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Optimized Genetic Algorithms: Study of the Impact on Load Distribution in the Power System

Sheng Huang[1], Ruibiao Xie[1], Jintao Wu[1],Yufeng Chen[2*] and Chuanjian Li[2]

[1] Measurement Center of Guangdong Power Grid Co., Ltd, Guangzhou
Guangdong, China

[2] Guandong Power Grid.Co.,Ltd., Guangzhou, Guangdong, China
E-mail: cyf_jd@sina.com,

Abstract. In order to balance the power flow, voltage and current between renewable energy power generation and thermal power generation, this paper takes renewable energy as the research object, analyzes the power flow and voltage after grid connection, and proposes an improved genetic algorithm for research. Firstly, the log function is used to analyze the power flow and voltage data before and after grid connection, reduce the complexity of the data, and calculate the proportion of photovoltaic energy. Then, the load analysis of the power system was carried out by genetic iteration to identify the overloaded nodes, and the identification standard was greater than 80% of the rated load. Finally, a load set is formed, and information such as changes, power flow, and voltage of different power generation nodes is recorded. The results show that the genetic algorithm can maximize the proportion of renewable energy to 50% and reduce the power flow change rate of the power system to 10%. At the same time, improve the load efficiency of the power system, so that the node load is between 75~80%, average the load of each node, especially the photovoltaic matrix and fan, and shorten the load deployment time, so that it is 10s smaller. Compared with the previous algorithms, the genetic algorithm proposed in this paper is better, which can meet the load distribution requirements of the power system and expand the energy proportion of renewable energy.

Key words. Genetic Algorithm Optimization, Power System, Load Distribution, Renewable Energy.

1. Introduction

In the process of operation, the power system adopts a hybrid power supply mode, which is mainly supplemented by thermal power generation and new energy. In the process of power supply, the power flow, current, and voltage of the distributed grid are not stable [1], [2], so it needs to be continuously distributed to ensure the stable operation of the entire power grid. At present, there are two difficulties in the problem of load distribution in the power system: on the one hand, the real-time data of the power system is huge and difficult to analyze; On the other hand, the power environment in which the power system is located and the power supply needs of customers are complex and difficult to effectively solve. Therefore, some scholars believe that the new energy grid and the thermal power grid should be separated and analyzed independently to ensure the effective integration between the two [3], [4]. However, the fragmented power system cannot be computationally computational, which leads to controversial research results. For this reason, some scholars believe that the uncertainties in the photovoltaic power grid should be eliminated and the load of the power system should be analyzed independently, but the analysis results are controversial with the actual operation. Therefore, some scholars believe that the application of intelligent algorithms to distributed power grids and thermal power grids can effectively integrate the relationship between the two and balance their power flow voltage and current, but there are still problems such as large power flow fluctuations and many influencing factors of voltage and current. The load distribution of the power operation system belongs to the optimization problem of operation scheduling and load planning in the power system, and solving the load distribution problem in the power system can improve the reliability and safety of the power operation system. After the target of load distribution of the power system, the load distribution of each unit is carried out scientifically. Under the conditions of grid operation constraints, intelligent algorithms can minimize the power generation cost of the grid [5], [6]. At present, the main algorithms suitable for system analysis are bee colony algorithm, genetic algorithm and logic analysis method. Among them, the genetic algorithm has the most improved methods and is widely used in current systems, so this paper analyzes many aspects, firstly, aiming at the problem of rare processing of load distribution data in power system, an objective function is proposed to calculate the data type and uncertainty. Then, the constraints such as grid loss and threshold of grid-connected power grid are set, and the solution results of the load distribution of the power system are optimized and analyzed to form a cluster result set related to load distribution, so as to realize the adjustment and optimization of power flow, current and voltage of the power grid. Among them, the difference function is used to carry out the comparative analysis of the load allocation problem, and the mutations and intersections in the optimal results are identified and verified, so as to form the final set of optimization results. In this paper, the main research is to increase the proportion of new energy in the power grid, reasonably distribute the load of the power grid, and ensure the power flow, voltage and current of the power grid.

