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IMPACT OF DG ON POWER SYSTEM FAULTS IN RADIAL DISTRIBUTION SYSTEM

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Abstract— The Purpose of protection equipment in the power system is to disconnect the faulty part and minimizing the damage caused by the faults. Pickup value of fault current plays a major role for the operation of protection equipment. Therefore, before connecting protection equipment to the network fault analysis is done for setting the pickup value of fault current. But with the insertion of DG to the network the magnitude of fault current is increased. Due to this increased fault current relays may operate operation of the protection equipment disturbed. So that fault current calculations are needed before inserting DG to the network. In this work mainly focused on balanced three phase radial distribution network. MATLAB software is used for modeling the network and simulation of results under different fault conditions. Fault currents are found out under different fault conditions like LG, LL, LLG and LLLG without any insertion of DG to the network. Fault currents are found out to the same network with the insertion of DG for the above fault conditions and compare the results with DG and without DG.

Keywords— Distributed generation(DG), Line to ground fault (LG), Line to line fault (LL), Double line to ground fault(LLG), Three phase to ground fault (LLLG)

I. INTRODUCTION

In radial distribution system power flow is unidirectional that means power is flow from grid to the load. The protection equipment used in the radial distribution system designed to operate in unidirectional power flow. The fault current flows in radial distribution is flows from grid to load, and they will not be designed operate in bidirectional power flow. The pickup values of protection equipment are fixed at designed stage. IEEE publisher (2007) and Youngwook Kim et al.(2016) addressed the relays operation and superconducting fault current operation in the distribution system [1-2]. But in the present smart grid distributed generation plays a major role due to automation of every system in the world leads to increasing demand for the electricity. With the increasing demand increasing of power generation is not recommended, by the consideration of transmission and distribution lines cost point of view. Hence DG in distribution network is the best alternative solution to meet the increased load demand. Thong Vu van et al. (2005) and Metra K (2015)

addressed the DG integration and its impact on distribution system [3-4].

But with the insertion of DG into the network causes the increase in fault current magnitude and direction power flow is bidirectional. With the increased fault current the existing protection equipment may not operate and coordination of protection system disturbed. Operation of power system will be damaged. Hence before inserting DG into the network fault analysis was done. Muhammad Aslam Usailin et al. (2014) and Dulan Lucian Ioan (2014) addressed the impact of DG on the fault current in distribution system [5-6].

II. FAULTS IN POWER SYSTEM

Power system operate at different voltage and current levels so it is necessary to convert the all the ratings into a common value called per unit quantities with the common base value. Reactance diagram is used for unsymmetrical fault analysis. Symmetrical faults are analyzed using bus impedance matrix and by using the venin's theorem. Faults in power system can be classified into two types and they are 1.Symmetrical faults 2.Unsymmetrical faults .William patrick Davis (2012) addressed the faults in transmission line [7].In the symmetrical faults the fault current flowing in the three phases are equal in magnitude, it is also called as balanced fault three phase fault is an symmetrical fault. In the unsymmetrical faults the fault current flowing in the each phase is different in magnitude. Symmetrical components are used for the unsymmetrical fault analysis. LG, LL and LLG faults are the examples of the unsymmetrical faults.

A.Line to ground fault-

Figure 1 shows the line to ground fault occurred at point k in phase a through fault impedance.

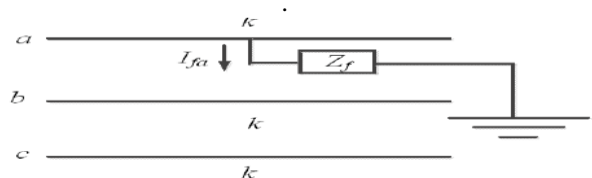


Fig.1. Line to ground fault in phase a

$$I_{a1} = (V_{pf}) / ((Z_1 + Z_2 + Z_0) + 3 Z_f) \quad (1)$$

$$I_{a1} = I_{a2} = I_{a0} \quad (2)$$

$$\begin{aligned} I_{fa} &= 3 I_{a1} & (3) \\ I_{fb} &= 0, I_{fc} = 0 \end{aligned}$$

Where I_{a0}, I_{a1}, I_{a2} are the zero, positive and negative sequence components of current.

Where I_b and I_c are the current flowing in the phases b and c

V_{pf} = Prefault voltage

I_{fa} = Fault current in phase a

Z_0, Z_1 and Z_2 are the zero, positive and negative sequence components of impedance.

Z_f = Fault impedance

The magnitude of fault current value depends on the impedance value. Single line to ground fault is the most common type of faults occurring in the distribution systems.

B. Line to Line fault -

Figure 2 shows the line to line fault occurred at point k in phase b and c phases through fault impedance. The magnitude of fault current value is depends on the impedance value. The fault current is flowing in the b and c phases.

