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Detection of Fault Direction and Location in Compensated System using Sequence Component

S. Akter*, H. Badhai, P. Das and B. K. Saha Roy

Department of Electrical Engineering, National Institute of Technology Agartala, Agartala – 799046, Tripura, India; samima.akter1989@gmail.com, hemantabadhai140@gmail.com, priyanathdas@yahoo.co.in, bksr12@gmail.com

Abstract

Objectives: The proposed scheme presents a fault direction estimation as well as fault location determination technique for short transmission line using positive sequence component. An objective of the suggested work is to recognize direction of fault and locate it in short transmission line using positive sequence component. **Methods/Analysis:** Solution is given based on difference between positive sequence post-fault and steady state current phasor and difference of magnitude among post-fault and steady state positive sequence voltage phasor for fault direction estimation. Fault location is estimated by two-terminal method. Fast Fourier Transform is considered to detect the direction of fault and Discrete Fourier Transform is used to find the location of fault. The proposed work is estimated by simulated data in PSCAD and MATLAB/SIMULINK for a compensated line. **Findings:** Fault detection as well as fault location estimation in both sections of compensated line considering transmission line issues is identified properly. Many techniques are available for fault direction estimation and fault location determination. Sometimes available methods do not provide proper result of different issues which are present in compensated system. The proposed method is tested for forward power flow, reverse power flow, voltage inversion and current inversion cases. Simulation results show that proposed technique properly detects the direction of fault and locating the exact location of fault. **Novelty/ Improvement:** This approach deals with detection as well as location identification of fault in compensated system, so it is computationally efficient.

Keywords: Compensated System, DFT, Fault Detection, FFT, Fault Location, PSCAD, Sequence Components

1. Introduction

Fault detection and location estimation are vital tasks to protect the transmission lines. Transmission lines are three types; short, medium and long transmission line. Considering fault and without fault condition system performance is calculated. Since system performance is calculated during fault and without fault situation therefore detection and location of fault is very important for the system. Fault detection in transmission line usually consists of three main tasks. These are identifying fault, classifying the fault and locating the fault. Few algorithms to these three main tasks have been proposed for find the direction of fault, classifying faults and find the location of fault. Most of the faults are unbalanced faults. From Tenaga Nasional Berhad's (TNB) five year tripping statistics (2001 to February 14, 2006), more than 90% of the tripping was Single Line to Ground (SLG) fault. For SLG fault, the fault resistance is the combination of arc resistance, tower resistance and tower footing resistance[1]. Directional relaying algorithm is shown by[2] for fault occurrence near the relay connected bus in case of compensated system. In[3] presented an article for directional relaying considering special technique for protection of compensated system, voting technique uses four classifier so proposed technique is time consuming technique. In[4] reviewed on compensated system considering transmission line (i.e. uncompensated and compensated line) challenges. In[5] proposed a new fault type identification and fault location estimation procedure considering MLP

**Author for correspondence*

neural networks in DG connected systems. In[6]also proposed a new scheme of protection in distributed systems including distributed generator in a system.

In[7] proposed a faulted point assessment technique for compensated system. This paper uses angle difference in sequence current and magnitude difference in sequence voltage during fault period. They have used PSCAD/EMTP software for testing the performance of the proposed system. In[8] presented a fault direction identification technique using current only. Direction of fault is obtained by seeing fault current phasor compared to reference voltage phasor, in measurement location of the system. In[9] has shown faulted point estimation algorithm for one source and two source uncompensated models. Designed algorithm is verified using data obtained after simulation from Matlab/Simulink.In[10] has shown a four-classifiers based fault direction estimation technique. In[11] proposed a fault direction estimation and location method for compensated system, algorithm based on traveling waves and wavelet transform. In[12] described a three-dimensional thermal model using this thermal behavior of the Bimetal strip is analysed during fault and pre-fault condition. In[13] has shown a new distance relaying algorithm for unbalanced system.

Negative-sequence current-based fault direction determination technique is proposed by[14] considering power swing in compensated system simulated in EMTDC/PSCAD. In[15] addressed a fault direction assessment method for a system with TCSC considering different issues (i.e. current inversion, voltage inversion issues) in transmission line. In[16] described directional relaying technique for double-circuit lines with the presence of capacitor. In[17] has given a directional relaying methodology through SPT for single and double-circuit lines in PSCAD/EMTDC platform. In[18] worked on uncompensated line to estimate the direction of fault considering post fault current by using PSCAD/EMTDC. In[19] presented an effective faulted point determination approach for line with a combination of post fault voltage and current magnitudes and phase angles through DFT. In[20] presented a new fault location technique using wavelet transform and Fourier transform and showed that wavelet transform is better compare to Fourier transform for locating the fault location.