2. A Description of the Problem in the Power System

A. Proportion and Energy Consumption of New Energy in the Power System

The proportion of renewable energy grid-connected includes photovoltaic power generation, geothermal power generation, wind power generation, etc., so thermal power generation is required to be minimized, and energy consumption is minimized for optimization [7-8], as shown in Eq. (1).

$$F(t)=\sum_{t=1}^{T} f_i(x_i)+\Delta\lambda \tag{1}$$

where: F(x) is the proportion of renewable energy; T the proportion of renewable energy; $f_1(x)$ is the trend after grid connection; $f_2(x)$ is the voltage after grid connection; $f_3(x)$is the total energy consumption of the power system. $f_t(t)$can be expressed as:

$$f_1(t)=C_i \tag{2}$$

where:C_i is the power flow of each generator set.

$$C_i=a_iP_i(x)+a_jP_j(x)+\Delta\lambda[a_1P_1(x)+a_kP_k(x)] \tag{3}$$

where: a_i , a_j , a_1 are a_k wind, thermal power, geothermal and hydroelectric power flow, respectively; $P_i(x)$, $P_j(x)$, $P_k(x)$, $P_1(x)$ are 20%, 40%, 60% and 80% of renewable energy, respectively. $f_2(x)$ can be expressed as:

$$f_2(t)=C_{ch}+C_{dis} \tag{4}$$

where: C_{ch} is the instantaneous voltage, is the C_{dis} overall voltage.

$$\begin{cases} C_{ch}=p(x)\sum_{i=1}^{n}\frac{P_{i,ch}(x)}{\eta_{i,ch}}+\varepsilon \\ C_{dis}=p(x)\sum_{i=1}^{n}P_{i,dis}(x)^2\rightarrow\eta_{i,dis}+\varepsilon \end{cases} \tag{5}$$

where: $p^{(x)}$ is the tide of renewable energy; $\eta_{i,ch}$ for renewable energy can not be speeded; $\eta_{i,dis}$ is the storage of electricity for energy storage batteries; $P_{i,ch}(x)$ is the output voltage of renewable energy [9]; $P_{i,dis}(x)$ is the output power of renewable energy. $f_3(x)$ can be expressed as:

$$f_3(x)=C_{grid} \tag{6}$$

where: C_{grid} energy consumption in different periods.

$$C_{grid}=p_{grid}(x)-P_{grid}(x)+\Delta C_{grid} \tag{7}$$

where: $p_{grid}(x)$ energy consumption for thermal power generation; $P_{grid}(x)$ Reduce energy consumption for new energy sources.

When the energy consumption of new energy is reduced by 50%, $P_{grid}(x)$ is negative value is taken; When $P_{grid}(x)<0$ the energy consumption of new energy is reduced by 20%, $P_{grid}(x)$ is non-negative value is taken, that is$P_{grid}(x)\geq 0$. Considering that renewable energy will reduce the energy consumption of power generation, the following objective function is defined:

$$F_2(x)=\sum_{t=1}^{T}\left(P_c(t)\rightarrow\eta_c^p\rightarrow\eta_c^e\rightarrow\eta_c^f\rightarrow\eta_c^a-\frac{P_d(x)}{\eta_d^p\cdot\eta_d^e\cdot\eta_d^f\cdot\eta_d^a}\right) \tag{8}$$

where: $P_c(x)$ sum $P_d(x)$ is t the energy consumption of grid .connection at the moment; $\eta^p{}_c$, $\eta^e{}_c$, $\eta^f{}_c$ and energy $\eta^a{}_c$ consumption of wind, fire, geothermal, and hydro, respectively; $\eta^p{}_d$, $\eta^e{}_d$, $\eta^f{}_d$ and $\eta^a{}_c$ are wind, fire, geothermal, and hydro respectively to reduce energy consumption.

B. Load Distribution Design after Grid Connection

After grid connection, the load will be distributed differently, so load scheduling should be carried out. Considering that the process of wind, thermal power, geothermal and hydropower generation is affected by many factors such as weather and geography, it is necessary to analyze the load after grid connection, and the specific formula is as follows.

$$F_3(x)=\sum\frac{\lambda\cdot\left[P_i^d(x)-\sum_{t=1}^{T}P_i^c(x)\right]+K_{i,n}}{n_i} \tag{9}$$

where: λ is the proportion of the load of thermal power generation; N is for the load of renewable energy (N=4); $K_{i,n}$ is the load generated by i the first condition of n the first renewable energy; $P_i^d(x)$ is the i load of the first condition;

