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Electrical faults diagnoses and classification adoptring an intelligent relaying system

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Abstract---This paper demonstrates the construction, designing analysis and control strategies for electrical faults diagnoses and classification adoptring an intelligent relaying system while supplying power. Relays are installed devices that can be added to any electrical circuit and allow remote wireless control of anything else connected to that circuit. The main purpose of the proposed smart protection system in the current study is to improve the dynamic performance of IEEE 9-Bus network to try to reduce interruptions and power outages due to some emergencies or intended accidents in the electric system through. The installation of a protection system with an intelligent relay using fuzzy logic control to protect the electrical system by separating the parts that have malfunctioned while keeping the parts that did not fault by issuing a disconnection signal or directing the circuit breaker in charge, Therefore, the protection system must be active and resolute by separating the symmetrical and asymmetrical faults from the electrical system and within the local and international standard specifications of the approved protection systems. It is worth noting that the MATLAB program and mathematical simulation, version R2019, were used to demonstrate the performance of the system. It is concluded that faults diagnoses and classification-based FLC is more robust and efficient compared with classical overcurrent protection scenarios.

Keywords---Smart Microcontroller, Fuzzy Logic Controller, Faults diagnoses and classification, Smart Overcurrent Relay.

Introduction

Protection schemes are one of the indispensable elements of the electric power system, which isolates the system's problematic component from the healthy part. The system must develop a robust protection mechanism to safeguard humans and other components from any damage resulting from the abnormal operation. Protection systems detect and automatically disconnect any malfunction in the power supply. Occasionally, anomalous operations occur in a related system. As a result, equipment damage and incorrect interruption of the supply linked to the electrical system may occur [1]. Many types of defensive schemes protect the equipment in an electric power system. They must disconnect malfunctioning or overloaded equipment or pieces from the system to minimise excessive equipment damage.

System protections are a special sort of protection. Their job is to keep the system from collapsing [2]. In switching stations, protective equipment is placed on recognizing and separating system defects and external forces. Protective relays keep a constant eye on the condition of the equipment and systems they are supposed to safeguard from harm. [3-4]. A major role of the protective manipulator is providing data about position and disruption. A variety of relay implementations monitor for physical plant and mechanical characteristics depending on the equipment they protect [5]. The electricity networks must be safeguarded according to their importance for saving lives and money to avoid abnormal conditions and ensure the continuation of electric power in healthy areas. The transmission line is a critical power system component, and researchers are developing secure operating techniques. The protective relay is the most important component of the protection system. The relay does not affect the occurrence of defects. It can only take action after the error has occurred. Depending on the failure strategy and the part to be protected, there are many relays. A protection study for some parts of power system components was conducted to present the development of the digital protection scenarios. To maintain the system's stability and synchronization and prevent damage to healthy parts, the abnormal effect of the operation must be detected and isolated from the electrical grid as soon as possible. The protection system must be designed to ensure these conditions based on the causes. Instead of analogue systems protection, digital systems have effective and fast operation. The aim of this research is to develop a digital power system protection scheme using digital relays Since electrical networks are important systems. Therefore, there is a necessity to have a smart interactive relaying system [6].

The current study can be summarized as follows: section 2 presents mathematical representation and relay modeling utilization of FLC in power system protection, section 3 focuses on using Fuzzy Logic in power system protection. Section 4 discusses the proposed protection modeling, simulation, and finally conclusion and remarks has been discussed in section 5.

Mathematical Representation and Relay Modeling

This study simulated three types of relays for the suggested conservative system. Differential and overcurrent relay for bus-bar protection, differential and overcurrent relays for transformer protection, and distance and overcurrent relays for transmission line protection are examples.

Differential Relay

Differential relay is a common type of relay. It compares the C.T. currents at the zone's input and output. If the phasor sum is not zero, the relay uses its testing processes to see if there is an internal problem, which varies according to the type of the protected part. Bernard rice and Charles H. Merz developed the first differential protection strategy in 1904. The benefits of the suggested approach were recognized, and it was widely implemented [3]. However, it is becoming increasingly apparent that relay circuitry differences cause inappropriate differential protection functioning, excessive current and inrush current (induced by overvoltage), or C.T error.

Modeling of Differential Relay

The idea of differential comparison can be understood in Figure 1.

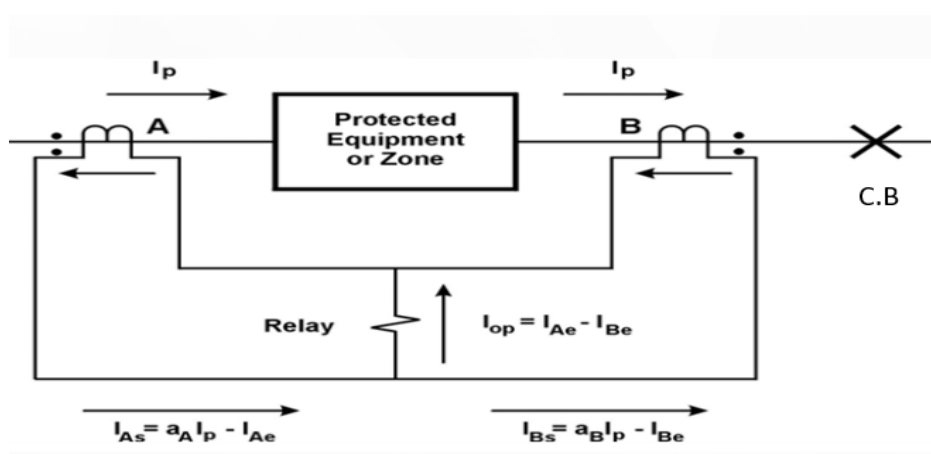


Figure 1. Differential Protection External Fault or Normal Operation

Under normal operation, the current I_p entering the unit equals the current leaving it [3-4]. Let us use current transducer A; the secondary current is:

$$I_{As} = a_A I_p - I_{Ae}$$

(1)

where,

a_A is the current ratio for transformer side A.

I_{Ae} is the excitation current of C.T side A.

Similarly, the current transformer B is:

$$I_{Bs} = a_B I_p - I_{Be}$$

(2)

where;

a_B is the current ratio for transformer side B.

I_{Be} is the excitation current of C.T side B

If, $a_A = a_B = a$, I_{op} is given by:

$$I_{op} = I_{Ae} - I_{Be}$$

(3)

The relay operating current I_{op} is small during normal and unnormal operation but never zero [3]. If a fault occurs within the protection zone of equipment, the relay operation current I_{op} does not equal zero; consequently, the differential relay will operate.

Utilization of Fuzzy Logic in Power System Protection

Fuzzy reasoning and fuzzy signal processing methods, which are members of the AI family, have received much attention during the past 15 years. Numerous investigations have been carried out in outstanding research facilities. Numerous decision-making issues can be solved with fuzzy logic. Using F.L based decision modules or classifiers, one of the many jobs that may be efficiently completed is the analysis of power system breakdowns and other abnormal events [4,5].

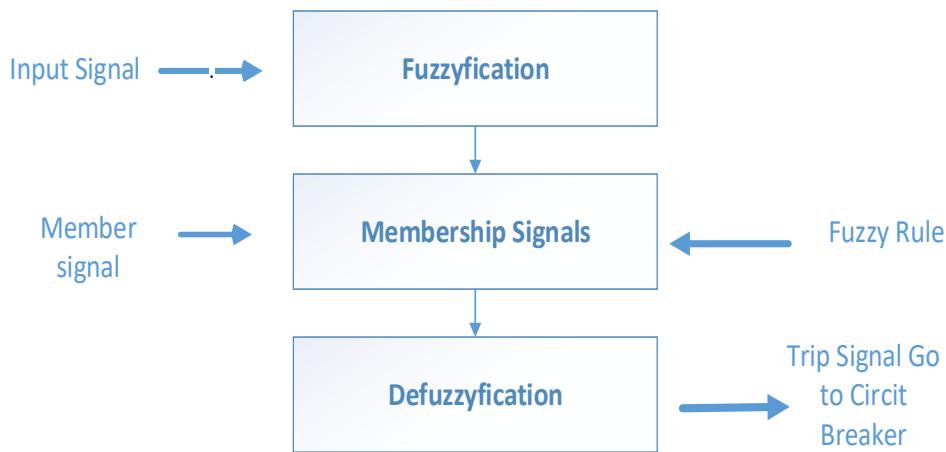


Figure 2. Block Diagram of FLC

Fuzzy modelling or classification typically uses different forms of FIS. The FIS scheme functions in several phases, as shown in Fig. (2):

- Determine the membership amplitudes of each linguistic word, the fuzzification process compares the input values with membership functions.
- The shaky logic (triggering the basics and providing their fuzzy consequents).
- Defuzzification (aggregating rule results to create a clear response).

Proposed Protection Modeling and Simulation

The IEEE – 9 busbar protection system is classified into Two parts, which are:

- 1- Bus bar protection system with transducers and a circuit breaker, comprising a differential manipulator as the primary protection.
- 2- Low-frequency transformer protection system with transducers and C.B comprises a differential relay as the main protection.

Simulink Model of Smart Differential Relay

As previously mentioned, the main protection relay is a differential relay for the low-frequency transformer and busbar. This work modifies a protection restraint current relay using MATLAB/SIMULINK R2019 with variable–step, the relative tolerance of (1) msec and sampling time of (50) μ sec . FLC rules for fault detection and diagnosis are listed in the table (1).

