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Evaluation of Benefit of Virtual Power Plant and Intelligent Power Supply System Based on Multi-Target Monitoring

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Through advanced communication technology and control systems, the virtual electric field realizes the aggregation of multiple distributed energy sources, which can effectively promote the absorption of dispersed clean energy and enhance the safe and stable operation of a power system. The rapid development of virtual power plants will help to achieve the goal of energy transformation and energy saving and emission reduction in China. This paper proposes a method of designing and applying the distribution automation system in intelligent power supply system management (IPSSM). It not only overcomes the defects of the classical distribution automation system, but also solves the problem of intelligent power supply system management. The simulation method is compared with the VNM algorithm. Finally, the effectiveness of the design method is verified by the application of the distribution automation system in intelligent power supply system management.

Keywords: Virtual power plant; dispatching model; power supply system; multi-target monitoring

1. INTRODUCTION

A Virtual power plant is a kind of integrated power plant which combines the energy management system and the smaller distributed energy controlled by it through information, control, communication and other technologies [1]. Distributed energy is usually distributed generation, demand response resources and distributed energy storage equipment that can be connected to a power system [2–3]. With the development of energy Internet technology, the owners of virtual power plants can directly participate in the balance of power supply and demand, optimize the load curve and promote the consumption of renewable energy [4]. Against the background of supply-side structural reform and energy saving and emission reduction, virtual power plants can effectively manage decentralized distributed energy resources and promote their participation in power system operation and power trading [5–6]. Through advanced information communication, measurement monitoring and control technology, it aggregates a variety of distributed energy resources into a special power plant to participates in power market operation and power system operation management [7]. Based on the background of market-oriented development, the optimal dispatching strategies of different types of virtual power plants are discussed [8]. Demand Response Virtual Power Plant (DSVP) has the characteristics of peak-shaving and valley-filling, flexible operation, and demand response based on peak-valley time-of-use price (TOU) that has been widely used in China [9–10]. Combining with the process of market-oriented reform in China, this paper analyses the

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implementation mechanism of peak-valley time-of-use tariff in power selling companies and establishes a peak-valley time-of-use pricing model with power selling companies as the main body of implementation. This can provide a reference for formulating demand-response resources and participation in market-oriented transactions [11]. The integrated virtual power plant based on multi-distributed energy is connected with the external power grid. It can not only provide stable power supply for specific users by signing agreements, but also be regarded as the traditional power plant participating in power market transactions [12–13]. The economic and environmental dispatching model under the market trading environment can be established for the integrated virtual power plant [14]. Market operation provides the basis of decision-making.

With the development of the competitive environment in the national market, the level of industrialization is increasing gradually [15–16]. The demand for electricity consumption by commercial users, production users and social residents is increasing, and the power supply department is required to provide a safe and stable power supply service [17]. At present, the service level of intelligent distribution automation system is low in our country, and the functions of the system remain to be perfected [18]. The system designers lack integrated design ideas, which lead the power supply department to start multiple systems and to ensure the normal operation of the power grid. The phenomenon of "multi Island automatic power supply" is further formed [19]. The intelligent distribution automation system mainly includes the SCADA dispatching automation system, the GIS image display system, the remote meter reading system and the power load management system etc. Low integration, management decentralization and individual maintenance have increased the capital cost of the power supply department, and because all the different automation systems belong to the independent operation of the power distribution systems. Its sharing, connectivity and openness are weak, so it is difficult to exchange and share data among different systems. The basic structure of the distribution automation system in the management of an intelligent power supply system is to improve the component unit effectively by two kinds of ways and realize the high efficiency redundancy of the components. In this paper, in the course of the study, the security and reliability of the system will be continuously improved through a certain data acquisition information method in the calculation of online data, and the basic construction of the distribution automation system in the management of the intelligent power supply system will be realized. The main problem facing the early stage is how to balance the data of all kinds of fettered information. In the process of solving this problem, the basic solutions include: Firstly to make a specific analysis of the different problems. The overall data algorithm involves the application of various comprehensive objectives. In addition, the multiple target methods aimed at the whole data can be solved by a sequential algorithm in the way of one followed by one calculation. In recent years, the management of the intelligent power supply system has been gradually applied to the problem-solving process of multiple management in various management processes.

