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INTELLIGENT FAULT ANALYSIS IN TRANSMISSION LINES USING FUZZY LOGIC

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Abstract: The electric current during abnormal condition in power system network is known as fault current and the situation is known as fault. When it occurs it must be cleared as soon as possible within seconds to prevent the power system network from being damaged due to this fault. Before clearing the fault it is very important to detect the nature of fault and determine the location of fault, whether it has actually happened or not, it must be detected and where it has happened that location must be determined. The detection, performance and location determination will be more efficient with intelligent methods like fuzzy logic, neural network. In conventional methods fault can be detected easily but which type of fault has occurred and in which part of transmission line it has occurred could not be determined easily. Here a new approach for fault detection, classification and fault location in transmission line using fuzzy logic has been presented.

Key Words: Fuzzy logic, MATLAB/Simulink, Transmission line fault, fault location…

I. INTRODUCTION

When low impedance is connected across high voltage supply then huge amount of current will flow across the circuit, this condition is known as short circuit and this current is known as short circuit current. These are nothing but fault and fault current respectively.

A fault is a low impedance, low voltage, low power factor, high current and highly lagging phenomena.

It cannot be expected that a power system would always be fault ridden. If there a power system network exists, then definitely there will be occurrence of fault in that system, but the damages in a power system due to occurrence of fault can be avoided by clearing it as soon as possible within seconds.

1.1 Types of faults in transmission line

The faults in transmission lines may be classified as

(i) Symmetrical fault and (ii) Unsymmetrical fault

Three phase fault is known as symmetrical fault whereas all other fault come in the category of unsymmetrical fault like single line to ground fault, double line to ground fault, double line fault.

It may be also categorized as (i) Earth fault and (ii) Phase fault.

The chances of occurrence of earth fault is very large approximately 92% whereas 8% chances are for phase fault. LLL fault, LL fault are in the category of phase fault in which 3% chances of occurrence of LLL fault and 5% chances for LL fault. LG fault, LLG fault are in the category of earth fault in which 85% chances of occurrence for LG fault and 7% chances for LLG fault.

It can be seen here that the most probable chances of occurrence of fault is LG fault, but here not only LG fault but all combinations of fault in transmission lines will be detected, classified with their location of occurrence and will be determined using Fuzzy Logic.

S. Pati had proposed fault detection technique in power system network using superimposed component of fault current. In his paper he used conventional method for fault detection which are Cycle to Cycle comparison method and Sample to Sample comparison method.[1]

Prashant Gautam had proposed fault detection in EHV line i.e. 400Kv line using symmetrical component analysis with the help of Matlab/Simulink model.[2]

Aniva Sharma had shown output waveform of fault current at the time of fault in EHV line with the help of Matlab/Simulink model for conventional method for fault analysis.[3]

M.A. Faradonbeh has proposed impedance based fault technique for balance and single line to ground fault in electrical distribution system.[4]

1.2 Motivation and Ideas

The power system network has the network of electric devices components. The traditional measurement system does not measure the precise value due to synchronizing difficulties. Due to evolution of digital communication technology, the computer based measurement, protection and control system have become common feature of electric power substations.

Better relaying and fault location performance can be achieved using intelligence technology. As much as we work on intelligence method and do research there will be morechances for its applications and availability even in small electric substations apart from EHV transmission lines.

II. SYSTEM DESCRIPTION

Symbolic representation of system I that have been used for fault analysis is shown below in figure 1.

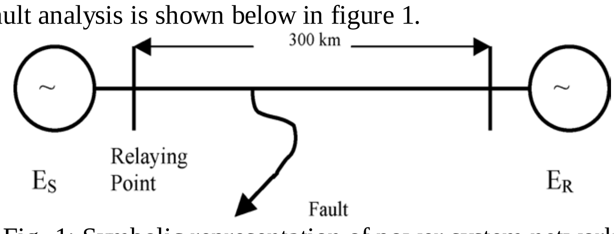

Fig -1: Symbolic representation of power system network

Since in this research work fault analysis have been performed in Extra High Voltage transmission line therefore

400 kV transmission line is taken with 300 km length (long transmission line).