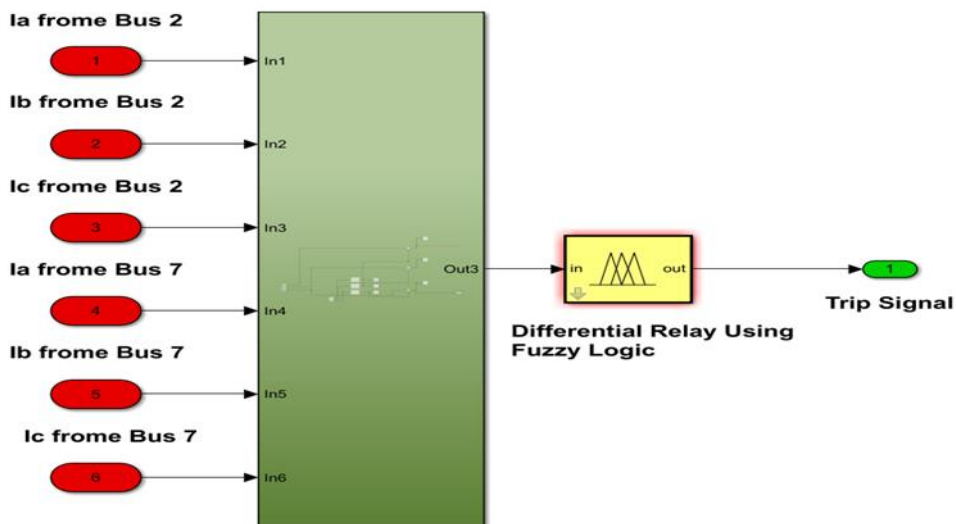


Figure 3. MATLAB Simulation of Differential Smart Relaying

Table 1
Rules for Fault Diagnosis using FLC.

Faults Type	$i_{a2} - i_{a1}$	$i_{b2} - i_{b1}$	$i_{c2} - i_{c1}$
Healthy Case	Low	Low	Low
AG	High	Low	Low
BG	Low	High	Low
CG	Low	Low	High
AB	High	High	Low
AC	High	Low	High
BC	Low	High	High
ABC	High	High	High

A membership is a function that specifies the path of each point in the input and is mapped to an amplitude bounded between [0,1]. This section depends upon the designer's experience and the problem under consideration. The input of F.L for power transformer protection consists of two groups. The first group is the different r.m.s current of input and out of the transformer. The second group is the membership of the second harmonic differential current. The computer flowchart in Fig. (4) is simulated as follows:

Step 1: Enter the information from the C.Ts.

Step 2: Data computation. For the amplitude calculation, if $\|I_{d1} - I_{d2}\| > 0$, logic one shows the case of an inrush current or an internal fault. Otherwise, logic zero clarifies a discovery of an exterior fault. The harmonic calculation is performed. If, $(0.3 * I_{f1} < I_{f2} < 0.7 * I_{f1})$, then the logic zero occurs, estimating the inrush current. Otherwise, logic one indicates that an interior or exterior fault occurs.

Step 3: Tracking the final process. If the logic cases received from both cases (a & b) in step two are both (1), that indicates a detection of an internal fault. Then a trip signal is released to stop the simulation.

For the other logic options of (0,1) means an external fault, (1,0) means an inrush current, or (0,0) indicates an occurrence of an inrush current or an external fault, and the simulation goes back to step two to start the calculation again for the next sample.

