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Energy Distribution Method Based on Hybrid Intelligent Algorithm

Linying Che*

Case Western Reserve University, USA

**corresponding author*

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Abstract: Energy is the cornerstone of the progress of human society. As the world gradually moves towards modernization, the shortage of energy in various countries has become an important problem restricting their economic development. It is very important to reduce energy costs and improve system economy to allocate energy as reasonably as possible under the requirements of ensuring the stable operation of the power system. The purpose of this paper is to study energy distribution methods based on hybrid intelligence algorithms. The static load distribution mathematical model of the power system is established, and the static load distribution program based on the hybrid algorithm is designed. The IEEE3-machine 6-bus system is used for the example simulation. Particle swarm optimization and hybrid intelligence algorithm are used to test the objective function in three cases, respectively. The results show that the hybrid intelligence algorithm is better than the particle swarm algorithm in both the convergence speed and the optimal solution quality when solving the static load distribution.

1. Introduction

With the rapid social and economic growth and the transformation of the traditional energy industry, issues related to the energy environment have become a hot topic in the world. In order to meet the future energy demand of mankind and reduce the impact of pollutant emissions on the environment, society needs to improve energy efficiency and allocate energy strategically [1-2]. The establishment and implementation of the electricity market mechanism involves a wide range of factors such as technology, economy, and policy [3]. With the deepening of research on energy distribution, in order to achieve better energy operation effect, people have added a lot of constraints to the objective function that need to be considered in the actual production and life process. It is difficult to achieve satisfactory results, but people are still studying the problem of energy distribution and strive to obtain the greatest economic benefits [4].

Because of the significant economic benefits it can bring to the problem of energy distribution, the research on its solution has always been the direction that people are pursuing [5]. Mehrabi A studies the optimal dispatch of electric vehicles in a geographically large-scale smart energy distribution system, and the flexible deployment of smart charging stations (CS) in spaces powered by a single battery proposed a low-complexity online decentralization algorithm that intelligently promotes each EV to the most profitable CS using efficient heuristics [6]. Vahidinasab V provides a comprehensive review of distribution network expansion planning (DEP), including DEP modeling, optimization models , extended distributed energy resources (DER), uncertainty of the problem, etc. The requirements for an integrated energy regional master plan are discussed to avoid conflicts between regional planning goals for energy independence. Finally, the main future research and development trends in the field of distribution network planning are described [7]. Scientifically and rationally realize the optimization of energy distribution, and effectively guarantee the safe, reliable, high-quality and economical operation of the power system [8].

In this paper, a method combining simplex method and particle swarm optimization algorithm is used to realize the energy distribution optimization problem. Simplex method is a relatively effective local search algorithm, but it cannot guarantee the global convergence of the algorithm. The particle swarm optimization algorithm is simple and easy to implement and has a fast convergence speed, but in practical applications, the results obtained cannot meet the requirements. Combining the two algorithms with each other is innovative.

2. Theories Related to Energy Distribution

2.1. Power System Energy Allocation Considering Economics

Technological progress factors play a key role in energy distribution. While optimizing power system energy distribution, technological progress can promote economic growth and reduce energy consumption [9-10]. This phenomenon further complicates the relationship between technological progress and energy efficiency and energy consumption.

In the actual production of the power system, the purchase price of water, fire and gas energy is quite different. Assuming that the price of a certain commodity fully reflects the actual value of the production of the commodity, the price represents the input and the income obtained from the production of the commodity. profit, so from an economic point of view, the more expensive it is to buy electricity, the more society will pay when using this type of supply [11-12].

2.2. Power Storage Technology

Energy storage is critical for power systems with high penetration of renewable energy. The role of energy storage technology in the power grid is shown in Table 1. Different energy storage technologies have made significant progress in improving energy storage system performance, life, energy storage safety, energy density and response time [13-14]. Access technology measures, power grid security and stability, power quality and other issues. As a potential technology to improve power grid performance and support high efficiency in the future, the promotion of this technology also urgently requires an accurate cost estimation and technology evaluation mechanism for the power system [15].

