

Optimization Research of AC/DC Power Grid Considering Complementary Characteristics of Multiple Power Source

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Abstract. With the rapid development of wind power generation and photovoltaic power generation. The power grid stability influence by randomness and intermittence of wind and solar energy more and more serious. Although the hybrid wind/photovoltaic power generation system with energy storage (HPWS) utilize the complementary characteristics of wind and solar energy, it can improve the power generation system output power stability at some level. However, in the long term the development trend of the large HPWS is realizing the HPWS controllable operation and making the HPWS included in the AC/DC power grid scheduling system. Thence the active power control become a key problem of unite power generation system. In this paper, firstly emphatically introduces the quantum optimizing algorithm, analyze principle and advantages of the algorithm. And build HPWS active power optimization model. The aim for power generation most stability using the quantum optimizing algorithm obtain the model optimal solution. It illustrates the important of the optimal scheduling in the HPWS.

Keywords: AC/DC system; Wind power generation; Photovoltaic power generation; Energy storage system; Quantum optimizing.

1. Introduction

Application of renewable energy has become a global trend. Both solar and wind energy have the characteristics of low energy density and strong randomness. Therefore individual photovoltaic or wind power generation system are difficult to provide stable power output, and introduce energy storage device can help improve this defect, but it greatly increased the investment in AC/DC system [1-3]. Considering power complementary characteristics, utilize optimization algorithm obtaining the optimum scheduling strategy. Reasonable scheduling daily energy storage device charge-discharge time can improve the power output of wind and photovoltaic complementary system. It can make the power system has highest power supply reliability [4-6].

Now, the research of HPWS energy distribution (management) mainly in three aspects [7-9]: One, introduce the distributed technology for example the multi-Agent to HPWS. The distributed technology of multi-Agent is introduced into the HPWS. The wind power generation, photovoltaic power generation and energy storage subsystem as decentralized

Power. The distributed modules of the Agent are used as agents for each micro-power supply. Using this approach to optimize energy distribution strategy. In [10], introduce the Agent technology, study in divergent power generation scheduling of wind and photovoltaic complementary system, planning and designing the hybrid power generation problem from the perspective of macro; In [11], in order to improve the reasonable of HPWS energy management system, using unfixed and master-slave multi-Agent cooperation mechanism, According to the greatest efforts in the sample time to determine the master-slave relationship between the Agent, finally, Using digital simulation prove the feasibility of energy management system. Two, research in energy storage battery charge and discharge management. In [12] discuss the energy management of distributed power generation system, and utilizing the Super Capacitor Energy Storage (SCES) to improve the system stability. In

[13], discuss an independent wind and photovoltaic complementary system energy management based on the process of control energy storage, analyzed the energy flow and completed the simulation test. In [14], study the storage battery energy management in HPWS, Put forward smoothing power output, tracking planning output, peak load shifting three scheduling models. Three, research in energy distribution system implemented in different platforms. Using intelligent energy distribution system in computer platforms, the HPWS can independent uninterruptible provide power to all kinds of load.

In this paper surrounding the HPWS energy distribution strategy expansion. Firstly introduces the quantum optimizing algorithm, introduced the concept of quantum bits. Combining the traditional Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) with quantum bits, Constituting the quantum genetic algorithm and quantum particle swarm optimization use in this paper, and explain the principle of quantum optimizing algorithm. Then analyzed the current influence of power stability when the large scale wind power generation and photovoltaic power generation connected to power grid. According to this aspect analyzing to show that it is an urgent problem to improve the HPWS stability of active power output by optimizing the active power control system. So, in this paper depth analysis the grid power scheduling and

Planning for active power quality requirement of the wind power generation and photovoltaic power generation connected to the grid. And wind power generation and photovoltaic power generation active power scheduling models, .using the models as the basic goal and design basis of HPWS energy distribution strategy, utilizing the quantum genetic algorithm solve the models .At last, the stochastic programming theory is introduced into the containing wind power generation power system dynamic economic scheduling problem. Based on the wind speed prediction, considering unit commitment build the containing wind power generation power system dynamic economic scheduling stochastic model. Utilizing quantum particle swarm optimization solve the models, compare with the traditional particle swarm optimization show that the new algorithm has better convergence speed and search performance.