From the review of above stated work, it is clear that various fault direction estimation methods and also fault location calculations techniques are used separately and jointly in case of compensated (i.e. connecting capacitor

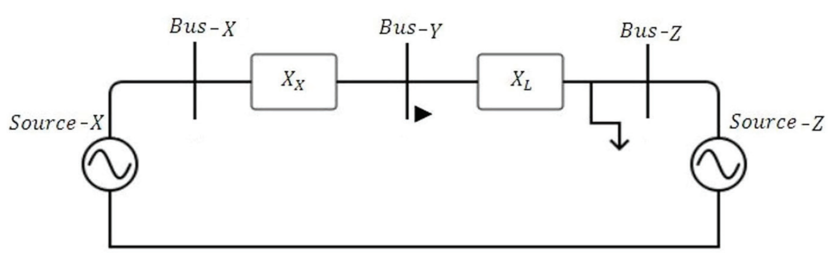

Figure 1. Reactance diagram of uncompensated system.

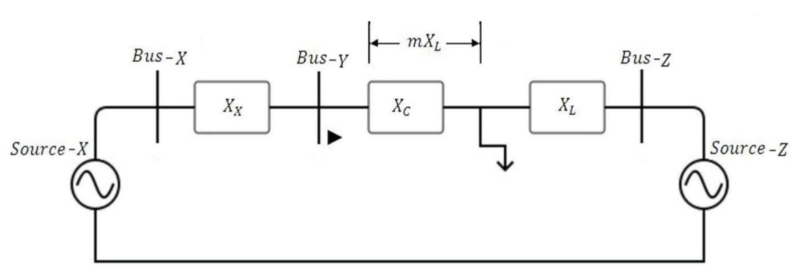

Figure 2. Reactance diagram of compensated system.

or placed FACTS devices in lines) and uncompensated power system networks. This paper shows some works which has been done using Fast Fourier Transform (FFT) for estimation of fault direction and finding the location of fault in same system. Now a day for quick and reliable operation of the power network it is important to estimate the direction of fault simultaneously obtain location of fault as fast as possible. Otherwise, it may make an enormous loss in terms of money and consumer satisfaction. In most of the above cases the methods used to determine either of direction of fault or location of fault. In this paper direction of fault estimation is solved by using two classifiers; these are angle difference among positive sequence post-fault and steady state current phasor and difference of magnitude among post-fault and steady state positive sequence voltage phasor[7] and fault location is estimated by two-terminal method[19]. The tested system is verified through different test systems with EMTDC/PSCAD and MATLAB/SIMULINK for series compensated system. For fault detection tested system is verified using EMTDC/PSCAD software and data are collected using FFT block after collecting data logic will be developed by MATLAB coding, for fault location calculation tested model is simulated using MATLAB/SIMULINK software and fault location is obtained accurately.

2. Problem Statement for Fault Detection and Location Calculation

Relay in the protection scheme plays an important role by sensing the fault and initiated the circuit breaker to break the system, but relay does not provide location of faulted point. There are so many techniques are available for fault direction estimation, fault location determination, both fault detection and location purpose in compensated system but sometimes these methods do not provide proper result for different issues which are present in compensated system. Different problems in compensated system are as follows; voltage and current inversion in case of directional relaying, over reach and under reach in case of distance relaying scheme. In this paper, two source systems are considered for the detection of fault direction as well as fault location estimation in series compensated system.

Figure 1 and 2 shows reactance diagram of simple compensated system. Relay is connected at bus *Y*, left side of the relay is known as backward side and right side of the relay is known as forward side of the relay. X_X is the inductive reactance of source X, X_Z is the inductive reactance of source Z, X_C is the series capacitor's capacitive reactance and X_L is the inductive reactance of line.

The necessary conditions for inversion of relay voltage and current at relay bus are given below[4, 5].

$$X_C > mX_L \text{ and } mX_L + X_S > X_C \tag{1}$$

$$X_C > mX_L + X_S \tag{2}$$

From Figure 3 and Figure 4, it is observed that in case of uncompensated system voltage seen by the relay leads the current seen by the relay but during compensated system voltage seen by the relay lags the current seen by the relay. In another case, from Figure 5 and Figure 6, it is observed that incase of compensated system current seen by the relay leads the voltage. So, voltage and current inversion are tremendous problems in a transmission

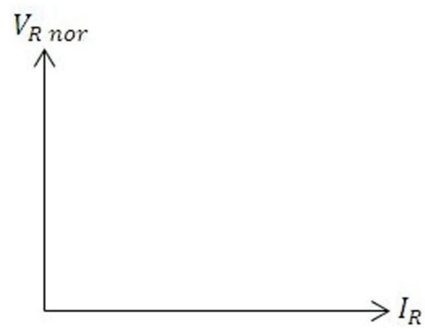

Figure 3. Fault voltage phasor in uncompensated system.

