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Concept of Symmetrical Component as a Technique for analysis of fault and Improvement of Over current Protection Scheme

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***ABSTRACT*- Electrical energy is one of the fundamental resources of the modern industrial society. Electrical power is available to the user instantly, at the correct voltage and frequency, at exactly the amount needed. The power system maintains its steady state mainly because of the correct and quick remedial action taken by the protective relaying equipment. The response of the protection system must be automatic, quick, and should cause a minimum amount of disruption to the power system. Concept of Symmetrical component for an enhancing protection scheme shows an outstanding feature. The method of symmetrical components provides a practical technology for understanding and analyzing power system operation during unbalanced conditions. Such as those caused by faults between phases and/or ground, open phases, unbalance impedances, and so on. Also, many protective relays operate from the symmetrical component quantities. Thus a good understanding of this subject is of great value and very important tool in protection. In this paper how the concept of symmetrical components helps for improvement of different protection schemes.**

Index Terms—Fault, overcurrent relay, type of Faults, symmetricalComponents, Transformer energizing.

1. Introdution

The development of deregulation in power systems leads to a higher requirement on power quality. In the area of relay protection this means that a faster protection is needed, while undesirable operation of the protection system is almost unacceptable. A faster protection can guarantee that an abnormal operation mode somewhere in a system, such as voltage sag caused by faults, can be quarantined quickly, so as not to propagate to the rest of the system and cause instability. To do this, a relay protection should be sensitive. Unfortunately, high sensitivity sometimes causes undesirable operation of relay protection when there is no fault in the system. In a deregulated power market this directly leads to penalty compensation to the users that suffer from the blackout [1]. Therefore, identification of those factors that produce this undesirable operation of the relay and introducing procedures for their discrimination from the real fault cases are very important. In [1], such factors have been introduced from the view point of over current relays. Power system switching, such as motor starting and transformer energizing, is the most important source of undesirable operation of the relay protection. In [2], a method has been also recommended to study the effect of over currents due to the switching on the operation of over current relays. However, [1] and [2] have not introduced a method that could discriminate these no-fault cases from the fault cases for over current relay.

2. Methodology:

The Concept of symmetrical components provides a practical technology for understanding and analyzing power system operation during unbalanced conditions such as those caused by faults between phases and/or ground, open phases, unbalance impedances, and so on. Also, many protective relays operate from the symmetrical component quantities. Thus a good understanding of this subject is of great value and a very important tool in protection.

For any unbalanced or nonsymmetrical network, such as unsymmetrical fault occurs or having unbalanced load, symmetrical component conversion can decouple three-phase system into three independent sequence equivalent networks, namely positive, negative and zero sequence network. Therefore these three sequence networks can be analyzed separately. Then we can convert the sequence value back into phase variables. This analysis procedure is commonly used in analyzing the unbalanced system network, including fault. Symmetrical components can be viewed as a mathematical tool on which we can entirely based to analysis system without converting back to phase variable. For example, the amplitude of zero sequence signifies the degree of unbalance, and therefore can be used to detect the unbalanced fault.

2.1 Theoretical background

The symmetrical component transformation for an arbitrary three-phase set of variables (balanced or unbalanced), for example the three-phase current, and inverse transformation is given in (1) and (2).

$$\begin{bmatrix} I0 \\ I1 \\ I2 \end{bmatrix} = \frac{1}{3} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \times \begin{bmatrix} Ia \\ I\,b \\ Ic \end{bmatrix} \text{-------- (1)}$$

Here I_1 , I_2 and I_0 denote the positive, negative and zero sequences respectively. And

$$\alpha = 1\llcorner 120^0 = -0.5 + j0.866$$

In general application in power system analysis, we typically begin with information in "phase variables" denoted by subscripts a, b, and c. Note that phase variables corresponds to actual physical quantities. The value of converting physical quantities to symmetrical components is in visualizing and quantization the degree of unbalanced system network. For a balanced three-phase system, it won't be difficult to calculate that the zero and negative sequences are zero, and the positive sequence is equal to phase a, no matter current or voltage.

There are many electrical types of equipment in power system used or various purposes and needs protection scheme so as to have stable operation and eliminate the disturbances due to faults like active fault, overloading, overheating and switching etc, Transformer is most critical items in a power system and has high capital value. So as to achieve the full benefit of this, it is important to have the most effective means of identifying any deterioration or malfunction.

