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Locating Unsynchronized Fault on Three Terminal lines Based on Negative Sequence Voltage Magnitude

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Abstract - ***This paper presents an approach to estimate fault using the both ends data of the faulted circuit. It uses the negative sequence voltages magnitude. Now- a- days a keen interest has been developed on impedance measurements which depends on fundamental frequency currents and voltages. A two-ended fault location method is used to estimate the accuracy of fault distance measurements significantly by using data from the two ends of the line to cancel the effect of fault resistance. Negative sequence circuit is considered in double-circuit transmission line as there is no mutual coupling between the negative sequence components of two circuits. The main objective of locating unsynchronized faults on double-circuit transmission line needs only the voltage data at both ends of the lines to estimate the fault location. As, it locates the unsymmetrical faults, it is independent of fault resistance and fault type. Fault classification is not required to estimate fault location. Estimation of fault is tested for different cases based on unsynchronized measurements, which depends on fault type and fault resistance. Unsynchronized techniques are analysed to study the three-terminal lines.***

Keywords: ***Fault Location Techniques, Unsynchronized Measurements, Two end and one end methods, Negative sequence voltages, Impedance Measurements.***

I..INTRODUCTION

Parallel transmission lines have been used in power system to increase transmission capacity and reliability and security. Protecting the double –circuit transmission lines and estimate the fault is a task as it is independent on fault resistance and mutual coupling. There are two are types of fault location methods as it is a single-circuit or double-circuit transmission lines.

TYPES OF FAULT LOCATION METHODS

1. One end based methods: As, one-end based methods has many drawbacks so that two end based method has been introduced ,Even they need data of only one end it may suffer from errors due to fault incidence angle, variations of source impedance and loading conditions.
To overcome this problems, two end based methods is to be introduced.
2. Two end based methods: Two end based methods requires the data on both ends whether it a voltages or currents data as it need communication to obtain better results

Two end based methods can be classified into

- Synchronized Measurements
  Methods using Global Positioning Satellites (GPS)
  (Data synchronization is the first step)
- Unsynchronized Measurements
  Methods need phase alignment
  (There is no need of synchronization)

II .FAULT LOCATION TECHNIQUES

Different types of fault location techniques are Technique based on fundamental-frequency voltages and currents, primarily on impedance measurement [4,5 ,6,7] Technique based on high-frequency components of currents and voltages generated by faults [3,8,9]. Technique on travelling-wave phenomenon [1,11].Knowledge-based approaches [2,10]. Technique based on the fundamental frequency currents and voltages at line parameters and line terminals is the simplest and easiest way to estimate the fault. Impedance calculated using the faulted line segment is a measure of the distance to fault .It uses fundamental frequency of voltage and current phasors . It depends on the data is taken from one end or from both ends. As using high frequency components of currents and voltages generated by faults suffers from the limitations due to fault-path resistance, line loading and source parameters etc. As a result, the accuracy of the fault location is to be limited.The traveling-wave method depends on calculation of time for the line disturbance to reach the end of the line as to estimate the fault. This method uses the global positioning system (GPS) to calculate the time as its cost is high. Knowledge based approaches involves artificial neutral networks as it costs high and consumes more time.

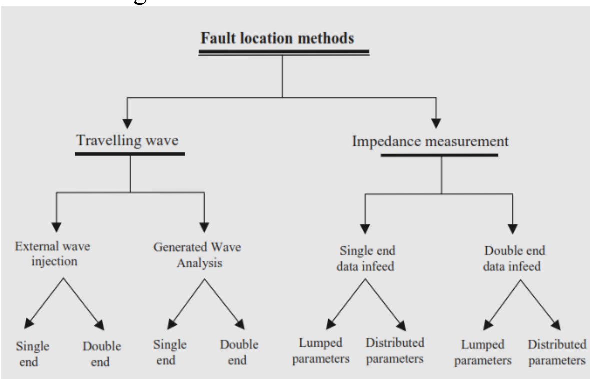

Fig.1 Classification of fault location methods

III. DIFFERENT CASES OF FAULT LOCATION

Different cases are involved to locate the fault of the system are considered as follows:

Case 1: Calculation of estimation errors
Case 2: Consideration of shunt capacitances
Case 3: Obtain sensitivity analysis