2. Quantum evolutionary algorithm

2.1 Quantum Genetic Algorithm.

Quantum Genetic Algorithm (QGA) [15-16].Based on the concept of quantum bits and quantum superposition. In the quantum computer the quantum bits or quantum bits are the smallest information unit. A quantum bit can be in $|0\rangle$ state, $|1\rangle$ state, and between $|0\rangle$ state and $|1\rangle$ state arbitrary superposition state. A quantum bit state can be describe:

$$|\varphi\rangle = \alpha|0\rangle + \beta|1\rangle \quad (1)$$

Where: α , β are complex number. Called the quantum bit corresponding state probability amplitude. $|\alpha|^2$ is the probability of quantum bit can be observed $|0\rangle$ state, $|\beta|^2$ is the probability of quantum bit can be observed $|1\rangle$ state, and satisfy the normalization condition:

$$|\alpha|^2 + |\beta|^2 = 1 \quad (2)$$

If a system there are m quantum bits, then the system can be described 2^m states, however, when observe the system it collapses a certain state.

Traditional evolutionary calculation of chromosome coding can take many forms: Binary, Decimal, Symbol encoding etc. The coding form utilize based on quantum bit in the QGA.

A quantum bit can be defined by the probability amplitude as $\begin{pmatrix} \alpha \\ \beta \end{pmatrix}$, so can define the m quantum bits

as:

$$\begin{pmatrix} \alpha_1 & \alpha_2 & \cdots & \alpha_m \\ \beta_1 & \beta_2 & \cdots & \beta_m \end{pmatrix} \quad (3)$$

Where: $|\alpha|^2 + |\beta|^2 = 1, i = 1, 2, \dots, m$. The advantage of this describe is that it can express arbitrary superposition state. For example the system has three bits, with three pairs of probability amplitude:

$$\begin{pmatrix} \frac{1}{\sqrt{2}} & 1 & \frac{1}{2} \\ \frac{1}{\sqrt{2}} & 0 & \frac{\sqrt{3}}{2} \end{pmatrix} \quad (4)$$

Then, the system states can be described as: $\frac{1}{2\sqrt{2}}|000\rangle + \frac{\sqrt{3}}{2\sqrt{2}}|001\rangle + \frac{1}{2\sqrt{2}}|100\rangle + \frac{\sqrt{3}}{2\sqrt{2}}|101\rangle$. The above results show that probability of the system as $|000\rangle, |001\rangle, |100\rangle, |101\rangle$ respectively are $1/8, 3/8, 1/8, 3/8$. So by the formula (4) describe three bits system, it can obtain four states information.

Because of quantum system can describe superposition state. So, the coding form based on quantum bit compare with traditional evolutionary algorithm has better swarm diversity. For the chromosome described by formula (4), just need one chromosome can express four states, but the traditional evolutionary algorithm at least need for chromosomes: (000), (001), (100), (101). The swarm description based on quantum chromosome also have the diversity. When $|\alpha_i|^2$ or $|\beta_i|^2$ trend to 0 or 1, the diversity will gradually disappear, the quantum chromosome convergence to a certain state. It show that the quantum chromosome both have exploration and development ability.

In QGA, The swarm scale means the quantum chromosomes, the number of quantum chromosomes are constant. The QGA has better swarm diversity and convergence performance Because of the quantum in a superposition state,

2.2 Quantum Particle Swarm Optimization

Particle Swarm Optimization (PSO) [17-18], the intelligent optimization algorithm was proposed by American psychologist Kennedy and electrical engineer Eberhart in 1995. They inspired by birds feeding behavior. As an important optimization tool, The PSO has been successfully apply to system identification, neural network training and many areas.

The Quantum Evolutionary Algorithm (QEA) generate a binary solution through observing the state of quantum chromosomes, but the solution has a great randomness because the process of a probability operation. In this paper directly utilize the quantum bit probability amplitude express the solution of optimization problem. In this way, not only avoid the randomness by observing, but also avoid the decoding process of from binary to decimal.

