Stakeholder Behaviours and Grid-Source Coordinated Planning Mode under Market Circumstance

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Abstract. Under market circumstance, the power generation side is divided into several power generation companies that have autonomous right of decision-making. The competition pattern of pluralistic stakeholders brings new challenge to the power planning of power grid and source coordination. The paper systematically studies the impact of power system reform on the three sides of power source, grid and load, analyzes the decision-making behaviours of pluralistic stakeholders under market circumstance, and proposes the mode of source-grid coordinated planning.

1. Introduction
As the reform of power system deepens, the power system planning under the market circumstance turns out to be an important topic in urgent need of study. Under the market circumstance the uncertainties of the power source side, grid side and load side all increase significantly. At the load side, the extent of flexible load response influences the prediction of power demand. On the source side, the diversified investors of power generation are greatly affected by many factors like future market price volatility, national policy, energy price, load change, etc. in source planning, and due to their dissymmetrical information and variant conditions, they may encounter big uncertainties of investment[1]. At the grid side, the reform of power market offers more options of power purchase to retailers and large consumers that may easily lead to unbalanced flow distribution in the power system[2]. In addition, the lack of systematic and comprehensive planning of power sources may cause uncoordinated grid-source planning, and fails to give full play to the benefits of power sources.

Given the uncertainties of the three sides of source, grid and load, power planning should constantly play a leading role and meanwhile respect the decisive function of market allocation of resources, i.e. the guiding role of market price signals[3]. The paper systematically studies the characteristics of power planning under market circumstance and the behaviours of various stakeholders, and proposes the mode of source-grid coordinated planning. Since the power grid naturally has the monopoly nature, its planning can be generally performed by national power planning authorities. The power source investment is autonomously decided by market players as per the price signals of a competitive power market.

2. Influence of power system reform on power planning
For the purposes of higher efficiency of energy utilization and better energy conservation and environmental protection, China's power system reform will concentrate on the market-oriented development of power trading, promote and guarantee the development and consumption of clean
energy, comprehensively open the distributed energy market, enhance the management of demand side and relevant technological innovation, proactively advance interprovincial and interregional power trading, and encourage the investment by social capital in power distribution and sale services. The implementation of relevant policies and measures will significantly affect the power system planning.

2.1. Influence of power system reform on load
The No. 9 document and its supporting documents of the Central Government clearly require the strengthening of demand side management so as to reduce or transfer the power load in peak time, save considerable investment in power source and grid, consolidate the emergency support capacity of electric power, consume the power generated by renewable energy, promote the application and development of new technology of smart grid, boost energy conservation and emission reduction, etc. The flexible load involved in response at demand side and the proliferating number of distributed power sources will alter the traditional behaviour of power consumption that further influences the load curve and load prediction[4].

2.2. Influence of power system reform on power source
In the power market, the power source investors select sites and evaluate profitability by dependence on tariff. The tariff prediction is more difficult than load prediction. The growth of feed-in-tariff is not linear and it is affected by many uncertain factors such as supply and demand change, fuel price fluctuation and grid congestion[5-6], which are hard to measure and quantify, or involved in tariff prediction model, thus making the decision on power source development even more challenging.

2.3 Influence of power system reform on grid flow
In the power market, various power plants arrange production under the principle of maximum profit and keep adjusting the price competition policy. Since users can select power suppliers at their own discretion, the change of power supply and demand will be more frequent that leads to constantly varying market equilibrium point[7]. Besides, in the grid dispatching, the transaction tariff, transaction volume of priority sequence of dispatching will be decided by the tariff quotes of power plants that may exacerbate the uncertainty of system flow.

3. Behavioural characteristics of stakeholders under market circumstance

3.1 Main body of power source planning
The core issue of power source planning is the determination of the time, location, type and capacity of power plant construction. The power source planning should be in accordance with the forecast of incremental power load within the prescribed time of planning, so as to not only satisfy the increasing load brought by economy growth but also gain consideration economic earnings. The power source planning in the context of power market differs a lot from that in the traditional system. The distinctive features include:

- The target of power source planning shifts from minimizing the total cost of the entire power generation system to maximizing of the investment return of every power generation company;
- When planning power sources, each generation company needs to take into account the possible investment strategies of other competitors in the power market;
- All the power generation companies under the market circumstance will encounter more uncertainties, and the investment risks must be considered;
- The leapfrog development of the power generated by renewable energy may greatly hinder the resilience of power system. Therefore in power source planning the impact of uncertainty of renewable energy must be taken into account.
3.2 Main body of grid planning
After the reform of power market, the status and functions of grid have changed significantly. First it has the physical function by connecting the power generator, distributor/retailer and user; second it has market and economic function by offers an arena of fair competition. Specifically the power grid is to yield the following effects:

- The grid should have adequate capacity of power transmission to guarantee the effective trading of power market. Only with an equivalent transmission scale can a fully competitive power market be formed.
- It should optimize the resource allocation to guarantee the national energy security and propel the national economy development.
- The power transmission channels are opened in a fair and impartial manner to provide a platform of competitive power transaction, and ensure the standardized and effective competition of power market.
- The reasonable pricing of power transmission should be determined to offer appropriate incentives for the power sources and users.
- The planning of power transmission should be publicized together with the information of power demand, tariff prediction, etc. to guide the planning of power generation.
- One of the key objectives of grid expansion is to reduce the existing or possible grid congestion in the future. Since the marginal node price can reflect the congestion situation of the power grid to a certain extent [8-9], the congestion position and weak links of the grid can be inferred by analysing the marginal price difference between the nodes of the network.

4. Mode of source-grid coordinated planning under market circumstance
Under market circumstance, the grid planning is made by power planning authority, and the relevant information is released under the supervision of relevant national authorities for the reference of power source investors in their investment decisions. In the whole process the information is square and transparent and all source investors compete for their own shares in a fair environment so that the profits are maximized under the conditions of equilibrium. The paper proposes a source-grid coordinated planning method of “grid priority, reference planning”. The steps are as follows:

- The future evolution of power generation load is assessed. Based on the incremental load in the planned period and under the premise of prioritized grid planning, several power source investment options are formulated, one of which the decision-maker selects the reference source planning option. In general, new power generation companies should select the locations with higher LMPs for investment and construction[10].
- When the reference source and grid planning option is chosen, the tariffs by year are estimated and such information is disclosed to the source investors.
- With regard to the tariff information, various power source investors develop their own investment and power generation strategies from the perspectives of cost efficiency, technology, etc. and feedback the results of source planning.
- The summary of planning results of power source investors may somewhat differ from the reference source planning result. In this case when the conditions of load by year within the planned period are satisfied, the power source planning options and tariffs by year should be reassessed and adjusted, and the tariff information is disclosed one more so that the power source investors can readjust their strategies. Through rounds of strategy optimization, adjustment and comparison, the planning result acceptable to all stakeholders of power system can be finally achieved.

5. Conclusions
The paper studies the latest changes of power source side, grid side and load side under the power market circumstance and their influence on power planning, on the basis of which further analyzes the changes of decision objectives and behavioral characteristics of the main bodies responsible for power
source planning and grid planning. Under the market circumstance, market signals such as tariff signal and capacity signal will be more considered in source and grid planning where the target of source planning shifts from minimizing the total cost of the entire power generation system to maximizing of the investment return of every power generation company; in grid planning, the grid option can be determined by LMPs. Last but not least the paper proposes the feasible method of source-grid coordinated planning, i.e. "grid priority, reference planning" that can provide reference for exploring the pluralistic-agent coordinated planning in China.

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