

Symmetrical Components in Analysis of Switching Event and Fault Condition for Overcurrent Protection in Electrical Machines

Dhanashree Kotkar¹, N. B. Wagh²

¹ M.Tech.Research Scholar, PEPS, SDCOE, Wardha(M.S.),India

²Associate Prof. Elect. Deptt.,DESCOET, Dhamangaon(M.S.),India

Abstract: The transient current is quite common in power system. It can be represented for fault as well as switching events. The overcurrent is for very short duration of time caused by switching events, which does not cause any damage to the system. But due to negligence of the fault or switching event the system gets disturbed, due to the tripping of overcurrent relays. In this paper, a condition of overcurrent protection using concept of symmetrical components for the power equipments such as transformer energizing, induction motor switching etc. is presented. In this approach first, the concept of symmetrical components is reviewed and secondly analyzed of how the concept of symmetrical component can be used to improve the scheme. The proposed algorithm and criterion function is shown for fault condition and switching events by using MATLAB software.

Keywords: Switching event, fault, overcurrent, symmetrical components, transformer energizing, I.M. switching, relay

I. INTRODUCTION

The increasing rate of deregulation in the power system leads to the power quality issues. Due to overcurrent, the system gets disturbed, and un-necessarily system trips; it may be a loss to the system. To analyze the condition of fault or/and switching so that the system will not be disturbed, the concept of symmetrical components is introduced in this paper. Due to the inrush current in motor, the efficiency of motor will be less hence speeds as an output will be very less. It may cause the heating of motor and rotor losses. Also in case of transformer due to the inrush current the even and odd harmonics are produced and results as an undesirable output. Hence to overcome all these adverse effects in case of transformer or motors the analysis is presented with the help of review by using symmetrical components and the algorithm is proposed.

This paper reviews the concept of symmetrical components and a method for preventing the undesirable relay operations due to over currents following a switching. In this method, a criterion function versus these components is introduced. The proper performance of this function can be studied by simulation of various faults and switching cases (motor starting and transformer energizing) using MATLAB software. Since the basis of the recommended algorithm is the data obtained from the sampled current, which is taken normally from the over current relays, it prevents the undesirable relay operations with no extra hardware cost needed[1].

II. METHODOLOGY

The first methodology reviews, for any unbalanced or asymmetrical network, such as asymmetrical 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].

Symmetrical components are commonly used for three phase electrical power systems analysis [3]. If the phase quantities are expressed in phasor notation using complex numbers, a vector can be formed for the three phase quantities. For example, a vector for three phase voltages can be written as follows:

$$V_{abc} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

1)

Therefore, the three symmetrical components phasors arranged into a vector are as follows:

$$V_{012} = \begin{bmatrix} V_0 \\ V_1 \\ V_2 \end{bmatrix}$$

2)

where the subscripts 0, 1, and 2 in (2) respectively refer to the zero, positive, and negative sequence components. A phase rotation operator 'a' is defined in (3) to rotate a phasor vector forward by 120 degrees. Matrix A can be defined using this operator to transform the phase vector into symmetrical components:

$$A = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}$$

3)

The phase voltages are generated by the sequence equation.

$$V_{abc} = AV_{012}$$

4)

Conversely, the sequence components are generated from the analysis equations.

$$V_{012} = A^{-1}V_{abc}$$

5)

Where:

$$A^{-1} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}$$

6)

When transformer is switched, inrush current will happen. This current have some features, which it is enough for identify itself. In this paper, with extract these features, a new criterion is proposed to discriminate inrush currents from internal faults in power transformers. The point is the value of negative sequence is different from positive sequence in faulty conditions. Helping this rule, the criterion is introduced. Every voltage and current can be written as follows:

$$\begin{bmatrix} I_0 \\ I_1 \\ I_2 \end{bmatrix} = \frac{1}{3} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}$$

7)

$$\alpha = \alpha \angle 120^\circ \Rightarrow I_a = 1 \angle 0^\circ, I_b = 1 \angle +120^\circ, I_c = 1 \angle -120^\circ$$

8)

In faulty condition, it is obvious that the value of I_2 (negative current) is larger than I_1 (positive current) in normal condition. Using this feature, define new below criterion:

$$\text{Criterion} = \frac{I_1^2 - I_2^2}{I_1^2 + I_2^2}$$

9)

