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Decision - making of Direct Customers Based on Available Transfer Capability

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Abstract. Large customer direct-power-purchasing is a hot spot in the electricity market reform. In this paper, the author established an Available Transfer Capability (ATC) model which takes uncertain factors into account, applied the model into large customer direct-power-purchasing transactions and improved the reliability of power supply during direct-power-purchasing by introducing insurance theory. The author also considered the customers loss suffered from power interruption when building ATC model, established large customer decision model, took purchasing quantity of power from different power plants and reserved capacity insurance as variables, targeted minimum power interruption loss as optimization goal and best solution by means of particle swarm algorithm to produce optimal power purchasing decision of large consumers. Simulation was made through IEEE57 system finally and proved that such method is effective.

1. INTRODUCTION

With the development of Chinese electricity market reform, the large customer and power companies signed a bilateral contract has become the important way to solve electricity market supply and demand problem [1-3]. Large customer direct-power-purchasing (DPP) improve the price formation mechanism and enhance the level of optimal allocation of power resources to stimulate the potential of the electricity market. Therefore, large customer direct-power-purchasing is an important way of the electricity market reform.

The electricity demand for the large users of is relatively stable and has high reliability requirements of the power supply, If transmission is interrupted, large customer will suffer great economic losses, so how to control the grid failure caused the loss of power become the hot topic in the direct-power-purchasing. Currently, for the large consumers direct-power-purchasing mainly research using game theory analysis of generation companies and large consumers offer trading strategies [4-5] and Conditional Value at Risk Based on the theory of large user optimal purchase decision. [6-8]

Above all, how to reduce the large consumers direct-power-purchasing power loss from the power generation companies and grid failure. In this paper, we establish available transfer capability model and take uncertain factors into account. The model is applied to large customer DPP transactions to improve reliability of power supply during DPP by introducing insurance theory. Customer loss suffered from power interruption is also considered in ATC model. Large customer decision model is established, taking purchasing power quantity from different power plants and reserved capacity insurance as variables and minimized power interruption loss as optimization goal. The model is solved with particle swarm algorithm to produce optimal power purchasing decision for large consumers. Simulation is performed with IEEE-57 system and validity of the method is verified.

2. CONSIDER THE UNCERTAINTY FACTOR ATC MODELS

Available transfer capability is the basis of the existing transmission protocol, but also consider the ability of the system safe and reliable transportation after various margin and energy constraints, it is not only a technical indicator of the power system, but also reflects the power transmission capacity market signals . Apply ATC to the large consumers direct-power-purchasing can be accurately determined period of time power suppliers and large customers through the transmission grid capacity. It has a positive guiding in large consumers direct-power-purchasing.

ATC calculation can be attributed to a nonlinear programming problem:

$$\min(-\lambda)$$
$$\text{s.t.}\begin{cases} \boldsymbol{f}(x,\lambda)=\lambda y_d+\boldsymbol{h}(x)=0 \\ G_{\min}\le G(x)\le G_{\max} \end{cases} \tag{1}$$

where: $\boldsymbol{f}(x,\lambda)=[f_1(x),...,f_m(x)]^{\mathrm{T}}$ is the extended flow equation; $x\in \mathrm{R}^n$ is the state control variable; $\boldsymbol{h}(x)=[h_1(x),...,h_m(x)]^{\mathrm{T}}$ conventional power flow equation; $\boldsymbol{G}(x)=[G_1(x),...,G_r(x)]^{\mathrm{T}}$ for the security constraints; $G_{\min}$, $G_{\max}$ for the security constraints limit; $y_d\in \mathrm{R}^m$ for the load change direction; $\lambda\in \mathbf{R}$ to reflect ATC parameter; when λ = 0 refers to the ground state case.

We use an iterative linear AC power flow and linear sensitivity method, the thermal stability constraints, the voltage amplitude of the voltage stability constraints and constraint conditions N-1 fault filtered to give the most serious fault set. Finally, the Primal-Dual Interior Point Method (PDIPM) is used to obtain the exact solutions of ATC according to the results of most serious fault set:

$$\{A_{\mathrm{ATC1}},A_{\mathrm{ATC2}},...,A_{\mathrm{ATC}i},...,A_{\mathrm{ATC}m}\} \tag{2}$$

Formerly calculate ATC without considering the probability of catastrophic failure centralized component failure, usually with a minimum of ATC values directly released. This will allow the grid resources can't be fully utilized, it also did not take into account the generation companies and large users of energy production and consumption. This article will consider trends and weather component failure probability model[9] introduce uncertainty factors, the probability of failure to give serious failure centralized ATC corresponding:

$$\{G_{\mathrm{op1}},G_{\mathrm{op2}},...,G_{\mathrm{op}i},...,G_{\mathrm{op}m}\} \tag{3}$$