In this paper, the improved QEA fusion into PSO. Propose a new Quantum Particle Swarms Optimization (QPSO) algorithm. The algorithm quantum bit code the current position of the particle and search the particle optimal position by quantum rotation gate, the quantum not gate can achieve particle position mutation to avoid precocious convergence. The simulation result show that this algorithm optimizing capacity and optimization efficiency is better than traditional PSO algorithm.

The n-dimensional space optimization problem as n-dimensional space point or vector, then the continuous optimization problems can describe as $\max f(x_1, \dots, x_n)$, where: $a_i \leq X_i \leq b_i; i = 1, 2, \dots$. The number of optimization goals are n; the definition domain of variable X_i are $[a_i, b_i]$, the objective function is f , it value can be as particle adaptability. The QPSO detail implement process as follows:

(1) Generate Initial Swarm

Directly utilize the quantum bits probability amplitude coding for the particle current position in the QPSO. Considering the randomness of code process in the initial swarm, in this paper adopt coding method below:

$$P_i = \begin{pmatrix} \cos(\theta_{i1}) & \cos(\theta_{i2}) & \dots & \cos(\theta_{in}) \\ \sin(\theta_{i1}) & \sin(\theta_{i2}) & \dots & \sin(\theta_{in}) \end{pmatrix}$$

Where: $\theta_{ij} = 2\pi \times \text{rnd}$; The rnd is a random number between (0,1); $i = 1, 2, \dots, m; j = 1, 2, \dots, n$; m as the swarm scale; n as the dimensional space; Thus the every swarm particle occupy two position in

searching space. The two position probability amplitude corresponding quantum state $|0\rangle$ and $|1\rangle$ respectively as follows:

$$p_{ic} = (\cos(\theta_{i1}), \cos(\theta_{i2}), \dots, \cos(\theta_{in})) \quad (5)$$

$$p_{is} = (\sin(\theta_{i1}), \sin(\theta_{i2}), \dots, \sin(\theta_{in})) \quad (6)$$

For expression convenient, the p_{ic} called cosine position; the p_{is} called sine position.

(2) Solution Space Transformation

In the QPSO, Because of the particles search space for $[-1, 1]$ in every dimension. For calculating advantage or disadvantage in current particle position, the solution space need transform. The two position occupied by particle from unit space $1^n = [-1, 1]^n$ map to the optimization problem solution space. Every quantum bit probability amplitude corresponding an optimization variable. Record the i th quantum bit is $[\alpha_i^j, \beta_i^j]^T$ in particle P_j , then the variable in solution space as:

$$X_{ic}^j = \frac{1}{2}[b_i(1 + \alpha_i^j) + a_i(1 - \alpha_i^j)] \quad (7)$$

$$X_{is}^j = \frac{1}{2}[b_i(1 + \beta_i^j) + a_i(1 - \beta_i^j)] \quad (8)$$

Thus, every particle corresponding two solutions in optimization problem. The quantum state $|0\rangle$ probability amplitude α_i^j corresponding X_{ic}^j ; the quantum state $|1\rangle$ probability amplitude β_i^j corresponding X_{is}^j , where: $i = 1, 2, \dots, n$; $j = 1, 2, \dots, m$;

(3) Update Particle State

The particle position moving implement by quantum rotation gate in QPSO. Thus in the traditional PSO updating particle moving speed transform updating particle quantum rotation gate of rotation angle and updating particle position transform updating particle quantum bit probability amplitude. Without loss of generality, it is assumed that the particle p_i currently search optimum position is cosine position as follows:

$$p_{il} = (\cos(\theta_{il1}), \cos(\theta_{il2}), \dots, \cos(\theta_{iln})) \quad (9)$$

The whole swarm currently search optimum position as:

$$p_g = (\cos(\theta_{g1}), \cos(\theta_{g2}), \dots, \cos(\theta_{gn})) \quad (10)$$

Based on above supposing, the principle of updating particle state can describe as follows:

1) Quantum bit position angular increment update in particle p_i as follows:

$$\Delta\theta_{ij}(t+1) = \omega\Delta\theta_{ij}(t) + c_1r_1(\theta_l) + c_2r_2(\theta_{ij}) \quad (11)$$

Where:

$$\Delta\theta_l = \theta_{il} - \theta_{ij} \quad (-\pi \leq \theta_{il} - \theta_{ij} \leq \pi) \quad (12)$$

$$\Delta\theta_g = \theta_{gi} - \theta_{ij} \quad (-\pi \leq \theta_{gi} - \theta_{ij} \leq \pi) \quad (13)$$

2) Quantum bit probability amplitude update based on quantum rotation gate:

$$\begin{bmatrix} \cos(\Delta\theta_{ij}(t+1)) \\ \sin(\Delta\theta_{ij}(t+1)) \end{bmatrix} = \begin{bmatrix} \cos(\Delta\theta_{ij}(t+1)) & -\sin(\Delta\theta_{ij}(t+1)) \\ \sin(\Delta\theta_{ij}(t+1)) & \cos(\Delta\theta_{ij}(t+1)) \end{bmatrix} \begin{bmatrix} \cos(\theta_{ij}(t)) \\ \sin(\theta_{ij}(t)) \end{bmatrix} = \begin{bmatrix} \cos(\theta_{ij}(t) + \Delta\theta_{ij}(t+1)) \\ \sin(\theta_{ij}(t) + \Delta\theta_{ij}(t+1)) \end{bmatrix} \quad (14)$$

Where: $i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$;

After updating the particle two new position respectively:

$$\tilde{p}_{ic} = (\cos(\theta_{i1}(t) + \Delta\theta_{i1}(t+1)), \dots, \cos(\theta_{in}(t) + \Delta\theta_{in}(t+1))) \quad (15)$$

$$\tilde{p}_{is} = (\sin(\theta_{i1}(t) + \Delta\theta_{i1}(t+1)), \dots, \sin(\theta_{in}(t) + \Delta\theta_{in}(t+1))) \quad (16)$$

It show that the quantum rotation gate through changing the quantum bit phase (expression particle position) implement two position moving in the same time. Therefore the situation of a swarm scale is

constant, adopting quantum bit coding can expand searching ergodic, it benefit to improve the algorithm optimization efficiency.

(4) Mutation Processing

The main reason of PSO algorithm easy to fall into local minimum value is that swarm diversity lost in the process of searching. Introduced the mutation operator in the process of evolution, it can increase the swarm diversity to avoid precocious convergence. The operate processing of mutation by quantum not gate as follows:

$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} \cos(\theta_{ij}) \\ \sin(\theta_{ij}) \end{bmatrix} = \begin{bmatrix} \sin(\theta_{ij}) \\ \cos(\theta_{ij}) \end{bmatrix} = \begin{bmatrix} \cos(\frac{\pi}{2} - \theta_{ij}) \\ \sin(\frac{\pi}{2} - \theta_{ij}) \end{bmatrix} \quad (17)$$

Where: $i \in \{1, 2, \dots, m\}$, $j \in \{1, 2, \dots, n\}$.

The mutation probability can suppose P_m , every particle can set a random number $rndi$ between (0, 1), if $rndi < P_m$ the random number select $[n/2]$ quantum bits in particle and utilize quantum not gate exchange two probability amplitude. The memory of particle optimum position and rotation vector remain unchanged.

3. Optimality schedule model

This paper creates a power system collaborative scheduling model, the model contain all energy storage devices, wind and photovoltaic power generation and considering output uncertainly at the same time. It can smooth renewable energy output fluctuations in a day. Firstly, exporting the output levels probability distribution of energy storage device, wind power generation and photovoltaic power generation system, then the objective function analytical expression formula of smooth renewable energy output fluctuations can be exported. Based on that, the considering energy storage device charge-discharge and network security constraints random optimization scheduling model can be established. Secondly, utilizing the QGA solve the developmentally optimization model. At last, the simulation result show that the model can effectively reduce the output fluctuations of renewable energy for power grid and improve the economics of power system operation.