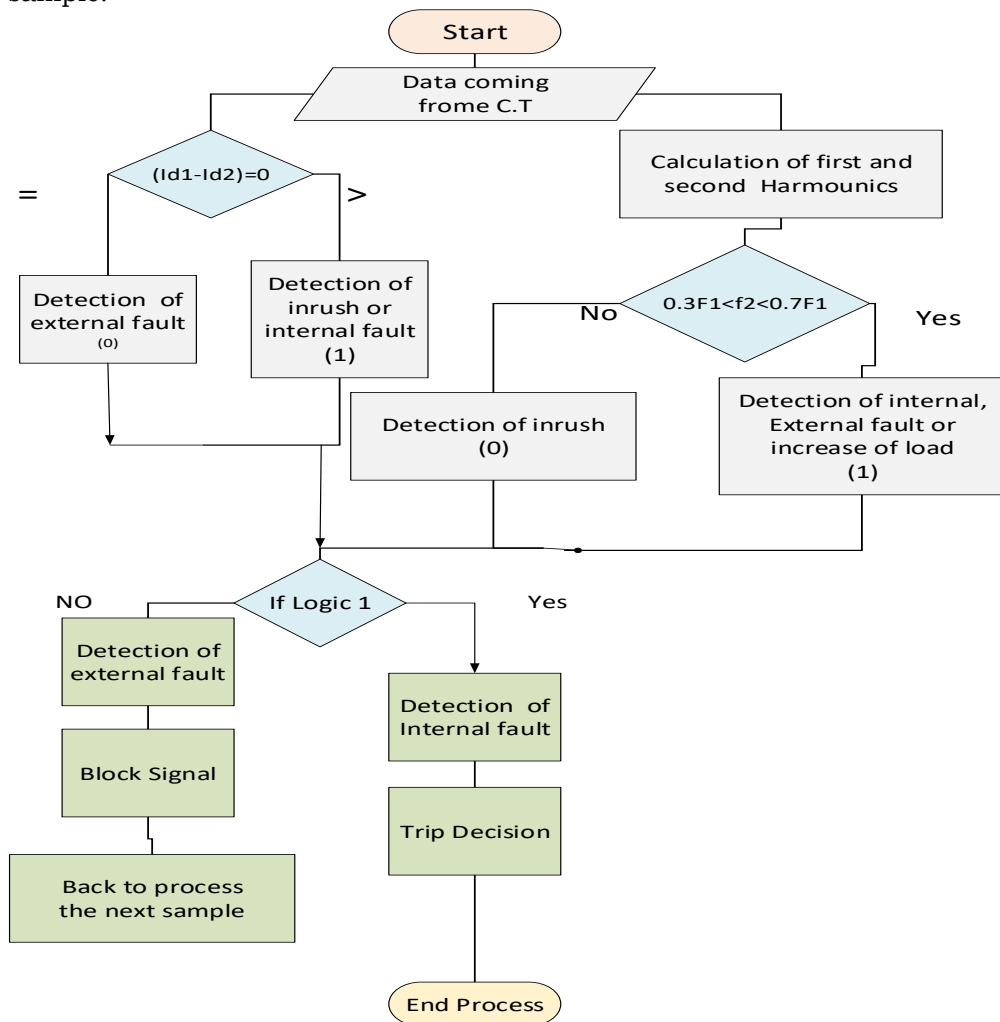


Figure 4. Flowchart of Differential Relay Scheme Based Fuzzy Logic-Control

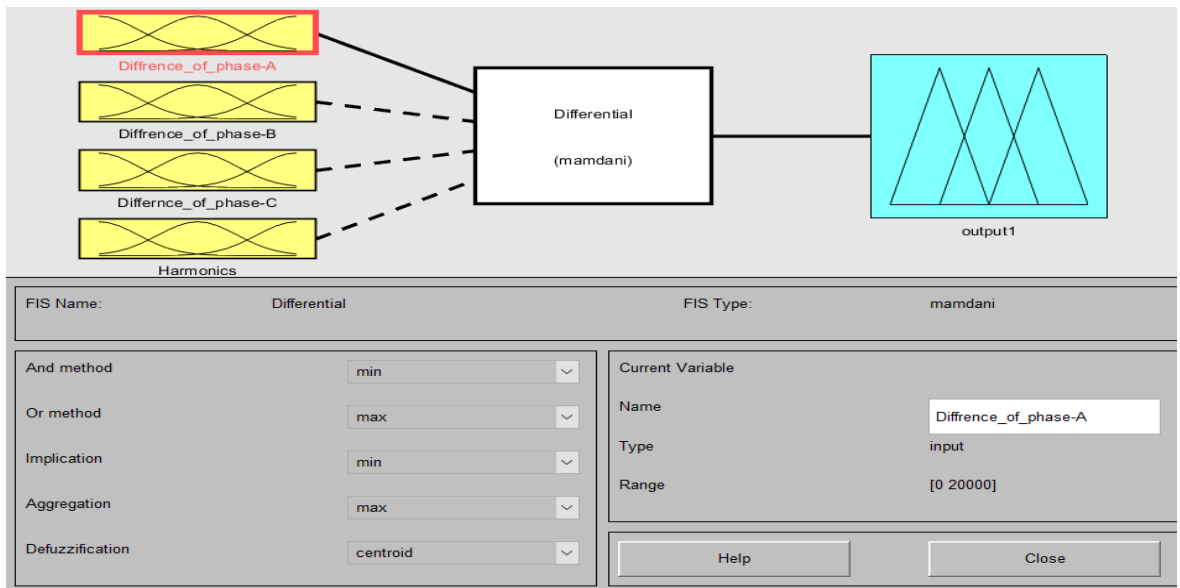
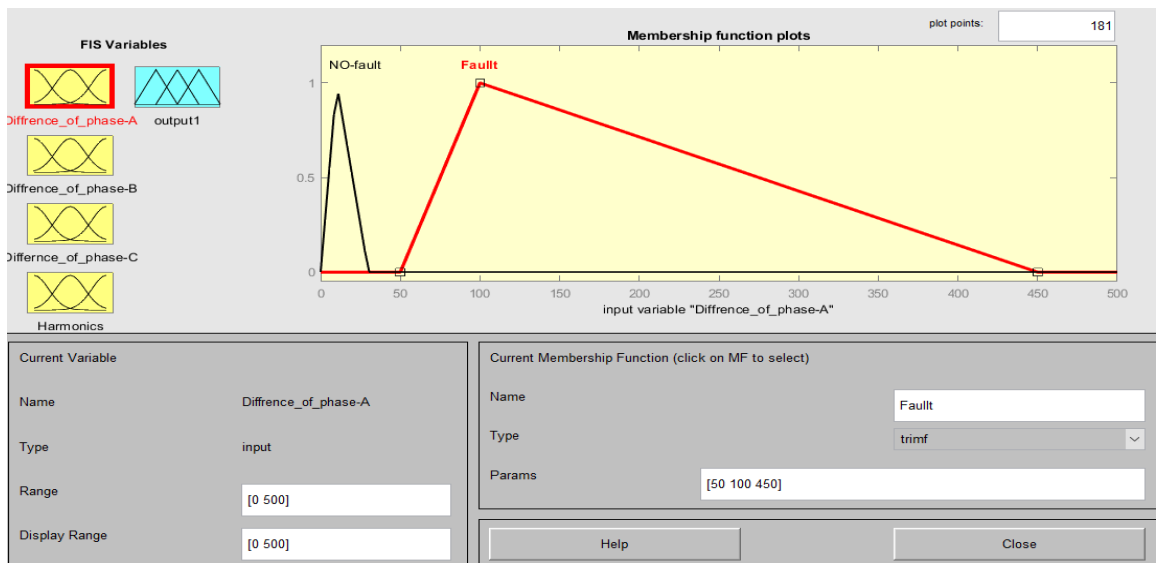


Figure 5. Fuzzy Logic Design of Smart Differential Relay

Figure (5) shows the FL design from the toolbox in MATLAB environment R2019. It shows the type of fuzzy interface system used. There are various methods used in defining rules, and the defuzzification method.

