

# INSTANTANEOUS AND DEFINITE TIME OVERCURRENT PROTECTION ALGORITHMS

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**Abstract:** The paper is focused on the instantaneous and definite time overcurrent protection algorithms. Overcurrent protection is one of the most used type of protection function. Algorithms are proposed according to IEC 60255-151. Prediction algorithm, which will be used for instantaneous overcurrent protection, is proposed for determination of the peak value of the signal.

**Keywords:** overcurrent, instantaneous overcurrent algorithm, definite time overcurrent algorithm

## 1. INTRODUCTION

A protection relay is device which is used to isolate a faulty section of the electrical power system after the fault has occurred. This action ensures that non-faulted part of the electrical power system can continue in operation and protects system from further damage.

A well-proposed protection relay must comply with these qualities

- Selectivity
- Speed
- Sensitivity and accuracy
- Dependability

One of the most used type of protection is overcurrent protection. The overcurrent protection relay protects against dynamic and thermal effects of the overcurrent. Its algorithm is not so difficult but it is demanding to speed. Trip signal must be sent as soon as possible, there can not be any delay. A small delay of trip signal can lead to a big disaster.

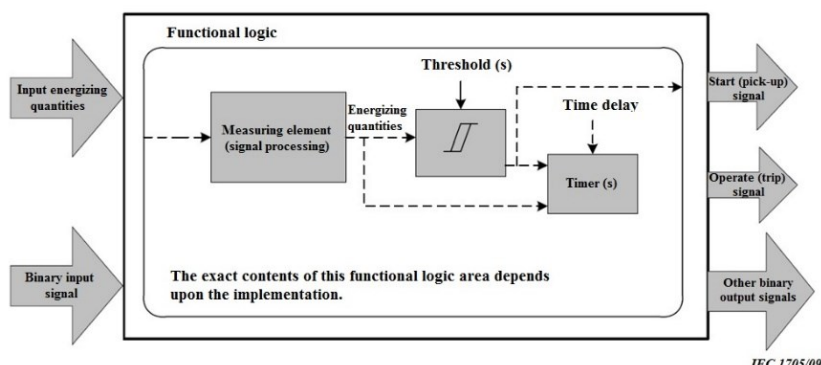
These proposed algorithms will use sampled values. According to IEC 61850-9-2 there are 80 samples per cycle for protection functions. It means that sampling frequency is 4000 Hz.

## 2. OVERCURRENT PROTECTION RELAY

The standard IEC 60255-151 [1] deals with functional requirements for over/under current protection. It specifies minimum requirements for over/under current relays. This standard includes a specification of the protection function, measurement characteristics and time delay characteristics. According to this standard the instantaneous and definite time overcurrent protection algorithms were proposed.

This type of protection is used to protect against over currents. Basic algorithm of overcurrent protection compares the measured value of current with preset value. If the input current exceed preset value, protection algorithm evaluates that overcurrent occurred and send trip signal to the circuit breaker. Circuit breaker opens its contact to disconnect protected equipment and avoid damage.

The protection function with its inputs, outputs, measuring element, time delay characteristics and functional logic is shown in Figure 1 according to IEC 60255-151.



