

An objective decision model of power grid environmental protection based on environmental influence index and energy-saving and emission-reducing index

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Abstract. Based on modelling the environmental influence index of power transmission and transformation project and energy-saving and emission-reducing index of source-grid-load of power system, this paper establishes an objective decision model of power grid environmental protection, with constraints of power grid environmental protection objectives being legal and economical, and considering both positive and negative influences of grid on the environmental in all-life grid cycle. This model can be used to guide the programming work of power grid environmental protection. A numerical simulation of Jiangsu province's power grid environmental protection objective decision model has been operated, and the results shows that the maximum goal of energy-saving and emission-reducing benefits would be reached firstly as investment increasing, and then the minimum goal of environmental influence.

1. Introduction

Along with economy swift development and living standards yearly enhancement, the requirement of environmental protection is increasing in many countries. Under state environmental protection strategy, any behavior of power grid enterprises should follow the demands of low carbon economy and can perform higher than legal environmental standards, as well as provide leading technology actively for regulatory agencies and industry, to establish market barriers or the first-mover advantage of the enterprise. Driven by external environmental pressure and internal clean development, power grid environmental protection has gradually become an important content of grid enterprise development strategies, and a top priority of grid environmental protection is its objective, which is the general strategy and roadmap of grid development, also is a fundamental basis of compiling power grid plan.

Environmental protection was seldom considered in the existing grid planning works or researches which are presented in [1-5], and influence of some environmental protection factors, such as electromagnetic environment, noise, waste and landscape, to decide environmental protection objective also seldom involved, and the objective optimizing decision of power grid environmental protection. At present, some grid environmental policies and standards has been enacted in china. However, only environmental limits are given in all these standards, the staged quantitative indicators can be used to guide the grid environmental protection work haven't get involved. Scholars have made some exploration in grid environment protection planning, such as, Wang discusses some ideas about



planning environmental impact assessment in [6], MAO establishes the regional grid environmental protection planning method and framework in [7], ZHU quantifies some indexes to establish a grid planning model related to environmental protection in [8]. Generally, grid environmental protection planning just started, researches of grid environmental protection objectives optimizing decision should be strengthened.

In this paper, an objective decision model of power grid environmental protection is established to guide power grid enterprises planning their grid environmental protection strategies, based on modeling the environmental influence index of power transmission and transformation project and energy-saving and emission-reducing index of source-grid-load of power system, and considering both positive and negative influences of grid on the environmental in all-life grid cycle.

2. Model design

Power grid environmental protection has the characteristics of wide range and big significance. For example, equipment like transformers and transmission lines has different environmental standards in their different life cycle, and as the connection of generation side and demand side, power grid will affect environmental protection work of the whole electric power industry indirectly.

