

Retraction

Retracted: Adaptive Current Protection Technology for Distribution Network with Distributed Power Sources Based on Local Information

Mobile Information Systems

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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- [1] S. Cui, P. Zeng, Z. Wang, and Y. Zuo, "Adaptive Current Protection Technology for Distribution Network with Distributed Power Sources Based on Local Information," *Mobile Information Systems*, vol. 2021, Article ID 5137749, 8 pages, 2021.

Research Article

Adaptive Current Protection Technology for Distribution Network with Distributed Power Sources Based on Local Information

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Because the distributed power supply is connected to the distribution network, its structure has also changed the original traditional method. The original single power supply method was originally used. The network provided is a radial network and it is connected to the distributed power supply. Later, it became a structure with small- and medium-sized power supplies inside, and its network power supply became dual or multiple power supplies. Such a structural change affected the coordination of power distribution protection devices, which would impose current on the distribution network. Protection has a negative impact. This paper aims to study the adaptive current protection technology of distribution network with distributed power based on local information. On the basis of analyzing the characteristics of distributed power, the classification of distributed power, and the operation mode of distributed power, according to the access of IIDG, as well as different influences of relay protection of distribution network, an improved protection scheme with adaptive current quick-break protection as the main protection is proposed, so that different fault characteristics of the distribution network have different setting values, and then simulation experiments are carried out on this scheme. The experimental results show that the setting value of three-phase short-circuit fault proposed in this paper can well protect the protection range, which is larger than the traditional protection setting and self-adaptive setting.

1. Introduction

Distributed power supply unit refers to a small modular and environment compatible independent power supply with a power of several kilowatts to 50 MW. These power supplies are owned by the power department, power users, or a third party to meet the specific requirements of the power system and users, such as peak shaving, power supply for remote users or commercial and residential areas, saving power transmission and transformation investment, and improving power supply reliability. Distributed power supply is a new type of power supply technology in today's society. In

the process of successively promulgating sustainable development policies around the world, with the continuous advancement of technology, distributed power generation has gradually become popular [1, 2]. Distributed power source itself has only a small capacity. Usually its capacity is in the range of several kilowatts to several megawatts. It usually appears in some devices, such as power plant equipment, fuel, and photovoltaic batteries, to achieve power generation. Wind power is used to achieve power generators, miniature gas turbines, and so forth [3, 4].

At present, although distributed power sources have obvious advantages in alleviating energy problems and grid

development needs, when various forms of distributed power sources are connected to the traditional main grid on a large scale, new problems and challenges emerge [5, 6]. At present, China's current regional development is still unbalanced, and the distribution network infrastructure in different regions is quite different, especially the ability to accept distributed power sources. The current protection of the traditional radial structure distribution network has been seriously affected by the large-scale distributed power grid connection, and it will also consume a lot of manpower, financial resources, and material resources for grid maintenance and operation [7, 8]. It can be seen that it is necessary to conduct a more in-depth study on the impact of distributed power grid connection on the relay protection effect of the distribution network. The relay protection solution of the distribution network containing distributed power should be well adapted to the grid structure. The safe and stable operation of the power grid must be effectively guaranteed. After the distributed power supply is connected to the distribution network, the direction of the power flow and the size of the short-circuit current are changed accordingly. The current protection scheme of the distributed distribution network is mainly designed in accordance with the traditional single power supply and radial structure. When the distributed power supply is connected to the distribution network and when the power grid is connected, the original single-supply radiation structure of the distribution network can be transformed into a double-ended or more active network structure. The relay protection scheme designed according to the original distribution network structure will no longer conform to the new power grid. Therefore, it is necessary to make corresponding adjustments to the protection of the traditional power grid or reestablish a protective measure to eliminate the possible damage to the traditional power grid protection caused by the incorporation of distributed power into the distribution network. Otherwise, it includes distributed power. If the internal distribution network system fails, it will not be able to remove one of the faults in time and accurately, and it will not be able to effectively ensure the safety and stability of the power supply network and the normal operation of the equipment [9, 10]. Note that the advantages of distributed generation mainly include being economical, environmental protection, flexibility, and safety. Among them, distributed generation has various forms, which can reduce the dependence on single energy and alleviate the expansion of energy crisis to a certain extent. At the same time, distributed generation is scattered, is not easy to be affected by unexpected disasters or emergencies, and has the potential to resist large-scale power outages.

