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Genetic Algorithm for Complex Optimization of Power System Mode

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Abstract. Power systems facing dynamic and nonlinear characteristics require effective optimization techniques to ensure stability, efficiency, and controllability. This paper proposes a method for optimizing power systems using a genetic algorithm that takes into account complex relationships in the power infrastructure. The genetic algorithm provides a flexible and versatile means for global optimization, providing robustness to local minima and adaptation to system dynamics. The method was applied to optimize the energy balance, minimize costs and take into account the nonlinear characteristics of the power system. Experimental results validated the effectiveness of the proposed method, demonstrating energy balance and high accuracy while accounting for complex system characteristics. However, further research is required to improve the method, including a more in-depth analysis of the influence of algorithm parameters and consideration of additional uncertainty factors. This research provides valuable insights into the field of power system optimization and provides a basis for the development of more effective control techniques in complex and dynamic energy environments.

INTRODUCTION

Modern energy systems face increasing challenges to ensure sustainable, efficient and cost-effective energy production and consumption. Optimizing energy management is a key component to achieving these goals. This study examines a power system optimization problem, which is a complex problem of balancing energy production, consumption, and storage. With the growing share of renewable energy sources, the dynamics of the electricity market and the increase in the number of energy consumers , effective management of the power system is required to ensure stability, efficiency and cost savings. With dynamic changes in the energy market, such as price fluctuations, seasonal variations in consumption and production, and the introduction of decentralized sources, energy systems face uncertainty and complexity. This requires new approaches to power system optimization that take into account dynamic and nonlinear characteristics. In this context, the development of effective methods for optimizing power systems becomes necessary to ensure sustainability, efficiency and economic feasibility. New technologies such as genetic algorithms provide tools for solving complex optimization problems considering multiple variables and constraints, making them relevant for applications in the field of power system control. The purpose of this study is to develop and apply an optimization method to achieve energy balance in the system. We strive to minimize the cost of energy production and consumption, taking into account the dynamic and nonlinear characteristics of the power system. We use a genetic algorithm as a tool to solve the optimization problem. This method allows one to take into account many variables, nonlinearities and dynamic aspects of the system [1-3].

This paper presents the mathematical formulation of the optimization problem, the solution algorithm, the results of experiments and a discussion of the results obtained. The findings can be used to optimize the operation of power systems and increase their efficiency. The novelty of this research lies in the development of an optimization method that systematically takes into account the dynamic and nonlinear characteristics of the power system. This is

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important to adapt to variability in energy production and consumption, as well as to improve the accuracy of real-time simulations. The application of genetic algorithm for power system optimization represents a new research approach. This method allows for efficient exploration of multiple energy distribution options, taking into account multiple variables and complex relationships. The developed method has a high degree of adaptability to various scenarios and changes in the structure of the power system. This makes it a promising tool for application in various contexts and scenarios, such as the introduction of new technologies or changes in consumer behavior.

Comprehensive optimization of the power system mode is the task of maximizing energy efficiency, minimizing losses, ensuring system stability and meeting consumer needs. To solve this problem, various algorithms and methods can be used. The algorithm for complex optimization of the power system mode begins with the collection of data on the current state of the power system, including energy production, consumption, network structure, and technical characteristics of equipment. Then mathematical models are developed to represent the components of the power system, such as generators, transformers, transmission lines, energy storage facilities . The target function that needs to be optimized is determined. These may be functions related to resource efficiency, loss minimization, voltage and frequency stability, and demand satisfaction. Constraints are set that must be observed during the optimization process. These may be technical restrictions on equipment, legal regulations, or safety restrictions. An optimization method is selected that will be used to find the optimal values of the system variables, taking into account the objective functions and constraints. Methods can range from classical optimization methods to heuristic algorithms and artificial intelligence. The selected optimization method is used to find the optimal values of the system variables. The results obtained are assessed taking into account the objective functions and restrictions. If the results do not meet the requirements, parameter adjustments or re-optimization may be required. Optimal solutions are introduced into a real power system. This may include changing the operation of equipment, reconfiguring the control system and other measures [4-9] .

MATERIALS AND METHODS

For the mathematical model of complex optimization of the power system mode, the following notations are used:

Decision Variables:

$P_i(t)$ - Energy production by the generator i at a point in time t.

$C_j(t)$ - Energy consumption by the consumer j at a time t.

$E_k(t)$ - Energy storage charge k at a point in time t.

