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Design and Simulation of Three Zones Distance Protection Scheme

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distance relay ,transmission line protection , three zones , single line to ground fault , MATLAB/ SIMULINK

A B S T R A C T

This work describes the protection mechanism of transmission line at fault. Transmission line is divided into three zones and it is also provided by a backup protection MATLAB simulation was used to represent the three steps protection under single line to ground fault in different zones. Distance Relay was used to measure impedance as a part of power system, when the fault impedance dropped below the predetermined value a trip signal will transmit to the circuit breaker. MATLAB simulation is used to simulate the proposed model for three zones. The results illustrated the fault impedance at each zone and finally it has been concluded that the lower impedance is obtained at zone B (27.33 Ω) in phase T.

1. Introduction

Distance protection is widely recognized as the predominant method for safeguarding transmission lines, playing a crucial role in ensuring the reliable operation of power grids. The utilization of this protective strategy in numerical relays is significantly facilitated by its ability to operate solely on local measurements, obviating the need for interfacing with the alternate line terminal. The distance relay, known for its reliability, selectivity, simplicity, suitability, and economy, is extensively utilized in safeguarding transmission lines. Its operation relies on assessing the impedance from the relay point to the fault location. When the fault impedance falls within the protection characteristic, the relay initiates a trip; otherwise, it remains inactive [1]. The fundamental concept that underlies distance protection is the calculation of fault impedance through the utilization of local voltage and current measurements. Subsequently, this impedance value is compared against a predefined impedance threshold in order to ascertain whether the fault resides within its specified operational domain. The functionality of distance protection relays is described in terms of accuracy of reach and operation duration. Reach accuracy entails evaluating the actual ohmic reach of the relay in practical conditions against the preset value in ohms. The precision of reach is notably affected by the magnitude of voltage presented to the relay during a fault occurrence. Moreover, the methodologies employed for impedance measurement in unique relay configurations play a role in this assessment [2]. The term "distance protection" is deemed appropriate due to the ability to infer the fault distance based on the impedance value, given that the length of the transmission line is directly proportional to the distance. [3]. Protection systems, encompassing various protective relays, occupy a position of paramount importance in power systems, as they are entrusted with the task of safeguarding the transmission of electrical energy[4]. The incidence of short circuit faults, which may occur in various locations within electrical power systems, can be ascribed to a variety of factors such as lightning strikes, high-speed winds, ice accumulation, seismic activities, fires, explosions, falling trees, airborne objects, animals, human activities, hardware failures, aging of equipment, improper hardware usage, incorrect operations [5-8].

2. Principle of Operation

The power system's single line diagram with the protection unit as shown in Figure. 1

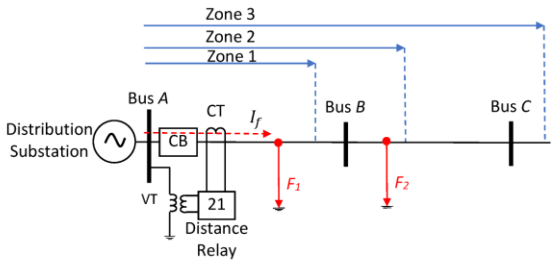

Figure.1 Single line with protection unit

Impedance represent the ratio of voltage over current the digital relay operates on an essentially simple working principle. The current relay is equipped with a potential transformer that supplies the necessary voltage and a current transformer to enable its functioning. The circuit is connected in series throughout. It is significant to remember that a distance relay is usually used to protect transmission lines since it monitors the impedance from the generation side to the potential fault location. Any variations in the current to voltage ratio that it detects can be handled by this relay. The operation in the distance relay is dependent on the impedance expressed as the previously indicated ratio of V/I. In essence, the relay will turn on when the impedance which is measured by the ratio of voltage per ampere(V/I) drops below a set threshold. Moreover, there are several varieties of distance relays, such as reactance, admittance, and impedance relays, each of which has a distinct function in terms of security. In this instance, the ratio of voltage to AC current is greater than the point of reach, indicating that the relay's reach is farther than the fault location. Determining a relay's reach that is, the separation between the relaying point and the fault location is crucial. Finally, it is important to note that a number of complex computations can be used to determine the voltage on the primary voltage transformer, or VT.