This paper aims to study the adaptive current protection technology of distribution network with distributed power based on local information, an improved protection scheme with adaptive current quick-break protection as the main protection is proposed, so that different fault characteristics of the distribution network have different setting values, and then simulation experiments are carried out on this scheme.

2. Adaptive Current Protection Technology for Distribution Network with Distributed Power

2.1. The Characteristics of Distributed Power. Distributed energy system is not simply using traditional power generation technology, but it is based on new technologies such as automatic control system, advanced material technology, and flexible manufacturing process. It is a new energy production system with low pollution emission, flexibility, convenience, high reliability, and high efficiency. The power generation system composed of distributed energy system has the following characteristics: efficiently using the waste energy generated by power generation to generate heat and electricity; renewable energy system on site; and including an energy recycling system that uses on-site waste gas, waste heat, and excess differential pressure to generate power.

- (1) From the perspective of economy, since the types of distributed power sources are distributed and the energy is used in cascades, the efficiency of energy utilization is relatively high compared to traditional power sources. If distributed power generation technology becomes more mature and widely used, the country's dependence on the construction of large power plants or power grids will decrease. It saves investment in power grids and power plants. At the same time, the reduction in the number of power grids will correspondingly reduce power grid network losses and improve power quality [11, 12].
- (2) From the perspective of environmental protection, distributed power generation technology is mostly used for clean and renewable energy power generation such as small gas turbines, wind power generation, photovoltaic power generation, and biomass power generation. Compared with traditional thermal power generation, the cleanliness has qualitatively improved. The emission of pollutants and exhaust gas and environmental pressure are reduced. Distributed power transmission with a large number of on-site power supplies can effectively reduce electromagnetic pollution on power lines and at the same time reduce the trees damaged by the construction of the power grid. It is very beneficial to environmental protection [13–16].
- (3) From the perspective of power system peak shaving, in the peak period of power system power consumption, distributed power sources use natural gas multigeneration and three-system cogeneration of cooling, heating, and power to solve the power system peak in summer and winter. The problem of the period plays the role of peak shaving and valley filling in the role of peak shaving.
- (4) From the perspective of the electricity market, DG's access to the power grid brings vitality to the electricity market. By raising funds to build small-scale, small-capacity distributed power sources, the

construction period is short, reducing risk investment. The power market is conducive to the development of the power market through a competitive mechanism.

2.2. Classification of Distributed Power Sources

2.2.1. Solar Photovoltaic Power Generation Technology. Solar energy mainly refers to the energy released by the hydrogen atoms inside the sun for hydrogen nuclear fusion. Although the energy radiated by the sun from the sky to the deepest layer of the earth is only one part of 2.2 billion of the total energy radiated by it, it has exceeded 173,000 tw; that is to say, the total energy of light radiated from the sun to the earth is equal to 500 per second. If this part of energy is fully utilized, there will be no possibility of energy crisis. Solar photovoltaic power generation is abbreviated as PV, which uses the photovoltaic effect of semiconductor materials to directly convert solar energy into electrical energy. The principle is simple, stable, and easy to control.

Currently, the more common photovoltaic cells include monocrystalline silicon, polycrystalline silicon, and thin film materials. Among them, monocrystalline silicon has the highest efficiency and polycrystalline silicon has the lowest price. The above factors are comprehensively considered in the actual project, so that various batteries can be packaged into battery components to meet higher power output values, and, at the same time, it is easy to control. Its output power is as follows:

$$P_G = I \times A \times \eta \quad (1)$$

An example diagram of a photovoltaic power generation system connected to the distribution network is shown in Figure 1.

