Research on the operation modes of hydropower station based on complementary characteristics

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Abstract

Including wind-PV-ES (Wind/Photovoltaic/Energy storage) hybrid power generation system into the scheduling system of grid is the development tendency of safe grid-connection and operation of large wind-PV-ES hybrid power generation system. To solve the active power control problems in hybrid power generation system, this paper analyzes genetic algorithm and quantum genetic algorithm, and also analyzes the importance of energy storing devices in scheduling. Based on this, an optimization model of active power in wind-PV-ES is established. With the expectation of power output fluctuation of the power generation system as the objective function, the optimal scheduling scheme for the model is sought through genetic algorithm and quantum genetic algorithm respectively. The results of Matlab experiment show that the optimal scheduling scheme obtained by means of quantum genetic algorithm is superior to the scheduling scheme obtained by means of traditional genetic algorithm.

Keywords: Hybrid power generation system, Power control, Genetic algorithm, Quantum genetic algorithm

1 Introduction

With the developing of industry in modern times, energy problems have become a puzzle challenging the economic development of all countries in the world. As traditional energies are limited, for instance, petroleum and coal resources, in addition, traditional energies may bring unrecoverable damages to the environment, therefore, the development strategy of "Vigorously developing hydropower, optimally developing thermal power, actively developing nuclear power, and industriously to developing new energies" has been recognized by all countries in the world in recent years [1].

As a technically mature renewable energy power generation, hydropower is an important measure to guarantee energy supply. With the advantages of renewability, low operation expenses, being clean and environmental-friendly, strong ability in peak-load shaving and frequency modulation and the ability of restoring biological environment etc., more and more attention has been paid to hydropower. The construction of hydropower stations has taken shape in China. By far, over 170 hydropower stations have been built in 12 hydropower bases in upper and middle reaches of the Yellow River and Wujiang in China [2]. See Table 1 for the conditions of hydropower stations.

TABLE 1 Construction conditions of hydropower stations in China

Reservoir	Total storage (hundred million m^3)	Normal water level (m)	Installed capacity (ten thousand kw)	Annual energy output (hundred million kw)
The Three Gorges	393	175	1820	847
The Gezhou Dam	15.8	66	271.5	157
Ertan	58	1200	3300	170
Gongzui	3.1	48	70	34.18
Liyuan	7.27	1618	240	97.53
Ahai	8.82	1504	200	88.77
Guanyinyan	20.72	1134	300	122.4
Wudongde	76	975	870	387
Baihetan	188	820	1200	515
Xiluodu	126.7	600	1386	571.2
Xiangjiaba	51.63	380	640	307.47
Shuibuya	45.8	400	1600	39.2
Gaobazhou	4.3	80	25.2	8.98
Geheyan	34	200	120	30.4
Longyangxia	247	2600	128	23.6
Lijiaxia	16.5	2180	200	59
Liujiaxia	57	1735	122.5	55.8
Yanguoxia	2.2	1619	45.2	22.4
Wanjiazhai	8.96	977	108	27.5
Tianqiao	0.67	834	12.8	6.07
Liujiaxia	57	1735	122.5	55.8
Xiaolangdi	126.5	275	180	51
Xiaolangdi	126.5	275	180	51
…	…	…	…	…

See Figure 1 for the typical diagram of hydropower station.

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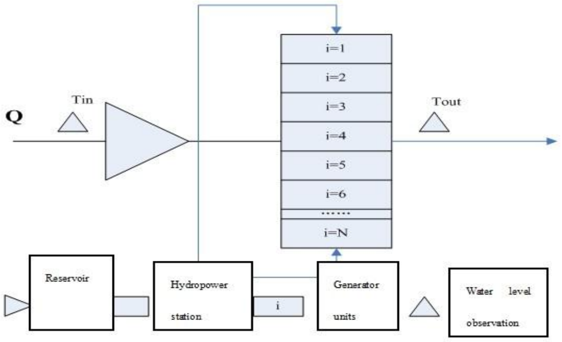
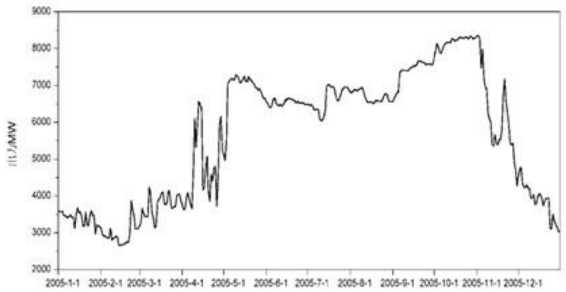


