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Bi-level Multi-objective Environmental Economic Dispatch with Wind Farm

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Abstract: A bi-level multi-objective environmental economic dispatch model with wind farms is established based on decomposition coordination principle and users' side resources. Considering the level of system load and users' satisfaction degree, a multi-objective optimization mathematical model was established to determine fitting load of the system and time sharing price. Considering the randomness of wind power output, a multi-objective environmental economic dispatch model is established to determine the generation plan. A hybrid universal gravitation algorithm and tabu search algorithm is proposed to solve the model. The optimal scheduling scheme is determined by the method of approximate ideal solution based on entropy weight. Simulation results show that: Considering the influence of resources of source side in the scheduling process not only can improve load level of the system operation, the satisfaction of using electricity and absorptive capacity of wind power, but also can effectively in reduce the generation costs and pollution emissions.

Introduction

The traditional power system economic dispatch is to arrange the load distribution reasonably under the constraint of the power balance, the rotation reserve and the unit output limit, so that the power generation cost is minimized[1,2,3]. A multi-objective dynamic environment economic dispatch (dynamic economic emission dispatch, DEED) model is established which gives dual attention to the systems operation efficiency and environmental benefit and the randomness of wind power output is considered in literature [4], but it had not control the costs. In view of the randomness of wind power output, the DEED model is used to effectively manage the risk of pollution emissions which is based on the theory of multiple scenarios and the risk of pollution emissions in literature [5], But only considering the scheduling scheme under different wind power scenarios, the effect of wind power generation on the system scheduling can't be fully analyzed.

Aiming at the above problems, this paper sets up a double layer multi objective DEED model which is based on the interaction between the user and the user side and contains wind farm. The optimization model is used to fit the load as the constraint condition which is considered the environmental benefit and the wind power output randomness. A multi-objective tabu search gravitational (MTS-GSA) is proposed to solve the model, and technique for order preference by similarity to ideal solution to determine the final scheduling scheme based on the entropy weight of the auxiliary decision-making.

Dynamic Environmental Economic Model of Bi-level and Multi-objective

The Multi-objective Optimization Model of Upper Level

The level of system load can be described by the daily load rate and the minimum load factor. The greater the value of the system load, the more gentle. Increasing the level of system load can reduce the loss of system power and improve the safety of system operation[6,7]. The corresponding specific objective function is:

$$\max F_1 = k_1 \frac{P_{\mathrm{D,av}}}{P_{\mathrm{D,max}}} + k_2 \frac{P_{\mathrm{D,min}}}{P_{\mathrm{D,max}}} \tag{1}$$

where F_1 is the system load index; k_1 and k_2 are respectively the weight coefficients of the daily load rate and the minimum load factor; $P_{\mathrm{D,av}}$ is the average daily load of the system; $P_{\mathrm{D,min}}$ and $P_{\mathrm{D,max}}$ is the minimum value and maximum value of the load in the scheduling cycle.

The Multi-objective Optimization Model of Lower Level

The objective function of the total cost of power generation for conventional thermal power unit is:

$$\min F_1 = \sum_{t=1}^{T}\sum_{i=1}^{N}[U_{i,t}C_{i,t}(P_{i,t}) + U_{i,t}(1-U_{i,t-1})S_{i,t}] \tag{2}$$

where F_1 for the total cost of conventional thermal power generation; N is the thermal power units; $U_{i,t}$ is the working condition of first i thermal power unit in the period of t. $U_{i,t}$=1 means that the power unit of i is in the boot state. $U_{i,t}$=0 indicates that the thermal power unit of i is in a shutdown state. $C_{i,t}(P_{i,t})$ for the fuel costs of the fire motor group of i in the period of t. $P_{i,t}$ for the output active power of the fire motor group of i in the period of t. $S_{i,t}$ for the start and stop moving costs of the motor group of i in the period of t.

The constraint conditions of the lower optimization model are:

(1) Power balance constraint

$$\sum_{i=1}^{N} P_{i,t} + P_{\mathrm{w,t}} - P_{D,t} - P_{\mathrm{loss},t} = 0 \tag{3}$$

where $P_{\mathrm{w},t}$ is the active power output of wind farm in t period; $P_{\mathrm{D},t}$ is the fitting load of the system after the implementation of TOU. $P_{\mathrm{loss},t}$ is the active loss of the system in the period of t.

