PERFORMANCE IMPROVEMENT FOR DISTANCE RELAY BASED FUZZY LOGIC FOR ALL PROSPECTIVE FAULTS

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Abstract:- *The advanced application of fuzzy logic was introduced recently in protection of power system transmission lines. In this paper, a three-phase distance relay was designed by using an adaptive neuro-fuzzy inference system algorithm (ANFIS) that produced a fuzzy logic system (FS), which used to protect the overhead transmission lines where these lines are exposed to the faults continuously being built in outdoor and accompanied with the fault a high electrical current to large values lead to the destruction of electrical equipment in the power system. The paper had studied of adding a load to the end of the line as (over load) and also adding a load in the center of the transmission line (adding an intermediate station as load) where the designated distance relay with fuzzy system was successful in distinguishing between these cases and cases of real faults in the transmission line on at variance of the classical distance relay that cannot distinguish between disturbance cases and faults cases.*

The ANFIS was designed to generate FS into two parts:

The first part: works to detect the faults in the transmission line by measuring the voltage signal and current for each phase and calculate the value of line impedance and through it, the fault will be detected and its location within the first zone or the second zone so that if the fault occurred within the first zone, the distance relay will issue instantaneous trip signal to circuit breaker (C.B) to separate the fault from the transmission line, or if the fault occurred within the second zone , the distance relay will delay trip signal to circuit breaker. The second part: works to detect the location and type of the fault in the transmission line by measuring maximum peak value of currents of the three phases in order to determine the fault location as well as the type of the fault. Final results show the performance improvement for distance relay based fuzzy logic for fault detecting and distinguish the cases of the disturbance as well as determine the protection zones, location and type of faults in the transmission line.

Key Words: Transmission Line, Fault Location, Fault Classification, Distance Relay, ANFIS, and Fuzzy Relay.

1. INTRODUCTION

The overhead transmission lines one of the main parts in the power systems. Since the transmission lines are exposed to the surrounding environmental conditions and the possibility of a fault occurs on these lines is higher than other major parts of the power system [1]. When a fault occurs on the transmission line, it is necessary to detect and identify the type and the location to separate the fault and return the power system to its normal as soon as possible. Because the required time to know the location of the fault along the transmission line will affect the quality of power distribution, and for this, that the speed of determining the fault location must be found that will provide time for repair and maintenance of the transmission line in which the fault was occurred in the system in order to restore and distribution of electric power transmission. The detecting of disturbance that occur in power systems are necessary to cut in the distribution of electric power to consumers [2].

In general, faults can be classified into two types:

1. Symmetrical Faults [3]:

These occur because of the short circuit of the current of the three phases and they are most influential types of faults that effect on the system and less occurred. The appropriate percentage of occurrence of this fault is 3%

2. Non-symmetrical Faults [3]:

There are usually several types can be summarized in following with the appropriate percentage of occurrence:

i. Single line to ground fault (SL-G) 70-80%
ii. Line-to-Line to ground fault (DL-G) 10 -17%
iii. Line-to- Line fault (DL) 8-10 %

2. Distance Relay

Due to the growth of power systems in terms of size and complexity needed to use protection relays with high speed performance to protect the main parts and maintain the stability of power system. There are several protection systems are used to protect the transmission lines with high voltage of 400kv or higher. Distance relays have a good advantage to give an elementary protection and back up protection for the transmission line, and this protection is based on the measurement of voltage signal and the current signal at the relay location to calculate the value of impedance for the protected line (impedance account that is at the fundamental frequency) which compare with the pre-calculated impedance called (setting impedance) that are sensitive for existing the fault when a difference occurred in impedance of the transmission line from the reference impedance (setting impedance) so it will issue trip signal.[4]

Because of errors in the measurement transformers and changes in loads in additional to the sources of the power system and different fault conditions depend on ground resistance .The distance relay may not provide complete protection along the protected line from one side ,so the protection zones are coordinated to distance relay as shown in Figure (1) that shows the first protection zone ,the second protection zone and the third protection zone if a third zone was required to consecutive in terms of operating time for each zone and in terms of gradation as the following:[5][6]

1- The first zone covers almost 80% of the length of the section.