$P_i^c(x)$ is Load adjustment for the first i condition. Load distribution is to summarize the power of the entire power grid, and distribute the load, so as to realize the uniform release of power of each generator set and avoid overload work and reactive power. Load adjustment can reduce the cost of power generation, reduce the energy consumption of power generation, and reduce the power consumption of the generator set. Therefore, load distribution is the process of maximizing the utilization of power, and the transformation from active power to reactive power is completed, which is calculated as follows.

$$F_4(x)=[f_{AC}\rightarrow P_{AC}(x)]\times[f_{WM}\rightarrow P_{WM}(x)] \tag{10}$$

where: f_{AC} is the renewable energy load; $P_{AC}(x)$ is Reduction of renewable energy loads; f_{WM} is the load of the thermal power grid; $P_{WM}(x)$ is the load reduction of the thermal power grid, as shown in Figure 1.

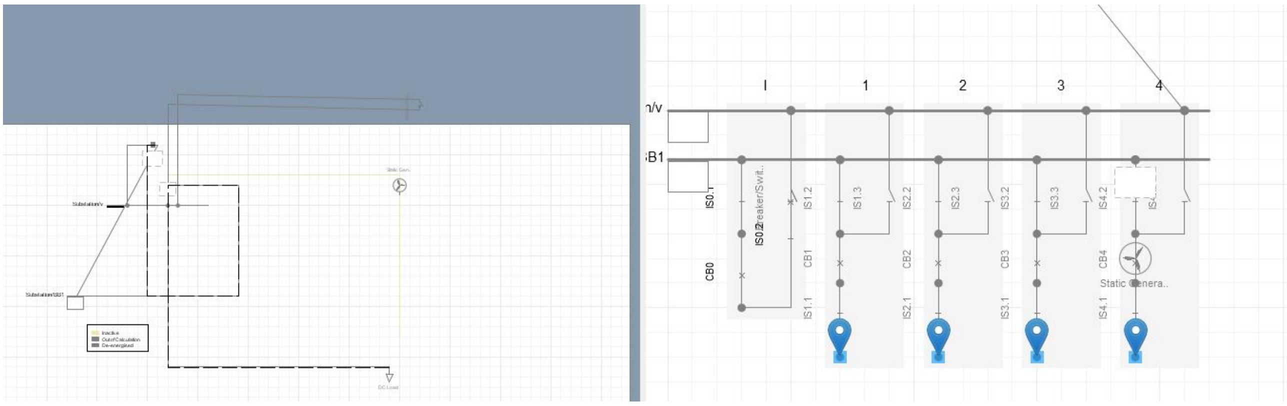

Figure 1. Load distribution Design of Renewable Energy and Thermal Power Grids

As can be seen from Figure 1, in the process of load design, it is necessary to ensure

3. Case Study of Load Distribution in Power Systems

A. Introduction to the Power System

In this paper, the IEEE 14.0 experimental network is taken as the research object, including 4 sets of photovoltaic generators, 4 sets of wind turbines, 2 sets of thermal power generators, the power of thermal power is 1120KW/h, the power of wind and photovoltaic grid is 602KW/h, the rated load is 1200KW, the observation time is 30d, the daily detection time is 18h, and the testing equipment is the grid automation management system 2022 type. The voltage is 220V, the power flow is 720KW/s, and the current is 12~24A, and the simulation diagram of the specific power system is as follows.

