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Preliminary study of generation expansion planning For provincial power grid

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Abstract
Under the new stage of the economic development pattern being transformed, the scale of renewable energy was increasingly expanded and the ecological environment constraints gradually were enhanced. Scientific and reasonable power generation expanding planning (GEP) of turned out to be the significantly important. Base on the information of structure and layout for power generation and regional characteristics of power supply and demand in a typical province, the method of GEP for provincial power grid had been discussed in the paper, together with the principles of power planning being refined. A completely optimal system for the power planning in a provincial power grid had been formed in the paper, which had laid a solid foundation for future research on GEP.
Key words: *electric power; generation expansion planning; provincial power grid; planning principles*

1 Introduction
In China, in order to adding new electric power facilities, generation expansion planning (GEP) is a very important job for saving the total investment and operating costs on the base of satisfying the reliability, fuel mix, and the demand standard or criterion. The aim for developing a perfect GEP is to resolve the problem of determining 'WHAT' type of generating units to be commissioned and 'WHEN' the generating units to be committed online[1,2]. At the same time, the work for GEP under market conditions is facing much more uncertain factors, such as the transformation of economic development mode, the enhancement of ecological environment constraints and the promotion of the electricity market reform. In order to solve the problems of GEP, many researchers have been conducted deeply researches. Many different technologies have been used to solve combinatorial optimization problems, for instance, linear programming, integer programming and dynamic programming (DP)[3,4]. The constraint conditions of the balance of electric power, the minimum of start-up capacity and reliability, etc , had been discussed on the base of considering the power plants investment, the operation costs and the engineering residuals value in GEP[5,6]. The balance of

energy supply and power demand were studied from the viewpoint of regional energy resources balance [7,8]. The impacts of renewable energy (wind and solar energy) on economy, system reliability, long-term operation and planning of the system were analyzed [9,10]. A GEP model of the peak-valley with difference constraints was established, which incorporated the peak regulation problem into the technical and economic constraints of GEP [11,12]. Lots of researches on regional power flow planning had been taken [13-15].

It is a high challenge to make decision related to provincial GEP in China, since provincial GEP problem was heavily restricted by the provincial characteristics, including regional economy, industrial structure, population structure, besides essential characteristics of GEP problem being constrained, nonlinear and discrete. To some extents, a higher requirement on the medium and long-term electric power supply should be put forward in order to obtain a high-quality, safe, green and sustainable power supply for sustainable development of a provincial economy. However, fewer researches have been carried through on provincial GEP problem. Paying more attentions on the problems of the generation arrangement and structures on the base of the electricity demand as guidance and the power market being as core might be a potential solution for provincial GEP problem.

The generation planning principles and methods were presented in the paper. In order to promote the generation structure and layout of provincial generation power, The integrated GEP system was set up as the guidance of the future GEP , which would play a very important role in enhancing the investment benefits, safety, reliability and economy of the provincial power systems.

2 Principles of GEP

2.1 Optimal principles of structure and layout for power generation

GEP could be heavily affected by the types of power supply. As shown in Fig. 1, in this typical province, the sources of power supply were constituted by coal power, gas power, nuclear power, and so on. The coal power occupied a large ratio of power supply. It had great risk on the regional environment and ecology, which should be reduced and enhancing regional energy cooperation[16].

Based on the characteristics of regional economic development, regional energy cooperation should be enhanced and west-to-east electricity transmission should be increased reasonably. Secondly, new energy and renewable energy power should be developed vigorously in order to focus on the construction of wind farms and solar energy utilization projects. Thirdly, nuclear power should be expanded as a green and pillar energy efficiently and stably based on security. Fourthly, natural gas utilization project should be carried out actively, corresponding with promoting natural gas of combining cooling, heat, power supply and distributed power generation project as well. Fifthly, coal-fired power should be developed optimally, and the clean coal-fired generating technology should be promoted actively. Finally, but not restricted to, pumped storage and natural gas peaking power plant should be constructed orderly and reasonably in order to meet the needs of the power system peaking[17].

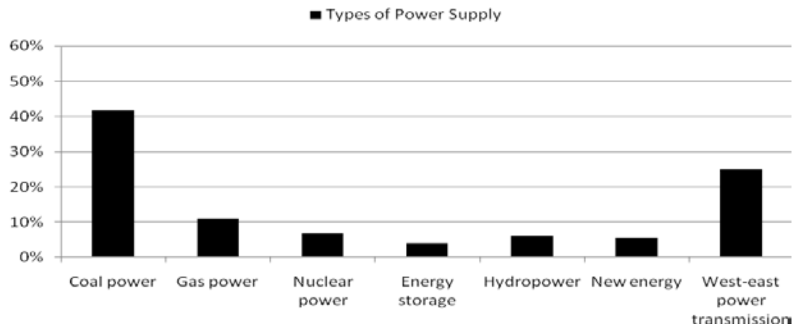

Fig. 1 Types of power supply in a typical province in 2016According to these principles, we predicted that the characteristics of provincial power supply could be sharply changed, together with structure and layout for power supply being greatly optimized in 2020. As shown in Fig. 2.

