

Overcurrent Protection with DSP based Numerical Relay

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ABSTRACT

The primary purpose of a power system is to ensure uninterrupted power supply despite various faults such as overcurrent, ground fault, phase faults etc. Thus, various protective devices are used to protect the power system, of which digital signal processor (DSP) numerical relays are capable of significantly improve protection operations. These relays are able to perform complex processing faster and with higher accuracy because the DSP is optimized for real-time signal processing. Various DSP techniques such as Fast Fourier Transform (FFT), Discrete Fourier Transform (DFT) and Wavelet Transform along with Artificial Neural Networks (ANN) can be used to detect spurious signals and disturbances. This article focuses on the implementation of an overcurrent relay with inverse defined minimum time (IDMT) characteristics. The proposed relay model can be implemented in MATLAB/Simulink or using C code as discussed here.

Keyword: - Numerical Relay, DSP, IDMT, Overcurrent Protection

1. INTRODUCTION

The main purpose of a power system is to generate, transmit and distribute electrical energy to customers in the most cost-effective and reliable manner without interruption. Power systems suffer from many disturbances such as phase disturbances and ground faults [1]. Most of these faults lead to a sudden increase in current. Therefore, overcurrent protection is essential to minimize failures caused by system faults and ensure continuous power supply.

Therefore, it is common to connect key elements of the power system such as generators, power transformers, and transmission lines using protective devices such as fuses, switchboards, circuit breakers, and relay types [2].

Overcurrent relays used for short-circuit protection monitor the current and activate when the current exceeds a predetermined value. Standard inverting minimum definite time (IDMT) overcurrent relays include standard inverse (SI), very inverse (VI), extra inverse (EI) and definite time (DT).

A very important aspect of relay performance is that it must be able to detect all fault conditions, but not trip due to spurious signals generated during power system transients. The DSP-based numerical relays described in this white paper are better able to detect these conditions due to their increased fault current waveform processing capabilities compared to electromechanical and solid-state relays.

1.1 Concept of Numerical Relay

Because of their improved ability to handle current waveforms, numerical relays can minimise incorrect tripping. They use DSP cards, which include devoted microprocessors designed specifically to handle digital signals. It makes use of the concept of "Open System Relaying," where different relay functions may be obtained from fixed fixtures by adjusting an internal computer circuit register. Across the various types of relays, it also reduces capital expenditures and support expenses. Based on their intended purposes, numerical relays are broadly categorised into four different types: overcurrent relays, distance relays, directional relays, and differential relays [3].

A minimal collection of fitted modules and novel digital and mathematical relay functions make up the generalised mathematical relay. It is demonstrated how to draw a statement's mathematical relay form.

1. Isolation and scaling of analogue signals: Instrument transformer current and voltage waveforms are captured and scaled to useful voltage levels for use in the numerical relays.
2. Low-pass filters are employed to prevent the effects of analogue anti-aliasing filtering.
3. Analog-to-digital conversion: As digital processors can only handle logical or numerical data, the waveforms of inputs must be sampled at discrete times. As a result, a multiplexer sends each analogue signal, one at a time, to an Analog-to-Digital Converter (ADC), after it has passed through a sample-and-hold module.
4. The amplitude and phase of the waveforms sent to the relay are estimated using a software algorithm that is implemented in a microprocessor.

The equations unique to the protection method and the related trip logic for the relay algorithm

5. Relay algorithm and associated trip logic: The software of the processor utilised in the relay implements the protection algorithm-specific equations. It determines the phasors that represent the inputs, obtains the switch state, performs calculations for the protective relays, and then generates outputs for operating the circuit breakers. In addition, the CPU might help with duties like target display, time clocks, self-testing, and communications.

Many functions, including as self-checking capabilities, numerous protection characteristics, adaptive protection characteristics, instrumentation, remote communication, motor protection, data storage, and others, are available on numerical relays [1]. It is superior to other relays in a variety of ways, including size, cost, speed, and the amount of protection components.

Yet by integrating a variety of characteristics into a single Nevertheless, numerical relay focuses on the concerns of availability and reliability by condensing several capabilities into a single piece of hardware. Compared to applications where various functions are implemented by independent hardware components, a numerical relay failure may result in the loss of a great deal more functionalities. Also, it needs a constant power supply. The cost of a numerical relay is compared to electromechanical and static relays in Figure 2 [1].