Malfunctioning of transformers is mainly because of following reasons:

Due to magnetizing inrush current, Harmonics generated due to occurrence of internal faults, Short Circuit in core winding, Symmetrical or Asymmetrical Faults

Symmetrical components consist of three quantities: positive-sequence (exists during all system conditions, but are prevalent for balanced conditions on a power system including three-phase faults); negative-sequence (exist during unbalanced conditions); zero-sequence (exist when ground is involved in an unbalanced condition). Negative and zero-sequence components have relatively large values during unbalanced fault conditions on a power system and can be used to determine when these fault conditions occur. Negative-sequence components indicate phase-to-phase, phase-to-ground, and phase-to-phase-to-ground faults. Zero sequence components indicate phase-to-ground and phase -to-phase-to-ground faults

3. Operation and Principle of Overcurrent Relays

There are two characteristics for overcurrent relays: 1) definite- time characteristic and 2) inverse-time characteristic. In the definite-time characteristic relays, if the current amplitude exceeds a pre-defined value, the relay trips after a definite time. In the protection of motors, these relays are used to prevent the unbalanced operation of the motors. According to IEC standard [19], the characteristic of inverse time overcurrent relays (excluding induction type) is depicted by the following expression:

$$T = \frac{c}{(\frac{I}{\mathrm{Is}})^{\alpha} - 1} \text{ ----- (2)}$$

T- the relay operation time;
C- constant for relay characteristic;
I_s-current setting threshold;
I- current detected by relay (normally the effective value) ; $I > I_s$
α- constant representing inverse-time type $\alpha > 0$

By assigning different values to α and C, different types of inverse characteristics are obtained. Table I shows the definitions of various relay characteristics type by the IEC standard. Here, the detected rms current is implicitly assumed to be constant, which is not true when transients are involved. If function is *f(t)* defined for the denominator of (2) as follows:

$$f(t) = \left(\frac{I(t)}{Is}\right)^{\alpha} - 1$$

and t_1 is defined as the instant *I(t)* that exceeds I_s , then inversetime overcurrent relay trips when the following condition meets

$$\int_{\mathrm{t1}}^{\mathrm{t1+T}} f(t)dt \geq C, t \in [\,\mathrm{t1}, \mathrm{t1} + \mathrm{T}\,] \text{ ------- (3)}$$

If *f(t)* waveform fluctuates, it is possible to adjust *C* and I_s to find one interval during which (4) holds and command is issued [1]. To prevent the improper operation of the relay in this case *C* and I_s, or can be increased, but the sensitivity of the relay drops. Considering the details described in [1], the suggested algorithm concentrates on the relays with inverse-time characteristic.

4. Proposed Algorithm

Any three-phase voltage and current consist of three components in sequence space which are related to each other as follows:

$$\begin{bmatrix} I0 \\ I1 \\ I2 \end{bmatrix} = \frac{1}{3} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \times \begin{bmatrix} Ia \\ I\,b \\ Ic \end{bmatrix}$$

Here I_1 ,I_2 and I_0 denote the positive, negative and zero sequences respectively. And

$$\alpha = 1 \angle 120^0 = -0.5 + j0.866$$

Also $1+\alpha+\alpha^2=0$ if currents I_a, I_b and I_c are balanced (i.e., $I_{a,=} I \angle 0$, $I_b = I \angle -120^0$ and $I_c = I \angle +120^0$). So existence of the negative components means that the system is unbalanced. except over a transient period that may be as a result of different switching method or non identical saturated case of three-phase transformers, three phases are almost affected simultaneously during switching event. Consequently, the negative component is not considerably changed in this case. On the other hand, faults are classified into symmetrical and asymmetrical parts. The major feature of these faults is the large value of the negative component, such that there are the theoretical following cases-

For phase–ground fault

$$I_2 = I_1 = \frac{V_f}{Z_0 + Z_1 + Z_2 + (3Z_f)} \qquad \text{...... (4)}$$

Where Z_f is the fault impedance between the line and ground Z_0, is the zero component impedance Z_1, is the positive component impedance, and Z_2 is the negative component impedance.

For phase-phase fault:

$$I_2 = -I_1 = \frac{V_f}{Z_1 + Z_2 + Z_f}. \qquad \text{..... (5)}$$

For phase-phase- ground fault:

$$I_2 = (-I_1) \times \frac{Z_0 + 3Z_f}{Z_0 + 3Z_f + Z_2}. \qquad \text{...... (6)}$$

Therefore, the negative component in the asymmetrical faults is considerable. For symmetrical faults the negative component tends to zero. Not often, the three-phase fault occurs and the negative component of the current is negligible and almost equal to zero similar with the switching case. The criterion function for discriminating fault from nonfault switching is defined as follows

The criterion function for discriminating fault from non fault switching is defined as follows:

$$R = \frac{|I1| - |I2|}{|I1| + |I2|} \qquad \text{----- (7)}$$

Since there is a considerable negative component in the asymmetrical fault case, according to criterion function the value of R is close to zero. In the switching case, the negative component is very small and R is close to 1.