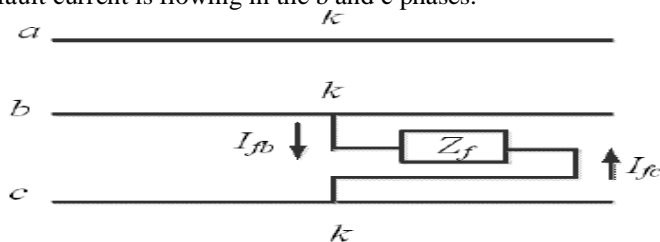


Fig.2. Line to Line fault in phase's b and c

$$I_{fb} = -I_{fc} \quad (6)$$

$$I_{a1} = (V_{pf}) / (Z_1 + Z_2 + Z_f) \quad (7)$$

$$I_{a2} = -I_{a1} \quad (8)$$

$$I_{a0} = 0, I_a = 0$$

The fault current is calculated from the symmetrical components.

C. Double Line to ground fault-

Figure 3 shows the double line to fault occurred at point k in phases b and c through fault impedance.

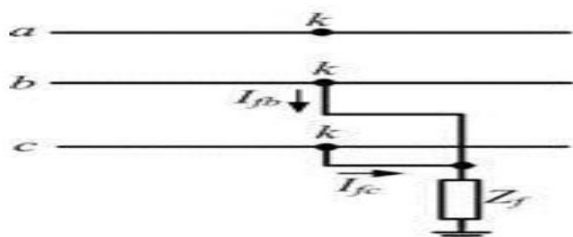


Fig.3. Double line to ground fault occurred in phase's b and c

$$I_a = 0, \quad I_{a0} = -(I_{a1} + I_{a2}) \quad (9)$$

$$I_{a2} = V_{a2} / Z_2 \quad (10)$$

$$V_{a2} = V_{a1} \quad (11)$$

$$V_{a1} = V_{pf} - Z_1 I_{a1} \quad (12)$$

$$I_{a1} = \frac{V_{pf}}{Z_1 + \frac{Z_2(Z_0 + 3Z_f)}{Z_1 + Z_2 + Z_0 + 3Z_f}} \quad (13)$$

$$I_{fb} = I_{fc} = 3 I_{a0} \quad (14)$$

$$I_{a0} = -(I_{a1} + I_{a2}) \quad (15)$$

D. Three phase to ground fault-

Figure 4 shows the three phase to ground fault occurred at point k. The fault current flowing in the three phases are equal. And the value of fault current magnitude depends on the fault impedance.

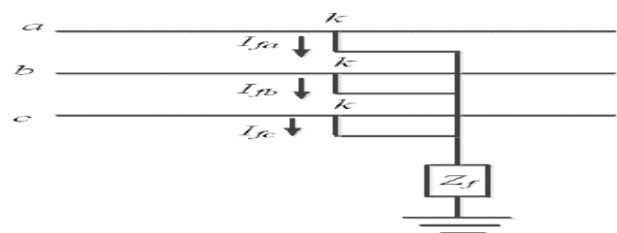


Fig.4. Three phase to ground fault through fault impedance

The order of severity of faults in the power system are LLLG, LLG, LL and LG. Probability of occurrence of faults in power system are LG(70%), LL(15%), LLG(10%), LLLG(5%).

III. DISTRIBUTED GENERATION IN POWER SYSTEM

DGs are small scale generating units up to the rating of 10MW. And they are connected to the placed at near to load centers. As the fast growing technology of power system distributed generation plays a vital role. DGs are made with renewable energy sources in order to decrease the environmental pollution compared to the traditional grids uses fuel as coal and oil. DGs are renewable energy sources like solar, wind, biomass and hydro power generation. DG to the system increases the advantages like improved voltage profile, transmission and distribution line losses reduced, transmission and distribution lines cost can be reduced, satisfying of the load during the peak hours. Insertion of DG to the network also causes the disadvantages like power flow direction is reversed, increased in the fault current magnitude, false tripping of healthy feeders and voltage fluctuation. Ekuel A.O et al. (2015) and Pepermanns G et al. (2005) addressed the DG in distribution system [8-9]. There are many negative impacts occur in the system due insertion of DG into the network. Kauhaniemi K et al.(2004) and Barker P et al.(2000) addressed the impact of DG in power system protection [10-

11]. In the traditional radial distribution system power flow is unidirectional but with the insertion of DG causes the power flow is bidirectional, with the bidirectional power flow existing protection equipment may operate. Without integration of DG into the network the fault current supplied by the source only. But with the integration of DG into the network causes the increase in fault current magnitude. The fault current supplied by the both source and DG hence the level of fault current can be increased Digambar R et al.(2017)addressed the impact of DG in the fault current and fault current limiter in distribution system [12]. Suppose two feeders are from a sub station and DG is connected to one of the feeder. When fault is occur in the next feeder the DG connected healthy feeder feeds fault current through the substation bus bar and healthy feeder relay may mal operate Zayandehroodi Hadi et al. (2011) addressed the impact of DG in protection system [13].