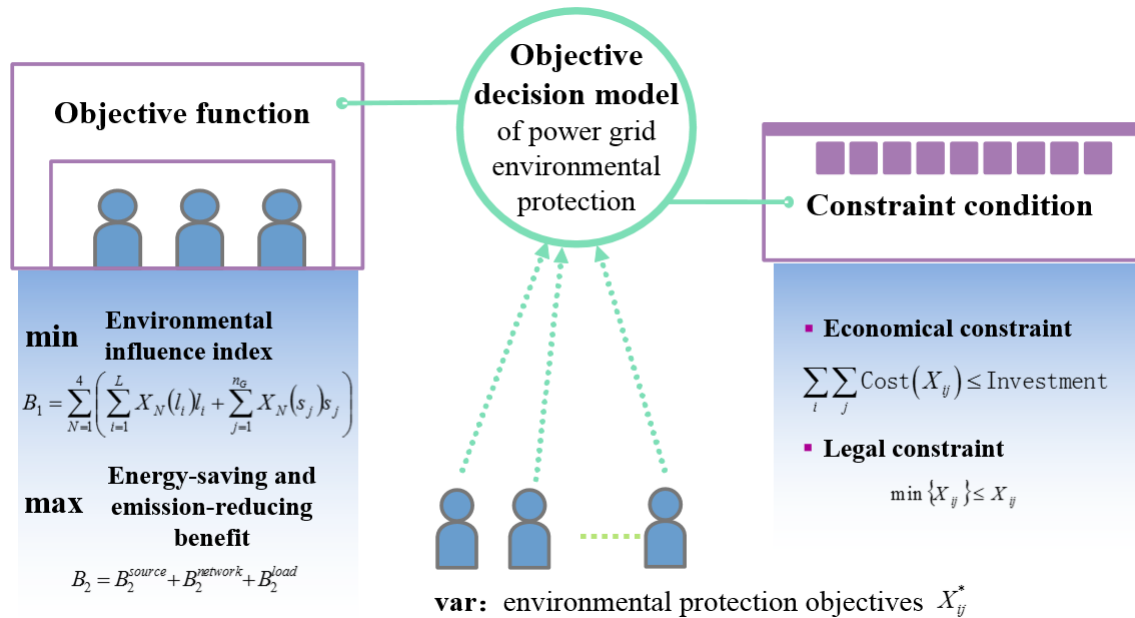


Figure 1. Objective decision model of power grid environmental protection.

Comprehensively considering both the positive role and negative influence of grid to the environment in its whole life cycle, including construction, operation and retirement, the concept of grid environmental protection factor is given. The positive role of grid mainly reflects in promoting its upstream and downstream, which is power generation side and demand side, to conserve energy and reduce emissions. The negative impact of grid mainly reflects in producing waste, landscape effect, electromagnetic environment and noise in its life cycle process. Therefore, the objective decision model of power grid environmental protection will be established as the following steps.

Step 1. Define grid environmental protection factor, including electromagnetic, noise, landscape and waste, and model all the factors specifically in their all-life grid cycle, including construction, operation and retirement.

Step 2. Study and model the each benefit of energy-saving and emission-reducing from power generation side, grid side and demand side, caused by environmental protection strategies of grid enterprises.

Step 3. Establish objective decision model of power grid environmental protection, with minimal grid environmental protection factor and maximum benefits of energy-saving and emission-reducing.

3. Power grid environmental protection factor modelling

To structure the power grid environmental protection factor, we mainly considers environmental influence indexes of power transmission and transformation project in the processes of construction, operation and retirement, including electromagnetic index, noise index, landscape index and waste index. And then modelling the energy-saving and emission-reducing index of source-grid-load of power system, by used of analyzing the benefits of grid promoting its upstream and downstream, which is power generation side and demand side, to conserve energy and reduce emissions.

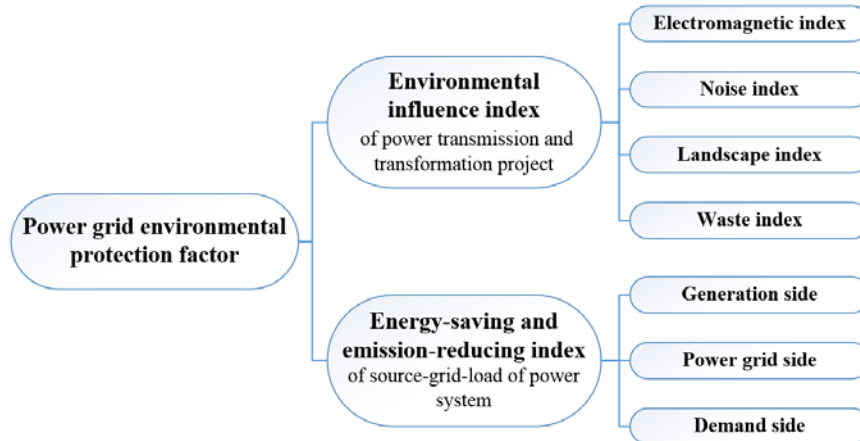


Figure 2. Power grid environmental protection factor.

3.1. Environmental influence index of power transmission and transformation project

Refer to some models in [9-11], environmental influence indexes includes electromagnetic index, noise index, landscape index and waste index. Power grid environmental influence index in all-life grid cycle is showed in figure 3, and meanings of symbols will be explained in the following.