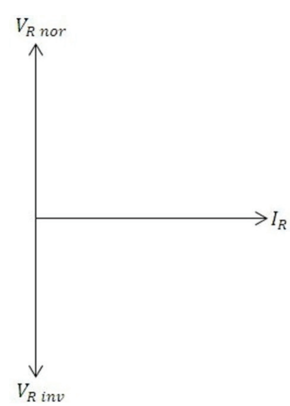

Figure 4. Fault voltage phasor in compensated system.

line. Due to these, sometimes miss-operation is done by the relay in compensated system.

3. Methodology of Solution

Solution approach for fault detection and fault location are discussed in section 3.1 and section 3.2 respectively.

Figure 5. Fault current phasor in uncompensated system.

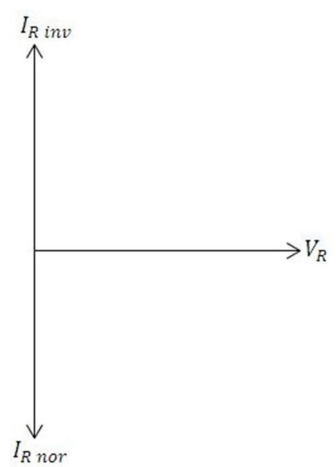

Figure 6. Fault current phasor in compensated system.

3.1 Proposed Approach for Fault Detection

A two source system is taken for the simulation considering relay at bus-Y. Left side of the relay known as backward side of the relay and right side of the relay connected bus is known as forward side of the relay. At any fault in Section-XY is taken as backward side fault (i.e. F_A fault) and fault in Section-YZ is considered as forward side fault (i.e. F_B fault). Single-line diagram of two source system is shown in Figure 7.

The steady state current can be stated as

$$I_{Steady} = (V_X - V_Z)/Z_{XZ} \tag{3}$$

where V_X = voltage of source X, V_Z = voltage of source Z, V_{XZ} = total line impedance between two sources.

3.1.1 Power Transfer in between Bus X to Bus Z (Forward Power Flow)

Power transfer in between bus X to bus Z is shown in Figure 8. In case of backward side fault, current during fault (I_{F_A}) is transfer from source Z to F_A point and is given by

$$I_{F_A} = V_Z / Z_{Z F_A} \tag{4}$$

Sequence current $(I_{A F_Z})$ is seen by the relay is given below:

$$I_{A F_Z} = I_{steady} - I_{F_A} \tag{5}$$

It is observed from Figure 10 that, in case of forward side fault (F_B) fault current transfer from bus X to point (F_B)

$$I_{F_B} = V_X / Z_{X F_B} \tag{6}$$

Now, current during fault $I_{B F_X}$ (positive sequence) flowing through relay connected bus Y is shown below

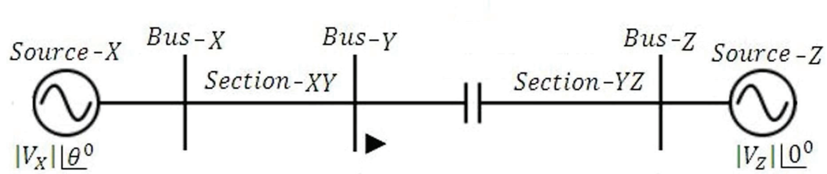

Figure 7. Two source model.

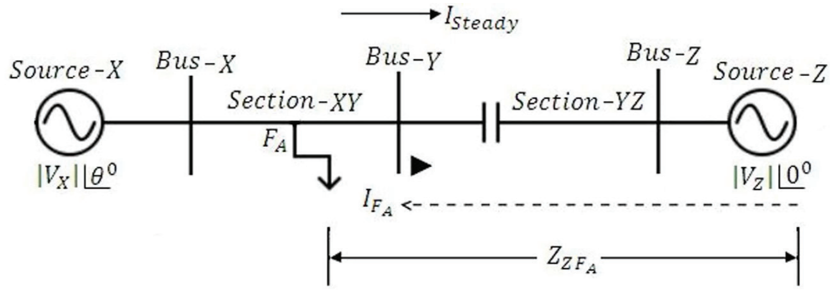

Figure 8. Fault at F_A (forward power flow).

$$I_{BF_X} = I_{steady} + I_{F_B} \tag{7}$$

It is obtained from Figure 9 and Figure11 that the phase difference among post-fault and steady state positive sequence current phasor $(\Delta\alpha_A)$ is positive for backward side fault (at F_A) and negative $(\Delta\alpha_B)$ for forward side fault (at F_B) respectively. Figure 12 shows phasor diagram of current inversion during forward power flow.

