Operation Controllable Index Optimization of Virtual Power Plant with Electric Vehicle Based on 5g Technology and Cloud Computing Platform

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Abstract. For the controllable index optimization of virtual power plant with electric vehicles, the traditional optimization method has low environmental benefits due to the reduction of electricity sales and the use of more clean energy. Therefore, this paper proposes the controllable index optimization of virtual power plant with electric vehicles based on 5g technology and cloud computing platform. The cloud computing platform is used to calculate the deviation degree of controllable indexes of power plant operation and decompose the indexes, so as to allocate reasonable resources for the calculation of unit units. Taking the calculation results as the input parameters, an optimization model with power generation cost and environmental benefits as the objective is established. The membership function is used to solve the optimal solution of the model, and the controllable indexes are optimized. The experimental results show that: Based on 5g technology and cloud computing platform, the controllable index optimization method of virtual power plant with electric vehicles has low power generation cost and high environmental benefits, which can meet the operation needs of virtual power plant with electric vehicles.

Keywords: Cloud computing platform · Electric vehicle · Virtual power plant · Index optimization

1 Introduction

Virtual power plant adopts advanced communication mode and software system to aggregate distributed generation, energy storage system, controllable load, electric vehicle and a variety of distributed energy, so that it has sufficient capacity and stable output [1]. Like generation side distributed generation, demand side resources represented by controllable load play an increasingly important role in power system and become an important part of virtual power station [2]. The emergence of virtual power plant, using advanced intelligent measurement, data processing, network communication and other means, not only breaks through the traditional power management mode of power system, but also

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effectively integrates the flexible load resources of power grid demand side, which is of great significance for the management of power system source and load side [3]. Virtual power plant is a new resource with the identity of "producer" and "consumer", which provides technical support for the development of smart grid [4].

At present, the theoretical research and project implementation of virtual power plants all over the world are mainly from Europe and the United States [5]. The implementation form of the two virtual power plants projects is very different. European countries have implemented some virtual power plant projects, and the implementation situation is also different. At present, some demonstration projects of virtual power plants have been carried out in China. Virtual power plant can manage the distributed renewable energy generating units in the distribution system, solve the problems of safe grid connection and stable operation, and give full play to its advantages in clean energy substitution and environmental friendliness; it can also make use of advanced communication means and demand response technology to save cost and reduce peak load of EV and other controllable loads Valley and other aspects play a positive role [6]. The research on virtual power plant has taken a solid and key step to realize the bright vision of smart grid and energy Internet.

However, electric EV virtual power plants are not stable traditional power plants, large, distributed, random and intermittent, operation indicators are easy to deviate, resulting in low energy efficiency and waste of power resources, and the research on this problem is not comprehensive, this paper uses 5g technology and cloud computing platform to solve the optimal solution of the model with membership function to optimize the operation index of electric vehicle virtual power plant, increase automobile electricity and save power resources.

Cloud computing as a current research hotspot, mainstream information technology companies such as Amazon, IBM, Google have proposed their own cloud computing infrastructure [7]. Cloud computing refers to the supercomputing mode connected through the Internet, including distributed computing, parallel computing and grid computing [8]. Cloud computing is a new computing mode, which integrates distributed operating system, distributed database, grid computing and other technologies. It can make full use of hardware resources and software resources [9]. Therefore, in order to reasonably allocate resources and build an optimization model aiming at power generation cost and environmental benefits, based on the above research background, this paper introduces 5g technology and cloud computing platform to optimize the operation controllability index of electric vehicle virtual power station, and uses cloud computing platform to calculate the deviation degree of controllable index of power plant operation At the same time, the membership function is used to solve the optimal solution of the model, optimize the controllable index, and solve the problems of low environmental benefits and poor environmental protection existing in the traditional index optimization method.