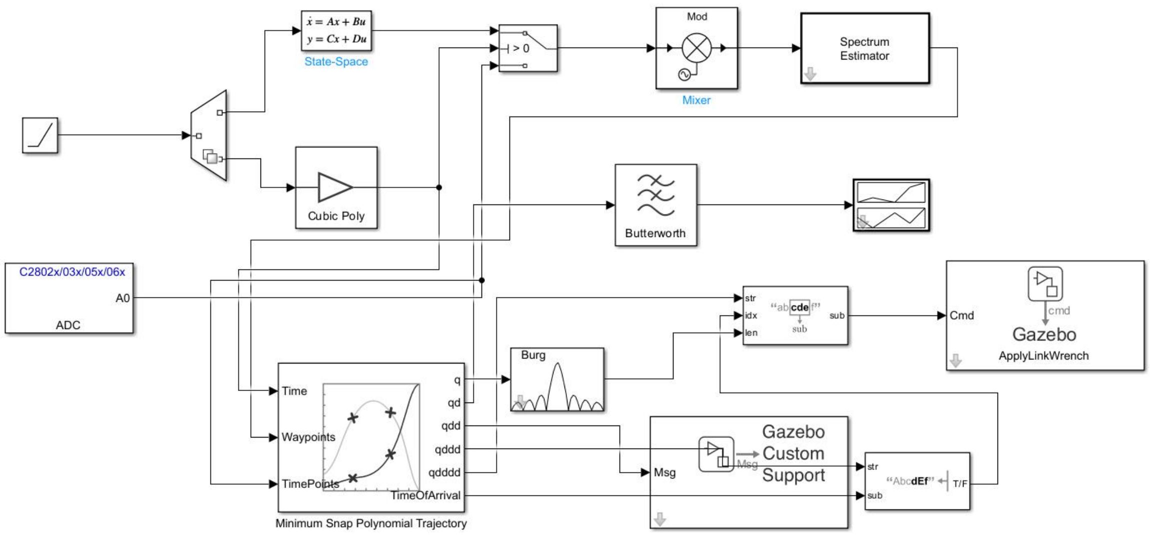

Figure 2. Model Construction of a Hybrid Power System

As can be seen from Figure 2, the load of the power system is distributed, and the load distribution analysis can be carried out in the later stage without considering the power grid loss. Moreover, in order to avoid the randomness problem of the algorithm, 30 independent iterative analyses are adopted, and the convergence curves of the test cases are obtained.

B. Load Distribution of the Hybrid Power System

The hybrid power system is continuously monitored to obtain the change in load, as follows.

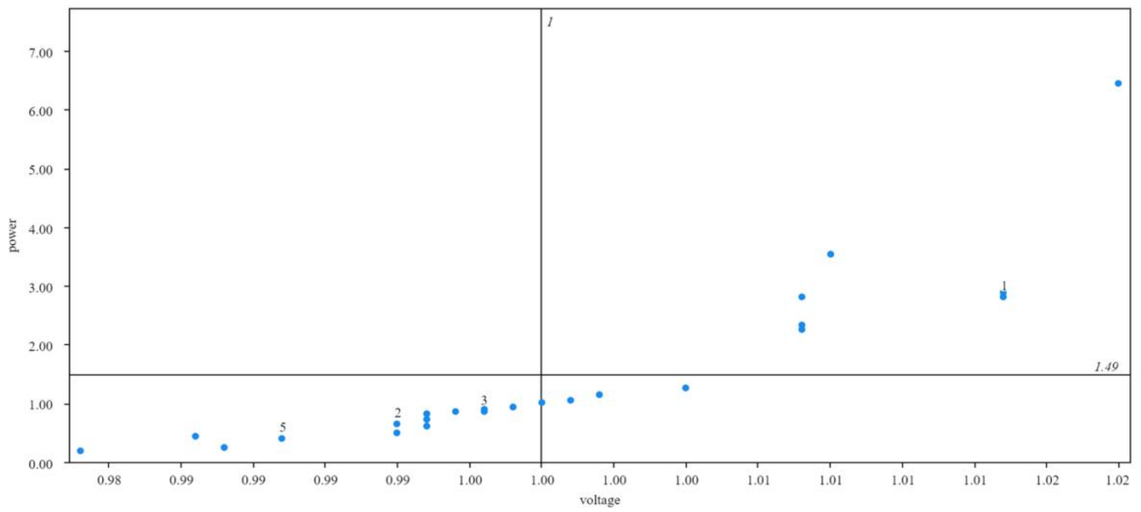

Figure 3. The Relationship between Load and Power Flow

As can be seen from Figure 3, there is a positive correlation between load and power flow, indicating that the power flow of the hybrid power grid also increases with the increase of load, and the increase is large, showing an offline state, and the specific comparison results are as follows.