3. RISK FOR LARGE CUSTOMERS

Large consumers DPP means between large users and power companies through negotiated and signed power purchase contract transactions, generally divided into direct purchase and the Over the net Direct Power Purchase. Among them, a single point of power, grid structure is weak, the direct purchase can easily lead to a series of safety problems, reliability of power supply can't be guaranteed. It is common practice to use over the net direct purchase of electricity. However, if the power plant or grid breaks down, the large users would cause great damage to property.

3.1. Large customers expect losses

Suppose there is a system failure occur independence (that only one fault occurs), corresponding to the current expected losses under purchase power mode:

$$E_{\mathrm{loss}.i}=\begin{cases} \sum G_{\mathrm{op}i}(P_k-A_{\mathrm{ATC}i}), & A_{\mathrm{ATC}i}\le P_k\le A_{\mathrm{ATCmax}} \\ 0, & P_k<A_{\mathrm{ATC}i} \end{cases} \tag{4}$$

Where: $G_{\mathrm{op}i}$ is the probability of component i failure; $A_{\mathrm{ATC}i}$ is an element i available transfer capability;

Due to limitations of the power grid transmission capacity in order to maintain normal and stable operation of the power grid, large consumers direct purchase of electricity does not exceed a serious fault set largest ATC.

When power suppliers failed (provided that only one power supplier failure) to provide the electrical power expect loss:

$$E_{\mathrm{loss}.k} = \sum G_{\mathrm{op}k}(s - P_k) \tag{5}$$

Where: $G_{\mathrm{op}k}$ is the power suppliers k outage probability; s is large users Electricity demand.

It is expect to power loss over time for large customer

$$E_{\mathrm{loss}} = E_{\mathrm{loss}.k} + E_{\mathrm{loss}.i} \tag{6}$$

4. ESTABLISH INSURANCE SYSTEM LARGE USER OPTIMAL PURCHASE DECISION

Insurance as a mature risk transfer measures, the contract user can reduce their own losses by insurance contracts, Since the electricity grid fault uncertainty makes the reliability of the power supply grid decline, so the members of the electricity market is facing a huge loss of revenue risk, which brings new business opportunities for insurance companies [10]. References [11] describes the user can not only reduce power loss through the purchase of insurance, but also promote the power grid companies to strengthen grid structure for its own benefit. Reference [12] describes the possible applications of the present stage of the four kinds of reliability insurance model. Reference [13] proposed a spare capacity of goods, insurance theory and spare capacity in combination to improve the efficiency of ancillary services.

4.1 Insurance reserve capacity basis

Spare capacity ancillary services is an important commodity in power system, it is mainly used to provide power when failure and improve reliability. Current spare capacity market are generally centralized processing, as determined by the system operator, to buy power suppliers required reserve capacity, Then the corresponding fee in accordance with the power-sharing to the user, making it difficult to ensure the efficiency of ancillary services [14-15]. Therefore, the spare capacity and the insurance theory combines not only able to motivate spare capacity vendors improve power supply reliability while strengthen the power grid construction, but also to make the purchase of insurance by reducing the expected risk of blackouts.

5. LARGE USER OPTIMAL PURCHASE DECISION

In this paper, we use IEEE 57-bus system show in figure 1. Large consumers direct purchase contracts shown in Tab. 1

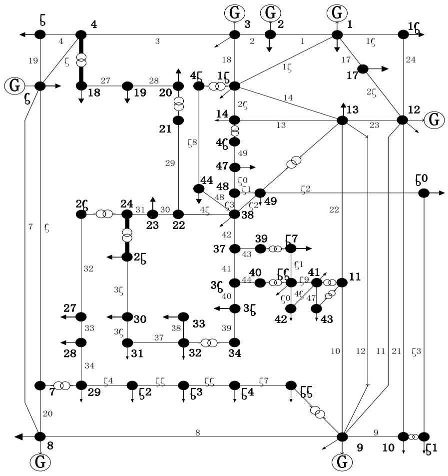

Figure 1. Electrical connection diagram of IEEE 57-bus system

Table 1. Data of purchase contract

Generation Companies	Purchase power /MW	Purchase price /(yuan/MW)
A	P_A	50
B	P_B	46

Efficiency function $B(s)$ can show users purchase power income, so we constructed the $B(s)$ as relatively simple quadratic function benefits:

$$B_{\text{net}}(s) = B(s) - C(s) \tag{7}$$

The $C(s)$ represents the cost of electricity users to buy s, and $C(s) = \sum P_k Q_k$ where: Q_k is the contract price.