2 Optimization of Controllable Operation Index of Electric Vehicle Virtual Power Station

2.1 Operation Index Decomposition of Virtual Power Plant

The development of 5g also comes from the growing demand for mobile data. With the development of the mobile Internet, more and more devices are connected to the mobile network, and new services and applications emerge endlessly. With the acceleration of the marketization of the power industry, information technology plays an increasingly important role in the process control and operation management of the power industry, and power informatization has become an important factor in promoting the development of the power industry [10]. In order to understand the situation of power production and operation in time, the main problem for power enterprises is how to respond to the new economic situation. At present, small index management method has been applied in many power plants. The calibration value of small index and its completion directly reflect the technical level and management level of operators. In order to ensure the most economical operation mode of the whole plant, various works have been carried out in various power plants to find the most reasonable small operation index quota under various operation conditions as the basis for operation of operators [11–13].

After careful study, it is determined to use the results of the cloud computing platform to calculate the expected value and actual value of each index and parameter under the current working condition, and then get the completion rate of each index, get the deviation degree of each index under the current working condition, and establish the scheme with the load rate and cycle efficiency completion rate under the current working condition as the assessment index, and the small index as the monitoring index. Departments control the completion of major indicators, operators and special engineers focus on analyzing the influencing factors of assessment indicators, and use the deviation degree of each small indicator to determine the small indicators to be analyzed, so as to guide the operation [14].

The framework of cloud computing is that each unit is composed of a single master job scheduling node and a slave task allocation node in each node cluster under the jurisdiction of the unit. The master node is responsible for scheduling all the tasks that constitute a job. The data resources of these tasks are distributed in the user image slices on the storage resources of different slave nodes, and the master node monitors their execution. The slave node is responsible for executing the tasks assigned by the master node. After receiving the assignment from the master node, the slave node starts to find the appropriate computing node for its subordinate storage nodes. First, the node detects its own computing resource surplus. If the remaining computing resources are enough to meet the amount of jobs submitted by users, it will give priority to allocating its own computing resources; if the resources have been exhausted or are not enough to meet the minimum amount of computing resources, it will report to the master node to search for other suitable computing resources in the cloud environment, and then calculate.

According to the actual situation of the virtual power plant with electric vehicles, a hierarchical index system is established, and each index is decomposed as follows.

Since the virtual power plant operates in the unit system, the first level indicators are described as: coal consumption and power supply, which are the company's performance indicators, the calculation formulas of the total length efficiency and unit power plant efficiency of the virtual power plant are as follows:

$$Q_0 = \frac{W_0}{\sum_{i=1}^{N} \frac{W_i}{Q_i}} \tag{1}$$

$$Q_i = Q_g \times Q_J \times Q_D \tag{2}$$

In the formula, Q_0 is the efficiency W_0 is the whole power plant, W_i is the power generation of the whole plant, Q_i is the unit power generation, N is the efficiency of the unit power plant, Q_g is the number of power plants in the unit, Q_J is the boiler efficiency, Q_D is the steam turbine efficiency and the pipe efficiency. The second index is based on boiler efficiency, steam turbine efficiency and pipe efficiency. Boiler efficiency: refers to the utilization rate (degree) of the fuel consumed by the boiler to produce steam by burning fuel coal (oil). There are about 30 indexes affecting boiler efficiency. But the main indexes that can be adjusted in daily operation include: main steam pressure, main steam temperature, boiler evaporation, reheat steam pressure, reheat steam temperature, inlet air temperature of forced draft fan, oxygen content, air leakage coefficient and exhaust gas temperature.

Steam turbine efficiency: it refers to the utilization degree of steam by steam turbine generator set. It indicates the operation economy of steam turbine. The calculation formula of steam turbine efficiency is as follows:

$$Q_J = \frac{3600}{Z_J} \times 100\% \tag{3}$$

The heat rate of steam turbine is expressed in the formula Z_J. There are about 25 indexes affecting the operation economy of steam turbine, but the main indexes that can be adjusted in daily operation include main steam pressure, main steam temperature, regulating stage pressure, reheat steam pressure drop, reheat steam temperature, feed water temperature, circulating water temperature, circulating water temperature rise, condenser end difference, exhaust temperature, condenser vacuum degree.