DGs are different types but in this paper renewable energy based hydro power DG is used Akhtar Kalam et al. (2011) addressed the DG operation in smart grid technology [14]. Photo voltaic system:solar energy is primary input fuel for the photo voltaic system.Solar energy is freely available in the nature. The fuel cost is zero in the PV system.The output voltage produced from the PV system is DC and it is converted into AC with the help of inverters. Wind power system: The wind power generation depends on speed of the wind. Wind turbine is connected to the shaft of the generator to produce power. Hydropower generation:Water at high head used for the hydro power generation.Hydro power generation is the renewable energy power generation and environmental pollution free generation.

IV. RADIAL DISTRIBUTION SYSTEM WITHOUT DG

Figure 5 is single line diagram of radial distribution network without any connecting DG to the network.

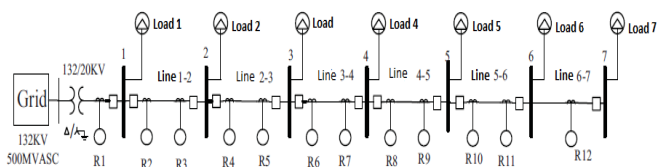
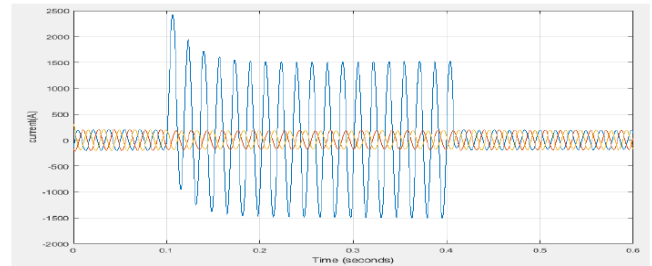


Fig.5. single line diagram of radial distribution network

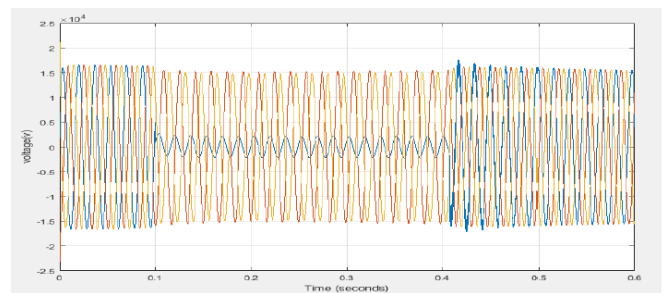
The lines and load data is given in the appendix. It consists of 7 bus radial balanced three phase three wire distribution network. Grid is an synchronous machine type and it is connected to the network through 132/20 KV,30 MVA transformer and it is an delta to star grounded transformer operate at a frequency of 60HZ.Different types of faults like LG, LL, LLG, LLLG applied in line 5-6 Without any connection of DG.

Case 1: LG fault in line 5-6 Without DG-

Depending on the type of transformer connection the value of fault current varies under LG fault condition. Circuit is running up to $t=0.6$ seconds, and fault duration time is $t=0.1$ seconds to 0.4 seconds. Without any protection equipment circuit is simulated under LG fault conditions.



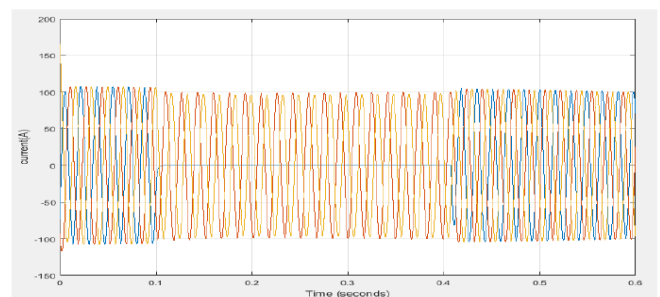
6(a)



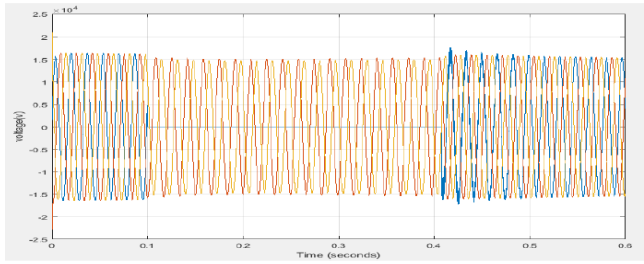
6(b)

Fig. 6 (a) and (b) current and voltage waveforms at bus 5

Before fault the peak value of current in all the three phases is 200A. During fault duration the level of fault current in the phase A is increased to 1500A and the current in the remaining two phases is maintains at 200A. After fault the level of current be maintains at 200A in all the three phases.