Table 1. The role of energy storage in the grid

Energy storage location	Effect
Power generation end	Fast-response frequency regulation service; increases the penetration of renewable energy in the grid while effectively avoiding clean
Transmission terminal	Effectively improve the reliability of the power transmission system; reduce unnecessary system upgrades.
Distribution terminal	It can improve the quality of electric power and the reliability of electric power.
End user	Optimize electricity prices; ensure the quality of electricity.

2.3. Basic Particle Swarm Optimization Algorithm

Particle swarm optimization algorithm is an intelligent algorithm based on sorting. The main idea is to build a group with memory, mostly determined by the magnitude of the values [16]. It can change course and share information based on its location. The so-called best position is the maximum or minimum point of the fitness function [17].

The algorithm may not be effective for global value matching, but it does show that the algorithm will eventually converge to a better solution.

2.4. Nelder-Mead (NM) Simplex Method

The simplex method is a local search algorithm for solving unconstrained optimization problems without any derivative information of the objective function. For the function minimization problem of D variables, the NM method uses operations such as reflection, expansion, contraction, and compression. By comparing the objective function values of the (D+1) vertices of the simplex, the simplex is continuously updated through gradual iteration, and finally the simplex is The shape will approach the optimal solution of the problem [18].

The NM simplex method is simple and easy to implement, and has low requirements on the analytical properties of the objective function (it does not require the objective function to be continuous or derivable). Therefore, the application of this method is very wide. However, it has two main drawbacks: one is very sensitive to the selection of the vertices of the initial "simplex"; the other is that the global convergence of the algorithm cannot be guaranteed.

3. Design of Energy Distribution Method Based on Hybrid Intelligent Algorithm

3.1. Static Load Distribution

(1) Objective function

The objective function of the model should be to minimize the total cost of global power acquisition under the condition that the power demand of each node is met. Since the node electricity price is directly affected by energy distribution, the total cost of obtaining electricity at each point also corresponds to the final node average electricity price level at each point, namely:

$$\min F_M = \min(\sum_{t=1}^{n} F_{Mi}) = \min(\sum_{t=1}^{n} P_l \times E_{Di}) \quad (1)$$

In the formula, FM——the total cost of obtaining electric energy globally, and the sum of the total cost of obtaining electric energy for each node in the world.

(2) Constraints

The power generation energy constraint of each node, that is, the energy available to a node is not less than the sum of the energy used for power generation by the node itself and the energy transferred to other nodes, and there is a maximum energy limit.

$$R_{G,ij} + \sum_{\substack{j=1 \\ j\neq 1}}^{n} R_{T,ij} \le R_{s,j} (i = 1,2,...,n) \quad (2)$$

where RG, ij——the amount of energy used locally for power generation at node i.

3.2. Design of Static Load Distribution Program Based on Hybrid Algorithm

The steps to solve the static load distribution problem using the NMPSO algorithm are as follows:

Step1: Particle initialization and parameter setting. For static load distribution with n units, the particle dimension is set to n, the number of particles is 2n+1, and each particle represents an economic load distribution scheme; each particle is initialized within the power limit range of each unit , and set the algorithm parameters.

Step2: Calculate the objective function value of each particle of the particle swarm, initialize the individual optimal and global optimal of the particle swarm, that is, select the optimal allocation scheme as the global optimal, and take the optimal scheme in the update process of each particle as the individual optimal .

Step3: According to the particle update formula, update the particle speed and position, that is, make adjustments to all the distribution schemes according to the algorithm rules.

Step 4: Update the global optimum and individual optimum of the particle swarm, select the adjusted optimal allocation scheme as the global optimum, and take the optimal scheme in the update process of each particle as the individual optimum.

Step5: Determine whether the number of iterations of the PSO algorithm reaches X, if not, go to Step3, and if so, go to the next step.