Pipeline efficiency: including heat loss of high temperature pipeline, leakage loss of system steam and water, and various heat losses not included in efficiency of generator and furnace. There are five indexes affecting the efficiency of pipeline. Heat loss of blowdown and other heat losses not included in boiler and turbine efficiency. There are five indicators that affect the pipeline efficiency. The make-up water rate is taken as the operation department, and the average load rate and cycle efficiency of each value are taken as the team assessment index, and the steam turbine and boiler efficiency index is taken as the assessment index of the steam turbine and boiler specialty, and the load rate index and auxiliary power index are decomposed into the specialty as the performance index. The cloud computing platform is used to analyze the small index deviation and find out the reasons for the evaluation index deviation. The reasons for the deviation of index assessment are shown in the Table 1.

Based on the decomposed indexes and environmental benefits, a multi index optimization model is designed to optimize the controllable indexes of the virtual power plant with electric vehicles.

Table 1. Operation energy consumption index system of electric vehicle virtual power plant

Professional assessment index	Coal consumption impact	Analysis of monitoring indicators	Coal consumption impact
Unit load rate	0.14% affected 1 g/kWh	Power shortage point	1 MPa affects 1.4 g/kwh
	0.3% affects 1 g/kWh	Dispatching power completion rate	1C affects 0.11 g/kWh
Vehicle efficiency	The auxiliary power consumption rate increased by 1%, and the energy consumption increased by 3.0 g/kWh Coal consumption impact 0.14% affected 1g/kWh 0.3% affects 1g/kWh	Main steam pressure	1C affects 0.1 g/kWh
		Main steam temperature	1C affects 1 g/kWh
		Regulating stage pressure	1C affects 1 g/kWh
		Reheat steam temperature	1C affects 1 g/kWh
		Circulating water temperature	1C affects 1 g/kWh
		Circulating water temperature rise	1% affects 3 g/kWh
		Condenser end difference	1C affects 0.12 g/kWh
		Undercooling	Coal consumption impact
		Condenser vacuum	1 MPa affects 1.4 g/kwh
		Feed water temperature	1C affects 0.11 g/kWh
Boiler efficiency	0.14% affected 1g/kWh 0.3% affects 1g/kWh The auxiliary power consumption rate increased by 1%, and the energy consumption increased by 3.0 g/kWh Coal consumption impact	Main steam pressure	
		Main steam temperature	
		Boiler evaporation	
		Reheat steam pressure	
		Reheat to steam temperature	
		Inlet air temperature of forced draft fan	10 C affects 0.12 g/kWh

(*continued*)

Table 1. (*continued*)

Professional assessment index	Coal consumption impact	Analysis of monitoring indicators	Coal consumption impact
		Oxygen quantity	1% affects 1 g/kWh
		Air leakage coefficient	
		Exhaust gas temperature	10 °C affects 1.4 g/kwh
		Combustibles in fly ash	
Pipeline efficiency	The auxiliary power consumption rate increased by 1%, and the energy consumption increased by 3.0 g/kWh	Reheat steam pressure loss	
		Main steam temperature drop	
		Reheat steam temperature drop	
		Feed water temperature drop	
		Water supply rate	1% affects 3 g/kwh
		Heat loss	

2.2 Establish Multi Index Optimization Model

In a dispatch cycle, the objective function of minimizing the generation cost of conventional units is as follows:

$$\min S_0 = \sum_{t=1}^{T}\sum_{m=1}^{M}\left(s_{m,t}v_{m,t} + p_{m,t} + b_{m,t}\right) \tag{4}$$

The formula T represents the number of research periods, the number of unit units M, m is the unit number, $s_{m,t}$ is the total fuel expenditure cost m of conventional units in the period t, $v_{m,t}$ is the operation status of units, $p_{m,t}$ and $b_{m,t}$ the start-up and stop costs of units.

The pollution gases emitted from coal combustion seriously affects the environmental quality and is not conducive to the sustainable development of the environment and resources. Generally speaking, the main pollutants emitted by conventional generating units include CO_2, SO_2, NO_2, etc.

$$\min E_0 = \sum_{v=1}^{R}\sum_{t=1}^{T}\sum_{m=1}^{M}\left(v_{m,t}\begin{pmatrix}\alpha_{m.v} + \beta_{m,v}K_{m,v} \\ + \eta_{m,v}\left(K_{m,v}\right)^2\end{pmatrix}\right) \tag{5}$$

In the formula, R the pollutant classification number is expressed, E_0 the total pollutant emission amount is expressed, and the pollutant emission coefficient $\alpha_{m.v}$ of the unit is expressed respectively. The relationship $\beta_{m,v}$ between the coefficient $\eta_{m,v}$ and the output $K_{m,v}$ is quadratic. The more the output, the greater the pollutant emissions.

