Electricity Market Long-term Equilibrium Modeling Based on System Dynamics under Uncertain Conditions

Daoxin Liu[1, a]

[1] School of Economics and Management, North China Electric Power University, Beijing, China;

[a]hdlr123456@163.com

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Abstract. Recent years, with changes in energy security, climate crisis, environmental protection and other social environment, investment and construction of the electricity market must be improved on the basis of the original design on the market to adapt to the new trend of social development. Based on a series of assumptions, this paper uses system dynamics model to analyze electricity market, and then make a case study which contains hard coal (HC), combined cycle gas turbine (CCGT) and gas turbines (GT) three power technologies used to supply base load, middle load and peak load. Finally, get the relationship between price, cost and investment in order to promoting the efficient allocation of power resources.

1. Introduction

A Cost-effective and appropriate scale of competitive electricity market is significant to guarantee the safe and stable operation of the power system[1,2]. Under the background of a low-carbon economy, wind power, photovoltaic which representing low-carbon energy get rapid development , making electricity market subjects more diversity, the interests become more difficult to coordinate, and the system safe and stable operation are faced with more potential risks [3]. In view of this, it is urgent to explore how to use the market to allocate power resources more effectively to promote reasonable investment in generation capacity, and then enhance the stability of the electricity market.

At this stage, power market's long-term equilibrium has been widely carried out, and most of which use of the Nash equilibrium and competitive equilibrium to go on research [4-6]. But the partial equilibrium model can not reflect the long-term economic equilibrium's deviation, such as the business cycle. Based on the drawbacks of traditional equilibrium models, this paper points at the structural features of electricity market, such as feedback, delay and nonlinear, and uses dynamic model to study on the system.

2. Applicability analysis of system dynamics applied to long-term equilibrium of electricity market

System dynamics is a discipline of analysis and research on the information feedback system, also a comprehensive discipline for understanding and solving system problems. Starting from the microscopic structure of system for modeling, the system dynamics excavates problems generation mechanisms within the system with system thinking concepts, and builds basic structure of systems with the help of the computer simulation technology, and makes qualitative and quantitative analysis for the research system, and then simulates and analyzes the system dynamic behavior.

The issues involved in the long-term operation of the electricity market are interdependent and dynamic, relationship between the variables is non-linear, and exsit delay and information feedback structures, such investors' deterministic delay decision-making, which makes system dynamics an ideal tool.

3. Model Description

Assumptions of system dynamics which used in long-term electricity market dynamic equilibrium are as follows:

(1) This paper simplified considers three different thermal power generation technology system, including hard coal (HC), combined cycle gas turbine (CCGT) and gas turbines (GT). And the investment decisions of these techniques are all determined by the endogenous variables.

(2) Investment costs, as well as other important model parameters are given as an exogenous variables.

(3) Economic profit is defined as the difference between total revenue and total costs, including the opportunity cost of capital.

Electricity market long-term dynamic equilibrium system flow diagram is as Fig. 1.

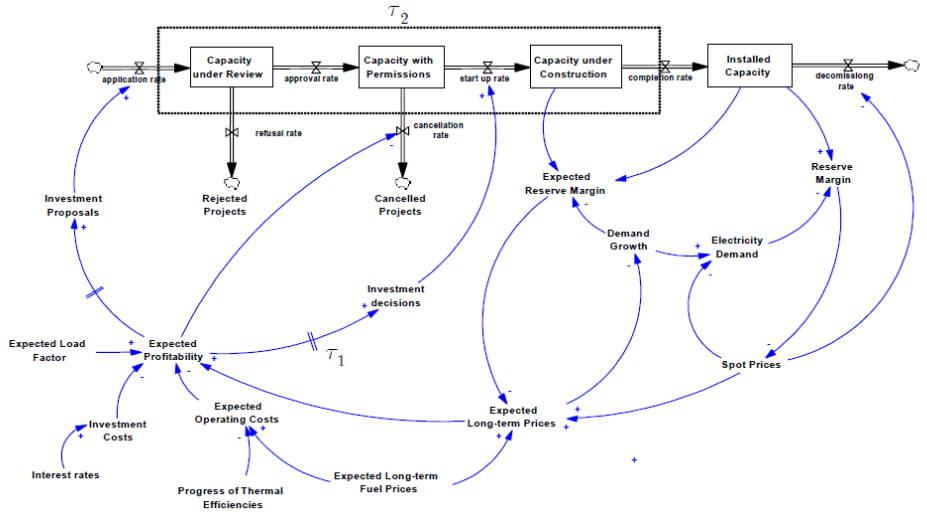

Fig.1 electricity market long-term dynamic equilibrium system flow diagram

Operational capacity is increased by construction completion rate r_c and decreased by retirement rate r_r, while $P(0)$ is the initial capacity. This is mathematically represented as:

$$P(t) = \text{INTEGRAL}(r_c - r_r)dt + P(0) \tag{1}$$

On the other hand, the flow equations, using the capacity retirements, as an example, are given as follows:

$$r_r = P(0) / t_{life} \tag{2}$$

Where t_{life} is the operational life.

All the flow variables used in the model have the similar construct as Eq. (2). Once mathematical equations are settled, a computer simulation model is constructed.

4. Simulation results analysis

System's initial simulation state is stationary. And fuel prices, investment costs and load growth rate remained stable in the simulation range, and is known for market participants. Table 1shows the simulation parameters.

