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ORIGINAL ARTICLES

Improved differential relay for bus bar protection scheme with saturated current transformers based on second order harmonics

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KEYWORDS

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Abstract Differential relays security to the external faults is affected by the saturation of branches' current transformers (CTs). In this paper, a simple scheme is proposed to enhance the security of differential numerical relay by extracting the 2nd order harmonic using Fast Fourier Transform (FFT) to produce a restraint signal to inhibit the relay operation during external faults. The operation signal of differential relay is produced by comparing the vector addition of secondary currents of branches' CTs (differential current) with pre-set value; the restraint signal is produced by comparing the algebraic sum of 2nd order harmonic of individual secondary currents with the 2nd order harmonic of differential current. The proposed scheme is investigated using PSCAD/EMTDC simulation and tested during internal and external faults for saturated CTs. The obtained results reveal how this scheme is effective and secure to the external faults for different suggested scenarios. The proposed scheme is using the simplest technique of signal processing compared to other proposed techniques.

1. Introduction

Bus bars are the connection points for a number of transmission lines and many electrical apparatus, so differential relays are used for bus bar protection as shown in Fig. 1. Bus bar protection is considered as the most important part of power system protection because if any incorrect operation occurs, it will lead to disconnecting healthy circuits connected to the bus bar.

The principle operation of differential bus bar protection depends on the Kirchhoff current law, which states that the sum of currents that enter the bus equals the sum of currents that leave bus; on the other hand, it can be expressed as the vector sum of all currents entering and leaving the bus bar equals zero as in (1):

$$\sum \bar{I}_j = 0. \quad (1)$$

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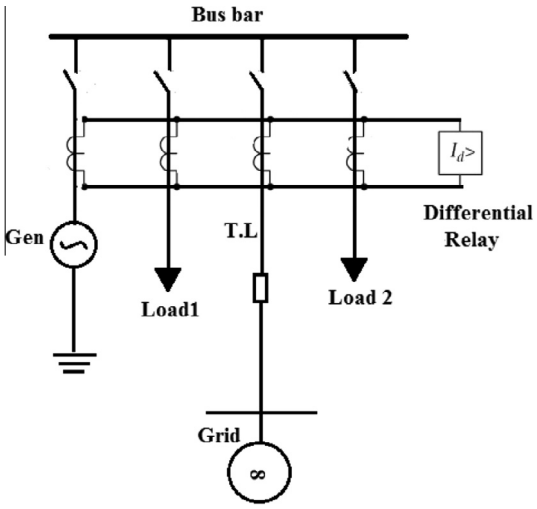

Figure 1 Differential bus bar protection.

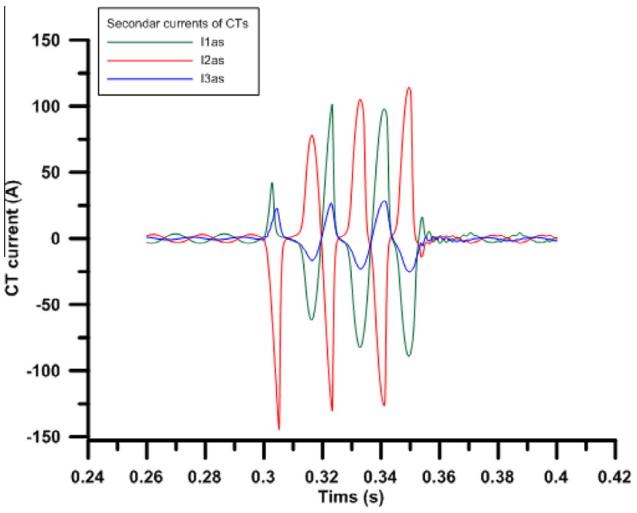

Figure 3 Secondary currents of saturated branches' CTs.

where j is the branch connected to bus bar, $\bar{I}_j$ is the vector current of j branch which is measured by current transformer CT as in Fig. 2(a). If an internal fault is incepted in the bus bar as shown in Fig. 2(b), then the vector sum of all branches' currents will equal the fault current as in (2):

$$\sum \bar{I}_j = I_f \tag{2}$$

where I_f is the fault current. If the fault is located out of the protection zone of the differential protection of the bus bar as shown in Fig. 2(c), which is called external fault, then the vector sum of all branches' currents should equal zero as in (1).

The major problem with bus protection is unequal core saturation of branches' CTs during external faults as shown in Fig. 3.

The basic requirement is that the total scheme must provide the degree of selectivity necessary to differentiate between an internal and an external fault (Kang et al., 2008). For electromechanical relays, the harmonic component current as restraint was used to prevent incorrect operation of differential relays in the presence of unbalanced currents due to various causes such as CT saturation (Kennedy and Hayward, 1938).

In recent differential numerical relays, signal processing techniques are used to enhance the performance of differential relays such as a wavelet transform to detect bus bar faults and discriminate them from external faults (Eissa, 2014, 2013, 2004; Fernandez, 2001; Kang et al., 2008).

Adaptive digital band pass filter is used to extract the fundamental frequency components of differential and through current signals (Basha et al., 1996). Measuring the power system source impedance at the relay location is used to detect CT saturation (Fernandez, 2001), which requires current and bus voltage measurements.

Positive and negative sequence of measured currents and voltages at bus bar location are used to detect the CT saturation and ratio mismatch (Sachdev et al., 2000). A graph theory is used for selecting the bus protection zones in microprocessor relays (Qin et al., 2000).

In this paper, Fast Fourier Transform (FFT) technique is used to extract the 2nd order harmonics of secondary currents of individual branches' CTs and differential current signal. FFT is the most widely used technique in signal processing which makes this proposed scheme simple and robust.

2. Proposed scheme for bus bar protection

The proposed scheme shown in Fig. 4 is producing two signals to enhance the performance of differential relay: first signal is the operating signal which is produced by calculating the dif-

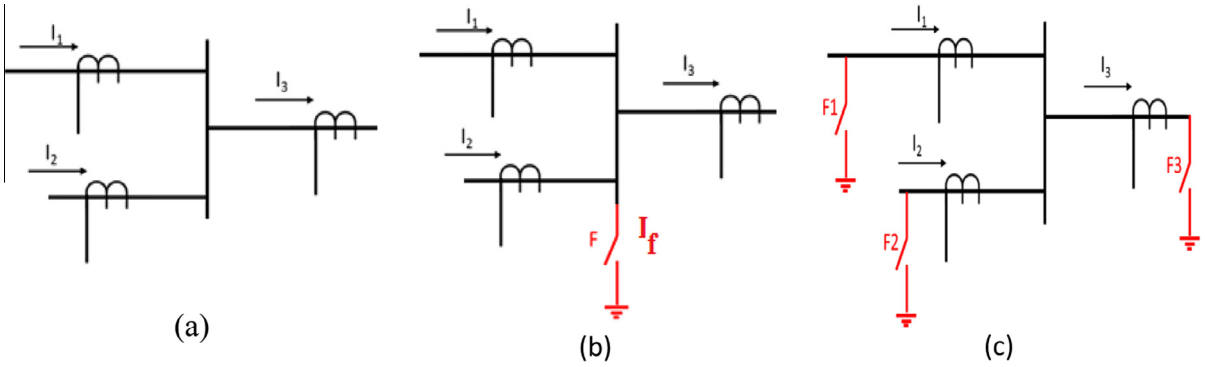

Figure 2 (a) No fault; (b) internal fault; (c) external fault.

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