When dealing with multi index optimization problems, the complex problems can be simplified by single index optimization.

In order to solve the above problems, the method of fuzzy membership degree is introduced. The membership function of the objective function was established to fuzzify it, and the appropriate membership function is selected to solve the problem.

The basis of the problem is to reduce the cost of power generation and pollution emissions as much as possible under the premise of meeting the constraints, so as to ensure optimal environmental benefits. In view of the above situation, for different objective functions, the ascending half straight line shape and the falling half straight line shape are used as the membership function. As can be seen from Fig. 1, the closer the membership degree is to 1, the better the optimization standard is, and the higher the satisfaction degree of the optimization strategy is. The membership functions of the two objective functions are the conventional power generation cost and pollution emissions. The reduced semi linear membership function is used to maximize the consumption of new energy.

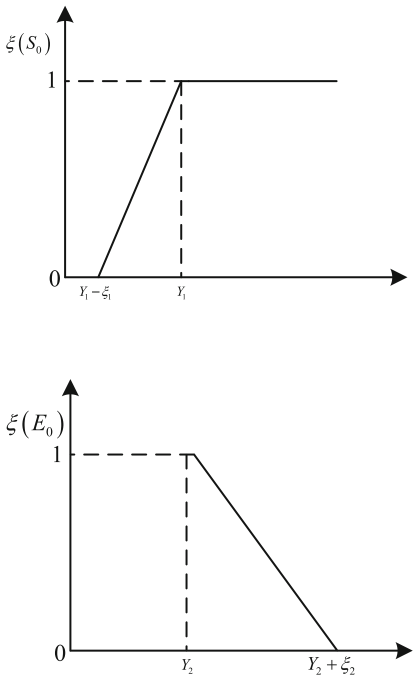


Fig. 1. Membership function corresponding to each objective function

The Fig. 1 shows the target value of power generation cost, ξ_1 represents the expansion value of generation cost with acceptable satisfaction, Y_2 represents the target value of pollutant emission, and ξ_2 represents the expansion value of pollution emission with acceptable satisfaction.

Assuming that the final objective function takes the minimum value of the two membership functions, this value is used to represent the overall satisfaction of the multi index optimization.

$$\xi = \min\{\xi(S_0), \xi(E_0)\} \tag{6}$$

At this point, the original multi index optimization problem is transformed into a nonlinear optimization problem to maximize the satisfaction of single index.

$$\max \xi, s.t. \begin{cases} -S_0 + \delta_1 \xi \le -Y_1 + \delta_1 \\ E_0 - \delta_2 \xi \le Y_2 + \delta_2 \\ 0 \le \xi \le 1 \end{cases} \tag{7}$$

The model is solved according to the solution flow shown in Fig. 2.