The overall data verification characteristics of intelligent power supply system management in the production of automatic power supply system processing and automation power supply system need to use a number of information sets to achieve the overall optimization of multiple target data problems. In this paper, a design method of distribution automation system in intelligent power supply system management is proposed to solve the integration problem of distribution automation system.

2. INTELLIGENT POWER SUPPLY SYSTEM MANAGEMENT

In this paper, the distribution automation system in the intelligent power supply system management is set up. In the process of fully satisfying certain basic conditions and environments, the related distribution automation system is realized with lowercost. It promotes and helps component cells achieve maximum data redundancy in certain reliable distribution automation system data. Its main distribution automation system structure can be represented as $\frac{2}{m_i}$ distribution automation systems, in which m_i represents i sub distribution automation system. The framework of the system is as follows:

1) The basic component unit structure of the distribution automation system in the normal condition presents different working conditions. One is the working state, the other is the state after the failure of the component unit.
2) The components of different sub distribution automation systems are separate but interdependent.
3) The components between the same group distribution automation system will become more redundant.
4) The failure of the component unit is not repaired.
5) Each component unit and the failure component are interworking.

In the general production process, the target monitoring component unit distribution automation system data calculation method is as follows:

$$\begin{aligned}
\max \quad & R_s\left(r_{ij}, m_i\right) = \prod_{i=1}^{n} R_i\left(r_{ij}, m_i\right) \bullet R_{iV} \\
\min \quad & C_s\left(r_{ij}, m_i\right) = \sum_{i=1}^{n}\sum_{j=1}^{m_i} C_{ij}\left(r_{ij}, m_i\right) \\
s.t. \quad & R_i = \sum_{k=2}^{m_i} C_{m_i}^{k} \bullet r_{ij}^{k} \bullet \left(1 - r_{ij}\right)^{m_i - k} \\
& C_{ij} = \beta_{ij} - \frac{\beta_{ij}}{\alpha_{ij}} \bullet \ln\left(1 - r_{ij}\right) \\
& R_s \geqslant R_0 \\
& 0 < r_{ij} \leqslant 1 \\
& m_{\min} \leqslant m_i \leqslant m_{\max};\ i = 1, \cdots, n;\ j = 1, \cdots, m_i
\end{aligned} \tag{1}$$

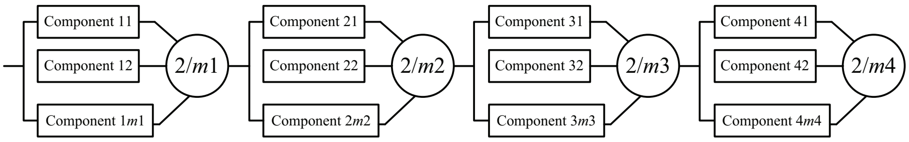

Figure 1 Reliability diagram of redundant distribution automation system for distribution automation system.

In the formula: R_s is expressed as the reliability of the corresponding distribution automation system, C_s is a trusted cost based on its basis, and R_i represents the basic credibility of i under the distribution automation system, and R_{iV} represents the reliability of the component units of the same i with the same interrelation. C_{ij} represents the basic cost of i in the different component units of the same sub distribution automation system, and r_{ij} is the cost algorithm for the j component unit in the i process of the entire sub distribution automation system. m_i indicates the corresponding redundancy at the base cost of the component unit of the distribution automation system i, and $m_{\min}$ and $m_{\max}$ each act as the maximum and minimum of the related basic cost redundant numbers. α_{ij} and β_{ij} are regarded as the creditability references of the j component units of different distribution automation systems, and R_0 and C_0 are the total cost of the overall distribution automation system.

