Impacts on Operation and Benefit After New Energy Generation Access to Power Grid

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Abstract. As the development of social economy, the demand for energy is increasing rapidly. At the same time, energy shortage and environmental pollution problem is more and more serious, which is a big challenge for grid construction. New energy represented by wind and solar generation is flexible, safe and clean, and it provides a new idea to relieve the shortage of energy, solve the environmental pollution problem, and improve the reliability and flexibility of the grid. This paper analyzes the influences on power system operation and economic benefit by new energy generation access. The investing and construction direction for power grid enterprise in new energy industry is proposed.

1. Introduction
With the development of social economy, the traditional centralized single-mode of power supply is awkward and fragile, which can not meet the demand of power users on high quality and reliability of power supply. On the other hand, the environmental pollution problem is more seriously because of the massive consumption of fossil fuels. New energy generation represented by solar and wind generation is flexible, safe and clean, which can save the problems of energy shortage and environmental pollution.

To ensure the power supply, the combination of new energy generation and power grid is the direction in the future instead of the single-mode power supply [1]. After the access of new energy to the grid, the traditional power grid structure will be changed into a grid with power sauces and users throughout the grid. As a result, the operation of power system and the income for power grid enterprises will be influenced. This paper elaborates the effects of new energy access on the balance of electric power and energy, utilization rate of the equipment and power grid construction. And the effects of new energy access on power grid enterprises’ income is analyzed by some new energy project. It can provide ideas in realizing the coordinate development between new energy generation and power grid.

2. Effects on Power Grid Operation

2.1. Balance Of Electric Power And Energy
The access of new energy generation changes the grid from radial single-terminal power source system into a system with multi-power sources [2]. The two-way load flow can break the balance of electric power and energy between load and source, therefore the grid operation will be influenced. Take some local intensive photovoltaic project for example. This project installs photovoltaic unit on the roof of local residents. The solar generation will be used locally and the surplus will be exported to the power grid. According to the data of solar radiation and the load supply, the typical daily solar generation curve and load curve are gotten as figure 1. Area 1 represents user’s power purchase; area 2 represents the power exported to the grid; area 3 represents the solar generation used locally.

![Typical daily solar generation curve and load curve](image1)

Figure 1. Typical daily solar generation curve and load curve.

The solar generation is used locally in the prior way, and if the solar generation produces more electricity than the consumption, the surplus will be exported to the power grid. The load curve will be changed as figure 2.

![Load curve with solar generation access](image2)

Figure 2. Load curve with solar generation access

According to the load curve, the access of new energy can take on the task of reducing peak. And the surplus exported to the grid can be used by power supply area nearby. Therefore the power shortage of the power supply area during peak energy periods can be relieved.

### 2.2. Equipment Utilization Rate

As the project shows, the access of new energy can be used to reduce the load peak, especially for residential customers. The load characteristic is typical and the load focuses on the noontime when is the generation peak of solar. So the solar generation can meet the demand for power supply.
The peak load before and after the access of new energy is shown as Table I. According to the table, before the access of new energy, the load peak appears at 11:15 and the peak is 40kW. After the access, the load peak at noon disappears, and there is surplus to be exported to the grid. The load of this area is very typical. The load in rural area is mainly for farming. The villagers have strong conception of resource-saving. After the access of the new energy, there is always surplus electricity to be exported to the grid during the daytime. This means that the distribution transform will be standing in no-load condition during the day. Although the capacity of the transformer in rural area is lower according to the differentiation principle, the transformer will be long-term idle because of the access of new energy. Therefore, the equipment utilization rate will be declined sharply which will increase the cost of power grid enterprises indirectly.