Es is sending end voltage and ER is receiving end voltage having value of 400∠0 kV and 400∠δ kV respectively where δ is load angle.

The fault impact in any location in the transmission line will be detected and analyzed using intelligent algorithm.

III. FAULT DETECTION USING CONVENTIONAL METHOD

This is the first process of fault analysis. Protective relay must be able to sense the increment in fault parameters, and if exceeds threshold value it must operate circuit breaker as soon as possible within second to isolate the unhealthy part to prevent damages in power system network. There are many methods available for fault detection out of which two simple methods are (i) cycle to cycle comparison and (ii) sample to sample comparison. In this paper Fuzzy logic algorithm in cycle to cycle comparison for fault detection and classification have been applied. Apart from these a Simulink model for Fault identification for conventional method has also been described below.

3.1 Simulink model of Fault Identification using conventional method

Three phase source of 400 kV (RMS value) input with 50 Hz frequency is taken and the load is taken here is of same value as source to make it synchronizing with each other. Three phase fault is created between source and load in a power system network with the help of MATLAB. The current and voltage can exceed the threshold value with the help of 'Step' in which the time can be set at which current and voltage will increase, i.e. the time after which fault will occur in the transmission line. It depends on the user. After increase in the value of current and voltage it will be measured by V-I measurement system by which relay can sense the increased value and since it is exceeding the threshold value, relay will operate the circuit breaker which will isolate the faulty part from source point or healthy part of power system.

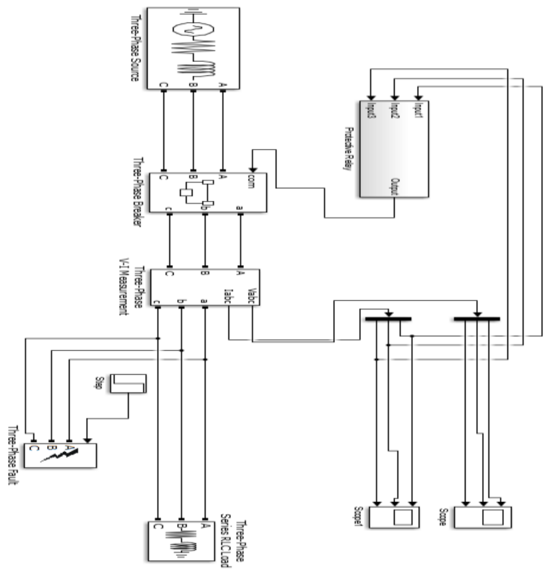

Fig -2: Simulink model for fault detection using conventional method

The three phases mentioned here can be any of the transmission line faults. The type of fault can be changed by clicking on three phase block of the Simulink Model. The output waveform of current and voltage is given below for step time of 0.2 seconds for a three phase fault.

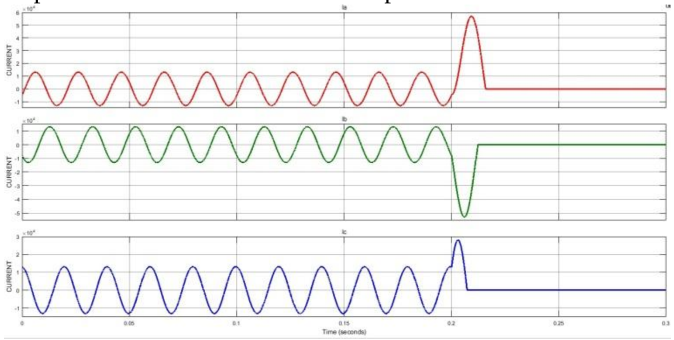

Fig -3: Output waveform of three phase fault current

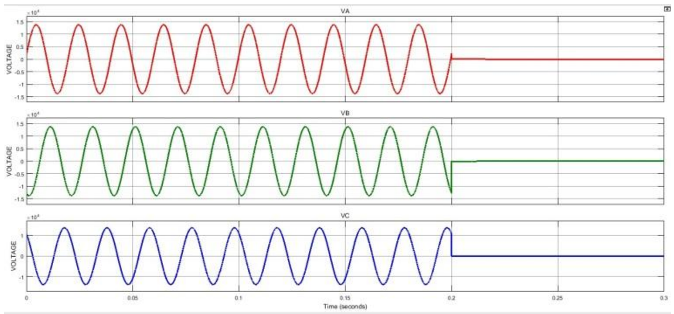

Fig -4: Output waveform of three phase fault voltage

Similarly, the output waveforms of all possible combinations of fault by changing the type in three phase fault block in simulation model can be obtained.

