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Fault Detection & Classification of 3-Phase Transmission Line

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Abstract – ***Three phase transmission line are soul of power system. In this paper different types of fault are classified in the three phase transmission line. In the present scenario the both end ratios are considered for the data acquisition of voltage and currents. This states are measured and fed to the control panel for the fault analysis and detection. These techniques are very much accurate for the short and medium transmission line. But for long transmission line classification needs the accuracy and actual detection of the fault and direction of the fault. For a 400kV, 100MVA, and 112km transmission is simulated and worked in MATLAB/SIMULINK environment.***

Key Words: *Transmission Line, Fault Classification, L_G, LLG, LLL faults. Distance Protection*

1. Introduction

Protection of power system transmission line have great impact on the economic consideration of any state or country. It also directly affects the people life and indirectly to the growth of any nation. There are various duties of protection system including to isolate the healthy system from the faulty system. Along with, the isolation from the healthy system it is very necessary to classify the nature of fault for the further studies and the report generation. The classification of fault provides the information regarding the faulty phase, severity level of fault etc.

Post fault analysis is also an important aspect of the power system protection of the power network. In this paper symmetrical component based algorithm is used to classify the faults. In addition, popular power system distance protection strategy is used for the detection of the faults.

A power system can experience various ten different types of line shunt faults. These faults are single-phase-ground; (LG), phase-to-phase (LL), Phase-to-phase-Ground (LLG) and three phase (LLL) faults. The severity level of these fault is given in table-I. The reported table is based on the past two decades data for power system fault and the occurrences of faults in power system. Transmission line tower data has been given in table-II according which system for simulation has been modeled. Many methods has been reported till date which uses the both end or single end voltage current instantaneous data for the classification of fault. These methods are divided into some categories. In very first categories of measurement the fault analysis and classification uses the single end of data and complex algorithm for the detection of the fault.

Most of the algorithms are based on this category. In this

1. Under-impedance;
2. Torque;
3. Over-current Technique;

A wide range of relaying techniques are developed for the relaying and data-acquisition purpose. Somehow, they fulfilled the basic requirement and classification. However, the techniques are highly affected by the nature of the faults, modeling of the system, system parameters and other functionality as ambient temperature.

The purpose of this paper is to present an accurate method to classify the different fault in the line including the recorder for the report generation.

Table I Occurrences and severity level of Fault

Type of Fault	*Percentage Occurrences*	*Severity Level*
L-G	70-74%	Minor(less)
LL	12-14%	More
LL-G	16-18%	More
LLL	2-4%	Highly Severe

1.1 Fault Classification Techniques

The under-impedance and torque technique are based on the impedance of the system which are highly dependent on the ambient conditions as temperature and pressure of the environment. While it is dependent on how accurately system has been modeled for the analysis of the content and the fault behavior of the line. Long transmission line are modeled as distributed line which corresponds to the anatomic conductance and capacitance with mutual effects. In the modeling mutual behavior produces large

effect on the system parameter with the adjacent transmission line. Both the algorithms are based on the close encounter of the fault with very strong source.
For high impedance fault the over-current technique provides good results. There are two version of the over-current relays; instantaneous over current relay depends on instantaneous value of current and requires accurate modeling of the system so that one can get accurate sinusoids. In second version pre-scaled values are compared and the recorded the threshold value for the same.

1.2 Methodology

Idea and purpose is to classify and detect fault based on the symmetrical components with their phase angle and magnitude of current. The phasor values of three phase system can be converted into the equivalent symmetrical components. Only, positive and negative components have been used in this paper to perform the classification of faults. In the present scenario, zero sequence components give the definite ground fault but during unbalanced system zero sequence component may present. Although in the un-faulted condition zero sequence may occur in the system.

