Adaptive Overcurrent Relay using Fundamental Component and Cosine Adaptive Filter

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***Abstract*- This paper presents a new logic of operation for time overcurrent relays. With the application of the proposed technique, the sensitivity of time overcurrent relays is increased. In this paper, we have proposed a new relay algorithm using fundamental component where the trip time of relay is not set using only the initial current, rather it is updated using the current as the fault progresses. The value of fundamental component used for the algorithm is calculated by using a Cosine adaptive filter using both the possessing both the peak as well as cosine filter characteristics which has improved the performance even in case of high saturation.**

***Index terms*: Adaptive Overcurrent Relay, CT saturation, Cosine adaptive filter, Fundamental Component.** .

I. INTRODUCTION

The most commonly used relays in power system is overcurrent type. They could be classified by operating quantities including individual phase, residual and negative-sequence current. They are used for both primary and back-up protective relays and are applied in every protective zone in the system. The application of time overcurrent relays in power system presents serious limitations in terms of sensitivity and selectivity. Therefore in many situations it is supplemented by directional relaying. Digital form of such relays are being mostly used which has advantages of data recording and adaptive features etc [1]-[3].

At present, distribution system protection schemes have some form of adaptive capabilities. These adaptive capabilities are initiated by pre-planned human intervention. Switching of low-current instantaneous (LCI) relays and disabling of the automatic reclosing sequence during live line maintenance, periodic modification of relay settings and characteristics when new loads are added, and disabling of reclosing relays and reclosers when circuits are restored following extended outages are some examples of existing adaptive practices in distribution systems.

An adaptive algorithm has been suggested at a substation level in which the relay settings could be modified from a central computer in the substation. Updating adjustments of relays through communication channels using online algorithms has also been proposed .In isolated or highly connected networks in which it is not cost-effective to implement an adequate communication strategy, it is possible to carry out an automatic setup relay using local current [3].

II. PRINCIPLE OF DIGITAL OVERCURRENT RELAY AND COSINE ADAPTIVE FILTER

The functional diagram of time overcurrent adaptive relay is shown in Fig. 1. The digital filter receives the digitalized samples of the input signal, and delivers the phasor module of the current fundamental component at its output. The pickup current controller determines the pickup condition of the time element; the main function of the pickup current controller is to detect a fault. The pickup current that is calculated is variable in function of the load current and restricted by the maximum value defined by the user. The signal is formed at the output; if a fault has been detected , the pickup condition is fixed and the integration process starts on behalf of the time element. The signal is a blocking order that blocks the relay operation.

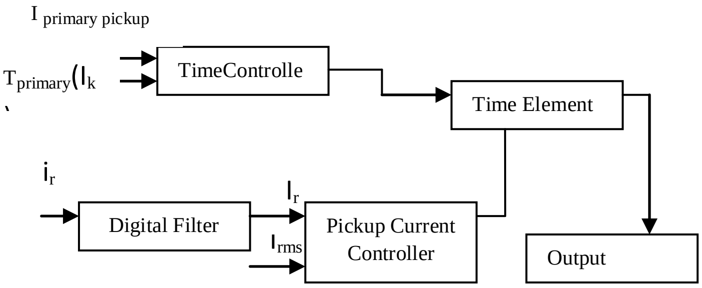

Fig.1 Functional diagram of adaptive digital relay

The Cosine filter has an excellent performance with respect to dc offset and removal of harmonics. The bipolar peak detector has the best magnitude acquisition in situations of extreme CT saturation. Combining of the two filters

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provides an efficient solution for the ideal instantaneous element. This instantaneous element shown in Figure 2 is called a Cosine-Peak Adaptive filter since it incorporates both filters. The Cosine filter supplies the magnitude for normal sine wave operation. The bipolar peak detector provides magnitude for saturated waveforms. A detector measures the degree of saturation by evaluating the level of distortion and switches the input to the bipolar peak detector when the distortion reaches a predetermined value. When the distortion exceeds the threshold value, the waveform magnitude measurement is taken from bipolar peak detector output. When the distortion is less than the threshold value, the waveform magnitude is taken from the Cosine filter output.

