

SIMULATION AND DESING OF THE DISTANCE RELAY BY USING ANFIS TO DETECT FAULTS IN (BAIJI - WEST BAGHDAD) TRANSMISSION LINE

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Abstract— In this research, a three-phase distance relay was designed by using an adaptive neuro-fuzzy inference system algorithm (ANFIS) 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 adaptive neuro-fuzzy inference system (ANFIS) was designed 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 instantous 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.

Index Terms— Transmission Line, Fault Location, Fault Classification, Distance Relay, ANFIS.

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, we find that the speed of determining the fault location 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].

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Faults are classified into two types:

1. Symmetrical Faults [3]: these that 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 - 3%
2. Non-symmetrical Faults [3]: they are usually several types such as and the appropriate percentage of occurrence of these faults:
 - 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 of performance to protect the main parts and maintain the stability of the system. There are several protection systems are used to protect the transmission lines with high voltage of 400kv or higher which are distance relays that 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) and then this impedance 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 for measurement transformers and changes in loads and the sources in the power system as well as different fault conditions as ground resistance .The distance relay may not provide complete protection along the protected line 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].

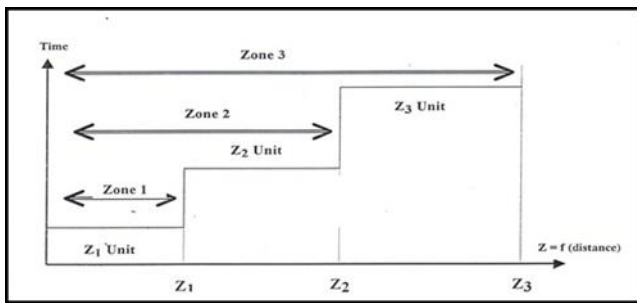


Fig.1 Explain the time- the distance drawing for protections zones for distances relays.[5]

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, complex-

ity 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 Fig. (2) which contain two rules as below:[9]

Rule1: If x is A1 and y is B1 then $f_1 = p_1 x + q_1 y + r_1$ (1)

Rule2: If x is A2 and y is B2 then $f_2 = p_2 x + q_2 y + r_2$ (2)

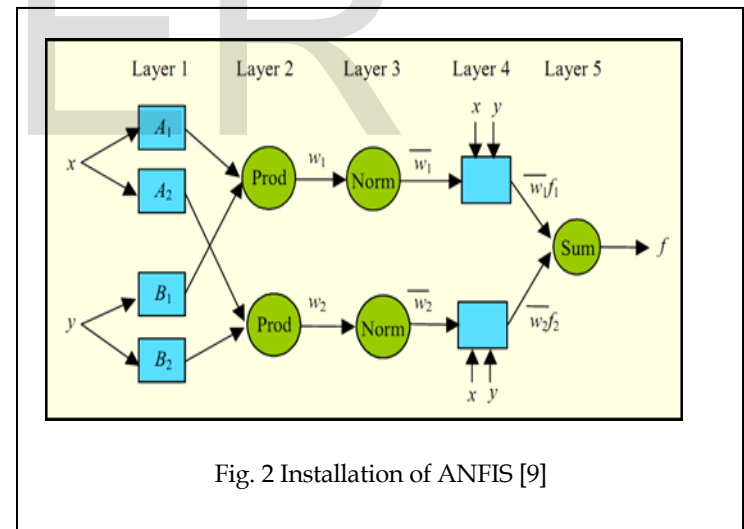


Fig. 2 Installation of ANFIS [9]

We notice from Fig. 2 that the fuzzy inference is divided into five layers below is detailed explanation of each layer [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 we get less error possible in the output.