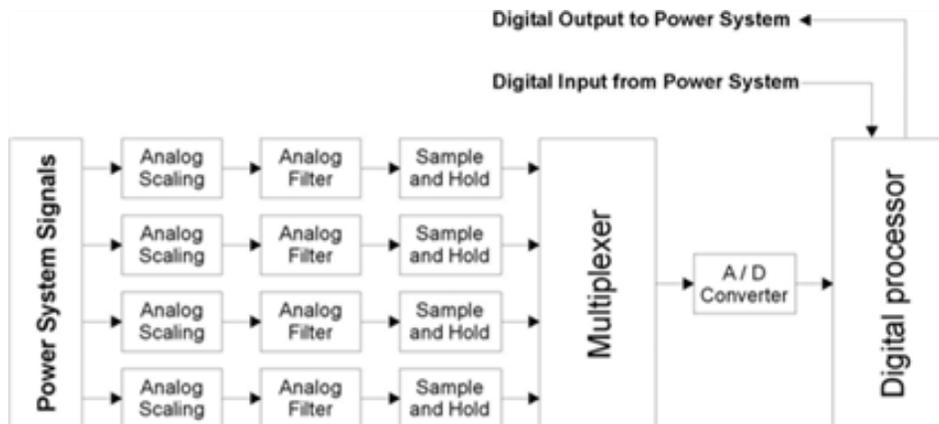


Fig-1 Numerical Relay Structure

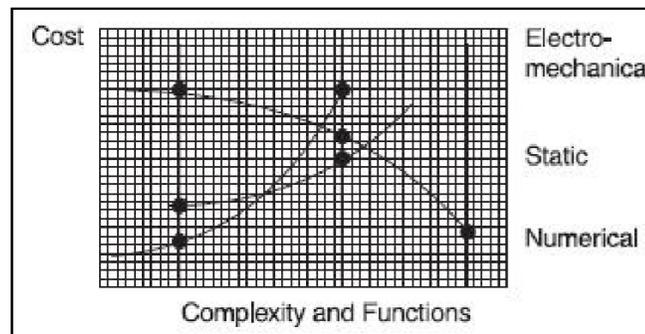


Fig-2 Cost comparison of Relays

1.2 Characteristics & Implementation

The ANSI overcurrent relay device number is 50 for instantaneous overcurrent (IOC), 51 for time overcurrent (TOC). In a typical application, an overcurrent relay is connected to a current transformer and calibrated to operate at or above a specific current level.

The principle of operation is based on the time of operation of the relay and the preset value of the current. If a fault occurs, the calculated rms value of the current exceeds the set value, and then the relay calculates the tripping (operating) time using the characteristics of the tripping time against the current.

The operating time of the relay for a specific setting and the magnitude of the action variable can be determined from the relay characteristic. Overcurrent relays are also equipped with elements with independent or definite time characteristics. These characteristics provide a ready means of coordinating several relays in series in situations where the system fault current varies greatly due to changes in source impedance, since there is no change in time with the change in fault current.

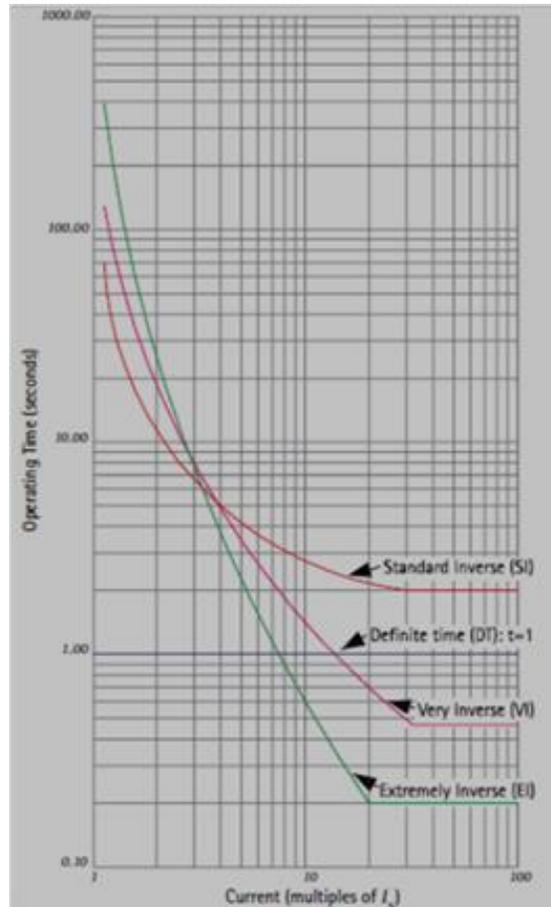


Fig- 3 IEC Characteristic

The reverse curve is the curve in which the excitation time shortens as the excitation value increases. However, as the excitation value increases, the time becomes constant. A well-defined time curve is a time curve where the operating time is slightly affected by the magnitude of the operating flow. However, conventional relays also have slightly opposite characteristics. Inverse properties with well-defined minimum times are also called IDMT properties [6].