3.1 Probability Distribution of Wind Turbines Output

The research shows that can think of in t moment the wind speed meet the distribution of Rayleigh [20-22]:

$$f(v) = \frac{v}{\sigma_w^2} \exp(-\frac{v^2}{2\sigma_w^2}) \quad (18)$$

$$\sigma_w = (\frac{\pi}{2})^{\frac{1}{2}} v \quad (19)$$

Where: the v called wind speed; σ_w called the distributed parameter.

The expression formula of wind turbines output:

$$P_w = \begin{cases} 0 & 0 \leq v(t) \leq v_{in} \text{ or } v(t) \geq v_{out} \\ av(t) + b & v_{in} \leq v(t) \leq v_r \\ P_{wr} & v_r \leq v(t) \leq v_{out} \end{cases} \quad (20)$$

$$a = \frac{P_{wr}}{v_r - v_{in}} \quad (21)$$

$$b = -av_{in} \quad (22)$$

Where: v_{in} , v_r , v_{out} , P_{wr} respectively express cut-in wind speed, rated wind speed, cut-off wing speed; rated power.

The expression formula of wind turbines output expectation ($E(P_w)$) and 2-order moment about the origin ($E(P_w^2)$):

$$E(P_w) = a[-v_r \exp(-\frac{v_r^2}{2\sigma_w^2}) + -v_{in} \exp(-\frac{v_{in}^2}{2\sigma_w^2}) + \sqrt{2\pi}\sigma_w (\phi(\frac{v_r}{\sigma_w}) - \phi(\frac{v_{in}}{\sigma_w}))] \quad (23)$$

$$E(P_w^2) = 2a^2\sigma_w^2[(\frac{v_{in}^2}{2\sigma_w^2} + 1)\exp(-\frac{v_{in}^2}{2\sigma_w^2}) - (\frac{v_r^2}{2\sigma_w^2} + 1)\exp(-\frac{v_r^2}{2\sigma_w^2})] - 2ab[-v_r \exp(-\frac{v_r^2}{2\sigma_w^2}) + v_{in} \exp(-\frac{v_{in}^2}{2\sigma_w^2}) + \sqrt{2\pi}\sigma_w (\phi(\frac{v_r}{\sigma_w}) - \phi(\frac{v_{in}}{\sigma_w})) - b^2(\exp(\frac{v_r^2}{2\sigma_w^2}) - \exp(\frac{v_{in}^2}{2\sigma_w^2}))] \quad (24)$$

Where:

The $\phi(\cdot)$ called standard normal distribution function.

The variance of wind turbines output power:

$$D(P_w(t)) = E(P_w^2(t)) - E^2(P_w(t)) \quad (25)$$

3.2 Probability Distribution of Photovoltaic Power Generation System

The research shows that can think of in t moment the solar light intensity $r(t)$ meet the distribution of Beta [23-25]:

$$f(r(t)) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} (\frac{r(t)}{r_{\max}(t)})^{\alpha-1} (1 - \frac{r(t)}{r_{\max}(t)})^{\beta-1} \quad (26)$$

Where: $r_{\max}(t)$ called the max light intensity in t moment; $\Gamma(\cdot)$ called Gamma function; α and β called the Beta distribution parameters.

The expression formula of photovoltaic power generation output:

$$P_s = r(t)A\eta \quad (27)$$

Where: The A express the area of photovoltaic array. The η express photoelectric transformation efficiency.