By using a certain method to analyze the different problems in the conditional environment, the following formula can be obtained:

$$f_1 \begin{cases} f_1 \;\; if \;\; f_1 \geqslant R_0 \\ f_1 + \delta * (R_0 - f_1) \;\; otherwise \end{cases}$$
$$f_2 \begin{cases} f_2 \;\; if \;\; f_2 \geqslant C_0 \\ f_2 + \mu * (C_0 - f_2) \;\; otherwise \end{cases} \tag{2}$$

In the formula: f_1 and f_2 represent two different objective function values, while δ and μ represent the numerical variables in their process.

3. DISTRIBUTION AUTOMATION SYSTEM BASED ON INTELLIGENT POWER SUPPLY SYSTEM MANAGEMENT

3.1 Intelligent Power Supply System Management Method

When $K > 1$ forms an intelligent management strategy pool $\zeta = \{S_1, \cdots, S_K\}$, different management methods meet the corresponding vector $P(gen) = (p_1(gen), \cdots, p_K(gen))$, where $p_k(gen)$ is the probability of the first k strategy in the gen generation, and satisfies $\sum_{k=1}^{K} p_k(gen) = 1, \;\; \forall$ gen: $p_{\min} \leqslant p_k(gen) \leq 1$. $p_{\min}$ can fully verify each basic small probability value, without being lost, it can implement the probability operation $p_k(gen)$, $q_k(gen)$ for the data information strategy of the basic quality $q_k(gen)$. The update operation is as follows:

$$q_k(gen+1) = q_k(gen) + \alpha \bullet [r_k(gen) - q_k(gen)] \tag{3}$$

In the formula, α is the adaptive law, and $r_k(gen)$ is the return value of the credibility distribution value of the k strategy in the gen generation. The calculation of $r_k(gen)$ is as follows:

$$r_k(gen) = \zeta_k^*(gen) = \max\left[\zeta_k^t(gen)\right]_{t=1,\cdots,|T_k|} \tag{4}$$

In the formula: $\zeta_k^t(gen)$ is relative fitness improvement value of the strategy K adopted in the gen generation.

$$\zeta_k^t(gen) = \begin{cases} \frac{f_{best}}{f_c^t(gen)} * \left| \left| f_p^t(gen) - f_c^t(gen) \right| \;\; if \right. \\ f_c^t(gen) \;\; is \; better \; than \;\; f_p^t(gen) \\ 0 \qquad otherwise \end{cases} \tag{5}$$

In the formula: the real maximum function and value, f_{best} can replace and calculate the mean value of different functions represented by $f_c^s(gen)$, $f_p^s(gen)$. After calculation, the effective adaptation of the improved value can be achieved by $T_k(g) = \left\{\zeta_k^1(g), \cdots, \zeta_k^{|T_k|}(g)\right\}$ as the set of relative fitness improvement values obtained by the k strategy in the gen generation, and $|T_k|$ is the potential of T_k.

The renewal probability of distribution automation system selection probability is as follows:

$$p_k(gen+1) = p_{\min} + (1 - K * p_{\min}) * \frac{q_k(gen+1)}{\sum_{k=1}^{K} q_k(gen+1)} \tag{6}$$

The management strategy adopted in this paper constitutes the management choice strategy pool.

$$\psi(\sigma) = \sigma^2\omega_a + \sigma\omega_b + \omega_c \tag{7}$$

In the formula: σ is generated based on the interpolation probability p_{inter}, $\sigma = \begin{cases} U[0,2] \;\; if \;\; rand \leqslant p_{inter} \\ U[2,3] \;\; otherwise \end{cases}$, and the definition of individual ω_a, ω_b, ω_c is as follows:

$$\omega_a = \frac{x_c - 2x_b + x_a}{2}$$
$$\omega_b = \frac{4x_b - 3x_c - x_a}{2}$$
$$\omega_c = x_c \tag{8}$$

In the formula (8), because x_a, x_b, x_c is selected as the different subbody of the whole particle, the probability value of the whole particle will change with the change of the random amount.

