Comprehensive benefit evaluation of direct power-purchase for large consumers

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Abstract. Based on "several opinions of the CPC Central Committee and the State Council on further deepening the reform of electric power system" in 2015, this paper analyses the influence of direct power-purchase for large consumers on operation benefit of power grid. In three aspects, such as economic benefit, cleaning benefit and social benefit, the index system is proposed. In which, the profit of saving coal energy consumption, reducing carbon emissions and reducing pollutant emissions is quantitative calculated. Then the subjective and objective weights and index scores are figured out through the analytic hierarchy process, entropy weight method and interval number method. Finally, the comprehensive benefit is evaluated combined with the actual study, and some suggestions are made.

1. Introduction

Developing direct power-purchase for large consumers is a measure of the country to promote the power system reform on the opening power-sold side. The purpose is to optimize the allocation of electric power resources, to break the pattern of exclusive purchase of electric power by power grid enterprises, to promote competitive bidding, to accelerate the establishment of competitive and open electricity market, to explore and establish a reasonable transmission and distribution price mechanism. Large consumers which refer to the power users that purchase electricity and use electricity reached a certain standard are the main part of direct power-purchase. With the continuous expansion of direct power-purchase for large-consumers scope and access conditions, it will bring about the change on the participation of power generation enterprise, the economic operation of power grid and the consumers using electricity.

In order to study the impact on the whole society after developing direct power-purchase for large consumers, especially the clean energy to participate in direct power-purchase for large consumers, this paper carries out the construction of evaluation index and the evaluation study on the comprehensive benefits of developing direct power-purchase for large consumers from three aspects. The three aspects include economic benefit, cleaning benefit and social benefit.

2. Analysis on the comprehensive benefit of the direct power-purchase for consumers transaction model

2.1. Economic benefit

2.1.1. The change of power grid enterprise income. This part mainly analyses the benefit of power grid enterprise in terms of electrovalence after direct power-purchase for large consumers. The evaluation index is the change of transmission and distribution income before and after the transmission and distribution pricing. The reform of transmission and distribution price and the investment plan of transmission and distribution network play an important role in ensuring the investment return of power grid.

- Change rate of electricity price after carrying out direct purchase of power grid enterprises

$$\Delta P_g = \frac{P_{gL} - P_{go}}{P_{go}} \tag{1}$$

- As in equation (1), PgL is the transmission and distribution price for power grid enterprises; Pgo is difference between the selling price and the benchmark price. The change rate of electricity prices after carrying out the direct purchase can directly reflect direct revenue unit price changes after participating in the direct power-purchase.
- Change rate of transaction income after carrying out direct purchase of power grid enterprises

$$\Delta S_g = \frac{S_{gL} - S_{go}}{S_{go}} \tag{2}$$

- As in equation (2), SgL is the income of power grid enterprises for participating in the direct power-purchase, which mainly includes transmission and distribution of electricity revenue. Sgo is the revenue of power grid enterprises before participating in the direct purchase of electricity. ΔSg is the change rate of transaction income after carrying out direct purchase of power grid enterprises, which can directly measure the change of the power grid enterprise income.

2.1.2. The change of power generation enterprise income.

- Change rate of electricity price after carrying out direct purchase of power generation enterprises

$$\Delta P_p = \frac{P_{pL} - P_{po}}{P_{po}} \tag{3}$$

- As in equation (3), PpL is the transaction price of direct power-purchase for consumers; Ppo is the benchmark price of power generation enterprises before direct purchase. Electricity price change rate after carrying out direct purchase of power generation enterprises can reflect the profit conversion grade of direct power-purchase for power generation enterprises.
- Change rate of new energy utilization hours

$$\Delta \mathrm{H} = \frac{H_z - H_b}{H_b} \tag{4}$$

- As in equation (4), Hz is the utilization hours after participating in direct power-purchase for large consumers; Hb is the ensured utilization hours before participating in direct power-purchase for large consumers. Change rate of new energy utilization hours can accurately reflect the market changes that direct power-purchase of large consumers provided for clean energy generation.
- Transaction income change rate of power generation enterprises participating in the direct purchase of electricity

$$\Delta S_p = \frac{S_{pL} - S_{po}}{S_{po}} \tag{5}$$

As in equation (5), S_{pL} is the income brought by power generation enterprises participating in the direct power-purchase for large consumers after carrying out direct power-purchase transaction; S_{po} is the income brought by power generation enterprises selling the same sales. ΔS_p is the transaction income change rate of power generation enterprises participating in the direct power-purchase that can accurately reflect the income situation of power generation enterprises after participating in the direct power-purchase.