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

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

Where

μ_{Ai} and μ_{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:

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

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.

$$O_{3,i} = (w_i)^- = w_i / (w_1 + w_2) \quad i=1,2 \quad (6)$$

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

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

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

Where $(w_i)^-$ 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):

$$\text{Overall output} = O_{5,1} = \frac{w_1 f_1 + w_2 f_2}{w_1 + w_2} \quad (8)$$

4. REPRESENTATION OF POWER SYSTEM

The system was represented by using a (MATLAB 2013a) program which consists of the power system from generating station with 400Kv , frequency of (50Hz), transmission line length of 242Km and the linked load in the end of line with a value of (P=310MW,Q=35MVAR) and distance relay to protect transmission line as in fig. 3

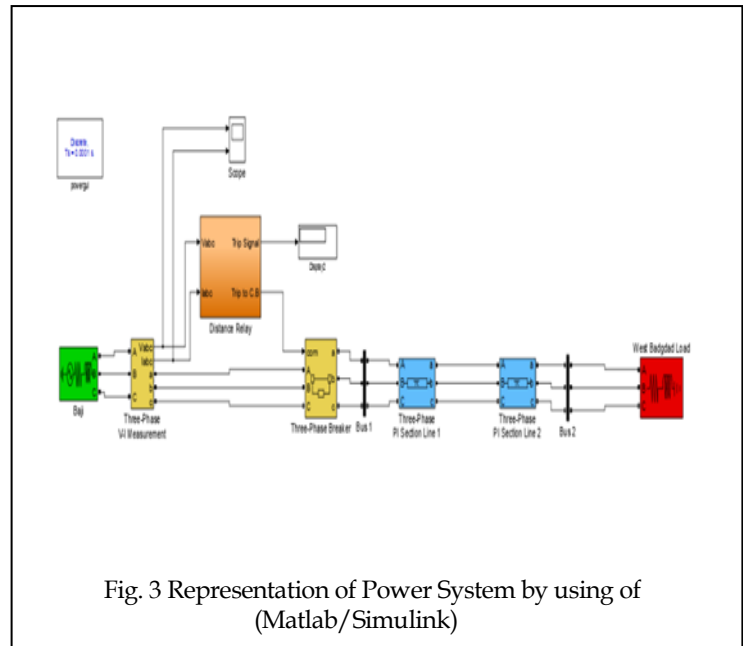
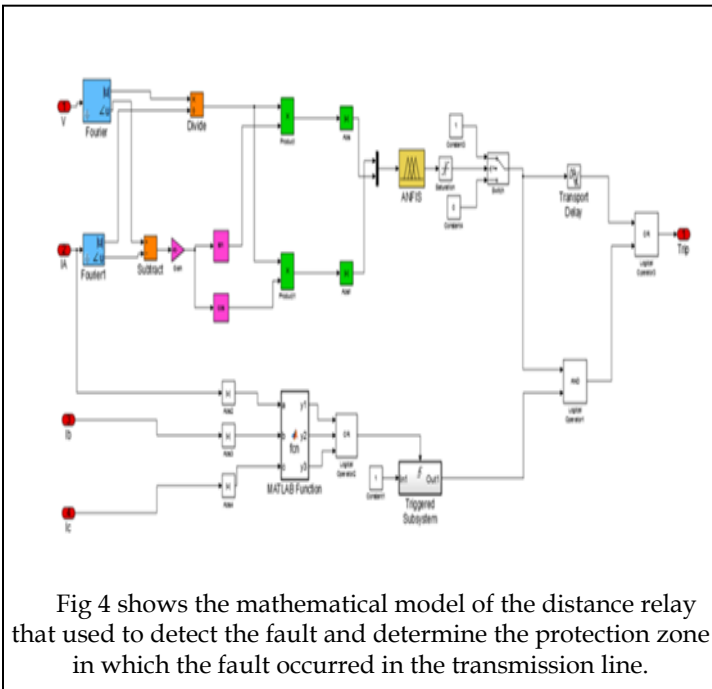


Fig. 3 Representation of Power System by using of (Matlab/Simulink)

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
 $[RL1, RL0] = [0.034, 0.3] \quad \Omega/\text{km}$
 $[LL1, LL0] = [0.001, 3.1e-3] \quad \text{H/km}$
 $[CL1, CL0] = [23.23, 14.7] \quad \text{nF/km}$
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 shows (the Mathematical Model) for distance relay where issues a trip signal to circuit breaker instantaneously in event of a fault within the first zone but if the fault occurred in the second zone there is a time delay in the trip signal.



