ISSN: 2664-9640

Research on improved artificial bee colony algorithm for combinatorial optimization of multi-objective groups

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Abstract

Economic dispatch (ED) is a hot research topic in power system scheduling optimization. Its essence is to meet the power demand of end users by reasonably arranging the operation mode of units and flexibly distributing the carrying load of units under various constraints of power system. Different from the traditional electric power economic dispatch problem, environmental/economic dispatch considers environmental pollution, power cost and dynamic factors at the same time in order to respond to the national economic call for energy conservation and emission reduction and relieve the pressure of global energy and environmental problems. EED has become an urgent problem to be solved in the new market environment. A large number of artificial intelligence optimization algorithms have been applied to solve this kind of optimization problem which contains dynamic, multi-objective and high-dimensional attributes. The artificial bee colony algorithm proposed based on the biological background of bee foraging behavior is in number. The field of value optimization is widely used. Based on the above background, this paper takes environmental economic scheduling considering environmental factors as the starting point of practical problems, studies the dynamic and multi-objective economic scheduling model and solves the model through improved artificial bee colony algorithm. The main work of this paper is summarized as follows

(1) Establish an environmental economic dispatching model, that is, an environmental economic dispatching model that considers both environmental factors and fuel cost as two optimization objectives, and comprehensively considers valve point effect, upper and lower limit constraints of unit output, climbing rate, working dead zone and unit output power balance. (2) Dynamic adjustment of colony size of artificial Bee Colony Algorithm (ABC), adaptive artificial Bee colony algorithm (ABC), Adaptive ABC), by introducing the memory feedback mechanism (MFM) and the concept of evolution rate during the operation of the algorithm to improve the efficiency of the algorithm. To achieve a balance between exploration capability and exploitation capability in the algorithm operation. (3) The experimental simulation mainly includes two parts: one is the validity verification of the adaptive artificial bee colony algorithm based on benchmark function, which proves the superiority of the proposed method in the optimization effect. The second is the solution of the environmental economic scheduling model based on the TEST set of IEEE 6-Unit system, and the weight coefficient method is applied to realize the multi-objective transformation solution of the adaptive artificial bee colony algorithm in the environmental economic scheduling problem. The experimental results show that the adaptive artificial bee colony algorithm achieves better optimization effect in solving the dynamic multi-objective environmental economic scheduling model.

Keywords

Economic scheduling, environmental economic scheduling, adaptive artificial bee colony algorithm, multi-objective optimization.

ISSN: 2664-9640

1. Project background and research purpose and significance

The stable operation of electric power system plays an important role in the development of national economy. How to improve the operation efficiency of electric power system and realize the rational allocation of electric power resources has important practical strategic significance for the economic structure transformation advocated by China at the present stage and stride forward to the direction of energy-saving economy. Data show [1] that in the first half of 2018, the total electricity consumption in the whole society increased by 9.8% year on year, and the highest power grid load in July 2017 and 2018 maintained a year-on-year growth rate of more than 7%. The highest power grid load in East China accounted for more than 90% of the dispatchable non-new energy power generation installed during the period. The power grid is faced with severe regulation pressure, which poses great challenges to the flexibility of power grid in China. So how to optimize the resource allocation of the power system and improve the operation efficiency of the power system is of great significance to the operation of the national economy. First of all, the introduction of the new energy as one of the important measures to alleviate the pressure of the power grid to adjust is gradually carried out, in 2006 promulgated the "renewable energy law related policy, the role of new energy become more important, but the new energy own existence volatility as well as many unstable factors and corresponding supporting system is not perfect wait for a reason, The absorption of new energy has become a new problem to be solved in electric power field. Therefore, thermal power still serves as the main power source of the power system. Data [1] show that the installed capacity has reached 900 million kW, but the peak adjustment depth of large-capacity thermal power units is less than 50%, and the peak adjustment depth of thermoelectric units in northern China is maintained at about 20%. In early November 2016, China's Energy Bureau and the relevant departments of the National Development and Reform Commission issued the "thirteenth five-year" related policies for electric power development, emphasizing to fully explore the potential and flexibility of the existing power market peak regulation, improve the flexibility of the power market, especially the peak regulation capacity of thermal power units. Therefore, it is an important task in the energy strategy of the 13th Five-Year Plan that how to make overall planning from the grid side, namely the supply side, the user side, namely the demand side and the power side to enhance the flexibility of thermal power units, improve the peak adjustment depth of thermal power units and absorb a variety of new energy into the network.

