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Comparative Analysis of PI, PID and Fuzzy Logic Controller Based Relay for Power System Protection

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ABSTRACT: In modern protection system the key challenge is the trade-off between the security demands (no false tripping), the speed of operations and the dependability requirements. To meet this challenge properly, the application of a protective relay, using PI controller, PID controller and fuzzy logic controller in power system protection has been proposed in this thesis along with the simulated data. The examined technique based on PI controller, PID controller, fuzzy logic controller and value estimation to control the protection action of the protective relay was intended to improve the performance of a conventional protective relay control for human safety and system reliability with the use of a PI controller, PID controller and fuzzy logic controller. The difference between estimated and sampled values was used to form the rule base. Proposed relay architecture was used as a detector and was developed to predict faults and to protect particular sections of a designed prototype radial power system at an early stage. Performance analysis of the developed model is simulated using Simulink® and found satisfactory output.

KEYWORDS: PI Controller, PID controller and Fuzzy Logic controller, Protection System, Relay Architecture.

I. INTRODUCTION

Modern civilization makes use of large amounts of energy to generate goods and services. From the industrial plants, the providers of public services to the ordinary man, all of them need energy to satisfy and create the well being of modern society. The purpose of electric power systems is to provide energy for human use in a secure, reliable and economic manner. Electric power systems are made up of facilities and equipment that generate, transmit and distribute electrical energy. Electric power systems are one of the largest and more complex systems man has ever built.

Power system protection is a branch of electrical power engineering that deals with the protection of electrical power systems from faults through the isolation of faulted parts from the rest of the electrical network. The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation. Thus, protection schemes must apply a very pragmatic and pessimistic approach to clearing system faults. For this reason, the technology and philosophies utilized in protection schemes can often be old and well-established because they must be very reliable.

Protection system in power networks consist mainly of relays and their associated circuit breakers. Protective relays detect faults in power systems through current and potential transformers and subsequently activate the appropriate circuit breakers to isolate the faulty equipment from the system. They essentially act as switching mechanisms that disconnect the faulty region quickly, so as to minimize the damage. The general philosophy of relay application is to be dividing the power system into zones that can be protected adequately using fault recognition and removal, producing a disconnection of as few sections of the network a possible. The element in a power system typically consists of generators, transformers, buses, transmission/distribution circuits and motors. Each of these elements is protected by circuit breakers, located in three different zones of protection: primary, secondary and tertiary. In the event that a fault occurs, the circuit breakers in the primary zone are activated by the relays and trip first. The circuit breakers in the secondary zone provide backup protection to circuit breakers in the primary zone, in case they do not operate. Tertiary zone circuit breakers backup the circuit breakers in the secondary zone.

II. FAULT

In an electric power system, a fault is any abnormal electric current. For example, a short circuit is a fault in which current bypasses the normal load. An open-circuit fault occurs if a circuit is interrupted by some failure. In three-phase systems, a fault may involve one or more phases and ground, or may occur only between phases. In a "ground fault" or "earth fault", charge flows into the earth. The prospective short circuit current of a fault can be calculated for power systems. In power systems, protective devices detect fault conditions and operate circuit breakers and other devices to limit the loss of service due to a failure.

In a polyphase system, a fault may affect all phases equally which is a "symmetrical fault". If only some phases are affected, the resulting "asymmetrical fault" becomes more complicated to analyze due to the

simplifying assumption of equal current magnitude in all phases being no longer applicable. The analysis of this type of fault is often simplified by using methods such as symmetrical components.

III. PROPOSED SCHEME

The main objective of this paper is to help the power system control operators in quick identification of all cases of faults and circuit breakers maloperation.

This automated incident detection Simulink® model has the following objectives:

1. To determine faults along power sections using the states of circuit breakers and relays.
2. To determine the faulty current and its duration.
3. To have a high detection rate by accurately localizing the actual fault areas.
4. To compare the value of fault current and its duration in case of fuzzy logic controller PI controller and PID controller.

It is requisite that the average fault detection rate be as high as possible. Fault section estimation aims to identify fault components in a power system using the post fault status of protective relays and circuit breakers. For that fuzzy logic controller, PI controller and PID controller have been developed.

IV. SIMULINK MODEL & RESULTS

Relay and circuit breakers are necessary for the protection of power system. Here under voltage relay is used to sensing the abnormal condition in power system and gives signal to the circuit breaker for tripping and protect the power system. Sample and hold circuit to the multiplexer is in the form of relay which senses the abnormal condition in power system. Two circuit breakers are used in this circuit, one is for taking the signal from the relay and another one is a fault circuit breaker.

In the proposed and designed relay architecture, a novel value estimation method was used as opposed to previous works. It is essential in this method to estimate the voltage value at (t+2) sampling instant. The estimated voltage value was formed by using the previously sampled values, which belong to the values at (t+1) and (t) sampling instant. The proposed method had no dependency on sampling interval and sampling frequency. To establish a relationship between estimated and previously sampled values, a mathematical expression was defined as in Eq.1

$$X_{estimated} = A.\sin\left(2.arc\sin\left(\frac{X_{sampled}(t+1)}{A}\right) - arc\sin\left(\frac{X_{sampled}(t)}{A}\right)\right) \quad \ldots\ldots(1)$$

Where A is the magnitude of sampled value and x(.) is the sampled value related to sampling instant. Using the above algorithm, the expected value was estimated before the (t+2) sampling was done. A closed loop was constructed for all values to obtain continuous operation. Error and change of error between sampled and estimated value were used as input values for the fuzzy logic controller.

