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A new digital filter directional relay technique using active/reactive power portrait

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ABSTRACT

The present paper discusses some conventional directional relay drawbacks, which are based on the relationship between voltage and current, in order to determine fault direction. In addition, it presents a new fault detection technique based on instantaneous active and reactive energy that is measured and analysed at the relaying point. This energy has a distinct characteristic which is used to distinguish the fault direction. The suggested relay has determined the fault direction in a rather short time after fault occurrence, even in 2–5 ms, depending on the characteristics of the fault generated travelling waves. The algorithm used in this method has been modified in order to improve the performance of the relay. Simulation studies showed that the directional relay based on this new technique has fast speed operation with reliability and dependability.

1. Introduction

A directional relay is one of the main pieces of equipment used for protection in transmission lines. There are some external influences which may affect the directional decision, for instance mutual coupling, capacitive current, types of load, fault resistance, fault location in a long transmission line, transformer connection and zero sequence source. These factors have forced the directional decision to operate in the wrong zone and affect relay security, selectivity and reliability. The directional element technique has been discussed many times in the literature in seeking to solve these problems. The algorithms of directional relay can be classified into three types:

(a) Directional element based on the relationship between voltage and current [1–5]. The relay characteristic angle is a setting used in the relay to define the operating zone and the tripping zone. Studies have been conducted on the literature in order to find out the optimal relay characteristic angle. Over-current or earth fault schemes are also dependent on the system type, including the types of grounding, length of transmission line etc. These methods have some drawbacks because they may be affected by a zero sequence source and fault resistance.

(b) Directional elements based on power frequency components [6–12] that can be classified into: positive sequence component, which calculates the angle between positive-sequence voltage and current in order to locate the fault direction. It cannot work at the terminal without a source supply behind it for directional discrimination. This cannot be used in single source systems, even in double source supply systems with a heavy transition load.

A negative sequence component based relay, which calculates the angle between negative-sequence voltage and the current at the line terminal, is used for locating the fault direction. It may show an incorrect direction estimation on a symmetrical fault, but for all types of asymmetrical faults, it performs well in both single source and double source supply systems, even in high fault resistance situations or in a neutral isolated system.

The zero sequence component based relays calculate the angle between the zero sequence voltage and current which is used to locate the earth fault direction; it is affected by the zero sequence source, transformer connection and load types.

(c) Directional elements based on the instantaneous component [13–16], such as a polarity comparison of travelling waves, amplitude comparison of travelling waves and surge impedance based on the directional element etc. These types catch the initial travelling wave which has the highest speed and was unaffected by grounding resistance. The main

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drawback for this method is the uncertainty of the travelling waves that has made it difficult to be applied to a real network. As a directional element based on a digital phase comparator [17], it is a high speed directional relay and based on the calculation of normalised average power within one semi-period of the input voltage and current signals.

The foregoing work has found that most of the algorithms which were used in the directional element still suffer from some problems and, therefore, a new algorithm has been shown in this research in order to overcome the pervious problems.

The present paper presents a new direction relay based on instantaneous power. The energy being transmitted under fault conditions possesses a distinct direction characteristic from the fault point to the system. The characteristic of energy direction can be used as the directional element. The directional element based on energy detection does not need to extract the power frequency component or catch the exact initial travelling wave from the fault signal. Therefore, the speed of this kind of directional element is faster than the principle based on power frequency component, but lower than the principle based on the initial travelling wave. It has some drawbacks, for example the distribution of the instantaneous energy is difficult to study when calculating to calculate the appropriate settings, and the relay tolerance angle θ is a critical angle. It has an effect on the directional relay decision. If it is large, the relay may fail to distinguish the right direction and, if it is small, the relay may fail to see any direction because the energy curve falls out of the detection region.

2. Problem area from commercial relays

Whereas a conventional directional relay is still generally used in practical life, these studies have explained that there are a lot of problems still facing the conventional directional relays such as those mentioned in paragraph (a). To reveal some drawbacks of this method, some problems will be discussed here.