Table 1. THE Peak Load before and after the Access of New Energy

| Time   | Load (kW) | Time   | Load (kW) | The hours of usage during peak-load (h) |
|--------|-----------|--------|-----------|----------------------------------------|
| Before | 11:15     | 40.08  | 18:15     | 44.68                                  |
|        | 12.45     |        |           |                                        |
| After  | 11:15     | 0      | 18:45     | 39.35                                  |
|        | 7.14      |        |           |                                        |

2.3. Power grid Reconstruction

The access of new energy is a challenge for the present grid’s ability of power generation absorption and grid structure strength. To the area with weak network configuration, the large scale new energy connected into the power system can not be heard. When the power flow is reversed, the voltage at the terminal of power line will be increased [3], even be out of the voltage limit. Reversed power flow will also increase the line loss rate and lower the operation efficiency. But new energy access takes the responsibility of energy saving and emission reduction, therefore the power grid reconstruction caused by new energy access is of great importance for the society.

To rural area with weak grid structure, the bottlenecks and single radiation line should be solved firstly to adapt to the large-scale intensive new energy access [4]. To urban area with strong grid structure, the development of solar, wind and other new energy resources should be taken into consideration. For different area’s new energy access, the weakness of the grid structure should be analyzed. Reconstructing the power grid specifically to improve the new energy access ability is necessary.

Considering the access of new energy, the no-voltage auto-recloser is necessary for overhead line. As a result, voltage transformer should be added for overhead line with auto recloser. If there is new energy access to the grid, the interconnection switch of local transformer substation should has no-voltage auto-recloser. For the access of new energy by high voltage, the grid-connected line or power line be provided with longitudinal difference protection to ensure the safe operation of power grid. The grid-connected line, grid-connected breaker and metering device for new energy access are invested and constructed by power grid enterprise. Therefore the investment of grid reconstruction will be increased greatly. And that is the requirement to ensure the safety and reliability of new energy access to the grid.

3. Effects on Economic Benefit

The access of new energy is invaluable for social society. Although power supply enterprise takes important social responsibility that it should pay the cost of grid reconstruction, the effect of new energy access on power supply enterprise’s economic income is still a concerned question. The stakeholders in new energy access are mainly include investor and user [5]. The investor of new energy generation can be power grid enterprise or independent investor. Power grid enterprise has the characteristics of large investment amounts and good credit. As the investor, it will be convenient to coordinate the conflict of interest between new energy and power grid. The starting point for grid
enterprise is not its own maximum interests, but the maximum of social benefits. Because of the large amount of reconstruction cost, the economic benefit for grid enterprise in new energy project may not be significant. Independent investor can be new energy market participants, and they want to pursue profits and expand market share. Users act as power consumer in new energy project, and they can get some compensation by providing their roof or open space for new energy generation device.
Take some rural area intensive photovoltaic project for example. The profit and cost of different operation pattern is calculated based on operating data during operation period, including purchase price of electricity, sale price of electricity, maintenance cost, etc. And the economic feasibility is analyzed.
According to the characteristics of intensive photovoltaic project, marginal utility theory should be used to calculate the economic benefit [6]. Marginal utility theory analyzes the effect when one unit is increased or reduced with other conditions unchanged. According to marginal utility theory, the incremental revenue and incremental cost should be calculated by “Availability of Comparative Law”. Therefore, the incremental revenue refers to the variation of electricity purchase/sale and solar subsidies. And incremental cost refers to the cost of project construction.
It should be noted that the reconstruction of rural grid is an important task for pushing forward the urbanization, and its social benefit can not be measured by the commodity attribute and economic value of electricity. Therefore, the economic benefit can not be the only basis for evaluating if the project decision is right or not. The effects of the project on grid safety, reliability, power supply quality and social benefit should be taken into consideration. At the same time, the financial support for the project by government should be calculated.

### 3.1. Incremental Revenue Calculation
The incremental revenue by this photovoltaic project mainly includes the income of electricity sale (when power supply enterprise is the investor, it will be the saved power purchase cost) and the policy subsidy by state (local) government. In the calculation, benchmark price of thermal power is 0.3815 yuan/kWh, resident electricity price is 0.49 yuan/kWh, and policy subsidy by state government is 0.42 yuan/kWh. The subsidy by local government is reversely calculated as a variable.