The loss of system network can be obtained by the B coefficient method. Specific expression is:

$$P_{\mathrm{loss},t} = \sum_{i=1}^{N}\sum_{j=1}^{N} P_{i,t}B_{ij}P_{j,t} + \sum_{i=1}^{N} P_{i,t}B_{i0} + B_{00} \tag{4}$$

where B_{ij}、B_{i0}、B_{00} is loss coefficient of the network.

(2) The output constraint of thermal power units

$$P_{i,\min} \le P_{i,t} \le P_{i,\max} \tag{5}$$

where $P_{i,\min}$、$P_{i,\max}$ is the upper and lower limit of output power of the thermal power unit in the period of t. The power output adjustment of the thermal power units in each period is detailed in the literature [4].

DEED Algorithm of Bi-level and Multi-objective

Tabu Search- Gravitational Search Algorithm of Multi-objective

Combined with tabu search in the process of optimization complement each other, and the congestion distance calculation strategy, the cumulative ranking adaptive assignment strategy and the elite reservation strategy are introduced[8]. A multi objective tabu search algorithm is proposed, which can solve the problem.

Assistant Decision Making

The final scheduling scheme is determined by the decision makers through comparing a sort of approximate ideal solution[9] based on entropy weight and pareto front solution order method. "The optimal solution" and "the worst solution" are respectively the virtual solution which makes the objective function to the optimal and the worst in the feasible domain. The optimal solution and the worst solution does not exist due to the presence of a competition between the various objective functions.

Case Analysis

In order to verify the rationality of the proposed model and the effectiveness of MTS-GSA, the 10 machine system with wind farm is simulated and calculated Algorithm parameter settings: the population size of the particle is 80. The maximum number of iterations is K_{max}=100; gravity coefficients of the initial value is G_0=100; GSA algorithm with a constant is ETA = 20; tabu table length is L=10.

DEED Based on Bi-level Optimization

(1) Optimization of upper level

The weight coefficient of the power consumption satisfaction and electricity expenditure satisfaction v_1 and v_2 are both 0.5. The weight coefficient of daily load rate and the minimum load factor k_1 and k_2 are both 0.5. The optimal solution of the upper layer model is determined by using TOPSIS method which based on entropy weight to sort the Pareto front solution. The extreme solutions and the optimal solutions of the various indicators see Table 1.

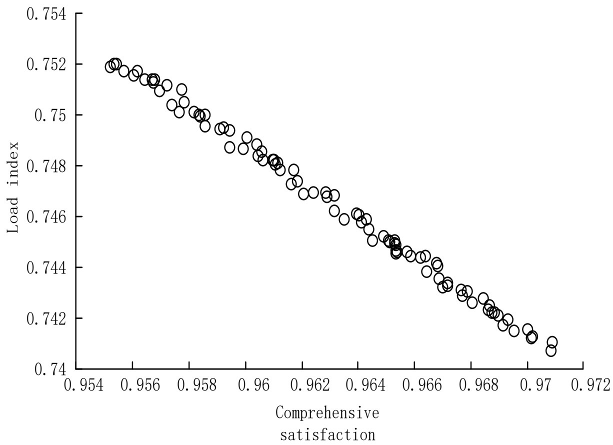

Figure 1. Pareto of the upper optimization.

Table 1. Extreme solutions and best solution of the upper optimization.

scheme	load index	load rate	comprehensive satisfaction	electricity satisfaction	peak time electricity price /(kW·h yuan)	valley time price /(kW·h yuan)	pull apart
load optimal	0.7520	0.8439	0.9552	1.0102	1.1208	0.4135	0.8300
optimal degree of satisfaction	0.7410	0.8311	0.9709	1.0424	1.0106	0.4509	0.6033
optimum solution	0.7468	0.8379	0.9620	1.0241	1.1097	0.3706	0.7212

From Figure 1 shows, due to the algorithm of MTS-GSA combined with the optimization characteristics of TS algorithm and GSA algorithm, the global and local search performance of the hybrid algorithm is balanced. The precision and the speed of convergence is improved and got a better Pareto frontier and non-inferior solution set is widely dispersed evenly. As table 1 shows, with the increasing of open ratio, load index also increased. There is a clear positive correlation between the two, which is because of the change of pull apart can adjust the difference of price between peak and valley. The bigger of the open ratio, user's response is greater to TOU, peak sharpening effect is more obvious. Electricity expenditure satisfaction is greater than 1, which means that after the implementation of TOU, the user's electricity spending has been reduced, which is consistent with the principles of TOU. In conclusion, the interests of users and power grid company are both taken into account in the pricing scheme, which can provide a reference for the decision makers. On the basis of the optimization of the upper layer, the optimal system load is used as the initial value of the load, and the interaction between the upper and lower layers is achieved by the limit of the thermal power unit's output and the limit of wind power penetration.