CASE 1.CALCULATION OF ESTIMATION ERRORS

First in the case, the fault location error is given as:
Percentage error in fault-location estimate based on the total line length: (error) = (instrument reading – exact distance to the fault) divided by (total line length). When performing the evaluation of the accuracy for the particular fault location method, different measures for the fault location error are determined. Instrument reading is calculated from the data [5……195km] Exact distance to the fault is calculated using

$$m = \frac{2(1-k)X_{2S}X_{2R} + X_{2S}X_{2L}}{X_{2L}(X_{2S}+kX_{2R})}. \quad (1)$$

k=The ratio between the magnitudes of negative-sequence voltages at the sending S, and receiving R, ends of the faulted circuit
Total line length =200km.
Different cases of estimation errors are calculated based on the fault types and fault resistances.

CASE 2.CONSIDERATION OF SHUNT CAPACITANCES

To consider the effects of the line shunt capacitances on the proposed method, a PI model for the double-circuit transmission line is used. The PI model is quite accurate to obtain steady state results where the shunt capacitances should be considered [12]. Based on the PI model, if an fault occurs at location m (in p. u.) from relay in one circuit of the double circuit transmission line, the negative-sequence circuit will be as shown in Fig. 2. The basic circuit of the capacitances are parallel to those of sending and receiving ends of the faulted circuit. The sending and receiving ends of equal capacitances will be obtained as follows:

$$C_{2S} = \left(\frac{1+m}{2}\right) C_{2L} \quad (2)$$

$$C_{2R} = \left(\frac{2-m}{2}\right) C_{2L} \quad (3)$$

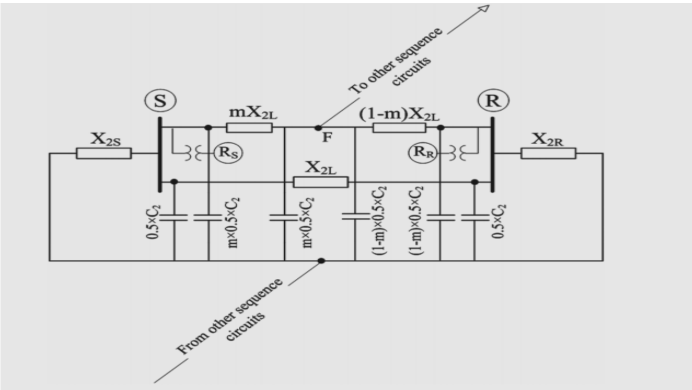

Fig.2 Line shunt capacitances considered in the negative-sequence Circuit of the double-circuit transmission line.

CASE 3. OBTAIN SENSITIVITY ANALYSIS

The source parameters and line parameters and are required for estimation of fault location. The line reactance and capacitance can be accurately measured but the source reactance may not be obtained as accurately as the line parameter. It is assumed that the expected value of (the ratio of negative-sequence voltage magnitude at the sending-end relay to the one at the receiving-end relay) is first measured while the fault location varies along the line. Having known the variation of, the sensitivity of fault location to the aforementioned parameters will be obtained as follows.

$$m = \frac{2(1-k)X_{2S}X_{2R} + X_{2S}X_{2L}}{X_{2L}(X_{2S} + kX_{2R})}. \quad (4)$$

Taking the derivative of (m) in terms of yields the sensitivity factor to the source reactance behind the sending-end relay as

$$S_S = \frac{X_{2S}kX[2(1-k)X_{2R}+1]}{m(X_{2S}+kX_{2R})} \quad (5)$$

The sensitivity factor to the source reactance behind the receiving-end relay is obtained by taking the derivative of (m) in terms of as

$$S_R = \frac{X_{2S}kX[2(1-k)X_{2R}+1]}{m(X_{2S}+kX_{2R})} \quad (6)$$

IV. RESULTS AND DISCUSSIONS

The system under study is a 400-kV, 50-Hz double-circuit transmission line of 200- km length. Double-circuit transmission lines are protected by the distance relays of sending and receiving ends. It depends on the voltage data and capacitive voltage transformers (CVTs) were in detail as per data given in [12]. The parameters of the transmission line and those of the sources given in the appendix

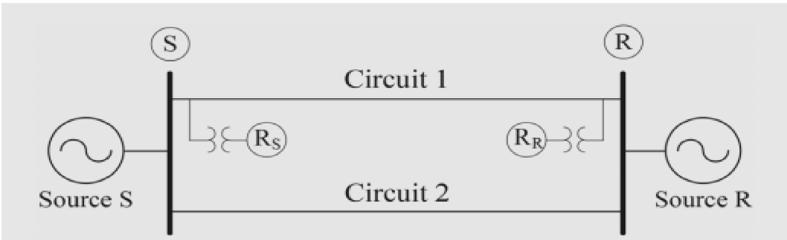

Fig. 3 Double-circuit transmission line protected by the distance relays of sending and receiving ends.

