Analysis of the Influence of Distributed New Energy Access on Relay Protection

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ABSTRACT

Access to new energy large scale has changed our traditional characteristics produced during operation of electric power system, relay protection of our traditional and automatic safety devices bring higher requirements and challenges [1-2]. This paper introduces the situation of new energy power generation connected to a power grid, analyzes the operation risk of new energy access on distance protection and safety device and puts forward some suggestions and measures to resist the risk of power grid relay protection and self-installation. Research and analysis on relay protection and safety device for distributed new energy access to a regional power grid.

Keywords: distributed new energy access; relay protection; distance protection; impact analysis.

INTRODUCTION

With the rapid development of the times and the promotion of social economy, China's power network has also been an unprecedented development [3]. As new energy sources such as wind power and photovoltaic power have become important components of power networks, they have been vigorously developed and widely used. With the large-scale access of new energy grid, the power system has a direct impact on the current, voltage and power, resulting in various parts of the grid relay protection placed in the protection of itself changes [4]. The configurations and regulations of relay protection need to be corrected and targeted to take some measures to meet the current new energy environment. Otherwise, new energy access will adversely affect relay protection and safety device. This paper analyzes the impact of “new energy” access device for relay protection [5].

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NUMERICAL INVESTIGATION

Present Situation of Access to New Energy Sources in A Certain Area in Northwest China

In the study area, there are abundant new energy sources. In 2016, the power grid newly invested and expanded 41 power plants with a total installed capacity of 2711.5MW, including 5 wind farms with a total installed capacity of 745MW and 31 photovoltaic power plants with a capacity of 1564.5MW. With the development of new energy and access, new energy power generation accounts for more than 50%. The power grid is located at the end of the main network in Shaanxi, and the grid structure is weak. Stochastic and intermittent energy access, represented by new energy such as wind energy and solar energy, will lead to grid relay protection and self-installation risk operation. In summary, we need to expand the relevant research and reserve related technologies to provide technical support for the safe and reliable operation of the power grid.

Analysis of The Risk of Distributed New Energy Access on Relay Protection

Distributed new energy access 110kV and below the grid, It can cause a change in the size and distribution of the grid short circuit current. Grid inverter control, island protection, non-synchronization devices may be configured with different [6]. It will bring many problems about relay setting, sensitivity and reclosing. Large-scale access to new energy has changed the operating characteristics of traditional power systems in the region [7]. Therefore, the traditional relay protection in the area brings higher requirements standards and challenges. In the past, relay protection has not been able to ensure the efficient and stable transportation of new energy sources [8].

PHOTOVOLTAIC POWER FAILURE CHARACTERISTICS AND FAULT MODELS

The fault characteristics of a photovoltaic (PV) system depend on the control characteristics of the PV inverter. In general, the maximum overcurrent capacity of IGBT can’t exceed twice its rated current. Therefore, for grid-connected inverter systems, the maximum current provided by the inverter during system-side faults should not exceed twice its rated value due to the limitation of the overcurrent capability of the power electronic devices themselves.

In order to ensure that the short-circuit current in the event of power system failure does not exceed the limit value of the inverter, a limiting step is added to the control strategy. Before the PV inverter reaches twice the rated current, the PV power can be equivalent to constant active power supply. The limiter module takes effect when the short-circuit current provided by the PV power supply is greater than the maximum short-circuit current allowed by its inverter. The PV inverter control strategy limits the short-circuit current to 2 times the rated current, and the PV power is equivalent to a constant current source. The I-V characteristic and fault equivalent model of the photovoltaic power source are shown in Figure 1.
THE RISK OF DISTRIBUTED NEW ENERGY ACCESS ON DISTANCE PROTECTION

Distributed power DG (including wind power, photovoltaic, small thermal power and other distributed power) access to the power system diagram shown in Figure 2. The distributed power DG is connected to the B bus and analyze the influence of distributed power access on the upstream protection 1, the downstream protection 2, 3 and the parallel protection 4 to 7.

( I ) Distance protection section I

The distance protection section I only reflects the fault of this line. The measured impedance is the positive sequence impedance at the point of fault to the protective installation. Therefore, the access to distributed power has no effect on the distance protection section I.