	Construct	Operate	Retire
Electromagnetic	$X_{11}^{construct}=0$	$X_{11}^{operate}(l_i, s_j)$	$X_{11}^{retire}=0$
Noise	$X_{12}^{construct}=0$	$X_{12}^{operate}(l_i, s_j)$	$X_{12}^{retire}=0$
Landscape	$X_{13}^{construct}$	$X_{13}^{operate}$	$X_{13}^{retire}=0$
Waste	$X_{14}^{construct}$	$X_{14}^{operate}$	X_{14}^{retire}

Figure 3. Power grid environmental influence index in all-life grid cycle.

3.1.1. Electromagnetic index. In the process of operation, $X_{11}^{operate}(l_i)$ is the electromagnetic influence of transmission line l_i . In equation (1), n is the segments of line l_i , p_i is the population density of the segment i region, L_i is the length of segment i , W_L is the distance of transmission line's side and the central line, $E_L(x)$ is the function of electromagnetic influence depends on the distance from the central line which can be calculated by the method recommended by International Conference on Power Grid.

$$X_{11}^{operate}(l_i) = \sum_{i=1}^n \left(p_i L_i \int_{-W_L}^{W_L} E_L(x) dx \right) \quad (1)$$

In the process of operation, $X_1^{operate}(s_j)$ is the environmental influence of substation s_j . In equation (2), p_s is the population density of the substation, W_s is the distance from the substation, $E_s(x)$ is the function of electromagnetic influence depends on the distance from the substation.

$$X_1^{operate}(s_j) = p_s \int_0^{W_s} (E_s(x) 2\pi x) dx \quad (2)$$

3.1.2. Noise index. In the process of operation, $X_2^{operate}(s_j)$ is the noise influence of transmission line l_i . In equation (3), $N_L(x)$ is the function of noise influence depends on the distance from the central line which also can be calculated by the method recommended by International Conference on Power Grid.

$$X_2^{operate}(l_i) = \sum_{i=1}^n \left(p_i L_i \int_{-W_L}^{W_L} N_L(x) dx \right) \quad (3)$$

In the process of operation, $X_2^{operate}(s_j)$ is the noise influence of substation s_j . In equation (4), $N_s(x)$ is the function of noise influence depends on the distance from the substation.

$$X_2^{operate}(s_j) = p_s \int_0^{W_s} (N_s(x) 2\pi x) dx \quad (4)$$

3.1.3. Landscape index. In equation (5), X_3 is the landscape index, and S_d is the distance of a line or a substation away from the affected point, S_p is the affected population, which includes floating population and fixed population active around the affected point, S_t is the possibility of lines or substations appearing by the viewer around the affected point, which can be calculated by the ratio of lines' or substations' area being viewing and the whole affected point area. Landscape index in the process of construction and operation can be expressed as $X_2^{construct}$ and $X_2^{operate}$.

$$X_3 = S_d S_p S_t \quad (5)$$

3.1.4. Waste index. In the process of operation, $X_4^{operate}$ is the waste influence, including liquid waste and solid waste. In equation (6), $|\alpha p D|$ is the normalized index of liquid waste emissions, which α is the waste reduction factor, p is the resident person-time during the construction process, D is engineering water quota. $|W_{muck}|$ is the normalized index of solid waste emissions, which W_{muck} includes concrete waste of telegraph poles, insulator waste, and so on.

$$X_4^{construct} = |\alpha p D| + |W_{muck}| \quad (6)$$

In the process of operation, $X_4^{operate}$ is the waste index, including liquid waste, gaseous waste and solid waste. In equation (7), $|W_{oil}|$ is the normalized index of substation oil waste emissions, $|W_{SF_6}|$ is the normalized index of SF_6 emissions.

$$X_4^{operate} = |\alpha p D| + |W_{muck}| + |W_{oil}| + |W_{SF_6}| \quad (7)$$

In the process of retirement, X_4^{retire} is the waste index, including oil waste, gaseous waste and battery waste.