Case	Fault type	Fault resistance (Ω)	Actual fault location (km)
1	Ph-G	10	[5…195] every 1 km
2	Ph-G	50	
3	Ph-G	100	
4	Ph-Ph	5	
5	Ph-Ph	20	
6	Ph-Ph	50	
7	Ph-Ph-G	10	
8	Ph-Ph-G	50	
9	Ph-Ph-G	100	

Table.1: Different Fault Cases Considered For Evaluation Studies

Case	Lumped Model		PI Model	
	Max |Error (%)|	Mean |Error (%)|	Max |Error (%)|	Mean |Error (%)|
1	0.2311	0.1484	0.2436	0.0877
2	0.2272	0.1493	0.2437	0.0886
3	0.2245	0.1515	0.2442	0.0901
4	0.2424	0.1497	0.2430	0.0851
5	0.2399	0.1486	0.2443	0.0853
6	0.2258	0.1492	0.2454	0.0865
7	0.2823	0.1458	0.2550	0.0862
8	0.2801	0.1461	0.2524	0.0860
9	0.2805	0.1466	0.2523	0.0861

Table.2 Maximal and Mean Values of Absolute Errors for Each Fault Case Based On the Lumped and Pi Models

SIMULATION RESULTS

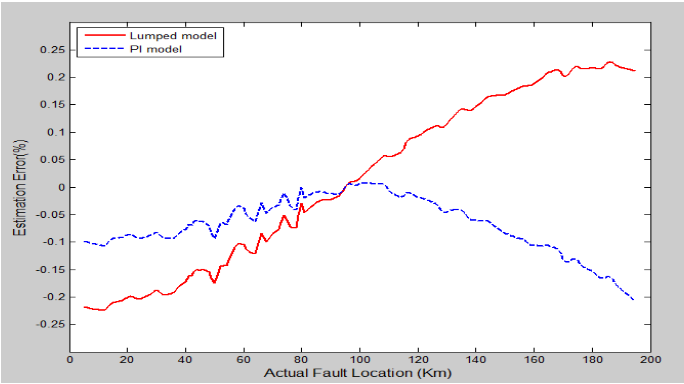

Fig 4: Case-1 Fault Type: Ph -G Fault Resistance:10 ohms

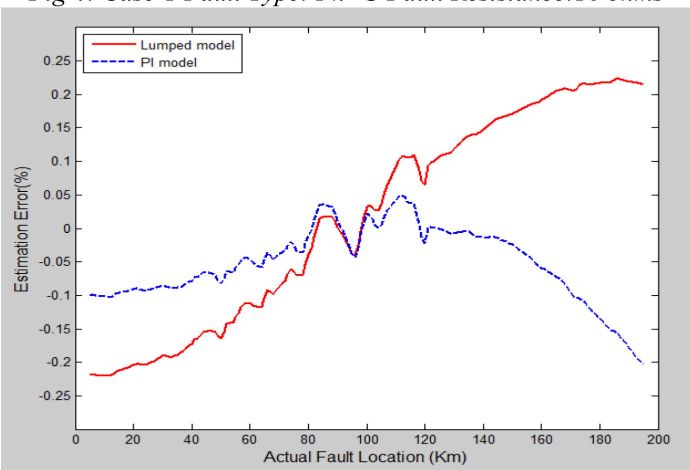

Fig.5: Case-2 Fault Type: Ph-G Fault Resistance:50ohms

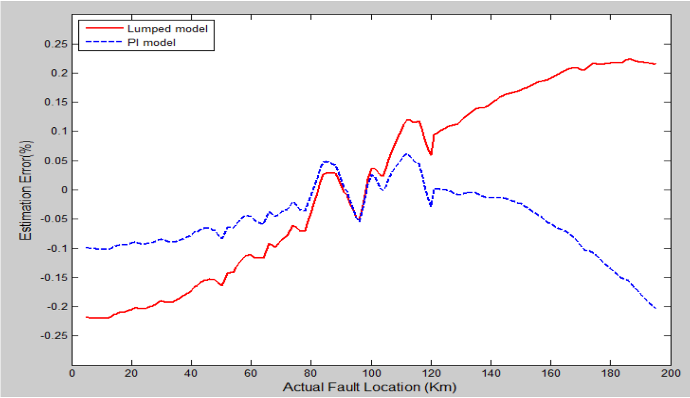

Fig.6: Case-3 Fault Type: Ph-G Fault Resistance:100ohms

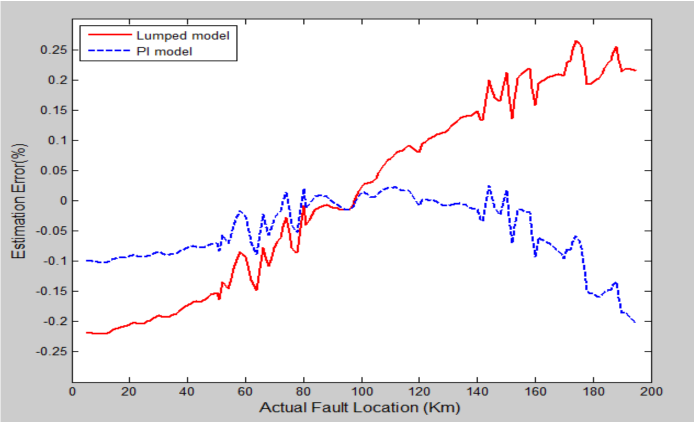

Fig.7: Case-4 Fault Type: Ph-Ph Fault Resistance:5ohms

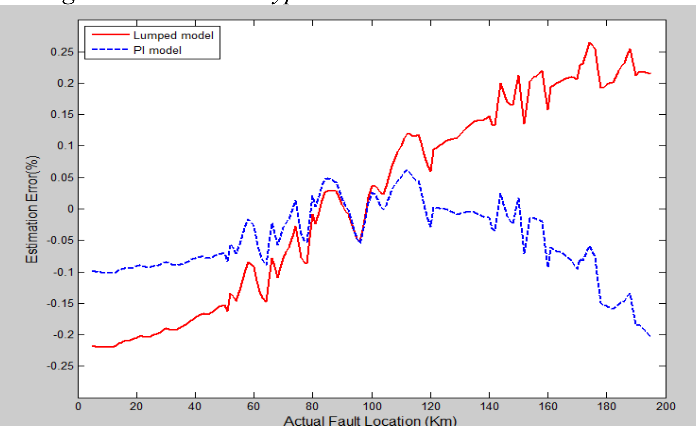

Fig.8:Case-5 Fault Type:Ph-Ph Fault Resistance:20ohms