In figure 3 the current was uniform till 0.2 second after that as fault appeared due to which current went very high. As relay operates the circuit breaker, the faulty part was isolated from source point therefore the value of current becomes zero after that.

Once fault had occurred, current becomes very high but it does not change the voltage very much which can be seen in output waveform of voltage but after isolation it also goes to zero.

The Protective relay used in conventional method trips only when the fault parameter goes above the nominal value, but the phase wise reference value cannot be determined due to which nature of fault cannot be identified in this method.

In the conventional method of fault identification, exact location of fault cannot be determined.

If there are 10 zones (say) in power system network then for every zone there will be digital controller for fault location determination but this system will be complicated and these zones are not synchronized to each other. If fault occurs in any zone then it will be identified and this knowledge will be limited to that particular zone only, the operator and controller of other zone will not able to know it's occurrence, if somehow we can make this to happen with conventional method then it will be very complicated, but in power system network we must do it efficiently and easily.The switching time of protective relay is a so high as compared to other switch as it has a mechanical contactor. So if there is a short time fault in the order of millisecond occurs in between faults than it cannot be identified. The digital controller used for fuzzy logic works with frequency up to 8 MHz that means it can work for fault occurred in the order of micro second.

3.2 Fault Identification using cycle to cycle and sample to sample comparison method

In this paper fault identification using fuzzy logic is based on the algorithm for cycle to cycle comparison method. These two methods are simple and efficient for fault identification. During fault only current changes very much therefore for further process only current signal will be taken.

In cycle to cycle comparison some samples are taken suppose 40 samples of current value in one cycle are taken. Now, the difference of these samples of current with its corresponding samples in its previous cycle will be taken into account, if the difference exceeds the predefined threshold value of current which is 2 Ampere then fault will be detected. This increment or change in current must be detected even for inception for very less time.

In the below figure we can see the cycle to cycle comparison of current samples before the fault and during the fault.

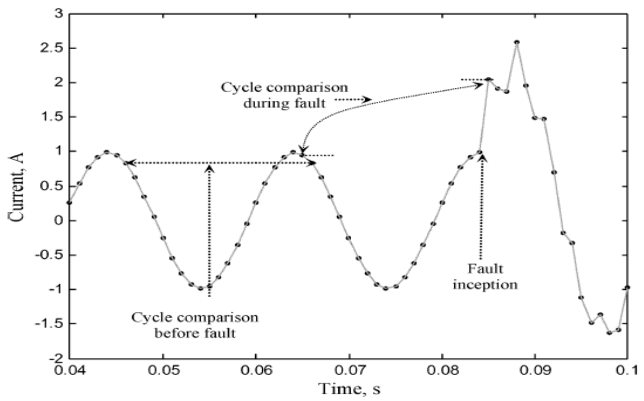

Fig -5: cycle to cycle comparison of current

The mathematical equation for cycle to cycle comparison is given below.

$$I_k = |s_k - s_{k-N+1}| \quad (1)$$

Where, k and N are number of cycle and number of samples per cycle respectively.

A fault will occur if $I_k$is more than threshold value say, t.

$$I_k > t \quad (2)$$

This method is used here for fault detection and for faulty phase identification sample to sample comparison method is used.

In sample to sample comparison method standard deviation of current samples in each cycle is considered. This is applied to each phase of transmission line including ground. If deviation of current samples in real time with respect to its previous sample value exceeds the threshold value then fault will be detected and the phase in which deviation is observed will be treated as faulty phase.