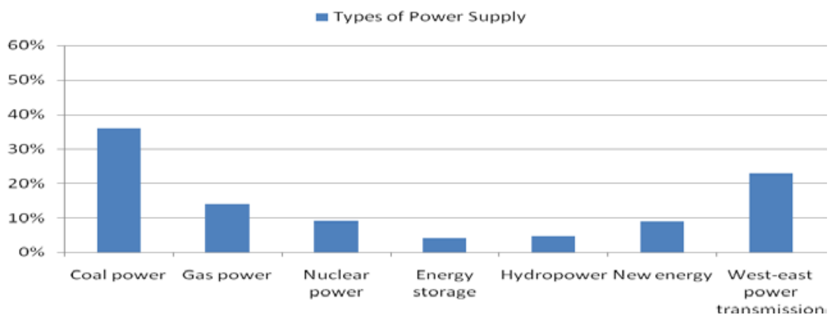

Fig. 2 Types of power supply in a typical province in 2020

It is priority to distribute supporting-power supply and distributed power supply in the power load center area which could be consumed on the spot in order to improve the self-capacity of the center. Then, power supply of large backbone should be established at the neighboring area to reduce the long-distance transmission of electricity [18].

2.2 Principles of Minimum Power Flow

According to China's electric power industry standard of "guidelines for the power system security and stability of relevant provisions", in order to improve the whole level of security and stability of power system, power grid should be divided hierarchically and regionally according to power grid voltage grade and reasonable power supply area. The partition was deemed as the receiving end system which being as the core, and the external power supply being connected to the receiving end system to form a basic balance between supply and demand of area, then being connected with the neighboring areas by tie lines.

In order to achieve the goal of minimum power-flow, electric power stratification, zoning and local electrical balance should be promoted, together with the power exchange between regions being reduced as far as possible.

For example, the province grid of the typical province could be divided into two big areas of east and west. Power layout work could be carried through based on the planning principles of minimum power flow. According to power load distributions of the two big areas and the power construction conditions, the west and east partitions of the typical province could be divided into two types areas of load center partition and power construction partition, respectively. Surplus electricity quantity of power construction partition could reached 5500 MW which could basically satisfied the power demand of 5700 MW for the load center partition in the east partitions of the typical province in 2020. Surplus electricity quantity of power construction partition could reached 7100 MW which could effectively meet the power demand of 6500 MW for the load center partition in the west partitions of the typical province in 2020. Obviously, the west and the east of the typical province could achieved self-balance of power in 2020. Power flow diagram for the self-balance of power in the typical province was shown in Fig.3.

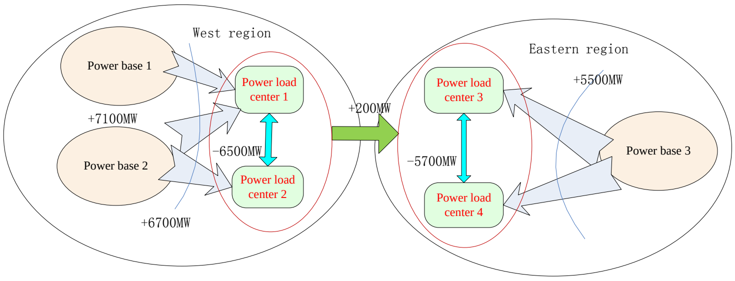

Fig.3 Power flow diagram for the typical province

2.3 Principles of construction progress for generation power

Priority should be given to the electric power projects which had been incorporated into the energy development plan of the nation and various provinces, and approved to start-up by the National Development and Reform Commission of China. On the other hand, the construction period of electric power project should be considered by the following points: (1) The period of newly-build natural gas power plant project should be taken into account for 3 years. (2) The period of new coal-fired power project should be considered for 4 to 5 years. (3) The period of new nuclear power and pumped storage projects should be think about for 5 to 7 years. (4) The period of the expanded project should be considered 1 year shorter than the new projects of the same type.

2.4 Analytical Principles of Supply, Demand and Peak regulation for electric power

Two kinds of calculation methods had been used to measured the construction scheme of electric power supply. The first method was analyzing the electric power development space, power flow and power utilization hours of the each subarea and whole province. Another method was measuring the system's peak load demand based on peaking balance analysis of power system. Finally, by combining the two kinds of methods, the total volume, structure and layout of the generation power supply could be determined in the provincial scale.