7(a)



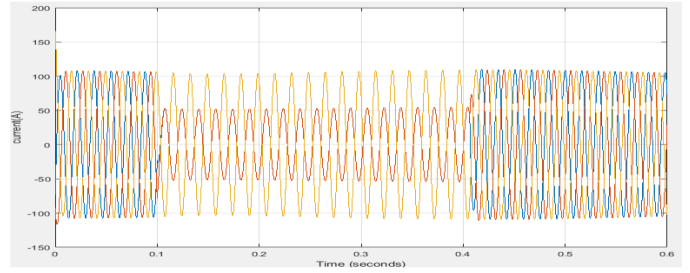
7(b)

Fig. 7(a) and 7(b) Current and voltage waveform at bus 6

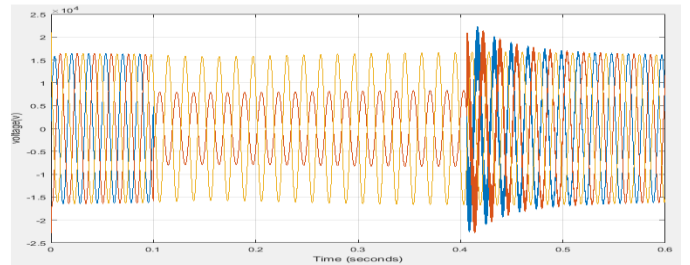
Before fault at bus 6 the peak value of current in all the three phases is 100A. During fault duration the value of current in the phase A is zero. The current in the remaining two phases are maintained at the same value. After fault the value of current in the three phases are maintained at 100A.

Case 2: LL fault in line 5-6 Without DG-

Running time of circuit is $t=0.6$ seconds and fault duration time is $t=0.1$ seconds to 0.4 seconds. Without any protection equipment circuit is simulated under LL fault conditions.



9(a)



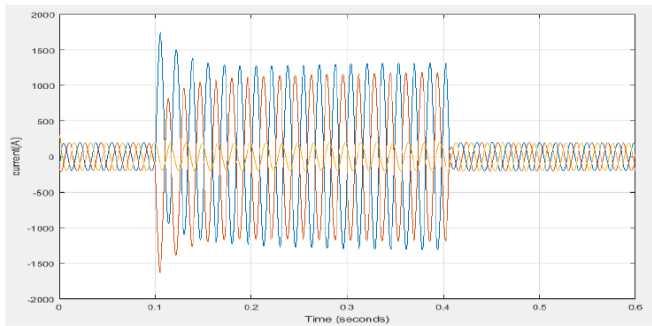
9(b)

Fig. 9(a) and 9(b) Current and voltage waveform at bus 6

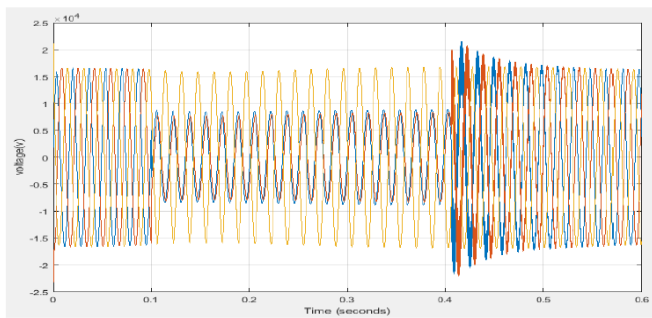
Before fault at bus 6 the peak value of current in all the three phases are 100A. During fault duration the value of current in the phase A is 0A and phase B is 50A. The current in the remaining phase is maintained at the same value 100A. After fault the value of current in the three phases are maintained at 100A.

Case 3: LLG fault in line 5-6: Without DG-

Running time of circuit is $t=0.6$ seconds and fault duration time is $t=0.1$ seconds to 0.4 seconds. Without any protection equipment circuit is simulated under LLG fault condition.



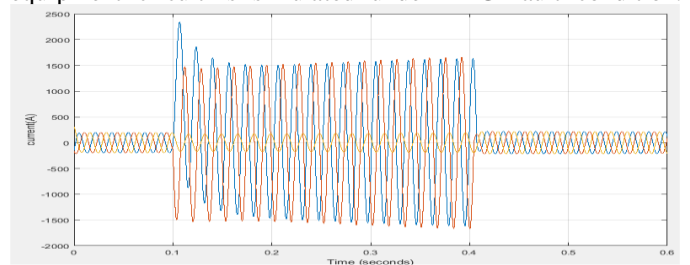
8(a)



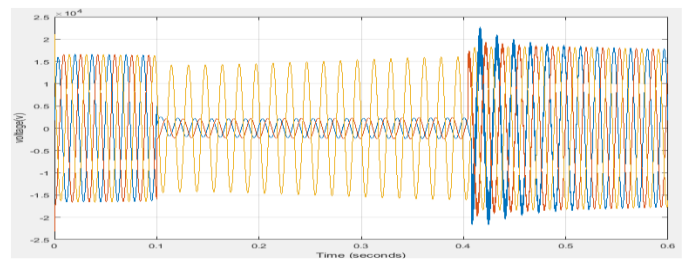
8(b)

Fig. 8(a) and 8(b) current and voltage waveform at bus 5

Before fault the peak value of current in all the three phases are 200A. During fault duration the current in faulted phases are A and B are increased to 1280A, the remaining phase current is maintained at 200A. After fault duration the level of current in all the three phases are maintains at 200A.