$$V_T = \frac{Ea * Z_f}{Z_1 + Z_2 + Z_0 + ... + 3Z_f} \qquad (1)$$

Where :
V_T : primary voltage transformer
E_a : Voltage Source
Z_f : Fault Impedace
Z_0 , Z_1 , Z_2 : line impedances

And Fault current is given as [9] .

$$I_a = \frac{Ea}{Z_1 + Z_2 + Z_0 + ... + 3Z_f} \qquad (2)$$

Where :
I_a : Fault Current

To measure the impedance is used the following relationship and the relay impedance can be calculated as a ratio of voltage per current (V/I) , with the aim of evaluating their respective values and potentially determining any discrepancies or inconsistencies that may exist between them[10] .

$$Z_m = (\frac{U_m}{I_m}) * (\frac{CT_{ratio}}{VT_{ratio}}) \qquad (3)$$

Where :
Z_m : Measured Impedance
Um: Measured voltage
Im: Measured current
C_T :Current Transformer

3. Types of Fault :

Within the transmission network setting as a whole, it is evident that potential defects fall into two different categories: balanced faults, also called symmetrical faults, and unbalanced faults, also called unsymmetrical faults. It is crucial to realize that these defects fall into two further categories: series faults and shunt faults[11].

3.1 Series Faults

These faults are known to happen in situations when there is an imbalanced series impedance condition in the line and there is an opening in the conductor. When the system comes across one or two broken lines, or when impedance is introduced into one or more lines, this kind of malfunction can happen. Practically speaking, or to put it another way, in real-world circumstances, this error happens when the circuit breaker manages the lines without opening all three phases, which allows one or two phases to open while the other remains closed. The observed increase in voltage and frequency, along with a decrease in current in the impacted phases, can be used to classify series malfunctions[12].

3.2 Shunt Faults

The most common type of defects found in power systems are shunt faults, which include power conductors, conductors to ground, and short circuits between conductors. According to reference, line-to-ground faults are responsible for about 70% of fault incidences. When any one of the phases in a transmission line makes contact with the ground, a specific kind of fault occurs [13].

4. Flowchart of Distance Relay Three Zones Protection

Figure.2 : Illustrate the flow chart of three protection zone setting (Z1,Z2,Z3) for a distance relay according to the analytical method on a 400 kv transmission lines .

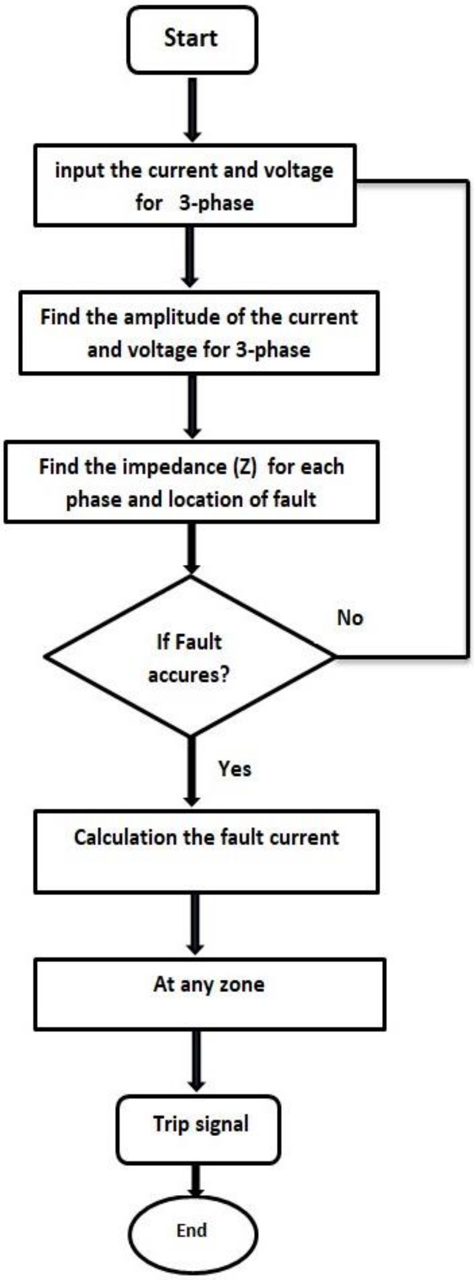

Figure.2 Flowchart of distance relay three zones protection

5. Matlab Simulation of Protection Zone

The protection zone encloses the power equipment. If a malfunction occurs in any of the zones, only the circuit breaker associated with that particular zone will trip. As a result, only the malfunctioning part will be unplugged, with no effect on the other parts of the system .The circuit diagram that follows will show the zone A protection plan.The transmission line modeling circuit with a three zone protection circuit is shown in (Figure. 3)

