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A novel scheme for current-only directional overcurrent relay

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ABSTRACT

Overcurrent relays are widely used as main protection in sub-transmission and distribution systems. In mesh and multi-source networks, application of directional relay is unavoidable. Traditional directional overcurrent relays use the reference voltage phasor as the polarizing quantity to estimate the direction of the fault. Traditional direction distinguishing scheme is unreliable in the case of close-in faults. In this paper, a novel algorithm for directional overcurrent relay is proposed. The new algorithm uses only current signals for determining the fault direction. It uses superimposed component of the current signal and does not require phasor estimation. This new algorithm uses pre-fault current signal as the polarizing quantity. The proposed method is tested on simple power system in different situations. The results show it leads to fast and reliable directional protection.

Introduction

Traditional directional overcurrent relay

Directional protection is one of the main protections in power systems. It has been used widely for distribution lines protection and as a backup protection for transmission lines. Directional overcurrent relaying is necessary for multiple source networks, when it is essential to limit relay tripping for faults in only one direction. It would be impossible to obtain correct relay selectivity using a non-directional overcurrent relay in such cases. Traditional directional overcurrent relays are combinations of directional and overcurrent relay units in the same enclosing case. Any combination of directional relay, inverse-time overcurrent relay, and instantaneous overcurrent relay is available for phase- or ground-fault protection [1]. In fact, when fault current can flow in both directions through the relay location, it may be necessary to make the response of the relay direction by introducing a directional control facility which is provided using additional voltage inputs for the relay. The ability to differentiate between a fault in one direction and another direction is obtained by comparing the phase angle of the operating current phasor, which varies directly with the direction of the fault, and some other system parameters that are not dependent on the fault location. This constant parameter is referred to as the polarizing quantity [1]. In fact, directional relays require two inputs, the operating current and a reference, or polarizing quantity (voltage) that does not change, considerably with fault location to distinguish between forward and reverse faults.

The traditional voltage polarization-based directional relay has some serious problems. This relay is unreliable when the fault is closely proximate to the relay (close-in faults). In this case, the relay is almost grounded by the short circuit and the traditional directional method fails [2]. As mentioned above, traditional directional overcurrent relays utilize the reference voltage phasor for estimating the direction of the fault. This requires measurement of both current and voltage using respective sensors. This makes the directional overcurrent relays more costly than the current-only directional relay.

The other issue of directional relays is determining the correct connection from the well-known options, shown in Fig. 1 (90° Connection, 30° Connection, 60° Connection; these connections are presented in details in [3]). Determining the best connection, for any system and fault conditions, depends on analyzing the phasors within the relay for the most probable conditions of load angles, faults and the effect of arc resistance [1]. If any of these conditions change, the preferred connection will also change. The current-only directional relay is useful in these cases.

Paper review

Many research works have been done on directional relaying methods. In [4,5], series capacitor problems in line protection schemes have been indicated; then a positive-sequence directional relaying algorithm has been presented, to solve these problems. A directional protection based on instantaneous power for UHV transmission lines has been presented in [6]. Using instantaneous

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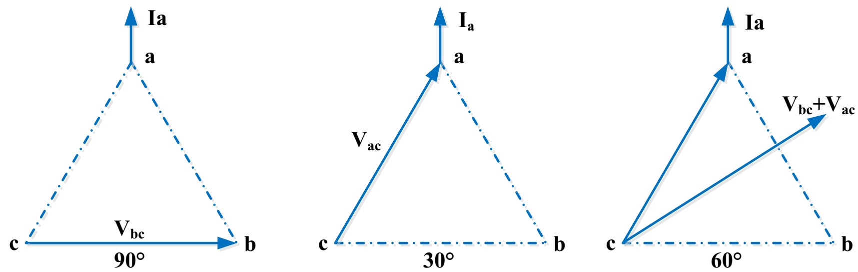

Fig. 1. Various connections of directional relays.

