# Simulation of A Digital Overcurrent Relay using SIMULINK

## تمثيل المرحل الرقمى للوقاية من زيادة التيار باستخدام SIMULINK

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الملخص:

يمثل هذا البحث طريقة تمثيل مرحل رقمي للوقاية من زيادة التيار  باستخدام برنامج SIMULINK الذي يمثل احد الادوات المصاحبة لبرنامج MATLAB . من اجل استخدام قيم حقيقية لخصائص المرحل الرقمي للوقاية من زيادة التيار تم الاستعانة بخصائص المرحل الرقمي للوقاية من زيادة التيار  الخاصة بشركة SIEMENS . يتم في هذا البحث عمل نموذج كامل لمولد متوافق محمل، بالاضافة الى المرحل الرقمي للوفاية من زيادة التيار المستخدم لحماية هذا المولد. الغرض من هذا التمثيل هو دراسة خصائص عمل المرحل الرقمي للوقاية من زيادة التيار و  مراقبة مدي نجاحه في القيام بمهامه الوقائية و تم في هذا البحث تقسيم مراحل عمل المرحل الرقمي للوقاية من زيادة التيار  حتى يتسنى تمثيل كل جزء و دراسته على حدة و تم اختبار كفاءة عمل المرحل الرقمي للوقاية من زيادة التيار  في حالات اعطال مختلفة و اثبت نجاحه في حماية المولد.

## Abstract:

This paper prese   e the simulation of  digital overcurrent relay through the  graphic interface SIMULINK which is one of the MATLAB toolboxes. The operating characteristics of SIEMENS inverse time overcurrent relay module was used as actual characteristics of the digital relay. The technique used is based on integrating the modeling of a loaded synchronous generator together with its digital overcurrent relay. The purpose of the paper is to provide a complete structure of the digital relay in order to check  its performance. Various elements of the digital relay are implemented as single modules to represent the actual system. The computer digital relay module is tested under up normal conditions, and the results are very successful.

## 1. Introduction:

Relays are devices connected to the power system in order to detect intolerable and unwanted conditions in the power system. Due to the recent developments in the area of  simulation information, the use of digital relays is arising thoroughly during the last few years. During the same time relay modeling plays a significant role in performance evaluation of new and existing designs and for performing a variety of studies. Digital relays consist of software and hardware. An integral and important part of the software is the algorithm, which is a set of mathematical instructions used to process input variables to estimate whether the system is sound or faulty and consequently initiate the necessary action [1]. Many researchers suggested different software for modeling and simulation of the suggested relay algorithms  In this respect, the use of EMTP MODELS is suggested for simulating the distance-relaying algorithm [2]. Also the use of TACS functions within EMTP in order to provide an educational tool for investigating relay concepts by modeling digital relays has been conducted  [3].  Kezunovic and Chen suggested the simulation of power transients using EMTP, while protective relays can be modeled using MATLAB [4]. Also

Wilson and Nordstrom, compared the digital relay created using EMTP with the laboratory results for the same actual model [5]. Through Chudhary and Phadke total FORTRAN capability has been added to the EMTP in order to simulate computer relay algorithms [6]. It could be seen that all the above trials used either MATLAB and / or EMTP in their representation of the protective system.

In this paper, we use the MATLAB toolbox SIMULINK [7] which is a graphic interface software and allows simulation of different components of power system. The design, setting and testing of the inverse time overcurrent relay for protection of a synchronous generator is presented. The actual design values of inverse time overcurrent relay were taken from SIEMENS instruction manual [8]. In the following sections, the flow chart of the suggested relay module is implemented. The detailed description of the relay module items will be discussed and finally the complete system is tested under normal and fault conditions.

## 2. Implementation of Inverse Time Overcurrent Relay using SIMULINK

SIMULINK is a software used for modeling, analyzing and simulating any dynamical system. The power system block set together with the digital signal-processing block set has been used for the required simulation of the  operation of inverse time overcurrent relay. The role of operation of the proposed relay could be observed through the flow chart in Figure 1.
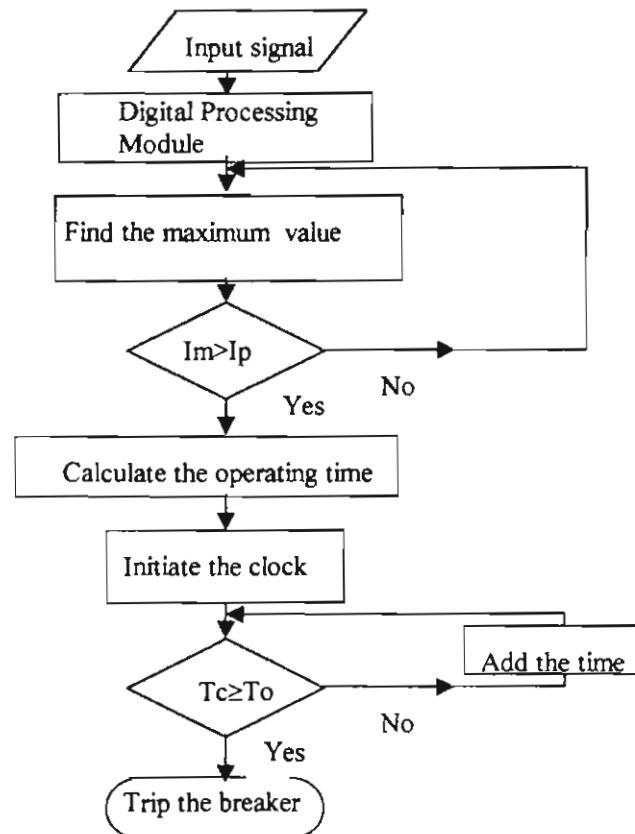