2- The second zone covers almost 120% of the length of the section.

3- The third zone covers almost 200% of the length of the section.

If a fault occurred in the first zone a trip signal will be issued from the relay to circuit breaker instantaneously and quickly to separate the fault from the transmission line but in the second and third zone, the relays are delayed with duration of time to minimize the possibility of erroneous prediction for the faults [5].

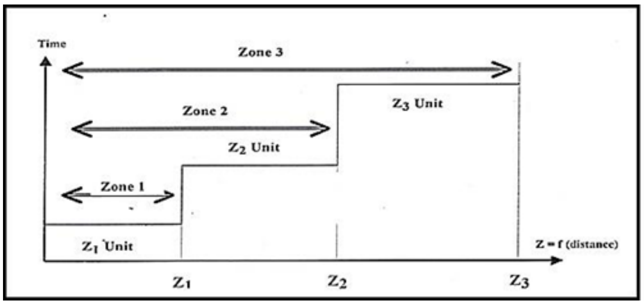


Fig-1: Explain the time- the distance drawing for protections zones for distances relays [5].

3. THE ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM (ANFIS)

The using of fuzzy controller lonely is often followed by the difficulty in the formation of fuzzy rules as well as how to design membership functions from the degree of overlap between them and its dimensions due to the evolution, complexity and increasing of the systems requirements, and this in turn requires the development of fuzzy controller to ANFIS controller for collect the benefits of each of the artificial neural networks and fuzzy logic[7] .The capability of learning of neural networks giving a good way to adjust the design of the fuzzy controller that self-generate fuzzy rules and membership functions for meeting of the required specifications and this in turn reduces from design time. The definition of membership functions forms, numbers and extent of each of them, as well as overlapping points, has a great impact on system response. Where it is often the designer uses a method of (trial and error) to find acceptable values as well as the overlap between membership functions, as fuzzy logic and neural networks have some common features such as guessing and the ability to process the data.[8]

3.1 Adaptive Neural Network Structure

In this system, a method of fuzzy inference, type of (Takagi-Sugeno) and the output of each rule can be a linear component for input changes plus a constant value, or to be only a constant value. The final output is a weighted average to output of each rule, where we suppose the presence of only two entries for (ANFIS) network ,(x,y) and one output (f) as in Figure (2) which contain two rules as below:[9]

Rule1: If x is A_1 and y is B_1 then $f_1=p_1 x+q_1 y+r_1$ (1)

Rule2: If x is A_2 and y is B_2 then $f_2=p_2 x+q_2 y+r_2$ (2)

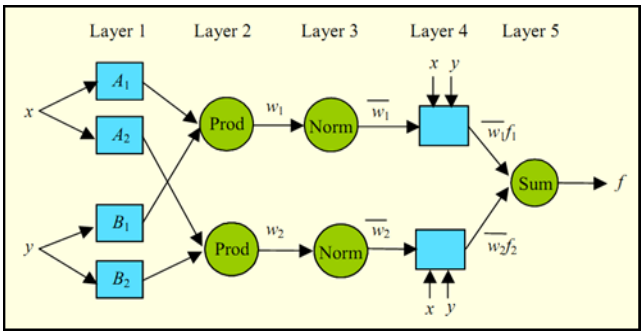


Fig-2: ANFIS construction [9].

From Figure (2) the fuzzy inference is divided into five layers can be summarized as follows [10][11]:

The first layer: This layer describes the type of membership functions of the input, and each node (i) in this layer is adaptive node with node function. Where in the training process the elements of this node is changed (which are membership functions for input, So less error can get possible in the output.

