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Developing Busbar protection with new differential characteristics to solve the breakpoint settings of digital commercial relays

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ABSTRACT

The current commercial characteristics of the digital differential relays have many breakpoint settings of time delay due to Current Transformer Saturation "CT-SAT" and error. This can decrease the sensitivity of the Merz-Price circulating current protection relays. However, to enhance the stability of this type of relays, the operating threshold boundary is increased. This will cause serious limitations for the relays during faults occurrence inside the Bus-bar zone. The protection characteristic of such relays is based on the phasor quantities, in such case the secondary current during the CT-SAT equals to zero. To improve the Merz-Price circulating current protection characteristic, the relay operation should depend on the features of the faulted instantaneous current rather than the phasor quantities. The paper develops new Merz-Price circulating current characteristic based on the wavelet transform of the noises generated by the fault. The captured noises have valuable information during the CT-SAT. The study shows the performance improvement in system sensitivity and stability of the new characteristic. All types of the faults are successfully detected due to current saturation, ratio mismatch, early and late saturation.

1. Introduction

The traditional Merz-Price circulating current concept is based on the current magnitude for estimating the restraining and biasing values. The significant imbalance comes from the secondary current of a current transformer with a resistive burden which collapses to zero when SAT occurs and it remains at zero until the time when the next zero crossing would have occurred [1].

The Merz-Price circulating current concept is carried out by balancing the secondary current of the CT for all of the circuits connected with the bus and then bridging this balanced circuit with the operating coil of the relay. Current transformers may saturate and cause the Merz-Price circulating current to work in not ideal case. The low impedance measuring principle employs the zone-selective Merz-Price circulating current as the operating quantity and the sum of the current magnitudes as the stabilizing signal. The measuring principle must ensure protection stability with SAT on external faults.

Unfortunately, the current transformer may saturate and thus may cause the Merz-Price circulating current to operate in different way. The protection of Busbar requires fast operation, reliability and dependability. The operation of Busbar methods is enhanced in [2,3].

Based on Merz-Price circulating current protection concept, some papers are discussed in [4–11]. Some authors dealt with the problem of the CT-SAT [12–14]. Some other authors applied the wavelet using many types of functions [15–18]. Most of the techniques ignored the effect of SAT. Some papers have provided additional measures. These methods do not provide accurate solution during severe and early CT-SAT and do not improve the sensitivity of the Merz-Price circulating current characteristic. The differential protection should maintain security during CT-SAT for external faults while keeping high sensitivity and speed of operation for internal low faults. Relay manufacturers provided very little information for the protection engineers to set the relay adequately [19]. Some authors in [20] enhanced the security of differential numerical relay by extracting the 2nd order harmonic using Fast Fourier Transform "FFT" to produce a restraint signal to prevent the relay operation in case of external faults. Some authors did block for the Merz-Price circulating current values during the period of the cycle that the current transformer is saturated. There are many techniques that have developed many break-point settings in the operating characteristic. New digital differential relays provide complex signal processing and decision logic that make their behavior under CT saturation difficult to predict. Some new relays use complicated algorithms to detect CT saturation and prevent relay operation under CT conditions.

The time and frequency localization properties of Continuous Wavelet Transform (CWT) offers a viable and improved option for analyzing the transient characteristics of defect signals. The CWT

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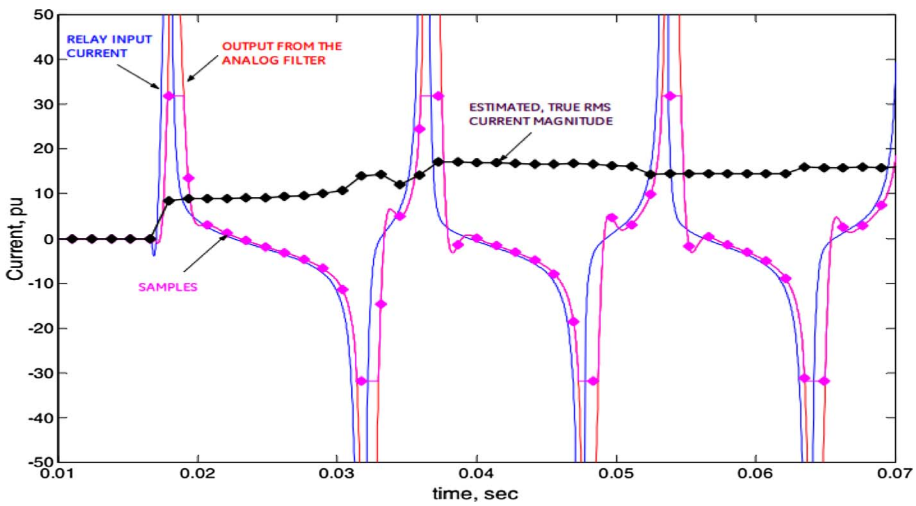

Fig. 1. The true RMS calculation during the CT-SAT [21].

depends on high frequencies superimposed on the faulted signal during SAT.

