Construction and Application of Energy Saving and Emission Reduction Index System for Grid Enterprise

Chengjie Wang[1, a]

[1] State Grid Energy Research Institution, Beijing 102209, P.R.China

[a]wangchengjie@sgeri.sgcc.com.cn

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Abstract. Focused on problems of the grid enterprise in the energy saving and emission reduction works at present, this paper systemically and comprehensively design the energy saving and emission reduction system for the grid enterprises by combining the current energy saving and emission reduction situations and future development trend, constructs the assessment model for influence on grid enterprise development and social benefits of the energy saving and emission reduction works, and also conducts the demonstration application research. The research results will help the grid enterprise to assess the energy saving and emission reduction works, recognize direction and focus of the energy saving and emission reduction management works, analyze the impact of energy saving and emission reduction on development of the grid enterprise, and develop rational energy saving and emission reduction management strategies.

Introduction

In recent years, energy saving and emission reduction has gradually become the breakthrough and starting point for national restructuring and growth pattern transformation, and is significant for promotion of sustainable economic and social development. The grid enterprise has the responsibilities of optimizing the allocation of power resources and providing power energy required by economic development, and will accomplish great deeds in terms of energy saving and emission reduction. To solve the problems that which energy saving and emission reduction works can be conducted by the grid enterprise, what benefits will be brought to itself and the power industry and how to determine the emphasis work direction for energy saving and emission reduction, it requires the aid of energy saving and emission reduction index system. From the domestic research results, the main research results in the index system construction focuses on energy production, energy utilization, exhaust emissions and other aspects, but such index systems have the common points of high comprehensiveness and poor operability, they are only suitable for the evaluation of the energy saving and emission reduction level of some country and some region, while many industries including the power industry are lack of energy saving and emission reduction index system [1-5]; in construction of quantitative evaluation model, there is yet not a perfect evaluation model system for the grid enterprise.

This paper constructed an energy saving and emission reduction index system including "12 key energy saving and emission reduction works and 29 characteristic indexes" based on "service grid, service industry and service society", aiming at the company's current situation of energy saving and emission reduction. The index system covers various indexes closely linked with production and operation of the grid enterprise, and provides the grid enterprise with a theoretical basis for analysis and evaluation of the energy saving and emission reduction works. This paper selected the characteristic indexes respectively from both social benefit and business performance to construct the index system, and established a quantitative analysis model to achieve the quantitative analysis of energy saving and emission reduction works of the grid enterprise.

Construction of Energy Saving and Emission Reduction Index System

Construction Idea. In the topic, firstly arrange the energy saving and emission reduction work and its sub-works conducted by the grid enterprise as the starting point of constructing the energy saving and emission reduction index system from “service grid, service industry and service society”; secondly, arrange, analyze and mine the characteristic indexes capable of visually representing the performance of each energy saving and emission reduction work; finally, organically integrate each characteristic index to obtain the energy saving and emission reduction index system for the grid enterprise.

Index Selection and System Construction. With breakdown of the energy saving and emission reduction works of the grid enterprise, this paper constructed an energy saving and emission reduction index system including "12 key energy saving and emission reduction works, 29 characteristic indexes and corresponding characteristic indexes" based on "service grid, service industry and service society", as shown in Table 1.

1) Energy Saving and Emission Reduction Index Selection for the Grid Enterprise(F1)

Currently, the grid enterprise’s energy saving and emission reduction works include line loss management (F11), grid construction(F12)and intelligent power utilization(F13).

With further breakdown of the work, the grid enterprise’s energy saving and emission reduction works can be broke down into seven sub-works, wherein line loss management is divided into reactive compensation(F111), metering device transformation(F112) and elimination of high energy consumption transformer(F113); grid construction is divided into novel transformer substation construction(F121)and extra-high voltage construction(F122); the intelligent power utilization is divided into electric car(F131) and intelligent household appliances(F132). Characteristic index corresponding to each sub-work is shown in Table 1.

2) Energy Saving and Emission Reduction Index Selection for the Power Industry(F2)

The energy saving and emission reduction works for the power industry include energy saving power generation dispatching(F21), power generation right trade(F24), small thermal power shutdown(F25), cross-region and cross-provincial trade(F26), support of distributed energy development(F22) and consumption of clean energy(F23).