Unit combination optimization refers to the start-stop and output plan of each unit within a period of dispatching period, under the premise of meeting the load demand and unit parameter requirements of the power system and aiming at the lowest total generation cost of the system. The main characteristics of unit combination include high dimension, non-convex, discrete and nonlinear. Because of these characteristics, it is difficult to find the optimal solution for unit combination problems. But because it can bring significant economic benefits, people never stop research, put forward a lot of algorithms to solve this problem. Group combination problem is to solve how to solve this problem in the process of studying, because of the different search mechanism of the swarm intelligence algorithm, the scope of application is different and the traditional intelligent algorithm can not meet the requirements, so to improve the existing algorithm becomes an effective way to improve the optimization performance of the algorithm. At present, most of the research on unit combination optimization is based on the power system scale of less than 100 units, and most of the optimization goal is to minimize the total generation cost of the system. As a matter of fact, with the rapid increase of total power generation capacity in China since the 20th century, more attention has been paid to the study of large-scale unit combination optimization. Moreover, in recent years, the national and social environmental protection efforts have gradually increased, low-carbon operation, reducing pollution and other targets have been included in the optimization of unit combination.

ISSN: 2664-9640

2. Research on economic load distribution model of generator set

In the electric power system, due to the difference in the price of coal in various thermal power plants, the loss of power grid in power supply is also different due to the region. Even if the same power plant has different installed models and different operating conditions of each unit, each unit has its own independent energy consumption benefit relationship, and the air pollution caused by each unit is also different. The problem of economic load distribution of electric power system environment system is to optimize these situations.

According to the different number of optimization targets, it can be divided into single-objective economic load distribution problem and multi-objective environmental economic load distribution problem. The single objective economic load distribution problem only considers the balance between supply and demand. Multi-objective problems can include balance of supply and demand of load distribution, reduction of environmental pollution, unit response speed and so on.

This chapter mainly introduces the evaluation standard of economic index of thermal power plant, summarizes the constraint conditions such as coal consumption cost, environmental cost and timeliness cost that affect the economic benefit of thermal power plant, and establishes the single/multi-objective model of electric power economic load distribution.

2.1. Economic indicators of load distribution problems

Thermal power plants mainly evaluate their economic operation indicators in the following ways:

1. The rate of heat loss

Heat consumption rate is the amount of heat consumed per unit power during unit operation. However, this approach does not take into account the loss of the large grid, as well as other factors such as power consumption, water consumption and air pollution. Therefore, the heat consumption rate can only describe the production efficiency of a single unit, but can not accurately measure the production efficiency of all units in the entire grid.

2. Standard coal consumption

Standard coal consumption is the index of economic load distribution based on the standard coal consumption consumed by production unit power. There is no need to calculate other costs, the objective function model is simplified, easy to solve. But this method also does not consider the network loss consumption, air pollution and other costs, so the standard coal consumption can not accurately measure the economic benefits of large power grid.

3. Power supply cost

Power supply cost refers to the calculation of economic input from the power supply side of the entire grid. It can reflect the production cost of each unit in the entire grid, the network loss of the grid, and the pollution forfeit cost in the power production, which is a comprehensive index that can reflect the overall economic benefits. Therefore, the power supply cost is an ideal economic index to reflect the economic load distribution of power grid.

Most of the current literatures also take power supply cost as economic index. In this paper, the objective function will be determined and optimized for specific problems.

2.2. Main factors affecting power supply cost

This section introduces the main factors of the load distribution problem model, including the coal consumption characteristics of the generator set and the valve point effect, the network loss of the grid, and other constraints of the load distribution problem.

ISSN: 2664-9640

3. Load distribution problem model of multi-objective power system

3.1. Basic artificial swarm algorithm

Honeybee is a kind of social and social animal. Although the behavior of individual honeybee is simple, the intelligent behavior of ascending swarm is very complex. Through observation, the bees first send the lead bees to look for the honey source, and then return to the hive to perform the "figure 8 dance", telling the following information such as the location and quality of the honey source. Follow the bees to observe the "figure-eight dance" of the leading bees, and decide which nectar source to collect honey. Usually, the more pollen there is in the nectar source, the more bees follow. When the current mining nectar source has been exhausted, the lead bees turn into scouts, searching for new nectar sources near the hive. Bees work together through division of labor and "figure 8 dance" to exchange information, and it is very efficient. ABC algorithm is a swarm intelligence algorithm which simulates the honey division and cooperation of bees.

Four elements are needed to simulate the process of honey gathering: nectar source, scout bees, lead bees and follow bees. There were four basic behaviors: leading bees to explore and announce nectar source information, following bees to choose nectar source, following bees to explore and giving up lighting nectar source; The process of bees searching for the best nectar source generally consists of the following three steps: 1) leading bees searching for the nectar source and displaying the nectar source information to the following bees; 2) Follow bees to select nectar sources and explore them; 3) When no better nectar source is found after repeated exploration around a nectar source, it is judged that the nectar source is empty, and the leading bee turns into a scout bee looking for a new nectar source, and turns into a leading bee to continue to collect honey after finding the nectar source.

Different from genetic algorithm and other swarm intelligence algorithms, role switching is a unique mechanism of ABC algorithm. Bees cooperate to find high-quality nectar sources through the transformation of the roles of lead, follower and scout bees [16,17].