Besides, grid-connected photovoltaic power generation system is that the DC generated by solar modules is converted into AC which meets the requirements of municipal power grid through grid-connected inverter and then directly connected to the public power grid. The grid-connected photovoltaic power generation system has centralized large-scale grid-connected photovoltaic power stations, which are generally national power stations. The main feature is that the generated energy is directly transmitted to the power grid and uniformly allocated by the power grid to supply power to users. However, this kind of power station has large investment, long construction cycle, and large floor area, and its development is relatively difficult. The decentralized small-scale grid-connected photovoltaic system, especially the integrated photovoltaic building power generation system, is the mainstream of grid-connected photovoltaic power generation due to its advantages of small investment, fast construction, small floor area, and strong policy support.

2.2.2. Wind Power Generation Technology. Wind power converts wind energy into mechanical energy through blades, mainly kinetic energy, and then drives a generator to generate electrical energy. In order to ensure that the blades

can rotate at low wind speeds, a gearbox is added; in order to stabilize the grid frequency and reduce fluctuations, a speed control system is added; in order to obtain the maximum power at all times, a tail rudder is added to track the wind direction. In this way, the breeze speed of about 3 m/s can drive the blades to generate electricity.

Wind power is different from traditional energy sources. It is derived from natural wind energy. Moreover, China is close to Siberia, and many cities are at the vents, which is convenient for mining. However, compared with traditional energy, the one-time investment cost is high, and the cost of subsequent maintenance is also high. However, with the development of wind power technology, the cost is declining year by year. We believe that, in the near future, wind power will be able to achieve large-scale grid connection.

Due to the unstable air volume of the wind turbine, the output of the wind turbine is 13~25 V alternating current, which must be rectified by the charger and then charged to the battery, so as to turn the electric energy generated by the wind turbine into chemical energy. Then the inverter power supply with protection circuit is used to convert the chemical energy in the battery into AC 220 V mains power, so as to ensure stable use.

2.2.3. Fuel Cell Power Generation Technology. The fuel cell solar power generation process is a solar power generation process that uses electrochemical reactions to convert the energy in the fuel cell into electrical energy. The fuel cell power generation system mainly includes oxygen supply system, fuel engine reforming power supply system, fuel engine power generation control system, automatic controller, and other parts.

Fuel cells are different from common dry-type batteries and accumulators. They can neither store too much energy nor are they just a device that converts energy. On the one hand, it is necessary to continuously supply fuel and oxidant to other equipment to ensure continuous power supply. When the supply is interrupted, the power generation process will also end. On the other hand, the fuel cell can also continuously supply and use its own battery and continuously discharge new products from the battery. As long as the battery is continuously supplied, it can continuously output more power.

The principle of fuel cell is an electrochemical device, and its composition is the same as that of general cells. The single cell is composed of positive and negative electrodes (negative electrode, i.e., fuel electrode, and positive electrode, i.e., oxidant electrode) and electrolyte. When the cell works, fuel and oxidant are supplied from the outside for reaction. In principle, as long as the reactants are continuously input and the reaction products are continuously excluded, the fuel cell can continuously generate electricity. Theoretically, fuel cells can operate at nearly 100% thermal efficiency and have high economy. At present, due to the limitations of various technical factors and considering the energy consumption of the whole device system, the total conversion efficiency of various fuel cells in actual operation is mostly in the range of 45%~60%, such as heat removal and utilization of more than 80%.

