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Optimization Scheduling Method of Power Grid Energy-Saving Based on Fuzzy Decision

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***Abstract*—As a reserve energy for the stable development of the society, the efficiency of the development and utilization of power resources indirectly affects the quality of electricity consumption of users and the quality of power marketing of power companies. In the process of transmission and distribution line operation, the multiple dimension power loss such as line power loss, electrical component power loss, transformer station loss and so on will be a non-negligible power loss. In the paper, the concept of membership function ratio is proposed, and the controller parameter optimization model with membership function ratio as optimization variable is established, and the intelligent bee colony algorithm is used to solve the problem. The method not only realizes the real-time scheduling of the power transmission and distribution joint system, but also improves the system's ability to absorb the photovoltaic in situ, and effectively reduces the operating cost of the system. The case analysis demonstrates the real-time and economical of the proposed method.**

Keywords-Fuzzy Decision; Power Grid Transmission and Distribution; Energy-Saving Optimization Scheduling

I. INTRODUCTION

In China's power system, transmission and distribution lines are the main carrier of electric energy transmission, and the coverage is wide. However, when power is transmitted to electricity, the power consumption is widespread due to the influence of various factors, which in turn directly causes serious waste of power resources in China. Therefore, a large-area improvement technology is adopted for the transmission and distribution lines, so that energy-saving and consumption-reducing skills are applied to daily life, and energy resources are efficiently utilized. The widespread use of this technology can not only reduce people's electricity consumption, but also promote the development of electrical energy systems and ecological environment[1-2].

By mining the historical behavior information of user groups to determine the rules of group dispersion behavior and cluster characteristics, the multiple agent system with controllable home appliance user groups is modeled. Based on the grid transmission and distribution power, an isolated network operation model is established for the micro-power of micro-grid, such as energy storage systems, fans, pumps and internal combustion engines. The model solving algorithm is based on fuzzy control theory and has the characteristics of fast response and good control effect, especially suitable for solving optimization problems such as complex nonlinear models.

II. Controller Parameter Optimization Based on Intelligent Bee Colony

A. Power grid energy-saving dispatching relationship

Traditional fuzzy control systems do not have the ability to learn. In the paper, the membership function ratio $k=\frac{d_1}{d}$ is specified, and the membership function is changed by adjusting the ratio, and the fuzzy controller output is adjusted to improve the adaptive ability of the fuzzy controller.

The relationship between the controllable ratio and other parameters of the membership function is:

$$D = b - a \tag{1}$$

$$d_1 + d_2 = d \tag{2}$$

$$d_1 = dk \tag{3}$$

$$D = (d_1 + d_2)n - (n-1)d_2, n \in N^* \tag{4}$$

In equations (1)(2)(3)(4): [a,b] is the variable domain; D is the domain width; d is the length of the bottom edge of the triangle membership function[3];d_1 and d_2 are the distances and overlapping widths of adjacent membership curves, respectively; *n* is the number of blurs. The number of fuzzy quantities is selected in table 1.

TABLE I. Fuzzy variable quantity selection

Controller input variable type	Number of membership function fuzzy quantities
Value symmetry	{x|x=2k+1,k∈N+}
Value asymmetry	{x|x∈N+}
Note: N+ is a positive integer set.	

From equations (1)(2)(3)(4), the relationship between the variable domain D and the base length d of the triangle membership function can be gotten.

$$D = (n - \frac{n-1}{K+1})d, n \in N^* \tag{5}$$

The k is made to derivation in equation (5).

$$0 = d'\left(n - \frac{n-1}{k+1}\right) + d\frac{n-1}{(K+1)^2} \tag{6}$$

It can be seen from equation (6) that the derivative function d' is less than zero, d and k are inversely related, and the d decreases as the k increases.