It can be done by calculating the root mean square or RMS value of the input current. The RMS value is then compared to the setpoint, the characteristic is detected based on the timer value, and the relay trip logic is activated. A comparison of the operating time and the timer value determines the characteristics of the relay. The whole process can be represented in the form of a flow chart as shown in Figure 4 [7], [8].

2. DSP APPROACH TO IMPLEMENTATION

Digital signal processing is the mathematical manipulation of information signals to modify or improve them in some way. It is characterized by the representation of discrete time or discrete frequency signals or other discrete amplitude signals by idmt features.

Digital signals are usually studied in the time domain (one-dimensional signals), the spatial domain (multidimensional signals) and the frequency domain. Domains for signal processing are chosen by trying different possibilities. A set of samples from a measuring device produces a time or space domain representation, while the discrete Fourier transform of the frequency domain information produces the frequency spectrum.

DSP techniques include techniques such as Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Short Time Fourier Transform (STFT), Wavelet Transform, Discrete Wavelet Transform (DWT) and Artificial Neural Networks (ANN).

A DSP (Digital Signal Processor) is a special microprocessor designed for common mathematical operations to manipulate digitally measured data. DSPs can process data at high speed and generate output data in real time. Additional hardware units built into the processor speed up mathematical operations.

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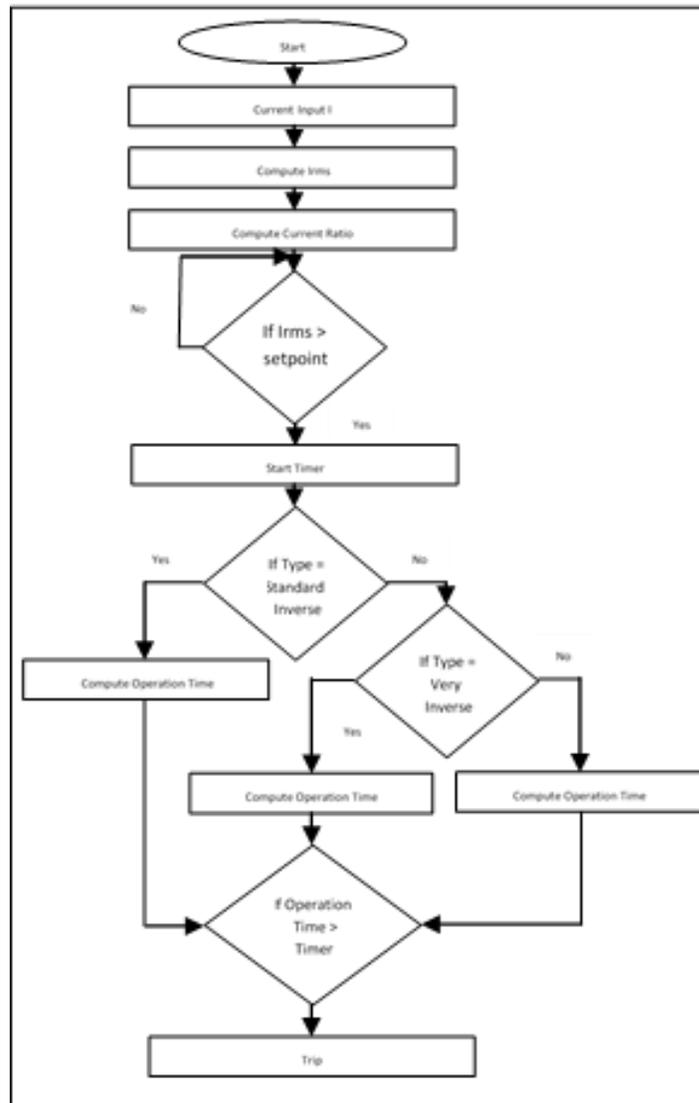


Fig-4 System Flow Chart

3. SYSTEM IMPLEMENTATION

Two methods can be used for proposed implementation on DSP. For the first method, the overcurrent relay simulation model from MATLAB/Simulink is directly downloaded into the DSP while, for the second method, C-Language codes are written for the relay in the DSP. These codes are then compiled, linked, downloaded and executed on DSP. The results from the execution are viewed from Code Composer Studio (CCS). CCS provides a single user interface where the contents of the memory saved in the DSP can be viewed.