Figure 6. Membership Function for Input of Smart Differential Relay



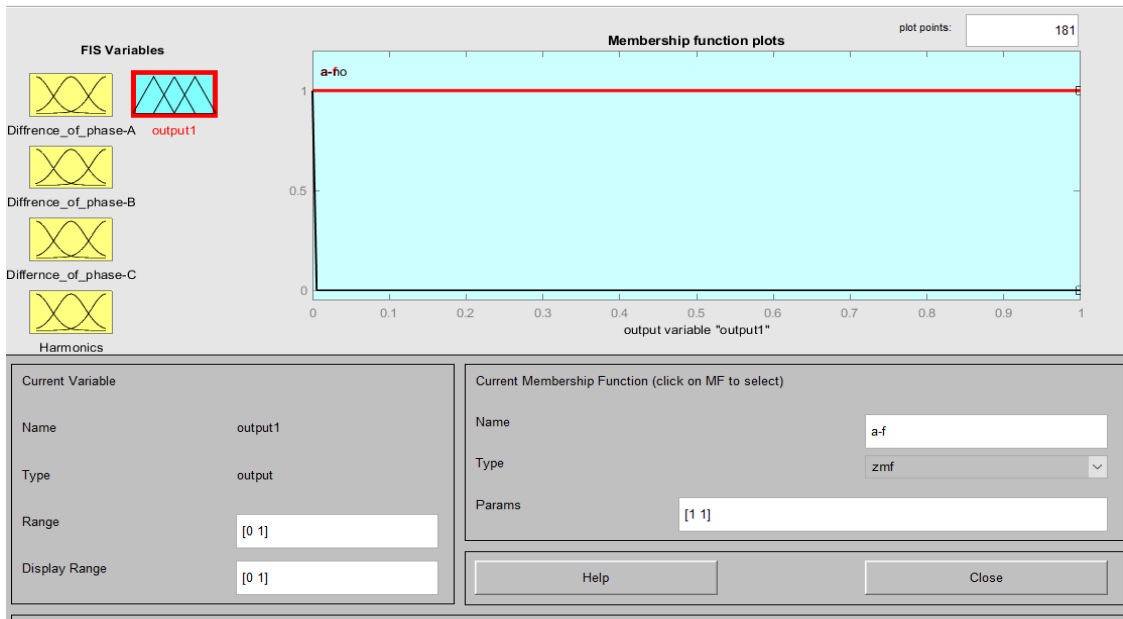


Figure 7. Fuzzy Logic Output for Smart Differential Relay

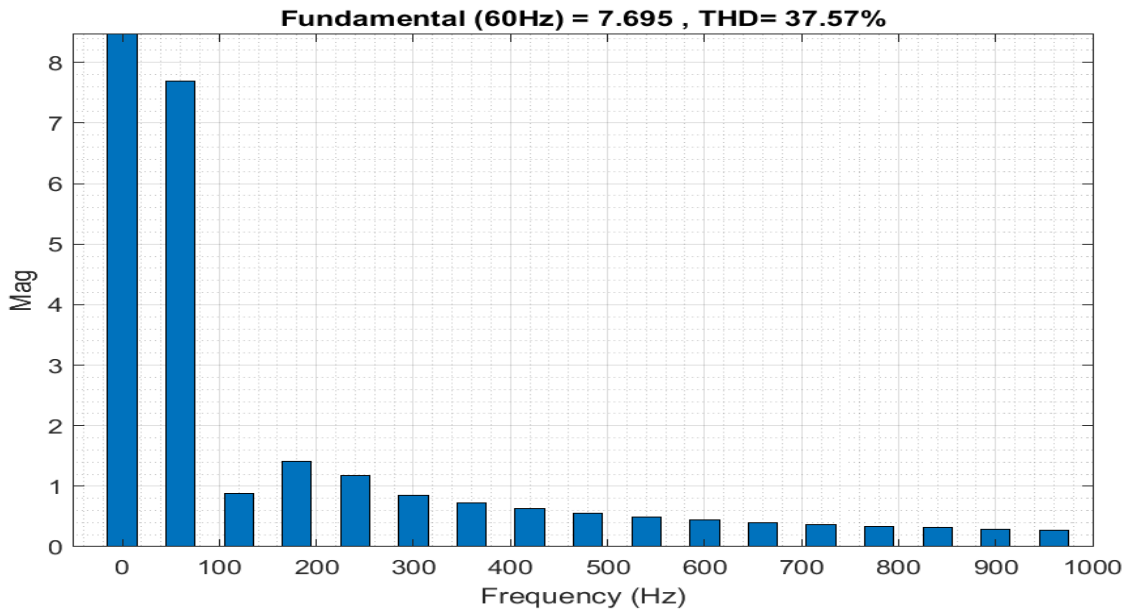


Figure 8. THD for AG fault in Three-Phase Transformer

The membership function of the output is shown in Fig. (6). It consists of two Trip and block functions; if the output amplitude is one, the trip signal is extracted, and if the amplitude is zero, then the block signal is extracted. Figure (7) shows the F.L output of the smart differential relay. Figure (8) depicts the THD in the case of phase AG fault current

computed Fig. (8), the harmonic component's amplitude decreases as the order of the harmonics increases.