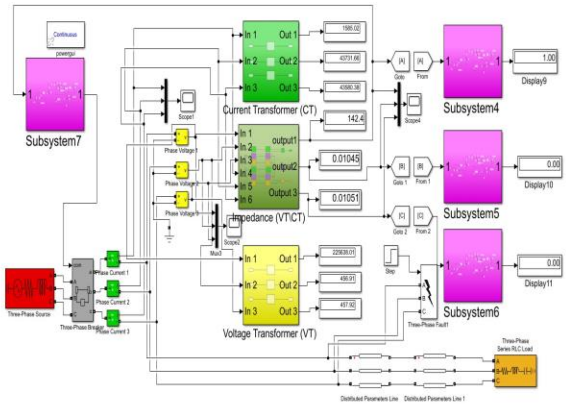

Figure.3. Matlab Simulation of the proposed Circuit of three zones

The circuit model that is provided consists of four separate subsystems. The average current value is determined by (C.T) subsystem. The average impedance value is found in the (Impedance) subsystem. In a similar vein, the (V.T) subsystem measures the average voltage. The design of a relay circuit, which activates anytime the impedance drops below a preset threshold of (1), takes up the final subsystem. The RMS and MEAN VALUE blocks can be utilized to evaluate the average values of certain parameters.

By dividing the average voltage(V.T) by the average current(C.T) in the corresponding phases, the average impedance in the subsystem is found. a relay is designed to sense any drop in impedance on the fault line that falls below a preset threshold. In order to disconnect the line, the relay circuit detects the fault and signals the circuit breaker to do so. The mean impedances of the three phases in(Impedance) subsystem are computed as shown in (Figure.4).

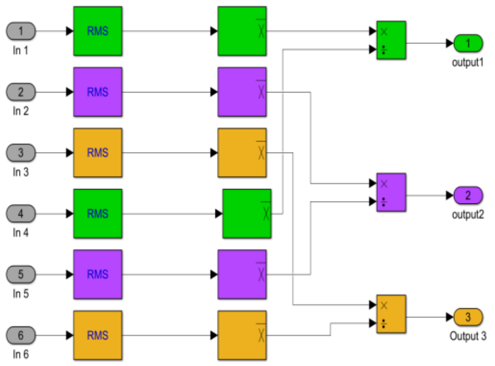

Figure.4 .logical impedance calculation

initially and normal transmission line voltages, currents, and impedances will exist prior to the fault being imposed. Right now, The phase's waveform voltage prior to the fault manifesting is shown in (Figure.5)

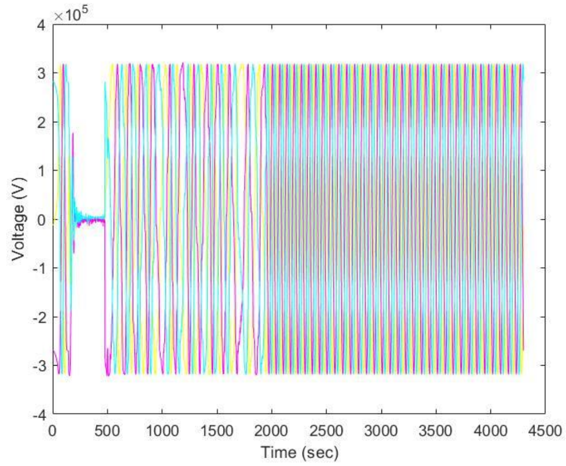

Figure.5 Phase voltage befor fault

The phase after fault voltage after fault waveform is displayed in the (Figure.6)

