Load Frequency Control of Two-region Power System based on Differential Evolution Algorithm

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Abstract

The load frequency control of the interconnected grid plays an important role in ensuring the safe and reliable operation of the grid, especially when new energy power generation is involved today, it is necessary to design a suitable controller and optimize the controller parameters so that the system frequency can be guaranteed even when the power system faces some random disturbances. Stability and stability of the exchange power of the tie line. Aiming at the optimization and tuning of load frequency controller parameters for two-region interconnected power grids, a controller parameter tuning scheme using differential evolution algorithm is proposed. This scheme uses the absolute value integral of minimizing the time multiplication error as the objective function, and uses the differential evolution algorithm to search to obtain the optimal load frequency controller parameters. And improved the differential evolution algorithm. A simulation model of the load frequency control system of the two-region interconnected power grid is established in matlab/simulink. The simulation results show that the proposed algorithm can effectively maintain the stability of the system frequency.

Keywords

Interconnected Power System; Load Frequency Control; Differential Evolution Algorithm; Wind Power.

1. Introduction

In the power system, frequency stability is an important indicator of the safe operation of the power system. With the rapid development of new energy power generation, especially the large-scale grid connection of wind power generation in recent years, it is foreseeable that the power system will face the challenge of frequency control problems [1]. Load Frequency Control (LFC) compensates for the power imbalance existing in the power grid by continuously adjusting the active output of the FM generator set, so that the interconnected system maintains the system frequency at the rated value and area when the interconnected system is in normal operation and is subject to external disturbances The exchange power of the tie line is near the planned value. Appropriate LFC controller design has an important impact on the dynamic performance of grid frequency regulation [2]. Literature [3] introduced an ant colony algorithm to design the load frequency controller based on the optimal adjustment of proportional plus integral (PI), and proposed a method based on ant colony optimization to increase the system frequency under various wind energy penetration scenarios. Performance method. Literature [4] uses the gray wolf optimization algorithm to optimize and tune the parameters of the PI/PID controller of the LFC system, which can achieve better control effects of tie-line power deviation and frequency deviation and system robustness in the interconnected system. The literature [5] [6] adopts an adaptive fuzzy logic structure and proposes a new intelligent LFC scheme in the interconnected large-scale power system. According to the variation of the regional control deviation,

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the fuzzy reasoning is used to modify the PID adjustment parameters online, thereby The control interconnected power grid is rapidly becoming dynamic and stable.

Based on this, the differential evolution algorithm in this paper is applied to the load frequency control of a regional interconnected power system containing wind power. First, LFC model of a two-region interconnected power system containing wind power is established. Wind power is added to the LFC model as a negative disturbance. Establish the controller parameter optimization tuning model, optimize its control parameters on the traditional PID control, use the optimized PID controller for load frequency control, and conduct simulation experiments on the studied system under different load conditions, verifying the difference based on The effectiveness of load frequency control based on evolutionary algorithm.

2. LFC model of interconnected power system with wind power generation in two regionsSub-section Headings

This paper takes the classic two-region interconnected power system as an example, and designs an LFC controller parameter optimization model after adding wind power disturbances $\Delta \boldsymbol{P}_{\boldsymbol{W}}$.