This method is used for fault classification in transmission line. The mathematical equation for sample to sample comparison is given below.

$$D_k = |s_k - s_{k-1}| \quad (3)$$

A phase will be treated as unhealthy if the deviation of current sample exceeds the threshold vaule.

$$D_k > t \quad (4)$$

Where, Dkis the deviation of current samples in real time.

If there is no fault in the transmission line i.e. system is operating in normal condition then the sample value in each and every cycle will be equal with respect to each other in corresponding cycle therefore no deviation will be observed and hence no fault will be observed. Once the deviation is detected it must be sensed by digital recorders after whichthis data will be fed to relay and then further process will be taken place for fault recovery.

IV. FAULT ANALYSIS USING FUZZY LOGIC

Fuzzy logic is a computational algorithm which combines the technique of human brain thinking and computer operations. Unlike conventional method, there are no any mathematical expressions in fuzzy logic. In conventional method we have value of either 1 or 0 i.e. yes or no but in fuzzy logic apart from the value of 1 and 0 we have the range between these two. For example suppose it has to be determined that how many students are tall and short in a class. Then, a mathematical formulation will be defined and a reference value say 5 feet will be set. Then the students whose height are less than 5 feet will be in the category of short and the students whose height are more than 5 feet will be in the category of tall. Similarly in the result the student whose height is 4.9 feet will be in the category of short and the student whose height is 5.1 feet will be in the category of tall. But there is not much difference between the heights of these two students but still they will be in different group therefore this is not précised value. If the same is performed with fuzzy logic then various membership functions will be defined. If 0 is shortest and 1 is tallest then between these value some membership functions like very short, medium short, extreme short etc. and similarly some membership functions for tall will be defined due to which resolution of fuzzy logic result will become very high and précised result will be obtained. In this paper the fuzzy logic algorithm is used for cycle to cycle comparison method for fault detection and sample to sample comparison method for fault classification. Once the deviation is observed in the sample value, this deviation and energy signal will be fed to fuzzy inference system. The current sample observed with deviation, threshold values etc. are crisp values. Fuzzy logic controller does not understand these values. To make it understandable for fuzzy logic controller membership functions for each and every possible value based on defined fuzzy logic rule based needs to be formed. This process of making crisp value understandable to fuzzy logic controller is known as fuzzyfication, after the process in fuzzy logic controller the result will be not crisp, to make it understandable to operator working with controller defuzzyfication process will be placed. Since the fault analysis is performed in EHV transmission lines, the transmission line of 400kV of length of 300km is taken. In

MATLAB for transmission line, either we can use pi line or T line. Here since long transmission line is used therefore pi line is considered. Each block of pi line is taken for the length of 30km and since 300 km is total length of line therefore total block of pi line will be 10. Each block is named with some number, and now transmission line having 10 zones named with a1, a2, a3, a4, a5, a6, a7, a8, a9 and a10 is created. Each blocks are synchronized with each other. The source is taken with 400kV with 50Hz frequency. The value of source resistance in EHV transmission line is 0.9 ohm. Therefore the pi line block should have such value of resistance so that the total sum of resistance of all pi line block will be approximately equal to source resistance. Here the value of length of pi line block can also be changed, if more resolution is desired then it can be divided into more blocks with small length, but for this the resistance and other parameters needs to be changed in such a way that total value gives approximately the source parameter value. A three phase fault is given between the source and load. Which type of fault will occur here, depends fully on the user. With the help of three phase fault block the type of fault can be changed and after which time fault will occur that time can also be set with the same block. Three values for current and three values for voltages are intact, these values for simplifications are kept at compact form in parameter block to avoid complexity in the model. The MATLAB/Simulink model for fault identification and fault location determination can be seen below.