With further breakdown of the work, the grid enterprise’s energy saving and emission reduction works for the power industry can be broke down into fourteen sub-works, wherein energy saving power generation dispatching is divided into first dispatch water electricity(F211), flexibly dispatch pumped storage power generation(F212), first dispatch new energy source such as wind electricity(F213), etc, and first dispatch low energy consumption conventional thermal power generating unit(F214); power generation right trade, small thermal power shutdown, and cross-region and cross-provincial trade are relative simplex and have no sub-works; support of distributed energy development is divided into support natural gas distributed power generation(F221), distributed photovoltaic power generation(F222), distributed wind electricity (F223)and distributed waste heat power generation(F224); consumption of clean energy is divided into consume wind electricity(F231), consume natural gas for power generation (F232)and consume small hydropower for power generation(F233). Characteristic index corresponding to each sub-work is shown in Table 1.

3) Energy Saving and Emission Reduction Index Selection for the Society(F3)

The grid enterprise’s energy saving and emission reduction works for the society include comprehensive resource strategy plan - demand side management(F31), total energy consumption control(F32) and energy saving service system construction(F33).

With further breakdown of the work, the grid enterprise’s energy saving and emission reduction works for the society can be broke down into eight sub-works, wherein the comprehensive resource strategy plan - demand side management includes orderly power utility(F311), load management(F312), energy efficiency powerplant(F313) and energy efficiency management(F314); the total energy consumption control does not have the sub-work; the is divided energy saving service system construction includes establishment of energy saving service company(F331), establishment

of energy efficiency network group(F332) and establishment of energy efficiency evaluation institution(F333). Characteristic index corresponding to each sub-work is shown in Table1.

Construction of Social Benefit Evaluation Model for Energy Saving and Emission Reduction Works of Grid Enterprise

Construct Social Benefit Influence Evaluation Index System. The social benefit influence evaluation index system is constructed based on the energy saving and emission reduction index system, including objective layer, criterion layer, measure layer and index layer. The objective layer is to evaluate the social benefit influence of the energy saving and emission reduction works; the criterion layer is to weigh the criterion of the social benefit influence of the energy saving and emission reduction works, i.e. improving resource utilization efficiency, improve the environment, drive the development of relevant industries, and influencing the power supply reliability, as shown in Figure 1.

Put Forward Social Benefit Influence Evaluation Model. The comprehensive evaluation model for social benefit influence of energy saving and emission reduction usually includes social benefit influence index reduction model for energy saving and emission reduction, index data uniformization model, index weight calculation model and comprehensive grading.

1)Index reduction model. In the social benefit influence index system for energy saving and emission reduction, there may a certain relativity between indexes, so it is necessary to remove the indexes with higher relativity through reduction so that the remaining indexes has lower relativity and the evaluation result is more reasonable.

2)Index data uniformization model. In the social benefit influence index system for energy saving and emission reduction, some are specific value indexes, and some are absolute amount indexes; due to attribute differences, different indexes have great data range gap. Therefore, the index data shall be uniformized.

3)Index weight calculation model. Calculation of index weight is to quantitatively express the importance degree of each index in the whole social benefit influence index system for energy saving and emission reduction.

4)Comprehensive grading. Comprehensive grading is to collect each index according to the weight, and obtain the comprehensive evaluation value for assessment of social benefit influence of energy saving and emission reduction.

Demonstration Analysis. Take a power group company of China as an example, the following analysis results were obtained: for the improvement of resource utilization efficiency, the Corporation can concentrate fund and resource on line loss management, intelligent power utilization, cross-region and cross-provincial trade and energy saving service system construction, especially the line loss management; for improvement of environment, the Corporation can concentrate fund and resource on power generation right trade, consumption of clean energy and small thermal power shutdown, especially the power generation right trade; for driving development of relevant industries, the Corporation can concentrate fund and resource on demand side management and energy saving service system construction; for influence of power supply reliability, the Corporation can devote greater effort on intelligent power utilization. as shown in Table 2.