**Figure 1:** Simplified protection function block diagram [1]

## 2.1. INSTANTANEOUS NON-DIRECTIONAL OVERCURRENT RELAY

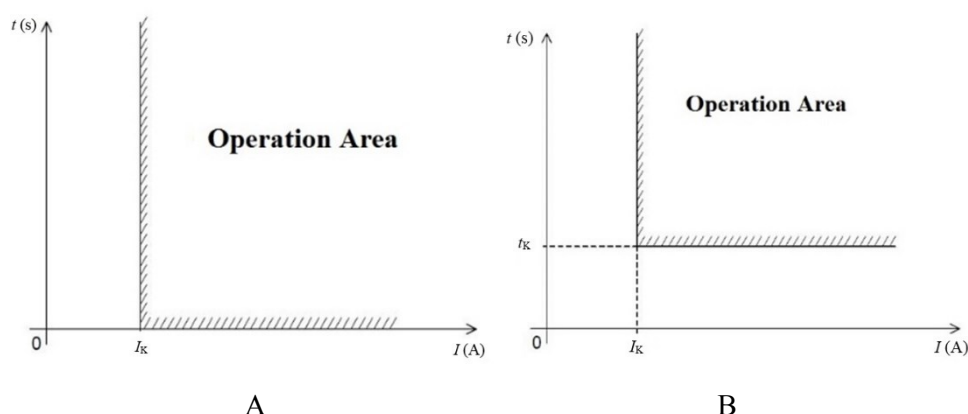
Instantaneous non-directional overcurrent relay sends trip signal immediately to the circuit breaker as soon as the overcurrent has occurred. There is no time delay. Instantaneous overcurrent relays are used close to the source where the fault current level is very high and a small delay in sending trip signal can cause big damage to the protected equipment. Instantaneous characteristic curve is shown in the Figure 2 A.

Instantaneous non-directional overcurrent relay has ANSI code 50 - device number according to ANSI standard. Protection Instantaneous Over Current (PIOC) is logical node according to IEC 61850-7-4. Instantaneous non-directional overcurrent algorithm is used for fast tripping of shorts.

## 2.2. DEFINITE TIME NON-DIRECTIONAL OVERCURRENT RELAY

Definite time non-directional overcurrent relay sends trip signal after a specific time to the circuit breaker. This type of overcurrent relay is usually implemented for backup protection. If the main relay does not operated and send a trip signal then backup overcurrent relay must operate and send trip command to the breaker. Overcurrent relay is time delayed by a specific time which must be greater than the normal operating time of the main relay plus the breaker operating time. Definite time characteristic curve is shown in the Figure 2 B.

Definite time non-directional overcurrent relay has ANSI code 51 - device number according to ANSI standard. Protection Time Overcurrent (PTOC) is logical node according to IEC 61850-7-4. Definite time non-directional overcurrent relay algorithm is used for delayed tripping of overcurrents.



**Figure 2:** A - Instantaneous characteristic curve, B - Definite time characteristic curve [2]

### 3. ALGORITHM OF INSTANTANEOUS NON-DIRECTIONAL OVERCURRENT RELAY

Inputs of algorithm

- Phase current  $i_1, i_2, i_3$  - instantaneous values of current – sampled values

Outputs of algorithm

- Trip signal

Parameters of algorithm

- $I_{\text{PRESET}}$  – preset value of the current

The algorithm works with instantaneous values of the current. It is based on predictive algorithm. This predictive algorithm works with 2 samples which are following each other. It is computed the peak value of the signal. Then the peak value is compared with the preset value. If the predicted peak value of the current is higher than preset value then trip signal will be sent.

#### 3.1. PREDICTION ALGORITHM

Prediction algorithm for instantaneous non-directional overcurrent relay must be fast and it should determine the peak of the signal from 2 samples. There are various techniques useful to calculate the R.M.S peak value of sinusoidal waveform such as: sinusoidal-wave based algorithm, fourier analysis and others. Each of them has its advantages and disadvantages.

The technique of the presented algorithm is based on the the “sample and first” derivative technique first reviewed by Makino and Miki. [3] Prediction algorithm uses samples taken at discrete instant of time form the signal waveforms.

Sampling interval  $\Delta t$  for sine waveform with 50 Hz frequency and sampling rate 80 samples per cycle:

$$\Delta t = \frac{1}{f} \cdot \frac{1}{80} = \frac{1}{50} \cdot \frac{1}{80} = 2,5 \cdot 10^{-4} \text{ ms} = 250 \text{ } \mu\text{s}, \quad (1)$$

where  $f$  is frequency of current.