2.1. Fault resistance effects (real data)

Fig. 1 shows an 11 kV Naser City distribution system in Egypt, 66kv/11kv-D/Y earthed power transformer with 11 Ω grounding resistance to limit the short circuit current, and the transformer feeds half switchgear busbars through double feeders. The directional over-current and earth fault scheme applied on the circuit breakers C.B 9 and C.B 10. The fault happened in the feeder transmitted power from EL Marwa transformer station to the right busbars of the switchgear. The mentioned fault was 6 km away from the transformer station. The data read from the relay for C.B 9 is also shown in Fig. 2.

Fig. 2 shows the voltages and currents waveforms of relay, in which the line of fault screen at 0.158 s indicates the trip point after 5 cycles from the pick up value, and the phasor of voltage and current in Fig. 3 represents this point. Due to the high fault resistance, the voltage V_A decreases to 4272.758 V (74.48% $V_{B.F}$) after fault occurrence by 2 cycles and decreases to 4633.950 V (80.77% $V_{B.F}$) after fault occurrence by 15 cycles, where the voltage before fault $V_{B.F} = 5737$ V. The current I_A decreases to 153.4 A (80.7% $I_{B.F}$) after fault occurrence by 15 cycles where the current before fault $I_{B.F} = 190$ A and I_o increases to 90 A from 30 A where it has a value of almost 30 A in the steady state due to an unbalanced current. The effect of the resistance was observed from the cable testing result where the cable insulation did not collapse with the testing voltage (10 kV DC/10 min), but the leakage current was approx.2 mA and this is not allowed, compared with low fault resistance V_A which may be decreased by 75% and the value of I_o may be increased up to 300 A and cable insulation collapse with the same testing voltage.

Fig. 3 shows the phasor diagram of the three phase voltages, currents after fault occurrence by 5 cycles. The angle between the voltage and current is reversed by 180° due to the relay connections where the current leaves of the relay coil at its dotted end.

Table 1 shows the data read for the relay located at C.B 9 during the trip time instant, wherein the relay distinguishes the fault as a forward fault because I_A is still in the forward zone which is a

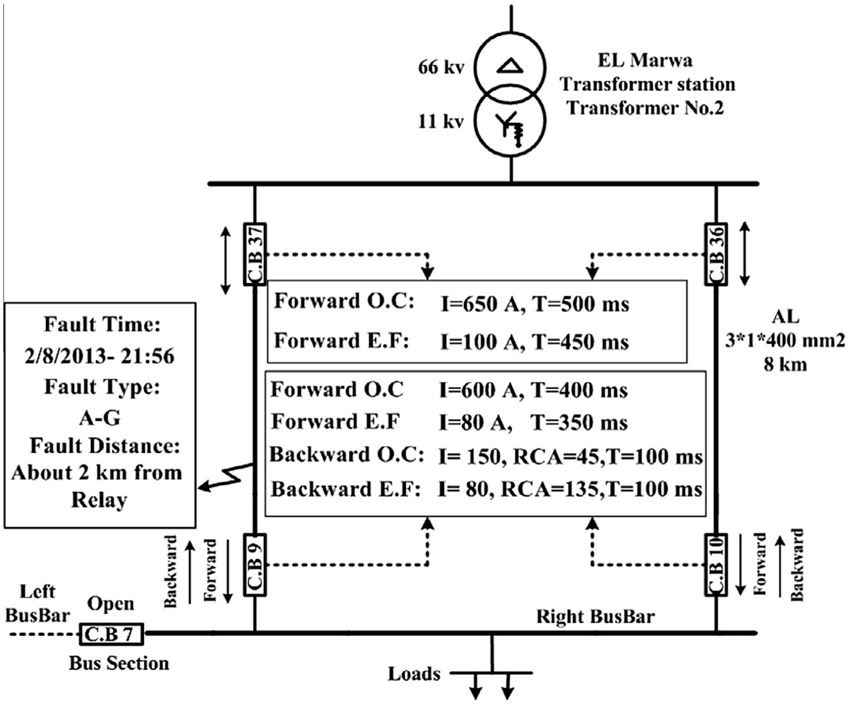

Fig. 1. A power network for 11 kV distribution system. Distribution network.