In the switching case, the negative component is very small and R is close to 1. Except over a transient period that may be as a result of different switching methods or a non identical saturated case of three-phase transformers, three phases are almost affected simultaneously and the three-phase network has not a major unbalance, during the switching event. In the calculation of I2 and I_1 in equation (1), Ia ,Ib , and Ic are phasor value (amplitude of the fundamental harmonic). Therefore, dc values and its harmonics are largely eliminated. So the difference in dc value in the current is not important. According to the above, $R<0.35$ indicates the fault; otherwise, over current is the result of switching. The suggested criterion is based on the different behavior of the current components during fault and non fault conditions and is independent of the amplitude of the current which is advantageous. The reason is that it operates based on the relative difference between the negative and positive component of the current. Another advantage of the suggested criterion function is that its proper operation is independent of the power system balancing. Actually, the suggested criterion function in the asymmetrical distribution networks also operates properly. The reason is that during the asymmetrical fault, the negative component of current increases and the value of R is much smaller than that before fault event. Thus, it is enough that the threshold value be lower than at the value of R in the normal state of the network.

5. Simulation Results

To show the advantage of the proposed algorithm, a part of a distribution system shown in Fig.1 is modeled; using the EMTDC/ PSCAD package. The network parameter of the 13-bus distribution system is illustrated in this figure. Several nonfault events are applied to this system along with some short circuit events at different times. The simulation results show that how the proposed algorithm could help the overcurrent relay to discriminate fault from nonfault events. The following cases are presented here:

- Transformer energizing;
- Induction motor starting;

5.1 Transformer Energizing

In order to study a transformer energizing, various inrush current conditions were simulated at different parts of the power system. Various parameters which have considerable effect on the characteristic of the current signal (e.g., core residual magnetization, nonlinearity of transformer core and switching instant)
were changed and the current signal was analyzed by the proposed method. In all cases, correctness of the proposed algorithm has been proved.

A detailed study of a typical case is presented below. In this case transformer at busbar 12 is switched on at instant t= 0.5s and three-phase currents are measured at busbar 7. Fig. 2 shows these three-phase currents. As shown in Fig. 3, except over a transient period, R is close to 1 and is larger than setting R= 0.35s that shows nonfault case. In this case tripping signal is prevented.

5.2 Fault

In this case a phase-ground fault (A-G) occurs at busbar 13 at instant t= 0.5s and three-phase currents are measured at busbar 7. Fig. 4 shows these three-phase currents. As shown in Fig. 5, *R* is close to zero that shows a fault case in which the tripping signal is issued.

5.3 Simultaneous Transformer Energizing and Fault Occurrence

In order to verify the proposed algorithm in the case of simultaneous fault and switching, different cases for transformer and motor were investigated and in all cases the accuracy of the algorithm was confirmed. One typical case is described in details below. In this case, transformer is switched on at busbar 12 at instant t= 0.5s and at the same time a two-phase fault (A-B) occurs.