Table1 Simulation parameters

Parameters	Generation technology		
	HC	CCGT	GT
The initial value of installed capacity（GW）	15.4	6.3	3.3
Lifetime (years)	40	30	20
The average size of the unit (GW)	400	250	100
The average construction period (months)	30	15	7
Discount rate (% / yr)	12.5	12.5	12.5

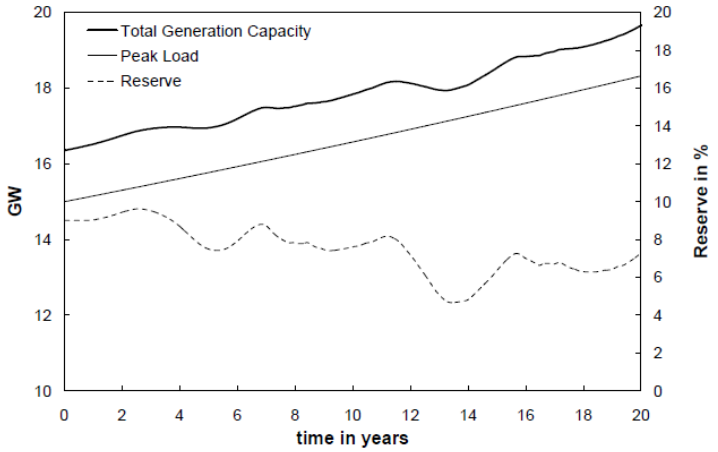

Fig.2 Trend of the maximum power demand and capacity

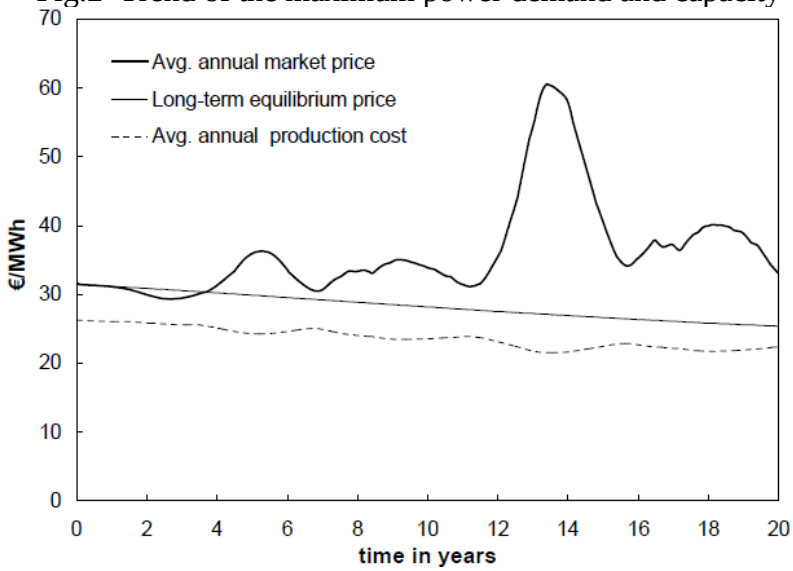

Fig.3 Trend of average electricity price and generation cost

Fig.2 and Fig.3 show the trend of maximum power demand and capacity as well as the average power price and generation cost respectively. It is observed that when prices begin to fall and electricity costs begin to rise, the capacity investment will suddenly decrease. Meanwhile, the increased investment capacity will make the price decline, and in this time the price is equal to long-term equilibrium marginal cost and profits will be zero, investors are reluctant to invest further, finally causing increased prices.

5. Conclusion

This paper is based on a series of assumptions, this paper uses system dynamics model to analyze electricity market, and then make a case study which contains hard coal (HC), combined cycle gas turbine (CCGT) and gas turbines (GT) three power technologies used to supply base load, middle load and peak load. Finally, get the relationship between price, cost and investment in order to promoting the efficient allocation of power resources. Conclusions can better explain China's power generation investment market, helping generation companies make rational decision-making of installed capacity planning, and then helping promote power resources' efficient allocation and electricity market's healthy development .

Further studies should consider a variety of factors, deeply study on the cost structure of different types of power supplies and the influence of electricity price, coal price and policy variables.

References

[1]. Wang Mianbin，Tan Zhongfu，Qi Jianxun，et al．A transfer model of two-part transmission and distribution price under electricity market in China[J]．Power System Technology，2008，32(15)：77-79．

[2]. Jia Yanbing，Yan Zheng，Yang Libing，et al．Dynamic character and sensitive analysis of power price in electricity market[J]．Power System Technology，2008，32(16)：101-105．

[3]. Tian Kuo，Zeng Ming，Yan Fan，et al．Analysis on investment decision of power generation project in electricity market considering flexible tactics[J]．Power System Technology，2010，34(11)：151-156．

[4]. FU Shut i. Summary and comment s on IEE E PES 2005 general meet ing: elect ricity mark et and EMS part. Power System Techn ology, 2006, 30(16) : 114.

[5]. Wang Wei，Shao Shan，Li Lei，et al．Efficiency theory of electricity market and its evaluation method[J]．Power System Technology，2009，33(14)：66-71．

[6]. Ding Junwei，Shen Yu，Kang Chongqing，et al．Organization and trading decision of reserve service market for power systems[J]．Automation of Electric Power Systems，2003，27(2)：29-32，59.