transition model of electricity market in [6] has tried to locate transition problems in developing countries and presented systematic analyses on the economic policy and historic development of electric industry in Thailand. When it referred to the liberalization in China, it did not pay much attention to the efficiency improvement problem. As the origination of our proposed model, special analysis of the market in China is given first as follows.

China has prepared its liberalization since the nineties. In 2003, as the first step, the generation was separated from the transmission. The state-owned grid companies were authorized to operate the system and bought electricity from independent power producers (IPPs). When the competition was introduced between the generators to build up a wholesale market, the reformers did not realize that the seriousness of some problems until the trials of electricity market failed in the Northeast Grid and the East Grid respectively. Severe conflicts exist between two kinds of generators, the old ones with small capacity and the new ones with large capacity. Years ago, the local government could approve the building of thermal generators with small capacity, 25 MW or less before 1993 and then 50 MW or less, to increase the total capacity [7]. Under the policy, many generators known as the first kind were built up. It was a rough manner to expand the total capacity of the system. The requirements on the technologies and the efficiency were rarely concerned. The integral system also supported the development of the generation strategically and financially when the electricity was not sufficient during the "boom time" of economy. With kinds of advantages, the fixed cost remained at quite low level. The total cost was also low even affected by higher fuel cost. In recent years, newly built generators known as the second kind were usually efficient and large-capacity ones with updated technologies, while the fixed cost also increased significantly. Especially after the separation of generation, the generators in the market as the independent participants received less support from the grid and other entities. The total cost was raised up even though the fuel cost was partly reduced. Considering the total cost of both kinds of generators, there has been the distorted market performance in the transition period that efficient ones were less competitive than inefficient ones which still kept active and had a considerable share of the market. Thus, the efficiency of the electric industry was hard to be improved. At present, the liberalization has been located in dilemma. The government is trying to get back to the traditional mode which is imagined to provide a centralized insurance of the efficiency at least. But it will not turn back actually. As indicated above, once the generation is separated, the generators would work for their own interest to a large extent. The government used political orders to shut down small thermal generators with a total capacity of 7683 MW from 2006 to 2010, but this way was slow and crude. Some of them may come again with new faces. EIA has expected the efficiency of coal generator fleet in China could exceed the one in the US by 2030 [4]. However, this expectation will be meaningless if there is still no effective way to get rid of inefficient generators.

In General, electricity market could be considered as the combination of the physical and financial systems. Traditionally the operators act on the physical system directly according to physical rules. To reflect the electricity's feature of commodity, the financial system is built on the physical one to cover the cost and create profit. It is also the procedure to transmit the operation point from the physical system to the financial system. Both of them are proposed to reach the coordination which means that the financial one could guide the physical one for higher efficiency; conversely, the physical one provides a larger space for the financial one for full competition under the security constraints [8].

Before the two systems could be coordinated, we need the market tools, financial based or physical based, to deal with the possible conflicts. The physical tool is more direct to take physical measures on the system, such as point-to-point transmission right applied in PJM electricity market [9], the generation right (GR) applied in China [10]. These physical tools are usually limited by the constraints from power flow, voltage, angle, etc. The operators have to be cautious to check the dynamic or static stability before implementing them. On the other hands, the financial tools are efficient in electricity market. Along with the spirit of the market liberalization, they achieve their goals by controlling the participants' rewards with different rules. There is a wide range of these kinds of tools, like the popular vesting contract [11], financial transmission right (FTR) [12], future contract [13,14], the tradable emission right [15] and financial bilateral contract [16]. Taking FTR as an example, the generators' loss caused by physical congestion could be partly compensated by it, so that the generators will be affected less by the transmission constraints and will be more active in the market. This is the typical application of financial tool to hedge the market risks.

Furthermore, it is expected that the financial tool is able to improve the physical efficiency in the transition period. Recalling the traditional mode to deal with the efficiency, the operators calculate and optimize the total fuel cost and determine the outputs of the generators. As the whole system is vertically integrated, almost all the generators are fairly rewarded according to the number of workers and will accept the dispatch with little argument about the price. During the transition period, the price does not become fair and strong enough, thus the higher profits of inefficient ones have to be changed with the help of the financial tool which is designed to be coordinated with the physical efficiency and generate a reverse effect from efficiency to price.

The proposition of this coordinated financial tool is inspired by the physical market tool GR. It could be traded between the generators. The ultimate owners of GR would be dispatched for output in the next period. Actually, the GR is rarely traded because of its physical based feature and unstable reward. In this paper, the coordinated financial tool named virtual generation right (VGR) is the virtual form of GR. That means the VGR does not determine the actual output of the generators, but it will affect the market rewards of the generators. VGR capacity is used to compare with the actual output. The similarity between them will determine part of the generator's reward called "encouragement" in this paper. What the operators need to do is appending the tool to the economic dispatch and changing the settlement.