Let  $i_k, i_{k+1}$  be current samples that are measured at times  $t_k, t_{k+1}$  respectively and let  $\Delta t$  be the sampling interval.

$$i_k = I \cdot \sin(\omega_0 \cdot t_k) \quad (2)$$

$$i_{k+1} = I \cdot \sin(\omega_0 \cdot t_{k+1}) = I \cdot \sin[\omega_0 \cdot (t_k + \Delta t)]$$

$$i_{k+1} = I \cdot \sin(\omega_0 \cdot t_k) \cdot \cos(\omega_0 \cdot \Delta t) + I \cdot \sin(\omega_0 \cdot \Delta t) \cdot \cos(\omega_0 \cdot t_k) \quad (3)$$

where  $\omega_0$  is angular frequency and  $I$  is amplitude of current.

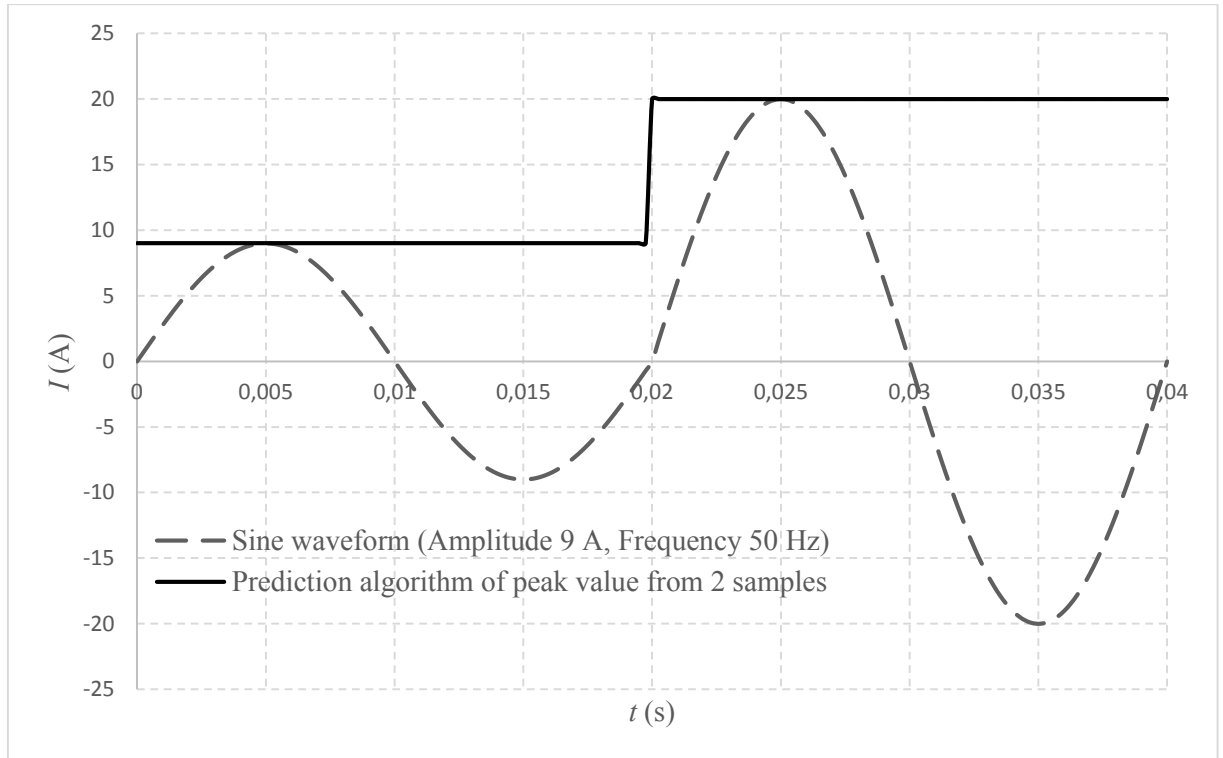
Substituting (2) and (3) and simplifying results in

$$\frac{i_{k+1} - i_k \cdot \cos(\omega_0 \cdot \Delta t)}{\sin(\omega_0 \cdot \Delta t)} = I \cdot \cos(\omega_0 \cdot t_k) \quad (4)$$