$O_{1,i}=\mu_{Ai}(x)$ for i=1,2 (3)

$O_{1,i}=\mu_{Bi-2}(y)$ for i=3,4 (4)

Where

μAi and $\mu Bi-2$ are degrees of affiliation to the input membership functions (x, y) are inputs to node (i)

A_i or (B_{i-2}) linguistic signals for input such as "small" or " large" sets and O_{1i} is membership function degree for fuzzy group (A)

The membership functions in (A) & (B) can take any form, such as triangular and trapezoidal and the elements in this layer called (premise parameters).

The second layer: Each node in this layer is a fixed node indicated by the symbol (Π) as the output of this node is in the fact a multiplication of all incoming signals to that node:

$O_{2,i} = W_i = \mu_{Ai}(x) * \mu_{Bi}(y) \quad i=1,2 \qquad (5)$

The output of each node in this layer represents a rule of fuzzy rules and in this layer no changing process or updating for the weights.

The third layer: Each node in this layer is fixed node indicated by the symbol (N) where the node (i) in this layer is calculated a participation rate of the rule (i)for the total participations of all rules.

$$O_{3,i} = \overline{W_i} = \frac{w_i}{(w_1 + w_2)} \quad i=1,2 \qquad (6)$$

The output of this layer are called (normalized firing strengths)

The fourth layer: Each node in this layer is adaptation node function as below:

$$O_{4,i} = \overline{w_i}\, f = \overline{w_i}\, (p_i\, x + q_i\, y + r_i) \quad i=1,2 \qquad (7)$$

Where $\overline{w_i}$ is output of the third layer and (r_i, q_i, p_i) are a group of elements of that node are called (consequent parameters).

The fifth layer: The single node in this layer is fixed node indicated by the symbol (Σ) As the output of this layer represents the final output of the system, which is a total of all incoming signals into this node or in other words (total of contributions from each rule):

$$\text{Overall output} = O_{5,I} = \frac{w_1\ f_1 + w_2\ f_2}{w_1 + w_2} \qquad (8)$$

4. POWER SYSTEM MODEL

The system was modeled using MATLAB-Simulink that consists of the 400kV, 50Hz generating station, 242Km transmission line length and P=310MW, Q=35MVAR load in the end of line. Distance relay is modeled to protect the transmission line as shown in Figure (3).

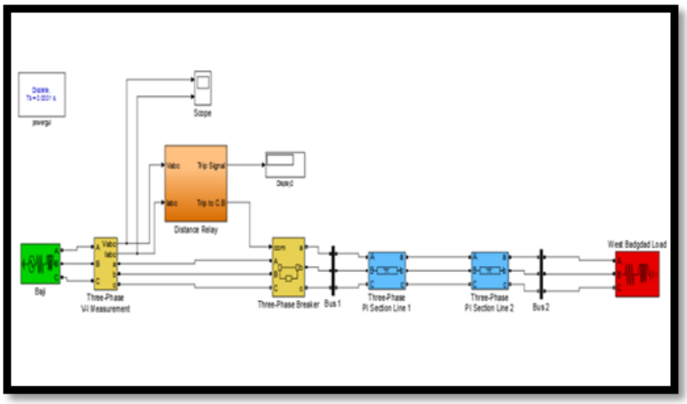


Fig-3: Matlab model of sample Power System.

1. Generating station: the voltage with 400Kv and frequency of 50Hz

2. Transmission line: transmission line was represented through the three-phase section of the following values:

Line length= 242Km

$[R_{L1}, R_{L0}] = [0.034, 0.3]$ Ω/km

$[L_{L1}, L_{L0}] = [0.001, 3.1e\text{-}3]$ H/km

$[C_{L1}, C_{L0}] = [23.23, 14.7]$ Ω/km

3. Distance relay: detect the appearance of faults in the transmission line and then identify the type and location of the fault.

4. Measurement template: used to measure the phase voltage and current line for each phase.

5. Circuit breaker: working on the separation of the power plant from the transmission line in the event of fault on the transmission line.

6. The load: the load attached at the end of the line and the value of load (P=310MW, Q=35MVAR).

The below Figure (4) shows (the Mathematical Model) for distance relay that generate a trip signal to circuit breaker instantaneously when fault occurs within the first zone but if the fault occurred in the second zone there is a time delay in the trip signal.