Mathematical expressions of the error and change of error were given in Eq.2 and Eq.3

$$e(t+2) = X_{sampled}(t+2) - X_{Estimated}(t+2) \quad \ldots\ldots(2)$$

$$ce(t+2) = e(t+2) - e(t+1) \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Scope1 gives the output of total fault current and fault voltage waveform and scope5 gives the output of relay fault current and fault voltage waveform.

The system can be divided in three major parts.

1. Voltage Sensing and estimation part
2. Error and Change of error calculation
3. PI controller, PID controller and Fuzzy Processer

1. Voltage sensing and estimation

The actuating quantity for this system is the change in voltage. To sense the voltage of the system a sample and hold circuit is used. After the sampling the sampled voltage is prepared for the other part by using amplifier. Then using delay the sampled signal is made as such so that the estimation block can estimate the future sample of the signal. The estimation block simply works by recognizing the fact the voltage is a sinusoidal wave function.

2. Error and Change of error (CE) calculation

The Error signal and change of error signal can be defined as:

$$\epsilon(n+2) = x_{sampled}\ (n+2) - x_{estimated}\ (n+2)$$

$$\Delta\epsilon(n) = \epsilon(n) - \epsilon(n-1)$$

By simply delaying and doing signal addition and subtraction the error and change of error of the sampled and estimated signal is determined.

3. PI controller, PID controller and Fuzzy Processer

Proportional + Integral (PI) controllers were developed because of the desirable property that systems with open loop transfer functions of type 1 or above have zero steady state error with respect to a step input.

A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs.

The Fuzzy logic processor in Simulink® is an extension of fuzzy logic toolbox in Matlab®. Using the fuzzy logic toolbox the logic was developed so that the processor will process change in error and error and give an output based on that.

A. Relay fault current and fault voltage waveform with PI controller

Here is a waveform of relay fault current and fault voltage with the help of PI controller shown in Fig. 1.

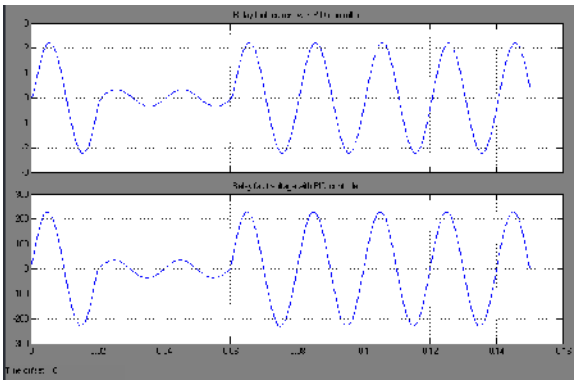

Fig. 1. Relay fault current and fault voltage waveform with PI controller.

B. Relay fault current and fault voltage waveform with PID controller

Here is a waveform of relay fault current and fault voltage with the help of PID controller shown in Fig. 2.

In the processor there are two inputs and one output function. The membership functions are all trimf. The Rule of the fuzzy processor is given below table 1.

Table 1.

Speed Deviation	Acceleration Deviation						
	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NM	NS
NM	NB	NM	NM	NM	NS	NS	ZE
NS	NM	NM	NS	NS	ZE	ZE	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	ZE	ZE	PS	PS	PM	PM
PM	ZE	PS	PS	PM	PM	PM	PB
PB	PS	PM	PM	PB	PB	PB	PB

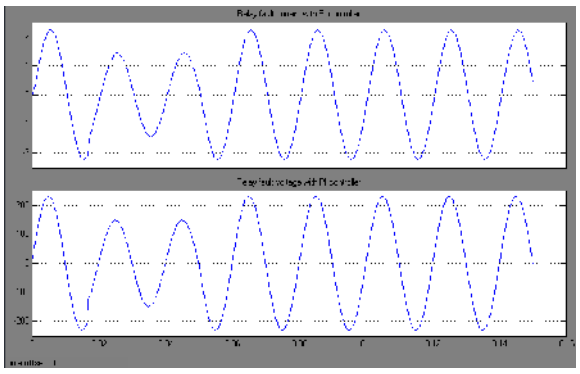

Fig. 2. Relay fault current and fault voltage waveform with PID controller.

C. Relay fault current and fault voltage waveform with fuzzy logic controller

Here is a waveform of relay fault current and fault voltage with the help of fuzzy logic controller shown in Fig. 3.

V. CONCLUSION

In this paper, experimental results of a protective relay based on PI controller, PID controller and fuzzy logic controller were presented. It can also detect Transient fault and handle it successfully. In addition to the theoretical aspect of fuzzy logic, mathematical definition of the value estimation, detection and measurement of faulty current and faulty voltage, determination of its duration for i.e. faulty current and faulty voltage, decision mechanism and detailed system architecture were also introduced.

Fuzzy inference is a process that makes a decision in parallel. Because of this property, there is no data loss during the process and so final fault detection will be far more precise than that of conventional relaying techniques.

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