The MATLAB/Simulink model of numerical relay for overcurrent protection is shown in Figure 5 [8], [9]. The overcurrent relay of IDMT type can be used for the same. In the simulation model shown here, the input currents of sine waveform with frequency of 50Hz can be generated. The inputs are then quantized in order to process them digitally. The input currents will be sampled at higher sampling frequency. The sampling frequency must be at least twice of the fundamental frequency. This is to ensure that the Nyquist criterion is fulfilled so that the aliasing of the input signals is avoided

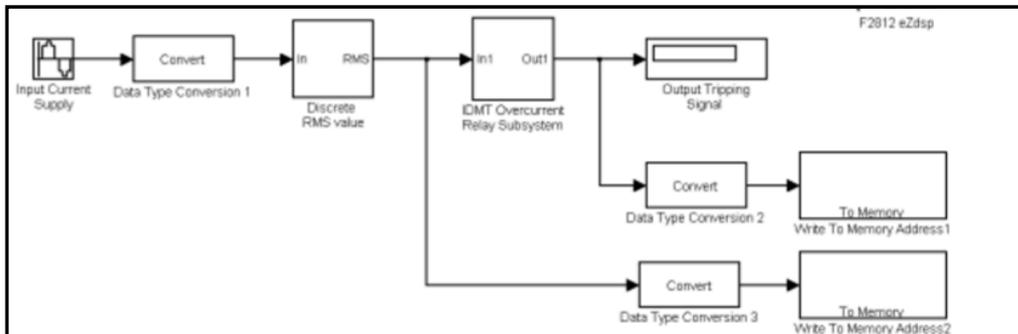


Fig-5 Simulink model of Overcurrent Relay

These samples are then used to calculate the root mean square (RMS) value of the input current. The RMS calculation is necessary to extract the fundamental component of the input current samples. These calculated effective currents are then supplied to the overcurrent relay. The effective values are then compared with the desired value to obtain the current ratio [7], [8].

The protection algorithm built into the protection will start the process of determining the operation time of the protection [9]. The algorithm is based on the IEC standard, which includes different types of inverse characteristics of IDMT relays. The algorithm requires the current setpoint, TMS and inverse characteristic type to determine the run time. The output trip signal is generated if the effective input current exceeds the set value or in other words when the current ratio is greater than 1. The overcurrent relay trips after the intended operating time which is calculated from the protection algorithm [9].

The proposed block diagram of the system is shown in Figure 6 [7], [8]. Relays modeled in MATLAB/Simulink can be directly downloaded into the target support package. Any DSP or rms calculation technique can be used to distinguish between transients and overcurrent surges well. C code written can implement

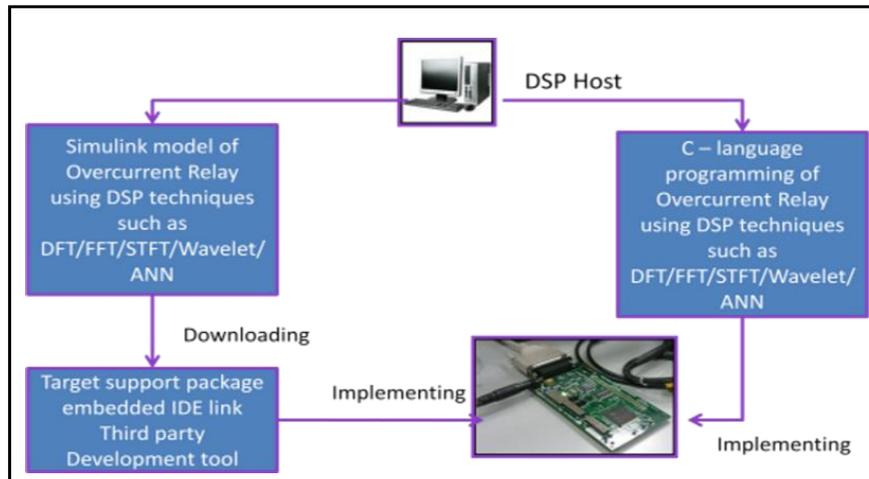


Fig-6 System Block Diagram

4. CONCLUSIONS

This paper shows one possible way to implement a numerical relay for overcurrent protection. IDMT relay features are selected for implementation. It also details the RMS value calculation method that can be used to implement IDMT features. Also described are MATLAB/Simulink and C language based methods to implement the proposed relay model, along with DSP techniques that can be used to implement IDMT features to improve system performance during fault trips.

5. REFERENCES

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