2.5 Principles of economy

It would take a full consideration of the indexes, including construction investment, energy supply and pollutant emissions indicators of the power supply project, when the electric power structure, layout and the power flow arrangements in province were carried out the optimized research. And the reasonable power construction scale and layout of the province should be discussed with the goal of minimum cost of national economy.

2.6 Optimal principles of Power planning scenario

According to different requirements of the investment subjects, various types of generation expansion plan should be prepared. Based on different scenarios of electric power supply planning, the results of power optimization were obtained to reveal influence and risk of the planning scheme for electric power supply, including the network power flow, the power dispatching operation and the investment estimation.

3 Planning method for Electrical Power supply

According to the above planning ideas and principles, optimized planning method for electrical power supply had been concluded for the generation power structure, layout and power flow for provincial power supply.

For the first step, the electric power market space of different province and its different regions should be calculated. The power supply space could be regarded as the province's remaining power supply development space, that means this space wouldn’t include the capacity of the running and constructing power projects, the nuclear power projects planned to build, the new energy power generation (including wind power, hydropower and solar energy) as well as the new West-to-East power transmissions.

For the second step, the effects of the energy price, energy demand and other uncertainties on the GEP should be taken into consideration, the largest installed capacity of coal and gas power in the whole province could be provided through the measuring the province's energy resources supply capacity and environmental capacity emissions. Then combining the ability and flow of sub-district transmission channel in the province as well as the technical indexes of coal power and gas power, the economy comparison would put forward to determine the suitable development capacity which could meet the power supply space requirements of the province between the two types of generation power.

For the third step, the peak load balance analysis of the whole province and its different region should be carried out on the basis of satisfying the demand and supply of electric power, if there was a peak shaving, a full life-cycle comparison of the national economic cost between the peak shaving gas unit and the new pumped storage of the same size would be made to determine the new installed capacity of peaking power tentatively.

For the fourth step, the related power planning optimization software would be used to optimize the scale, structure and layout of above-mentioned generation types based on the second and third step, which could tentatively determine the new increase of coal, pumped storage and gas power in the province, together with the goal of the total cost of national economy (including system investment, operation and maintenance, and environmental protection costs, etc.), the generation power optimized scenario would be obtained. Usually, the total costs includes multiple aspects: one part of them is the investment costs of power plant and power transmission projects, another part was the power plant operating costs which include fuel, maintenance and labor costs, etc. Considering the wide range of GEP, except for the above two charges, the planning targets also included the costs of environmental maintenance and many other factors, which depended on its constraints. The specific formula was shown in Eq. (1) [19].

$$P = \sum_{t=0}^{\tau} (Z_t + U_t + ...)(1+r)^{-(t-t_0)} \qquad (1)$$

Where P was the present value of total cost, Z_t was the investment in year of t, U_t was the operating costs in year of t, r was the discount rate, t_0 is the discount base year, τ was the last year which should be considered.

For the fifth Step: by making use of the power system simulation software, the monthly power system production simulation of the power optimized scenario for each planning level year was applied to check the balance of the electric power supply and demand in the province and every region, the balance of peaking shaving and the scale of transmission power flow. When the wind power or solar power curtailment condition appears, or the scale of the electricity transmission network exceeds the transmission capacity, the fourth and fifth steps should be carried out again until each index meets the requirements.

Finally, the power production simulation of the actual power progress would be carried out, and the power optimized scenario would be analyzed contrastively from the aspects which includes the provincial power flow, power grid dispatching operation, investment estimates for the large and small mode. Then the impacts and risks to power grid construction and operation would be revealed if only sorting the generation power by the early work schedule. General flowchart of generation expanding Planning was showed in the Fig. 1.

4 GEP system

According to the principles, methods and analysis of GEP, the planning system consists of three layers.

4.1 Overall demand layer

The first layer of the system was at the bottom of all layers and their task was to determine the generation power construction scale of provincial region and internal regions. The construction scale of generation power should meet the power supply and peak demand, consider the constraints from energy supply, environmental emission, land supply and other aspects, and based on the policy of developing new energy, nuclear power and the west-to-east transmission fully. In addition, the construction scale of generation power was the basis and general requirement of the subsequent correlation analysis.

4.2 Optimization layer of generation Power

The optimization layer of generation power was the central part of the whole system, which was guided by GEP principles. Optimized researches on the generation power structure of the planning were carried through in this layer under the requirement of scale control from overall demand layer. The optimized planning scenario could not only meet the demands of electric power supply and peaking, but also guarantee the safety and stable operation of the power system. As a result, the planning scenario could be effectively used to reduce the total costs of power supply, guide the development of power networks scientifically, harmoniously and orderly, and then was used to promote the effects of resources optimization for the whole society.