Adding the squares of (2) and (4), and noting that  $\sin^2 x + \cos^2 x = 1$ , it is obtained the equation for the square of the peak current.

$$I^2 = \frac{i_k^2 + i_{k+1}^2 - 2 \cdot i_k \cdot i_{k+1} \cdot \cos(\omega_0 \cdot \Delta t)}{[\sin(\omega_0 \cdot \Delta t)]^2} \quad (5)$$

These equations were used to determine the peak of the sine waveform with the frequency of 50 Hz and the amplitude of 9 A which was changed to 20 A after the first period. Algorithm was programmed in LabView. The results of the prediction algorithm were processed in MS Excel and the graph of the function is shown in the Figure 3.



**Figure 3:** Current on time dependence - Results of the prediction algorithm processed in MS Excel

#### 4. ALGORITHM OF DEFINITE NON-DIRECTIONAL OVERCURRENT RELAY

Inputs of algorithm

- Phase current  $I_{ef1}$ ,  $I_{ef2}$ ,  $I_{ef3}$  – Root Mean Square (R.M.S) or Fast Fourier Transform (FFT) – computed of sampled values  $i_1$ ,  $i_2$ ,  $i_3$

Outputs of algorithm

- Trip signal

Parameters of algorithm

- $I_{PRESET}$  – preset value of the current
- $P_{NULL}$  – reset ratio
- $T_{TRIP}$  – operate time
- $T_{NULL}$  – reset time
- $T_{DEACTIVATION}$  – deactivation time of tripping signal
- $S_{r1}$ ,  $S_{r2}$ ,  $S_{r3}$  – start signal
- $T_{i1}$ ,  $T_{i2}$ ,  $T_{i3}$  – integration variable
- $T_{z1}$ ,  $T_{z2}$ ,  $T_{z3}$  – recovery time

The algorithm works with R.M.S values, which are computed of instantaneous values every half-cycle according to equation (6).

$$I_{efX} = \sqrt{\frac{\sum_{i=0}^{N-1} i_X^2}{N}}, \quad (6)$$

where  $I_{efX}$  – R.M.S. value of current in phase  $X$  ( $X = 1, 2, 3$ ),  $N$  – amount of samples (half cycle – 40 samples) and  $i_X$  – instantaneous value of current in phase  $X$  ( $X = 1, 2, 3$ ).

If any of currents –  $I_{ef1}$ ,  $I_{ef2}$ ,  $I_{ef3}$  exceed  $I_{PRESET}$  start signal  $S_{fX}$  ( $X$  means phase in which overcurrent has occurred) is activated. Then variable  $T_{iX}$  ( $X$  means phase in which overcurrent has occurred) starts to integrate. When one of  $T_{i1}$ ,  $T_{i2}$ ,  $T_{i3}$  exceeds operate time  $T_{TRIP}$ , tripping signal is activated. If the current  $I_{efX}$  ( $X$  means phase in which overcurrent has occurred) falls below  $I_{PRESET} \cdot P_{NULL}$ , start signal is deactivated and recovery time  $T_{zX}$  ( $X$  means phase in which overcurrent has occurred) starts to integrate. If recovery time  $T_{zX}$  ( $X$  means phase in which overcurrent has occurred) exceeds reset time  $T_{NULL}$ , integration variable  $T_{iX}$  ( $X$  means phase in which overcurrent has occurred) is reset.

## 5. CONCLUSION

In this paper the algorithm for instantaneous and definite time overcurrent were proposed. For instantaneous overcurrent algorithm was proposed also prediction algorithm for determination of the peak value of the signal, which has been programmed in LabView. The results show that it is useful and it should be implemented in protection algorithm.

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