Construction of Operation Performance Evaluation Model for Energy Saving and Emission Reduction Works of Grid Enterprise

Selection of Key Energy Saving and Emission Reduction Work Influencing the Grid Enterprise Operation Performance. This paper comprehensively considered and analyzed the current ordinary and future-oriented energy saving and emission reduction works of the grid enterprise to obtain the key energy saving and emission reduction works of the grid enterprise, including line loss management, demand side management, intelligent power utilization, support of distributed energy development/consumption of clean energy and energy saving service system

construction, wherein line loss management and demand side management are current ordinary works of the enterprise and shall be assessed by the State; intelligent power utilization, support of distributed energy development/consumption of clean energy and energy saving service system construction are works that orient in future development and embody enterprise's social responsibilities, as shown in Figure 2.

Table 2.Social Benefit Influence of Energy Saving and Emission Reduction Work and Weight Value

	Energy Saving and Emission Reduction Work	**Weight**		**Energy Saving and Emission Reduction Work**	**Weight**
Improve resource utilization efficiency	Line loss management	0.783	improve environment	Power generation right trade	0.603
	Intelligent power utilization	0.156		Consumption of clean energy	0.232
	Cross-region and cross-provincial trade	0.020		Small thermal power shutdown	0.155
	Energy saving service system construction	0.013		Energy saving generation dispatching	0.010
	Comprehensive resource strategy plan - demand side management	0.012	Drive development of industries	Comprehensive resource strategy plan - demand side management	0.557
	Distributed energy development	0.009		Energy saving service system construction	0.443
	Energy saving generation dispatching	0.006	influence power supply reliability	Intelligent power utilization	0.903
	Grid construction	0.002		Consumption of clean energy	0.067
				Small thermal power shutdown	0.030

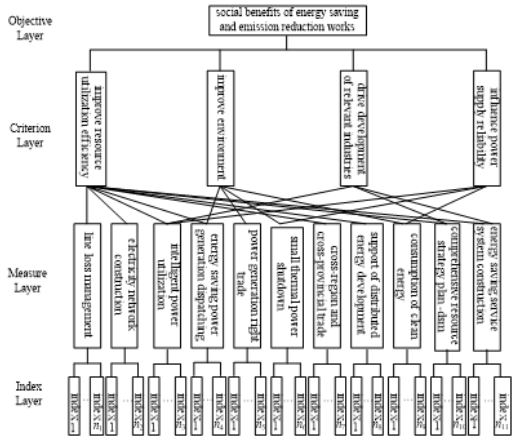

Fig. 1. Basic Structure of Social Benefit Influence Evaluation Index System

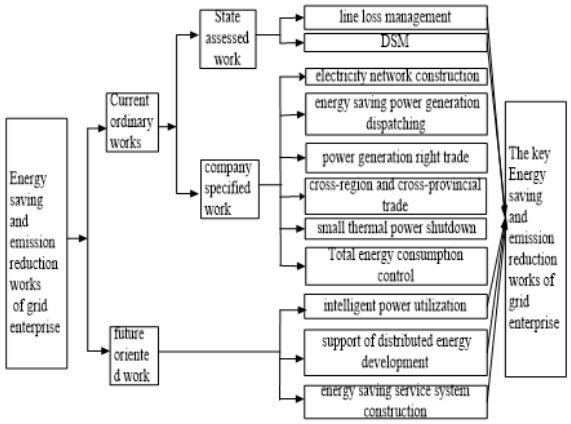

Fig. 2. Key Energy Saving and Emission Reduction Works of Grid Enterprise

Construction of Operation Performance Influence Evaluation Model. Key energy saving and emission reduction works included in the analysis process of operation performance influence of energy saving and emission reduction and analysis modes thereof are shown in Table3.

The model is constructed as follows:

1)Line Loss Management:

Assume that there is no change in power sale quantity of the grid enterprise before and after line loss management, the income change of the grid enterprise is the product of electricity saving quantity by on-grid electricity price, as shown in the formula as follows:

$$\Delta R=[\frac{Q}{(1-\alpha_0)}-\frac{Q}{(1-\alpha)}]\times P_0 \quad (1)$$

Where, ΔR means the income change value of the grid enterprise before and after line loss management; Q is the power sale quantity of the grid enterprise; P0 is mean electricity price; α_0 is the comprehensive line loss rate before line loss management; α means comprehensive line loss rate after line loss management.