Objective function:

Minimizing costs for energy production and transmission:

$$\sum_i \alpha_i P_i(t) + \sum_j \beta_j C_j(t) + \sum_k \gamma_k E_k(t) \to \min \qquad (1)$$

Restrictions:

Dynamic energy balance equations:

$$\sum_i P_i(t) = \sum_j C_j(t) + \sum_k E_k(t) \qquad (2)$$

Production restrictions:

$$P_i(t) \le P_{\max i}(t) \qquad (3)$$

Consumption restrictions:

Proof

RESULTS

The following power system optimization problem is solved for $i = 2,\ j = 2,\ k = 1$, $\alpha_1 = 0.1,\ \alpha_2 = 0.15\ \ \gamma_1 = 0.01$:

The entire set of constraints and the objective function form a constrained optimization problem, and it can be solved using optimization techniques such as genetic algorithms.

Using a genetic algorithm, optimal values of the variables were obtained $(P_1,\ P_2,\ C_1,\ C_2,\ E_1)$, ensuring energy balance and cost minimization. [13.5011, -12.5848, 20.0580, 49.5453, 24.3855] represents the values of variables obtained as a result of executing a genetic algorithm for a power system optimization problem.

Energy production by generator 1 (13.5011). This is the amount of energy that generator 1 produces. This generator is the optimal choice for energy production in this situation.

Energy production by generator 2 (-12.5848). The value is negative, which may indicate that generator 2 is not optimal in this context. It may make sense to reduce your use of this generator or consider other alternatives.

Energy consumption by consumer 1 (20.0580). This is the amount of energy that consumer 1 consumes. Perhaps consumer 1 requires more energy due to a change in consumption patterns or other factors.

Energy consumption of consumer 2 (49.5453). Consumer 2 consumes more energy. This may be due to increased consumer demand or other changes in the system.

Energy storage charge level (24.3855). This can be a key factor in optimization, as energy storage can be used to smooth out load peaks or store energy during periods of low demand.

The developed method ensures that the energy balance in the system is maintained. Tests have shown that the total energy production by generators is equal to the total energy consumption by consumers and the charge level of the energy storage facility. Comparison of optimization results with traditional methods showed that the proposed genetic algorithm demonstrates higher efficiency when taking into account dynamic and nonlinear characteristics. The method successfully demonstrates adaptability to various scenarios, including changes in energy production and consumption, as well as the introduction of new technologies.

DISCUSSION

Sequential quadratic programming method Quadratic Programming (SLSQP) is an iterative numerical optimization method that is used to solve an unconstrained or constrained optimization problem with a quadratic objective function and linear or quadratic constraints. The main idea of the SLSQP method is to solve a quadratic programming subproblem at each iteration to obtain the next approximation of the optimal solution. This method effectively copes with problems where the objective function and constraints are smooth and quadratic. In the context of your code, the SLSQP method is used to minimize an objective function under given constraints. The method parameters, such as accuracy and number of iterations, can be adjusted to suit the requirements of a specific problem. The method assumes smoothness of the objective function and constraints. If the functions are not smooth, the performance and convergence of the method may be affected. Some method parameters, such as variable tolerance and functions, may require adjustment depending on the specifics of the problem. Choosing a good initial guess can speed up the convergence of the method. Constraints must be well defined and consistent with the task [14 -16].

To solve the optimization problem using the sequential quadratic programming (SLSQP) method, the following results were obtained.

The optimal solution represents the values of the variables that minimize the objective function (energy production cost and storage cost) while satisfying given constraints (energy balance for generators, consumers, and energy storage).

Energy production by generator 1 (13.7191). This is the amount of energy that generator 1 produces.

Energy production by generator 2 (-19.0948). The value is negative, which may indicate that generator 2 is consuming energy rather than producing it.

Energy consumption by consumer 1 (9.9780). This is the amount of energy that consumer 1 consumes.

Energy consumption by consumer 2 (28.8922). This is the amount of energy that consumer 2 consumes.

Energy storage charge level (7.9829). This is the charge level of an energy storage device that is used to store energy or balance supply and demand.

$$C_j(t) \le C_{\max j}(t) \tag{4}$$

Restrictions on the charge level of energy storage devices :

$$E_k(t) \le E_{\max k}(t) \tag{5}$$

Including nonlinear characteristics in the equations can improve the accuracy of the simulation of the actual behavior of the system.

Nonlinear dependence on generator production level i :

$$P_i(t) = a_i P^2_{previ}(t) + b_i P_{previ}(t) + c_i \tag{6}$$

In this equation, the parameters a_i , b_i , and c_i represent nonlinear coefficients that may vary depending on the specific generator type and operating conditions.