active and passive powers at the relaying point, relay determines the fault direction. In [7], a directional protection for double-circuit lines has been proposed. The method solves the problems of far-end faults, cross country faults and series compensated lines protection issues. In [8–10] a high-speed directional relay based on energy of traveling waves of voltage and current signals has been presented. The neural network technique is another method, to detect direction of the fault. This method has been presented in details in [11]. In [12,13], a scheme for detecting fault direction based on superimposed components has been introduced. First, superimposed components are indicated, and then the directional relay algorithm is proposed. In [14], the development of directional comparison protection for series compensated transmission lines has been introduced. This method uses signal processing techniques to overcome protection problems of these lines. An only-current directional relay has been presented in [2]. This relay uses only current signal phasor to estimate the fault and its direction. A new protection scheme for transmission lines is presented in [15]. It introduces a directional comparison protective scheme using the average value of superimposed components. A new directional technique for discriminating between forward and reverse faults is presented in [16]. In this technique, a directional current signal is derived from the post-fault current signal, the absolute sum of the post-fault current signal and a reference current signal.

In this paper, a new algorithm is proposed for directional overcurrent relays which only uses current signal for estimating the direction of the fault. It uses samples of current signal and does not need phasor estimation which leads to a fast and simple directional protection, compared to the previous researches. One of the main characteristics of this method is its capability in direction discrimination in the case of close-in faults.

The rest of the paper is organized as follows. Section 'Proposed algorithm' presents the proposed algorithm. Section 'Simulation studies and analysis' presents the simulation results. Section 'Tech nical challenges' discusses the challenges and solutions, and Secti on 'Conclusion' concludes the paper.

Proposed algorithm

This section deals with demonstrating the proposed method in details which only uses the current signal for fault direction detection. The proposed algorithm uses current signal samples and does not need phasor estimation. Hence, it leads to a fast and simple directional protection compared to the other methods.

Fig. 2 indicates current phasor diagram of forward and reverse fault. Considering this figure, the current jumps from I_{pre} to I_R or I_F in the case of a reverse or forward fault, respectively [2].

Assume that reference voltage is $V_m \sin(\omega t)$. According to the figure, current signal will be equal to $I_1 \sin(\omega t - \theta_1)$ and $I_2 \sin(\omega t - \theta_2)$ for pre-fault and post-fault. Where, θ_1 is close to zero and θ_2 is close to -90° and 90° for forward and reverse faults,

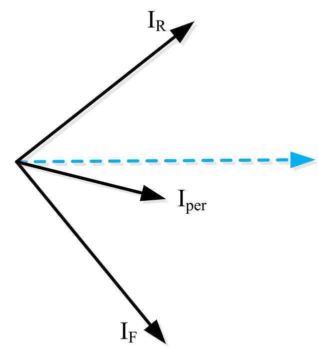

Fig. 2. Phasor diagram for reverse and forward fault, and pre-fault current.

respectively. From Eqs. (1)–(13) it is identified that the current signal and its superimposed component have some sign for forward fault, while their signs are different for revers faults.

For forward power flow and forward fault we have:

$$V = V_m \sin(\omega t) \tag{1}$$

$$i_1 = I_1 \sin(\omega t - \theta_1) \tag{2}$$

$$i_2 = I_2 \sin(\omega t - \theta_2) \tag{3}$$

$$\sup = I_2 \sin(\omega t - \theta_2) - I_1 \sin(\omega t - \theta_1) \tag{4}$$

$$\sup = I_2 \sin(\omega t)\cos(\theta_2) - I_2 \sin(\theta_2)\cos(\omega t) - I_1 \sin(\omega t)\cos(\theta_1) + I_1 \cos(\omega t)\sin(\theta_1) \tag{5}$$

$$\sup = \cos(\omega t)(-I_2 \sin(\theta_2) + I_1 \sin(\theta_1)) + \sin(\omega t)(I_2 \cos(\theta_2) - I_1 \cos(\theta_1)) \tag{6}$$

$$\begin{aligned} &\theta_2 \approx 90^\circ \\ &\theta_1 \approx 0 \end{aligned} \tag{7}$$

$$\omega t = 2\pi f t = 2\pi f \times nT = 2\pi f \times n \times \frac{1}{fN} = \frac{2\pi}{N} n \tag{8}$$

where

n: The sample number
N: number of sample per cycle which is assumed to be equal to 50
F: nominal frequency
T: inter-sampling time which is the inverse of sampling frequency

$$\sup = -I_2 \cos\left(\frac{2\pi}{N} n\right) - I_1 \sin\left(\frac{2\pi}{N} n\right) \tag{9}$$