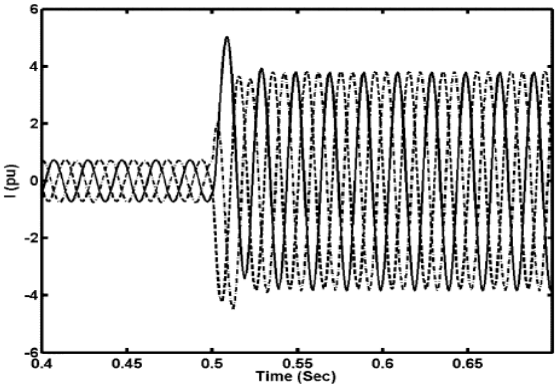

Fig. 2 Three phase current due to transformer energizing

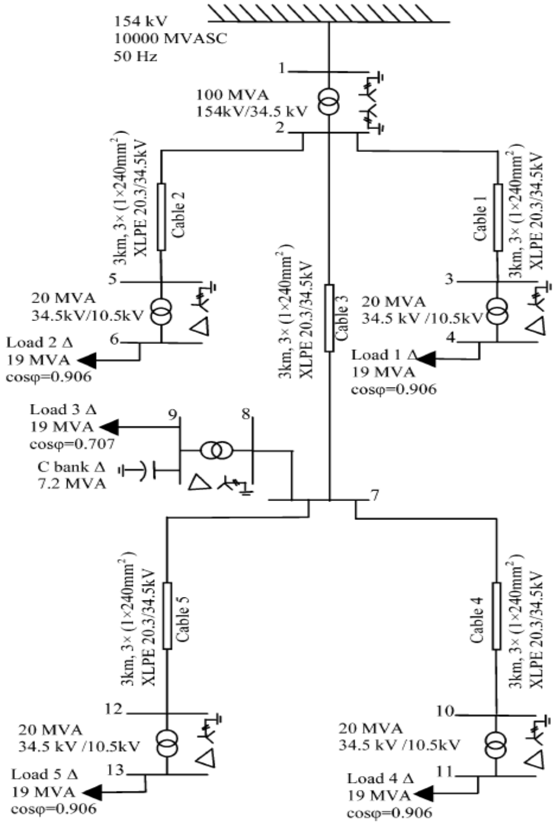

Fig. 1 (34.5 KV simulated distribution system)

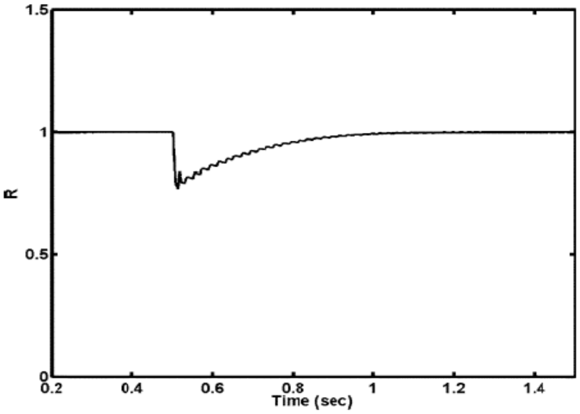

Fig 3. Value of R versus time due to transformer Energizing

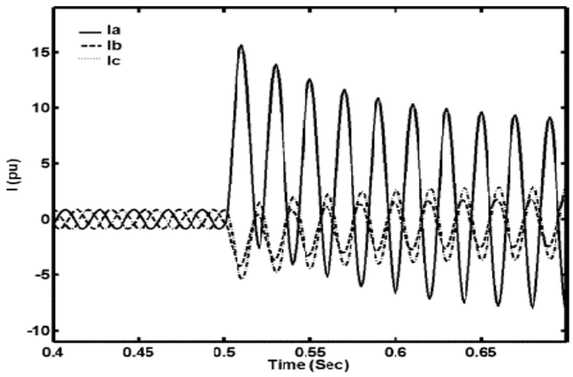

Fig 4 Three phase current due to fault (A-G)

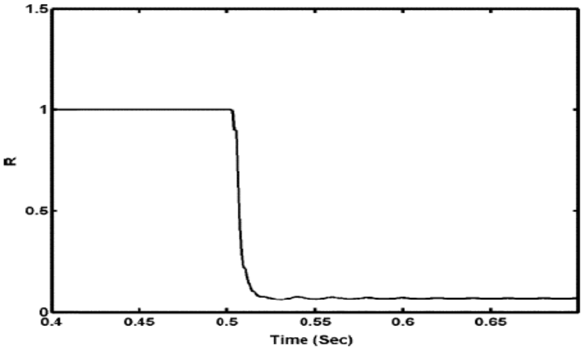

Fig. 5 Value of R versus time due to fault (A-G)

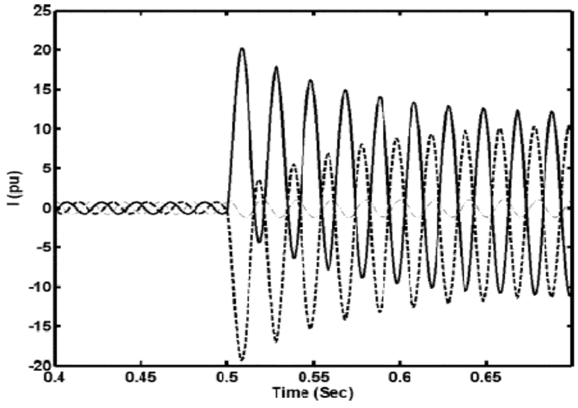

Fig 6. Three phase current due to transformer energizing and fault (A–B)

Three-phase currents are measured at the busbar 7. Fig. 6 shows these currents is close to zero which indicates that there is a fault and the relay trips. In fact, one more advantage of the suggested algorithm is that, in addition to the diagnosis of the fault in the individual occurrence from the nonfault case, it enables to discriminate a fault from simultaneous switching properly. This is necessary because, if in the case of fault, the operation of the relay is prevented and it is assumed switching case, it may lead to a serious damage.