FIGURE 1 Typical diagram of hydropower station

The output power ability of a hydropower station is affected by the total storage, water level, installed capacity and the quantity of generator sets etc., therefore, the generated energy of a hydropower station is generally nonlinear. Figure 2 shows the power generating condition of a hydropower station in one year.



FIDURE 2 Diagram of the output of a hydropower station

Being affected by the said various factors, it is difficult for hydropower cater to the terminal demand during peak electricity demand period. Considering the actual problems, this paper mainly discusses multi-energy complementary power generation under the condition when hydropower cannot cater to the users' terminal demand under ideal status. At this moment, the output of the hydropower station can be deemed as a constant value. Among various renewable energies, solar energy and wind energy have been widely utilized, and they have been both used for power generation. However, both solar energy and wind energy are featured by low energy density and instability etc., therefore, using solar power generation or wind power generation alone cannot provide stable power supply output. Traditional processing method is to add energy storing devices additionally; however, the effects of such practice generally increases the equipment input of the power plants. In view of the complementary characteristics of the power supplies, the optimal scheduling scheme can be obtained through corresponding algorithms. The output of electric energy of wind-solar hybrid power generation can be perfected by scheduling the charging and discharging time of the energy storing devices every day, so as to enable wind-solar hybrid power generation to provide stable and reliable electric energy like traditional thermal power generation [3].

Each evolutionary algorithm has its own advantages and disadvantages. To make multiple intelligence algorithms complement each other's advantages, integrating different algorithms for intelligent optimization by following the thought of "optimal combination" is an important research direction [4]. In this paper, quantum genetic algorithm (QGA) and quantum-behaved particle swarm algorithm are adopted by integrating quantum genetic algorithm and quantum-behaved particle swarm algorithm, and comparing the results obtained by means of the new algorithm with the results obtained by means of traditional algorithms.

2 Introduction to the algorithms

Genetic algorithm is a random search algorithm deduced by simulating biological evolutionism (the principle of survival of the fittest in natural selection, i.e., selecting the superior and eliminating the inferior) in biology. It adopts a probabilistic method, which can quickly acquire the optimal space, and adjust the searching direction automatically without presetting the searching rules. This technology has been widely applied to sectors such as solving combination optimization solution, artificial intelligence, digital processing and machine learning etc. Quantum genetic algorithm is the product of the combination of quantum computation and genetic algorithm. This algorithm makes all the individuals in the space form an independent sub-swarm according to certain rules, and traverses each individual by coding; then it evolves each individual by means of quantum rotating gate method and dynamic adjusting rotation angle, with each individual subject to independent evolution, thus obtaining the optimal individual [5, 6].

2.1 GENETIC ALGORITHM

Genetic algorithm can be simply narrated as problems that the genes in organisms seek the most dynamic chromosome. Like the nature, for the answer designated by the configuration, what genetic algorithm needs to do is to obtain the daughter chromosome with better viability through genetic algorithm [7]. In this algorithm, firstly, some number codes (i.e. chromosome) of the target problem are produced randomly, and these number codes shall be defined as the first generation population. Fitness assessment shall be carried out on each individual with the preset fitness function, in which the individuals with poor fitness shall be weeded out and the individuals with good fitness shall be selected for offspring inheritance. The inherited individuals shall form a new population which becomes the second generation population, and the third, the fourth generation subject to inheritance.