Figure 1 Flow chart for digital overcurrent relay

The flow chart of the suggested relay initiated by a digital signal module, which comprises mainly of sample and hold circuit together with a low pass digital filter in order to extract the fundamental signal on which the tripping decision will be taken. The maximum value of the filtered signal is calculated then compared with the pick-up current of the relay $I_P$. Unless the value of the current signal is higher than the pick up value the relay will not operate. When the current is exceeds the pick-up current a signal of the current is used in calculating the tripping time. Meanwhile a signal is send to an adder to begin the operation of a clock. When the time elapsed reaches the time calculated from the relay characteristics, a signal is given to the circuit breaker to open.

### 3. Relay Simulation:

For simulation of digital relay different block sets for defining the different stages of the relay are used. The main items of such simulation are: the current transformer, the analogue to digital conversion A/D, the digital relay and the relay operating characteristics.

### Current Transformer (C.T.):

The idea of the current transformer is to transform the current signal to values reasonable for current carrying capacity in relays. In SIMULINK a simple gain block set is used to simulate the current transformer. The transformation ratio is taken 400/5.

### A/D Conversion:

A simple switch is used to transform the signal from analogue to digital. This switch takes a value every 0.001 sec (sampling time) and transfer it to discrete value.

### Low –Pass Digital Filter:

In order to remove unwanted frequencies, which might cause errors in relay decision, a second order butter worth low pass filter is used. The transfer function of the filter is In the Laplace domain

$$H(s) = \frac{1}{s^2 + \sqrt{2}s + 1}$$
Eq. 1

By using bilinear transformation, the resulting transfer function in the Z plane will be

$$H(z) = \frac{A_0 + A_1 Z^{-1} + A_2 Z^{-2}}{B_0 + B_1 Z^{-1} + B_2 Z^{-2}}$$
Eq. 2

Taking the pass band cutoff frequency to be 100 and the sampling time 0.001 sec, we can find that:

| | | |
|---|---|---|
| $A_0 = 0.067$ | $A_1 = 0.134$ | $A_2 = 0.067$ |
| $B_0 = 1$ | $B_1 = -1.1453$ | $B_2 = 0.405$ |

**Relay Characteristics:**

The SIEMENS relay SIPROTEC 7SJ600 is used as an inverse time overcurrent relay for generator protection. The trip time characteristics could be shown in Figure 2. The equation governing the relay operation is given as in equation 3, [8]:
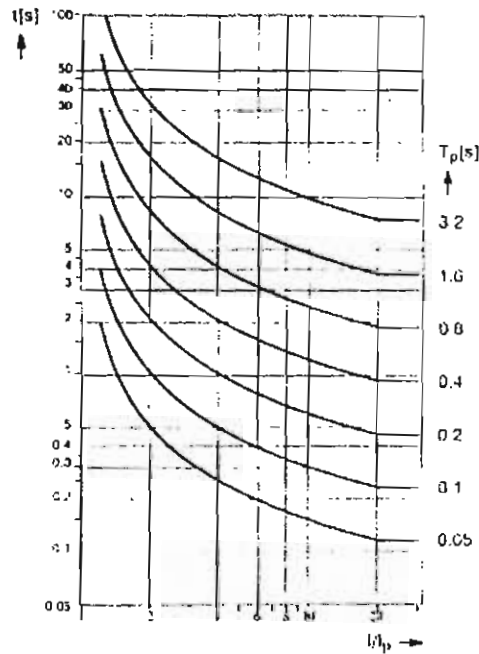


Figure 2. Trip time characteristics of inverse time overcurrent protection

$$t = \frac{0.14}{\left(\dfrac{I}{I_P}\right)^{0.02} - 1} T_P \qquad\qquad \text{Eq. 3}$$

where

| | |
|---|---|
| t | trip time |
| $T_P$ | set time multiplier |
| I | fault current |
| $I_P$ | set pick-up current |