3.1.2 Power Transfer in between Bus Z to Bus X (Reverse Power Flow)

Figure 13 shows reverse power flow system. Post-fault current (I_{F_A}) flowing between source-Z and the lowest potential point F_A in case of backward side fault is given by

$$I_{F_A} = V_Z / Z_{ZF_A} \tag{8}$$

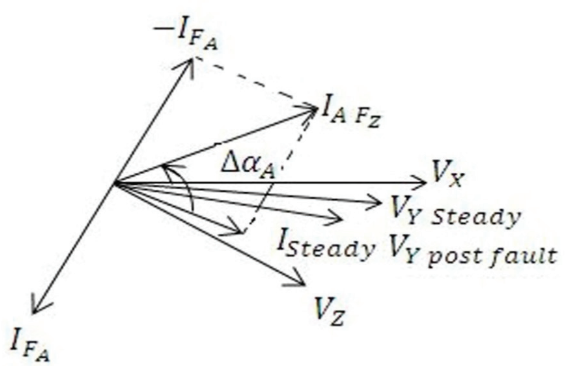

Figure 9. Phasor diagram for fault at F_A (forward power flow).

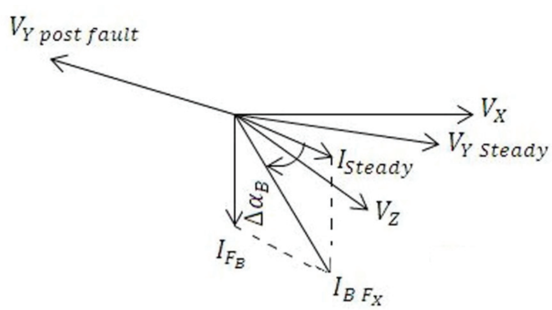

Figure 11. Phasor diagram for fault at F_B (forward power flow), voltage inversion condition.

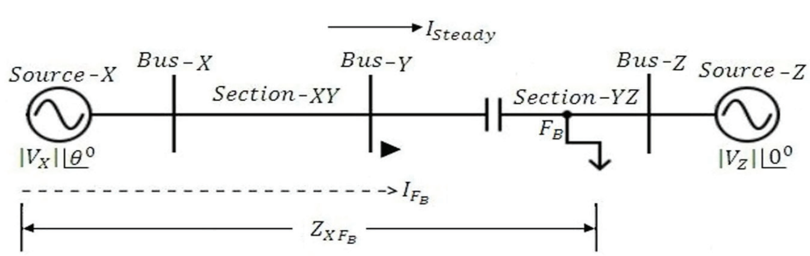

Figure 10. Fault at F_B (forward power flow), voltage inversion condition.

Positive sequence current (I_{AF_Z}) is seen by the relay is given below:

$$I_{AF_Z} = I_{steady} + I_{F_A} \tag{9}$$

It is seen from the above phasor diagram in Figure 14, that the phase difference is negative for backward side fault.

Figure 15 shows 3 bus 2 source power system considering capacitor and relay at bus Y. The fault path impedance changes in presence of capacitor. Relay indicates fault at Section-XY instead of original position of fault (at Section-YZ) during voltage inversion. In this paper, we are trying to detect the fault direction properly considering different issues in compensated system to overcome the said phenomenon.

Current after initiating fault at point F_B flowing between the generator-X to the lowest potential point F_B is given by

$$I_{F_B} = V_X / Z_{XF_B} \tag{10}$$

Positive sequence current I_{BF_X} seen by the relay

$$I_{BF_X} = I_{steady} - I_{F_B} \tag{11}$$

From Figure 16, it is clear that angle among post-fault and steady state current phasor is positive for forward side fault.

The phasor diagram for current inversion during reverse power flow is shown in Figure 17. It is found that, the angle $'\Delta\alpha_B'$ is negative at current inversion. So, relay is unable to identify the fault position properly. A new variable $'\Delta\nu'$ is used to overcome this mismatch.

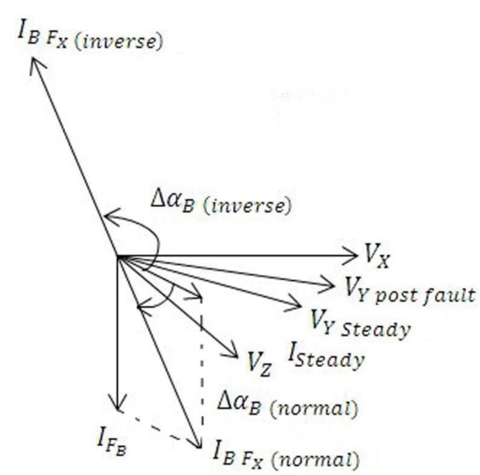

Figure 12. Phasor diagram for fault at F_B (forward power flow), current inversion case.

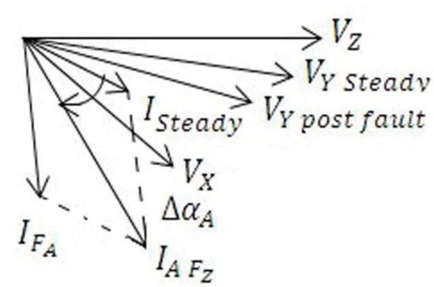

Figure 14. Phasor diagram for fault at F_A (reverse power flow).