The main characteristic parameters of the power grid are the state of charge and the power of transmission and distribution. The algebraic relationship between the two is

$$S_{ocn} = \frac{\sum_{i=1}^{n} p_b \Delta t}{E_{\max}} + \frac{E_{initial}}{E_{\max}} \tag{7}$$

In equation (7), S_{OCn} is the state of charge for power grid; $E_{initial}$ is the initial charge; E_{max} is the rated capacity. The relationship between the charge E_n of the grid and the power distribution is

$$E_n = E_{initial} + \sum_{i=1}^{n} p_b \Delta t \tag{8}$$

B. Optimization problem of constraints

Power balance constraint is[4]

$$p_{grid} + p_{pv} = p_{load} + p_b \tag{9}$$

When the system purchases electricity from the grid, the p_{grid} is positive; when the system sells electricity to the grid, p_{grid} is negative. The state of charge is constrained to

$$S_{OCmin} < S_{OC} < S_{OCmax} \tag{10}$$

In equation (10), S_{OCmin}, S_{OC}, and S_{OCmax} represent the minimum, actual, and maximum values of the grid output state, respectively. Transmission and distribution power constraints are

$$-p_{max} < p_b < p_{max} \tag{11}$$

In equation (11), p_{max} is the maximum distribution power.

C. Improved transmission and distribution strategy

When the electricity price is high, if the photo-voltaic power is greater than the load power, the excess energy will be stored in the power grid. The distribution power expression is

$$p_b = a_1 \cdot (p_{pv} - p_{load}) \quad 0 < a_1 \leq 1 \tag{12}$$

When the electricity price is low, if the power shortage of the micro-grid is large, the grid is discharged. The discharge power expression is

$$-p_b = a_2 \cdot (p_{load} - p_{pv}) \quad 0 < a_2 \leq 1 \tag{13}$$

In equations (12) and (13), a_1 and a_2 are energy storage and distribution coefficients, which are determined by the energy storage capacity. If the capacity of the energy storage system is large enough, the transmission and distribution coefficients for a_1 and a_2 take the maximum value.

D. Algorithm flow

The real-time intelligent optimization scheduling algorithm flow is shown in Figure 1[5-6].

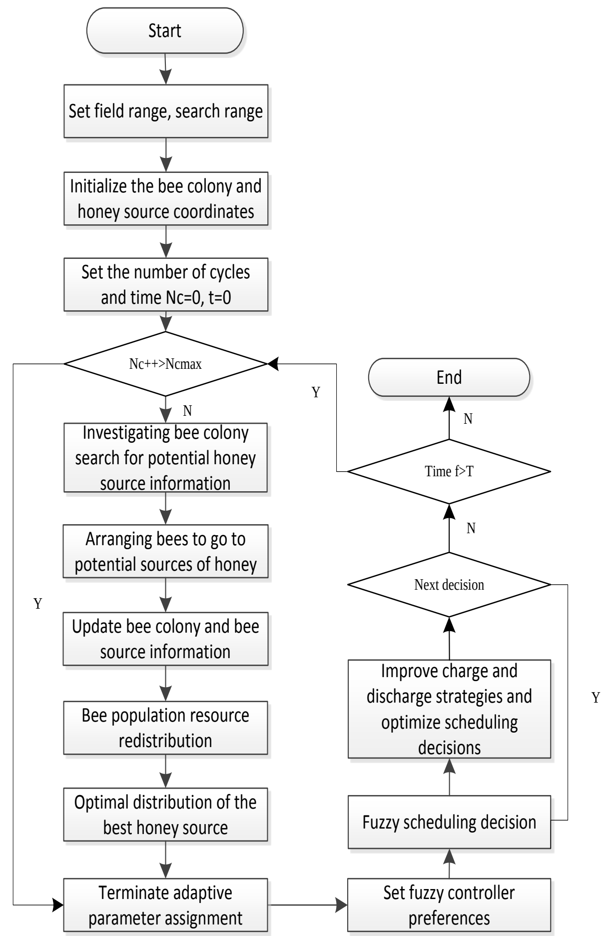

Figure 1. Flow chart of the optimization algorithm

In the figure 1, N_{Cmax} is the maximum set value of the number of cycles.

1) Initialization of the algorithm parameters. The parameters include the control parameter update period T, the number of bees collected, the number of observed bees, and the number of cycles NC.