2)Demand Side Management:

Income change resulted from demand side management work is equal to the change of the grid enterprise income, i.e. the product of reduced power sale quantity by difference between power sale price and on-grid electricity price, as shown in the formula as follows:

$$\Delta R = -Q \times (P - P_0) \times 0.3\% \quad (2)$$

Where, ΔR means income change resulted from demand side management by the grid enterprise, and minus means income decrease; Q means the total power sale quantity of the grid enterprise in last year; P and P0 respectively mean power sale price and mean power purchase price.

Table 3. Key Energy Saving and Emission Reduction Works and Analysis Modes thereof

Type	**Key Energy Saving and Emission Reduction Works**	**Consideration**	**Analysis Modes**
Current ordinary work (assessed by the State)	Line loss management	Assess the line loss rate	Quantitative evaluation model
	Demand side management	Assess 0.3% annual index	Quantitative evaluation model
Future-oriented work	Intelligent power utilization	They are still in the pilot and exploration stage, with little scale and uncertain influence degree and range on performance influence	Explorative quantitative study
	Support of distributed energy development/consumption of clean energy		
	Energy saving service system construction		

3)Intelligent Power Utilization:

This paper mainly focused on income resulted from electric car popularization. Income resulted from the electric car is relative to the future popularization quantity and annual travel distance of the electric car; the formula is as follows:

$$\Delta R = \frac{D}{(1-\alpha)} \times \varphi \times L \times (P - P_0) \quad (3)$$

Where, D means the power consumption per kilometer of the electric car; α means the comprehensive line loss rate; φ means the ownership of the electric car; L means the annual mean travel distance of the electric car; P and P0 respectively mean power sale price and mean power purchase price.

4)Support of Distributed Energy Development/Consumption of Clean Energy:

The income benefited from this measure is mainly represented in change of power sale income, i.e. sum of products of generating capacity of each distributed generator set by self electricity consumption and electricity price difference, as shown in the formula as follows:

$$\Delta S = -\sum_{i=1}^{n}\sum_{j=1}^{m}(Q_{ij} \times \lambda_{ij} \times (P\text{-}P_0)) \quad (4)$$

Where, ΔS means income change value caused by power sale quantity decrease of the grid enterprise, and minus means the decrement; Q_{ij} the jth generator capacity of the ith type distributed energy; λ_{ij} means the jth generator electricity consumption of the ith type distributed energy; P and P0 respectively mean power sale price and mean power purchase price.

5)Energy Saving Service System Construction:

The income benefited from this measure includes user-shared income and national reward fund. The formula is as follows:

The income benefited from energy saving service system construction of the grid enterprise is calculated as follows:

$$\Delta R = \sum Q_i \times \overline{P} \times \gamma + B \quad (5)$$

Where, Qi respectively means the saved power quantities of energy saving service company, energy efficiency service group and energy efficiency evaluation institution; $\overline{P}$ is the mean electricity sale price; γ means proportion of benefits shared by energy saving service and users, 0.7 in general; B means national reward fund.

Demonstration Analysis. Takes a power group company and a regional power company of China as examples, the following analysis results were obtained:

As the ordinary work, the line loss management brings significant benefits so the grid enterprise shall hold on it; demand side management and support of distributed energy development/consumption of clean energy will cause decrease of power sale quantity and increase of electricity purchase cost so as to cause negative benefit for the company and bring certain risks.

However, they are the important means for implementation of the energy saving and emission reduction objective, so the government department is suggested to continue supporting it substantially; although the intelligent power utilization with the electric car as the representative and the energy saving service system construction received limited income in increase of the power sale quantity, the grid enterprise shall further promote the two works for its wide involved industries and great after-sales service income. as shown in Table 4.