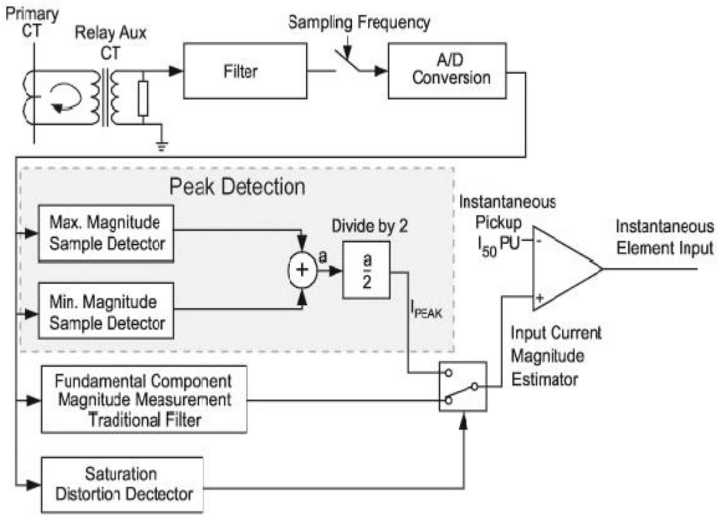

Fig. 2 Instantaneous Element Using the Cosine-Peak Adaptive Filter

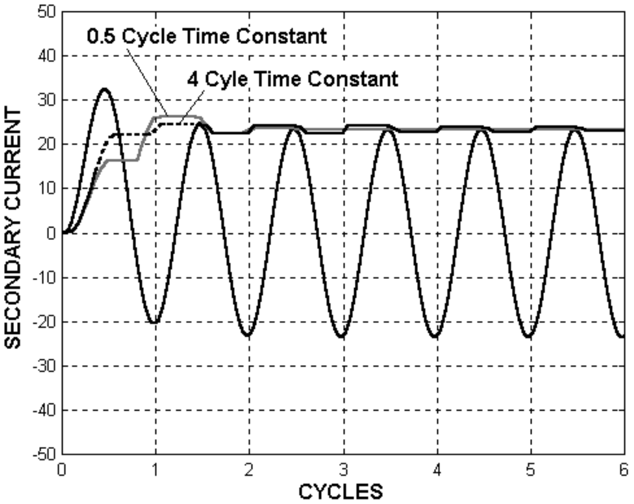

Fig. 3 Bipolar Peak Detector Transient Overreach

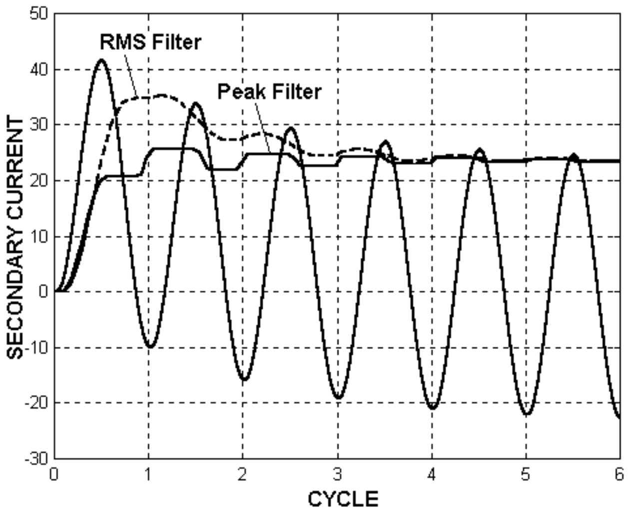

Fig.4 RMS Filter Transient Overreach Compared to Bipolar Peak Filter

. The bipolar peak filter computes the waveform peak value as the average of the absolute value of two consecutive positive and negative peaks. The maximum transient overreach of 112 percent occurs with a 1-cycle time constant and decreases as the time constant is increased as shown in Figure 3.

The magnitude of the fundamental in a severely saturated current waveform is a poor representation of the actual fault current. The RMS filter has a fast rising signal but exhibits a prohibitive 150 percent transient overreach because it must respond to dc offset as shown in Figure 4. Of the two filters, the comparison shows that the bipolar peak detector makes the best magnitude acquisition.

III. PROPOSED OVERCURRENT RELAY

There are two available characteristics for overcurrent relays: i) definite-time characteristic and ii) inverse-time characteristic (Fig. 5).

According to IEEE standard (Table 1), the characteristic of inverse time overcurrent relays is depicted by the following expression:

$$T = \frac{C}{\left[\frac{I}{I_s}\right]^a - 1} \qquad (1)$$

where T, the relay operation time;

C, constant for relay characteristic;

I_s , current setting threshold;

I , current detected by relay (normally the effective value) ;

a , constant representing inverse-time type.