Simulation Results of Busbar Fault Detection

As previously stated, the bus bar protection system comprises two subsystems: a main (unit) defence with a differential relay. Figure (11) depicts bus-bar protection simulated in one of the busbars for the IEEE - 9 bus. Main protection with differential relay must be activated in case of a fault near the midpoint of transmission lines between numbers (4-5), and if it fails, the local secondary protection must identify the fault, and then circuit breakers must isolate the disturbance. The technique is managed by a microcontroller created specifically for this purpose. Figure (9) depicts a three-phase fault utilized to the busbar over a time interval (0.4 - 0.5) sec. The performances of the bus-bar protection for faulty and healthy cases are shown in Fig. (10)

Figure (12) shows the trip signals for fault at the midpoint of T.L provided by overcurrent and differential relay. The time delay between differential and overcurrent relay is considered (0.005)sec. to avoid overlap or interchange in the operation of relays.

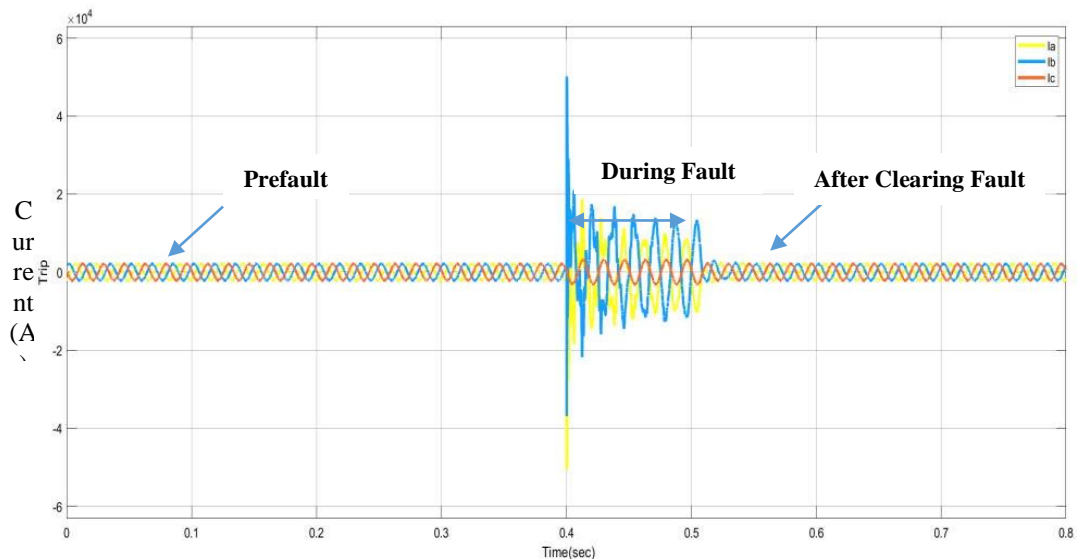


Figure 9. Current Waveforms for Lines (BC) Fault at Midpoint of T.L between Busbar No. 4 -5