Table 1. Correlation Analysis between Load, Voltage, and Power Flow

Index	→	Sub-Metrics	Distributed grid distribution coefficient	SE	Z	*p*	Mainnet load classification factor
Load	→	Voltage	0.281	0.145	1.933	0.053	0.367
Load	→	Tide	0.996	0.031	31.753	0.000	0.988
Load	→	Power	-0.514	0.173	-2.962	0.003	-0.517
Note: → indicates that the path affects the relationship							

As can be seen from Table 1, there is a positive correlation between voltage, current, power flow and load, indicating that the genetic algorithm can adjust the power flow and voltage according to the load to maintain the balance of the entire power system. Among them, the relationship between load and electric energy is negatively correlated, indicating that renewable energy can reduce the energy consumption of thermal power generation, and then there is a negative correlation between the two. Moreover, compared with other algorithms, the proposed algorithm has advantages in load distribution, as follows

Table 2. Load Allocation Results of Different Algorithms [Unit: %]

	Genetic Algorithms	Ant Colony Algorithm	Particle Swarm Algorithm
Average Value	81.87	65.72	72.87
Maximum	97.95	69.37	62.20
Minimum	97.79	728.49	72.28
Standard Deviation	0.05	12.76	10.65
Proportion Of Renewable Energy	>50%	>30%	>25%

Although the optimized genetic algorithm, ant colony algorithm and particle swarm method proposed in this paper can realize the load distribution of the power system, the rationality of the distribution is poor, which is much lower than that of the genetic algorithm. The genetic algorithm has a good overall control effect on the power flow and voltage of the distributed power grid, which can reduce the complexity of load distribution and maintain the stability of the entire load distribution. The genetic algorithm can effectively reduce the load distribution structure in the power system and maximize the power of wind turbines and photovoltaic matrices, and the amount of data is much lower than that of particle swarm optimization algorithm. At the same time, the allocation results also show that the genetic algorithm can effectively avoid the region falling into the local optimal solution, improve the convergence performance of the load allocation results, and increase the proportion of renewable energy. At the same time, in the process of solving the load distribution of the power system, the load results are relatively stable and less robust. The main reason is that in the early stage of the solution, the ant colony algorithm makes a comprehensive judgment on the units in the renewable energy grid, eliminates the units with low power in a short time, and obtains a high-precision load distribution scheme among different units.

C. Energy Consumption for Load Distribution in the Current System

In the process of load distribution of the power system, its energy consumption is an important index, mainly to evaluate the proportion of renewable energy in the thermal power grid, the instability of renewable energy itself, the higher the proportion, the greater the difficulty of load distribution in the power system, so the energy consumption of the analyzer and the stability of power flow and voltage is an effective means of analysis of the distribution of the mixed grid system, the energy consumption of the power grid is mainly to produce a large amount of carbon dioxide and transportation costs, etc., which gradually change, simplifying the calculation process In this way, carbon dioxide is the main indicator of energy consumption, and the energy consumption of transportation and labor costs is negligible, and the results can be seen through the black and white image display The genetic algorithm can effectively reduce the threshold in the distribution process of the power system, close to the result, as shown in Figure 4.

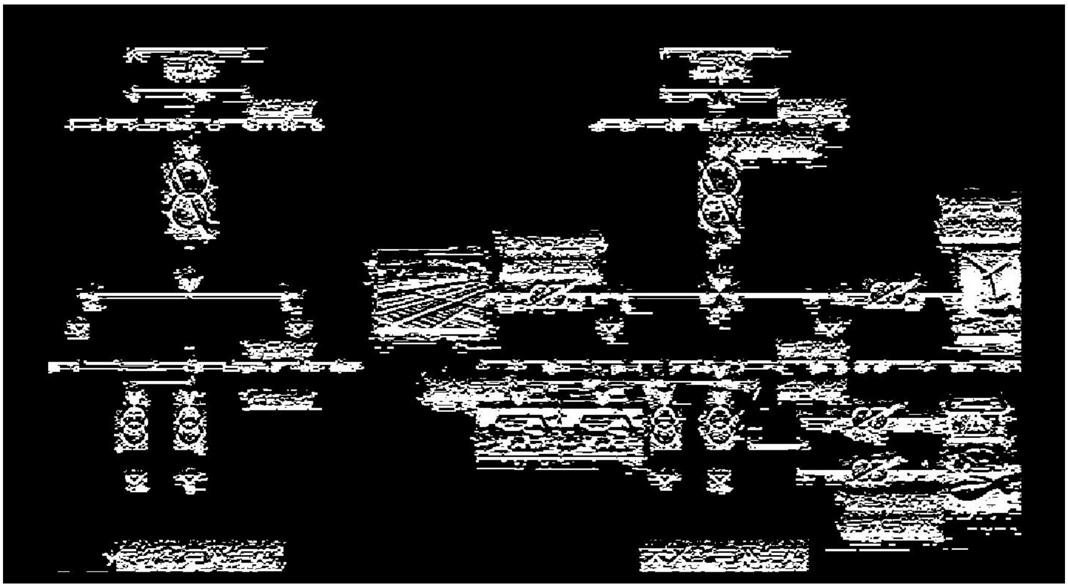

Figure 4. Energy Consumption Diagram of Load in a Hybrid Power System (Black and White)