The 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.

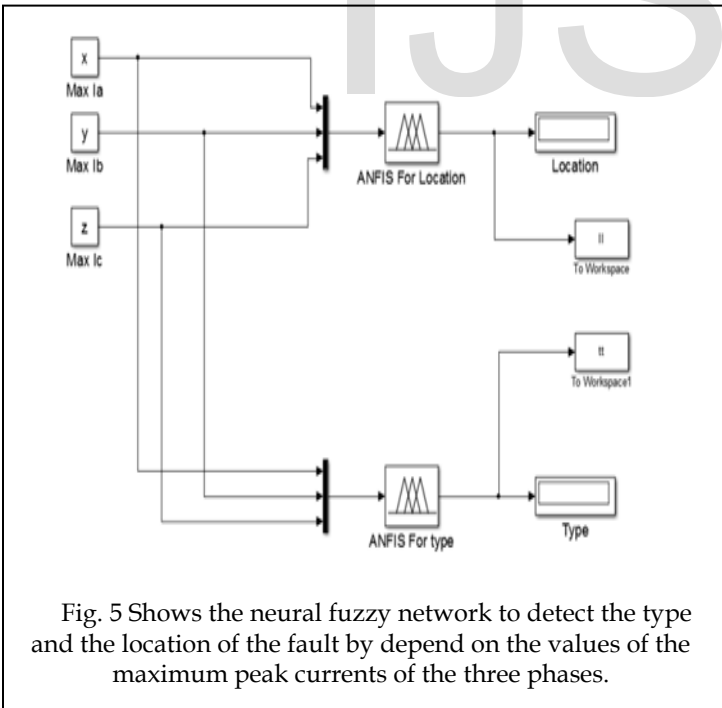


TABLE 1
 Shows the characteristics of ANFIS to detect the faults in the transmission line.

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

Membership Function 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

4.1 Designed distance relay by using ANFIS algorithm

After the shown Power System linked in the figure (3) in the modeling program (MATLAB R2013a). The system ran in a one second and the fault worked at 0.5 seconds. The sampling frequency that used equal to (10 KHz) meaning that each circuit of the voltage signal and the current of the system will be divided into 200 samples representing consisting of 200 element can be handled by using the (MATLAB), the sampling frequency that used equal to (10 KHz) to be the best in terms of execution speed and deformation wave compared with the rest of the highest and lowest frequencies of it.

The fig.6 Flowchart that represent three-phase distance relay algorithm shows by using an adaptive neural network (ANFIS) and 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 which is trip signal send a trip signal to the circuit breaker.