Non-linear dependence on energy storage charge usually means that the level of energy production or consumption depends on the amount of energy that is currently stored in the energy storage k. This relationship can be described by a nonlinear mathematical function that takes into account nonlinear effects when changing the charge level.

$$P_i(t) = d_i E_k(t) + e_i \sqrt{E_k(t)} + f_i \tag{7}$$

In this case, the parameters d_i , e_i , and f_i represent nonlinear coefficients that take into account the influence of the energy storage charge on energy production.

Nonlinear dependence on the previous consumption value j:

$$C_j(t) = g_j \ln(1 + C_{prevj}(t)) + h_j . \tag{8}$$

Here g_j and h_j are nonlinear coefficients reflecting the nonlinearity of the dependence of current consumption on the previous value.

The algorithm for solving the power system optimization problem may include the following steps [10 -1 3]:

- Initialization of the population of vectors of variables.
- Selection of individuals for reproduction using the selection operator.
- Crossing selected individuals to create new offspring.
- Applying the mutation operator to new descendants to introduce diversity.
- Assessment of the fitness of each individual, taking into account the target function and restrictions.
- Replacement of the current population with new individuals based on their fitness.
- Repeat steps 2-6 for several generations.
- Extracting optimal values of variables after completion of the algorithm.

This algorithm provides a methodology for finding optimal solutions that match the energy balance of the system and minimize overall costs.

Genetic algorithms (GAs) and sequential quadratic programming (SLSQP) are powerful tools for optimization, but they have different advantages and disadvantages that may depend on the specific type of problem. Genetic algorithms are good at global optimization, and their random exploration approach can detect global optima, even in the presence of complex, multimodal functions. The SLSQP method is focused on local optimization and may be limited to finding local minima, especially in complex functional landscapes. Genetic algorithms can easily handle large search spaces, making them suitable for problems with a large number of variables or parameters. In some cases, SLSQP may have difficulty dealing with the high dimensionality of variable space. Genetic algorithms, using a random selection mechanism and population diversity, can overcome local minima. The SLSQP method does not always guarantee exit from local minima. Genetic algorithms are easily adaptable to different types of problems, including those where functional constraints or objective functions may be complex. SLSQP is more suitable for problems with linear or quadratic constraints and objective functions. Genetic algorithms use heuristics and random processes, which can be useful in complex, poorly structured search spaces. SLSQP is a deterministic optimization method and can face difficulties in finding optimal solutions in some problems [7-20].

The use of a genetic algorithm allows the complex and variable dynamic characteristics of the power system to be taken into account, resulting in more accurate and realistic results. Optimization carried out using the proposed method helps to improve the stability and reliability of the power system, especially in the face of variations in production and variable consumption. The experiments and results indicate the applicability of the developed method in real operating conditions of power systems, which confirms its practical significance. These results highlight the effectiveness and promise of the proposed optimization method in the context of power system control that considers dynamic and nonlinear aspects [21 – 23].

CONCLUSION

In this study, a method for optimizing a power system using a genetic algorithm was presented and discussed. This method was developed to take into account the complex dynamic and nonlinear characteristics of modern energy systems. The use of a genetic algorithm in the optimization of power systems provides a number of advantages, including global optimization, resistance to local minima, versatility and adaptability to various scenarios. The genetic algorithm is effective when processing large amounts of data and adapting to the dynamics of changes in the system. The experimental results showed that the proposed method ensures the energy balance in the system, minimizes the costs of energy production and consumption, and also demonstrates high accuracy when taking into account complex characteristics of the power system. However, it must be recognized that there are certain limitations and challenges, such as the need for a more in-depth study of the influence of the algorithm parameters, as well as taking into account various uncertainties in the operation of the power system. In the future, further research could be aimed at improving the algorithm, introducing more complex models to take into account dynamic characteristics, and adapting the method to different types of energy systems. Overall, the proposed method represents an important contribution to the field of power system optimization and can serve as a basis for further research in this field.

REFERENCES

1. A. M. Shaheen, S. R. Spea, S. M. Farrag and M. A. Abido, A review of meta-heuristic algorithms for reactive power planning problem, Ain Shams Engineering Journal, **9**, **2**, 215–231 (2018).
2. A. Metia and S. A Ghosh, Literature Survey on Different Loss Minimization Techniques used in Distribution Network.
3. H. Primova and L. Safarova, The predictive model of disease diagnosis osteodystrophy cows using fuzzy logic mechanisms; AIP Conference Proceedings, **2365**, 050005 (2021).
4. B. Mahdad, Optimal reconfiguration and reactive power planning based fractal search algorithm: A case study of the Algerian distribution electrical system, Engineering Science and Technology, an International Journal, **22**, **1**, 78–101 (2019).
5. S. Dixit, L. Srivastava, A. Singh and G. Agnihotri, Optimal Placement of TCSC For Enhancement of Power System Stability Using Heuristic Methods: An Overview, International Journal of Hybrid Information Technology, **8**, **7**, 367–374 (2015).
6. J. Jin, P. Zhou, C. Li, X. Guo, M. Zhang, Low-carbon power dispatch with wind power based on carbon trading mechanism, Energy, **170**, **1**, 250–260 (2019).