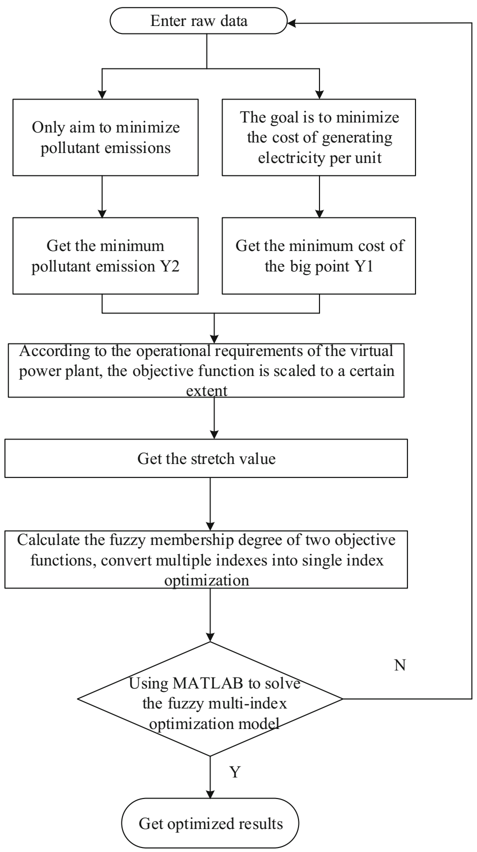


Fig. 2. Flow chart of solving multi index optimization model

Under the environment of MATLAB, the commercial software CPLEX is used to optimize the model, and the multi index model after the optimization of fuzzy membership function is solved. It is concluded that the unit output and pollutant emission under the maximum satisfaction degree are the optimal schemes of the model. So far, the design of controllable index optimization method of virtual power plant with electric vehicle based on cloud computing platform has been completed.

3 Experimental Analysis

3.1 Experimental Parameter Setting

Because the design of this paper is based on environmental efficiency optimization as the goal, electric vehicle type, charging load, motor voltage and power, members, power consumption per kilometer, EV type are related to the utilization efficiency of electric energy and pollutant discharge volume, so these projects as experimental parameters can fully reflect the optimization effect of the design method on environmental benefits, and can guarantee the realization of the experimental purpose. The differences in the experimental parameters will not affect the experimental results, but also make them more comprehensive and objective. According to the above contents, a virtual power plant with electric vehicles is selected as the research object, and the EV types and parameters are shown as Table 2.

Table 2. EV types and related parameters

EV type number of sets	Official vehicle	Business purpose vehicle	Private car		
			To work in an office	Family	Market
Charging load	600	400	2000	7000	1000
Motor voltage and power	12.18	12.18	7.06	3.52	23.96
Number of members	48 V/1000 W	60 V/1200 W	48 V/4000 W	48 V/4000 W	60 V/2800 W
Power consumption per kilometer	4	4	4	4	4
EV type	0.30 kWh/km	0.30 kWh/km	0.15 kWh/km	0.15 kWh/km	0.15 kWh/km

The environmental benefit standards formulated in the experiment are shown in Table3.

Table 3. Environmental benefit standard of polluted gas

Index	Penalty coefficient 10000 yuan/kg	Environmental value/(10000 yuan/kg)
CO_2	0.0075	0.01725
SO_2	0.750	4.50
NO_x	1.50	3.00

Based on the above experimental conditions, the traditional index optimization method based on neural network and the index optimization method based on cluster analysis are used to verify the actual level of different optimization methods with the goal of environmental benefit optimization.

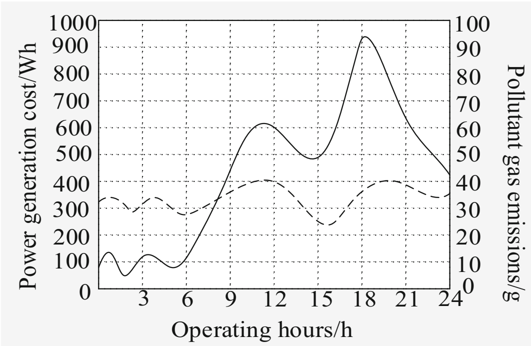
3.2 Experimental Results and Analysis

The experimental results of different optimization methods based on the above experimental conditions are shown in the Fig. 3.