The intelligent power supply system management is used in the redundancy of the distribution automation system, and the

Tchebycheff method is used to manage it. The mathematical expressions are as follows:

$$\min g - te\left(x|\lambda, z^*\right) = \max_{1 \leqslant j \leqslant m} \left\{\lambda_j \left|f_i(x) - z_j^*\right|\right\} \quad (9)$$

In the formula, $g - te$ is the Tchebycheff function, $x \in \Omega$ is the decision variable, $\lambda = (\lambda_1, \cdots, \lambda_m)$ is the weight vector, and $z^* = \left(z_1^*, \cdots, z_m^*\right)$, $z_j^* = \min\left\{f_j(x)\middle| x \in \Omega\right\}$, $j = 1, \cdots, m$, m is the number of objective functions.

The calculation of intelligent power supply system management for multiple data operation targets can achieve and mobilize the probability selection of the overall distribution automation system under the corresponding redundancy function, which can realize the operation of different frameworks within a certain number of management operations. In the case of $A > 1$, different distribution automation systems will make up the distribution automation system pool NSs to calculate the function value operation and the probability formula in the whole control process through the mutual components.

$$p_{c,G} = \frac{S_{c,g}}{\sum\limits_{c=1}^{C} S_{c,g}} \quad (10)$$

In the formula

$$S_{c,g} = \frac{\sum\limits_{g=G-LP}^{G-1} W - S_{c,g}}{\sum\limits_{g=G-LP}^{G-1} W_{c,g}} + \varepsilon, \ (c = 1, \cdots, C;\ G > LP)$$

When LP is set to a certain period of internship, $S_{c,g}$ is set to improve the basic proportion of the c different distribution automation systems within LP to succeed in the selection of the next group. When the total number ratio of the overall optimal solution is realized by $W_{c,g}$ distribution automation system, the mean value checking of the c distribution automation system in the above LP value can be calculated by the formula $W - S_{c,g}$, and the algorithm verification of the result probability can be realized.

3.2 Implementation of Algorithm Program

Step 1: initialization of the program

1) Measure and calculate distances by different vectors.
2) Generate a random uniform distribution of the initial frame $x^1, \cdots, x^N$ based on the random way matter basic framework, whose frame is $FV^i = F\left(x^i\right)$;
3) Initialize the data $z^* = (z_1, \cdots, z_m)$, $z_j = \min\limits_{1 \leqslant i \leqslant N} f_j\left(x^i\right)$, $j = 1, \cdots, m$ with the program.
4) Probabilistic analysis and calculation for different management strategies are carried out, the probability analysis is $p_k = \frac{1}{K}$, and the basic parameter $q = 0$ is obtained.
5) Equal probability analysis and calculation for different distribution automation systems are carried out, the estimated value is $p_{NS} = \frac{1}{A}$.

Step 2: effective optimization of field probability;
When the basic parameters cannot be realized, usually:

1) according to the different domain probability problem, we can realize the different domain probability T on the distribution power automation system through p_{NS}, measure the different vector distance, realize the different weight vector $i = 1, \cdots, N$, set up $A(i) = \{i_1, \cdots, i_T\}$, and $\lambda^{i_1}, \cdots \lambda^{i_T}$ is the nearest T weight vector of the distance λ^i;
2) determine the scope of management operation P $P = \begin{cases} A(i), & if\ \ rand < \zeta \\ \{1, \cdots, N\}, & otherwise \end{cases}$;
3) According to the basic probability p_k, the application of management arithmetic in different strategy choices is achieved, so as to get a new solution y. And a new solution y_m is realized on the basis of solving the problem.

