Research on Distributed Power Energy Grid-Connected Control Method Based on Big Data

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Abstract. In the process of modeling distributed power grid connection, the parameter control effect is not good, and the modeling is not stable. A distributed power energy grid-connected control method based on large data is put forward. Distributed power energy-energy grid-connected model is established, a DC/AC inverter model and a current inner-loop controller model are analyzed. And an equivalent circuit model analysis of the terminal voltage of the grid-connected inverter of the controller is analyzed. The fuzzy PID control algorithm is introduced to identify the unknown parameters in the distributed power energy grid-connected control, the fitness function of the inner ring controller and the fitness function of the outer ring controller are obtained. Expert database is initialized and updated, Until the maximum number of iterations or convergence accuracy is reached. The simulation results show that the proposed method can effectively improve the performance of the distributed power grid-connected control.

Keywords: Big data · Distributed power energy · Grid-connected control · Fuzzy PID

1 Introduction

With the gradual increase of the scale of grid-connected photovoltaic system, its effect on power grid is becoming more and more obvious, and the safety and reliability of grid-connected photovoltaic power generation have been paid more and more attention. Among them, distributed power energy grid-connected is the basis of simulation research on photovoltaic power supply system, and whether it can effectively reflect the dynamic characteristics of photovoltaic power generation system mainly depends on its reasonable model structure and accurate model parameters [1]. Therefore, it has great significance to study distributed power energy grid-connected control.

At present, many algorithms have been applied to distributed power energy grid-connected control. The commonly used algorithms include genetic algorithm, particle swarm optimization algorithm, ant colony algorithm and imitating electromagnetics algorithm [2, 3]. In reference [4], the proportional integral control algorithm is applied to the distributed power energy grid-connected control. The current is decomposed into positive and negative sequence by two current controllers in synchronous reference

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coordinate system. The PI control in synchronous coordinate system is carried out respectively, but this method has the disadvantage of complicated calculation process. In reference [5], the proportional resonance control algorithm is applied to the distributed power energy grid-connected control. The current can directly control the output current in two-phase static coordinates, but to some extent, this method is difficult to achieve. In reference [6], genetic algorithm is applied to distributed power energy grid-connected control. The performance of the system is degraded by eliminating positive and negative sequence decomposition by genetic algorithm. This method takes a long time and the efficiency is very low.

In order to solve the above problems, a distributed power energy grid-connected control method based on big data is proposed, the distributed power energy grid-connected model is established, and the DC/AC inverter model is analyzed. In the process of establishing the current inner loop controller model and the voltage outer loop controller model, the fuzzy PID control algorithm is introduced to identify the unknown parameters of the modeling of the grid photovoltaic power generation unit. The experimental results show that the proposed method can effectively improve the performance of distributed power energy grid-connected control.

2 Parameter Optimization Identification in Distributed Power Energy Grid-Connected Control

2.1 Establishment of a Distributed Power Grid-Connected Model

The distributed power energy grid-connected model is mainly composed of DC/AC inverter model, current inner loop controller model and voltage outer loop controller model. Below, the establishment of each model is analyzed in detail. The equivalent circuit diagram is shown in Fig. 1.

The establishment of DC/AC inverter model is the foundation of distributed power energy grid-connected model. Its model can be simulated by inertia link. Because the frequency of modulation wave is obviously higher than that of power grid frequency, the inertia delay time constant is very small. Then the DC/AC inverter model can be described as:

$$G_1(s) = \frac{1}{1 + 0.5sT_{SW}} \tag{1}$$

Wherein, S is used to describe the control signal, T_{SW} is used to describe the inertia delay time constant, and $T_{SW} = 1/f_{SW}, f_{SW}$ is used to describe the switching frequency of the inverter.

Based on the DC/AC inverter model, the current inner loop controller model is established, which provides the basis for the establishment of the voltage outer loop controller model. The inner loop must follow the transient change of the reference current quickly, and its response speed is much higher than that of the voltage outer loop controller [7]. The current formed by the outer loop control loop is regarded as the reference I_{sd_ref}, passing through a series of control stages. The grid-connected current