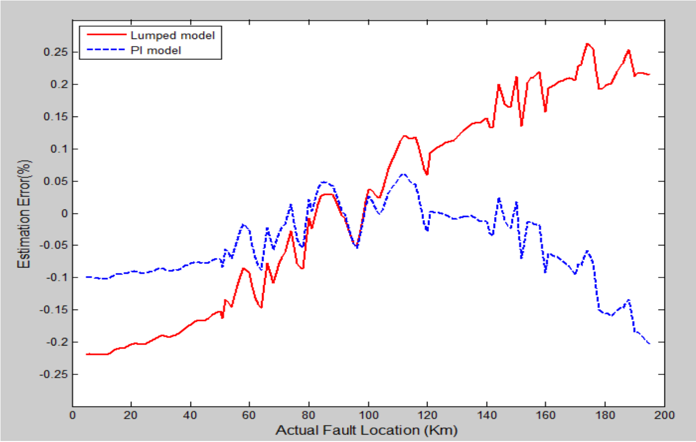

Fig.9:Case-6 Fault Type :Ph-Ph Fault Resistance:50ohms

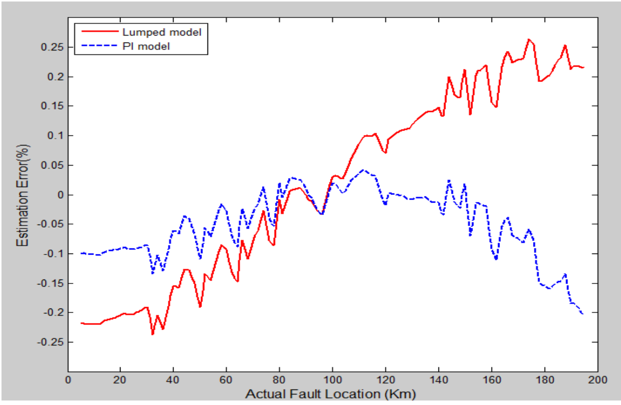

Fig.10:Case-7FaultType:Ph-Ph-GFaultResistance:10ohms

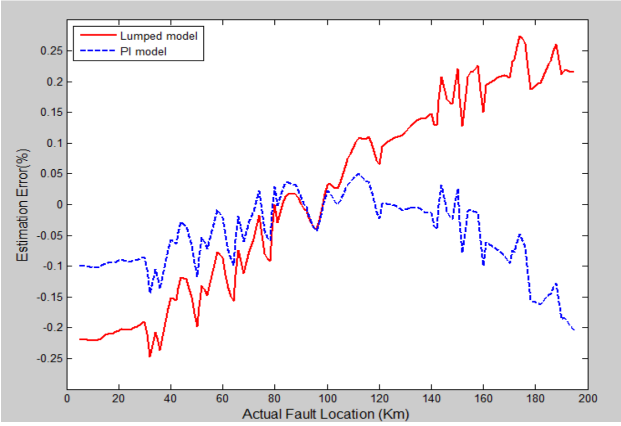

Fig.11:Case-8FaultType:Ph-Ph-GFault Resistance:50ohms

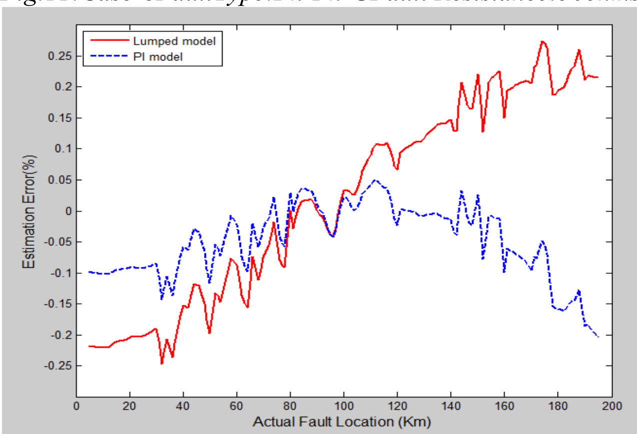

Fig.12:Case-9FaultType:Ph-Ph-GFaultResistance:100ohms

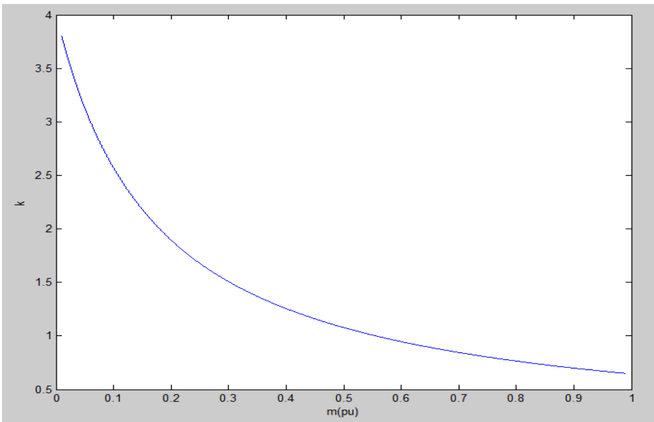

Fig.13:Variation of k for different fault locations

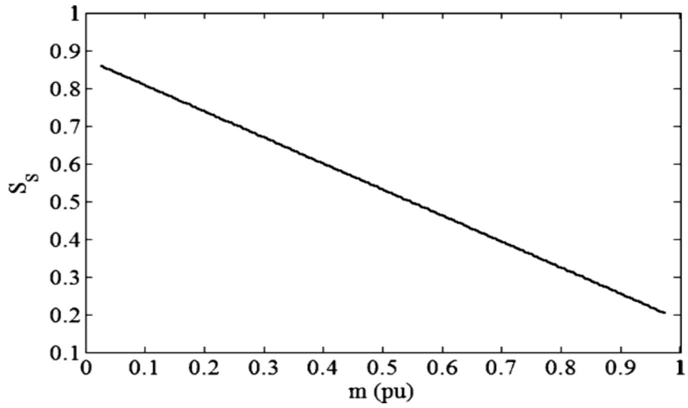

Fig.14: Sensitivity factor to the source reactance behind the sending-end relay