Steps of algorithm:

Step 1: Initialization. Setting the size of the first generation population n, generally, n is between 30 and 60, and randomly producing an individual set P_i (i=1,2,3…n) as the first generation population; set the maximum genetic algebra *M*.

Step 2: Selecting individuals. It is also known as individual assessment stage, i.e., carrying out fitness assessment on the individuals respectively with fitness function to select the individuals with good fitness and weed out those with poor fitness. Fitness function is f (also known as objective function), then f (P_i) is the fitness of individual P_i.

$$e(P_i) = \frac{f(P_i)}{\sum(P_i)}. \tag{1}$$

If Pi is selected, Formula 1 shall be used to calculate Pi's inheritance frequency in the next generation. As known from (1), when $f(P_i)$ is large, its inheritance frequency in the next generation will be large; when $f(P_i)$ is small, its inheritance frequency in the next generation will be small; that is to say, the factor determining the inheritance frequency in the next generation lies in the fitness of the population where the individual is in.

Step 3: Crossover operation. This algorithm is similar to the biological hybridization in the nature, the process where the two parent generations conduct genic hybridization and recombination to produce the filial generation. Crossover operation is the core of genetic algorithm as well as the main way to produce the filial generation. Firstly, randomly select the same positions of two individuals in the parent generation to hybridize them in line with crossover probability. This method can be simply interpreted by the following individuals. There are two individuals S1 and S2, where S1=111000, S2=000111. According to the hybridizing rule, the two parent generations reciprocal interchange half of their information to recreate the filial generation S1=000000 and S2=111111.

Step 4: Mutation operation. According to the mutation principle of biology, this is the process during which mutation is conducted on local information of individuals in the parent generation with small probability event, and the mutant is passed onto the next generation through mutation operation.

For instance, for individual in parent generation S=11111, mutant of parent generation S=100111 can be obtained through mutation 2 and 3, and the mutant is passed on to the next generation as the new parent generation through cross operation.

A next generation population can be obtained through step 2, step 3 and step 4.

Step 5: Judgment termination condition. In case the fitness of the optimal individuals surpasses the threshold value given in advance, then inheritance shall stop. In case the fitness of the optimal individuals is still larger than the given threshold value, then the operations in step 2, step 3 and step 4 shall be continued, until meeting the maximum genetic algebra or being larger than the given threshold value.

2.2 QUANTUM GENETIC ALGORITHM

Step l: Population initialization. According to formula

$$P_i = \begin{bmatrix} \cos(t_{i1}) & \cos(t_{i2}) & \cdots & \cos(t_{in}) \\ \sin(t_{i1}) & \sin(t_{i2}) & \cdots & \sin(t_{in}) \end{bmatrix}. \tag{2}$$

The first generation population shall be formed by the n chromosomes produced randomly. Set the change value of the step length of initial rotation angle as θ_0, and set the probability of mutant chromosomes in each generation as mutation probability p_m.

Step 2: Solving spatial alternations. Map the approximate solution represented by each chromosome to continuous optimization problem equation by means of unit space $I_n=[-1,1]^n$

$$\begin{cases} \min f(x) = f(x_1, x_2, \ldots, x_n) \\ \text{s.t. } a_i \le x_i \le b_i; i = 1, 2, \ldots, n \end{cases}. \tag{3}$$

Solve space *Ω*, and calculate the fitness of each chromosome according to formula

$$\text{fit}(x) = C_{\max} - f(x). \tag{4}$$

Record the optimal solution of the very generation as $\hat{X}_0$, record the chromosome individual set of the very generation as $\hat{p}_0$. Record the optimal solution of the previous generation as X_0. Record the chromosome individual set of the previous generation as p_0. If fit ($\hat{x}_0$) > fit (x_0), then $p_0 = \hat{p}_0$; if fit ($\hat{x}_0$) <= fit (x_0), then $p_0 = \hat{p}_0$.