## 4. Case Study :

The developed digital relay module is tested using a simple power system. The relay is used to protect a synchronous generator connected to a load. The simulated power system together with its suggested relay is shown in Figure 3. The synchronous generator is 2 MVA with 60 Hz operating frequency and 600 v rated line-to-line voltage. The connected load is 1800 kW at 0.9 p.f. lag.
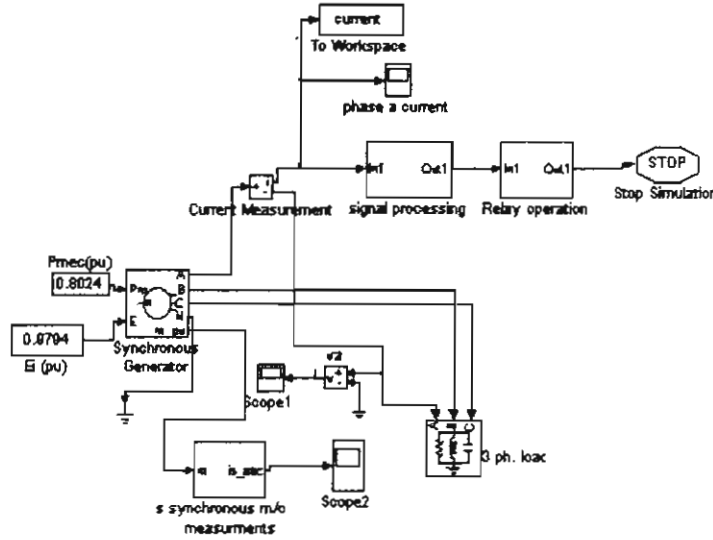
Figure 3 The power system with its protection relay

The signal-processing unit consisting of the analogue to digital converter together with the digital filter equation could be seen in Figure 4.
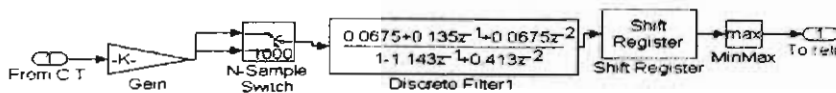
Figure 4  Digital signal processing unit

While the simulation of the relay operation including the time dial setting and operating characteristics of the relay is shown in Figure 5.
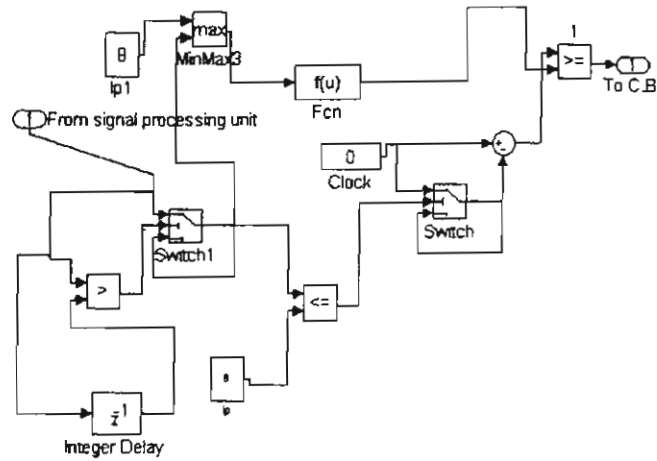
Figure 5. The relay operation unit

For testing the operation of the relay a three phase short circuit is applied at the terminals of the synchronous generator and the signal of the fault current at phase "a" is shown in Figure 6. It could be seen that the relay will give a trip signal to the C.B. t after about 0.3 seconds from fault inception instant.
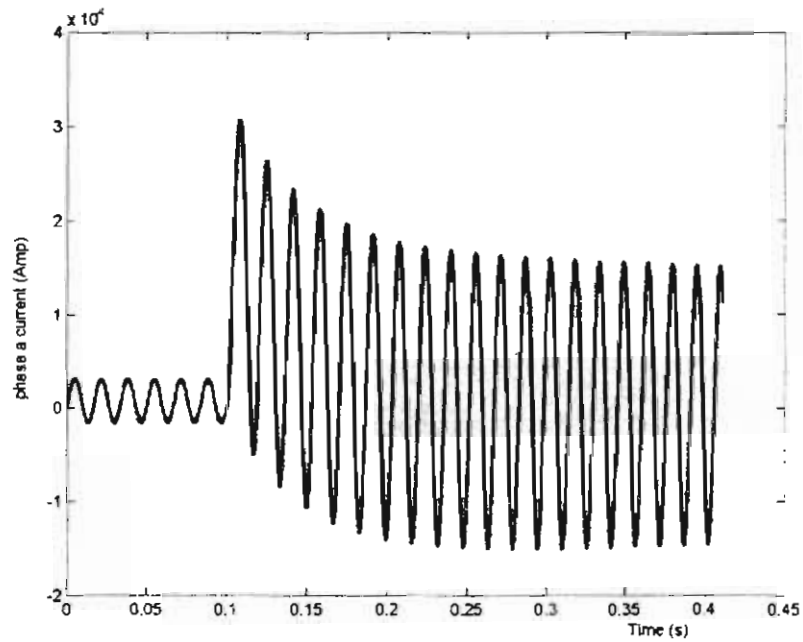


Figure 6. Phase "a" current under symmetrical short circuit

## 5. Conclusions:

The introduced relay model can be used as an educational model and also can be used for testing for a variety of protection systems. The use of SIMULINK as a user graphic interface enabled an accurate and simple simulation of the protective system. The different block sets available within the SIMULINK library allowed  for the Simulation of a mixed analogue and digital systems. Using the approach proposed it will be  possible to implement any other protective relaying schemes.

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