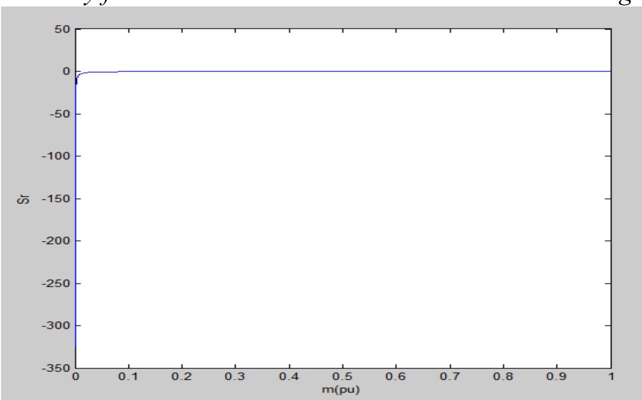

Fig.15:Sensitivity factor to the source reactance behind the receiving-end relay for different fault locations based on the lumped model

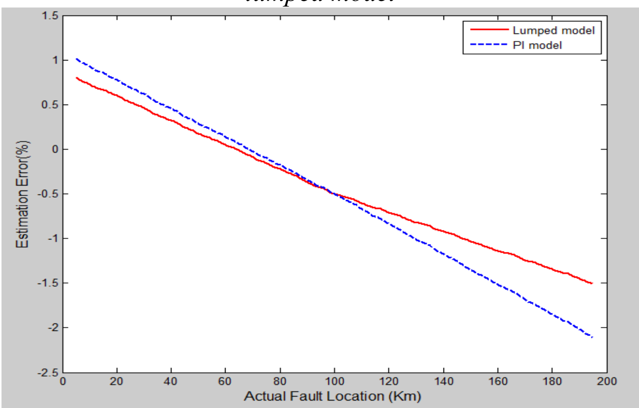

Fig.16: Estimation errors for a deviation of 10% in source reactances (1.1×$X_{2S}$and 1.1×X_{2R})

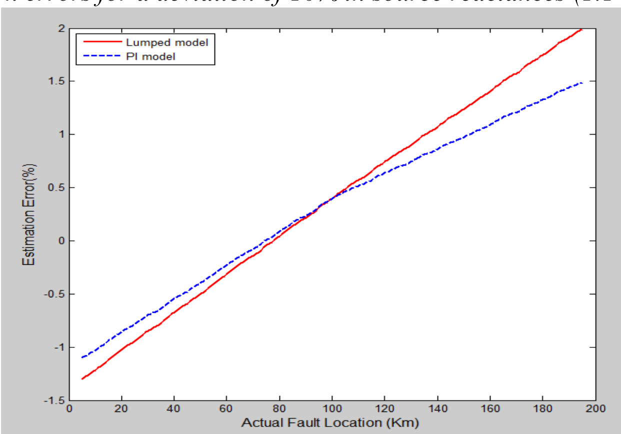

Fig.17: Estimation errors for deviation of 10% in source reactances(0.9×X_{2S} and 0.9×X_{2R})

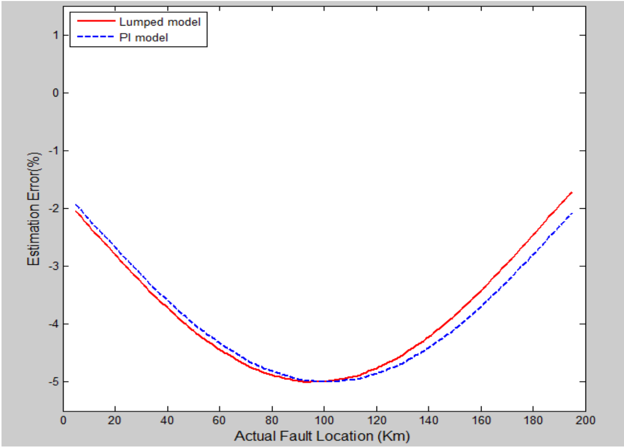

Fig.18 Estimation errors for deviation of 10% in source reactances(1.1×X_{2S} and 0.9×X_{2R})