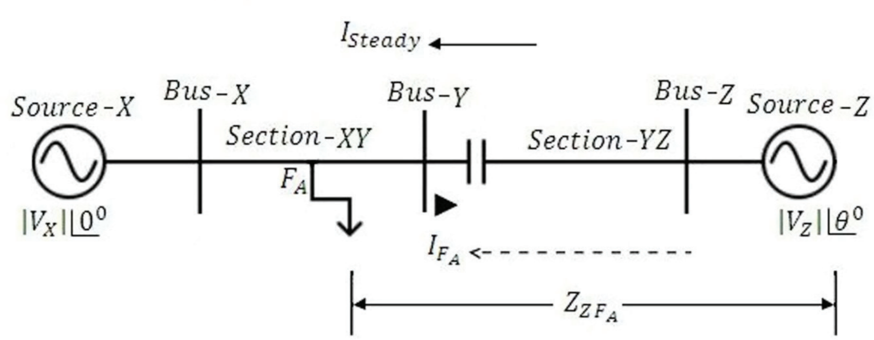

Figure 13. Fault at F_A (reverse power flow).

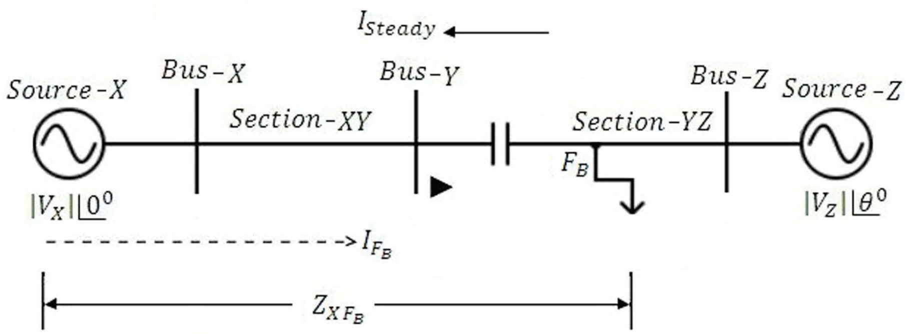

Figure 15. Fault at F_B (reverse power flow), voltage inversion condition.

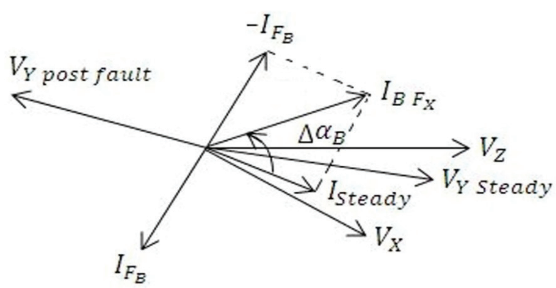

Figure 16. Phasor diagram for fault at F_B (reverse power flow), voltage inversion condition.

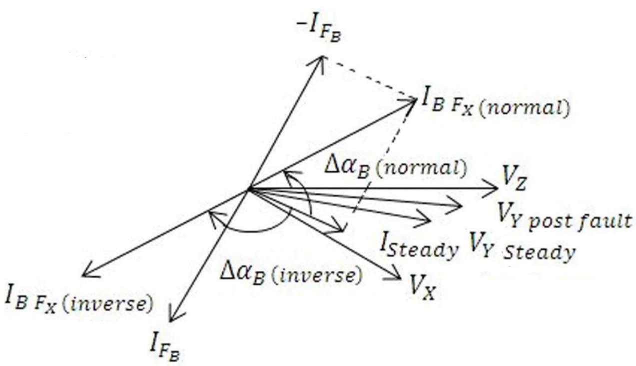

Figure 17. Phasor diagram for fault at F_B (reverse power flow), current inversion condition.

Normally, there is a drop in relay connected bus voltage in a transmission line during fault. But in current inversion situation, relay bus voltage is increased for different positions of fault current phasor which is also shown in Figure 17.

Above phasor diagrams lead to the fault direction estimation considering issues in capacitor connected system. An algorithm for the fault detection estimation is given below:

Step 1. Obtaining voltage and current data
Step 2. Steady state voltage and current phasor calculation
Step 3. Calculation of positive sequence voltage and current components
Step 4. Computation of angle difference among positive sequence post-fault and steady state current and magnitude difference among positive sequence post-fault and steady state voltage
Step 5. Apply fault direction estimation rule to obtained fault direction

3.2 Proposed Approach for Fault Location Calculation

Parameters are used in Figure 18 are shown :

V_X = voltage of the substation X; V_Z = voltage of the substation Z; I_X = current flowing from substation X to fault point; I_Z = current flowing from substation Z to fault point; SCs= series capacitors; n=distance from substation X or substation Z to the fault point; Zl=impedance of the transmission line and V_{F_A} =voltage at the fault point.