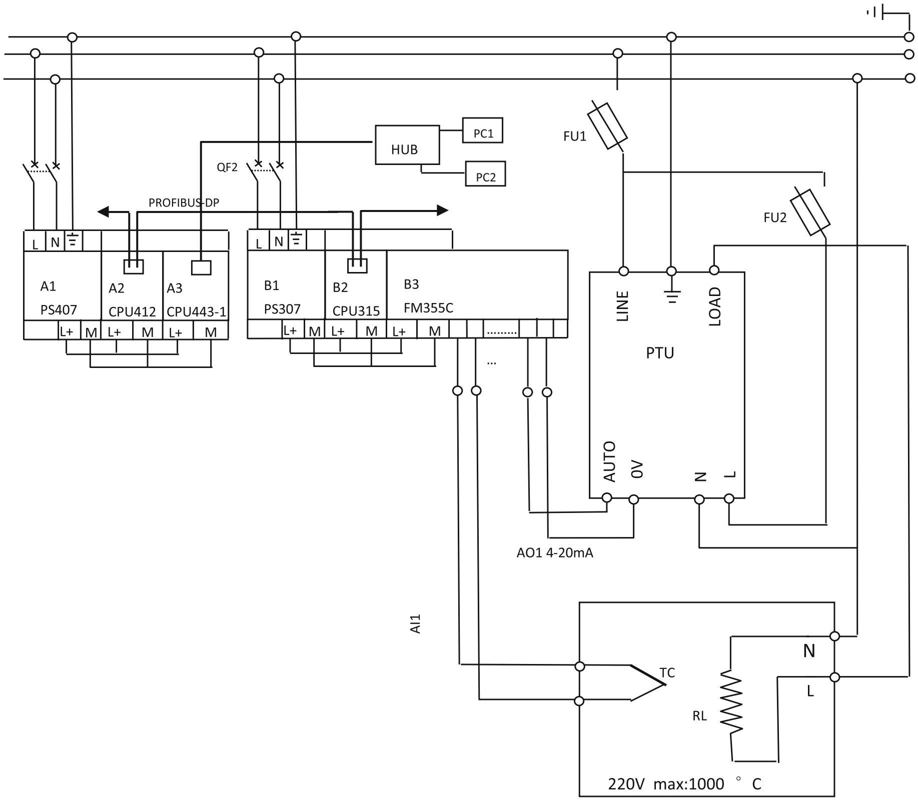

Fig. 1. Equivalent circuit diagram

of the converter is controlled, that is, the reference voltage U_{dq_ref}. The reference voltage U_{abc_ref} is transformed into the reference voltage U_{dq_ref}, needed by the inverter through the conversion of dp coordinates to form a trigger pulse. Therefore, the models of inner loop controller and outer loop controller can be established respectively.

T_s is used to describe the measurement sampling time, $\frac{1}{1+sT_s}$ is used to describe the control delay link, $\frac{1}{1+0.5sT_s}$ is used to describe the measurement sampling link, i_{d_ref} is used to describe the reference values of active current and reactive current, and Ls is used to describe inductance. i_d, i_q is used to describe the d, q axis component of the three-phase current fundamental wave on the grid-connected side; $G_{cuur\_d}(s)$, $G_{cuur\_q}(s)$ are used to describe the resistance of the grid-connected side line; it is used to describe the inner ring $d-axis$ and $q-axis$ current PI controllers, respectively. The formula is described as follows:

$$G_{cuur\_d}(s) = \frac{K_{P1}s + K_{11}}{sG_1(s)} \tag{2}$$

$$G_{cuur\_q}(s) = \frac{K_{P2}s + K_{12}}{sG_1(s)} \tag{3}$$

Wherein, K_{P1}, K_{11}, K_{P2}, K_{12} are used to describe the parameters of the axis PI controller of the inner ring d axis and Q, respectively.

In that model, the influence of the capacitance H on the current loop in the LC low-pass filter cannot be taken into account due to the influence of the power factor of the unit when the inverter is in operation, the expression of the inner ring current control model is as follows:

$$G(s) = \int \frac{T_s.G_{cuur\_d}(s)i_{d\_ref} * i_d}{T_{SW}.G_{cuur\_q}(s)i_{q\_ref} * i_q} \tag{4}$$

Both of them can be obtained by measurement, and the controller parameters are unknown and need to be identified [8].

2.2 Establishment of Voltage Outer Loop Controller Model

After the current inner loop controller model is established, the voltage outer loop controller model is established. Because the response speed of the outer loop controller is slow, in the process of modeling the voltage outer loop controller, it is necessary to complete the non-mechanism modeling equivalence of the current inner loop controller model [9]. According to the characteristics of the equivalent inner loop controller of the first order inertia link, it is called the equivalent inner loop control model, and the transfer function SF is the equivalent model of the current inner loop, which is mainly used in the control loop of the voltage outer loop. The equivalent $G_{eq}(s)$ voltage outer loop controller model can be described in Fig. 2.