$$X_4^{retire} = |W_{muck}| + |W_{oil}| + |W_{SF_6}| \quad (8)$$

3.2. Energy-saving and emission-reducing index of source-grid-load of power system

The mechanism of power grid environmental protection to promoting the whole power system of energy conservation and emissions reduction mechanism shows in figure 4. Respectively considering power grid enterprise environmental protection strategies to promote the benefits of the generation side, grid side and user side of energy conservation and emissions reduction. B_2 is the energy-saving and emission-reducing index of source-grid-load of power system in equation (9), and B_2^{source} , $B_2^{network}$ and B_2^{load} represent the benefits of generation side, grid side and user side, respectively.

$$B_2 = B_2^{source} + B_2^{network} + B_2^{load} \quad (9)$$

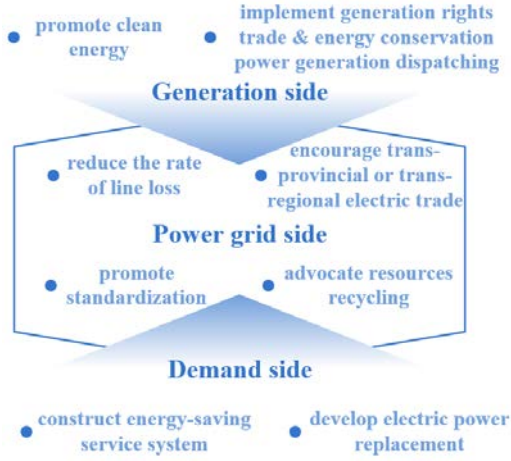


Figure 4. Process of energy-saving and emission-reducing of source-grid-load of power system.

3.2.1. Generation side. Mainly considered promoting clean energy and implementing generation rights trade or energy conservation power generation dispatching. In equation (10), X_{21}^{source} is the goal of clean energy development, X_{22}^{source} is the goal of implementing generation rights trade or energy conservation power generation dispatching, and B_{21}^{source} and B_{22}^{source} are their energy-saving and emission-reducing benefits, respectively.

$$B_2^{source} = B_{21}^{source}(X_{21}^{source}) + B_{22}^{source}(X_{22}^{source}) \quad (10)$$

3.2.2. Power grid side. Mainly considered reducing the rate of line loss, encouraging trans-provincial or trans-regional electric trade, promoting standardization and advocating resources recycling. In equation (11), $X_{2i}^{network}$ ($i=1,2,3,4$) are the goals of reducing rate of line loss, encouraging trans-provincial or trans-regional electric trade, promoting standardization and advocating resources recycling, respectively. And $B_{2i}^{network}$ ($i=1,2,3,4$) are their benefits.

$$B_2^{network} = \sum_{i=1}^4 B_{2i}^{network}(X_{2i}^{network}) \quad (11)$$

3.2.3. Demand side. Mainly considered constructing energy-saving service system and developing electric power replacement. In equation (12), X_{21}^{load} and X_{22}^{load} are the goals of constructing energy-saving service system and developing electric power replacement, and B_{21}^{load} and B_{22}^{load} are their benefits.

$$B_2^{load} = B_{21}^{load}(X_{21}^{load}) + B_{22}^{load}(X_{22}^{load}) \quad (12)$$

4. Objective decision model of power grid environmental protection

After defining and modeling every environmental protection objectives, objective decision model of power grid environmental protection is established. In the following model, L is the total transmission line length during the planning period and S is the total amount of substations during the same period.

4.1. Objective function

Objective function considers both the positive role and negative influence of grid to the environment in its whole life cycle caused by the environmental influence index of power transmission and transformation project and energy-saving and emission-reducing index of source-grid-load of power system.

$$\begin{aligned} \min B_1 &= \sum_{N=1}^4 \left(\sum_{i=1}^L X_N l_i + \sum_{j=1}^S X_N s_j \right) \\ \max B_2 &= B_2^{source} + B_2^{network} + B_2^{load} \end{aligned} \quad (13)$$

In equation (13), B_1 is the environmental influence objective, and every environmental protection influence objective function X_N includes construct objective $X^{construct}$, operate objective $X^{operate}$ and retire objective X^{retire} , which can be calculated by $X = X^{construct} + X^{operate} + X^{retire}$.