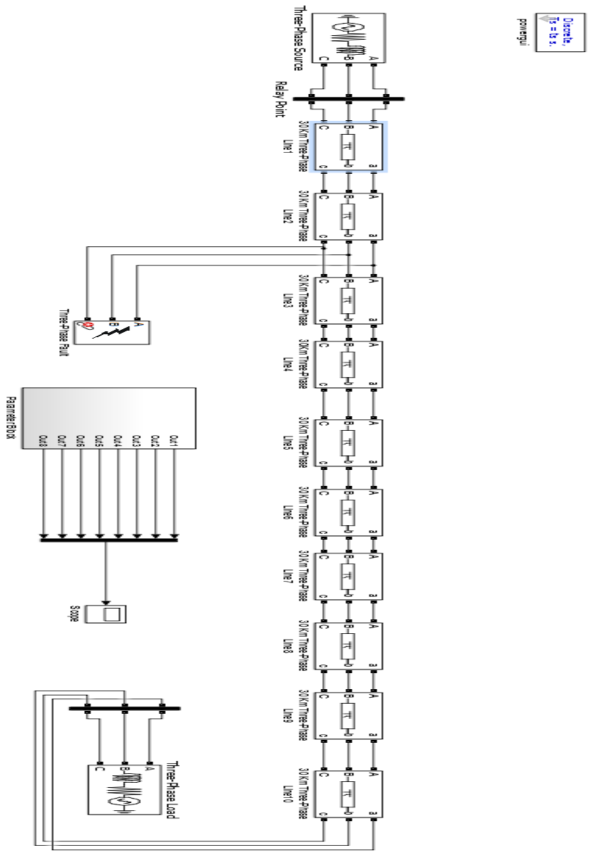

Fig -6: MATLAB/Simulink model for fault detection, classification and location

4.1 FAULT DETECTION AND CLASSIFICATION USING FUZZY LOGIC

The methodology used for fault analysis can be represented as the block diagram given below.

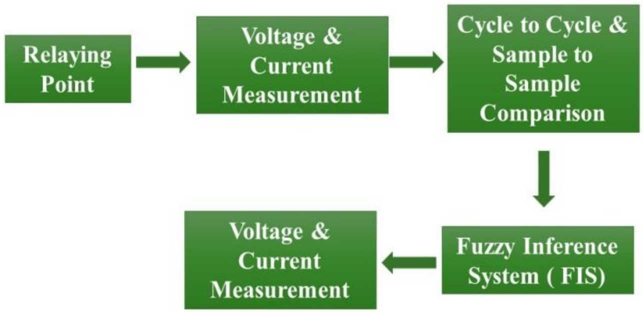

Fig -7: Methodology of fault identification using fuzzy logic

Any change in the voltage and current will be measured and with the fuzzy logic algorithm in cycle to cycle comparison and sample to sample comparison method the required energy signal will be fed to fuzzy inference system. For every variable the membership function will be defined according to the fuzzy rule defined below.

Table -1: Fuzzy Rule

Fault type	Input to FIS system
a-g	Energy of current signal of phase-a and ground
b-g	Energy of current signal of phase-b and ground
c-g	Energy of current signal of phase-c and ground
a-b	Energy of current signal of phase-a and phase-b
b-c	Energy of current signal of phase-b and phase-c
c-a	Energy of current signal of phase-c and phase-a
a-b-g	Energy of current signal of phase-c, a and ground
b-c-g	Energy of current signal of phase-b, c and ground
c-a-g	Energy of current signal of phase-c, a and ground
a-b-c	Energy of current signal of phase-a, b and phase-c
a-b-c-g	Energy of current signal of phase-a, b, c and ground

All possible combination of fault in transmission line for phases a, b, c and ground g are taken into account for fuzzy rule creation.

Here a-g, b-g, c-g are single line to ground fault, a-b, b-c and c-aare double line fault, a-b-g, b-c-g and c-a-g are double to ground fault, a-b-c and a-b-c-g are three phase fault.

The output of fault model can also be seen with fault classification algorithm after running it followed by fault model.

4.2 RESULTS FOR FAULT DETECTION AND CLASSIFICATION USING FUZZY LOGIC

The fault current is set at 0.2 second therefore we can see the deviation in waveform of faulty phase at 0.2 second and the phase in which the standard deviation of sample of current does not have the value sufficient as threshold value has linear waveform.

Results can be examined in below figure.