In the Figure 18, suppose a LG fault has occurred on the transmission line. Consider, distance of fault point from substation X is n and (1-n) from substation Z. The representation of LG fault occurred any phase of the system can be extended to its positive, negative and zero sequence components for substations X and substation Z.

Sequence component representation without considering capacitor of the network as seen from substation X is shown in Figure 19.

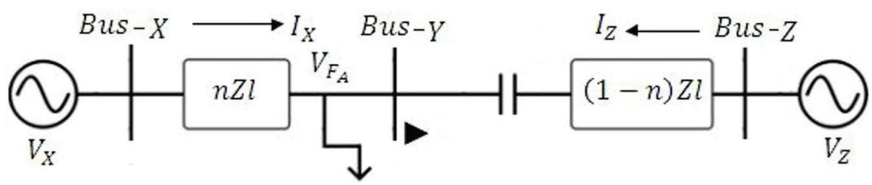

Figure 18. Series compensated line.

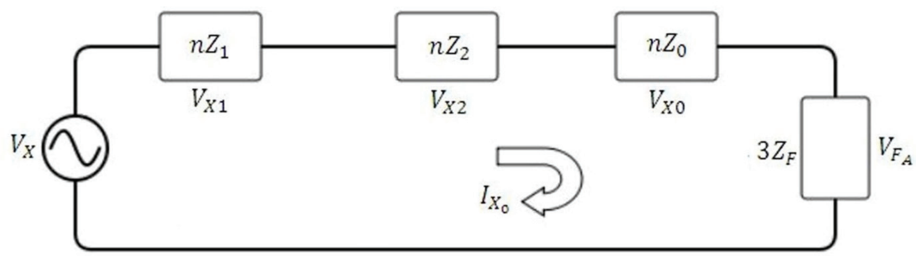

Figure 19. Equivalent sequence network for substation X.

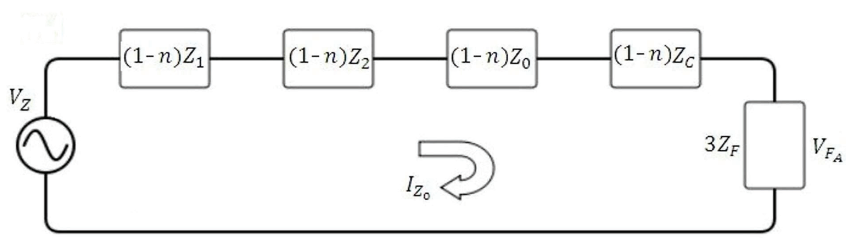

Figure 20. Equivalent sequence network for substation Z.

The equivalent sequence network after considering series capacitor seen from substation Z is given in Figure 20.

where Z_C, V_C = impedance and voltage of series connected capacitor; V_X, V_Z = source voltages of the substation X and substation Z; I_{X_0}, I_{Z_0} = zero sequence current; V_{F_A}, Z_{F_A} = voltage and impedance at low potential point (i.e. fault point).

$$V_{F_A} = V_X - n(Z_1 + Z_2 + Z_0)I_{X_0} \tag{12}$$

Similarly, LG fault voltage V_{F_A} seen from substation Z is

$$V_{F_A} = V_Z - (1-n)(Z_1 + Z_2 + Z_0 - Z_C)I_{X_0} \tag{13}$$

I_0 (i.e. zero sequence current) from substation X and Z are shown below

$$I_{X_0} = I_X/3$$

$$I_{Z_0} = I_Z/3$$

If we equate the equation (3) and (4) then we found

$$V_X - n(Z_1 + Z_2 + Z_0)I_{X_0} = V_Z - (1-n)(Z_1 + Z_2 + Z_0 - Z_C)I_{X_0} \tag{14}$$

$$V_X - n(Z_1 + Z_2 + Z_0)(I_X/3) = V_Z - (1-n)(Z_1 + Z_2 + Z_0 - Z_C)(I_Z/3) \tag{15}$$

From equation (6) we can find the expression for fault distance ‘n’ is

$$n=(V_X-V_Z+(I_Z/3)*(Z_1+Z_2+Z_0-Z_C))/((((I_X+I_Z)/3)*(Z_1+Z_2+Z_0))-(Z_C*(I_Z/3))) \tag{16}$$

For getting distance n from equation 16, magnitudes and phase angle of V_X, V_Z, I_X, I_Z, Z_1, Z_2, Z_0, and Z_C must be known first. All these values can be extracted from FFT during a fault. The compensation is applicable in the transmission line has a limitation and series compensation is recommended from 25% to 75%. Here the series compensation is done at 70%. The algorithm for the fault location estimation is given below:

Step 1. Obtaining voltage and current data
Step 2. Low pass filter is used for filtering out the harmonic components
Step 3. FFT is used to compute the fundamental component of input signals
Step 4. Apply two terminal methods for locating the location of the fault

4. Performance Evaluation and Discussions

Performance evaluation for fault detection and fault location are discussed in section 4.1 and section 4.2 respectively.