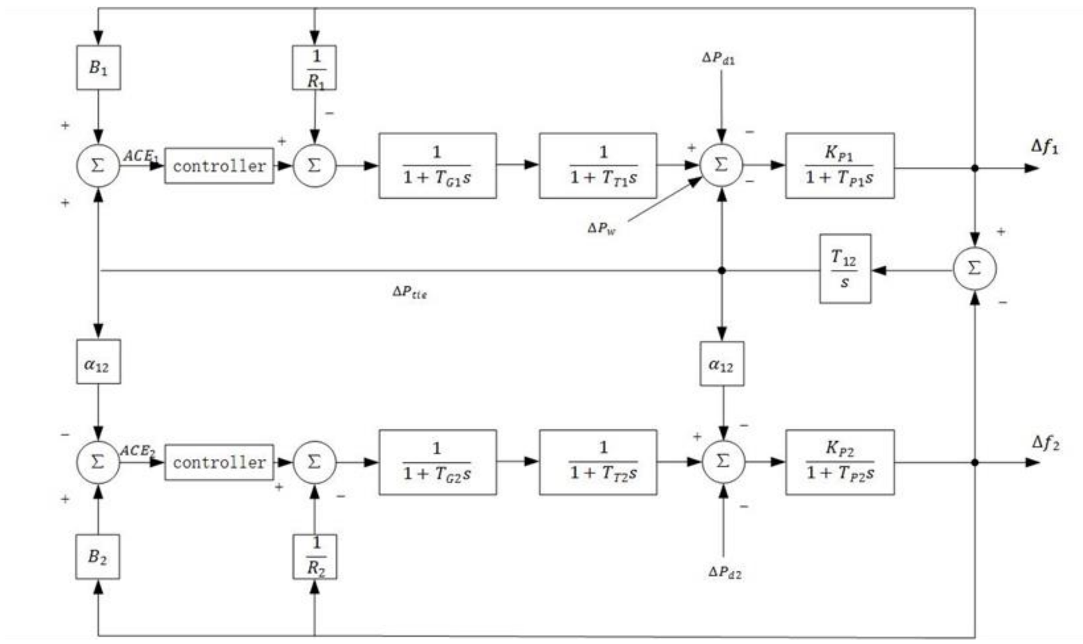

Figure 1. Two-region interconnected power system model

Among them: $T_{Gi}$is the governor time constant, T_{Pi} is the power system time constant, K_{Pi} is the power system gain, $T_{Ti}$is the steam turbine time constant, R_i is the adjustment coefficient, B_i is the frequency deviation coefficient, Δf_i is the frequency deviation of area i, $\Delta P_{tie}$is the tie line power deviation, α_{12} is the power conversion coefficient, T_{12} is the interconnection gain between regions, ACE_i is the regional control deviation, ΔP_{di} is the load disturbance, $\Delta P_W$is the wind power.

The purpose of LFC controller parameter optimization is to eliminate the system frequency deviation and tie-line power deviation in each area as soon as possible under the action of the controller when the system is subject to certain disturbances, and to keep the power generation output of the power system matched with the load power. Usually, the Integral of Time multiplied Absolute Error (ITAE) performance index of the simulation output signal can be used as the objective function of the optimization problem. For conventional PID control, the controller parameter optimization problem can be described as searching for a set of optimal K_p, K_i, K_d values in a certain parameter space to minimize the ITAE index. Thus, a two-zone LFC system PID controller parameter optimization tuning model is established, and its objective function is:

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$$J = \int_0^T t(|\Delta f_1| + |\Delta f_2| + |\Delta P_{tie}|)dt \quad (2.1)$$

$$K_p^{min} \leq K_p \leq K_p^{max} \ , K_i^{min} \leq K_i \leq K_i^{max} \ , K_d^{min} \leq K_d \leq K_d^{max} \quad (2.2)$$

3. Differential evolution algorithm and its improvement

3.1 The basic idea of differential evolution algorithm

DE algorithm is an evolutionary algorithm for optimizing the minimum objective function based on real number coding. It has the characteristics of fast initial convergence, strong robustness, and simple implementation [7], so it is widely used in various fields. It belongs to a population-based heuristic search algorithm, and each individual in the population corresponds to a solution vector. The operating process of differential evolution algorithm is similar to genetic algorithm, including mutation, crossover, and selection operations. Compared with genetic algorithm, the main difference lies in the mutation operation. DE starts from a certain set of randomly generated initial populations, randomly selects two different individual vectors and subtracts them to generate a difference vector. After assigning weights to the difference vector, it is added to the third randomly selected individual vector to generate a variation vector. The mutation operation method of the DE algorithm makes more effective use of the distribution characteristics of the group, so the search ability of the algorithm can be improved, and the deficiency of the mutation method in the genetic algorithm is avoided [8].

3.2 Differential evolution algorithm operation process

1) Population initialization: The DE algorithm uses NP D-dimensional parameter vectors as the initial population, and the initial population is randomly selected as:

$$X_t = (x_{1,t}, x_{2,t}, \dots, x_{N,t}) \quad (3.1)$$

$x_{i,t}$represents the i-th individual of the t-th generation, and this vector is a D-dimensional vector. The specific value method of the i-th individual is:

$$x_{i,t} = x_{min} + rand(0,1)(x_{max} - x_{min}) \quad (3.2)$$

The individual value range is$[x_{min}, x_{max}]$, rand(0,1) is a random number between 0 and 1.