(2) Optimization of lower level

The grid connected wind farm has 60 fans. The rated power of each Wind turbines is 2MW. The rate of wind power penetration limit is 10%, and the forecast output curve of wind farm's 24h is shown in figure 2. The optimal solution is determined by using TOPSIS method which based on entropy weight to sort the Pareto front. The Pareto front is obtained by MTS-GSA calculation as shown in Figure 3. The extreme solutions and the optimal solution of the various indicators see Table 2.

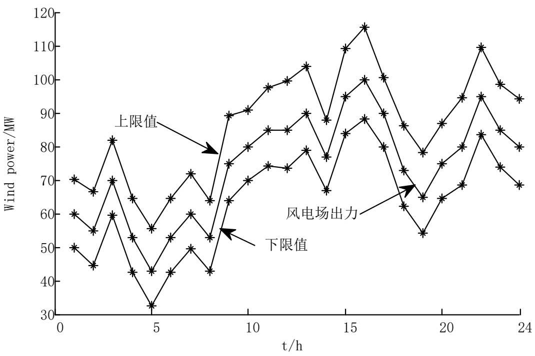

Figure 2. Hourly wind power and rang of power fluctuating.

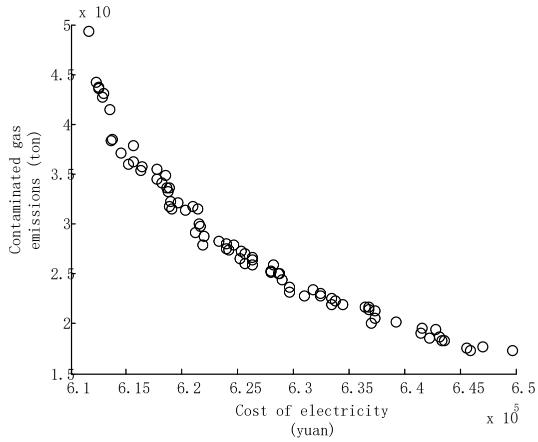

Figure 3. Pareto of the lower level optimization.

Table 2. Extreme solutions and best solution of lower level.

Scheme	**Power generation cost /(10^5yuan)**	**Polluting gas emissions /(10^5lb)**	**Start-up and shutdown costs /(yuan)**
Economic optimum	6.1159	4.9294	3740
Environmental optimal	6.4969	1.7288	4780
Optimum solution	6.2636	2.5901	4750

From Figure 2 and figure 3 we can see that, due to the wind farm output at each time period is similar, the system load is free distributed in the each thermal power unit, leading to the big difference between the power generation costs and pollution gas emissions of the Pareto front solutions. This increases the difficulty of DEED, and uses the TOPSIS method which based on entropy weight to analyze the Pareto front solution, which can provide the scientific generation plan for the dispatcher. From table 2 shows, the open and stop cost is minimum, when the economic is optimal. The start and stop cost is maximum, when the environment is optimal. Start and stop costs and power generation costs and pollution emissions are significantly positive and negative correlation trend, which is consistent with the actual power generation.

Conclusions

In this paper, a bi-level multi-objective DEED model with users' side resources is proposed and the following conclusions are obtained by the analysis of MTS-GSA:

1) From the angle of decision makers, considering the multiple aspects of the system load level, the users' satisfaction, environment and economy. The traditional scheduling model which blindly takes into account economic is changing by comprehensive analysis the factors of affecting the deed.

2) MTS-GSA algorithm combined with the advantages of GSA algorithm and TS algorithm. The convergence accuracy of the hybrid algorithm is improved and the Pareto front integrity is good. Non-inferior solution set is distributed widely and evenly. The scientific and reasonable scheduling scheme is selected by decision makers through using TOPSIS method based on entropy weight to analyze the Pareto front solution.

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