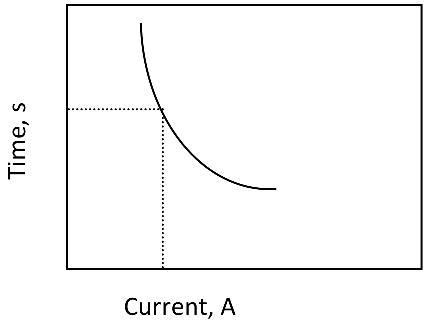

Fig. 5 Typical overcurrent relay characteristic

By assigning different values to a and C, different types of inverse characteristics are obtained (table1). As mentioned, the detected RMS current (I in this case) is implicitly assumed to be constant, which is not true when transients are involved or when during a fault the fault type may change (say, from line-to-ground to double-line-to-ground fault). This will lead to inaccurate decision time by the relay.

Table 1 Different types of relay Characteristic (for 1 multiplier setting)

Type of Relay Characteristic	A		C	
	IEC	IEEE	IEC	IEEE
Standard Inverse(SI)	0.02	0.02	0.14	0.0515
Very Inverse(VI)	1	2	13.5	19.61
Extreme Inverse(EI)	2	2	80	28.2
Long Inverse(LI)	1	--	120	--

Further these days for better selectivity and coordination of the relays fundamental component based overcurrent relays are employed; the positive and negative sequence overcurrent relays [2]. In the proposed algorithm the I and Is are considered to be fundamental current of a phase. To overcome the problem following approach is suggested.

If function f(t) is defined for the denominator of (1) as follows:

$$f(t) = \left[\frac{I}{I_s}\right]^a - 1 \qquad \textbf{(2)}$$

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

$$\int_{t1}^{t1+T} f(t)dt \ge C \qquad \textbf{(3)}$$

If I(t) waveform fluctuates, it is possible to adjust and to find one interval during which (3) holds and trip command is issued. Such algorithm takes into account the current value even though fault progress. It is to be noted that this feature is naturally available in a disc type overcurrent relay.

Even-order harmonics (2nd, 4th , 6th etc) represent higher frequency waveforms of respectively lower current in the neutral conductor. Even-order harmonics usually are not a problem, however, since each return leg is still separated by 120 degrees. Neutral current therefore remains at zero amperes. The situation changes when 3rd-order harmonics are present. Triple n harmonic currents (the 3rd harmonic and odd multiple so the third - 3rd, 9th, 15th etc) are additive in the neutral and can lead to overheating of the neutral conductor. Other odd order harmonics are not as troublesome since portions o f the waveform cancel each other out. When imposed on phase conductors, 3rd order harmonics can lower or raise the effective peak value of the phase current.

For a digital relay having a sampling rate of 32 samples/cycle, I_{rms} can be obtained as

$$I_{rms} = \sqrt{\frac{\sum_{n=1}^{32} I_n^2}{32}} \qquad (4)$$

Operating criteria of RMS based overcurrent relay:

$I_{rms} > I_s$.

Where I_s is max current allowable above which the circuit should be closed.

IV. RESULTS

(I.)

When a fault occurs in a power system the current increases substantially and that moment the CT should provide proportionate current to the relay. In many cases the CT may saturate (as in Fig. 6) at different points in a system and the corresponding decision may be improper or the coordination time may create problem. It is observed from Fig. 6 that the CT performs poorly at initial period. A digital relay taking decision using initial period only will be incorrect in decision or in time to trip.

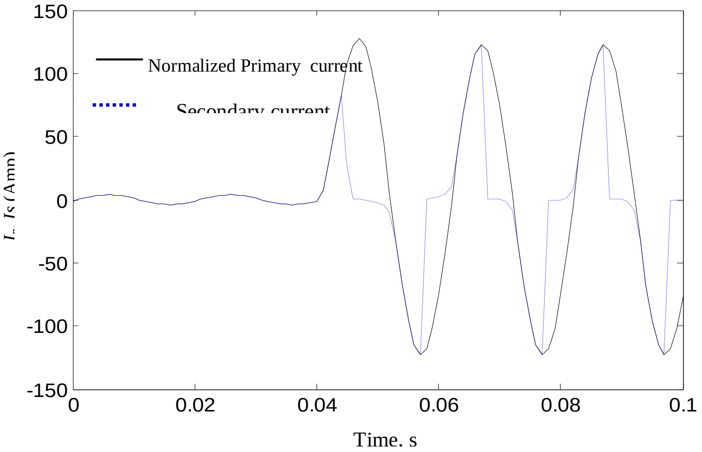

Fig. 6. Current waveforms with CT saturation

However, the fast rising response of the RMS and the peak filter is more representative of the actual magnitude. The responses of the peak, RMS, and Cosine filters are compared in Figure 7. The RMS filter has a fast rising signal but exhibits a prohibitive 150 percent transient overreach because it must respond to dc offset as shown in Figure 4. Of the three filters, the comparison shows that the bipolar peak detector makes the best magnitude acquisition.