2) The field range of parameters K1 and K2 is set to determine the search range of the honey source.

3) The position of the bees and honey sources is randomly initialized, the bee to the location of the honey source is taken, and the amount of nectar is updated.

4) According to equation (9), the bee is observed, the honey source is selected, and the honey source neighborhood is searched to update the honey source information. Note that a large amount of nectar can be allocated to more observation bees.

5) After observing the bee's completion of the search, the bee that did not obtain a better regional solution degenerated into a scout bee.

6) According to equation (10), the scouting bee randomly searches the two-dimensional solution space to find the potential optimal solution and prepares the honey source for the next iteration.

7) The best honey source to date is recorded, which are parameters K1 and K2.

8) Determining whether the parameter optimization termination condition is satisfied. If yes, the bee colony iteration should be ended and continue to the next step; if not, the algorithm goes to step 4).

9) The fuzzy controller control parameters K1 and K2 are set.

10) The controller outputs a decision scheme. According to the improved transmission and distribution strategy, the decision-making scheme is updated to control the operation of the grid transmission and distribution joint system.

11) Determining if it is the next decision point, and if yes, the algorithm goes to step 10); if not, the algorithm proceeds to the next step.

12) Determining whether the fuzzy decision parameter update condition is satisfied, if yes, the algorithm jumps to step 3); if not, the algorithm terminates the decision and enters the sleep state. When the time t is greater than the update period T or the system reaches the next decision point, the fuzzy controller is activated and the above steps are repeated.

III. Simulation Cases

A. Real-time verification

The simulation duration is shown in Table 2.

TABLE II. SIMULATION DURATION

Time Scale	Optimized calculation points	Simulation duration/s
day(24h)	24	0.094
month(744h)	744	2.31

It can be seen from Table 2 that the total time spent by the intelligent optimization algorithm on 24 optimization decision points is 9.4 ms, and the average decision time of each optimization calculation point does not exceed 0.5 ms. For the joint dispatching problem of grid transmission and distribution with time scale of month, the decision time of intelligent fuzzy scheduling method at each optimization calculation point does not exceed 0.32ms.

B. Economic verification

Different from the traditional day scheduling technology, the intelligent fuzzy decision method proposed in the paper is a real-time scheduling technology, which is a real-time decision based on the current system state, and the local optimal solution is obtained. Considering that the current research results of real-time energy storage scheduling are few, the day scheduling method is used as a comparison when verifying the economics of the intelligent fuzzy decision method.

TABLE III. ECONOMIC BENEFITS OF SCHEDULING CONTRAST

Scheduling method	1	2	3	4	5
Minimum value	-1.48	2.84	-1.16	-2.59	-1.37
Maximum value	2.74	7.33	3.84	2.15	3.28
Monthly fee/¥	18.65	78.51	44.99	12.7	23.65
Internet power/(kW.h)	182.6	1108.5	305.7	104.6	245.9

It can be seen from Table 3 that in the monthly operating cost of the system, the real-time joint adjustment of the grid transmission and distribution is between the forecasting zero error by day scheduling and the forecasting of 30% error by day scheduling. In the internet power, intelligent fuzzy decision is less than 1/5 of all PV access. In a word, the real-time scheduling technology of power transmission and distribution based on intelligent fuzzy decision improves the system's ability to absorb photo-voltaic locally by optimizing the dispatching of energy storage equipment, and effectively reduces the operating costs of the system. The optimization effect is between the day scheduling of predicting zero error and the day scheduling of prediction 30% error, which has strong engineering application value.

IV. Conclusions

The following works in the paper have been done for grid transmission and distribution scheduling:

1) A real-time optimal scheduling algorithm combining fuzzy logic control technology with energy storage and distribution strategy is proposed. The intelligent bee colony algorithm is used to optimize the controllable ratio of fuzzy membership function and improve the adaptive ability of fuzzy controller.

2) Based on the PJM market electricity price, the economical and real-time performance of real-time intelligent dispatching method for power transmission and distribution based on intelligent fuzzy decision-making is verified by comparing the daily scheduling method.

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