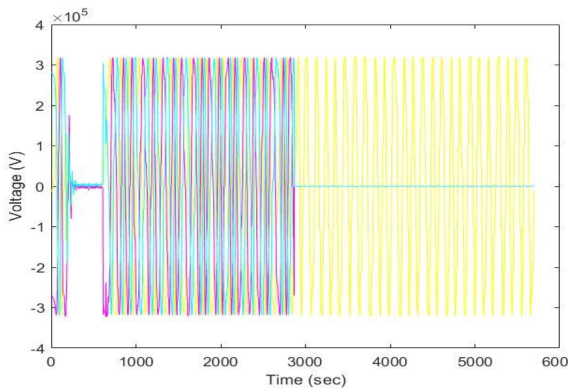

Figure.6 Phase voltage after faul

The phase's waveform current before to the fault appearing is shown in (Figure.7)

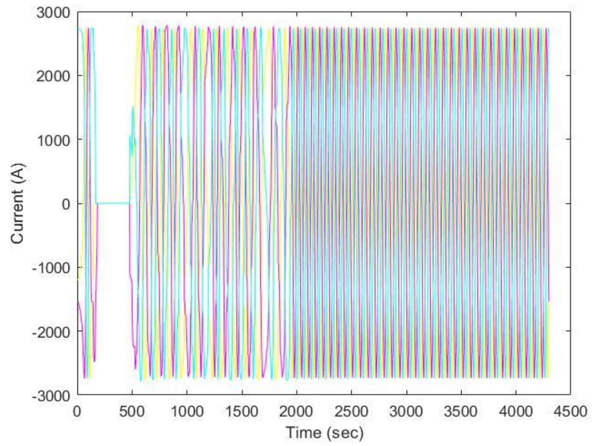

Figure.7 Phase current befor fault

The phase's waveform After a fault, the current will appear is shown in (Figure.8)

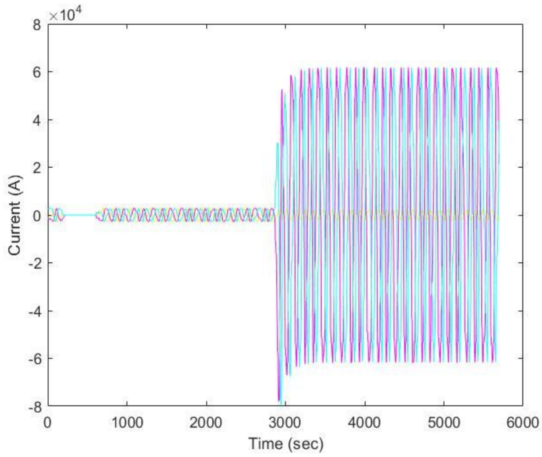

Figure.8 Phase current after fault

The phase's waveform Voltage prior to the problem manifesting in the (Figure.9)

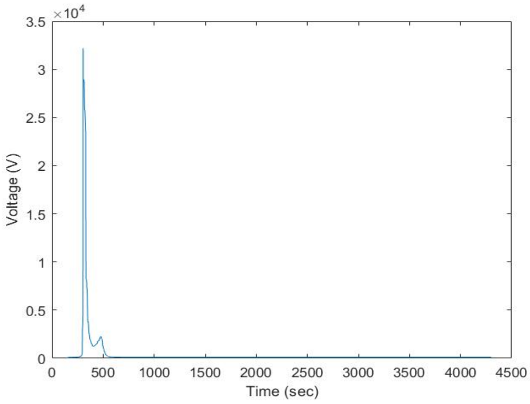

Figure. 9. Impedance waveform when fault is at Phase A

5.1 Impedance Relay Modeling :

The examination impedance relay is based on the Circuit model and the zone protection strategy in the next Simulink model that we will explore similar to (Figure.10):