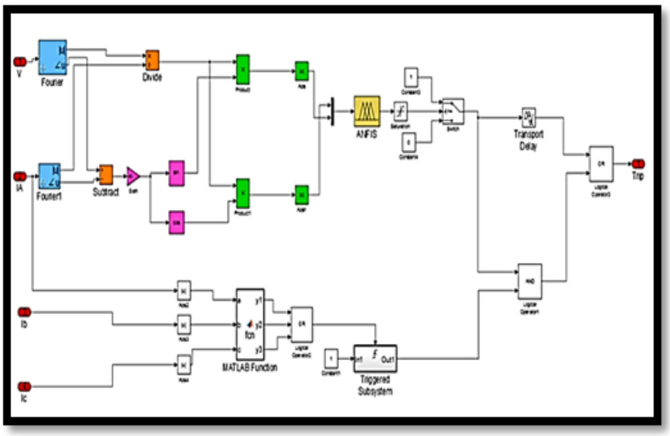


Fig-4: Mathematical model of a proposed fuzzy distance relay.

Figure (5) shows how to calculate the location and type of faults by depend on the values of the maximum peak currents of the three phases where there are two neural networks, one to calculate the location of the fault and the other to see the location of the fault. Table (1) and Table (2) show the characteristics of three proposed ANFIS.

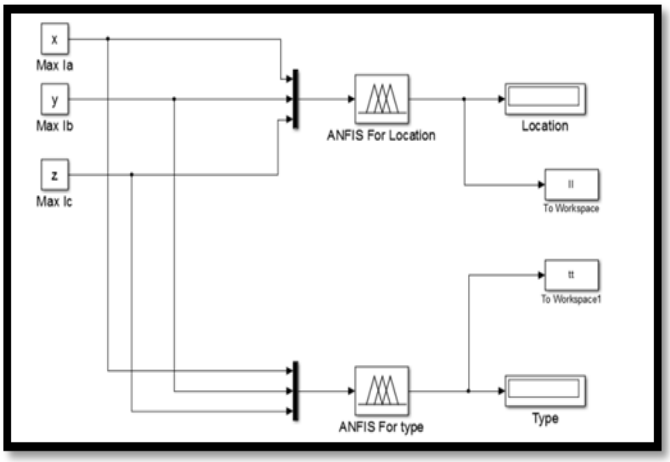


Fig- 5: Neural fuzzy networks to detect the type and location of the fault by depend on the values of the maximum peak currents of the three phases.

Table-1: Shows the characteristics of ANFIS to detect the faults in the transmission line

Membership Function Type	***Triangle***
The number of entries	***2 (R&X)***
Number of input nodes	***14 (7 each input)***
Number of rules nodes	***49***
Number of output nodes	***49***

Table-2: Shows the characteristics of ANFIS to detect the faults location in the transmission line.

MembershipFunction Type	***Gbell***
The number of entries	***3 (current of three phase)***
Number of input nodes	***30 (10 each input)***
Number of rules nodes	***1000***
Number of output nodes	***1000***

Table-3: Shows the characteristics of ANFIS to detect the faults type in the transmission line.

Membership Function Type	***Gbell***
The number of entries	***3 (current of three phase)***
Number of input nodes	***21(7 each input)***
Number of rules nodes	***343***
Number of output nodes	***343***

5. Designed Fuzzy distance relay using ANFIS algorithm

After a system was run in a one second and the fault duration for 0.5 seconds with a sampling frequency of 10 kHz that meaning the voltage signal and the current of the system will be divided into 200 samples, which consisting of 200 element can be handled by using the (MATLAB), the sampling frequency 10 kHz is the best in terms of execution speed and deformation wave compared with the rest of the highest and lowest frequencies of it.