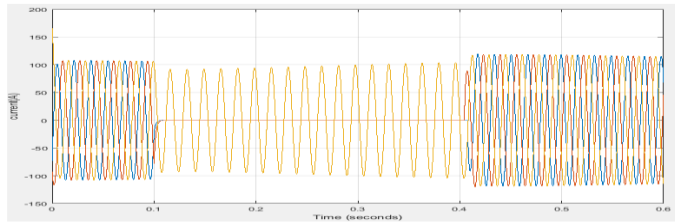
10(a)



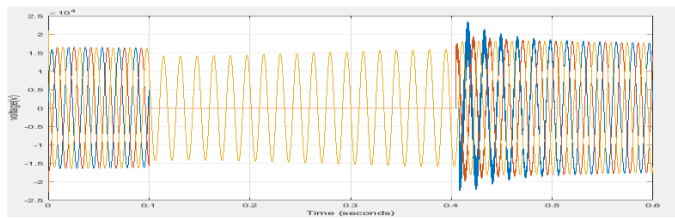
10(b)

Fig. 10(a) and 10(b) current and voltage waveforms at bus 5

Before fault the peak value of current in all the three phases are 200A. During fault duration the current in faulted phases A and B are increased to 1500A, the remaining phase current is maintained at 200A. After fault duration the level of current in all the three phases are maintained at 200A.



11(a)



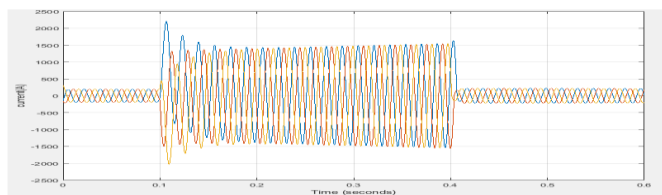
11(b)

Fig. 11(a) and 11(b) Current and voltage waveform at bus 6

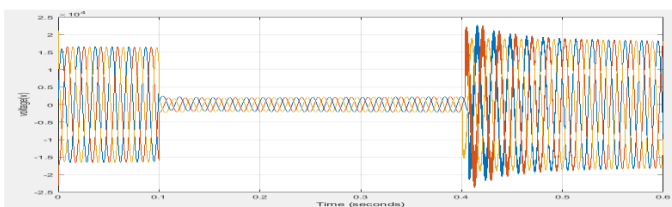
Before fault at bus 6 the peak value of current in all the three phases are 100A. During fault duration the value of current in the phase A is 0A and phase B is 0A. The current in the remaining phase is maintained at the same value of 100A. After fault the value of current in all the three phases are maintained at 100A.

Case 4: LLLG fault in line 5- 6: Without DG-

Running time of circuit is $t=0.6$ seconds, and fault duration time is $t=0.1$ seconds to 0.4 seconds. Without any protection equipment circuit is simulated under LLLG fault condition.



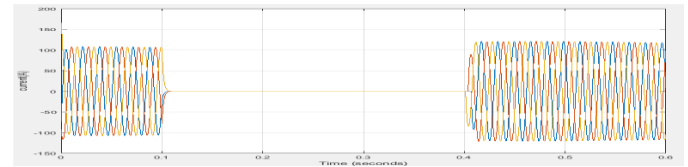
12(a)



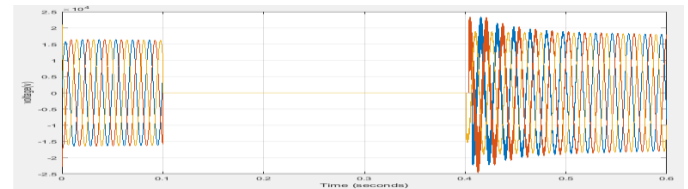
12(b)

Fig. 12(a) and 12(b) current and voltage waveform at bus 5

Before fault the peak value of current in all the three phases are 200A. During fault duration the current in all the three phases are increased to 1500A. After fault duration the level of current in all the three phases are maintained at 200A.



13(a)



13(b)

Fig. 13(a) and 13(b) current and voltage waveform at bus 6

Before fault at bus 6 the peak value of current in all the three phases are 100A. During fault duration the value of current in the all three phases are 0A. After fault the value of current in all the three phases are maintained at 100A.

V. RADIAL DISTRIBUTION SYSTEM WITH DG

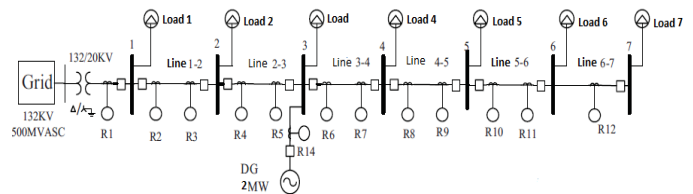
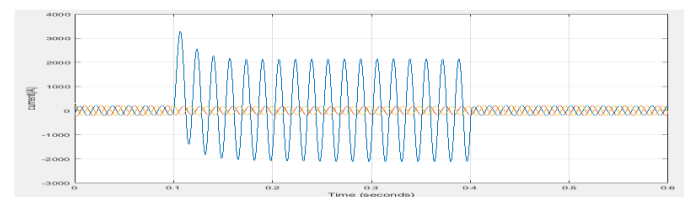