2) Mutation operation: The standard DE algorithm generates new individuals as follows:

$$v_{i,t+1} = x_{r1,t} + F \times (x_{r2,t} - x_{r3,t}) \quad (3.3)$$

In formula (2), $x_{r1,t}, x_{r2,t}, x_{r3,t}$are different random individuals, that is, $i \neq r1 \neq r2 \neq r3$. $F \in [0,2]$ is the scaling factor, The degree of scaling that affects the generation of new individuals, usually 0.5, can also be adaptively changed.

3) Crossover operation: Crossover operation can increase the diversity of the population. The expression of crossover operation is:

$$u_{ij,t} = \begin{cases} v_{ij,t+1} & rand \leq CR \text{ or } j = rand(i) \\ x_{ij,t} & rand > CR \text{ or } j \neq rand(i) \end{cases} \quad (3.4)$$

$CR \in (0,1]$ is the crossover probability, and rand(i) is a random integer between [1,N]. This crossover operation can ensure that at least one component in $u_{ij,t}$ is determined by $v_{ij,t+1}$ Provided.

4) Selection operation: According to the greedy optimization search strategy, the test individual $u_{i,t}$ generated after mutation and crossover operation is compared with the target individual $x_{i,t}$ in the current population. If the optimal function value of the test individual $u_{i,t}$ is better than the optimal function value of the target individual $x_{i,t}$, it can be selected as the offspring individual. Otherwise, directly select the target individual $x_{i,t}$ As an individual offspring. The calculation formula of the selection operation is:

$$x_{i,t+1} = \begin{cases} u_{i,t}, f(u_{i,t}) < f(x_{i,t}) \\ x_{i,t}, f(u_{i,t}) \geq f(x_{i,t}) \end{cases} \quad (3.5)$$

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3.3 Self-adaptive improvement of differential evolution algorithm

Improvement of the scaling factor F of the differential evolution algorithm: In practical applications, if F is taken as a constant, a too large F will slow down the convergence speed of the algorithm and reduce the accuracy of the global optimal solution; too small F will affect the diversity of the population, and the probability of premature maturity is greatly increased. Therefore, the scaling factor can be adaptively operated and set to a value that changes with the number of iterations. At the beginning of the iteration, a larger value of F can maintain the diversity of the population. As the number of iterations increases, the reduced F can preserve excellent population information and avoid destroying the optimal solution.

The improvement of the crossover probability CR of the differential evolution algorithm: the crossover operation can increase the individual difference between the populations and increase the population diversity of the algorithm. In the crossover operation, the size of the crossover probability CR controls the generation of new individuals. When the CR is large, it is beneficial to the local optimization to improve the convergence speed of the algorithm; when the CR is small, it is more conducive to the global optimization of the algorithm and maintaining the diversity of the population. In the standard differential evolution algorithm, the crossover probability is a constant, and it cannot take into account the relationship between global optimization and local optimization. It is also contradictory in maintaining population diversity and convergence speed. In order to solve this contradiction, an adaptively changing crossover probability operator is proposed. The value of this operator is small at the beginning of the algorithm operation, and it will increase in the later period. The value method is as follows:

$$F = F_{max} - G \times (F_{max} - F_{min}) \div G_m \quad (3.6)$$

$$CR = CR_{min} + G \times (CR_{max} - CR_{min}) \div G_m \quad (3.7)$$

Where G_m represents the maximum number of iterations, and G represents the current number of iterations.

4. Simulation and result analysis Conclusion

Assuming that at t=1s, area 1 is subjected to random disturbance from the outside: $\Delta P_{d1} = 0.025pu$, disturbance from wind power: $\Delta P_W = 0.025pu$, and area 2 is subjected to random disturbance from the outside: $\Delta P_{d2} = 0.025pu$. The traditional PID control and the PID control optimized by the differential evolution algorithm are used for simulation comparison. The dynamic response results of the system are shown in Figure (2-4).