4.1 Performance Analysis for Fault Direction Detection

The angular difference between the post-fault current signal and steady state current signal is used for detect the direction of fault in voltage inversion condition. In current inversion situation difference of phasor between the post-fault and steady state current phase as well as difference between magnitude of post-fault and steady state voltage is also used[7]. Positive sequence voltage and current signals are estimated by using FFT block in EMTDC/PSCAD tool. After collecting these signal faults direction estimation algorithm is implemented in MATLAB software. Data sample frequency (f_s) ratio was taken at 4 kilohertz. Phase A is taken as a reference phase. The cycle-cycle comparison technique[5] is followed to investigate the fault.

A series compensated system[7,18] is considered in Figure 7 with length of Section XY is 10 km and Section YZ is 12 km respectively. Relay was connected at middle bus, left side of the relay is considered as backward side (side of the source X) and right side of the relay is known as forward side (side of the source Z).

The phase difference between sources X and Z is changed for providing various power-flow conditions[18]. The obtained results for AG fault at point F_A and point F_B in voltage inversion case are presented in Table 1. It is obtained, if fault occur at backward side of the relay with and without C then $\Delta\alpha_A$ is positive, fault occur at the forward side of the relay with and without C then $\Delta\alpha_B$ is negative which is in agreement with the direction obtained from phasor diagram.

Table 2 provides results for single phase to ground fault at reverse power flow situation. It is obtained that if a fault occurs at backward side of the relay (i.e. at fault point F_A) with and without capacitor, then $\Delta\alpha$ is negative. Similarly, angular difference between the post-fault and steady state current signal is positive during fault occurring in the forward portion of the relay which matches with the phasor diagram.

Table 1. Result for AG fault, voltage inversion case

Faulted section and status of capacitor	Steady State Current phasor		Post-Fault Current phasor		Steady State Voltage phasor		Post-Fault Voltage phasor		$\Delta\alpha$ (rad)
	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	
Fault at F_A without C	0.0044	-1.4772	0.0108	-1.2308	0.7952	-2.4689	0.3914	-2.6801	0.2463
Fault at F_A with C	0.0046	-1.4843	0.0158	-1.2267	0.7952	-3.9435	0.5934	-2.6792	0.2476
Fault at F_B without C	0.0044	-1.4772	0.0118	-1.7530	0.7952	-2.4689	0.4300	-1.5863	-0.2758
Fault at F_B with C (voltage inversion)	0.0046	-1.4843	0.0128	-1.6927	0.7952	-2.4692	0.9221	-2.6524	-0.2084

Table 2. Result for AG fault, voltage inversion case (reverse power flow)

Faulted section and status of capacitor	Steady State Current phasor		Post-Fault Current phasor		Steady State Voltage phasor		Post-Fault Voltage phasor		$\Delta\alpha$ (rad)
	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	
Fault at F_A without C	0.0030	-1.6174	0.0080	-2.3000	0.7952	-2.5582	0.4471	-2.7194	-0.6826
Fault at F_A with C	0.0039	-1.6145	0.0087	-1.8795	0.7952	-2.5587	0.4788	-2.7189	-0.265
Fault at F_B without C	0.0030	-1.6174	0.0084	-1.3167	0.7952	-2.5582	0.3870	-2.3784	0.3007
Fault at F_B with C (voltage inversion)	0.0039	-1.6145	0.0095	-1.3747	0.7952	-2.5587	0.5188	-2.6995	0.2397

Table 3. Result for AG fault, current inversion case

Faulted section and status of capacitor	Steady State Current phasor		Post-Fault Current phasor		Steady State Voltage phasor		Post-Fault Voltage phasor		$\Delta\alpha$ (rad)	Δv (volt)
	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)		
Fault at F_A without C	0.0038	-1.6174	0.0108	-1.2308	0.7952	-2.4689	0.5812	-2.6801	0.3866	-0.214
Fault at F_A with C	0.0050	-1.4743	0.0095	-1.3784	0.7952	-2.3582	0.60	-2.6998	0.0959	-0.1952
Fault at F_B without C	0.0038	-1.6174	0.0090	-1.8563	0.7952	-2.4689	0.6300	-1.6530	-0.2389	-0.1652
Fault at F_B with C (current inversion)	0.0050	-1.4743	0.0116	-1.2827	0.7952	-2.3582	0.9321	-2.6524	0.1916	0.1369