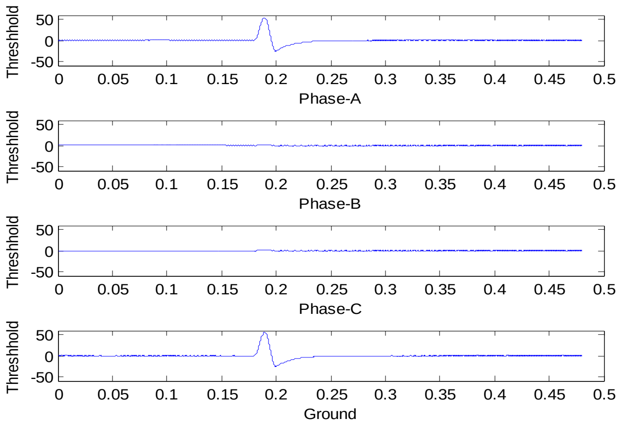

Fig -7: Output for LG fault (current vs time)

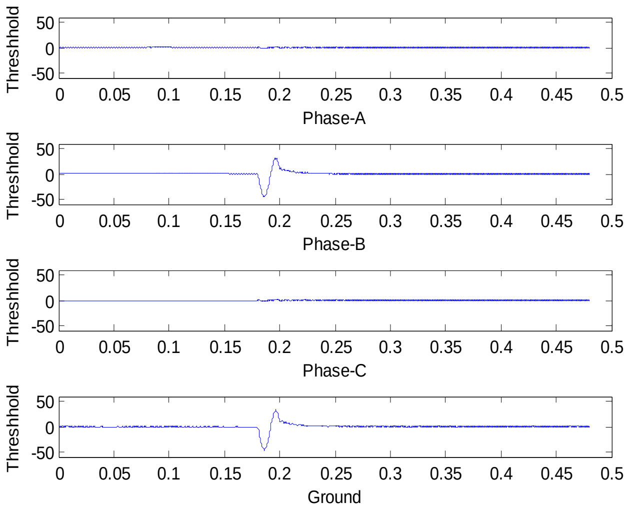

Fig -8: Output for LG fault (current vs time)

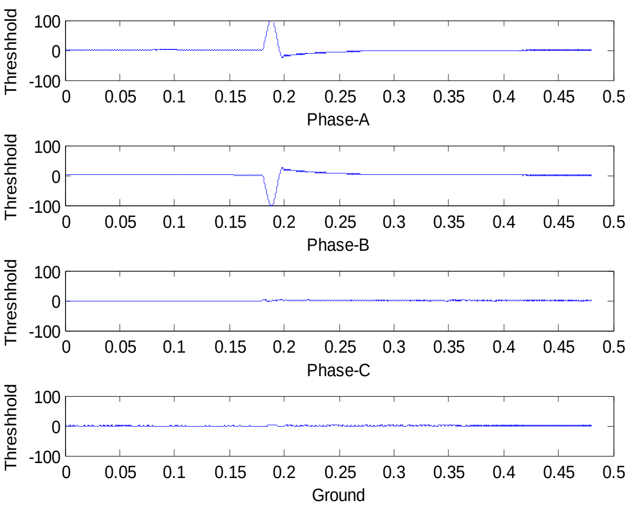

Fig - 9: Output for LL fault (current vs time)

4.3 ALGORITHM FOR FAULT CLASSIFICATION

The process of fault detection and classification can also be explained with the help of fuzzy logic algorithm through which programming of fuzzy logic controller is written. The algorithm can be given by flow chart given below.

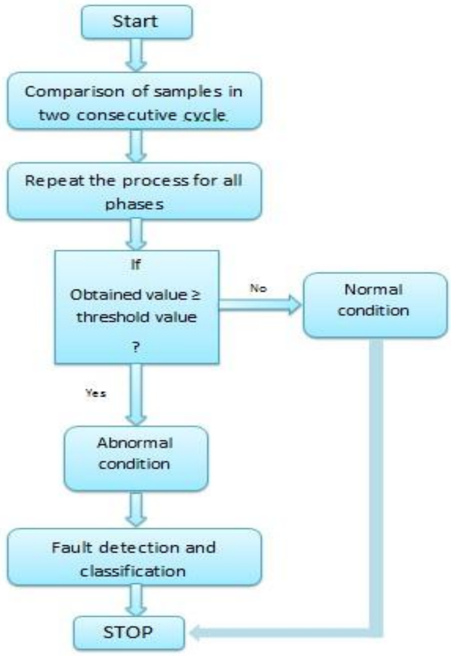

Fig - 10: flow chart for cycle to cycle comparison using fuzzy logic

The program through which result obtained in the MATLAB/Simulink model is created based on the algorithm of above flow chart.