This criterion has some advantages from other criterion, for example defined criterion works properly in over-flux condition or in CT saturation due to inrush or internal fault condition but introduced criterion cannot. In phase to ground fault, have: Where Z_f is impedance between phase and ground, Z_0 is zero sequence impedance, Z_1 is positive sequence impedance and Z_2 is negative sequence impedance. In phase to phase to ground fault have:

$$I_2 = I_1 = \frac{v_f}{Z_0 + Z_1 + Z_2 + 3Z_f}$$

10)

Where Z_f is impedance between phase and ground, Z_0 is zero sequence impedance, Z_1 is positive sequence impedance and Z_2 is negative sequence impedance. In phase to phase to ground fault have:

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

11)

Replacement (10) to (9), threshold of phase to ground fault, the criterion will be almost zero, and for the threshold of phase to phase to ground have:

$$\text{Criterion}_{\text{threshold}} = \frac{2Z_2(Z_2 + 3Z_f)}{(Z_0 + Z_2 + 3Z_f)^2 + (Z_0 + 3Z_f)^2}$$

12)

From both the method which is stated above, the second methodology is much better compare to the first.

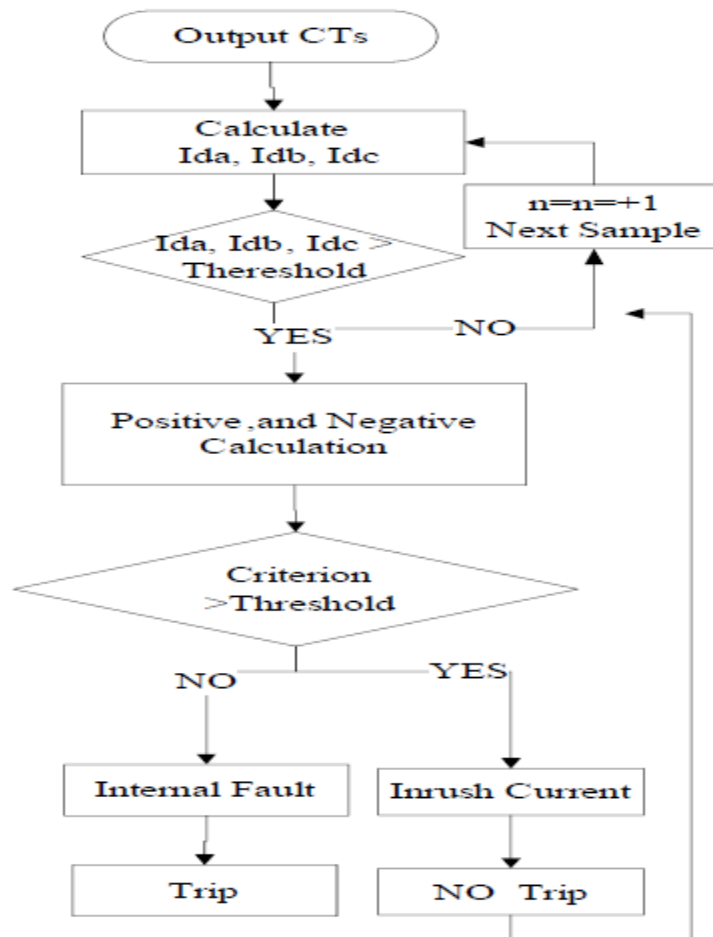


Fig.1. Proposed Algorithm Flowchart

III. EFFECT OF SWITCHING ON RELAY

Due to the fault, the harmonics produced in the system as well as due to the non-fault condition which distort the current waveform is stated [1] as follows:

1] Transformer Energizing:

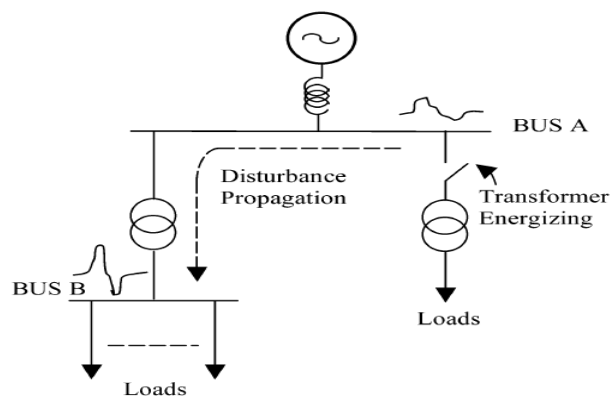


Fig.2. Disturbance propagation due to transformer energizing

When the primary winding of an unloaded transformer is switched on to normal voltage supply, it acts as a nonlinear inductor. In this situation there is a transient inrush current that is required to establish the

magnetic field of the transformer. The magnitude of this current depends on the applied voltage magnitude at the instant of switching, supply impedance, transformer size and design. Residual flux in the core can aggravate the condition. The initial inrush current could reach values several times full load current and will decay with time until a normal exciting current value is reached. The decay of the inrush current may vary from as short as 20 cycles to as long as minutes for highly inductive circuits. The inrush current contains both odd and even order harmonics.