Step 3: for each quantum bit on each chromosome in the population, set the corresponding quantum bit in p_0 as the target, determine the size of the rotation angle in line with Formula (2) according to the rotation angle orientation, and update the quantum bit by means of the quantum rotating gate.

Step 4: carry out mutation on each chromosome in the population according to mutation probability by means of quantum negation gate.

Step 5: Return to Step 2 for circulative calculation until meeting the condition of convergence or the algebra reaches the maximum limitation [8, 9].

3 Researches on the optimal scheduling of Wind-PV-ES power generation system

The basic requirement of electrical power system is safe and reliable, economical and practical as well as superior quality of voltage. The requirement of economic development on electrical power system increases year by year, meanwhile, electrical power system also sees earth-shaking changes year by year. Apart from traditional thermal power generation, a group of emerging operational modes of electrical power system are growing up gradually. Meanwhile, some new problems also occur accordingly [10]: environmental destruction problems are still unsolved, the users' electricity demand surpasses the transmission capacity of the grid, the users' requirement on the voltage quality of the grid is increasingly high, disturbance problem of the huge grid is increasing prominent, the maximum capacitance of the system turnaround cannot cater to the users' high load electricity demand, the users' technology for electric energy management lags behind etc.

At the beginning of this century, the US became the first to suffer from electricity shortage. The demand of users in some regions surpassed the generating capacity of power plants, which led to repeatedly power failure in those regions. After that, many countries in the world suffered from the problem of short supply of power plants to some different extents. China has seen power rationing phenomenon in many regions for many consecutive years since 2002, power shortage is particularly serious in those first-tier cities such as Beijing, Shanghai and Guangzhou etc. in summer. Electrical power system lags behind the users' electricity demand in respect of transmission capacity and system scheduling link. Moreover, this contradiction will continuously exert an influence worldwide in a long period, which will bring a long-term challenge for the operation of electrical power system [11].

Currently, electrical power system lacks of efficient compensation method and device for active power, while traditional method is to use standby generators, which has slow response speed. In electrical power system, in case of system failure, the standby generators cannot make corresponding change quickly enough, therefore, the stability of electrical power system cannot be guaranteed. Serious system failure may break down the electrical power system.

Energy storage technology is a kind of technology applied in electrical power system in early stage. This technology can solve the problem of unbalanced power supply of the grid to some extent. Currently, the main functions of energy storage technology in electrical power system include increasing the stability of electrical power system, improving power supply quality and voltage peak-load shaving etc.

The working principle of energy storing device is when the electrical load of the users are low, the energy storing device can charge as the load, and when the electrical load of the users are at the peak, the energy storing device can work as the power generating means [12]. This method can reduce the power consumption in electrical grid, and play the role of load shifting for the voltage in the grid, thus satisfy the stable work of the electrical power system. In addition, compared with diesel generators, energy storing device is provided with the advantages of low electricity cost and fast response speed etc. [13].

4 Probability distribution of the output by wind power, photovoltaic power and energy storage system

4.1 PROBABILITY DISTRIBUTION OF THE OUTPUT BY WIND GENERATOR UNITS

The data in literature [14] indicates that the variation of wind speed with time can meet Rayleigh distribution:

$$f(v) = \frac{v}{\sigma_w^2} \exp\left(-\frac{v^2}{2\sigma_w^2}\right), \tag{5}$$

where $\sigma_w = \left(\frac{\pi}{2}\right)^{-\frac{1}{2}} v$, is the distribution parameter, v is the speed at a certain moment.

The generating power of wind generator units is as shown in Figure 3.