3.2. Algorithm design

To apply an algorithm to practical problems, it is necessary to conduct modeling and use mathematical methods to calculate. In the actual operation of ABC, several key parameters involved are described as follows:

1) The Number of Population is NP. The population included all lead bees (EB) and follow bees (Onlooker Bee) OB. Total population NP EB OB .

2) Limit of maximum opening times for each nectar source: If no better nectar source is found after limit exploration around a nectar source, the secondary nectar source is considered empty, and this nectar source should be abandoned to lead bees to transform into scouts to find new nectar sources.

3) Maximum cycle algebra MaxCycle: when all bees have collected MaxCycle honey, the cycle is considered to be over and the optimal nectar source found is the optimal solution found.

4) Nectar source dimension D and up boundary UB low boundary LB limits: these were determined by the optimization problem. The problem dimension was nectar source dimension, and the upper limit of each dimension was nectar source dimension.

In ABC algorithm, the location of food source represents a potential solution in the space, and the amount of honey of each food source represents the quality of the potential solution, namely the fitness value (Fit). Set the initial nectar source and the number of leading bees as EB, and the number of following bees as OB, OB=EB, then the total population NP =EB+ OB, The colony algorithm firstly randomly generates the initial population containing EB nectar sources according to Equation

ISSN: 2664-9640

The nectar source is abstracted into points in the solution space, where UBi and LBi respectively represent the upper and lower limits of the solution, I (I =1,2... EB) represents the number of nectar source, D represents the value space of solution, and N represents the dimension of the problem. Formula was applied to solve the fitness value Fiti of nectar source Xi.

Where f (Xi) is the mass value of the ith nectar source. Each nectar source corresponds to a leader bee, and the leader bee updates the nectar source location according to Formula

Where xij is the location component of nectar source Xi. Vij generated the JTH position component of new nectar source Vi∈ D for the ith leading bee based on nectar source Xi. Rij is a random number on [-1,1]. XKJ was another nectar source randomly selected from EB bee sources in the population.

3.3. Improved methods of the algorithm are introduced

In general, the improvement and theoretical research on the bee colony algorithm are still insufficient, and there are many problems worthy of further research, which can be summarized as follows:

1) Algorithm parameter setting

Parameter setting of ABC algorithm has a very important effect on algorithm performance. Often, we find a better setting by trial-and-error based on the problem. Different population NP, maximum cycle algebra MaxCycle, update threshold limit and so on May be set for different problems. Therefore, according to the actual problem, the design parameters adapt to change, or introduce other parameters, so that the algorithm can adapt to the characteristics of the problem or search process.

2) Research on the search method of algorithm

ABC algorithm simply simulates the model of bee nectar gathering, how to find the best nectar source quickly, how to make the best nectar source more accurate, and minimize the calculation, mainly reflected in how to improve the bee colony search formula to make the evolution faster, always move towards the best nectar source side; How bees choose nectar sources can be used to explore better nectar sources while maintaining the diversity of the population. Or the introduction of other algorithms and parameters, so that the evolution of faster, later can be more in-depth mining; Moreover, the colony algorithm always gets only one optimal value, without considering the situation of multiple optimal nectar sources and how to find them all. Basic artificial colony algorithm, the sources of the dimensional parameters is of each other noninterference, but in real life, often between the independent variables is there are a lot of constraint conditions, such as the total dimension constraints or there is gap, etc., make when exploring the d mutual interference, affect the exploration, how to optimize the ABC algorithm, to explore able to adapt to more equality and inequality constraints. These are all topics worthy of further study.

3) Research on multi-objective ABC algorithmAt present, there are few researches on the application of ABC algorithm to multi-objective problems. How to design ABC algorithm to adapt to multi-objective applications and efficiently solve multi-objective problems is also a good research topic.

4) Improvement of ABC algorithm

The ABC algorithm model is relatively simple, but in real life, the bees' honey division and cooperation behavior is more complex. How to more realistically simulate the honey gathering of bees and make the algorithm more perfect, closer to nature and more suitable for the application in real life are all research topics that can promote the progress of ABC algorithm.

5) The parallel design of the algorithm

There are a lot of ABC algorithm is a process of single wire, and real life, especially now with the development of computer hardware and software and network technology, parallel and

distributed computing in big data complicated problem has innate advantages, how to apply the ABC algorithm to parallel and distributed computing, has important practical significance.

4. Conclusion

Compared with ABC algorithm, variation of ABC algorithm and the method in reference [53], the improved ABC method implemented in this paper achieves better optimal solution and convergence effect. The results above, this paper implemented the adaptive artificial colony algorithm considering dynamic and multi-objective economic operation showed good advantage in the problem solving, can achieve the goal of power economic dispatch problem, this article mainly from two aspects: dynamic and multi-objective verified the effect of algorithm, compared to other swarm intelligence optimization algorithm, The proposed method achieves good optimization results in considering dynamic factors and multi-objective optimization, and proves the high efficiency of the proposed method by comparing the convergence effects of different algorithms, which fully embodies the superiority of the adaptive artificial bee colony algorithm in solving the power economic scheduling problem.

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