Step6: Select the optimal top n+1 particles to construct a simplex, that is, select the optimal top n+1 allocation schemes and use NM optimization.

Step7: According to the function value of each scheme, select the optimal scheme, the worst scheme, the second worst scheme and the compromise scheme except the worst scheme.

Step8: Use NM algorithm rules to perform operations such as reflection, expansion, compression and contraction for each scheme.

Step9: Determine whether the number of iterations of the NM algorithm reaches Y, if not, go to Step7, and if so, go to the next step.

Step10: Determine whether the convergence conditions are met. If so, the optimization ends, and the optimal solution is output. If not, go to Step2.

4. Case Analysis of Energy Distribution

4.1. Simulation Experiment

In this paper, the IEEE3 generator 6 bus standard test system is taken as an example, and Matlab is used for simulation. The parameters of each generator are shown in Table 2. The system load is 500MW, the number of NMPSO iteration rounds is 40, the reflection coefficient in the NM algorithm is 1, the expansion coefficient is 1, and the compression coefficient is 0.5; the number of PSO iterations is 1600, the inertia weight range is [0.4, 0.95], and the learning factors are all is 2.

Table 2. Consumption characteristic coefficients of generators

Unit	Ai	Bi	Ci	Gi	Hi
1	0.0011	5.6	400	300	0.015
2	0.0015	5.8	200	200	0.035
3	0.0038	5.5	100	100	0.055

4.2. Comparison of PSO Algorithm and NMPSO Algorithm

For the following three cases, this paper uses the PSO algorithm and the NMPSO algorithm to conduct 100 independent simulations of this example, and the simulation results are shown in Figure 1, Figure 2 and Table 3. (1) The valve point effect is ignored, and the network loss is ignored. (2) Consider the valve point effect and ignore the network loss. (3) Consider the valve point effect and network loss.