Table 4. Influence of Partial Energy Saving and Emission Measures on Company Operation Performance

Energy Saving and Emission Reduction Work	**power group company Influence Value (hundred million Yuan)**	**regional power company Influence Value (hundred million Yuan)**
Line Loss Management	191.39	21.94
Comprehensive Resource Strategy Plan - Demand Side Management	-15.03	-1.42
Intelligent Power Utilization (Electric Car)	1.47	0.093
Support of distributed energy development/consumption of clean energy	-141	-17.04
Energy Saving Service System Construction	33.93	/
In total	70.76	3.573

Conclusions

This paper designs the energy saving and emission reduction index system for the grid enterprise and provides good basis for evaluating the energy saving and emission reduction works; it constructs the grid enterprise development. influence evaluation model for energy saving and emission reduction from both social benefit and economic benefit produced in the energy saving and emission reduction works, and thus provides the effective tool for analyzing and evaluating the energy saving and emission reduction works; it also provides the demonstration analysis with relevant energy saving and emission reduction index data of a power group company and a regional power company of China so as to show that the company can actively conduct the energy saving and emission reduction works in multiple fields and directions such energy saving and emission reduction organization management, plan policy establishment, electricity network construction, energy saving dispatching, power generation right trade, new energy industry development, energy saving service system construction, energy saving technology progress, etc.

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Table 1.Energy Saving And Emission Reduction Index System For Grid Enterprise

First Class Index	Second Class Index	Third Class Index	Fourth Class Index (characteristic index)
Energy Saving and Emission Reduction Index Selection for the Grid Enterprise F1	Line Loss Management F11	Reactive Compensation F111	Reactive Compensation Quantity, Reactive Compensation Capacity
		Metering Device Transformation F112	Metering Device Transformation Quantity
		Elimination of High Energy Consumption Transformer F113	Capacity and Quantity of High Energy Consumption Transformer to be eliminated
	Grid Construction F12	Novel Transformer Substation Construction F121	Line length and Transformer Substation Quantity
		Extra-High Voltage Construction F122	Extra-High Voltage Line length, Quantity, Capacity, Mean Power Supply Radius, Capacity-Load Ratio
	Intelligent Power Utilization F13	Electric Car F131	Popularization Quantity, Charging Station (Pile Quantity)
		Household Appliances F132	Household Appliances Quantity, Electricity Saving Quantity, Electricity Saving Rate
Energy Saving and Emission Reduction Index Selection for the Power Industry F2	Energy Saving Power Generation Dispatching F21	First dispatch water electricity F211	Water saving and increased generating capacity
		Flexibly dispatch pumped storage power generation F212	Capacity, generating capacity, on-grid energy
		First dispatch new energy source such as wind electricity, etc. F213	On-grid energy of new energy source such as wind energy
		First dispatch low energy consumption conventional thermal power generating unit F214	Generating capacity after the high energy consumption power generating unit is replaced by one with low energy consumption
	Support of Distributed Energy Development F22	Distributed gas engine set F221	Capacity, generating capacity, on-grid energy
		Distributed photovoltaic power generation F222	Capacity, generating capacity, on-grid energy
		Distributed wind electricity F223	Capacity, generating capacity, on-grid energy
		Distributed waste heat power generation F224	Capacity, generating capacity, on-grid energy
	Consumption of Clean Energy F23	Consume wind electricityF231	Capacity, generating capacity, on-grid energy
		Natural gas power generation F232	Capacity, generating capacity, on-grid energy
		Small hydropower F233	Capacity, generating capacity, on-grid energy
	Power Generation Right Trade F24	____	Trade electric quantity
	Small Thermal Power Shutdown F25		Shutdown capacity
	Cross-Region and Cross-Provincial Trade F26	____	Trade electric quantity and electric quantity structure (water, wind and fire)
Energy Saving and Emission Reduction Index Selection for the Society F3	Comprehensive Resource Strategy Plan - Demand Side Management F31	Orderly power utility F311	Project number, electricity saving quantity, and load saving quantity
		Load management F312	
		Energy efficiency powerplant F313	
		Energy efficiency management F314	
	Total Energy Consumption Control F32	____	Qualitative description of influence of the strategy on the company
	Energy Saving Service System Construction F33	Energy saving service company F331	Company quantity, group quantity, publicity investment, talent quantity, project quantity, project investment, energy saving quantity, energy saving capacity, output value
		Energy efficiency network F332	
		Energy efficiency evaluation institution F333	