$$y_{m,d} = \begin{cases} y_d + \xi_d \bullet \left(y_d^U - y_d^L\right), \ with\ probability\ p_m \\ y_d, \ \ with\ probability\ (1 - p_m) \end{cases} \quad (11)$$

In the formula

$$\xi_d = \begin{cases} (2 \bullet rand)^{\frac{1}{\sigma+1}} - 1, & if\ rand < 0.5 \\ 1 - (2 - 2 \bullet rand)^{\frac{1}{\sigma+1}}, & otherwise \end{cases}$$

τ and p_m are the total parameters of DE, and y_d^U and y_d^L are different variable information of d.

4) We can get the positive value of y_m by using the relevant range function of different variable information.
5) Update the framework in z^* to achieve each $j = 1, \cdots, m$, if $f_j(y_m) < z_j^*$, then $z_j^* = f_j(y_m)$;
6) Framework update: set $nr = 0$.

   ① If $nr = NR$ or P is empty (that is, the parent solution is not updated), output PS $\left\{x^1, \cdots, x^N\right\}$, PF $\left\{F\left(x^1\right), \cdots, F\left(x^N\right)\right\}$. Otherwise, rj will be selected randomly from the P framework.

   If $g - Tch\left(ym\left|\lambda^{rj}, z*\right.\right) \leqslant g - Tch\left(x^{rj}\left|\lambda^{rj}\right., z^*\right)$, then $x^{rj} = y_m$, $FV^{rj} = F(y_m)$, $nr = nr + 1$;

   ② Get r_j from P and return to ①
7) When the Tchebycheff value of y_m is superior to that of the previous generation, the formula (5) can be used to effectively calculate different values and values. The k data information is used to calculate the corresponding policy probability, and the effective return $r_k(g)$ is obtained in (4). Finally, the information data is updated $q(g)$ by (3), and the probability $p_k(g)$ is determined in the (6).

$$g = g + 1$$

Table 1 Basic parameters and performance of IGD.

Calculation method	Basic function	Sum of values	Performance variance ratio
IPSSM	ZDT	3.26×10^{-5}	1.81×10^{-2}
VNM		7.56×10^{-3}	6.16×10^{-6}
IPSSM	ZDT	3.14×10^{-4}	0.83×10^{-5}
VNM		0.1956	1.58×10^{-4}

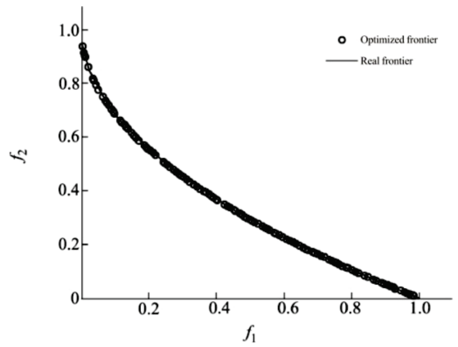

Figure 2 ZDT basic algorithm.

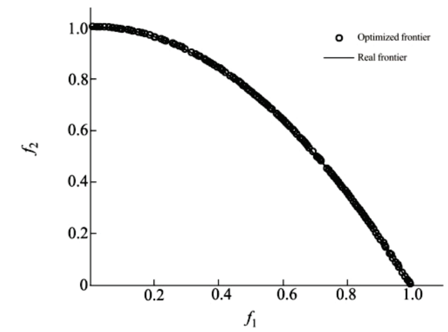

Figure 3 ZDT basic algorithm.

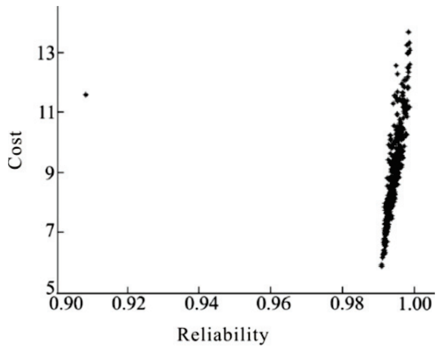

Figure 4 Redundant data parameters.