Figure 10. Voltage and Current Waveforms for Healthy Case Between Busbar No. 4-5

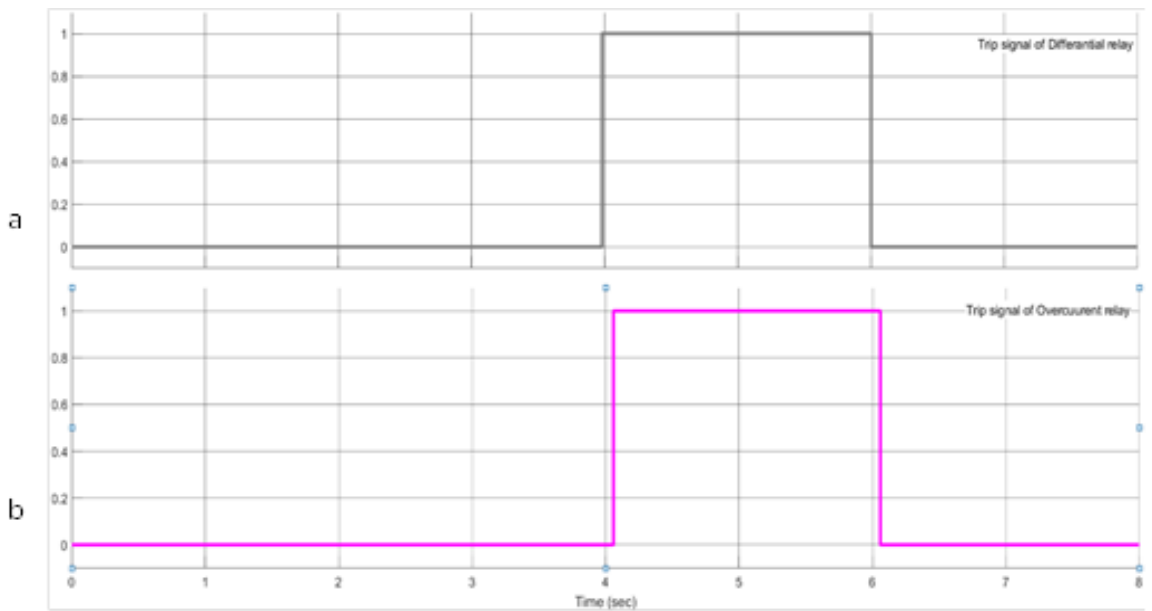


Figure 11. Trip Signals for fault between Busbar No. 4 -5
 (a) Differential Trip Signal, (b) OC Trip Signal.

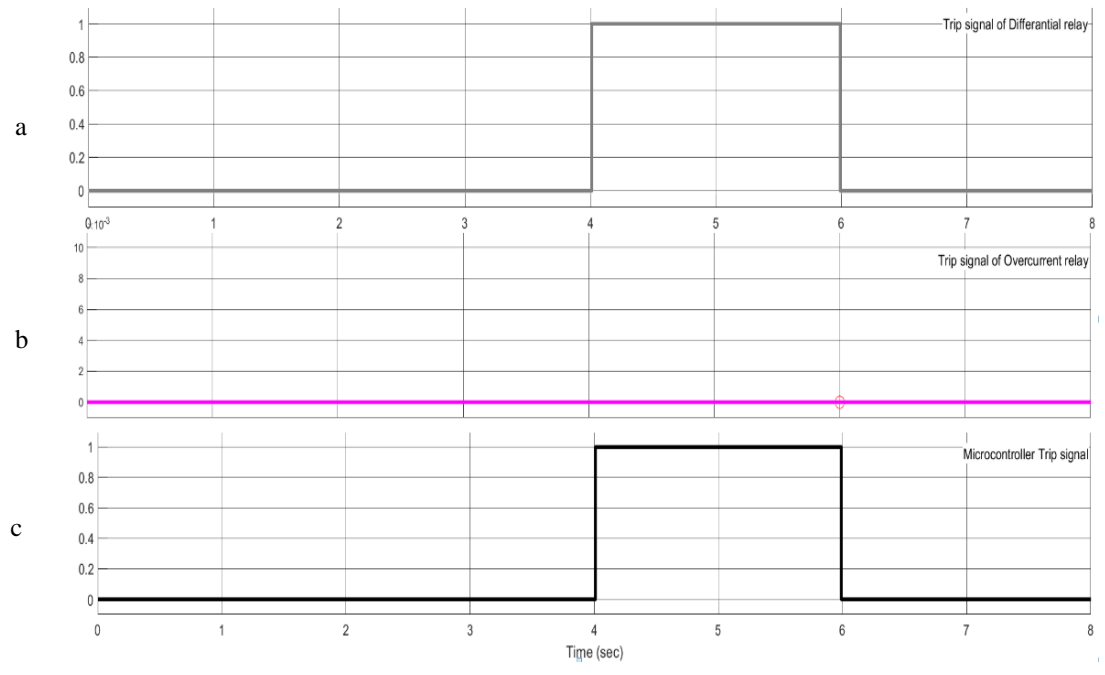


Figure 12. Fault at Busbar No. (5) (a) Unit Protection Signal (b) Local Protection Signal (c) Trip Signal for Microcontroller-based ANN