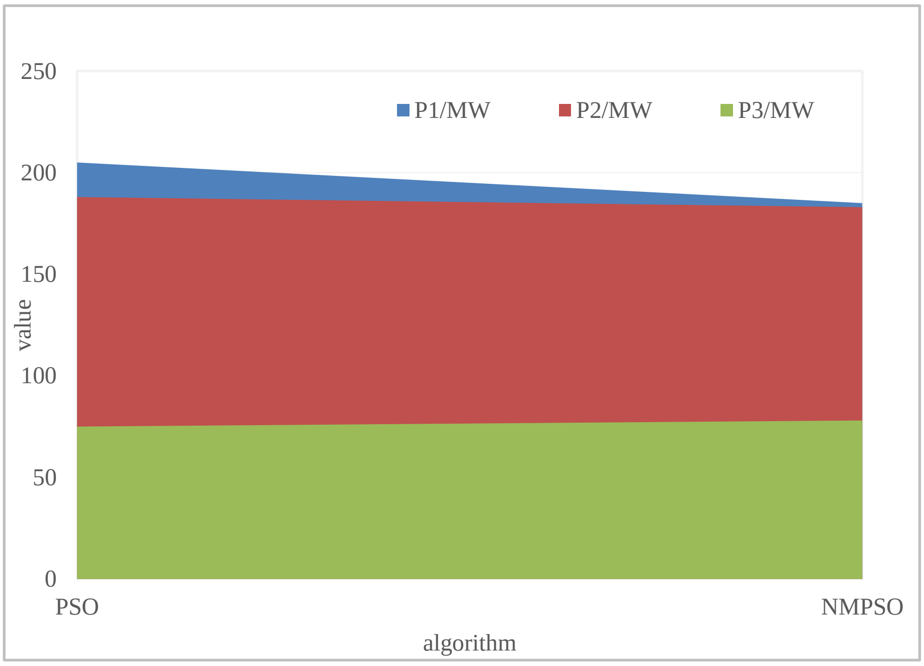

Figure 1. Case 1 simulation results

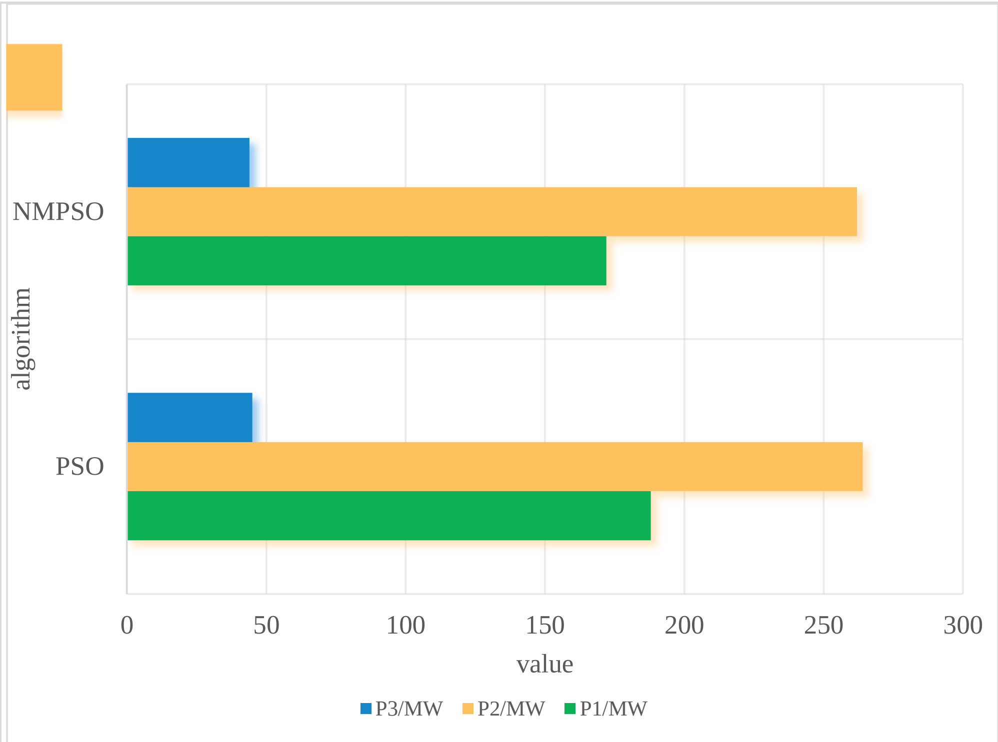

Figure 2. Case 2 simulation results

Table 3. Case 3 simulation results

Program	P1/MW	P2/MW	P3/MW	Total cost/Yuan
PSO	195	135	177	36884
NMPSO	218	155	62	36089

(1) In the three cases, the optimal solution obtained by NMPSO is obviously better than that obtained by PSO, indicating that the hybrid algorithm has a further improvement in the optimal solution compared with PSO.

(2) It can be seen from Figure 1, Figure 2 and Table 3 that considering the effect and network loss, the convergence speed of NMPSO is significantly faster than that of PSO, indicating that the hybrid algorithm is in the direction of the initial stage of guided search. .

(3) Considering the effect and network loss has a great influence on the optimization results, so it is more practical to consider the effect and network loss in practical situations.

5. Conclusion

In production and life, there are more and more optimization problems. How to solve optimization problems and achieve balance between multi-objectives to achieve maximum efficiency is the main direction of our research. As a typical multi-objective optimization problem, the energy distribution problem is of great significance for achieving high economic benefits and energy conservation and emission reduction. This paper mainly studies the static load distribution problem of power system. For the static load sharing problem, three different cases of ignoring valve point effect, ignoring network loss, considering valve point effect, ignoring network loss, considering valve point effect and considering network loss are solved, and the solution results under different conditions are analyzed. Compared with the NMPSO algorithm, the hybrid intelligence algorithm in this paper performs better.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Beckers J , Van D , Meijere C D , et al. Energy distribution functions for ions from pulsed EUV-induced plasmas in low pressure N_2-diluted H_2 gas. Applied Physics Letters, 2019, 114(13):133502.1-133502.5.