The technique is based on the windowed wavelet transform of the transients generated from the faults to distinguish between faults in a Bus-bar protection zone from external zone, particularly in case of severe and early SAT. These features can help discrimination the external faults in case of CT-SAT (severe and early cases). The paper introduces new Merz-Price circulating current busbar characteristic with values depending on a windowed signal captured from the transient generated from the faults. The time and frequency information during SAT can be obtained rather than the zero current values produced due to SAT when scan continues signal with specific properties on the current signal. The proposed idea depends on the featured noises of the current signal extracted from the saturation period not from the current magnitude. The time and frequency data impeded in the current signal during the SAT can be obtained instead of the zero current values. The proposed technique ignores the breakpoint settings of the commercial operating characteristic and introduces new Merz-Price circulating current characteristic depending on small pickup setting.

Fig. 1 shows an example of the relay input current and the output from the secondary during the CT-SAT. If the true RMS value is estimated from the secondary side, as shown in the figure the relay is subjected to 64kA of fault current, and measures "only" 10–15 pu of the current (50-75A secondary, or 500-750A primary). As shown in the figure it can be estimated by only about 1% of the true current, but still 10–15 times relay rated current [21]. All the current relays used are based on the current magnitude during the CT-SAT that cause relay failure. The relays consider the period of saturation equals to "zero". The proposed idea has the novelty while this period is studied well and more features rather than "zero" values are extracted from it. The provided idea ignores the multi-breakpoint settings of the commercial characteristic and introduces new Merz-Price characteristic without breakpoints and with small setting values for relay acceleration.

2. Limitation of commercial merz-price circulating current characteristic

The operating principle of the Merz-Price circulating current is based on current Kirchhoff's Law. This compares the amount of current entering and leaving the protected zone and the check zone. During normal operation, the current flowing into the area and the check zone concerned is equal to the current flowing out of the area. In this case, the net currents are canceled out. When a fault occurs the Merz-Price circulating current that arises is equal to the derived fault current. Merz-Price circulating current may also be generated under external fault conditions due to CT error. To provide stability for through fault conditions the relay adoptsa biasing technique, which effectively raises the setting of the relay in proportion to the through fault current thereby preventing relay mal-operation. The commercial bias Characteristic with Merz-Price circulating current technique depends on bias characteristic as given in Fig. 2(a). It is a comparison between the Merz-Price circulating and the restraining current. This is the most common characteristic for current commercial relays. A fault is detected if Merz-Price circulating current increases the set slope of the bias characteristic. Normally the characteristic is obtained to guarantee the stability of protection during external faults. Most of the error come from the different specification and characteristic of CTs. Consequently, such CTs cause differing performance. Most algorithms perform as follows:

Circulating Current: $i_{diff}(t) = |\sum \vec{i}\,|$ (1)

Bias or Restraining current:$i_{bias}(t) = \sum |\vec{i}\,|$ (2)

If the slope of the bias characteristic at certain zone (zone x below the slop) $= kx$The tripping can be permitted using the bias element as;

$i_{diff}(t) > kx.\ i_{bias}$

As shown in Fig. 2(a) for Phase Fault elements:

I_{DX}	*The threshold value*
x	*Indicates any one of the located curves* (*slopek*1 *or* *k*2 *etc*)

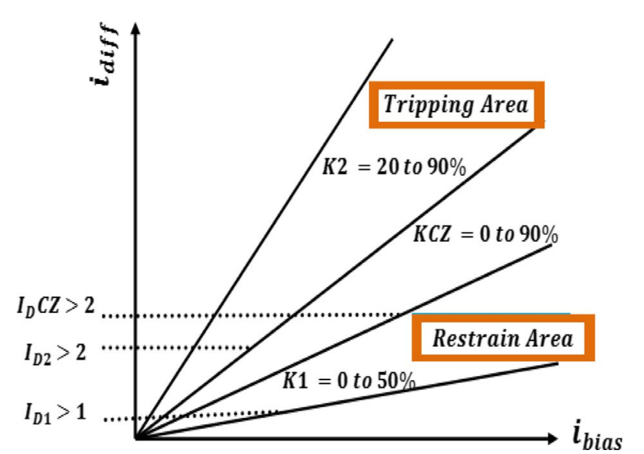

Fig. 2. (a) The P740 characteristic [22] (b) New Merz-Price circulating characteristic (c&d) Shannon wavelet effect during *SAT*.