( II ) Distance protection section II

As distance protection section I cannot protect the entire length of the line, install distance protection section II. Distance protection section II matches the next stage I. Set value calculation formula:

\[
Z_{set.1}^{II} = K_z Z_1^1 + K_{bmax} Z_{set.2}^1
\]

(1-1)

\( Z_1 \) — Protected line impedance;

\( Z_{set.2}^1 \) — Setting impedance of adjacent line section I;

\( K_{bmax} = 1 \) — The minimum value of the branch coefficient;
\( k, k' \) — Reliable coefficient, \( k \approx 0.8 \sim 0.85, \ k' = 0.8; \)

Sensitivity of distance protection section II:

\[
K_{\text{sen}} = \frac{Z_{\text{II}}}{Z_{1}}
\quad (1-2)
\]

(1) Impact on upstream protection I

Bus B access to distributed DG, for protection I, the minimum value of the branch coefficient \( K_{\text{max}} = 1 \), the minimum value of the branch coefficient \( K_{\text{max}} = 1 + \frac{Z_k + Z_{\text{AB}}}{Z_{\text{DG}}} \), which respectively represent the short-circuit impedance of bus A, the impedance of line AB, the short-circuit impedance of distributed power supply, the same formula behind. The purpose of the distance protection section II is to protect the faults outside the section I of this line and to provide a near backup for the protection of the section I of this line. It can be seen from the formula for the value and sensitivity of section II of distance protection that distributed power supply has no effect on the set value and sensitivity of the distance section II of the upstream protection when there is a fault in this line.

(2) Impact on Parallel Lines and Downstream Protection

Analysis of Figure 2 shows that when the distributed power is connected to the bus B, the protection factor is unchanged for the protection 4 and always equal to 1. The protection has no effect.

For protection 6, when distributed power is not access, the minimum value of the branch coefficient \( K_{\text{max}} = 1 + \frac{Z_k + Z_{\text{AE}}}{Z_{\text{E}}} \), when there is distributed power access, the minimum value of the branch coefficient \( K_{\text{max}} = 1 + \frac{Z'_k + Z_{\text{AE}}}{Z_{\text{E}}} \), \( Z'_k = Z_k / (Z_{\text{DG}} + Z_{\text{E}}) \).

When there is outlet failure of the protection 7, the measured impedance of the protection 6:

\[
Z_{\text{m,6}} = Z_{\text{AE}} + K_b Z_k
\quad (2-1)
\]

- \( Z_{\text{AE}} \) — the impedance of the line AE
- \( K_b \) — branch factor
- \( Z_k \) — the positive sequence impedance of protection 7 to the point of failure

Analysis shows that, due to the existence of distributed power supply, for the protection of 6, the branch coefficient decreases. If the setting is unchanged, there may be a risk that the distance protection section II will exceed the lower distance protection section I. When section I of the lower line refused to move, the upper and lower line protection of the section II has the risk of tripping at the same time.

The analysis of downstream protection 2 is the same as the protection of parallel routes. If bus C has no power, the branch coefficient is always equal to 1, bus B access to distributed power has no effect on protection 3. If bus C has power, its impact analysis is the same as protection 6.
Distance protection section III

The distance protection section III can protect the total length of the line and the total length of the adjacent line as the far backup of the adjacent line. The value of the protection section III is set according to the minimum impedance of the hiding line, and it is matched with the distance protection phase II of the adjacent lines.

As distributed power access bus B, the access point for the superior line protection I, the maximum value of the branch coefficient $k_{max} = 1 + \frac{Z_{AB} + Z_{DG}}{Z_{DG}}$, the maximum branch factor is 1.

When it not connected to distributed power supply. For protection I, the far backup verification formula for distance protection III:

$$k_{max}^{III} = \frac{Z_{AB} + Z_{DG}}{Z_{DG}}$$  \hspace{1cm} (2-2)

When the lower end of the line is short-circuited, it can be seen from the verification formula of the section III of distance protection that distributed power access has no effect on the value and sensitivity of the section III of the upstream protection.

INFLUENCE OF DISTRIBUTED POWER SUPPLY ON ZERO-SEQUENCE CURRENT PROTECTION

Figure 3 shows the system diagram of distributed power access to the power system. Distributed DG power access bus B. Analysis of the influence of distributed power access on zero-sequence current protection.

Figure 3. Distributed Power Access Power System Wiring Diagram.

Bus B access to distributed power supply, the single-phase ground fault as an example.