The same method is applied for fault location defined for each zone which are synchronized. Although transmission line is divided in ten zones but it is controlled by on controller based on fuzzy logic.

4.4 DETERMINATION OF FAULT LOCATION USING FUZZY LOGIC

Once the fault is classified, the next is to determine the exact distance of the fault from the relaying point.For this purpose it is proposed to compute the standard deviation and energy values for faults at different locations with varying inception angles, pre-fault load current values and different fault resistance in the fault path.

Output of FIS gives the fault location as zone number and percentage of distance from relaying end.

4.5 RESULTS FOR FAULT DETECTION AND CLASSIFICATION USING FUZZY LOGIC

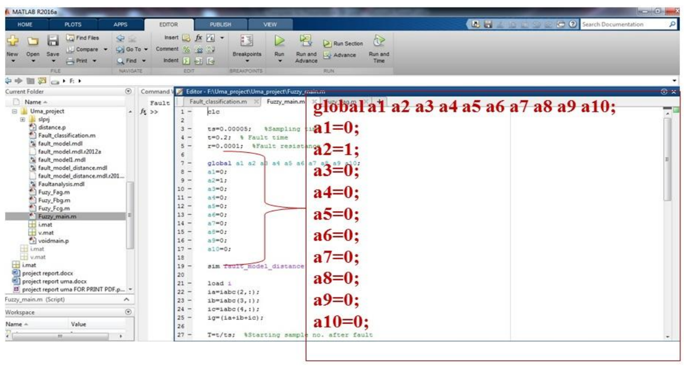

Fig - 11: Output for fault location as zone number

When the program is run for distance determination then the result as zone number is displayed. The zone number will be displayed as 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10. It means fault had occurred at respective zone. The fault zone number can be changed by selecting flag 1 for that particular zone.

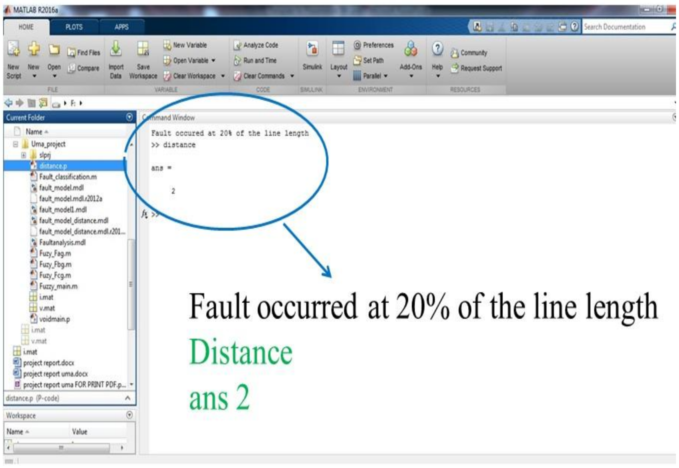

Fig - 12: Output for fault location as % of transmission line

In the result the percentage of transmission line up to which fault occurred will be displayed.

V. CONCLUSIONS AND FUTURE SCOPE

An efficient fault distance locator technique in transmission line using fuzzy logic is analyzed and simulated using MATLAB Simulink.

Sample to sample and cycle to cycle comparison of current samples were carried out to detect the faulty phases.

Pre-processed current sample are fed to a fuzzy inference system to classify faults as well as to locate the occurrence of fault as a percentage of distance from the relaying locationProbabilistic approach must be considered to account parameter variation that affects distance relaying.

Time frequency analysis may be considered to get the time and location of occurrence of faults.

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