### 3.2. Incremental Cost Calculation
Incremental cost refers to the cost of the photovoltaic project, including materials expense, repair expense, labor expense, depreciation expense, etc. Besides, the cost of raising funds (mainly includes loan interest) should taken into consideration.
In the calculation, the operation and maintenance cost is relatively low, and the annual cost can be 0.5% of the initial investment. The annual cost by rural grid reconstruction and new energy access project is 3% of the initial investment. Depreciation cost is 6.72% of the initial investment. The proportion of principal amount of loan is 30%, and the loan interest rate is 4.91%. The loan will be repaid in 5 years.

### 3.3. Statement Preparation
The photovoltaic project’s financial condition during operation period can be analyzed by profit and loss statement and cash flow statement.
In the calculation, corporate income tax is paid as 25% of the tax rate. The calculation period is 15 years considering the life of photovoltaic device.

### 3.4. Economic Evaluation (Power Grid Enterprise as the Investor)
The economic evaluation is based on four conditions:
1) Considering the investment of new energy system construction and power grid reconstruction caused by new energy access to grid;
2) Only considering the investment of new energy system construction;
3) Considering the investment of new energy system construction and power grid reconstruction, and the finance discount policy;
4) Considering the investment of new energy system construction and power grid reconstruction, the finance discount policy and the policy subsidy by local government; The results of economic evaluation are shown as Table II.

**Table 2. Economic Evaluation results (Power Grid Enterprise as the Investor)**

| Calculation condition                        | NPV   | IRR  |
|---------------------------------------------|-------|------|
| Considering grid reconstruction            | ¥-40.95 | 0.4% |
| Without grid reconstruction                 | ¥6.41  | 5.81%|
| Considering grid reconstruction and finance discount | ¥-25.95 | 1.79%|
| Considering grid reconstruction and increasing policy subsidy | ¥0.20  | 4.93%|

To the investment, when the IRR (Internal Rate of Return) is greater than loan rate (which is 4.91% in this project), NPV (Net Present Value) is greater than 0, the project is feasible. According to Table II, if the grid reconstruction cost is considered, only the increased local policy subsidy reaches more than 0.183 yuan/kWh, can IRR reach 4.93% (which is greater than loan rate 4.91%), and NPV reach ¥0.20 (which is greater than 0). And under that condition, this project will be feasible.

3.5. **Economic evaluation (independent investor)**

The results of economic evaluation are shown as Table III.

**Table 3. Economic Evaluation Results (Independent Investor)**

| Calculation Object        | NPV    | IRR  |
|---------------------------|--------|------|
| Independent investor      | ¥8.94  | 6.21%|
| Power supply enterprise   | ¥-58.56| -    |

According to Table III, the IRR of independent investor is greater than loan rate and the NPV if greater than 0. Therefore, it is feasible for independent investor to invest this rural area intensive photovoltaic project. On this condition, power supply enterprise takes the investment of grid reconstruction without economic profit. Therefore, the power supply enterprise’s economic benefit will suffer some loss.

**4. Conclusion**

New energy can meet the demand of global environmental protection and sustainable development. It is also a way to solve the problem of energy crisis and energy safety. The access of new energy to the power grid breaks the balance of electric power and energy, and the grid device’s utilization rate is decreased. The grid also needs to be reconstructed to adapt to large-scale new energy access, which will bring large amount of cost. And the economic benefit of the power grid enterprise will be influenced. Therefore, new energy access to the grid is a great challenge for power grid enterprise. Power grid enterprise should take social responsibility, at the same time, the way to get economic benefit still need to be found. Power grid enterprise should not only serve for new energy industry, but also expand the new energy market actively. And the financial support from the government is of great importance. Power grid enterprise should turn the challenge into a rare opportunity, and promote the coordinated development of new energy generation and power grid.
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6. References
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