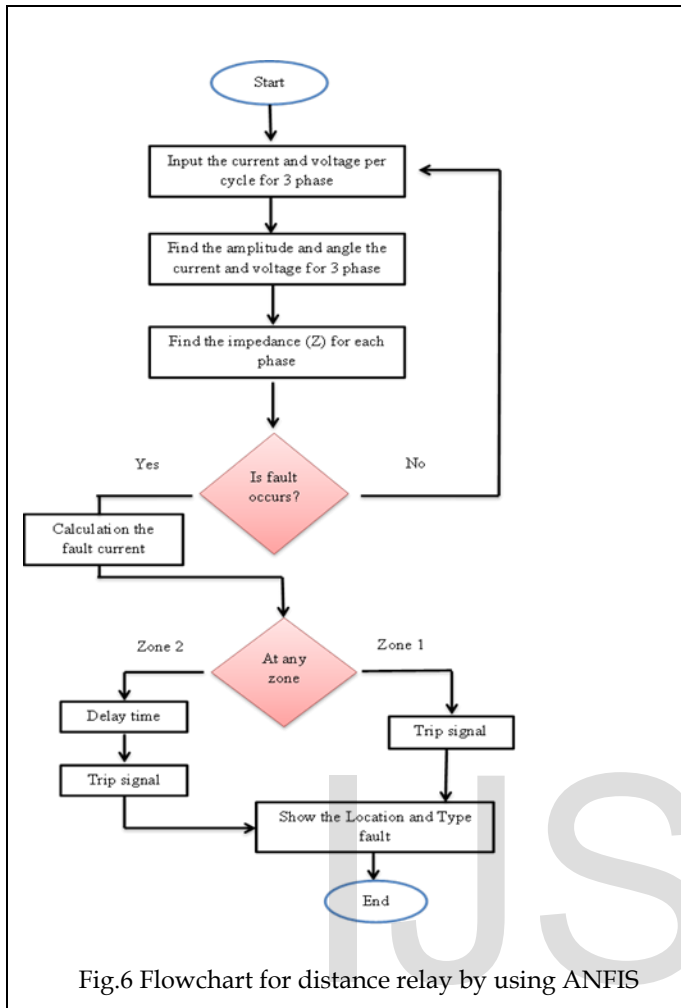


Fig.6 Flowchart for distance relay by using ANFIS

5. Designed relay algorithm of (ANFIS) Test Results

For testing the designed relay and to ensure its ability to detect the faults as well as the classification of the type of faults and determine the location of the faults in the transmission line and identification of protection zone, in which the fault was done. We doing many faults cases on the transmission line and at several locations on the line.

The table (4) shows the test results of the designed distance relay where the table shows the highest peak of the current values of the three phases (PA, PB, PC) at each fault case as well as detection of the location of the faults by the relay as well as a trip signal which the relay sent to circuit breaker to separate the fault and the percentage of error in the damping of the relay of the fault location during the following law:[12]

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

L_a : Actual fault location
 L_e : Estimated fault location
 L_{Total} : Line Length

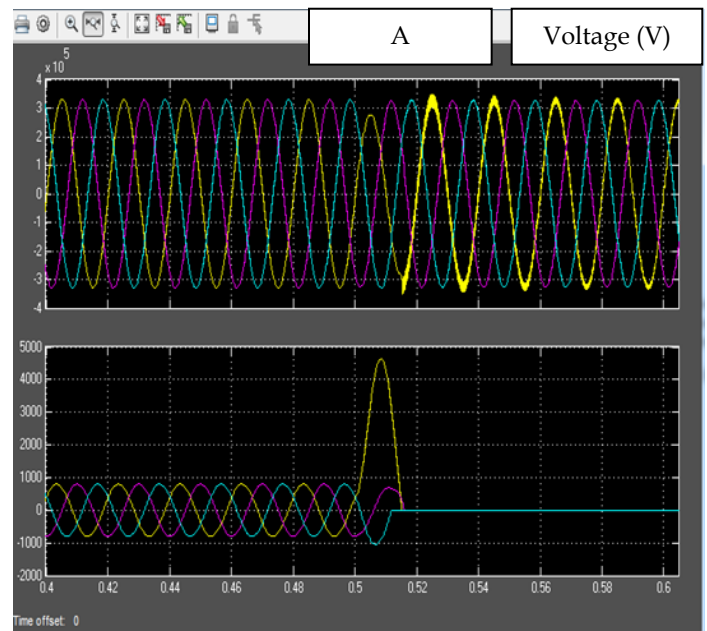
TABLE 4
Shows the test results for distance relay

No	Fault type	Actual fault location %	Actual fault location [Km]	Estimated fault location [Km]	Error %	Peak current I_a [KA]	Peak current I_b [KA]	Peak current I_c [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

5.1 Representation Results

The following forms show the case of voltages signal and the current of the system before and after the occurrence of the faults where the fault occurred at (t = 0.5 sec.)