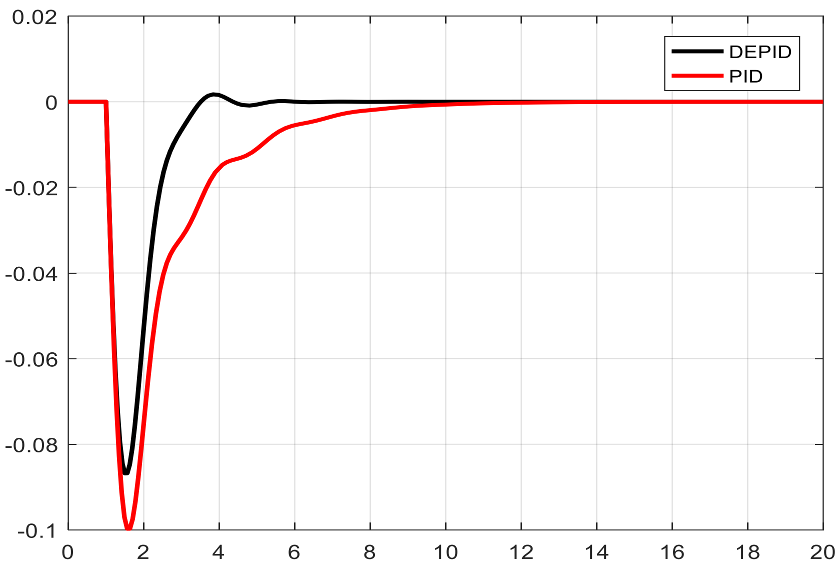

Figure 2. Zone 1 system frequency deviation

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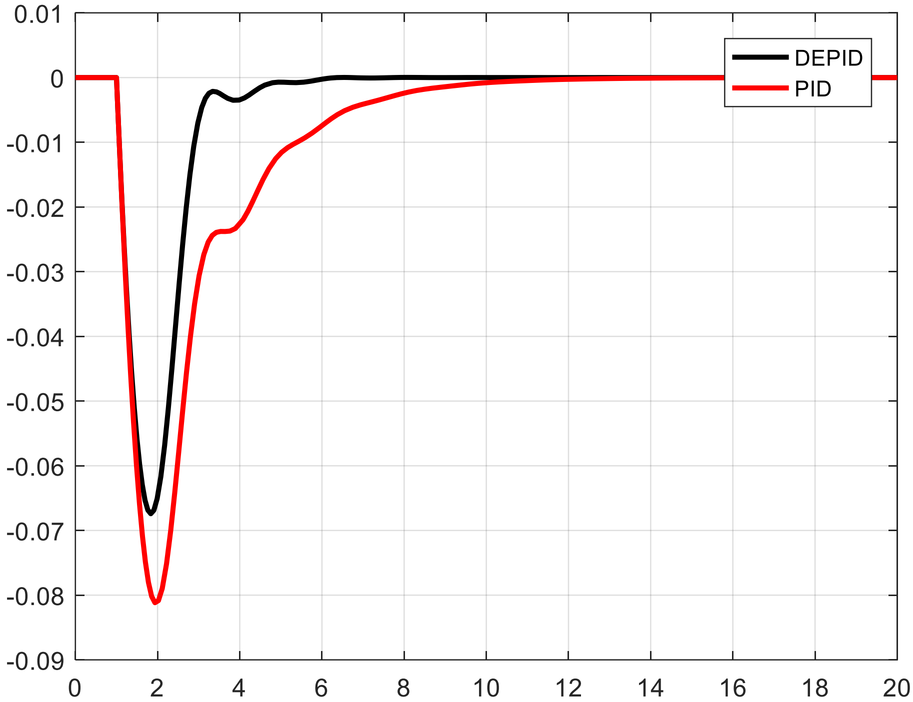