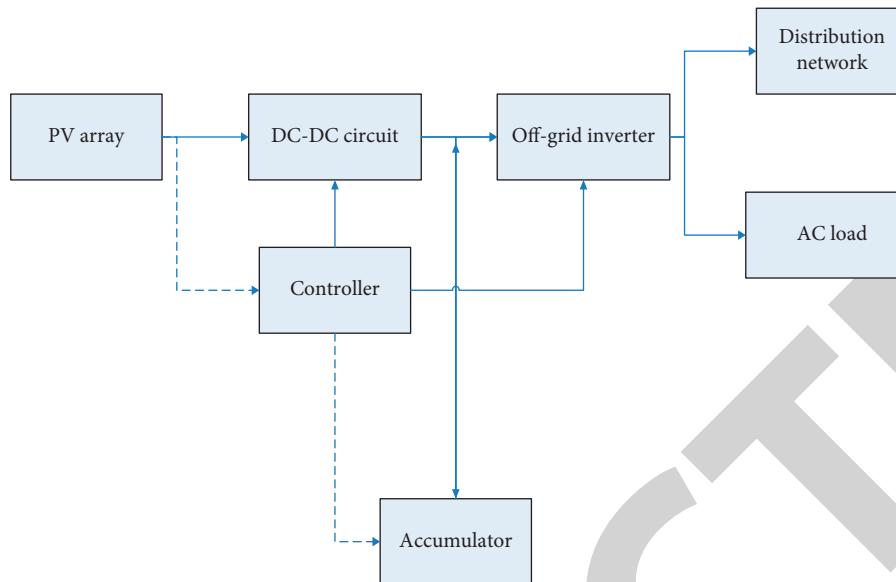


FIGURE 1: Photovoltaic power generation system structure diagram.

2.2.4. Micro Gas Turbine Power Generation Technology.

Micro gas turbines belong to a class of small and medium thermal power generators that have only recently been developed. The power of a single unit is generally controlled at 25–300 kw. The working principle of power generation is similar to that of conventional gas turbines. It is most suitable for distributed power generation, cogeneration, peak load power generation. Its advantages are low fuel consumption ratio, high noise, low pollution emissions, money saving, low maintenance costs, and the integration and expansion of multiple systems.

The pure power generation efficiency of micro gas turbine is not very high, but the energy utilization rate of cogeneration system with micro gas turbine as the core is even higher than that of large units. At present, 30~350 kW micro gas turbine is a typical model for commercial application at this stage. It is mainly used in distributed cogeneration system. Natural gas is generally selected as fuel, and the comprehensive efficiency can reach more than 80%. It is a promising energy-saving and environment-friendly power supply, which is suitable for popularization and application in urban, rural, and remote areas. However, at present, China does not have the ability to develop and produce micro gas turbines.

2.3. Distributed Power Supply Operation Mode. Distributed power sources and systems mainly include grid connection, island operation, and multiplexers. By adopting a reasonable control strategy, the movement transition between the two operation modes can be smoothed and transformed. The basic characteristics of these two operation modes are briefly introduced as follows:

- (1) Grid-connected operation: when designing and operating DG and large-scale grid-connected wind power systems, according to the different types and usage methods of the two wind power grid-connected interfaces, we can usually distinguish them,

that is, based on the traditional rotary wind power system class DG and large-scale grid-connected inverter DG for wind power generation based on wind power inverter interface. IIDG is a very important part of DG. The DG of the direct-exchange method is a kind of direct current that can be generated under specific power frequency conditions such as photovoltaic solar power generation systems and fuel power battery systems, which must be inverted before power frequency AC can be performed; AC-DC-alternating DG is a general term used in all gas turbines and parts that can adopt AC-DC-AC conversion doubly fed wind power generation. When driving, high-frequency AC power must be rectified before it can be inverted.

- (2) Island operation: the operation of grid islanding mainly refers to the way in which the DG in the power system and a type of grid in this type of grid are independently connected and operating. There are many main reasons for this type of grid islanding, and most of them may be in this type of grid. It is directly caused by the short-term operation of the grid system DG due to a fault in the system. At this time, in order to effectively ensure uninterrupted power supply for a user, the output power inside the island will be directly provided by the DG, and it must always be ensured that it remains constant between the output voltage and frequency inside an island. If a major failure occurs, if the DG is not removed in time, the DG may continue to be unable to supply power to the surrounding area, forming an unplanned island. The reliability of the power supply and the quality of the power supply are low, and this will affect our power equipment, and the personal safety of staff poses a major threat.

In addition, at present, wind power generation at home and abroad is mostly connected to the power grid on a large scale in the form of wind farms. Considering that different wind turbines have different working principles, their grid connection modes are also different. The common models of domestic wind farms mainly include asynchronous wind turbine generator, doubly fed asynchronous wind turbine generator, direct drive AC permanent magnet synchronous generator, and high voltage synchronous generator. The main grid connection modes of synchronous wind turbine are quasi-synchronous and self-synchronous grid connection; the grid connection modes of asynchronous wind turbine mainly include direct grid connection, step-down grid connection, quasi-synchronous grid connection, and thyristor soft grid connection.