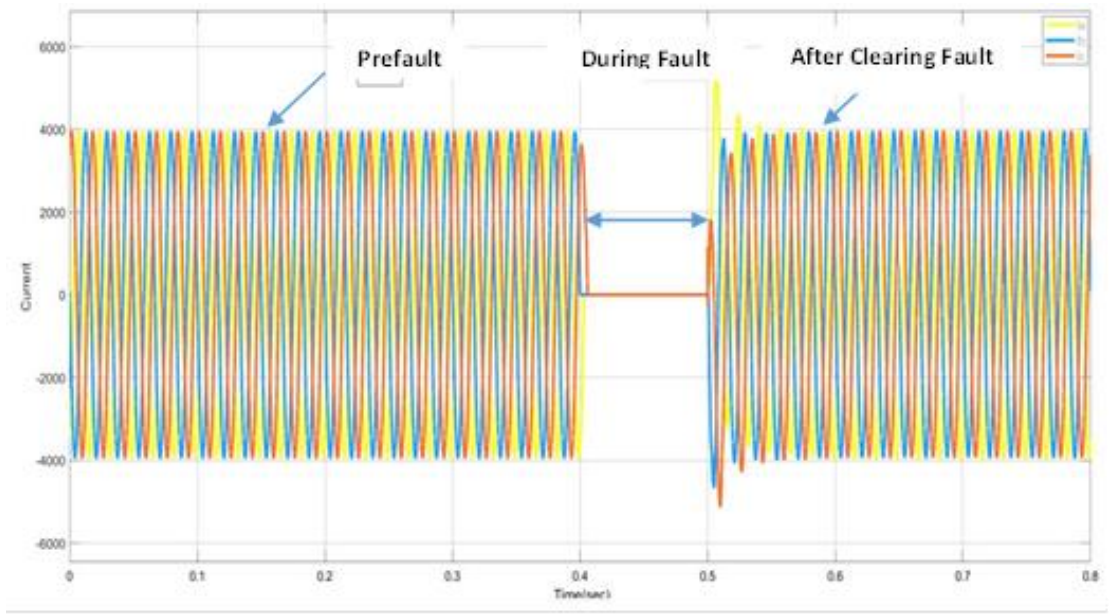


Figure 13. Three-Phase Fault Current Waveforms

The system seems to operate correctly between (0 - 0.4) sec., but a three-phase fault duration is between (0.4 - 0.5) sec. After the C.B switches and the problem is solved, the bus operation returns to the normal case in time interval (0.5 - 0.53) sec. Figure (14) shows the behaviour of the protective system in the event of a differential relay failure.

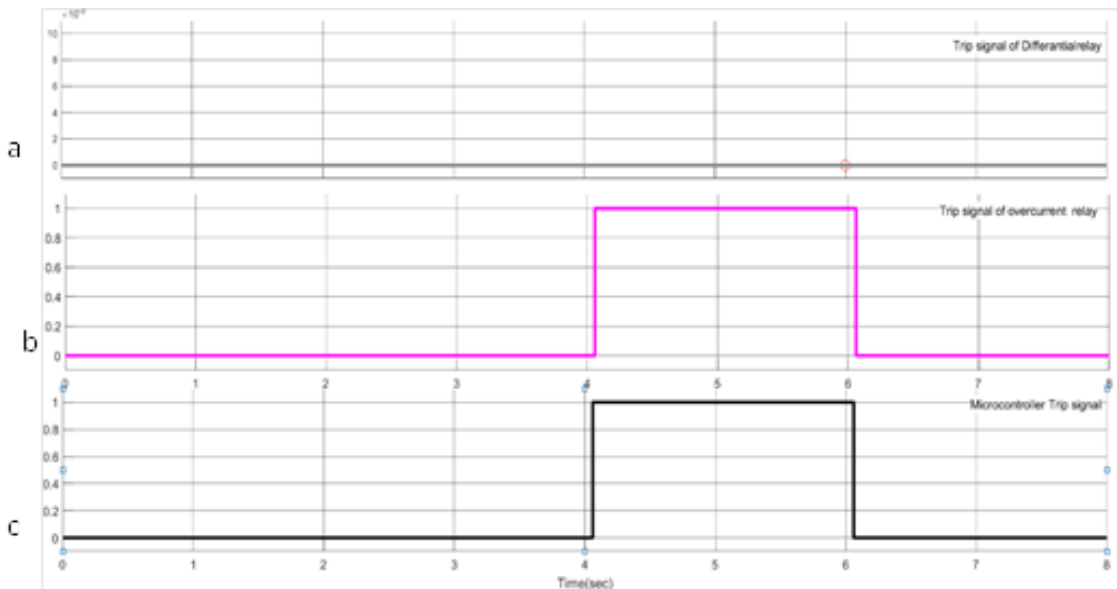


Figure 14. Trip Signals Near Busbar No. (5) (a) Main protection signal failure, (b) Backup protection signal , (c) Microcontroller-Based ANN Signal

Figure (15) shows the protection performance when a failure occurs in the specified relay. The overcurrent relay detects and isolates the fault where the main protection relay fails. From the simulation results and referring to figure (12), if the proposed scheme protects the busbar shown early and a fault happens at the busbar, it can be isolated through clearing the faulty one by switching off the contacts of the C.Bs linked to it. This is done with the assistance of the proposed microcontrollers using ANN that regularizes the relay signals. The above-proposed protection system has been applied to all the busbars that are not protected well in the whole system. The proposed protection system for these busbars was also tested by applying a three-phase fault for the time interval (0.4 - 0.5) sec.

Conclusion and Remarks

This study talks about the design and test of a smart relaying system applied on IEEE-9 Bus, related to a single line diagram for IEEE - 9 Bus Electrical Network. It consists of three generators, three low frequency power transformers, and three loads. The protection system

has smart relaying (differential and distance relays) and C.Bs to turn OFF the system when a fault occurs.

The main purpose of this study is to protect power transformers, buses and transmission lines by connecting the protection systems, which are differential, distance and overcurrent relays with circuit breakers on the terminals of transformers, buses and transmission lines.

Busbar and transformer are first protected from fault through the differential relay by sensing the fault differential relay, so the system turns OFF, and after the fault is removed, the system returns to work, and when protective relaying system maloperations, fault detection is not sensitive. The second backup protection system is an overcurrent relay that operates after a specified delay time, which causes the system to shut down.

The simulation has been tested in various scenarios and produced satisfactory results in all of them. All of the tests yielded positive results. There are some challenges in implementing the tested IEE 9 - bus system, such as the lack of MATLAB toolbox. There are no C.T measurements, and a mathematical gain can be used to solve the case.

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