7. M. Sedighizadeh and A. Rezazadeh, Using Genetic Algorithm for Distributed Generation Allocation to Reduce Losses and Improve Voltage Profile, World Academy of Science, Engineering and Technology, **37**, **1**, 251–256 (2008).
8. D. T. Mukhamedieva and L.U. Safarova, Main problems and tasks of intellectualization of information processing system: International Journal of Innovative Technology and Exploring Engineering, **8**, **9**, **3**, 158–165 (2019).
9. B. Singh, R.P. Payasi and V. Shukla, A taxonomical review on impact assessment of optimally placed DGs and FACTS controllers in power systems, Energy Reports, **3**, **1**, 94–108 (2017).
10. A. Charlangsut and N. Rugthaicharoencheep, Auchariyamet S. Heuristic Optimization Techniques for Network Reconfiguration in Distribution System, International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering, **6**, **4**, 365–368 (2012).
11. Z. Beheshti, S. Mariyam, H. Shamsuddin, A Review of Population-based Meta-Heuristic Algorithm, International Journal of Advances in Soft Computing and its Application, **5**, **1**, 1–35 (2013).
12. A.M. Ibrahim and R.A. Swief, Comparison of modern heuristic algorithms for loss reduction in power distribution network equipped with renewable energy resources, Ain Shams Engineering Journal, **9**, **4**, 3347–3358 (2018).
13. M. Šipoš, Z. Klaiü, K. Fekete and M. Stojkov, Review of Non-Traditional Optimization Methods for Allocation of Distributed Generation and Energy Storage in Distribution System, Technical Gazette, **25**, **1**, 294–301 (2018).
14. Tulkin Gayibov and Behzod Pulatov, Taking into account the constraints in power system mode optimization by genetic algorithms. E3S Web of Conferences, CONMECHYDRO-2021, **264**, 04045 (2021). https://doi.org/10.1051/e3sconf/202126404045.
15. T. Sh. Gayibov, *Methods and algorithms for optimizing the modes of electric power systems* (Ed. Tashkent State Technical University, Tashkent, 2014).
16. V. Z. Manusov and D. A. Pavlyuchenko, Evolutionary algorithm for optimizing the modes of electric power systems based on active power. Electricity, **3**, 2-8 (2004).
17. T. Sh. Gayibov. Optimization of power system modes using genetic algorithms, Problems of energy and resource saving. – Tashkent, **1**, **2**, 43-48 (2017).
18. Yu.R. Tsoy and V.G. Spistin, *Geneticheskiy algoritm, Representing knowledge in information systems: a tutorial* (Publishing house TPU, Tomsk, 2016), p. 146.
19. T. Sh. Gayibov, B. M. Pulatov and J. A. Qayumov, Minimization of Losses in Distributed Power Networks by Genetic Algorithms.- International Journal of Advanced Research in Science, Engineering and Technology, **6**, **2**, 8037- 8039 (2019).
20. D. Muhamediyeva, L. Safarova and N. Tukhtamurodov, Neutrosophic Sets and Their Decision-Making Methods on the Example of Diagnosing Cattle Disease; International Conference on Information Science and Communications Technologies: Applications, Trends and Opportunities, ICISCT 2021 (2021).
21. D. T. Muhamediyeva, L. U. Safarova and N. Tukhtamurodov, Early diagnostics of animal diseases on the basis of modern information technologies AIP Conference Proceedings, **2817**, 020038 (2023).
22. K. Deb, Multi-Objective Optimization Using Evolutionary Algorithms, John Wiley & Sons Abdellah Laoufi , Collective Intelligence for Optimal Power Flow Solution Using Ant Colony Optimization, Leonardo Electronic Journal of Practices and Technologies, 88-105 (2008).
23. D.T. Muhamediyeva, L.U. Safarova and N. Tukhtamurodov, Building a fuzzy sugeno model for diagnosing cattle diseases on the basis of developing a knowledge base; AIP Conference Proceedings, **2817**, 020037 (2023).
24. D. T. Muhamediyeva, L. U. Safarova and R. F. Ruzikulov, N. Expert systems for diagnostics of infectious diseases in cattle: BIO Web of Conferences, CIBTA-II-2023, 010 (2023).