2.4. Adaptive Protection Technology. Adaptive current protection is based on the current actual operation mode and fault status of the power system to perform real-time and automatic setting calculation without manual intervention. The setting value algorithm can be expressed as

$$I_{\text{set}} = \frac{K_{\text{rel}}K_F E_\phi}{Z_S + Z_L}. \quad (2)$$

In the above equation, K_{rel} is the reliability factor; K_F is the fault type factor; E_ϕ is the equivalent phase potential of the system; Z_S is the integrated impedance of the power supply side of the system; and Z_L is the impedance of the protected line.

3. Experiment

3.1. Establishment of Simulation Model. PSCAD uses time domain analysis to solve the complete power system and differential equations (including electromagnetic and electromechanical systems), and the results are not only very accurate. It is worth mentioning that it allows users to flexibly establish circuit models and conduct simulation analysis in a complete graphical environment. While simulating, users can change control parameters, so as to intuitively see various measurement results and parameter curves, which greatly facilitates users to improve the fun and efficiency of simulation. PSCAD provides a rich component library, from simple passive components to complex control modules, so that motor, facts device, cable line, and other models are covered.

PSCAD simulation software is used to build a distribution network with IIDG to verify the adaptive positive sequence current quick-break protection. The reference capacity of the system is 100 MVA, the reference voltage is 10.5 KV, the short-circuit capacity is 400 MVA, the route parameter per unit length is 0.347 Ω/km , and each bus on the feeder is connected to a load with a rated power of 1 MVA.

3.2. Protection Scheme Where the Fault Occurs Upstream of the IIDG

3.2.1. The Two Paths Are Short. Suppose that there is a short circuit at line α , the value range of α is $[0, 1]$, $Z_M = \alpha Z_{MN}$, and $Z_N = (1 - \alpha)Z_{MN}$.

It can be seen from Figure 2 that the positive sequence voltage and the positive sequence current flowing through the N point, which is the protection at QF₂, have the following relationship according to the knowledge of the circuit:

$$U_{\text{QF}_2(1)} - \frac{1}{2}E_S = \frac{1}{2}I_{\text{QF}_2(1)}[Z_S + (1 + \alpha)Z_{MN}]. \quad (3)$$

In the setting calculation, in order to ensure the selectivity, the maximum value of α can be set to 1, and the protection setting formula at QF₂ is as follows:

$$I_{\text{SET}}^{(2)} = K_{\text{rel}}^I \left(\frac{2U_{\text{QF}_2(1)} - E_S}{Z_{S-\text{min}} + 2Z_L} \right). \quad (4)$$

3.2.2. Three-Way Phase is Short. When a three-phase short-circuit fault occurs at point F, the voltage and current are at position where the fault point is located, and the current flowing through the protection at QF₂ meets

$$U_{(1)} = I_{(1)}Z_d. \quad (5)$$

In order to ensure the selective action of the protection, its current setting value is

$$I_{\text{SET}}^{(3)} = \frac{K_K U_{(1)}}{2Z_L}. \quad (6)$$

3.3. Protection Setting Where the Fault Point Is Located Downstream of the Distributed Power Generation. When the point of failure occurs downstream of the distributed power supply, the protection at QF₁ should remove the fault. In the setting calculation, it is not necessary to distinguish the types of faults and set according to the three-phase short-circuit setting formula (6) and then according to the measured two-phase fault current into the three-phase fault current at the same point and then set according to the three-phase short-circuit fault.

$$I_{\text{SET}}^{(3)} = K_{\text{rel}} \frac{U_{\text{eq}}}{(Z_S + Z_{AB} + 2Z_{BC})}. \quad (7)$$

4. Discussion

Three-phase short circuit refers to the short circuit of two or more lines; in terms of three-phase four wire, faults mainly include three-phase short circuit, two-phase short circuit, single-phase short circuit, and two-phase grounding short circuit. Two-phase grounding short circuit refers to the short

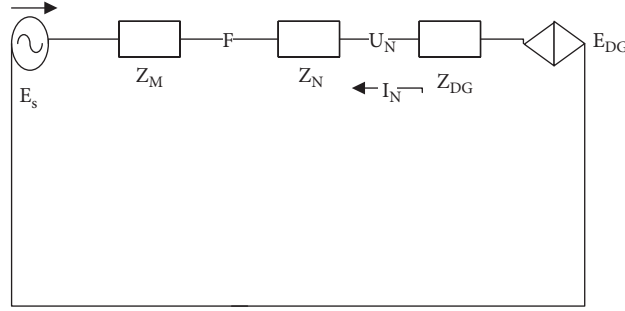


FIGURE 2: A simplified two-phase short circuit in a composite sequence network.