6. Conclusion

In this paper, a simple method for improving overcurrent relays operation has been introduced. The suggested algorithm is based on the different behavior of the current components during fault and nonfault conditions and is independent of the current amplitudes. Based on these differences, a criterion function has been introduced, considering that undesirable operation of the overcurrent relays due to the switching is prevented. The capability of the new method has been demonstrated by simulating various cases on a suitable power system. This paper studied some important factors that influence the operation of relays. However, in order to take into account other factors affecting the operation of relays more works are required

7. Reference

[1] F. Wang and M. H. J. Bollen, “Quantification of transient current signals in the viewpoint of overcurrent relays,” in *Proc. Power Eng. Soc. General Meeting*, Jul. 13–17, 2003, vol. 4, pp. 2122–2127.
[2] “Classification of component switching transients in the viewpoint of protection relays,” *Elect. Power Syst. Res.*, vol. 64, pp. 197–207, 2003.
[3] J. H. Brunke and H. J. Frohlich, “Elimination of transformer inrush currents by controlled switching-Part II: Application and performance considerations,” *IEEE Trans. Power Del.*, vol. 16, no. 2, pp. 281–285, Apr. 2001.
[4] M. A. Rahman and B. Jeyasurya, “A state-of-the-art review of transformer protection algorithms,” *IEEE Trans. Power Del.*, vol. 3, no. 2, pp. 534–544, Apr. 1988.
[5] P. Liu, O. P. Malik, C. Chen, G. S. Hope, and Y. Guo, “Improved operation of differential protection of power transformers for internal faults,” *IEEE Trans. Power Del.*, vol. 7, no. 4, pp. 1912–1919, Oct. 1992.
[6] T. S. Sidhu, M. S. Sachdev, H. C. Wood, and M. Nagpal, “Design, implementation and testing of a micro-processor-based high-speed relay for detecting transformer winding faults,” *IEEE Trans. Power Del.*, vol. 7, no. 1, pp. 108–117, sJan. 1992, .
[7] K. Yabe, “Power differential method for discrimination between fault and magnetizing inrush current in transformers,” *IEEE Trans.*

Power Del., vol. 3, no. 3, pp. 1109–1117, Jul. 1997.

[8] P. Bastard, M. Meunier, and H. Regal, "Neural network-based algorithm for power transformer differential relays," *Proc. Inst. Elect. Eng. C*, vol. 142, no. 4, pp. 386–392, 1995.

[9] M. C. Shin, C. W. Park, and J. H. Kim, "Fuzzy logic-based for large power transformer protection," *IEEE Trans. Power Del.*, vol. 18, no. 3, pp. 718–724, Jul. 2003.

[10] A. T. Johns and S. K. Salman, *Digital Protection for Power Systems*. Stevenage, U.K.: Peregrinus, 1995.

[11] S. Emmanouil, M. H. J. Bollen, and I. Y. H. Gu, "Expert system for classification and analysis of power system events," *IEEE Trans. Power Del.*, vol. 17, no. 2, pp. 423–428, Apr. 2002.

[12] W. A. Elmore, C. A. Kramer, and S. E. Zocholl, "Effects of waveform distortion on protective relays," *IEEE Trans. Ind. Appl.*, vol. 29, no. 2, pp. 404–411, Mar./Apr. 1993.

[13] J. F. Witte, F. P. Decesaro, and S. R. Mendis, "Damaging long-term over voltages on industrial capacitor banks due to transformer energization inrush currents," *IEEE Trans. Ind. Appl.*, vol. 30, no. 4, pp. 1107–1115, Jul./Aug. 1994.

[14] R. Rudenberg, *Transient Performance of Electric Power System*. Cambridge, MA: MIT Press, 1965.

[15] Improved Overcurrent Protection Using Symmetrical Components Saeed Lotfi-fard, *Student Member, IEEE*, Jawad Faiz, *Senior Member, IEEE*, and Reza Iravani, *Fellow, IEEE*

[16] Overcurrent Protection Solution based on symmetrical component Method; *Mr. K. K. Rajput, Mrs. K. D. Thakur Mrs. C. H. Chavan, Journal of Information ,knowledge and research in electronics and communication engineering, ISSN 0975-6779,Nov 10 to Oct 11 ,Vol-01,issue-02*