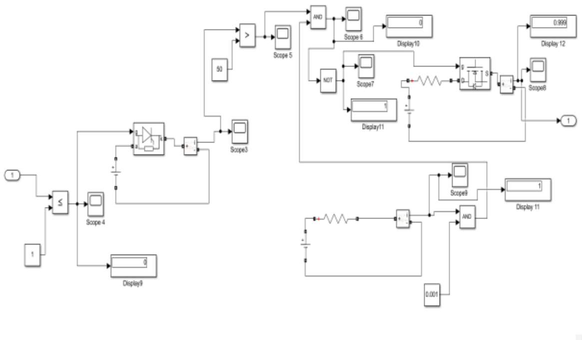

Figure.10 Relay Circuit diagram

We compared the first input, which is the phase impedance (A), using a relational operator based on the electronic circuit diagram above. It will be put into practice with a steady say (1) Phase A faults will cause the impedance to drop sharply and almost completely. The relational operator will produce an output of "1" as a signal. The next circuit's thyristor will be activated by this signal. The signal produced by the relational operator will cause the thyristor to be switched on, creating a current in the subsequent closed circuit. A current transformer (C.T) will be used to measure the current, and output value will then be compared with a low constant using a relationship operator. The output that this comparison procedure seeks to produce is,(1). An AND gate is then fed the previously presence of a logic high signal was noted in conjunction with a consistent high signal., producing an output that assumes a logic high state. The NOT gate, which is coupled to this logic high signal, then produces an output that assumes a logic low state, or "0." From the explanation above, we can deduce that if there are no faults in the line, the NOT gate will display (1), which will allow the MOSFET to shut the circuit and allow a specific amount of current to flow. Using a current transformer, which can provide an exact measurement of the current value, allows one to measure the current in a circuit. The circuit breaker is therefore able to carry out its primary duty of shutting the line thanks to the transmission of this measured value. When a malfunction occurs in the system, fascinating phenomena happens. An essential component of the circuit, the NOT gate produces a logical output of (0). This specific output is very important because it stops the MOSFET from conducting. The three phase transmission line opens as a result of the current transformer's inability to supply the circuit breaker with any current value. This operating procedure demonstrates the critical function of the impedance relay, which is made especially to activate when a problem occurs.

5.2 Impedance Relay of Operation :

Impedance Relays function when there is a change in impedance. They identify these changes and send a trip signal to the C.B.in order to the line is open. will display the impedance relay in the absence of an applied fault. (Figure 11) displays the average values of voltages(V.T), currents(C.T), and impedances(V.T⁄CT).

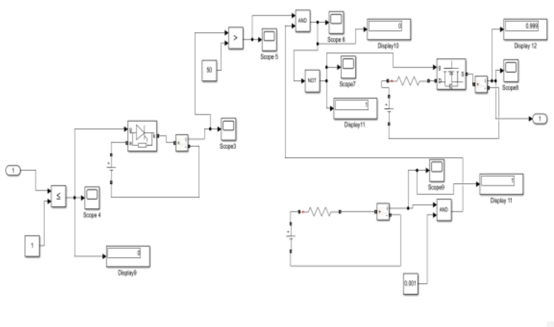

Figure.11. impedance relay diagram

6. The Functioning of Zone Protection Scheme

pertains to safeguarding the power system in a zone-specific manner. Illustrated in Figure 12, the subsequent circuit delineates the configuration of the Zone A protection scheme.

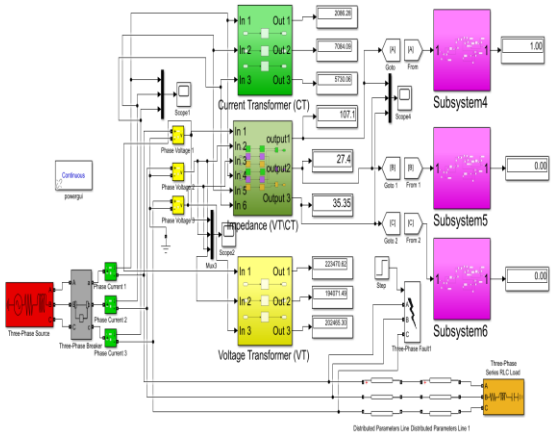

Figure.12 Zone 'A' Protection

When the fault is introduced at the generation end, specifically at zone 'A', the relay circuit incorporated within subsystem 4 will be triggered, resulting in the activation of the first display indicating (1). The appearance of only the first display (1) signifies the occurrence of the fault within zone 'A'.

