# *Impact of Distributed Generation on Protection of Power System*

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*Abstract*- **Day by day demand of Electricity is increasing so, in order to fulfill this demand we need to increase generation of power. Because of this increasing demand, non-renewable energy sources are on the verge of extinction so the solution is to use renewable energy sources. One such solution is to connect DG having renewable energy sources in power system. But the insertion of DG has some impact on a power system.**

**This paper deals with the evaluation of the impact of DG on the protection of power system. The work presented in this paper consists of a simulation of a radial power system in PSCAD /EMTDC software. Monitoring of both fault current and the load current is done in the simulation. The impact of DG on fault current under the influence of LG, LL and LLLG fault with and without protection is studied. Maximum magnitude of fault current is found in case of LLLG fault. Also, the impact of resistive fault current limiter on the magnitude of fault current is studied. Both DG and source is protected from fault current by using overcorrect protection with pick up value of 2kA and 4kA respectively.**

***Keywords— Distributed generation, renewable energy, Overcurrent Protection.***

## I. Introduction

The performance of distribution system is affected by distributed generation in various ways. As DG is related to renewable energy for lowering the environmental impact of power generation indicate a large scope for DG in future. DG improves voltage Profile but interfere with voltage regulation [1],[2]. The losses in a circuit can be minimized if DG is connected near to the load. The existing system did not deal with generation at distribution substation on radial feeder so such system where not designed to handle such power would be sent back to the source. Hence, accountable effect on the operation of existing protection may occur both false tripping and non-operations of protective devices are possible [3]. Selecting DG such a like that system operation will give a correct working after connecting DG in a network. Inserting DG will have an effect on the short circuit level, Transient stability of system, voltage and power quality. This paper gives an idea about the impact of DG on short circuit and load flow behavior are taken as a main disturbing parameter for effective protection. DG provides an additional fault current in the system. Fault current value depends on the parameter such as size, type, and location of DG. These additional fault current affect the performance of the system protection.

## II. Distributed generation

Distributed Generation [5] (DG) is one of the new technology that gives a focused for the last few years and day by day its use in distribution networks is increasing. It is presented in many forms such as solar (PV), wind (wind farms) with small scale ratings up to 10MW. It is referred to generate electricity and supplying this electricity to customers with their locations, it can also be interconnected to the utility grids. There are so many exemptions of a DG gives to the customer, this privileges various types of advantages to install a DG rather than constructing new distribution lines. This DG can be used to provide electric supply to customers during peak load hours, it can satisfy a consumer demand apart from the grid, thus it can also support to an intentional islanding. One of the major problems that have to be considered to achieve a safe and effectively use of DG is its interconnection to the utility grid.

## III. Types of Distributed Generation

DG can be classified into two major parts such as inverter based DG and rotating machine DG. After the generation process inverters are usually used in DG systems, as the generated voltage may be in DC form or AC. It has to be converted first to DC then back to AC so it is required to be changed to the nominal voltage and frequency with the nominal parameters through the rectifier.

### *A. Photo voltaic*

PV system is an eco-friendly system as it has no issue what so ever. These PV systems have being used the sun as its fuel source to generate DC voltage with a range of few megawatts and then transferred to AC with the help of inverters.

### B. Wind Turbine

A wind turbine uses the wind as an input. To rotate this turbine wind act a prime mover that is connected to the shaft of a generator. The generator provides an AC output voltage that is dependent on the wind speed. As the speed of wind is variable so the voltage generated has to be transferred to DC and back again to AC with the help of inverters. The wind power range generated by wind turbines is up to a few megawatts for each turbine.

### C. Fuel Cells

The operation of fuel cell is similar to that of a battery but it is continuously charged with hydrogen which can be extracted from any hydrocarbon source, this is the charge of the fuel cell along with air (oxygen). The fuel cell utilizes the reaction of hydrogen and oxygen with the aid of an ion-conducting electrolyte to produce an induced DC voltage which is proportional to the number of fuel cells.

### D. Micro-Turbines

The micro-turbines are based on the technology of very high-speed rotating turbines along with a generator to produce a high-frequency voltage output. These micro-turbines are usually operated by natural gas.

### F. Rotating Machines

Rotating machines are the types of DGs that include induction or synchronous machines such as induction and synchronous generators. These machines operate with fuel as its input to generate electricity, with different ratings starting from KW to few MW ratings. Rotating machines are mainly used as standalone or as Backup generation systems.

## IV. Impact of Distributed Generation on Power System

Insertion of DG in distribution systems has several impacts on it. These impacts may be positive or negative in power System [6], [11].and they can be considered as the advantageous and disadvantageous of the distributed generation. This part is addressing the effects of DG on different features of the network.