Fig. 14 single line diagram of a network with DG

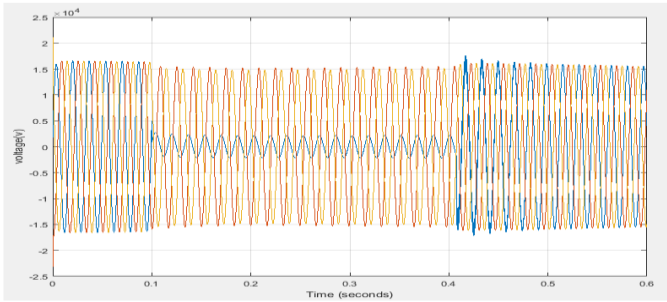
Hydro power generation is used as a DG in this work. And it is connected at the end of the 2nd bus and starting to the third bus with the 2MW of power generation. In this work impact of hydro power generation under fault conditions is studied.

Case 1: LG fault in line 5-6 With DG-

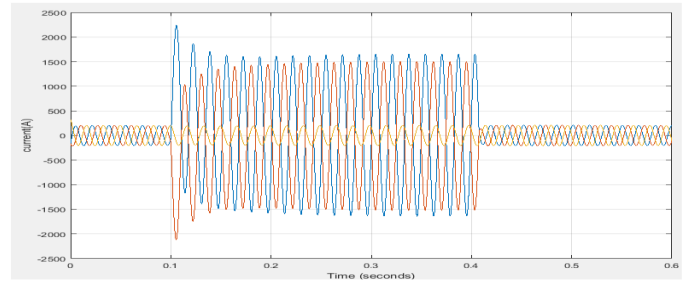
Running time of circuit is $t=0.6$ seconds and fault duration time is $t=0.1$ to 0.4seconds. Without any protection equipment circuit is simulated under LG fault condition.



15(a)

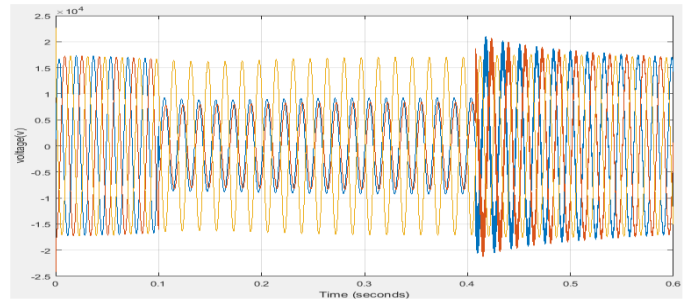


15(b)



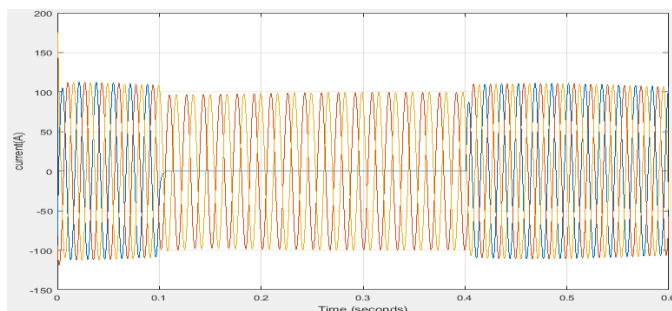
17(a)

Fig. 15(a) and 15(b) current and voltage waveform at bus 5
 Before fault the peak value of current in all the three phases are 200A. During fault duration the current in the phase A is increased to 2000A, the remaining two phases maintained at the same value of 200A. After fault duration the level of current in all the three phases are maintained at 200A.



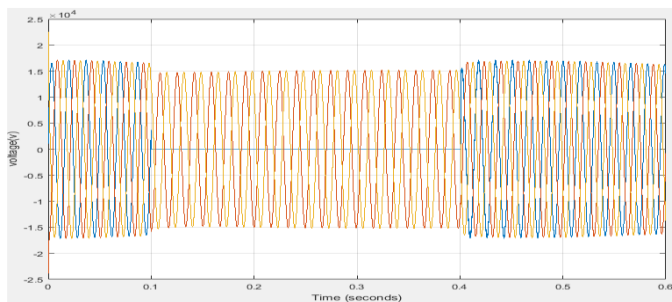
17(b)

Fig. 17(a) and 17(b) current and voltage waveform at bus 5



16(a)

Before fault the peak value of current in all the three phases are 200A. During fault duration the current in faulted phases are A and B are increased to 1500A, the remaining phase current is maintained at 200A. After fault duration the level of current in all the three phases are maintained at 200A.