When the grid fails, the power producer can't press the amount of time specified by the contract delivery to large electricity user, then the user through the large grid company before signing the insurance contract, to give priority to large spare capacity by the grid user to reduce the loss of large users. At this time net benefit for the use

$$B_{\text{net}.i} = B(s - E_{\text{loss}} + R) - C(s - E_{\text{loss}}) - C_{\text{E}}(R) \tag{8}$$

Where: $C_{\text{E}}(R)$ is the cost of purchasing spare capacity pay.

In order to minimize the outage cost optimization target large users purchase decisions:

$$\min(C_{\text{loss}}) = B_{\text{net}}(s) - B_{\text{net}.i}(s, E_{\text{loss}}, R) \tag{9}$$

According to equation (1) (2) (3) is calculated outage probability of catastrophic failure concentration values and the associated ATC Table 2.

Table 2. ATC and its failure probability in most severe faults set

A plant to large users		B plant to large users	
ATC/MW	Probability of failure	ATC/MW	Probability of failure
70.49	0.020 1	62.70	0.020 1
74.56	0.020 1	70.25	0.020 1

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79.83	0.031 1	74.95	0.034 0
80.42	0.032 2	75.62	0.021 2
83.74	0.042 6	79.03	0.080 1
85.42	0.375 5	80.71	0.082 0
86.04	0.041 2	83.19	0.612 1
86.97	0.080 3	83.29	0.050 1
87.73	0.214 1	84.53	0.021 1
90.49	0.601 8	85.22	0.038 1
90.85	0.313 2	85.68	0.321 5
91.49	0.031 0	86.08	0.042 0

Spare capacity insurance provides users with a way to transfer risk. So that large customers can choose to purchase electric power supply reliability to minimize losses. By the formula (8) (9) can be obtained when a fault occurs large customers buy electricity losses:

$$\begin{aligned} C_{\text{loss}} &= B_{\text{net}}(s) - B_{\text{net}.i}(s, E_{\text{loss}}, R) = \\ &B(s) - C(s) - (B(s - E_{\text{loss}} + R) - \\ &C(s - E_{\text{loss}}) - C_{\text{E}}(R)) \end{aligned} \tag{10}$$

$$\begin{aligned} E_{\text{loss}} &= \sum G_{\text{op}i}(P_{\text{A}} - A_{\text{ATC}_i}) + \sum G_{\text{op}i}(P_{\text{B}} - \\ &A_{\text{ATC}_i}) + \sum G_{\text{op}k}(s - P_k) \end{aligned} \tag{11}$$

Finally, calculate the minimum loss of large customers purchase decision by particle swarm algorithm shown in Table 3.

Table 3. Optimal direct-power-purchasing decision of large consumer

A purchase power MW	B purchase power /MW	Spare capacity purchase amount /MW	Large customers outage cost / yuan
86.81	83.19	11.07	404.97

As we can see in fig 2, insurance loss of large customers outage significantly reduced when compared with not purchased, indicating that participation in the insurance mechanism can effectively transfer risk, reduce the potential for power loss and improve the effectiveness of large customers buy electricity.

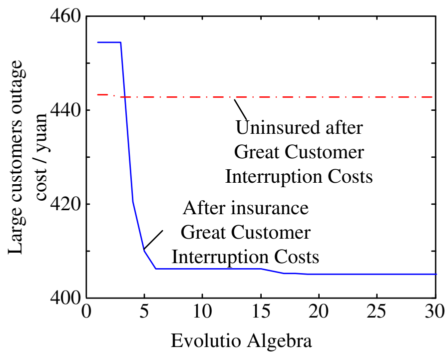

Figure 2. Comparison of the large consumers' outage loss when purchase insurance or not

6. CONCLUSION

In view of the existing large-user direct power purchase study, which does not take into account the carrying capacity of the power grid and component failure risk, this paper proposes the transmission capacity that can take into account the uncertainties to guide the direct purchase of large users and use of insurance theory as a risk transfer measure, discusses the large user of direct purchase of electricity optimal power purchase decision problem. Get the following conclusion:

- Reasonable purchase decision can reduce the risk of large outage.
- Spare capacity involved in the purchase of insurance significantly reduces the power loss of large customers.
- How to better motivate grid company functions as an insurer, so that the interests of users and grid company better integration is the focus of future research.

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