The cases shown in Figures 8 to 10 demonstrate the action of the switch. Figure 8 shows a case of low saturation where saturation vaue is low, and the Cosine filter produces the instantaneous trip. Figure 9 shows a case of high saturation where the instantaneous trip is produced by the bipolar peak filter. Figure 10 shows a case with no saturation and the Cosine filter provides the measurement.

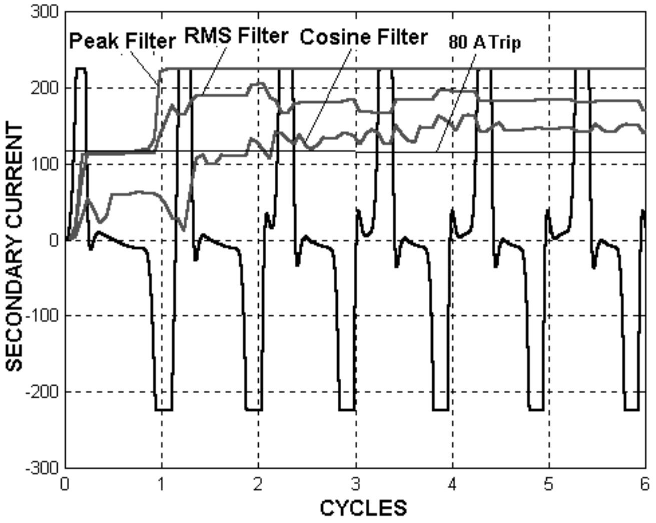

Fig 7 Filter Response, Fault 40 kA, X/R=20, C100, 200:5 CT, 0.5 Ω Burden

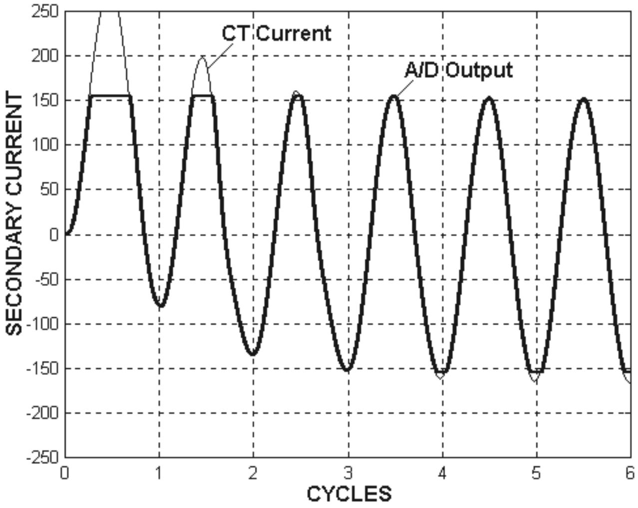

Fig 8 Cosine Filter Providing Trip for a Waveform With Low Saturation C400, 200:5, 4500 A Fault With X/R = 11.31

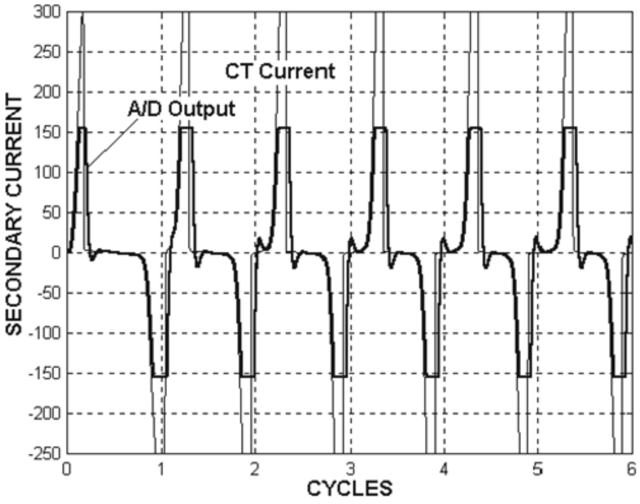

Fig 9 Bipolar Peak Filter Providing Trip for a Waveform Trip With High Saturation
C50, 200:5, 20 kA Fault With X/R = 11.31