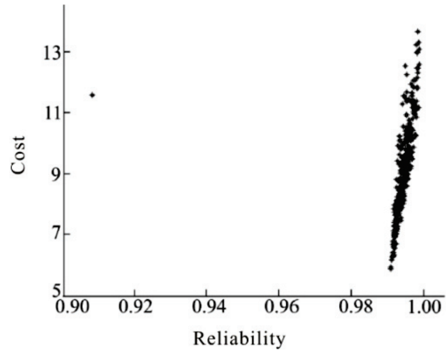

Figure 5 Redundant data parameters.

For all NS_S, update $W_{c,g}$ and $W_{-S_{c,g}}$, if mod (g, LP) $==$ 0, the corresponding distribution automation system information can be selected by the formula (10) for a certain probability selection ($p_{c,g}$), to make a new setting of $W_{c,g}$ and $W_{-S_{c,g}}$ to ensure the determination of the relative probability values.

Step 3: when the formula satisfies the basic condition and environment, output PS $\{x^1, \cdots, x^N\}$, PF $\{F(x^1), \cdots, F(x^N)\}$.

4. SIMULATION ANALYSIS

Generally, the setting of function parameters includes: calculating the number of frames and the value of probability function by means of intelligent management calculation. $N = 300$ can be set. By setting the basic function probability *CR=1.0*, the different values of $F = 0.5$ can be guaranteed, and the parameter mutation probability $P_{inter} = 0.75$ is realized under certain basic probability and value $P_m = \frac{1}{n}$, n is used as the basis function coefficient, and the maximum extreme value $G_{\max} = 500$ of different function parameters can be achieved by establishing variation and value parameter $\tau = 20$.

By using intelligent power supply system management, the basic parameter value $\alpha = 0.3$ can be set, and the minimum probability of mutation and value parameters can be calculated, which is $p_{\min} = 0.05$. Distribution automation system parameters: for the distribution automation system pool $NS_S = \{60, 90, 120\}$, different values can be realized to the maximum value $nr = 0.01 \bullet N$. In the distribution automation system, we can set probability value $\xi = 0.9$ and set up LP $=$ 50. From the corresponding numerical comparison in the table 1, we can fully understand that in the general text process, different Pareto can be obtained to achieve the answer to the maximum value. In the process of Pareto, the final determination of probability value can be carried out, and multiple objectives can be effectively optimized.

The distribution automation system is applied to the information redundancy of the distribution automation control data and the basic monitoring data of the component unit in the management of the intelligent power supply system. In the text, a certain data sensor system and subsystem are set up for relevant subsystem data, so as to guarantee the complete reliable proof of the whole subsystem.

According to the different parameter values of different component units, the basic threshold range can be set to

Table 2 Basic cost and data redundancy system under system data information.

Systematic-ness	Basic cost	Component unit-1	Component unit-2	Component unit-3	Component unit-4	Data redun-dancy	Data redun-dancy	Data redun-dancy	Data redun-dancy
0.998283	10.78545	0.848545	0.934641	0.851678	0.919642	4	3	3	3
0.998895	11.89654	0.844155	0.846517	0.871568	0.851687	3	4	4	3
0.998523	12.24144	0.816418	0.851267	0.811962	0.941545	4	3	4	4
0.998556	12.15565	0.771896	0.851567	0.841567	0.816745	4	3	4	3
0.998486	12.78464	0.815465	0.954894	0.719287	0.932945	4	3	3	3
0.998565	11.54628	0.756665	0.816789	0.950561	0.916943	5	4	3	4
0.998781	12.89454	0.878521	0.816745	0.819647	0.916942	3	5	3	4

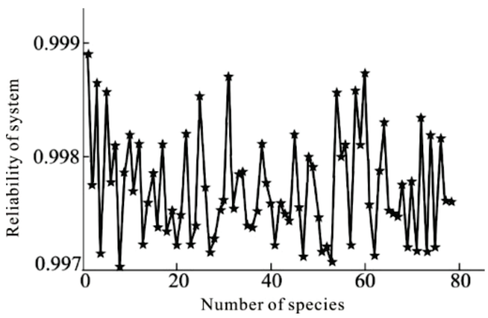

Figure 6 Frame state under iteration 300.