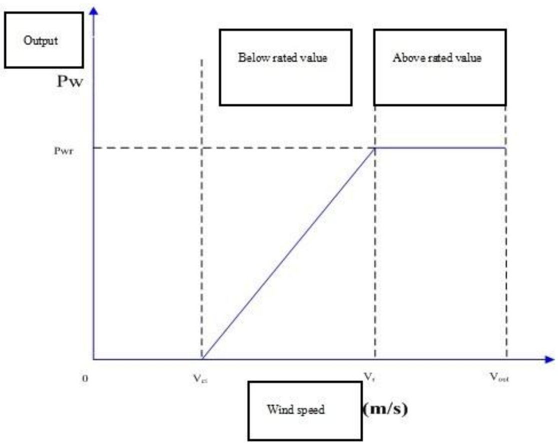


FIGURE 3 The generating power of wind generator units

The expression of the model that the wind generators units convert wind power is:

$$P_w = \begin{cases} 0 & 0 \le v(t) \le v_{ci} \quad or \quad v(t) \ge v_{out} \\ av(t) + b & v_{ci} \le v(t) \le v_r \\ P_w r & v_r \le v(t) \le v_{out} \end{cases}, \tag{6}$$

where

$$a = \frac{P_{wr}}{v_r - v_{ci}}, \tag{7}$$

$$b = -av_{ici}. \tag{8}$$

In the expression: v_{ci} is for cut-in wind speed, v_r is for rated wind speed, v_{out} is for cut-out wind speed, and P_{wr} is for the rated power.

The expectancy value of the output power of the wind generator units $E(P_W)$ and second order origin moment.

$$E(P_w) = a\left[-v_r \exp(-\frac{v_r^2}{2\sigma_w^2}) \pm v_{ci} \exp(-\frac{v_{ci}^2}{2\sigma_w^2}) + \sqrt{2\pi}\sigma_w\left(\Phi\left(\frac{v_r}{\sigma_w}\right) - \Phi\left(\frac{v_{ci}}{\sigma_w}\right)\right)\right] - b\left[\exp(-\frac{v_r^2}{2\sigma_w^2}) - \exp(-\frac{v_{ci}^2}{2\sigma_w^2})\right] - P_{wr}\left[\exp(-\frac{v_{out}^2}{2\sigma_w^2}) - \exp(-\frac{v_r^2}{2\sigma_w^2})\right] . \quad (9)$$

$$E(P_W{}^2) = 2a^2\sigma_W^2\left[\left(\frac{v_{ci}^2}{2\sigma_W^2}+1\right)\exp(-\frac{v_{ci}^2}{2\sigma_W^2}) - \left(\frac{v_r^2}{2\sigma_W^2}+1\right)\exp(-\frac{v_r^2}{2\sigma_W^2})\right] + 2ab\left[-v_r \exp(-\frac{v_r^2}{2\sigma_W^2}) + v_{in}\exp(-\frac{v_{ci}^2}{2\sigma_W^2}) + \sqrt{2\pi}\sigma_W\left(\Phi\left(\frac{v_r}{\sigma_W}\right) - \Phi\left(\frac{v_{ci}}{\sigma_W}\right)\right)\right] - b^2\left(\exp(-\frac{v_r^2}{2\sigma_W^2}) - \exp(-\frac{v_{ci}^2}{2\sigma_W^2})\right) - P_{wr}^2\left[\exp(-\frac{v_{out}^2}{2\sigma_W^2}) - \exp(-\frac{v_r^2}{2\sigma_W^2})\right] . \quad (10)$$

In the expression: Φ_0 is standard normal distribution function.

Therefore, the variance of the output power of the wind generator units can be easily obtained as follow:

$$D(P_w(t)) = E(P_w^2(t)) - E^2(P_w(t)) . \quad (11)$$

4.2 PROBABILITY DISTRIBUTION OF THE DISPOSAL BY PHOTOVOLTAIC POWER SYSTEM

The experimental data in literature [16] indicates that the change of solar illumination intensity with time can meet Beta distribution:

$$f(r(t)) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}\left(\frac{r(t)}{r_{\max}(t)}\right)^{\alpha-1}\left(1-\frac{r(t)}{r_{\max}(t)}\right)^{\beta-1} , \quad (12)$$

where $r(t)$ is for the solar illumination intensity at t; $r_{\max}(t)$ is the maximum solar illumination intensity every day; $\Gamma()$ is Gamma function, α and β are shape parameters of Beta distribution.