Figure 3. Zone 2 system frequency deviation

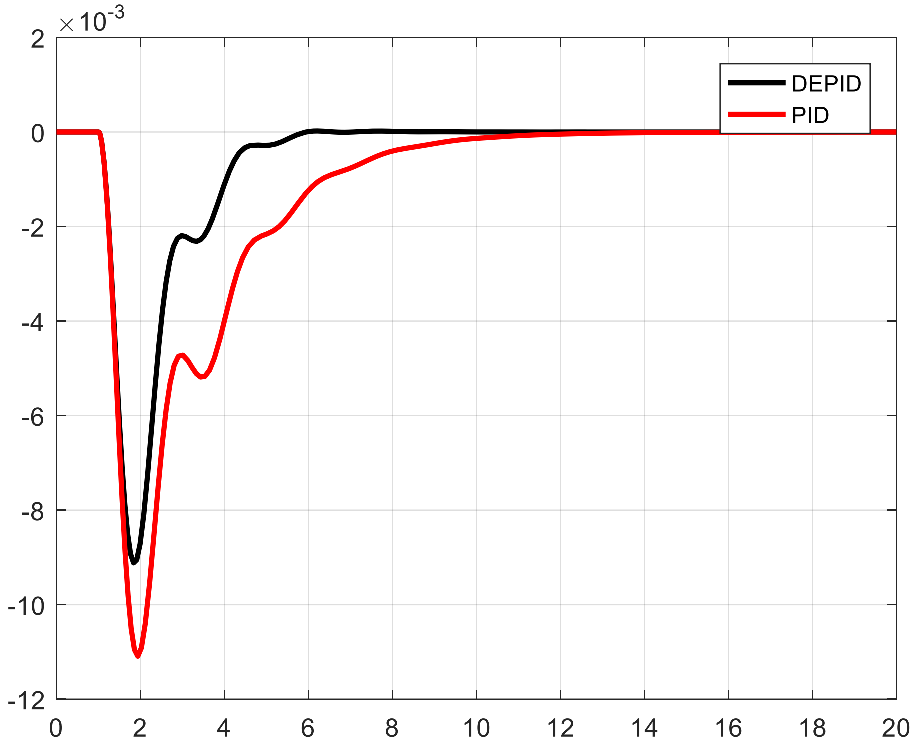

Figure 4. Tie line power deviation

From the simulation results in Fig. 2 to Fig. 4, it can be seen that the PID controller optimized by the differential evolution algorithm has a better control effect in the control of the frequency deviation of the two regions and the power deviation of the regional tie line, and the adjustment time is obvious. Shortened, its ITAE index is also much smaller than traditional PID controller.

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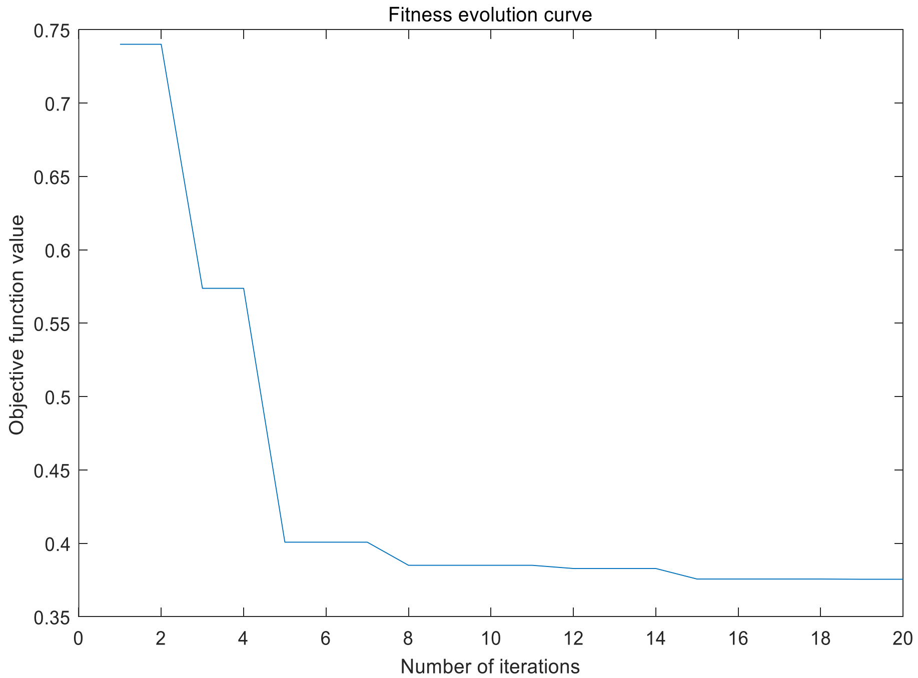

Figure 5. The fitness evolution curve of the improved differential evolution algorithm

The improved differential evolution algorithm is stronger than the ordinary differential evolution algorithm in iterative speed, and can approach the optimal value faster.

5. Conclusion

Aiming at the regional interconnected power system containing wind power, in order to achieve load frequency control more effectively, a PID controller using differential evolution algorithm is designed to optimize the controller parameters, and the algorithm is improved to ensure that the search strategy is In the initial stage of the search, the diversity of the population is maintained and a global search is performed. In the later stage of the search, the local search capability should be strengthened to improve the accuracy and convergence speed of the algorithm. The simulation results in matlab/ simulink show that the proposed control strategy can effectively suppress external random disturbances and wind power disturbances, and achieve better control effects than traditional controllers.

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