TABLE 1: Simulation results of the AD phase short-circuit fault.

IIDG capacity	α	Setting value	Measurements	Setting value	Measurements
		F1 point fault	QF ₃ point protection	F1 point fault	QF ₆ point protection
4	0.4	2.340	3.964	0.161	0.150
4	0.6	2.340	3.001	0.149	0.151
4	0.8	2.340	2.151	0.199	0.152
8	0.4	2.340	3.994	0.289	0.291
8	0.6	2.340	3.002	0.280	0.296
8	0.8	2.340	2.081	0.213	0.304

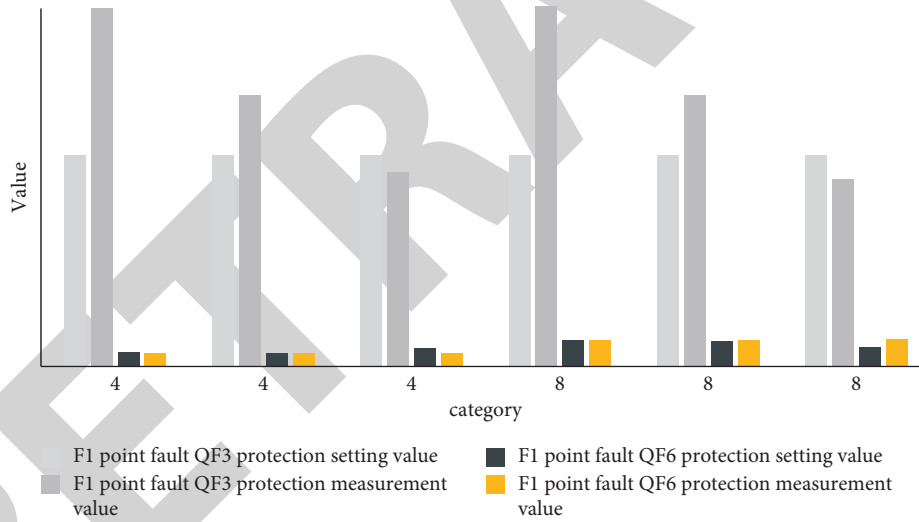


FIGURE 3: Simulation results of the AD phase short-circuit fault.

TABLE 2: Simulation results of the AD phase short-circuit fault.

IIDG capacity	α	Setting value	Measurements
4	0.4	1.311	1.688
4	0.6	1.384	1.546
4	0.8	1.473	1.375
8	0.4	1.344	1.732
8	0.6	1.416	1.580
8	0.8	1.501	1.409

circuit caused by single-phase grounding of any two phases in the neutral ungrounded system; two-phase short circuit refers to the short circuit between any two-phase conductors

in three-phase power supply and distribution system; three-phase short circuit refers to the short circuit between three-phase conductors in power supply and distribution system.