Where the transient output power of photovoltaic power generator units at t is:

$$P_S(t) = r(t)A\eta , \quad (13)$$

where, η is for photoelectric conversion efficiency (which is related to time point and the making technology of solar power generation panels); A is for the total area of solar power generation array [17].

The density function of photovoltaic output power is:

$$f(P_S(t)) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}\left(\frac{P_S(t)}{P_{S\max}(t)}\right)^{\alpha-1} \cdot \left(1-\frac{P_S(t)}{P_{S\max}(t)}\right)^{\beta-1} , \quad (14)$$

where, $P_{S\max}(t)$ indicates the maximum power output every day, the maximum power output of the photovoltaic power generator units $P_{S\max}(t)$ is:

$$P_{S\max}(t) = r_{\max}(t)A\eta . \quad (15)$$

To sum up, the expectation of the output power of photovoltaic power generator units $E(P_S(t))$ is:

$$E(P_S(t)) = \frac{\alpha}{\alpha+\beta}P_{S\max}(t) . \quad (16)$$

The second order origin moment of the output power of photovoltaic power generator units $E\left(P_S{}^2(t)\right)$ is:

$$E\left(P_S{}^2(t)\right) = \frac{\alpha(\alpha+1)}{(\alpha+\beta)(\alpha+\beta+1)}P_{S\max}^2(t) . \quad (17)$$

Thus, the variance of the output power of photovoltaic power generator units $D(P_S(t))$ is:

$$D(P_S(t)) = \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)}P_{S\max}^2(t) . \quad (18)$$

5 Model of energy storing device

5.1 OBJECTIVE FUNCTION

While ignoring the power consumption in power grid transmission (or attribute this part of energy consumption to power consumption at client side), the users' service power of the electrical power system during t time interval is $P_L(t)$, the output power of the wind generator units is $P_W(t)$, the output power of photovoltaic power generator units is $P_S(t)$, the sum of the powers in t time interval is recorded as power output fluctuation $P(t)$:

$$P(t)=P_L(t)-P_S(t)-P_W(t)-P_e(t), \tag{19}$$

when the system energy storing device charges, $P_e(t)$ will be a negative value; when the energy storing device discharges, $P_e(t)$ will be a positive value [19,20].

Assume N times of scheduling shall be carried out for the system, then the average value of power output fluctuation due to system scheduling is:

$$P_{avg}=\frac{1}{T}\Sigma_{t=1}^{T}P(t). \tag{20}$$

Through the above-mentioned analysis, the expectation of the power output fluctuation during the time interval of N times of scheduling everyday can be set as the objective function, and its function expression is:

$$\min F\left(P(t)\right)=E\left[\frac{1}{T}\Sigma_{t=1}^{T}\left(P(t)-P_{avg}\right)^2\right]=E\left[\frac{1}{T}\Sigma_{t=1}^{T}P^2(t)-\left(\frac{1}{T}\Sigma_{t=1}^{T}P(t)\right)^2\right]=\frac{1}{T}\Sigma_{t=1}^{T}E\left(P^2(t)\right)-\frac{1}{T^2}E^2\left(\Sigma_{t=1}^{T}P(t)\right), \tag{21}$$

where

$$E\left(P^2(t)\right)=E^2\left(P_L(t)-P_S(t)-P_W(t)-P_e(t)\right)=\left(P_I(t)-P_e(t)\right)^2+E\left(P_W{}^2(t)\right)+E\left(P_S{}^2(t)\right)-2\left(P_I(t)-P_e(t)\right)^2\left(E\left(P_S(t)\right)+E\left(P_W(t)\right)\right)+2E\left(P_S(t)\right)E\left(P_W(t)\right). \tag{22}$$

$$E^2\left(\Sigma_{t=1}^{T}P_S(t)\right)=\Sigma_{t=1}^{T}D\left(P_S(t)\right)+\left(\Sigma_{t=1}^{T}E\left(P_S(t)\right)\right)^2, \tag{23}$$

$$E^2\left(\Sigma_{t=1}^{T}P_W(t)\right)=\Sigma_{t=1}^{T}D\left(P_W(t)\right)+\left(\Sigma_{t=1}^{T}E\left(P_W(t)\right)\right)^2. \tag{24}$$

Substitute (22), (23), (24) in to expression (21), the objective function of the model can be obtained.