A FS flowchart that explain the operation for three-phase Fuzzy distance relay for the purpose of distinguishing between fault case and other transient cases as well as finding the value and the angle of each of the signal current and voltage (at a base frequency 50 Hz) to calculate the value of impedance and compare it with the setting impedance, and then find out whether the fault inside or outside the protected zone .the relay has six entries represented by currents and voltages of the three phases and has a single output that send as trip signal to the circuit breaker.

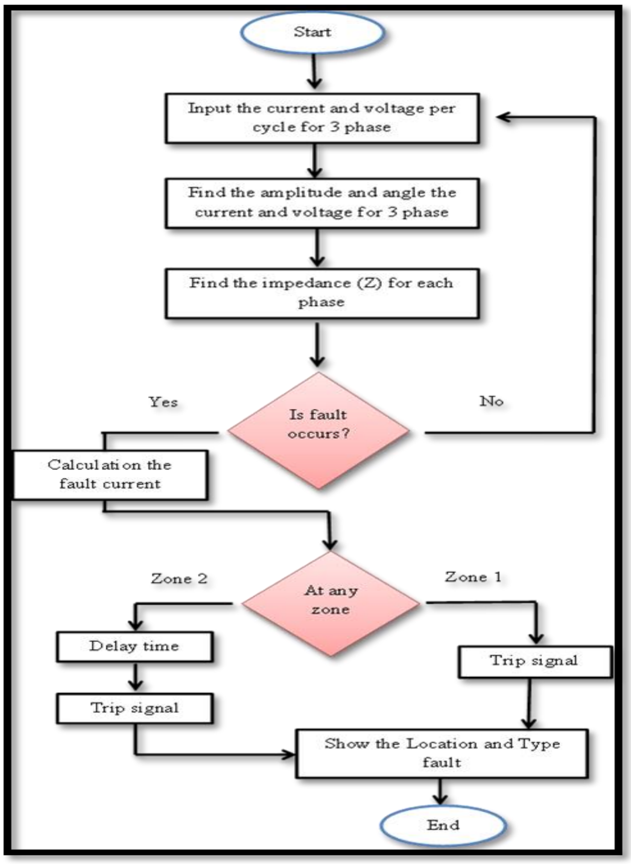


Fig-6: FS flowchart for distance relay.

6. SIMULATION RESULTS

The designed relay was testing to ensure its ability to detect the faults, possibility on classification the faults type, determine fault location in the transmission line and identification of protection zone. Many cases were doing for most prospective cases. Table (4) summarized the test results of the designed Fuzzy distance relay where the highest peak of the current values of the three phases (P_A, P_B. P_C) at each fault case as well as detection of the location of the faults by the relay and a trip signal that sent to circuit breaker to separate the fault. The percentage error in the damping of the relay also shown in this results table where the error can be calculate from equation (9) :[12, 13]

$$\text{Error\%} = \frac{L_a - L_e}{L_{Total}} * 100 \tag{9}$$

La: Actual fault location

Le: Estimated fault location

L_{Total} : Line Length

Table-4: Test results of proposed Fuzzy distance relay

No	Fault type	Actual fault location %	Actual fault location [Km]	Estimated fault location [Km]	Error %	Peak current Ia [KA]	Peak current Ib [KA]	Peak current Ic [KA]	Trip signal to C.B
1	A-G	73	176.66	177.38	0.29	4.613	0.80	1.054	Instantaneous Trip
2	A-G	97	234.74	235.95	0.5	3.67	0.80	1.06	Delay Trip
3	B-G	30	72.60	72.28	0.13	1.08	7.24	0.795	Instantaneous Trip
4	B-G	90	217.80	218.76	0.39	1.06	3.32	0.795	Delay Trip
5	C-G	10	24.2	24.17	0.01	0.88	0.87	14.20	Instantaneous Trip
6	C-G	85	205.70	201.58	1.7	0.793	1.09	3.36	Delay Trip
7	AB-G	15	36.3	36.3	0	17.3	14.4	0.97	Instantaneous Trip
8	AB-G	92	222.64	223.07	0.17	6	4.85	0.92	Delay Trip
9	BC-G	50	121	121	0	1.12	6.66	4.28	Instantaneous Trip
10	BC-G	88	212.96	214.62	0.68	0.939	4.51	3.52	Delay Trip
11	A-B	43	104.06	101.97	0.86	9.50	8.71	0.795	Instantaneous Trip
12	A-B	80	193.6	191.85	0.72	6.42	5.62	0.795	Delay Trip
13	B-C	66	159.72	158.82	0.37	0.793	4.75	4.06	Instantaneous Trip