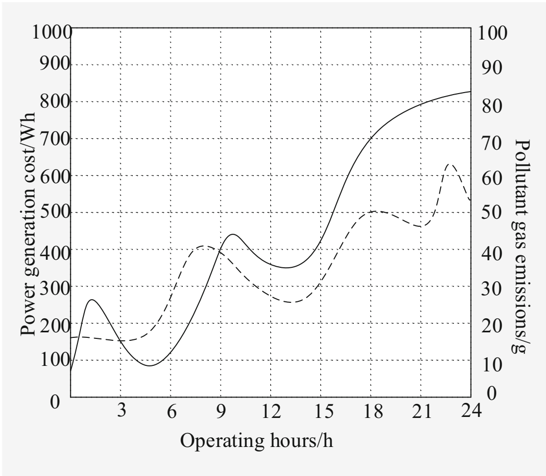
The solid line in the figure represents the cost of power generation, and the dotted line represents the emission of pollutants. Compared with the results in the observation chart, it can be seen from the results that the power generation cost of the index optimization method based on the cloud computing platform is lower than other methods, the highest cost of power generation did not exceed 500 Wh, and the pollutant emission is less than other methods, the emissions are below 20 g. From this feature, it shows that the index optimization method based on the cloud computing platform mainly considers the amount of pollution gas emitted by power generation, uses cleaner unit units to generate electricity, encourages internal load to actively participate in demand response, realizes peak shaving and valley filling, improves the utilization rate of wind power at night, reduces the cost and realizes environmental protection.

Based on the above results, the environmental benefits of different index optimization methods are obtained through calculation, and the differences between different optimization methods are intuitively displayed. The calculation results are shown in Table 4.

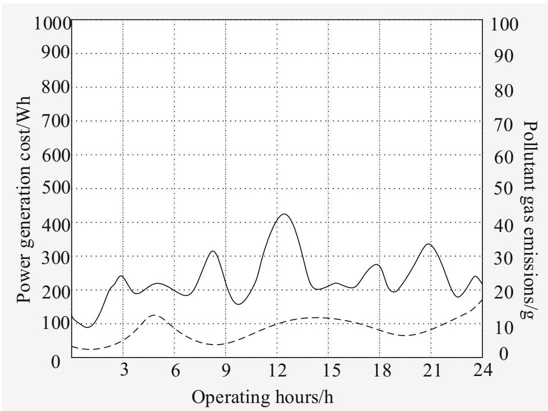
It can be seen from the data in the table that the index optimization method based on cloud computing platform has higher index benefit, index benefit all are above 9.45. The traditional index optimization method has lower environmental benefit. This is because the traditional optimization method uses more clean energy due to the reduction of electricity sales, which makes the overall income decline. Combined with the experimental results in the previous section, it can be seen that the design of cloud computing platform based operation controllable index optimization method with electric vehicle virtual power plant has high environmental benefits and more environmental protection.



(a) Experimental results of index optimization method based on Neural Network



(b) Experimental results of index optimization method based on cluster analysis



(c) Experimental results of index optimization method based on cloud computing platform

Fig. 3. Changes of power generation cost and pollution emission during power plant operation

Table 4. Calculation results of environmental benefits of different index optimization methods

	Environmental benefits of index optimization method based on neural network	Environmental benefits of index optimization method based on cluster analysis	Environmental benefits of index optimization method based on cloud computing platform
Unit 1	2.63	3.21	9.45
Unit 2	2.94	3.36	9.67
Unit 3	2.29	3.74	9.96
Unit 4	2.45	3.96	9.58
Unit 5	2.51	3.29	9.49

4 Conclusion and Outlook

Firstly, this paper investigates the background of virtual power plant planning and controllable index optimization, and clarifies the purpose and significance of the research. The concept and basic structure of virtual power plant are defined, and the implementation status and academic research results of virtual power plant projects at home and abroad are summarized. Then, starting from the optimization of controllable index of virtual power plant with electric vehicles, aiming at the problems existing in the previous optimization methods, the cloud computing platform is applied in the index optimization. Through comparative experiments, the high performance and high level of the controllable index optimization method of virtual power plant with electric vehicles based on the cloud computing platform is verified, which solves the traditional optimization method. The existing problems in this paper contribute to the operation of virtual power plant including electric vehicles. However, this paper starts with the optimization of controllable indicators of electric vehicle virtual power plants. The main goal of the design plan is to optimize environmental benefits without considering the economic benefit optimization of virtual power plants. Future research could serve as the direction to optimize the economic efficiency of electric vehicle virtual power plants and improve the market share of electric vehicles.

Fund Projects. The Science and Technology Project of State Grid Jiangsu Electric Power Co., Ltd. "Research on Key Technologies of Intelligent Management of Electric (Steam) Vehicles and Operation Mode of Virtual Power Plants".

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