2.1.3. User income. Based on electricity price change of users participating in the direct power-purchase for large consumers, compared with the D-value between direct transaction price and selling price, we can calculate how much the transaction volume brought the income change for users after

participating in direct power-purchase, so the transaction income change rate of users participating in the direct power-purchase is:

$$\Delta S_u = \frac{S_{uL} - S_{uo}}{S_{uo}} \quad (6)$$

As in equation (6), S_{uL} is the income brought by users participating in the direct power-purchase for large consumers after carrying out direct power-purchase transaction, which is the product of direct power-purchase price and transaction volume; S_{uo} is the cost paid by the user to purchase the same amount of electricity; ΔS_u is the transaction income change rate of users participating in the direct power-purchase, which can directly reflect the change of payment after the power consumers have participated in direct power-purchase.

2.2. Cleaning benefit

2.2.1. Saving coal energy consumption profit. Clean energy does not need to consume limited resources such as coal. Therefore, when it produces the same scale of electricity, the coal saving benefit ($B_{\text{saving coal}}$) achieved by Clean energy generation alternative thermal power generation is:

$$B_{\text{saving coal}} = Q_{\text{cleaning}} \times C_{\text{coal consumption}} \times P_{\text{coal}} \quad (7)$$

As in equation (7), Q_{cleaning}-Annual production of clean energy, unit is kWh; $C_{\text{coal consumption}}$-Comprehensive coal consumption of thermal power, unit is $\text{kg/kW} \cdot \text{h}$; P_{coal}-Coal prices during the statistical period, unit is yuan/t.

2.2.2. Reducing carbon emissions profit. According to the carbon emissions produced in all aspects of power generation and the check computation of main part which can produce carbon, we can propose to sign a carbon tax to measure the benefits of reducing carbon emissions by numerical B_{carbon} tax. Refer to foreign carbon tax levels (Australia's carbon tax is $23 / ton, France's carbon tax is $17 / ton), in this paper, it will be calculated according to 10 yuan (2012) to 40 yuan (after 2020) / ton.

$$B_{carbon\ tax} = \frac{E_i - E_{i-1}}{E_{i-1}} \times T_c \quad (8)$$

As in equation (8), E_i represents the carbon emissions of year i, unit is t; E_{i-1} is the carbon emission of year i-1, unit is t; T_c is the unit-price of carbon tax collection, unit is yuan/t;

2.2.3. Reducing pollutant discharge profit. The expression of reducing pollutant discharge profit is:

$$B_{\text{Pollution reduction}} = Q_{\text{clean}} \times C_{\text{coal consumption}} \times \sum \left(G_{\text{emission } i} \times V_i \right) \quad (10)$$

As in equation (9), $G_{\text{emission-i}}$ is pollutant discharge level of type i; V_i is the environmental value standard of type i pollutants, unit is yuan/t.

2.3. Social benefit

2.3.1. Improving the service ability of Power Grid Corp. As the role of power grid operation and maintenance, it makes power grid enterprises become the market carrier to participate in direct power-purchase for large consumers, the function is to ensure the safe and stable operation of the transmission channel and the implementation of the transaction contract, collect transmission fees in accordance with the provisions and relevant government funds, which is no longer the market subject of buying electricity and selling electricity.

After carrying out direct power-purchase for large consumers in a deep-going way, power grid corps will further ensure the safety and stability of transmission and distribution, and power grid corps will greatly enhance social influence.

2.3.2. Promoting the development of clean energy. Provinces and cities have introduced a number of policy statements. The policy statements refer that bringing clean energy power generation into the access list of power generation enterprises. Clean energy can be allowed to access power grid first and

be ensured full acquisition within the scope of planning. Above-mentioned policy can improve the utilization of clean energy and promote the development of clean energy power generation industry.

2.3.3. Adjusting energy structure. Making full use of renewable energy can reduce our dependence on oil, natural gas and other imported energy. While improving the quality of domestic energy shortage, it can greatly improve the energy structure dominated by coal.