The following test cases show the voltages and current of the system before and after fault occur:

1. Single phase to the ground fault (SL-G)

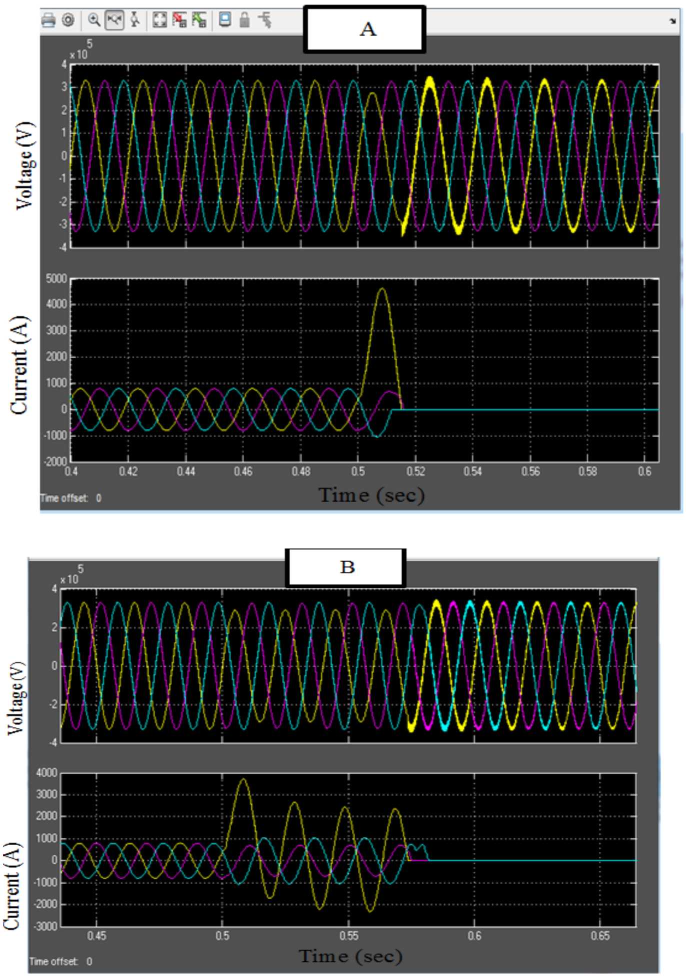
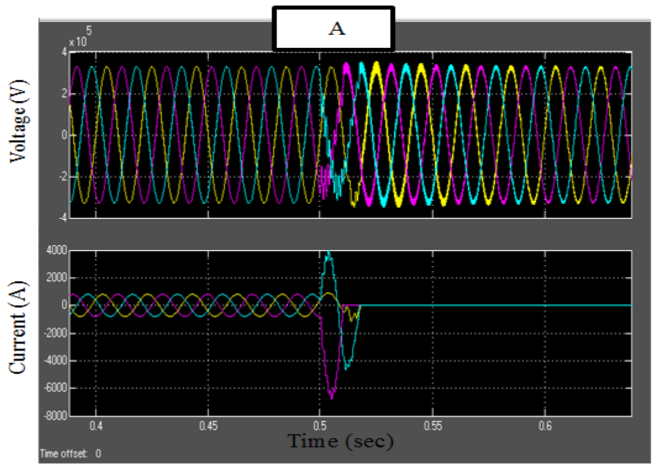


Fig- 7: Voltage and currents signals for fault case (A-G): where (A) within the first zone in the location of 73% of the length of the protected line and (B) within the second zone in the location of 97% of the length of the protected line.