The behaviour of the impedance with respect to time is show in (Figure.13)

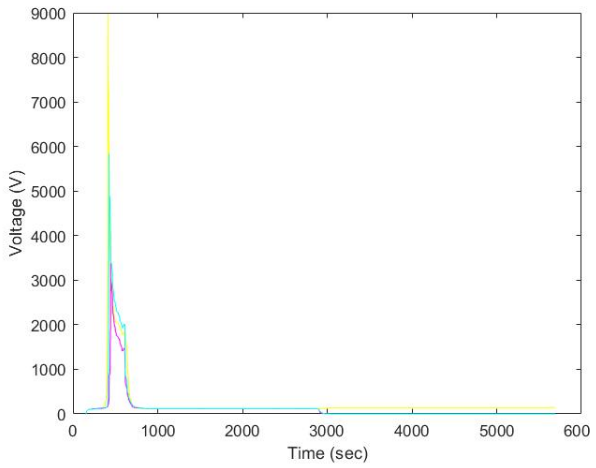

Figure.13. Three phases's waveforms of Impedance when the fault is at zone 'A'

The fault impedances for zone (A) are listed in tabe 1

Phase	Impedance (Ω)
A	107.1
B	27.4
C	35.35

Table 1. Fault impedances at zone(A)

In the following (Figure 14) will show the zone 'B' protection scheme.

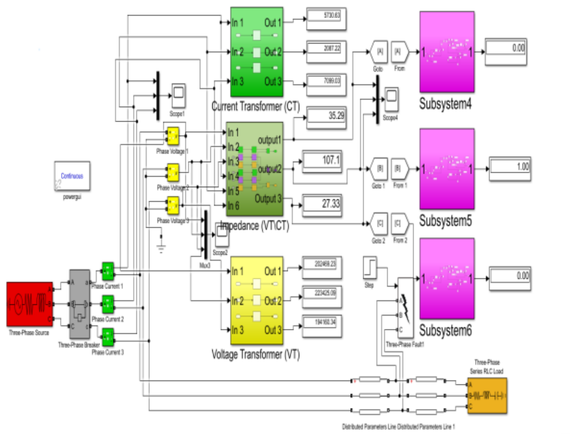

Figure.14. Zone 'B' Protection

When the fault is introduced in close proximity to the midpoint, specifically in zone 'B', the relay circuit incorporated within THE subsystem5 will be triggered, resulting in the activation of only the second displays. The occurrence of the number(1) on the second display indicates the presence of a fault in zone 'B'.

The behaviour of the impedance with respect to time when fault accured at zone (B) is shown in (Figure.15)

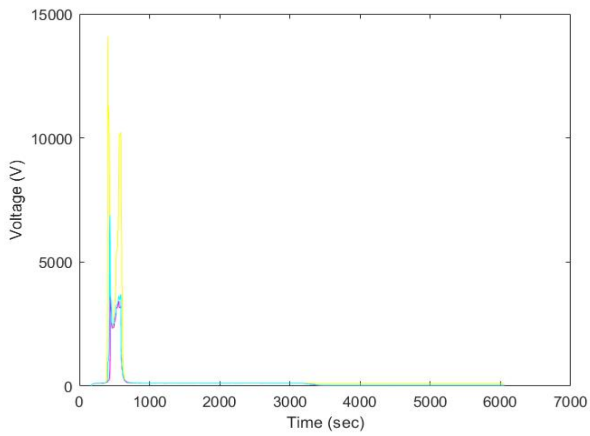

Figure.15. The three phases's waveforms of Impedance when the fault is at zone 'B'

The fault impedances for zone (B) are listed in tabe 2

Phase	Impedance (Ω)
A	35.35
B	107.1
C	27.33

Table 2. Fault impedances at zone(B)

In the following (Figure 16) will show the zone 'C' protection scheme.

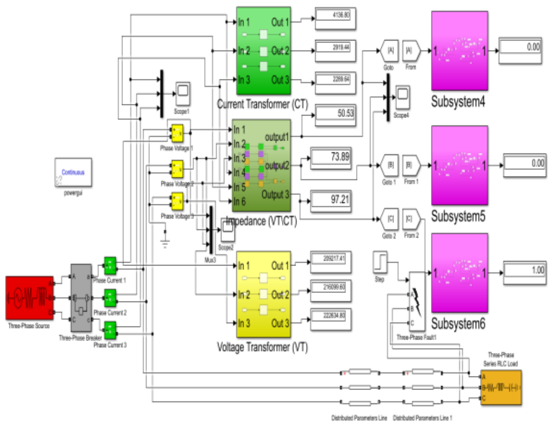

Figure.16. Zone 'C' Protection

When the fault is introduced in close proximity to the load point, specifically within zone 'C', the relay circuit of subsystem6 will be triggered, resulting in the indication displayed on the monitor. This indication signifies that the fault has taken place in zone 'C'.