3. Comprehensive benefit evaluation of direct power-purchase for large consumers

3.1. Comprehensive benefit evaluation index system of direct power-purchase for large consumers

The comprehensive benefit evaluation index system of direct power-purchase for large consumers is shown as table 1.

Table 1. Comprehensive benefit evaluation index system of direct power-purchase for large consumers

Target layer	Criteria Layer	Primary factor layer	secondary factor layer	illustration
Comprehe-nsive benefit evaluation index system	economic benefits (A)	Grid enterprise income (A_1)	Electricity price change rate (A_{11})	quantitative
			Transaction income change rate (A_{12})	quantitative
		Power generation enterprise income (A_2)	Electricity price change rate (A_{21})	quantitative
			Change rate of new energy utilization hours(A_{22})	quantitative
			Transaction income change rate (A_{23})	quantitative
		User income (A_3)	Transaction income change rate (A_3)	quantitative
	Cleaning benefit (B)	Income of saving coal energy consumption (B_1)		quantitative
		Income of reducing carbon emissions (B_2)		quantitative
		Income of reducing pollutant emission (B_3)		quantitative
	Social benefit(C)	Improving the service ability of Power Grid Corp (C_1)		qualitative
		Promoting the development of clean energy power generation enterprises (C_2)		qualitative
		Adjusting energy structure (C_3)		qualitative

3.2. Standard for comprehensive benefit of direct power-purchase for large consumers

This paper takes a certain area as an example and draws up the comprehensive benefit evaluation standard of direct power-purchase for large consumers. The detailed data is shown as table 2:

Table 2. Standard for comprehensive benefit of direct power-purchase for large consumers

Element layer	100	80	60	40	20
Electricity price change rate	+30%	+15%	0	-15%	-30%
Transaction income change rate	+50%	+25%	0	-25%	-50%
Electricity price change rate	+20%	+10%	0	-10%	-20%
Change rate of new energy utilization hours	+40%	+20%	0	-20%	-40%
Transaction income change rate	+40%	+2%	0	-20%	-40%
Transaction income change rate	-30%	-15%	0	+15%	+30%
Improving the service ability of Power Grid Corp	Excellent	very good	commonly	Poor	Very poor
Promoting the development of clean energy power generation enterprises	Excellent	very good	commonly	Poor	Very poor
Adjusting energy structure	Excellent	very good	commonly	Poor	Very poor

3.3. Comprehensive benefit evaluation grade of direct power-purchase for large consumers

According to the total score of the rating system and the level of the comprehensive benefit, it can form mapping, which can reflect the effect of direct power-purchase for large consumers and help

power generation companies, Power Grid Corp, users and other direct purchase of electricity trading entities to adjust the transaction model to improve transaction model development. For example, the total score of comprehensive benefit of direct power-purchase for large consumers is 90, then it can be learned from the chart that the region's comprehensive benefit rating is AAA, its benefits are excellent, the specific interpretation of the grade is shown as table 3:

Table 3. Comprehensive benefit evaluation grade of direct power-purchase for large consumers

Total score	Comprehensive benefit	Meaning
[100,90)	AAA	Excellent benefit, the design of electricity market transaction mode is in line with regional characteristics extremely.
[90,80)	AA	Very good benefit, the design of electricity market transaction mode is more coincident with regional characteristics.
[80,70)	A	Good benefit, the design of electricity market transaction mode is in line with regional characteristics extremely
[70,60)	BBB	Less good benefit, the design of electricity market transaction mode basically conform to regional characteristics extremely.
[60,50)	BB	Moderate benefit, Electricity market transaction model design is reasonable.
[50,40)	B	Poor benefit, power market transaction model design needs to be improved.
[40,30)	CCC	Very poor benefit, there are many problems in the design of power market transaction model.
[30,20)	CC	Particularly poor benefit, electricity trading model does not meet the characteristics of the region, which need to be re-enacted

4. Case study on comprehensive benefit evaluation of direct power-purchase for large consumers

4.1. The determination of index weight

According to the criterion layer: economic benefit, cleaning benefit and social benefit, the index weight judgment matrix is constructed. Through the analytic hierarchy process, we can get the weight of indexes constructed in table 4:

Table 4. Weights of comprehensive benefit evaluation index system for direct power-purchase of large consumers

Target layer	Criterion layer	weight	Primary factor layer	weight	Secondary factor layer	weight
Comprehensive benefit evaluation index system of direct power-purchase for large consumers	*A*	0.49	A_1	0.33	A_{11}	0.5
					A_{12}	0.5
			A_2	0.33	A_{21}	0.25
					A_{22}	0.5
					A_{23}	0.25
			A_3	0.33	A_3	1
	B	0.31			B_1	0.44
					B_2	0.39
					B_3	0.17
	C	0.19			C_1	0.12
					C_2	0.56
					C_3	0.32

After calculation, CR<0.01, so it passes the consistency check.

4.2. Comprehensive benefit score value of direct power-purchase for large consumers

The comprehensive benefit evaluation index of direct power-purchase for large consumers is divided into two categories: qualitative and quantitative indexes. The qualitative index is obtained by expert method, and in order to reflect the objective situation of the electric power enterprises, the index is expressed by interval numbers. Quantitative indicators can be obtained by calculating the enterprise

data and can also be expressed by interval numbers. At the same time, according to the formula, the original data is processed without any rigidity, the results are shown as table 5.

Table 5. Comprehensive benefit score value of direct power-purchase for large consumers

	Index value			Nondimensionalization		
Index	Region 1	Region 2	Region 3	Region 1	Region 2	Region 3
A_{11}	14.48%	20.57%	-9.88%	79.31	87.43	46.83
A_{12}	38.65%	45.37%	19.68%	85.77	96.30	75.74
A_{21}	9.92%	10.88%	6.39%	79.84	81.76	72.78
…		…			…	
C_2	85	80	70	85	80	70
C_3	85	80	75	85	80	75

4.3. Comprehensive benefit evaluation of direct power-purchase for large consumers in three regions

Table 6. Comprehensive benefit evaluation of direct power-purchase for large consumers in three regions

Index	Region 1	Region 2	Region 3
A_{11}	6.41	7.07	3.79
A_{12}	6.93	7.79	6.12
A_{21}	3.23	3.31	2.94
A_{22}	6.92	7.79	6.38
A_{23}	3.95	3.50	3.78
A_3	16.06	15.23	13.44
B_1	13.64	10.23	6.82
B_2	12.09	9.07	6.05
B_3	5.27	3.95	2.64
C_1	1.94	1.89	1.89
C_2	9.04	8.51	7.45
C_3	5.17	4.86	4.56
Score	90.66	83.20	65.85

From the above analysis, the maximum value of the comprehensive benefit in the region 1 is the highest, followed by the region 2, the lowest score is the region 3. The comprehensive benefit evaluation of region 1 is the AAA level, which indicates that the economic benefits, clean benefits and social benefits are excellent. The direct power-purchase of large consumers brought great benefits to power generation companies, power grid and users. The electricity market trading model fit the regional characteristics well, which can be carried out in the original direction. The comprehensive benefit evaluation of region 2 is the AA level, which indicates that the economic benefits, cleaning benefits and social benefits brought by the direct power-purchase of large consumers are good. And the benefits of power generation companies, Power Grid Corp, user transactions in the market are also good. Therefore, the electricity market trading model is suitable. However, the comprehensive benefit evaluation of region 3 is the BBB level, it needs to be improved.

5. Conclusion

This paper studies the comprehensive benefit evaluation of direct power-purchase for large consumers. The economic benefit change of power grid enterprises, generation enterprises and users after direct power-purchasing for large consumers is analysed. Moreover, cleaning benefit and social benefit

brought by cleaner energy alternative are evaluated. At the same time, the comprehensive benefit evaluation index system, the scoring standard and the evaluation grade of the direct power-purchase for large consumers are established. Finally, a case study is given, which shows the application of the evaluation system. This paper has a great significance to the comprehensive benefit evaluation technology for large consumers, it contributes to the participation of all parties to ensure their own economic benefits. The benefit evaluation method of direct power-purchase for large consumers proposed by this paper is reasonable and comprehensive, it helps the main bodies of electricity market to protect their own economic benefits.tr

Acknowledgement
This work is supported by National Power Grid Corp science and technology project (Contract No. SGSDDK00KJJS1600062)

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