Although digital relay's filter is used to extract the fundamental component of the current, the magnitude of the signal may lead to undesirable operation of the relay. Another concern about transformer energizing is transient propagation. This causes considerable amount of even harmonics and dc component in the voltage. These disturbances may propagate through transformers to the rest of the system, and be magnified due to resonance effect. Because of this, the load currents at other bus bars can be severely distorted, which might have detrimental impact on the locally installed current relays. Fig. 2 shows this propagation trend. The current through the load feeder at busbar B can be affected by the disturbance propagated from transformer energizing at busbar A.

2. Motor switching:

Starting the medium voltage (MV) and low voltage (LV) induction motors is another subject to be considered. The starting current of a large induction motor is typically five to six times the rated current. In fact, the starting current has a very high initial peak. That value is damped out after a few cycles, normally no more than two cycles depending on the circuit time-constant. Then, it drops rapidly to a multiple value of its nominal level, and is maintained during most of the acceleration process. The current is then smoothly reduced to the nominal value that depends on the mechanical load of the motor. This trend that corresponds to the direct starting of a three-phase motor connected to the supply at the worst switching angle.

IV. WORKING AND OPERATION OF OVERCURRENT RELAY

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. For the protection of motors, these relays are used to prevent the unbalanced operation of the motors [4]. The characteristic of inverse time overcurrent relays (excluding induction type) is depicted by the following expression:

$$T = \frac{C}{\left(\frac{I}{I_s}\right)^{\alpha-1}} \quad (13)$$

T - The relay operation time;

C - Constant for relay characteristic;

I_s -Current setting threshold;

I - Current detected by relay

α - Constant representing inverse-time type $\alpha > 0$

By assigning different values to α and C , different types of inverse characteristics are obtained.

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 (13) as follows:

$$f(t) = \left(\frac{I(t)}{I_s}\right)^{\alpha} - 1 \quad (14)$$

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

$$\int_{t_1}^{t_1+T} f(t) dt \geq C, t \in [t_1, t_1 + T] \quad (15)$$

If $f(t)$ waveform fluctuates, it is possible to adjust C and I_s to find one interval during which (10) holds and command is issued. 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. The suggested algorithm concentrates on the relays with inverse-time characteristic.

V. RESULT OF SWITCHING EVENT AND FAULT CONDITION

The review of result is presented by simulink using Software PSCAD/MATLAB.

1) For Normal Condition:

In this case the differential current is near to zero, shown in fig.3. Showing the three sequences and the calculated criterion function value as obtained by equation (12) which is further shown in fig.4

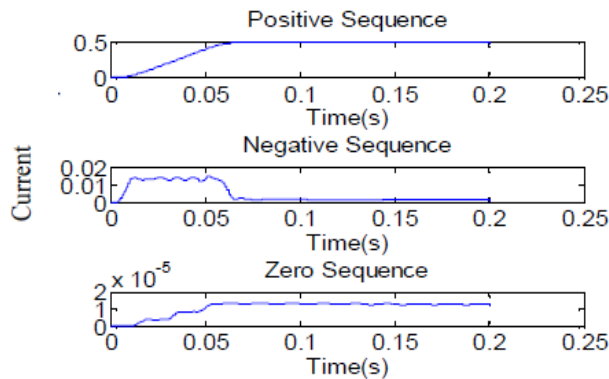


Fig.3. Sequence current in normal condition

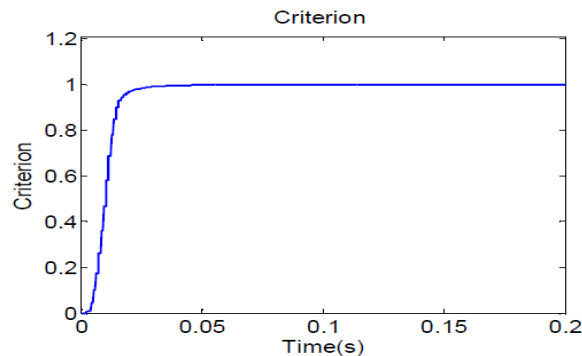


Fig.4. Criterion characteristics in normal condition

2) Inrush Current:

During switching action the inrush current is produced and is shown in fig.5 and the criterion function value which is calculated by using equation (12) is shown in fig. 6.