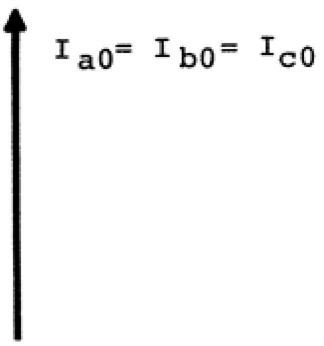

Figure 1 Zero Sequence Component of the System

Figure1, 2, and 3 shows the zero, positive and negative components

$$a = 1\angle 120° = -0.5 + j.866 \quad (1)$$
$$a^2 = 1\angle 240° = -0.5 - j.866 \quad (2)$$
$$a^3 = 1\angle 0 = 1.0 + j0 \quad (3)$$

Above set of equation depicts the alpha operator for the analysis of sequence components.

$$I_{a1} = I_1$$
$$I_{b1} = a^2 I_1 = I_1\angle 240° \quad (4)$$
$$I_{c1} = aI_1 = I_1\angle 120°$$

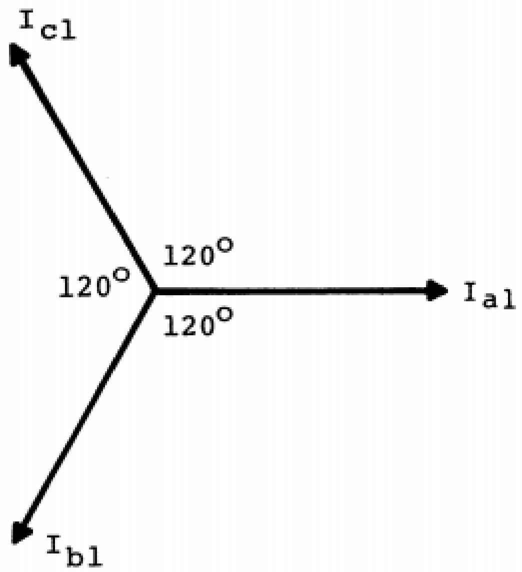

Figure 2 Positive Component of the System

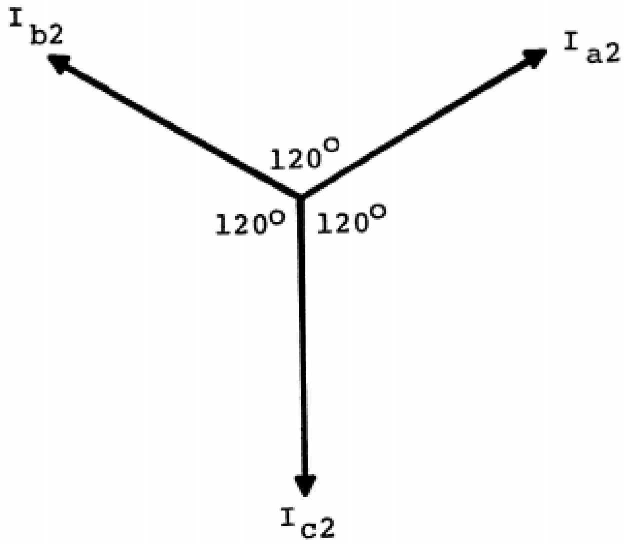

Figure 3 Negative component of the system

Equation set 4 and 5 gives the equivalent mathematical representation of figure 3 and 4 respectively. In these equations 'a' operator is fundamental rotation in space with phasor.

$$I_{a2} = I_2$$
$$I_{b2} = aI_2 = I_2\angle 120° \quad (5)$$
$$I_{c2} = a^2 I_2 = I_2\angle 240°$$

In this paper, angle of these rotation are base for classification of fault and can further use to improve the trip command to CB location.