The behaviour of the impedance with respect to time when fault accured at zone (C) is shown in (Figure.17)

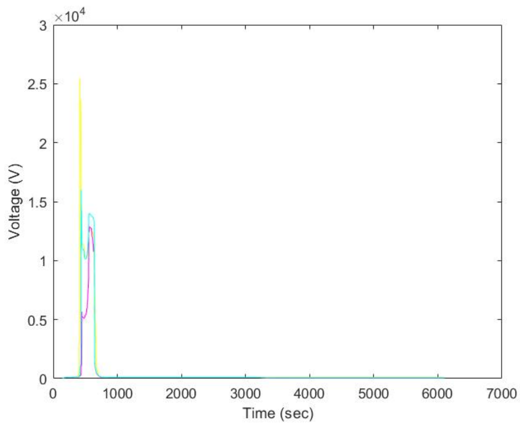

Figure.17. The three phases's waveforms of Impedance when the fault is at zone 'C'

The fault impedances for zone (C) are listed in tabe 3

Phase	Impedance (Ω)
A	50.53
B	73.89
C	97.21

Table 3. Fault impedances at zone(C)

7. Conclusions

From the waveforms, it is inferred that the voltage reaches zero and significant currents, approximately 500 amperes, traverse through the line. It has been concluded that the less impedances appeared in (phase T) for three zones, the less impedance was (27.33 Ω) in (zone B) and lower than that in (zone A) and (zone C) by (8.02 Ω) and (69.88Ω) respectively. As a result of this research, The crucial factors to be taken into account in the design of protection systems are delineated, consequently exerting a significant influence on their efficacy. These factors are encapsulated in a comparative framework, facilitating forthcoming studies on distance protection in operational distribution grids.

REFERENCES

[1] F Alasali, SM Saad, AS Saidi, A Itradat, W Holderbau , (2023) - Elsevier (IEEE Access 9 (2023):), PP. 1899-1924 “Powering up microgrids: A comprehensive review of innovative and intelligent protection approaches for enhanced reliability”

[2] V Psaras, D Tzelepis, G Burt (2023) , International Journal of Electrical Power , “HVDC grid fault location method using genetic algorithm on reconstructed frequency-domain voltage profiles”

[3] M Ginocchi, T Penthong, F Ponci, A Monti , (2024) , (IEEE Transactions on Power Delivery, 2024), “Statistical Design of Experiments for Power System Protection Testing: A Case Study for Distance Relay Performance Testing ,

[4] Halgamuge, Malka N. , (2024), “Leveraging Deep Learning to Strengthen the Cyber-Resilience of Renewable Energy Supply Chains: A Survey” (IEEE Communications Surveys & Tutorials (2024))

[5] Ahmed, A. R., et al., (2024), “Inexpensive short-circuit current limiter and switching device based on one commutation circuit for a three-phase system” , (Journal of Electrical Systems and Information Technology, (IEEE Access 8 (2020))

[6] Rao, HV Gururaja, Nagesh Prabhu, and R. C. Mala , (2020), “Adaptive distance protection for transmission lines incorporating SSSC with energy storage device ” (IEEE Access 8 (2020))

[7] Liang, Yingyu, et al. ,(2019) , "A novel fault impedance calculation method for distance protection against fault resistance , (IEEE Transactions on Power Delivery)

[8] Panahi, Habib, et al. (2021) , "Advances in transmission network fault location in modern power systems: review, outlook and future works."

[9] Hadi saadat , Power sysyem analysis , McGraw-Hill companies ,Stephen W. Director , University of Michigan Ann Arbor , pp:422 , Eq(10.62) .

[10] Wang, Hualei. The protection of transmission networks containing ac and dc circuits. Diss. University of Bath, 2014.pp:56

[11]. Rivas, Angel Esteban Labrador, and Taufik Abrao. "Faults in smart grid systems: Monitoring, detection and classification." Electric Power Systems Research 189 (2020).

[12] Wontroba, Aldair, et al. "High-impedance fault detection on downed conductor in overhead distribution networks." Electric Power Systems Research 211 (2022).

[13] Satria, Habib, et al. (2024) , "Development of energy conversion and lightning strike protection simulation for photovoltaic-wind turbine on grid." International Journal of Electrical & Computer Engineering