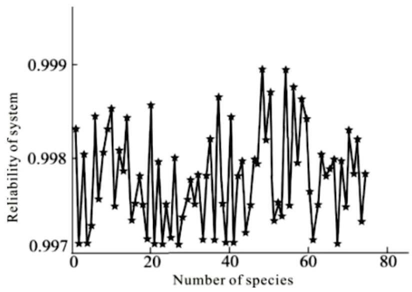

Figure 8 Frame state under iteration 600.

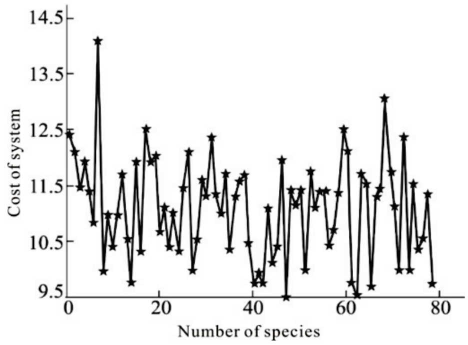

Figure 7 Frame state under iteration 500.

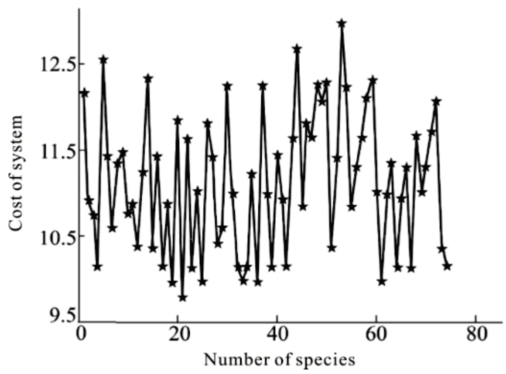

Figure 9 Frame state under iteration 800.

determine the coefficient of the updated basic unit. The coefficient of decision can be set to $0.7 \leqslant r_{ij} \leqslant 1$, and the basic numerical parameter of the information system is $2 \leqslant m_i \leqslant 5$. For different basic values, parameter performance and total value analysis of probability data can be realized.

It can be analyzed from table 2 that when the number of iterations is 300, the reliability of the system is greater than 0.9985.

The influence of the number of iterations on the system depends mainly on the reliability and redundancy of the component units, and the redundancy is redundant, so the optimized component units between the redundancy and the reliability in the table are not the same (5 × 332). When the reliability of the redundancy is 0.708638167, the reliability of the components is 0.87424889. The reliability of the final component is only 0.7045235, which can prove that the operation mode in the general algorithm of the system can increase the overall security and reliability of the component unit.

5. CONCLUSION

In this paper, the reliability of the distribution automation system managed by the intelligent power supply system is integrated, and the effective index test is carried out by using different VNM computing methods. Through the analysis of the comprehensive data and the index test, we can get that the IPSSM algorithm can achieve the balance of the function solution value in the Pare to process. By using the distribution automation system, the reliability and redundancy of the system can be optimized. The reliability and redundancy of the distribution automation system are optimized and allocated through the management of the intelligent power supply system. It can fully realize the recognition of the system reliability and the detailed change rule of the system cost in the system framework. At the same time, the change curve of system reliability and cost is higher than the base value of 0, and the decision maker can choose their own redundancy structure and component reliability according to their own needs.

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