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Transmission line individual phase impedance and related pilot protection

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ABSTRACT

This paper proposes a kind of new Individual Phase Impedance (IPI) and a novel pilot protection scheme for transmission line based on the IPI. The IPI is calculated by the ratio of the voltage difference of fault-superimposed component to the current difference of fault-superimposed component at both terminals of the protected line. The IPI has accurate mathematical expressions and reasonable physical definitions for various line models. The calculated result of IPI can be used to distinguish the internal faults from the external faults. When the IPI is identical to the value of line positive-sequence impedance, the external fault is detected; otherwise, the internal fault is detected if it differs from that value. The feature of the pilot protection scheme is that the inter-phase coupling relation and the distributed capacitance based on the three-phase line model are directly considered and included in the IPI expression. The novel pilot protection can be used for long distance HV transmission lines with some preeminent performances which are deficiency in the conventional directional comparison pilot protection and current differential protection. The test results obtained by EMTP simulation and from a laboratory model of a simplified real power system have demonstrated that the pilot protection is of high reliability and good adaptability.

1. Introduction

With the fast development and wide application of long distance EHV and UHV (750 kV and 1000 kV) transmission technology in China, power system security and reliability become more and more important. It puts forward the higher operating requirements to various transmission line relay protections. As modem power systems operate close to their security and reliability limits, high-speed fault clearing is desirable to maintain the system transient stability, reduce the fault bringing damages, minimize the outage duration, and improve the power supplying quality. Pilot protection is the best type for transmission line relay protection as it can provide high-speed and simultaneous fault clearing in a non-dead zone environment [1–4].

The conventional pilot protections contain the directional comparison pilot protection, the current differential protection and so on. In the directional comparison pilot protection, a phase angle is calculated by the voltages and currents at local terminal and transmitted to the remote terminal [5–7]. Its key element is the directional relay used to discriminate the fault direction. However, it may become very insensitive or even unreliable when the voltage amplitude at the terminal changes very small duo to some external factors (including the system impedances). The negative sequence and zero sequence directional comparison pilot protection have some advantages. For example, these pilot protections can effectively avoid the influences of the line distributed capacitances and the system oscillation. Unfortunately, they must be blocked on the incomplete phase operation mode due to the unbalance electric signals appear at that situation. The current differential protection transmits each phase current from the local terminal to the remote terminal to calculate the current unbalance values on the protected line [7–12]. The distributed capacitance of long distance line is the key factor to threat the sensitivity and reliability of the current differential protection. Various compensating methods can be used to reduce the impact of the line capacitance [13,14] as supplement and correction means. They are not the basic contents of the conventional pilot protections and have some limitative factors on the practical application.

To further improve the reliability of the pilot protection and reduce the influence of inter-phase coupling and line capacitance, a novel pilot protection scheme for transmission lines based on Individual Phase Impedance (IPI) is presented in the paper. The IPI is defined and calculated by doubling the ratio of the voltage difference of fault-superimposed components to the current difference of fault-superimposed components at both line terminals. The IPI may eliminate the inter-phase coupling when the grounded fault occurs and may compensate the line capacitance on various line models. It is more reliable than the directional comparison pilot protection and has higher sensitivity than the current differential protection, and the impedance algorithm is the complete individual phase algorithm. In frequency domain protection, the operating time of the pilot protection based on IPI basically equals to that of current differential protection. The sensitivity of the IPI may be

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