4.3 Evaluation layer of generation power planning

The main task of this layer was to evaluate and calculate the planning after the power optimization layer, including the calculations of power system production simulation calculation, the power supply and peak balance calculation, the significant power capacity calculation of transmission channel, and costs calculation of generation/ distribution, together with the calculation of environmental emissions indicators. Each calculation was used to evaluate the scientificity and feasibility of the GEP. If the result could not meet the relevant requirements, it could be fed back to the optimization layer of generation power for further research. Furthermore, this layer was at the top of the system.

The GEP system for provincial power grid was consisted of the above three indispensable layers. The establishment and optimization of the system was of great significance to enhance the unified planning of power, improve the planning function, strengthen the constraints and guide the planning. Researches on the system also had the functions for enhancing the authority of planning, optimizing the development of power plan and promoting the sustainable development of the whole society.

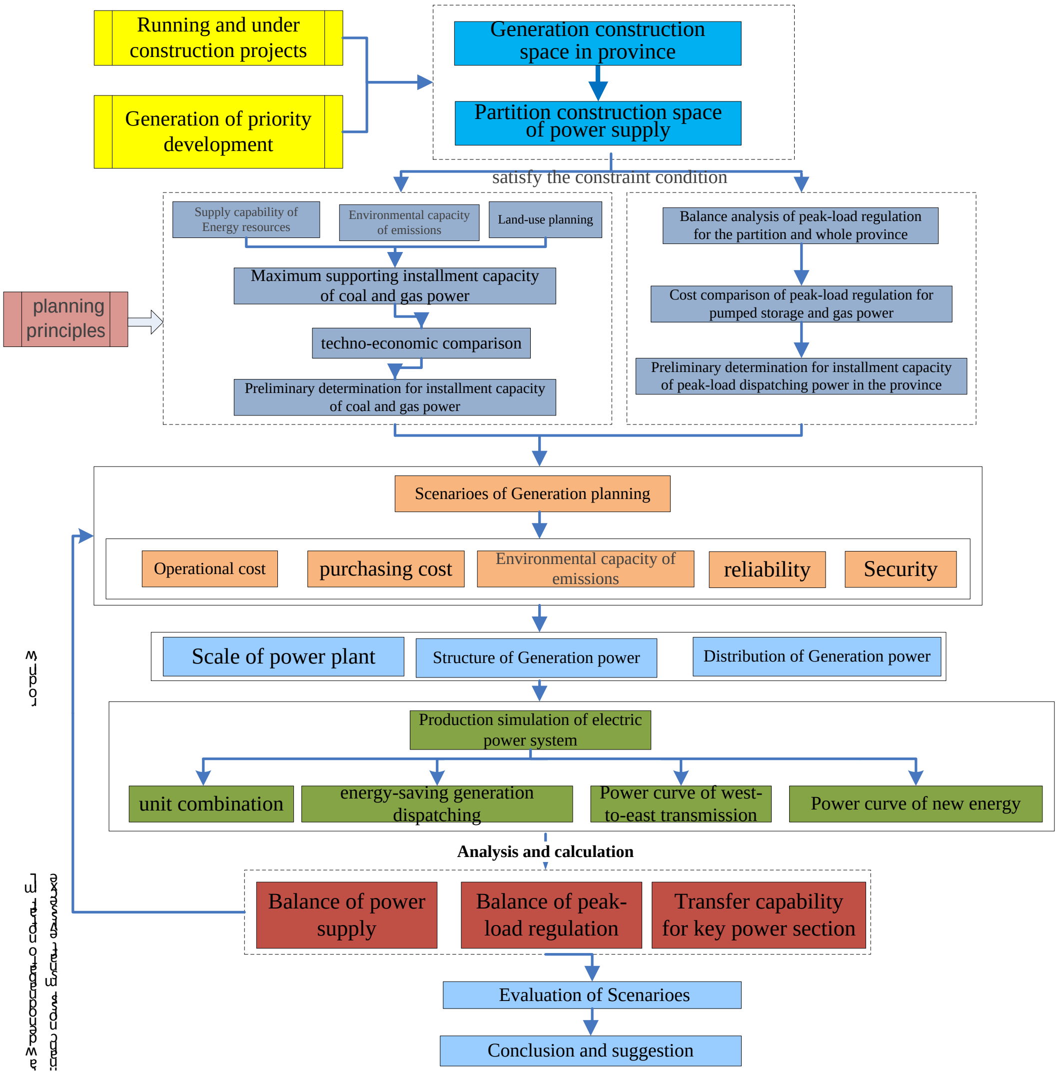

Fig. 4 Flowchart of the provincial GEP

5 Conclusions

Scientific and reasonable GEP was of great importance to the present economic development of china. The principles and the 6-step method should be followed in the course for establishing the provincial GEP. The optimal provincial generation expansion system with three levels was essential for enhancing the unified planning of electric power, improving the planning function, strengthening the constraints and guiding of the planning. The optimal provincial power planning system was of great significance for the sustainable development of the whole province.

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