Through the analysis of energy consumption of power system load distribution through black and white pictures, it can be found that the general algorithm optimizes the load distribution of power system well, and its energy consumption does not increase significantly, and the energy consumption is evenly distributed. This shows that the genetic algorithm can allocate the wind turbines in the renewable energy grid, so that the wind turbines can maintain the maximum power output, and reduce the idle value of the wind turbines in the process of maximum power output, and form an effective integration with the thermal power grid, so that the two-dimensional map of the energy consumption is uniform and clear. In order to conduct a more in-depth analysis of the distribution of the load of the power system, it is observed by the heat map, and it is found that there is no significant difference between the thermal grid load and the renewable energy grid load in the power system load, with a diameter of 2%, and the specific results are shown in the figure below

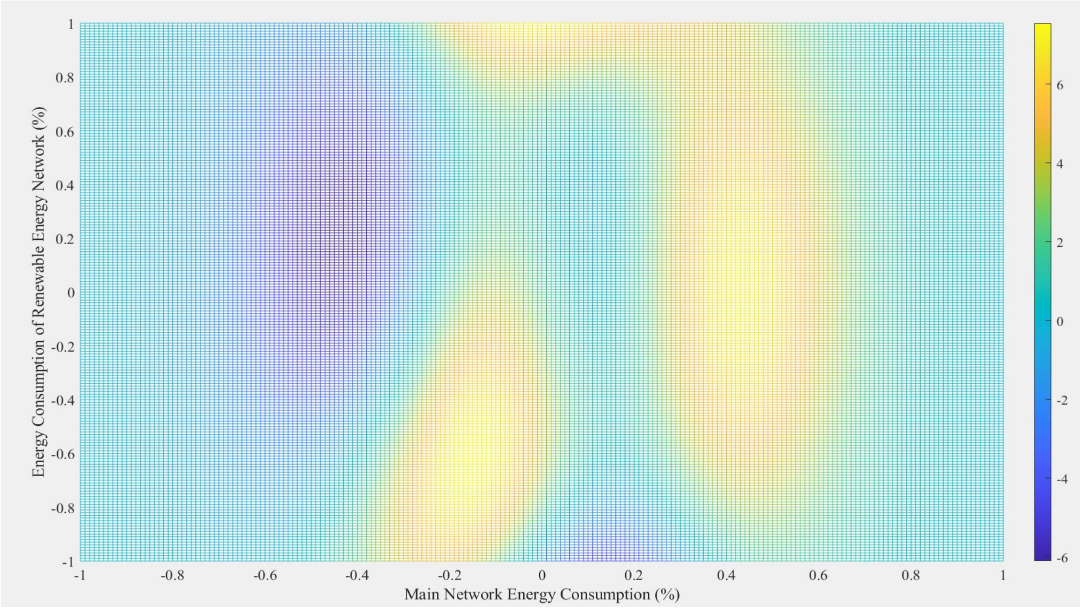

Figure 5. Heat Map of Genetic Algorithm for Load Allocation in Power System

From the data analysis in Figure 5, it can be seen that the load distribution heat map of the power system presents a uniform and concentrated change, mainly because the thermal power grid and renewable energy generation are relatively independent, so the heat map is independent. However, an analysis of the heat map shows that the difference between the color of the renewable power grid is yellow, and the color of the thermal power grid is purple and independent of each other, with only 2%. Therefore, it shows that the genetic algorithm is reasonable for the distribution of the load of the power system, and the independent analysis of the power system is carried out, and the iterative search and calculation of the power generation points are carried out to ensure the balance of the load of each power system. In the process of heat analysis, there is no abnormal independent hot spot description, and the genetic algorithm can play an effective role. The power and load of renewable energy generators have not exceeded their ratings. Although the black-and-white phase diagram and heat map have proved that the load distribution of the power system is reasonable, the results of the study are mainly local studies, and no global results are studied. In order to prove the validity of this study, it is necessary to conduct thermal observation studies on the power switch between the renewable energy grid and the thermal power grid, and analyze the calorific value of different lines to prove the stability of the current after grid connection.