[2] Delcorte A , Poleunis C . Mechanistic Insight into Gas Cluster-Induced Sputtering of Kilodalton Molecules Using Kinetic Energy Distribution Measurements. The Journal of Physical Chemistry C, 2019, 123(32):19704-19714.

[3] Nichelatti E , Ronsivalle C , Piccinini M , et al. An analytical approximation of proton Bragg curves in lithium fluoride for beam energy distribution analysis. Nuclear Instruments and Methods in Physics Research Section B Beam Interactions with Materials and Atoms, 2019, 446(MAY 1):29-36.

[4] Ahmadi E . On the structural energy distribution and cumulative damage in soil-embedded foundation-structure interaction systems. Engineering Structures, 2019, 182(MAR.1):487-500.

[5] Naito, Kozo, Wakayama, et al. Energy distribution mechanism and open-kinetic-chain characteristics of the upper body system in female volleyball spiking. Proceedings of the Institution of Mechanical Engineers, Part P. Journal of Sports Engineering and Technology, 2018, 232(2):79-93.

[6] Mehrabi A , Nunna H , Dadlani A , et al. Decentralized Greedy-based Algorithm for Smart Energy Management in Plug-in Electric Vehicle Energy Distribution Systems. IEEE Access, 2020, PP(99):1-1.

[7] Vahidinasab V , Tabarzadi M , Arasteh H , et al. Overview of Electric Energy Distribution Networks Expansion Planning. IEEE Access, 2020, PP(99):1-1.

[8] Guachamin-Acero W , Li L . Methodology for assessment of operational limits including uncertainties in wave spectral energy distribution for safe execution of marine operations. Ocean Engineering, 2018, 165(OCT.1):184-193.

[9] Febelyn, Reguyal, Ajit, et al. Site energy distribution analysis and influence of Fe_3O_4 nanoparticles on sulfamethoxazole sorption in aqueous solution by magnetic pine sawdust biochar. ENVIRONMENTAL POLLUTION, 2018, 233(Feb.):510-519.

[10] Galliano, Frederic. A dust spectral energy distribution model with hierarchical Bayesian inference - I. Formalism and benchmarking. Monthly notices of the Royal Astronomical Society,

2018, 476(2):1445-1469.
[11] Vos P D , Stapersma D . Automatic topology generation for early design of on-board energy distribution systems. Ocean Engineering, 2018, 170(DEC.15):55-73.
[12] Weekly, Propane, Newsletter, et al. Energy Distribution Partners Acquires Carolina Propane. Weekly Propane Newsletter, 2018, 48(38):3-3.
[13] Butane-Propane, News, Group. Energy Distribution Partners Acquires Carolina Propane. Butane-Propane News, 2018, 50(10):14-14.
[14] Fiaschetti, L, Antunez, et al. Monitoring and controlling energy distribution: Implementation of a distribution management system based on Common Information Model. International journal of electrical power and energy systems, 2018, 94(Jan.):67-76.
[15] Pepel V D , Webster P T , Logan J V , et al. Extraction of Trap Energy Distribution in Proton-Irradiated Focal Plane Arrays Using a High-Precision Random Telegraph Noise Detection Algorithm. IEEE Transactions on Instrumentation and Measurement, 2021, PP(99):1-1.
[16] Molina F , Sala-Alvarez J . Discontinuous User-Energy Distribution for Dynamically Ordered Successive Interference Cancellation. IEEE Communications Letters, 2021, PP(99):1-1.
[17] Mehrabi A , Nunna H , Dadlani A , et al. Decentralized Greedy-based Algorithm for Smart Energy Management in Plug-in Electric Vehicle Energy Distribution Systems. IEEE Access, 2020, PP(99):1-1.
[18] Vahidinasab V , Tabarzadi M , Arasteh H , et al. Overview of Electric Energy Distribution Networks Expansion Planning. IEEE Access, 2020, PP(99):1-1.