5.2 CONSTRAINT CONDITION

5.2.1 Installed capacity of the energy storing device

The electrical energy stored by the energy storing device cannot exceed the upper and lower limits of the capacity

$EES_{min} \leqslant EES(t) \leqslant EES_{max}$.

In the expression, EES(t) is the electrical energy stored in the energy storing device at the end of *t* time interval; EES_{max} and EES_{min} are the upper and lower limits of energy storage [21].

5.2.2 Constraint of the charge-discharge power of energy storing device

The charge-discharge power of energy storing device must be less than the maximum discharge power of the energy storing device, i.e. $|PRES(t)| \leq PES_{max}$.

In the expression, PES_{max} is the maximum high charge and discharge power of the energy storing device.

5.2.3 Constraint of energy balance

EES(t)=EES(t-1)- PRES(t)· Δ t.

In the expression, EES(t), EES(t-1) indicate the energy state of the energy storing device at the end of *t* and (*t-1*) moment respectively; the difference between the two indicates the energy discharged or absorbed during *t* time interval; PRES(*t*) stays unchanged in *t* time interval.

5.2.4 The energy in the energy storing device stays unchanged in the first and last time interval in one period

EES(t)=EES(0).

In the expression, EES(0) indicates the initial energy state, EES(t) indicates the energy state at *T* moment [19, 21].

6 Calculation examples and simulation results

Take an example of the wind-solar independent hybrid power generation system installed in a company domestically to optimize its energy storing. According to the above-mentioned design, the experimental data needed include: average sunshine data per hour every day at the installation site, see Table 2 for detailed data; the data of the average wind speed per hour in a day, see Table 3 for detailed data; the electricity utility condition at remote end, see Table 4 for the detailed data.

Parameters of wind generator units: cut-in wind speed v_{ci} is 4m/s, cut-out wind speed v_{out} is 24 m/s, rated wind speed v_r is 14 m/s, rated power P_{wr} is 200MW.

Parameters of photovoltaic power generation system: total area of solar array 3×10^6 m^2, photoelectric conversion efficiency η is 15%.

TABLE 2 Relative parameters of solar illumination intensity

Time interval	7	8	9	10	11	12	13	14	15	16	17	18	19
Maximum solar illumination intensity (W/m^2)	3	15	41	53	68	86	89	79	74	58	46	12	2

TABLE 3 Parameters of wind speed change

Time (h)	1	2	3	4	5	6	7	8	9	10	11	12
Wind speed (m/s)	20	15	14	8	10	14	15	16	16	7	8	10
Time (h)	13	14	15	16	17	18	19	20	21	22	23	24
Wind speed (m/s)	9	18	20	16	18	17	15	18	16	18	21	22

TABLE 4 Load parameters

Time (h)	1	2	3	4	5	6	7	8	9	10	11	12
Load (MW)	925	880	800	715	710	825	960	1075	1100	1125	1165	1225
Time (h)	13	14	15	16	17	18	19	20	21	22	23	24
Load (MW)	1200	1050	975	960	950	1025	1150	1150	1215	1150	970	935

6.1 RESULTS OF GENETIC ALGORITHM OPTIMIZATION

Parameters of genetic algorithm: take the population size as 200, crossover probability as 0.8, mutation probability as 0.1, evolution algebra as the 500th algebra, the variable number as 24, which represent the charge and discharge condition of the energy storing device per hour in the 24 hours every day. According to the said model, the following changing condition of objective function with the evolution algebra shall be obtained, which is as shown in Figure 4. The optimal charge and discharge time is as shown in Figure 5.