2- Two-phase faults to the ground (DL-G)



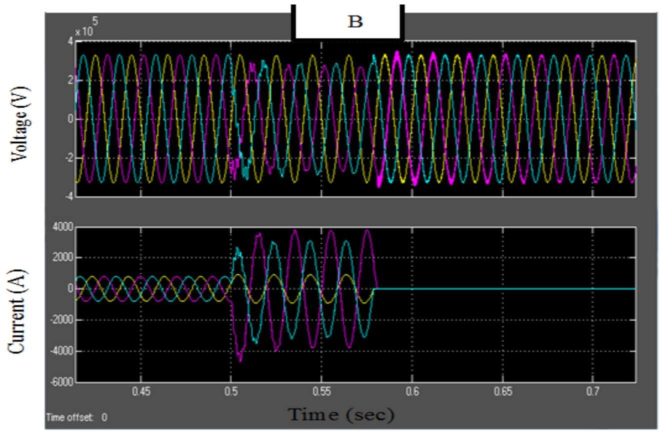


Fig- 8: Voltage and currents signals for fault case (BC-G) where: (A) within the first zone in the location of 50% of the length of the protected line and (B) within the second zone in the location of 88% of the length of the protected line.

3- Two-phase faults (DL)

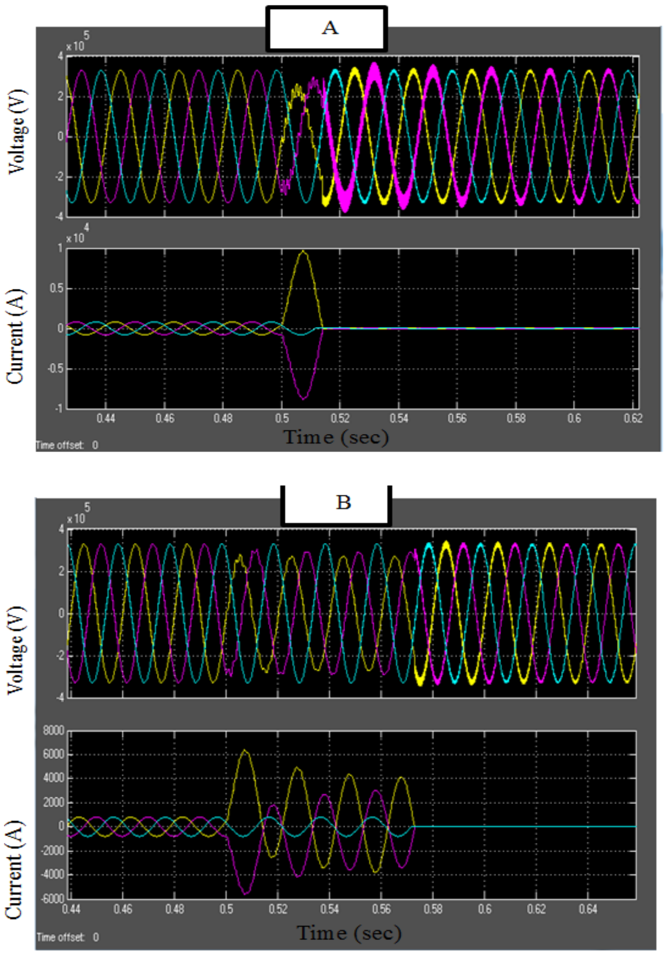


Fig- 9: Voltage and currents signals for fault case (AB) where: (A) within the first zone in the location of 43% of the length of the protected line and (B) within the second zone in the location of 80% of the length of the protected line.

7. CONCLUSION

The proposed Fuzzy distance relay that had been designed using an ANFIS was successful detected the faults in the transmission line as well as determine the location of the faults and classification the fault type. Through the results, it is concluded that the highest percentage of error in determining the fault location was 2.06% and the percentage of success in the classification of the type of fault is 100% so the relay was able to distinct between types of faults (single, double, double to ground and three phases.

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