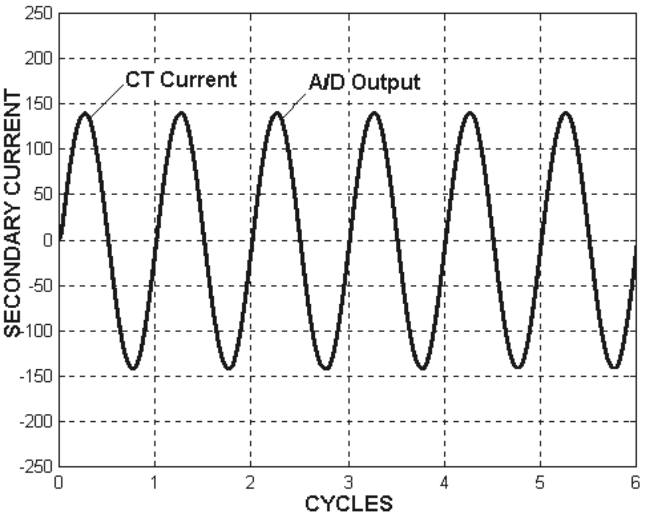

Fig. 10 Cosine Filter Providing Trip for a Waveform With No Saturation C100, 200:5, 4 kA Symmetrical Fault Current

(II.)

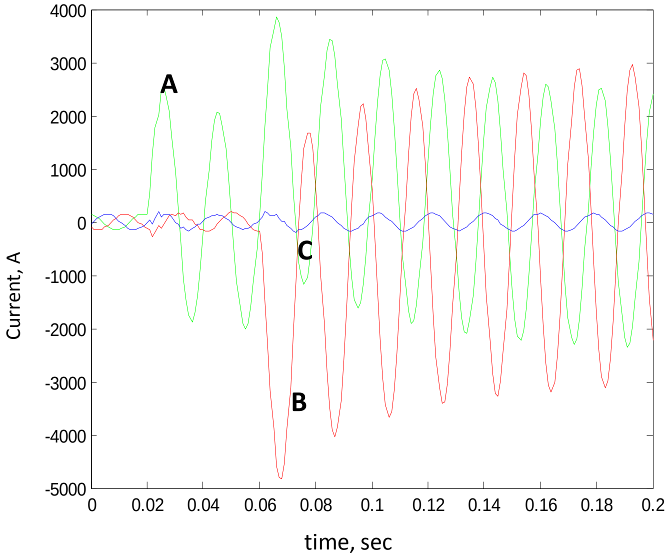

Fig. 11 Current amplitude change during a fault

As an example an overcurrent relay characteristic as of IEEE standard with C=19.6 and a =2 is considered. A typical power system is simulated and a CT of 1000:5 is considered. The secondary current from the CT is processed to compute the RMS/ fundamental component. Fault current of the system at a particular situation is shown in Fig. 3. It is to be noted that in this case the fault starts at 0.02 s as AG fault (single line-to-ground) and subsequently at 0.06 s the fault changes to ABG type (double line-to-ground). I_s= fundamental current setting for the relay =1A (say).

Initial fault current as computed from 1 cycle of fault, I=7.07A (RMS).
If this will be used to find the time of trip,
$\underline{T_{conventional} = 19.6/[(7.07/1)^2-1]= 0.4083 \text{ s.}}$

But in the present situation the fault after two cycles 0.04 sec has changed to ABG fault and current in phase A has substantially increased.

Applying the proposed approach (3), the values obtained are,

$f(t)$= 1 for 0.02<t<0.06 ,
= 3.5 for 0.06<t<T .

Solving (3) with C=19.6, we get, $\underline{T_{new\ method} = 0.1988 \text{ s.}}$

It is to be noted from the two time computed that the time computed through conventional way would have been 0.4083 s as compared to 0.1988 s by the method which provides obvious advantage in protection.

V. CONCLUSION

In this paper, a new method for improving overcurrent relay operations based on fundamental component has been introduced. The tripping time is calculated by using the fault signal upto the time of tripping. It is found through simulation that the approach provides lesser trip time as compared to conventional algorithm which is of importance in protection. The use of cosine adaptive filter has shown satisfactory results in case of low as well as high saturation conditions.

VI. REFERENCES

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VII. BIOGRAPHIES

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