The probability density function of photovoltaic output power:

$$f(P_s(t)) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} (\frac{P_s(t)}{P_{s\max}(t)})^{\alpha-1} \cdot (1 - \frac{P_s(t)}{P_{s\max}(t)})^{\beta-1} \quad (28)$$

Based on formula (2.6), the max output power $P_{s\max}(t)$ of photovoltaic power generation in the t moment, expression as:

$$P_{s\max}(t) = r_{\max}(t)A\eta \quad (29)$$

In combination with formula (2.4), the expression formula of photovoltaic power generation output expectation ($E(P_s)$), variance $D(P_s(t))$ and 2-order moment about the origin ($E(P_s^2)$):

$$E(P_s(t)) = \frac{\alpha}{\alpha + \beta} P_{s\max}(t) \quad (30)$$

$$D(P_s(t)) = \frac{\alpha\beta}{(\alpha + \beta)^2(\alpha + \beta + 1)} P_{s\max}^2(t) \quad (31)$$

$$E(P_s^2(t)) = \frac{\alpha(\alpha + 1)}{(\alpha + \beta)^2(\alpha + \beta + 1)} P_{s\max}^2(t) \quad (32)$$

3.3 Objective Function & Constraint Condition

3.3.1 The Objective Function

In this paper, the storage energy device equate the all storage energy devices in the power system.

Supposing that the storage energy device power $P_e(t)$ in the T period. Where: If $P_e(t) \geq 0$, the storage energy device in discharge state. If $P_e(t) \leq 0$, the storage energy device in charge state.

Considering the system load P_L , and the sum of photovoltaic power generation output power, wind turbines output power, storage energy device output power in the t period as follows:

$$P_X(t) = P_L(t) - P_S(t) - P_W(t) - P_e(t) \quad (33)$$

Order:

$$P_X(t) = P_L(t) - P_e(t) \quad (34)$$

Then:

$$P(t) = P_X(t) - P_S(t) - P_W(t) \quad (35)$$

When the energy storage device is in the charging state, the $P_e(t)$ take negative value. It is assumed that there are T scheduling stages per day, the average output of photovoltaic power generation system, wind turbine output and energy storage device as:

$$P_{avg} = \frac{1}{T} \sum_{t=1}^T P(t) \quad (36)$$

The output fluctuation of renewable energy power generation can be measured in total variance. The objective of scheduling is to minimize the expected variance of the total variance of the power active output of the renewable energy generation over T periods, which mathematically can be expressed as:

$$\begin{aligned} \min F(P(t)) &= E\left[\frac{1}{T} \sum_{t=1}^T (P(t) - P_{avg})^2\right] \\ &= E\left[\frac{1}{T} \sum_{t=1}^T P^2(t) - \left(\frac{1}{T} \sum_{t=1}^T P(t)\right)^2\right] \\ &= \frac{1}{T} \sum_{t=1}^T E(P^2(t)) - \frac{1}{T^2} E^2\left(\sum_{t=1}^T P(t)\right) \end{aligned} \quad (37)$$

$$\begin{aligned} E(P^2(t)) &= E^2(P_X(t) - P_S(t) - P_W(t)) \\ &= E(P_X^2(t) + P_S^2(t) + P_W^2(t) - 2P_X(t)P_S(t) - 2P_X(t)P_W(t) + 2P_S(t)P_W(t)) \\ &= P_X^2(t) + E(P_X^2(t)) + E(P_S^2(t)) - 2P_X(t)((E(P_S(t)) + E(P_W(t))) + 2E(P_S(t))E(P_W(t))) \end{aligned} \quad (38)$$

$$E^2\left(\sum_{t=1}^T P_S(t)\right) = \sum_{t=1}^T D(P_S(t)) + \left(\sum_{t=1}^T E(P_S(t))\right)^2 \quad (39)$$

$$E^2\left(\sum_{t=1}^T P_W(t)\right) = \sum_{t=1}^T D(P_W(t)) + \left(\sum_{t=1}^T E(P_W(t))\right)^2 \quad (40)$$

Substituting (6)-(8), (13)-(15), and (38)-(40) into (37), we get the final optimization objective function expression

3.3.2 The Constraint Condition

1) The capacity constraints of energy storage device.

The energy stored in the device not exceed limits of the capacity upper and lower:

$$EES_{min} \leq EES(t) \leq EES_{max} \quad (41)$$

Where:

The $EES(t)$ is the energy stored by device at the end of t moment. EES_{max} , EES_{min} express the storage of energy upper and lower limits respectively.