Table 4. Result for AG fault, current inversion case (reverse power flow)

Faulted section and status of capacitor	Steady State Current phasor		Post-Fault Current phasor		Steady State Voltage phasor		Post-Fault Voltage phasor		$\Delta\alpha$ (rad)	Δv (volt)
	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)	Mag (amp)	Angle (rad)		
Fault at F_A without C	0.0032	-1.6174	0.0094	-2.0400	0.7952	-2.5582	0.4471	-2.7194	-0.4226	-0.3481
Fault at F_A with C	0.0035	-1.4772	0.0108	-1.7163	0.7952	-2.4689	0.4972	-2.6530	-0.2391	-0.298
Fault at F_B without C	0.0032	-1.6174	0.0095	-1.5172	0.7952	-2.5582	0.4735	-1.1998	0.1002	-0.3217
Fault at F_B with C (current inversion)	0.0035	-1.4772	0.0097	-1.6747	0.7952	-2.5587	0.9158	-2.6995	-0.1975	0.1206

Results for AG faults are provided in Table 3, where first two rows represent results after faults at point F_A and last two rows shows the result after initiating faults at point F_B of the transmission line. During capacitor present in the circuit fault at Section XY, $\Delta\alpha$ is positive and Δv is negative. Similarly, fault at Section YZ with C, $\Delta\alpha$ as well as Δv both is positive. These results validate the direction of fault obtained from the phasor diagrams.

During AG fault in case of a current inversion situation (reverse power flow) obtained results are tabulated in Table 4. Angle differences are negative in case of fault at F_A without C; F_A with C; F_B with C and positive in case of fault at F_B without C. Magnitude of post-fault

Table 5. Result for LG fault

Sl. No.	Actual Fault Location (km)	Calculated Fault location without C (km)	Calculated Fault location with C (km)	% Error without C	% Error with C
1.	5	4.6741	4.7825	-1.4813	-0.9886
2.	8	8.2321	8.1208	1.055	0.5490
3.	11	11.2749	10.8406	1.2495	-0.7245
4.	15	14.8860	15.0751	-0.5181	0.3413
5.	18	17.8632	17.9216	-0.6218	-0.3563
6.	20	20.3857	20.1443	1.7531	0.65590

and steady state voltage is negative in first three rows and positive in last row of Table 4. Above results provide accurate direction of fault with direction obtained from phasor diagram also.

4.2 Performance Analysis for Fault Location Estimation

Transmission line parameter and source parameter are shown in appendix-I. The transmission line can be modeled using available Distributed Parameter Line or Three Phase Pi Section Line Blocks[19]. System is simulated using Matlab/Simulink software for obtaining fault location. During fault all harmonic components are present with fundamental voltage and current components. To segregate fundamental component from harmonic components low pass filter with pass band frequency 470 rad/s is used. Sampling time is 50×10^{-6} sec is used[19]. Fast Fourier Transform (FFT) block is used for obtaining current and voltage phase and magnitude from voltage and current waveforms. In this case Line-ground fault is considered. The V-I measurement block is used for obtaining the value of three-phase currents and voltages in simulating models. Two-terminal technique is used to find the LG fault location in the line[19]. Fault was simulated at 5 km, 8 km, 11 km, 15 km, 18 km and 20 km distance of the tested line. After simulating fault at different places of the transmission line results are provided in the following sections.

In order to evaluate performance of fault estimation algorithm, several cases, i.e. fault was simulated at lowest 5 km distance and highest 20 km distance were analyzed as shown in Table 5. In average, the error in calculating the distance to the fault point from source is a maximum 1.7531% for fault without capacitor and -0.9886% for fault with capacitor.

5. Conclusions

Fault detection as well as fault location estimation in both Sections of compensated line considering transmission line issues is proposed in this paper. The above method is tested for forward power flow, reverse power flow, voltage inversion and current inversion cases. Simulation results show that proposed technique properly detects the direction of fault and locating the exact location of fault. Tested system is developed in PSCAD software, algorithm is developed with MATLAB coding for detection of fault direction in Sections and for obtaining fault location MATLAB/SIMULINK software is used.

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Appendix-I

The parameters of each line are;

System voltage = 33 kV
System frequency = 50 Hz
Length of Section XY = 10 km
Length of Section YZ= 12 km
Positive sequence impedance of the lines = 0.106+j0.115 Ω /km
Positive sequence capacitance =12.74 *10-9 F/km
Zero sequence impedance of the lines = 0.502+j0.321 Ω /km
Zero sequence capacitance= 7.751*10-9 F/km

Source parameters[18] are;

Positive sequence source impedance = 0.038+j1.86 Ω
Zero sequence source impedance = 0.051+j2.15 Ω
% Error[19]= ((Calculated fault location-actual fault location)*100)/ (Line length)