1. Case of single phase faults to the ground (SL-G)



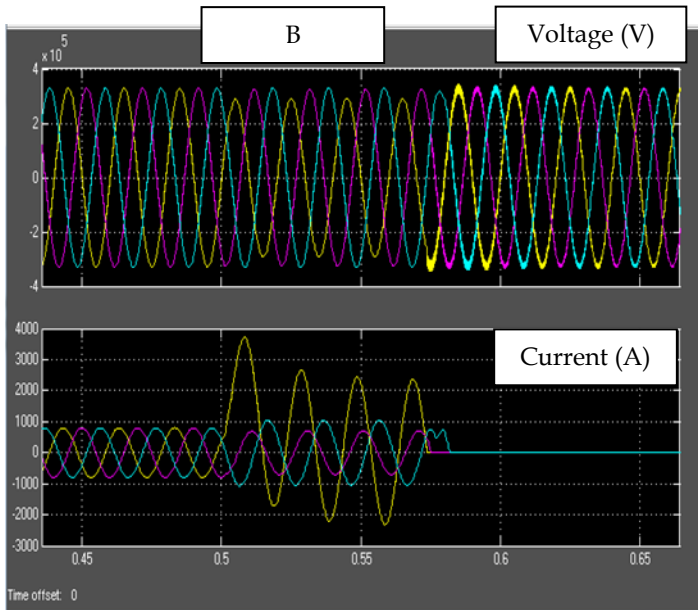


Fig. 7 Shows the voltage signals and currents for fault case (A-G): (A) within the first zone in the location of 73% of the length of the protected line (B) within the second zone in the location of 97% of the length of the protected line.

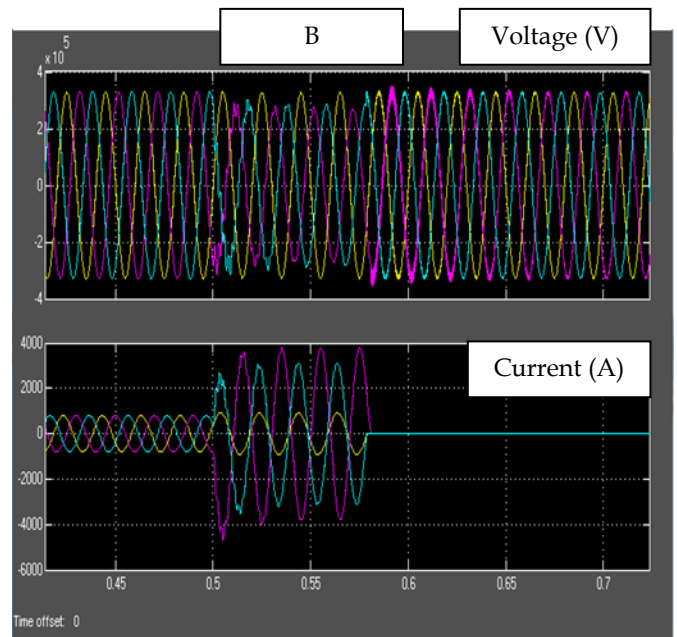
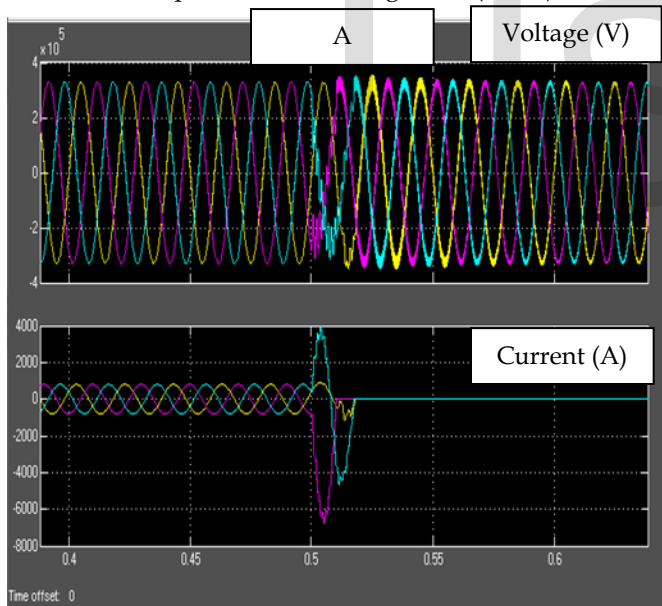
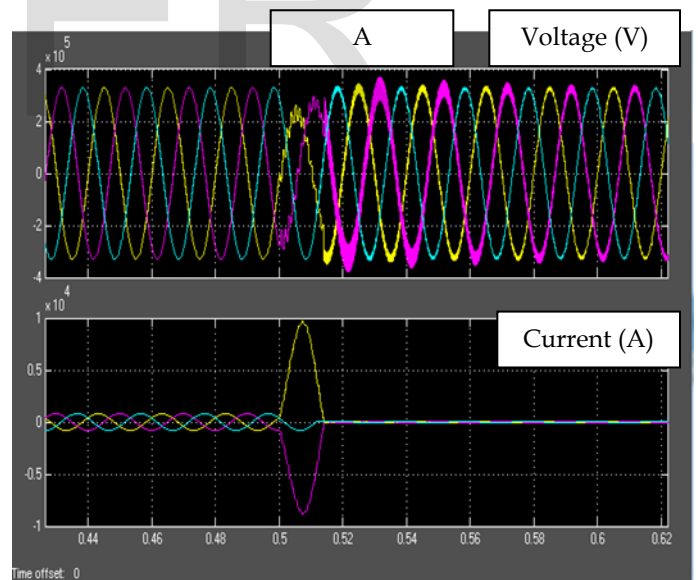