2. Classification

For LG FAULTS;

a-g Faults

$$arg(I_{a1}^f) - arg(I_{a2}^f) = 0$$

b-g Faults

$$arg(I_{b1}^f) - arg(I_{b2}^f) = 0$$

c-g Fault

$$arg(I_{c1}^f) - arg(I_{c2}^f) = 0$$

For LL Faults;

a-b Faults

$$arg(I_{c1}^f) - arg(I_{c2}^f) = 180°$$

b-c Faults

$$arg(I_{a1}^f) - arg(I_{a2}^f) = 180°$$

c-a Fault

$$arg(I_{b1}^f) - arg(I_{b2}^f) = 180°$$

For LLG Faults;

a-b-g Faults

$$arg(I_{a1}^f) - arg(I_{a2}^f) = 180°$$
$$Fault\ ratio > Prefault$$

b-c-g Faults

$$arg(I_{b1}^f) - arg(I_{b2}^f) = 180°$$
$$Fault\ ratio > Prefault$$

c-a-g Fault

$$arg(I_{c1}^f) - arg(I_{c2}^f) = 180°$$
$$Fault\ ratio > Prefault$$

For 3-phase Fault;

$$arg(I_a^f) - arg(I_{a1}^f) = 0$$
$$arg(I_b^f) - arg(I_{b1}^f) = 0$$
$$arg(I_c^f) - arg(I_{c1}^f) = 0$$

In above classification algorithm the faults are basically comprised of positive and negative sequence component. It is clear that whenever ground is involved in any of the fault algorithm the system shows the corresponding zero effect of difference.

During 3-phase bolted fault the differences between the symmetrical component and the line components does not have any angle magnitude. In such case the functional system does not show the involvement of negative sequence components.

3. Simulation and Results

Classification algorithms are applied to a system containing the data configuration of the 400kV transmission line. Fig-4 shows the tower and conductor placement with vertical and horizontal span. The ground wires are installed at top for the lightning protection. Figure-5 shows the simulation arrangement of the line of 400kV with 112km with fault occurred at 20km of line from source.

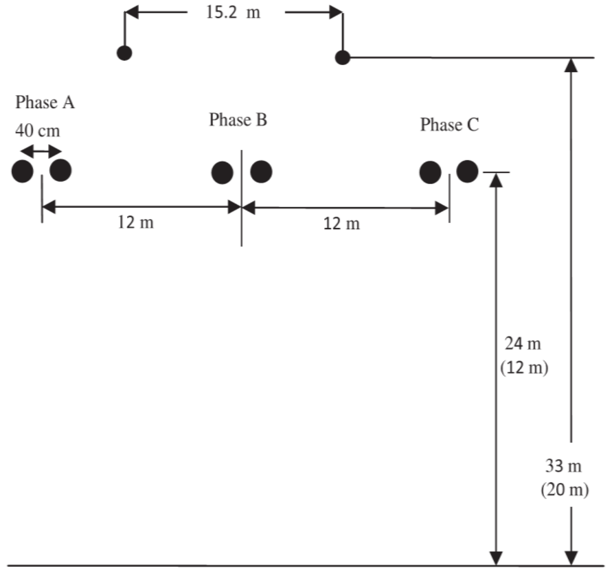

Figure 4 Tower specification of 400kV Transmission line tower and conductor configuration

In figure-5 Three phase source is considered as 400kV end of transformer as stiff source such that the input differentiation doesn't show the variation on the outage of the system.

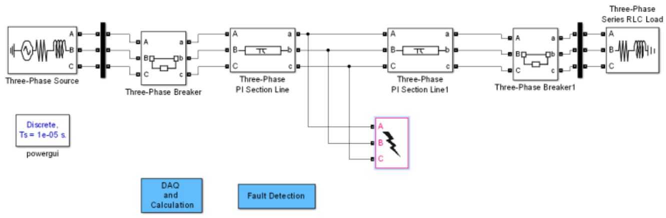

Figure 5 Simulation Arrangement of the system

In figure-6 fault classification strategy as explained in section 3 is modeled and the faults are observed as per the requirement. In this section all the line currents are converted in to the system location as per the required data of symmetrical component.