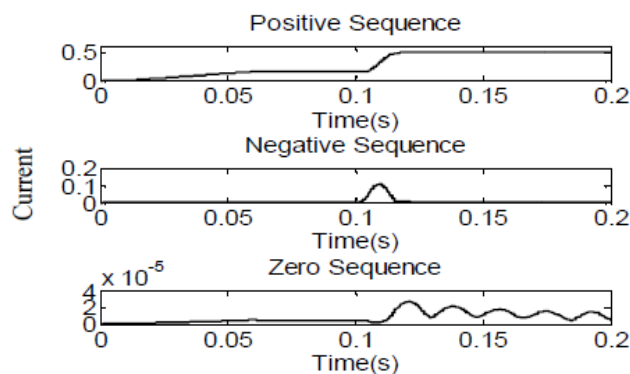


Fig.5. Sequence currents in inrush condition.

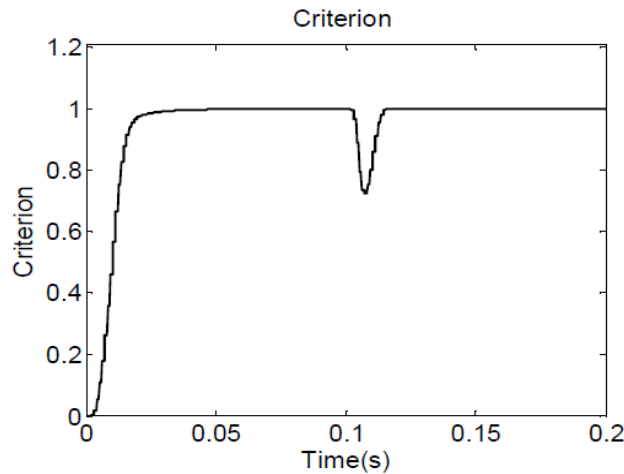


Fig.6. Criterion value in inrush condition

3) Internal Fault Condition:

The value of difference current is selected as 1.5 by criterion function. If it is less as compared to this value then the condition is of internal fault as shown in fig. 7 and fig. 8.

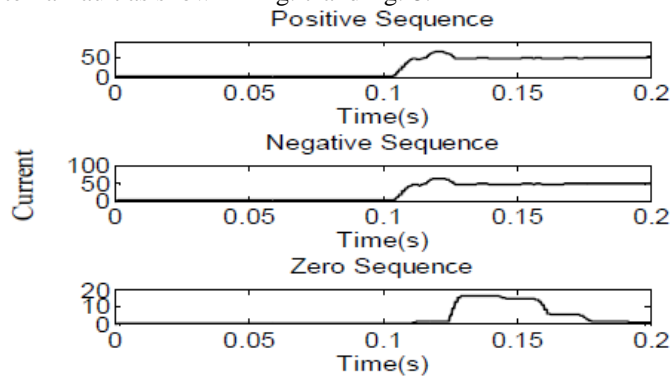


Fig. 7. Sequence current for internal fault

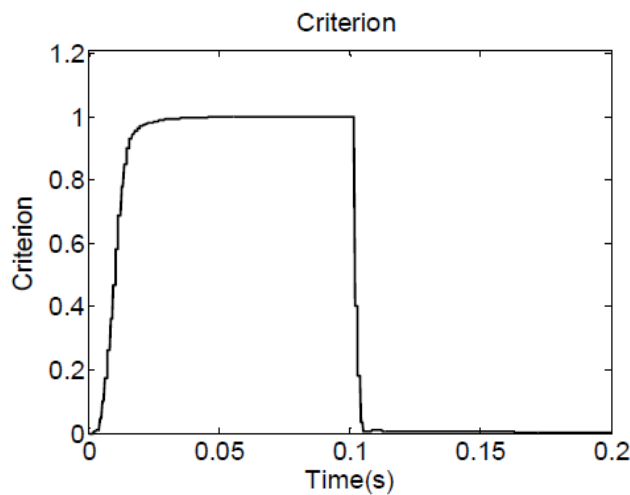


Fig.8. Criterion value for internal fault

4) External Fault Condition:

The external fault with CT saturation condition currents are not in common formation, so rms value of these changes is shown in fig. 9.