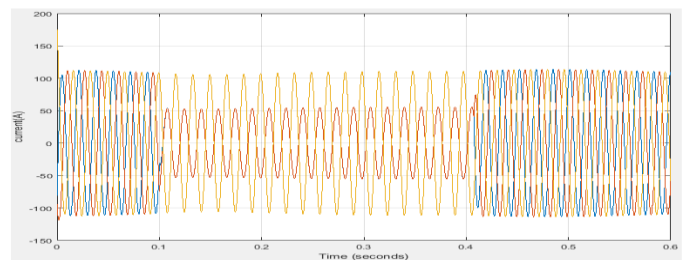
16(b)

Fig. 16(a) and 16(b) current and voltage waveform at bus 6

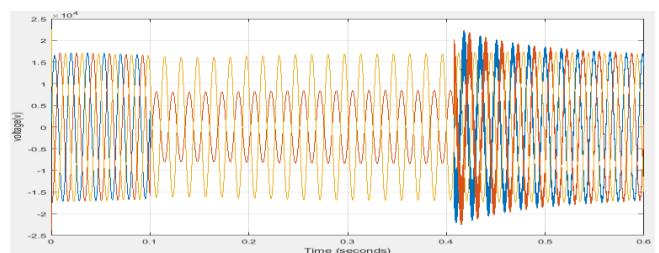
Before fault at bus 6 the current in all the three phases are 100A. During fault duration the value of current in phase A is 0A, the current in the remaining two phases are maintained at same value of 100A. After fault the value of current in all the three phases are maintained at 100A.

Case 2: LL fault in line 5-6 With DG-

Running time of circuit is $t=0.6$ seconds and fault duration time is $t=0.1$ to 0.4 seconds. Without any protection equipment circuit is simulated under LL fault condition.



18(a)



18(b)

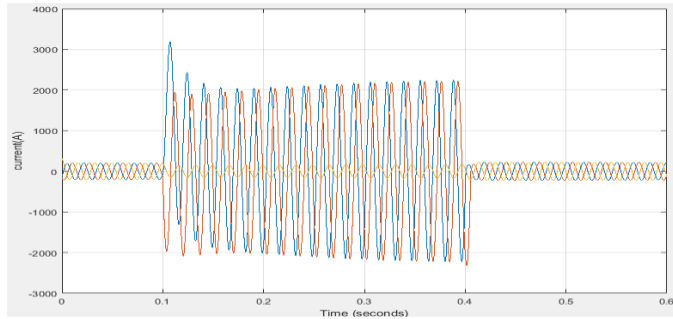
Figure 18(a) and 18(b) current and voltage waveform at bus 6



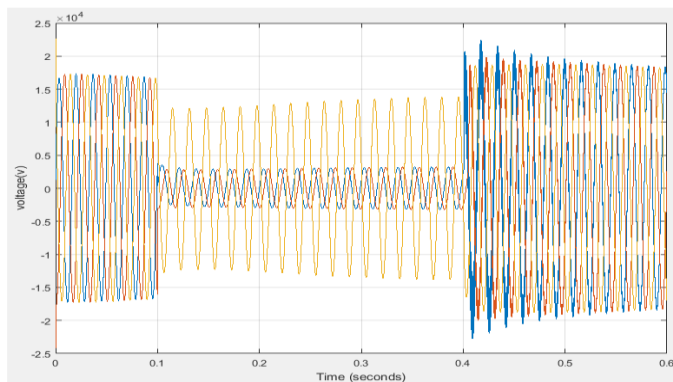
Before fault at bus 6 the peak value of current in all the three phases are 100A. During fault duration the value of current in the phase A is 0A phase B is 50A. The current in the remaining phase is maintained at the same value 100A. After fault the value of current in the three phases are maintained at 100A.

Case 3: LLG fault in line 5-6 With DG-

Running time of circuit is $t=0.6$ seconds, and fault duration time is $t=0.1$ to 0.4 seconds. Without any protection equipment circuit is simulated under LLG fault condition.



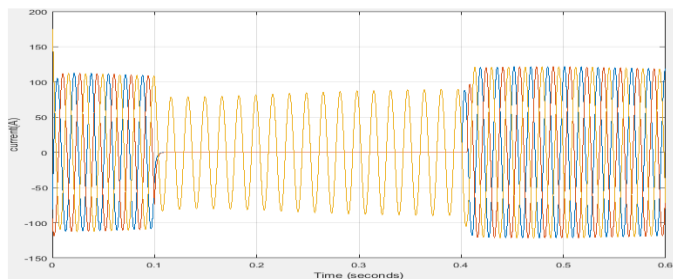
19(a)



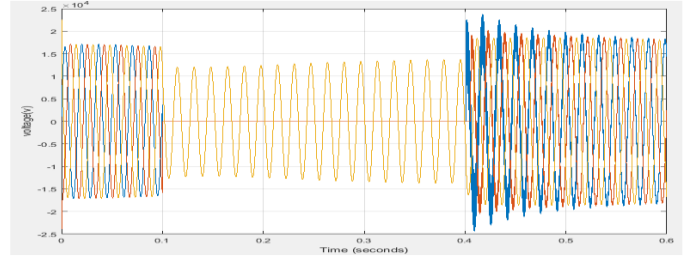
19(b)

Fig. 19(a) and 19(b) current and voltage waveform at bus 5

Before fault the peak value of current in all the three phases are 200A. During fault duration the current in faulted phases are A and B are increased to 2000A, the remaining phase current is maintained at 200A. After fault duration the level of current in all the three phases are maintained at 200A.