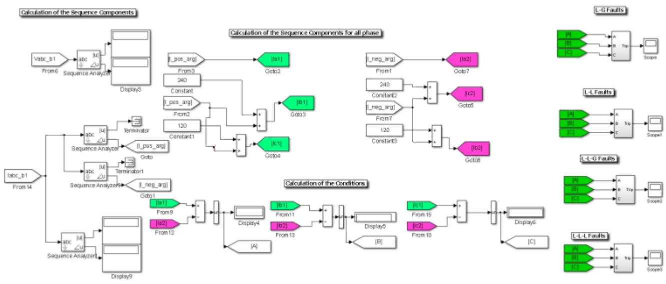

Figure 6 Fault classification of the system

In addition, different types of faults has detected and classified for the specific level. All ten types of faults are classified in this section.

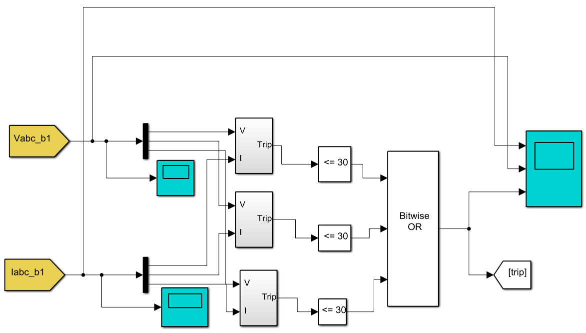

Figure 7 Fault location of the system

For any line distance protection algorithm is given by the most popular impedance protection. In this algorithm faults are detected and trip command is sent to the CB to isolate the healthy section from the faulty network. Table-II shows the transmission tower parameter as mentioned earlier section and for fig-4.

Table II: Data for 400kV, 112km, 3-phase line

Arrangements	Tower Specification
Phase Conductor	
Height at tower	24m
Height at midspan	12m
Phase Spacing	12m
Number of bundle	2
Radius of sub Conductor	1.521 cm
Spacing Between Sub-Conductor	40 cm
Geometrical Mean Radius (GMR)	1.2253 cm
DC Resistance	.0596 Ω/km
Ground Wire	
Height at Tower	33 m
Height at Midspan	20 m
Spacing	15.2 m
Radius	0.8 cm
DC resistance	0.3527 Ω/km

Before fault occurred in a system phase voltage and currents are healthy in nature and given in the figure 8 and fig 9 respectively. During this no trip signal is added in the system and works ideal.
As in figure 8 depicts the line voltage and the figure 9 as line current in healthy condition and each phase are displaced 120 degree in space.
Once L-G fault appear in the system the line voltage drops instantaneously and current appears very high magnitude 8-10 times the normal current. To prevent the current to pass through the load healthy section is isolated using the trip command.

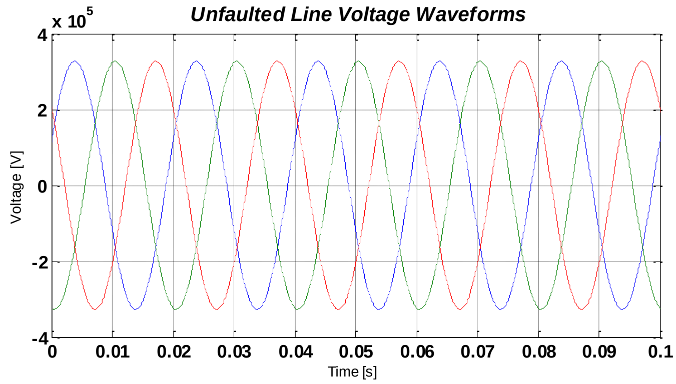

Figure 8 Healthy Line Voltages.