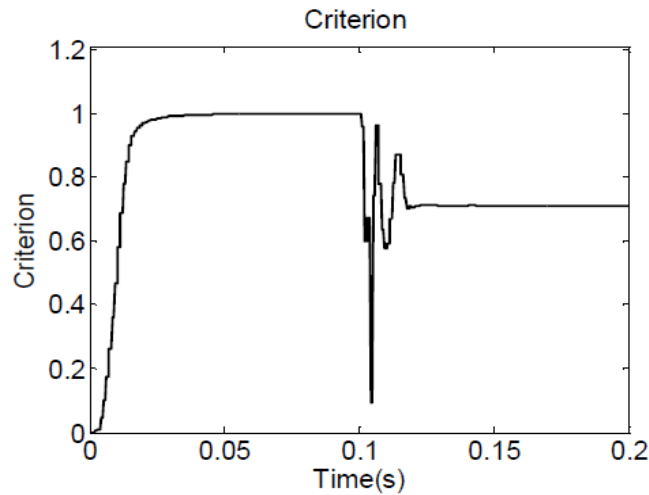


Fig. 9. Criterion value for external fault with CT saturation

5) Over-flux Condition:

In this case, the criterion value is over 0.15 hence it is the condition of over-flux. Fig 10. shows the sequence of current i.e. positive, negative and zero sequence and fig. 11. shows the characteristics by criterion function.

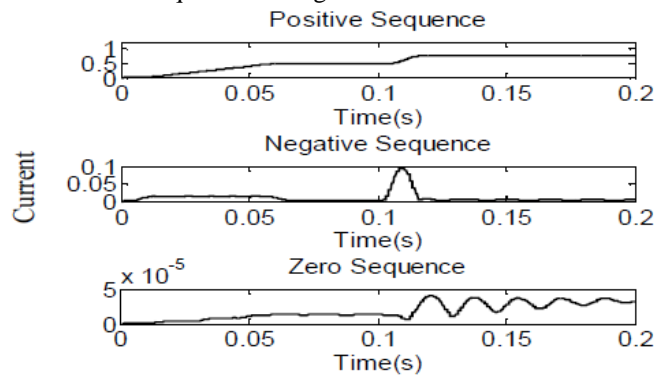


Fig. 10. Sequence currents for over-flux condition.

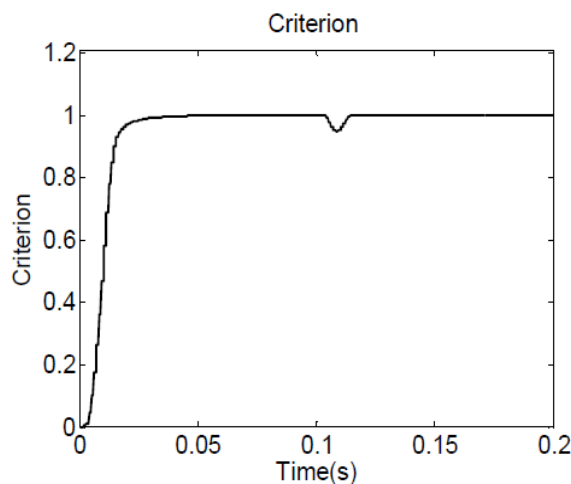


Fig.11. Criterion value for over-flux condition

From the above result the idea of switching events and the different fault conditions can be studied [3], so as to avoid any disturbance in the power system.

VI. CONCLUSION

In this paper the techniques of analyzing the switching event/action and fault condition the exact condition of either fault or switching are presented by finding the value of Idiff using criterion function for designing the algorithm which will further be used to design the model of Improved Overcurrent protection using symmetrical components in MATLAB/simulink for desired result.

REFERENCES

- [1] Saeed Lotfi-fard, Jawad Faiz, Reza Iravani, "Improved Overcurrent Protection Using Symmetrical Components", IEEE Transaction On Power Delivery, Vol. 22. No. 2 April 2007.
- [2] R. V. Katre, D. S. Chavan, S. S. Sardey, "Discrimination Of Fault From Non-Fault Event In Transformer Using Concept Of Symmetrical Components", International Journal of Computational Engineering Research, Vol. 3. Issue 3,2013.
- [3] H. Abniki, A. Majzooobi, H. Monsef, et. al., "Identifying Inrush Currents from Internal Faults Using Symmetrical Components in Power Transformers" Modern Electric Power System 2010.
- [4] Suchita Sardey, K. D. Thakur, Sunil Sardey, "Concept of Symmetrical Component As A Technique For Analysis Of Fault And Improvement Of Overcurrent Protection Scheme" International Journal Of Electrical And Electronics Engineering, Vol.-I, Issue-II, 2011.