2) The Charge and discharge power constraint of energy storage

The charging and discharging power of the energy storage device must be less than the maximum charging and discharging power, so:

$$|P_{RES}(t)| \leq PES_{\max} \quad (42)$$

Where:

The PES_{\max} is the maximum charging and discharging power of the energy storage device.

3) The constraint of energy balance

$$EES(t) = EES(t-1) - P_{RES}(t) \cdot \Delta t \quad (43)$$

Where:

The $EES(t), EES(t-1)$ express the energy storage device energy state at the end of t and $t-1$ moment. The $P_{RES}(t)$ remain unchanged in the t period.

4) The energy storage device remain the energy unchanged in begin and end of the cycle

$$EES(T) = EES(0) \quad (44)$$

Where:

The $EES(0)$ is initial energy state, the $EES(T)$ is energy state at the end of T moment.

4. The example and analysis

4.1 The example

Now, the example is based on a domestic company in the installation of a complementary hybrid wind and photovoltaic independent power generation system. According to the above design needs of the experimental data: the average sunshine hours for installation site in per hour of same day; the average wind speed curve; the equipment parameters include photovoltaic modules and wind turbines, batteries and so on (as shown in table 1-3).

Table 1. Light Intensity Related Parameters

Time period	Max light intensity (W/m ²)	α	β
7	3	0.9	0.85
8	15	0.9	0.85
9	41	0.9	0.85
10	53	0.9	0.8
11	68	0.9	0.8
12	86	0.95	0.95
13	89	0.95	0.95
14	79	0.9	0.85
15	74	0.9	0.85
16	58	0.9	0.85
17	46	0.9	0.85
18	12	0.9	0.85
19	2	0.9	0.85

Table 2. Wind Speed Change Situation

Time(h)	1	2	3	4	5	6	7	8	9	10	11	12
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
Speed(m/s)	9	18	20	16	18	17	15	18	16	18	21	22

Table 3. Load Situation

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

The QGA parameters: the swarm size are 200, the rotation step size is selected as 0.001π , the evolutionary number are 500 generations, the number of variables are 24, they represent the charging-discharging state of energy storage device per hour for 24 hours in a day.

The wind turbine parameters: the cut-in wind speed v_{in} is 4m/s, the cut-off wind speed v_{out} is 24m/s, the rated wind speed v_r is 14m/s, the rated power P_{wr} is 200MW.

The photovoltaic power generation system parameters: the total area of photovoltaic array are 3×10^6 square meters, the photoelectric transformation efficiency η is 15% [25-26].

Optimization is performed according to the aforementioned model, we get the curve about the following objective function with the evolutionary generations:

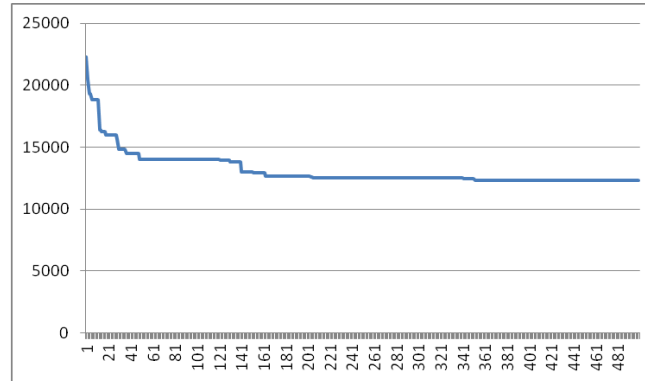


Figure 1 The change of objective function value

Finally, the objective function value converges to $1.2424e+004$.

The optimal charging and discharging time show in the following figure:

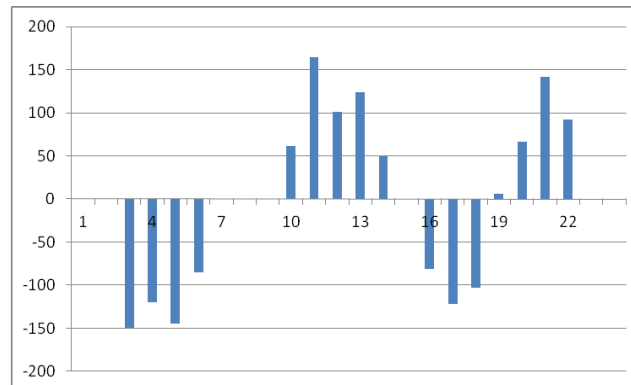


Figure 2 The optimal charging and discharging time

The results show that reasonable arrangements for energy storage device charging and discharging time can make the system fluctuation minimum, thence the system more stable.