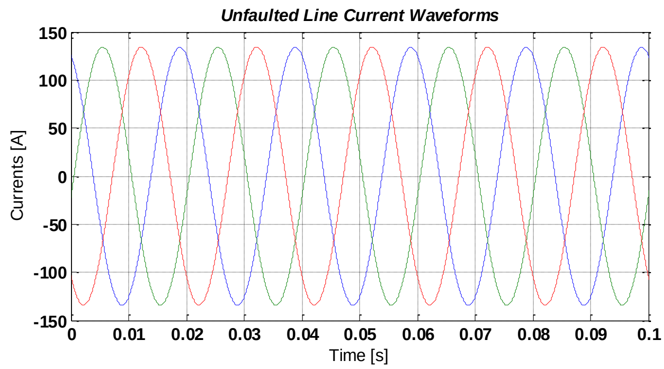

Figure 9 Healthy Phase Currents

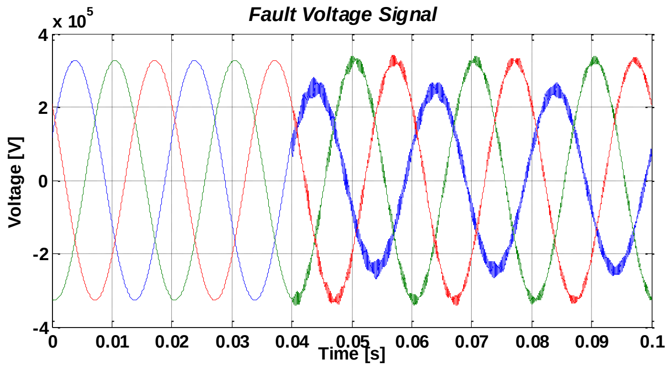

Figure 10 Faulted line Voltage.

All the voltage and current are measured at the source end with the specified time interval of .1seconds.

In the present scenario only one end of the fault voltage and currents are required for the protection and the classification of fault, which further reduces the relay complexity and the data management problem.

Moreover, the relay trip signal is given in fig 12 is sent to the circuit breaker for the further direction.

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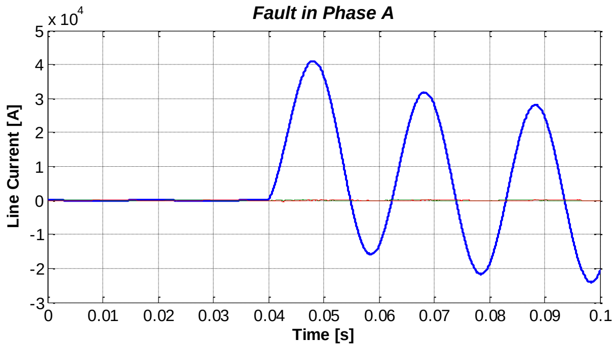

Figure 11 Faulted Line Current.

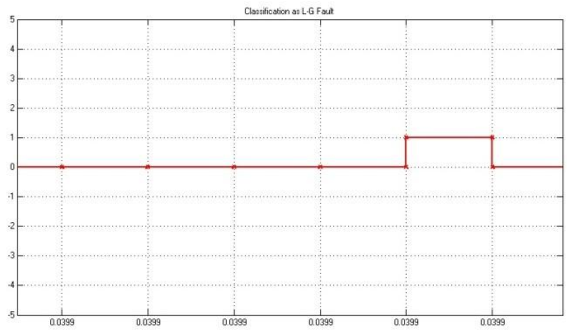

Figure 12 Trip and Fault Signal sent to the CB

Fig-10-13 is collected during the fault identification and classification algorithm and are real-time simulation signals.

3. CONCLUSIONS

In this paper all 10 types of fault has been classified successfully. The modeling and simulation is done in the MATLAB environment for the proper analysis. L-G, LL-G, LL, and LLL faults are classified for a 400kV, 112km transmission line. Methodology adopted work under the recorders installed at the any ends. In future work the directional relaying can be employed and cross verification for the 220km transmission line is adopted with the zone protection.

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