Fig. 8 Shows the voltage signals and currents for fault case (BC-G): (A) within the first zone in the location of 50% of the length of the protected line (B) within the second zone in the location of 88% of the length of the protected line.

2- Case of two-phase faults to the ground (DL-G)



3- Case of two-phase faults (DL)



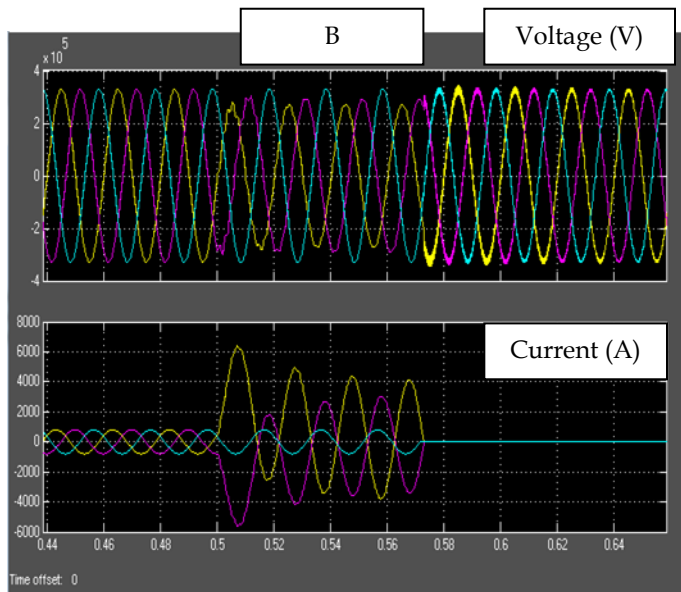


Fig. 9 Shows the voltage signals and currents for fault case (AB): (A) within the first zone in the location of 43% of the length of the protected line (B) within the second zone in the location of 80% of the length of the protected line

6 CONCLUSION

The distance relay that has been designed by using an The adaptive neuro-fuzzy inference system (ANFIS) was successful to detect the faults in the transmission line as well as determine the location of the faults and classification the fault type. Through the results, we note that the highest percentage of error in determining the location of the faults by the designed distance relay was 2.06% and the percentage of success in the classification of the type of fault is 100% where the relay was able to distinct between single and double faults phase, ground and non-ground.

Acknowledgment

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