4.2 The results of example

GA parameters: the swarm size are 200, the crossover probability is 0.8, the mutation probability is 0.1, the evolutionary number are 500 generations, the number of variables are 24, they represent the charging-discharging state of energy storage device per hour for 24 hours in a day.

Optimization is performed according to the aforementioned model, we get the curve about the following objective function with the evolutionary generations as shown in figure 3.

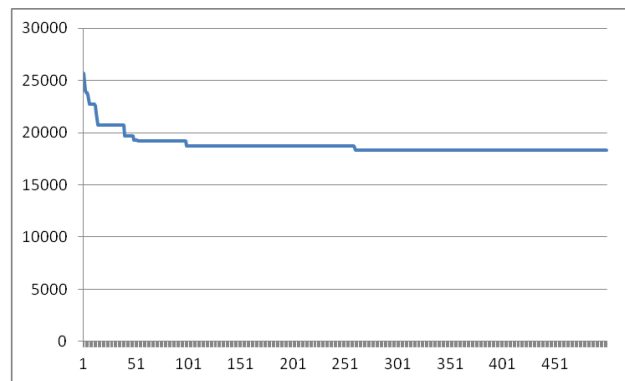


Figure 3 The change of objective function value according to GA

Finally, the objective function value converges to $1.8305e+004$.
The optimal charging and discharging time show in figure 4.

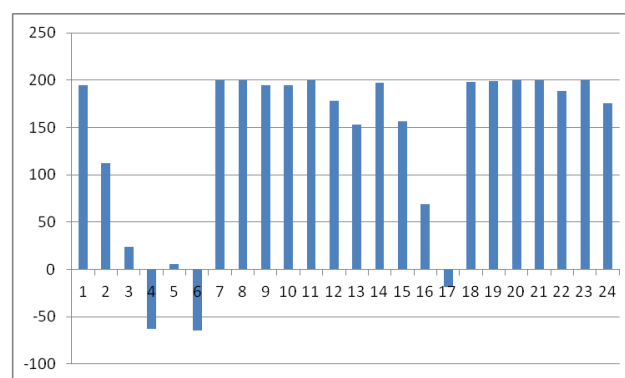


Figure 4 The optimal charging and discharging time according to GA

Based on the model created for this chapter, the QGA obviously superior to the GA. The optimized result of the QGA is more reasonable. It show that the quantum optimization algorithm has a broad application prospect and efficient optimization efficiency.

5. Conclusion

Both solar and wind energy have the characteristics of low energy density and strong randomness, Therefore individual photovoltaic or wind power generation system are difficult to provide stable power output, and introduce energy storage device can help improve this defect, but it greatly increased the system investment. Considering power complementary characteristics, utilize optimization algorithm obtaining the optimum scheduling strategy. Reasonable scheduling daily energy storage device charge-discharge time can improve the power output of wind and photovoltaic complementary system. It can make the power system has highest power supply reliability. Based on this, the paper creates a power system collaborative , randomness and optimization scheduling model, the model contain all energy storage devices, wind and photovoltaic power generation and considering output uncertainly at the same time.

Because of quantum system can describe superposition state. So, the coding form based on quantum bit compare with traditional evolutionary algorithm has better swarm diversity. When $|\alpha_i|^2$ or $|\beta_i|^2$ trend to 0 or 1, the diversity will gradually disappear, the quantum chromosome convergence to a certain state. It show that the quantum chromosome both have exploration and development ability. In this paper, the QGA is a relatively new optimization algorithm, and its application field is very small, however, from the points of this paper the efficiency of QGA can completely exceed the traditional algorithm in some aspects, the QGA can be widely used.

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