Take the positive sequence impedance equal to the negative sequence impedance $Z_{12} = Z_{21}$.

The fault point of the zero sequence current expression is $3I_{0k}$:

$$3I_{0k} = \frac{3E_{0k}}{Z_{1k} + Z_{2k} + Z_{3k}}$$

Due to the influence of distributed power supply, the positive sequence integrated impedance is reduced and the zero-sequence current at fault point is increased. The zero-sequence network remains unchanged, so the current flowing through the protection increases. For zero-sequence protection I and II, there is a risk of over-limit protection, which has no effect on zero sequence protection III and IV.
RISK ANALYSIS OF 110KV AUTOMATIC RECLOSING

110kV power grid is usually equipped with three-phase reclosing, which can improve the reliability of system power supply for transient faults. When the distributed power or local small thermal power access bus B, the general side of the system installed side A check pressure-free reclosing, distributed power supply side check the same period reclosing. 110kV both sides of circuit breakers 1 and 2 with the longitudinal difference, distance and zero sequence protection. When an instantaneous fault occurs on the line AB, there is a potential risk that the close coincidence may not coincide during the same period. Figure 4 shows the system diagram of the distributed power grounding system.

![Figure 4. Distributed Power Grounding Power System Diagram.](image)

When the DG access point downstream or parallel line failure, 110kV automatic reclosing acceleration, reclosing devices are installed at each circuit breaker. Taking K2 fault as an example, DG and system power are still directly connected after protection 3 trip, and there is no problem with protection and reclosure.

When the system power AB line K1 point of failure, the protection of 1 and 2 action cut off the fault line. Circuit breakers 1 side check no pressure synthesis success. When access to photovoltaic power supply, due to the principle of the pursuit of maximum power photovoltaic power supply design, do not have the ability to automatically adjust the frequency. DG island protection action disconnects the circuit breaker 6. Circuit breaker 2 does not meet the conditions of the same period; there may be a risk that the inspection side can not coincide.

STRATEGIES TO REDUCE THE IMPACT OF DISTRIBUTED NEW ENERGY ON DISTANCE PROTECTION

Distance Protection for Distributed Power Access

For the impact of new energy access on distance protection II and III, when a new energy source is connected, the access position should be connected to the end of the line, and the access capacity should be limited to a certain range of busbar short-circuit capacity of the access point. When the access capacity is large, calculate the branch coefficient and setting value of distance protection II according to the wind power and PV short-circuit capacity model.

Distributed power access affects only the distance protection III at the upper level of the access point. The polygon characteristic has its own load limit line. Load limit line in order to
avoid the minimum load impedance set, the value of the increase will not cause misoperation in normal operation. If the distance protection feature is a circle, increase the distance protection section III setting to avoid escaping the minimum load impedance. If the conditions can not be met at the same time, select the circle with load limit line characteristics.

New Energy Access Zero Sequence Protection

According to the 110kV busbar short-circuit impedance data in Yulin, the short-circuit impedance per unit range of the 110kV busbar maximum operating mode is generally from 0.05 to 0.1. The reference capacity is 100MW. 20MW photovoltaic power station transformer capacity is generally 31.5MW, The per unit of transformer impedance is \( X_t = \frac{u_t \% S_N}{S_N} \), considering the most serious situation, taking the 110kV bus maximum operating mode short-circuit impedance standard value of 0.1. The short-circuit impedance of distributed power supply is \( X_{*0} + 2X_* \). The photovoltaic power is approximately 1.5. Distributed power access short-circuit impedance after the standard value is \( 0.1/u = 0.091 \). Therefore, the risk of zero-sequence protection is limited.

New Energy Access Automatic Reclosing

For the access to new energy sources for wind power or photovoltaic, the connection line failure caused by the coincidence of new energy side inspection reclosing can not coincide with risk.

CONCLUSION

In summary, distributed new energy has the advantages of environmental protection, applied to the power system to meet the social development of the demand for electricity, the development of China's power industry has great significance to effectively reduce the power transmission losses and improve the quality of power. However, access to distributed new energy sources also has some drawbacks, which will change the distribution of current, prevent relay protection and make it prone to failure. Therefore, access to distributed new energy takes relevant protective measures to eliminate the impact on the relay protection to ensure the normal operation of the power grid.

REFERENCES

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