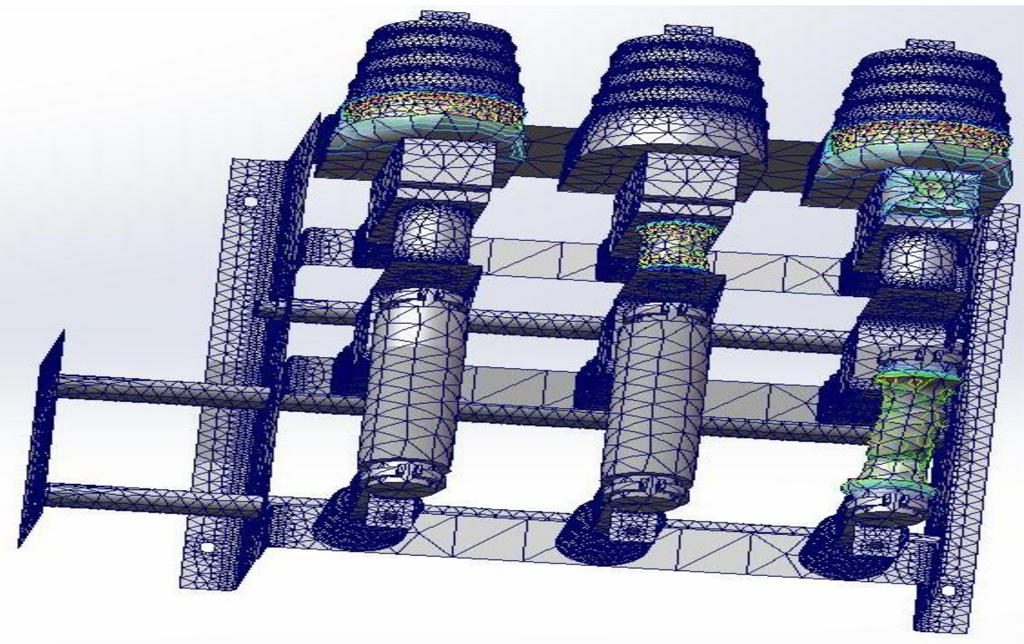
Figure 6. Calorific Value of Thermal Power Grid and Renewable Energy Grid

Through the analysis of the calorific value of the thermal power grid, it is found that the calorific value of the thermal power grid is 2 points, while the calorific value point of the distributed power grid is only 1 point. Thermal power grid is the main part of load distribution in the whole power system, and renewable energy is the auxiliary part of load distribution, but the difference in the proportion of renewable energy distribution between thermal power grids is relatively small. This shows that renewable energy is playing an increasing role in the power system, and that it is possible to reduce the energy consumption generated during power generation and to achieve sustainable power generation in the grid.

4. Conclusion

Load distribution is the main index of power system management, but the load distribution process of power system is very complex, involving the stability of power flow, voltage and current, the previous algorithm mainly adopts the form of independent distribution for analysis, but the analysis process occupies a large amount of management resources, and there is a large deviation. The results show that the genetic algorithm can improve the rationality of load distribution in the hybrid power system and reduce the energy consumption of the system, and the reduction of the energy consumption of the system is less than 10%, and the genetic algorithm can increase the proportion of renewable energy in the hybrid power system and promote the development of renewable energy. Compared with other algorithms such as particle swarm, the accuracy of genetic algorithm for power system load allocation is higher than 90%, while the accuracy of other algorithms is between 70%~80%. In addition, the analysis error of electromagnetic algorithm is less than 5%, and the analysis error of other algorithms is less than 10%. It can be proved that the accuracy of the genetic algorithm for the load distribution of the power system is better, which is mainly attributed to the fact that the genetic algorithm sets the load of the power system full-time and searches for the nearby generator sets to maximize the output rate of the generator. At the same time, the application of the proposed algorithm in the load distribution of the power system has limitations, mainly the complexity of data monitoring, and the research indicators will be added in the future, and the comprehensiveness of the research will be improved, and the proportion of renewable energy in the power system and the dynamic load distribution will be solved.

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