4.2. Constraint condition

Constraint conditions includes environmental protection objective being legal and environmental protection cost being under limit.

Equation (14) gives the legal environmental protection objective constraint.

$$\min \{X_{ij}^*\} \leq X_{ij}^* \quad (14)$$

In equation (14), $\min \{X_{ij}^*\}$ is the minimum requirements to environmental protection objective of state policies, laws or regulations.

Equation (15) gives the environmental protection cost under limit constraint.

$$\sum_i \sum_j \sum_* C_{ij}^*(X_{ij}^*) \leq C_{max} \quad (15)$$

In equation (15), $C_{ij}^*(X_{ij}^*)$ is the cost of achieving the environmental protection objective X_{ij}^* , and C_{max} is the maximum grid environmental protection investment of grid enterprises.

5. Example

Taking Jiangsu province as a sample example, to calculate the objective decision model of power grid environmental protection, and figure 5 shows the feasible solutions and optimal solutions under different grid investment. The results shows that, the maximum goal of energy-saving and emission-reducing benefits and the minimum goal of environmental influence will be both considered when the grid environmental protection investment being small, the maximum goal of energy-saving and emission-reducing benefits will be reached firstly as investment increasing, and when the investment being big enough, both goal will be achieved.

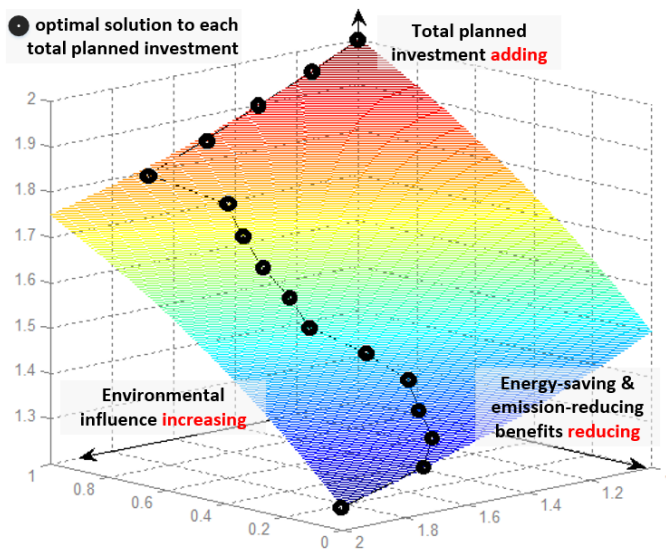


Figure 5. Environmental protection objective decision under variable investment.

6. Conclusion

In this paper, an objective decision model of power grid environmental protection is constructed, based on the constraints of grid environmental protection factors and grid environmental protection investment. Under the premise of electric power enterprises carrying out environmental protection policy actively, to optimize and control several kinds of grid environmental protection index can minimize the negative impact of grid construction and operation on the environment, also maximize the positive impact to the environment, and eventually to achieve the coordinated development of grid and environment. A sample example of Jiangsu province is given, and the results shows that the maximum goal of energy-saving and emission-reducing benefits would be reached firstly as investment increasing, and then the minimum goal of environmental influence.

Based on this method, future grid environmental protection planning objectives can be helped to determine, and then the quantified objectives can be calculated by used of data from the power grid enterprises' environmental information platform. Such as, to realize the coordinated development of grid construction or operation and ecological environment, indications like rates of environmental impact assessment and environmental protection acceptance check, rates of sulfur hexafluoride gas recycling and utilization, etc., to reach the standards, to complete state's or enterprise's energy conservation and emissions reduction requirements, to improve environmental protection organization system and keep the grid environmental protection supervised and managed in the whole process, to reach the international leading level of grid environmental protection science and technology, and so on.

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