20(a)



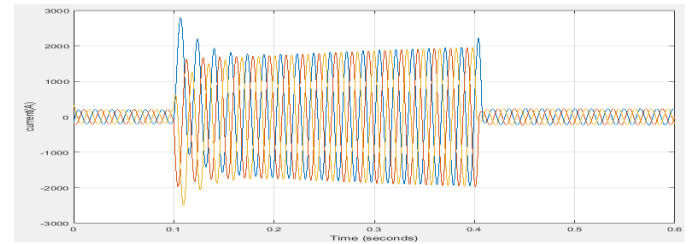
20(b)

Fig. 20(a) and 20(b) current and voltage waveform at bus 6

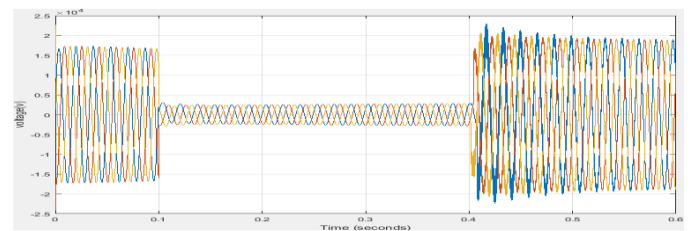
Before fault at bus 6 the peak value of current in all the three phases are 100A. During fault duration the value of current in the phase A is 0A and phase B is 0A. The current in the remaining phase is maintained at the same value of 100A. After fault the value of current in all the three phases are maintained at 100A.

Case 4: LLLG fault in line 5-6 With DG-

Running time of circuit is $t=0.6$ seconds and fault duration time is $t=0.1$ to 0.4 seconds. Without any protection equipment circuit is simulated under LLLG fault condition.



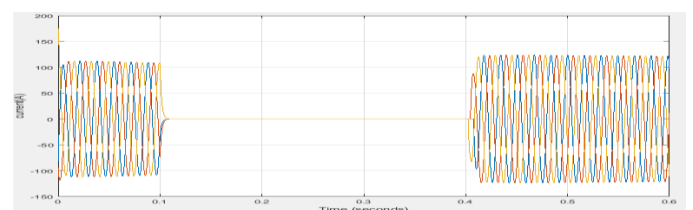
21(a)



21(b)

Fig. 21(a) and 21(b) current and voltage waveform at bus 5

Before fault the value of current in all the three phases are 200A. During fault duration the current in all the three phases are increased to 1500A. After fault duration the level of current in all the three phases are maintained at 200A.



22(a)

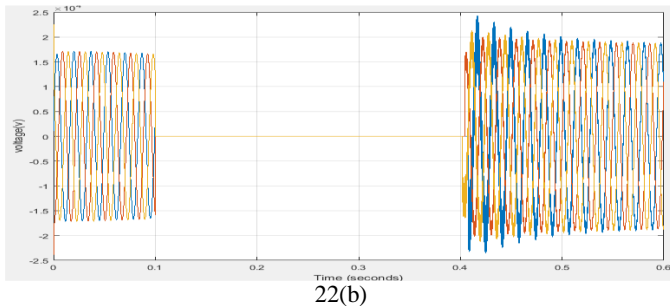


Fig. 22(a) and 22(b) current and voltage waveform at bus 6 Before fault at bus 6 the current in all the three phases are 100A. During fault duration the value of current in the all three phases are 0A. After fault the value of current in all the three phases are maintained at 100A.

Table -1 Comparison of fault current with DG and without DG

Type of fault	Without DG fault current(A)	With DG fault current(A)
LG fault	1500	2000
LL fault	1280	1500
LLG fault	1510	2000
LLLG fault	1500	2000

Table 1 shows the comparison fault current with DG and without DG. The level of fault current is increased with insertion of DG to the network.

VI. APPENDIX

Table -2 Line data

Line id	R(ohms)	L(H)
Line 1-2	0.0799	0.004917
Line 2-3	0.1143	0.005533
Line 3-4	0.196	0.0028117
Line 4-5	0.342	0.00305
Line 5-6	0.668	0.003395
Line 6-7	0.668	0.001697

Table-3 load data

Load id	P(MW)	Q(MW)
Load 1	1.61	0.99
Load 2	0.87	0.5626
Load 3	1.5867	0.9414
Load 4	1.99	1.394
Load 5	1.4259	0.9582
Load 6	0.69344	0.3742
Load 7	0.9792	0.606

VII. CONCLUSION

DG plays a major role in the power system. Hence analysis of the impact of DG on power system is necessary. And in this work impact of DG on radial distribution network is analysed. DG placed mainly at the load side in order to meet the load

requirement. Simulations are done for finding the Fault current in radial distribution network, under various fault conditions like LG, LL, LLG and LLLG without any distribution generation to the taken radial distribution network .And observed the fault current values. Simulations are done for the finding fault current in test distribution network, under various fault conditions like LG, LL, LLG, and LLLG with the addition of distribution generation observed the fault current values. Compared the fault current values with DG and without DG and observed the increased fault current value with the addition of distributed generation to the network. By the addition of DG into the network causes the increased in the fault current values.

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