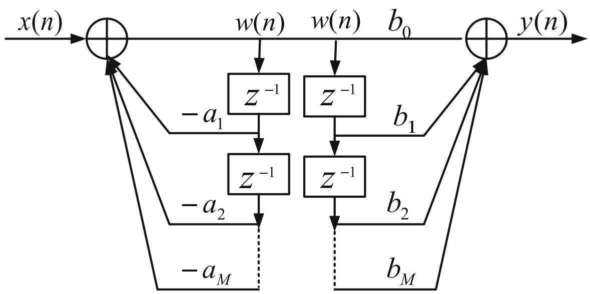

Fig. 2. Equivalent DC voltage outer loop controller model

After completing the equivalence of the inner loop current controller, it is necessary to identify the parameters K_{eq} and T_{eq}, so as to establish the voltage outer loop controller model more accurately. DC voltage control method is usually selected for outer loop control, which operates with a unit power factor. Therefore, suppose the reference value of $Q - axis$ current $i_{q\_ref} = 0$, is mainly responsible for providing $d - axis$

reference current i_{d_ref}. Therefore, the outer loop controller model is mainly affected by the d-axis current inner loop model. The model expression is as follows:

$$G_{eq}(s) = \frac{K_{eq}G(s)}{1 + T_{eq}s} \tag{5}$$

In the outer loop voltage control model, U_{dc_ref} and U_{dc} can be obtained by measurement, and the parameters K_{eq} and T_{eq} need to be obtained by identification. Above, the establishment of distributed power energy grid-connected model is analyzed, but the model parameters cannot be determined. The fuzzy PID control algorithm is applied to distributed power energy grid-connected control to obtain unknown model parameters in each stage.

3 Distributed Energy Grid-Connected Control Based on Big Data

After the distributed power energy grid-connected model is established, the parameters of the model need to be identified. Because the fuzzy PID control (HS) algorithm is a heuristic global optimization algorithm, when performing music, musicians through their own memory, by constantly changing the music of each musical instrument in the band. Finally, a process simulation of the optimal harmony state is obtained [10]. Therefore, in this paper, the fuzzy PID control algorithm is used as the parameter optimization method to identify the unknown parameters in the previous analysis model, and the best fitting process can be achieved according to some principles. Then the objective function can be described as:

$$F = \sum_{k=1}^{M} |e(k)|G_{eq}(s) \tag{6}$$

Where, F is used to describe the fitness function, $e(k)$ is used to describe the error between the measured value and the identified calculated value, and M is used to describe the length of the data. The fitness function of the inner loop controller may be described as:

$$F_{inner\_dq} = \sum_{k=1}^{M} F\left|i_{dq}(k) - i_{dq\_cal}(k)\right| \tag{7}$$

Similarly, the fitness function of the outer loop controller can be described as follows:

$$F_{outer\_dq} = \sum_{k=1}^{M} F|i_d(k) - i_{d\_cal}(k)| \tag{8}$$

Where, i_{dq} is used to describe the dq axis component of the measured inverter output current, and i_{dq_cal} is used to describe the calculated value of the dq axis component of the inverter output side current identified by the fuzzy PID control algorithm. i_{d_cal} is used to describe the d-axis component of the measured three-phase current fundamental wave on the grid-connected side, and i_{d_cal} is used to describe the $d-axis$ component of the identified three-phase current fundamental wave on the grid-connected side.

The detailed process of identifying unknown parameters in distributed power energy grid connection model by PID algorithm is as follows:

(1) Problem and algorithm parameter initialization: the parameters of the optimization problem are mainly the target function F_{inner_dq} and F_{outer_dq}, the variable set $x = \left\{K_{P1}, K_{11}, K_{P2}, K_{12}, R, L, K_{eq}, T_{eq}\right\}$, the lower limit L_{x_i} of each variable value and the upper limit U_{x_i}; the parameters of the HS algorithm are mainly the expert database size (HMS), the expert database consideration probability (HMCR), a fine-tuning probability (PAR), a maximum number of iterations (NI), and a termination condition;
(2) Initializing the expert database: randomly generating HMS initial solutions are stored in the expert database, and the objective function values of each solution are obtained at the same time.
(3) A new solution is generated: any random number $R1$ is selected, and if $R1 < HMCR$, a variable is selected in the expert database; on the contrary, the value is randomly selected outside the expert database. If you select a value in the expert database, you need to select another random number $R2$, if $R2 < PAR$, you need to complete the disturbance processing of the value. A new solution can be formed by using the above rules for all variables.
(4) If that new solution is better than the optimal solution in the expert database, replace the worst solution to the expert database;
(5) The above process is carried out continuously until the maximum number of iterations or convergence accuracy is reached.

4 Simulation Experiment Analysis

In order to verify the effectiveness of the fuzzy PID control algorithm applied to distributed power energy grid-connected control, it is necessary to carry out relevant experimental analysis. In the experiment, the genetic method is compared and analyzed. The experimental software platform is based on the simulation software of MATLAB 7.0. the hardware system platform of the simulation experiment is as follows: model Dell 2210b, processor is Intel Core2 Duo1.80 GHz, 1 G memory, the hardware system platform of the simulation experiment is model Dell 2210b, the processor is Intel Core2 Duo1.80 GHz, 1 G memory, the main frequency is DDR2 667.