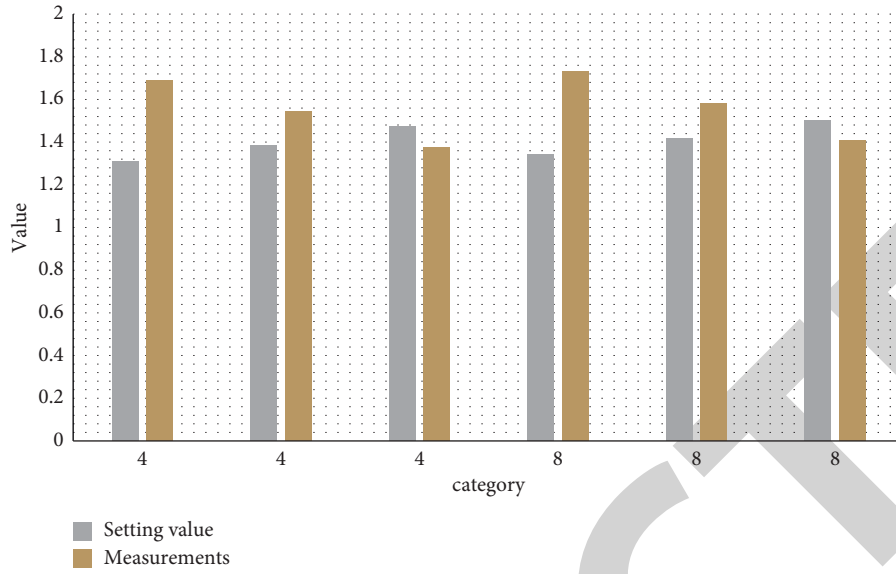


FIGURE 4: Simulation results of the AD phase short-circuit fault.

TABLE 3: The simulation results of the three-phase short circuit.

IIDG capacity	α	Setting value	Measurements	Setting value	Measurements	Setting value	Measurements
		F ₁ point fault protection	QF ₃ point	F ₂ point fault protection	QF ₄ point	F ₃ point fault protection	QF ₁ point
4	0.8	4.530	4.719	2.712	2.825	4.533	4.533
4	0.9	4.625	4.282	2.929	2.712	4.627	4.627
8	0.8	4.530	4.719	2.835	2.953	4.541	4.541
8	0.9	4.625	4.282	3.055	2.829	4.633	4.633

4.1. Two-Way Phase Is Short

4.1.1. When the Fault Occurs at a Different Position on the Upstream Line AD of the IIDG. When the back side of the protection is set with the direct access of IIDG, according to the setting formula proposed in the article, extract the positive sequence voltage at the protection site, the negative sequence voltage, and current on the system side, and obtain the system side impedance; the reliability coefficient is 1.2, and the fault is located at $\alpha = 0.4, 0.6, \text{ and } 0.8$, respectively, taking the capacity of IIDG 4 MW and 8 MW for simulation. The simulation results are shown in Table 1.

According to Figure 3, in the simulation, by changing the IIDG access capacity which is different, the simulation analysis fault occurs at different locations of the line. The value of the current flowing through the protection QF₃ does not change much. When the fault occurs upstream of the IIDG, there is no DG access on the back side of the protection, which has little impact on the protection. The fixed-value setting scheme proposed in this paper is feasible. The protection range at QF₆ is calculated to be 63.7%, and the protection here can change its setting value according to changes in the capacity of IIDG, fault location, and so forth to achieve a certain sense of self-adaptation.

4.1.2. When the Fault Occurs Downstream of IIDG. The simulation results are shown in Table 2 and Figure 4.

The protection range here is 68.7%, and the protection here can adaptively change its setting value according to the changes of the IIDG capacity, operation mode, and fault location.

4.2. Three-Way Phase Short. As shown in Table 3, changing the capacity of IIDG, the reliability factor is 1.2, and the protection range reaches 83.3% of the total length of the line and is not affected by other factors. The protection value changes its setting value adaptively according to the changes of IIDG’s capacity, operation mode, and fault location. Therefore, the setting value of the three-phase short-circuit fault proposed in this paper can well protect the protection range, which is larger than the traditional protection setting and self-adaptive setting.

5. Conclusions

At present, the problems of environmental degradation and the exhaustion of traditional fossil energy have become increasingly prominent. In order to alleviate these energy and environmental problems, distributed power generation technology has become an important research direction in the new century. This paper analyzes the relationship between the positive sequence voltage at the protection installation and the positive sequence current flowing through the protection when two-phase interphase short-circuit

faults and three-phase short-circuit faults occur at different locations and proposes an adaptive current protection principle based on local information to solve. The original current protection brought by DG access may not meet the selectivity problem, and the protection performance is improved. Through a large number of experiments, the effectiveness and superiority of the proposed algorithm are effectively verified, which is far better than other algorithms. It can provide some reference ideas for subsequent related research.

Data Availability

The data underlying the results presented in the study are available within the manuscript.

Conflicts of Interest

The authors declare that there are no potential conflicts of interest in this paper.

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