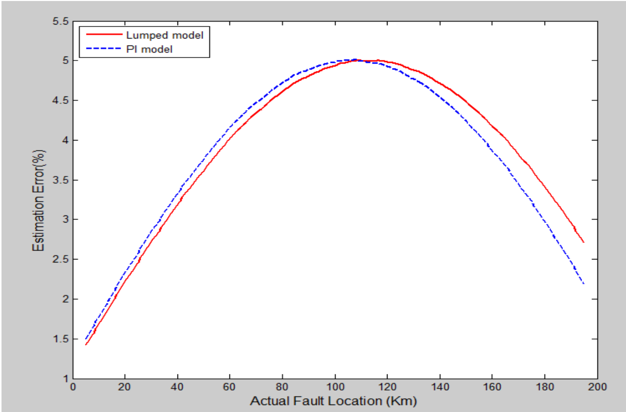

Fig.19 Estimation errors for deviation of 10% in source reactances(0.9×X_{2S} and 0.9×X_{2R})

These 9 cases are based on lumped and pi model at different fault resistances and fault types. When the small difference in the estimation errors occurs then the fault type and fault resistance vary can be attributed to the errors generated by the instrument transformers (CVTs) and with numerical calculation. It is shown that the accuracy of the method will be quite high and if required parameters are close enough to their real values. If fault locations are more than 0.2 p.u, then it indicates that both sensitivity factors are less than 1 which indicates a low sensitivity of the method to the variation of source reactance. At 0.3 p.u , it is calculated as 0.66 and 0.75.For given 10% tolerance, then the fault location will be estimated in the range of [0.280, 0.320]. For 10% tolerance, then the fault location will be estimated in the range of [0.277, 0.323]. The accuracy will even be higher if the fault location is farther from relay.

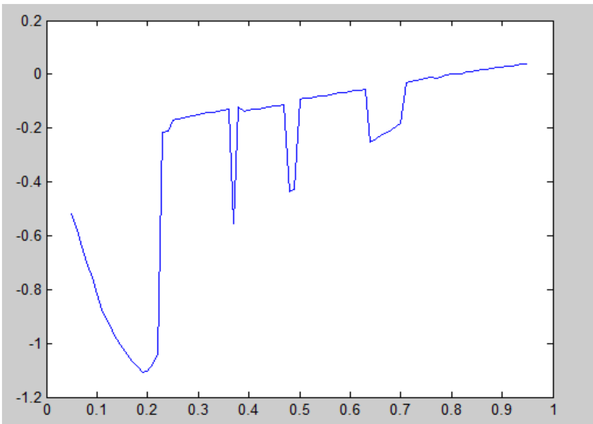

Fig.20 Curve shows that Estimation error fault location

Estimation used for source reactances are given either 110% or 90% of their real values. In this sense, It has four possible cases for the source reactances

1) 1.1X_{2s} ,1.1 X_{2R} ;
2) 0.9X_{2s} ,0.9 X_{2R} ;
3)1.1 X_{2s} ,0.9 X_{2R} ;and
4)0.9X_{2s} ,1.1 X_{2R} .

If even though , At the same time if both source reactance deviate 10% from their real values , then the estimation errors fall in a reasonable range with a maximum error of 5%. To locate unbalanced faults on three-terminal lines using the negative-sequence voltage magnitudes measured at three ends sources of the three-terminal line. The major advantages of three terminal lines are:

1. *Most of the existing methods which requires both the data of voltage and current measured at either two or three terminals, as it uses only the voltage data , then the errors produced by the CT measurements can be eliminated.*
2. *It is independent of fault type and fault resistance.*
3. *It needs the negative-sequence voltage magnitude which it completely removes any concern about data synchronisation.*
4. *There is no need for fast and online data transfer and a simple low demanding low-speed communication.*
5. *For faults located very close to the tap point, then the faulted section can be reliably identified and fault location can be given with a small error.*
6. *The method is simple and can be easily implemented in the digital relays, even in spite of high accuracy.*

V. CONCLUSION

In double circuit transmission lines, locating the fault using negative sequence voltages to obtain the better accuracy even in the lumped model and in the pi model. Using the three terminal lines there is no need for fast and online data transfer and a simple low demanding low-speed communication link can be used. , it provides quite satisfactory results even for long lines as the ratio between two voltage magnitudes is used.. Results shows that with three terminal lines using voltage sources improved than double circuit transmission lines.

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