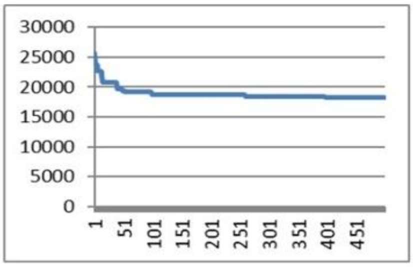


FIGURE 4 The changing condition of objective function value obtained by means of genetic algorithm

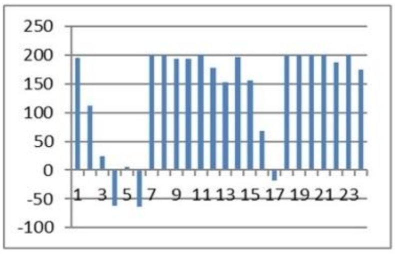


FIGURE 5 The optimal charge and discharge time obtained by means of genetic algorithm optimization

The final objective function value is converged to 1.8305×10^4.

6.2 RESULTS OF QUANTUM GENETIC ALGORITHM OPTIMIZATION

Parameters of quantum genetic algorithm: take the population size as 200, rotation angle length as 0.001π, evolution algebra as the 500th algebra, the variable number as 24, which represent the charge and discharge condition of the energy storing device per hour in the 24 hours every day. According to the previous discussion, the following changing condition of objective function with the evolution algebra shall be obtained, which is as shown in Figure 6. The optimal charge and discharge time is as shown in Figure 7.

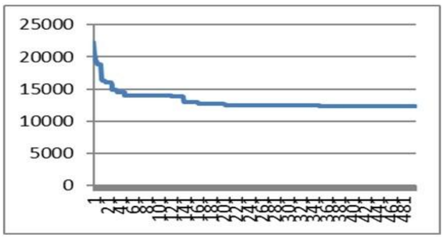


FIGURE 6 The changing condition of objective function of by means of quantum genetic algorithm

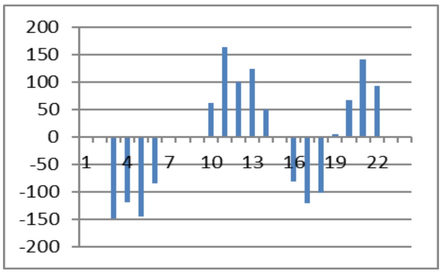


FIGURE 7 The optimal charge and discharge time value obtained by means of quantum genetic algorithm

The final objective function value is converged to 1.2424×10^4.

The results show that, reasonably arranging the charge and discharge time of the energy storing device can minimize the fluctuation of the system, thus making the system more stable. In the model established in this paper, its' obvious that quantum genetic algorithm is superior to genetic algorithm, with the optimization results obtained by quantum genetic algorithm more reasonable. This indicates that quantum genetic algorithm has broad application prospect and efficient optimization efficiency.

7 Conclusions and prospect

The model constructed in this paper takes into consideration the complementary characteristics among the power generations systems, and obtains the optimal scheduling scheme by means of genetic algorithm and optimized genetic algorithm. Reasonable charge and discharge for the energy storing device can effectively improve and even solve the deficiencies in respect of power generation by renewable resources, which can effectively improve the stability of the system's output voltage. In the model constructed in this paper, the assumption is wind speed subject to Rayleigh distribution and solar illumination intensity subject to Beta distribution, the objective function is power output fluctuation, corresponding constraint conditions are set, and the optimal scheduling scheme is obtained by means of genetic algorithm and quantum genetic algorithm. The experimental results show that the optimal scheduling scheme obtained by means of quantum genetic algorithm is superior to that obtained by means of traditional genetic algorithm. The quantum genetic algorithm adopted in this paper is also a relatively new optimization algorithm whose application field is very small; however, seen from some respects in this paper, the effectiveness of quantum optimization algorithm can completely surpass traditional algorithm, and can be widely applied.

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