50 simulations are carried out by using this method and the traditional genetic method, and the number of iterations, the time consuming and the statistical results of the model simulation accuracy are counted and described in Table 1.

Table 1. Simulation results of two methods.

	Number of iterations			Time/s			Accuracy/%
	Minimum number of iterations	Average number of iterations	Maximum number of iterations	Minimum number of iterations	Average number of iterations	Maximum number of iterations	
Method of this paper	5	21	68	0.004	0.021	0.042	97
Genetic method	12	45	100	0.032	0.065	0.098	89

It can be seen from the analysis of Table 1 that the number of iterations of this method is lower than that of the genetic method. In addition, the time consuming of this method is obviously less than that of the genetic method, and the accuracy is much higher than that of the genetic method.

In order to further verify the effectiveness of the proposed method, the performance indexes of the two methods are compared and analyzed, and the results are shown in Table 2.

Table 2. Comparison results of performance indicators of the two methods.

Number of experiments	Proposed method		Genetic method	
	Time delay/s	Overshoot/%	Time delay/s	Overshoot/%
1	8	0	16	2.3
2	12	0.3	18	1.8
3	14	0.8	22	2.9
4	12	0.5	24	1.5
5	8	0.3	18	2.1

The analysis of Table 2 shows that compared with the genetic method, the overshoot produced by this method is smaller and the time required for the whole simulation process is shorter, which shows that the energy saving control performance of this method is much better than that of genetic method. The effectiveness of the proposed method is further verified.

Figures 3 and 4 respectively illustrate the comparison between the fitness value of the target function of the inner ring and the outer ring controller model and the optimal fitness curve obtained by the method and the genetic method of the present invention with the increase of the number of iterations.

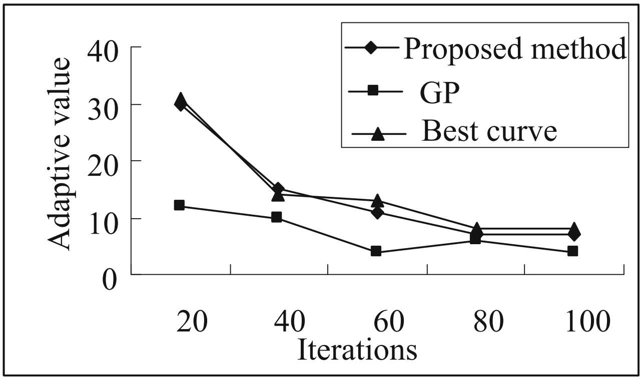

Fig. 3. Comparison of fitness of two methods of inner loop controller model

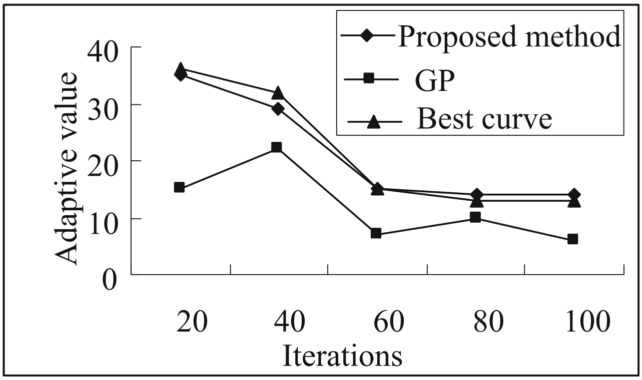

Fig. 4. Comparison of fitness of two methods of outer loop controller model

Figures 3 and 4 show that the fitness curve of this method is closer to the optimal fitness curve than the genetic method for both the inner loop controller model and the outer loop controller model. It is shown that the distributed power energy grid-connected model under this method has higher fitting accuracy. The output dynamic response of the inner ring and the outer ring is closer to the output curve of the detailed model than the genetic method, which shows that it is reasonable and effective, and the structure of the model is greatly simplified by using the method in this paper, which is beneficial to the identification of the model parameters.

5 Conclusions

In this paper, a method of applying fuzzy PID control algorithm to distributed power energy grid-connected control is proposed, the distributed power energy grid-connected model is established, and the DC/AC inverter model is analyzed. In the process of establishing the current inner loop controller model and the voltage outer loop controller model, the fuzzy PID control algorithm is applied to the identification of unknown parameters in distributed power energy grid-connected control. The fitness function of the inner loop controller and the fitness function of the outer loop controller are given, and the expert database is initialized. According to the objective function, a new solution is generated and the expert database is updated. Until the maximum number of iterations or convergence accuracy is reached. The simulation results show that the proposed method can effectively improve the performance of distributed power energy grid-connected control.

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