### A. Impact of DG on Voltage Regulation

In the radial distribution system, the main regulating method is used of load tap changing transformer at substations with additional line regulators on distribution and switched capacitors feeders [9]. The voltages are maintained within a range through mentioned devices. The voltage regulation criteria is based on radial distribution power flow from the substation down to all loads, DG insertion changes the radial characteristics and the system loses its stability and power flows in various directions and creates a new power flow scheme in a system. Losing stability of the system impacts the effectiveness of standard voltage regulation technique.

### B. Impact of DG on Losses

One of the major effects of Distributed generation is on the losses in a feeder. One of the important criteria is to locate a DG in a system to give a better performance with reduced losses, and this reach towards the optimal performance of the system. So to Reduced this loss, we find the optimum location of DG.

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### C. Impact of DG on Harmonics

DG can be a source of harmonics to the network; harmonics produced can be either from the generation unit itself (generator) or from the power electronics equipment such as inverters used to transfer the generated form of electricity DC to AC to be injected into the network. The old inverter technologies that were based on SCR produced high levels of harmonics, while the new inverter technology is based on IGBT's (Insulated Gate Bipolar Transistor) operating with the pulse width modulation technique in producing the generated "sine" wave.

### D. Impact of DG on Short Circuit Levels of the Network

Penetration of DG in a network has a direct impact on the short circuit levels of the network; it causes an increase in the fault currents when compared to the normal network conditions at which the substation is the only generating unit. This increase will be obtained even if the DG is of small generating capacity[12].The contribution of DG to faults depends on some factors such as the generating capacity of the DG (size of the DG), the distance of the DG from the fault location and the type of DG.

## V. Impact of Distributed Generation on Protection

### A. False Tripping of feeder

When DG is interconnected with distribution feeder it may cause a false tripping on a healthy feeder. If the fault occurs on any adjacent feeder then the fault current is contributed by connected DG in that feeder [10]. If contributed fault current values are greater than protective device rating then healthy feeder also goes out of service till the fault is clear on the faulty feeder.

### B. Nuisance Tripping Of Feeder

Nuisance Tripping term is related to disconnection of DG this occurs due to the power surge in the DG facility [7], [8]. In distribution network power Surge occurs due to loss of large load such as a motor in presence of a DG. This loss of large power flow in a grid causes a relay to trip. A fault occurring outside the protective zone may cause nuisance tripping of DG means a sudden loss of generation from DG.

### *C. Unintentional Islanding*

Unintentional islanding occur in a distributed network when DG are connected because of failure of feeder or maintenance purpose and due to that portion of a power system is disconnected from the grid and it is feed by DG [13] [14].This islanding is generally avoided since it uses unacceptable limit of operating voltage, frequency, and power quality issue.

## VI. System under Study

Fig.1 shows PSCAD simulation of two bus radial power system. Simulated system configuration is given in Appendix. In this system source is connected to bus 1 and induction motor load is connected to bus 2. DG is connected to bus 2.

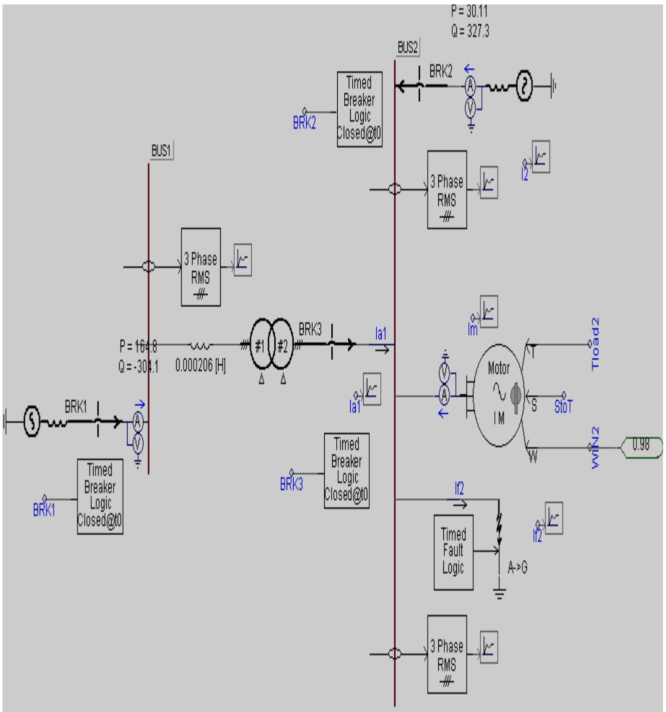


Fig. 1 PSCAD simulation of two bus system

## VII. Simulation Results

The work presented in this paper consists of following eight cases.

Case I. In this case initially the only source is connected in the system with a fault occurring at 2sec for a duration of 1 sec and DG (wind generation) is inserted at 2.5sec. Here we have considered LL, LG and LLLG faults and DG is inserted at 0°, 45° and 90° instant of blue phase close to 2.5sec instant.

Fig. 2 represents the waveforms of current drawn by the induction motor, current supplied by the source, current supplied by DG, RMS voltage of sending end, RMS voltage of receiving end and fault current under the influence of L-G fault during 2-3sec.

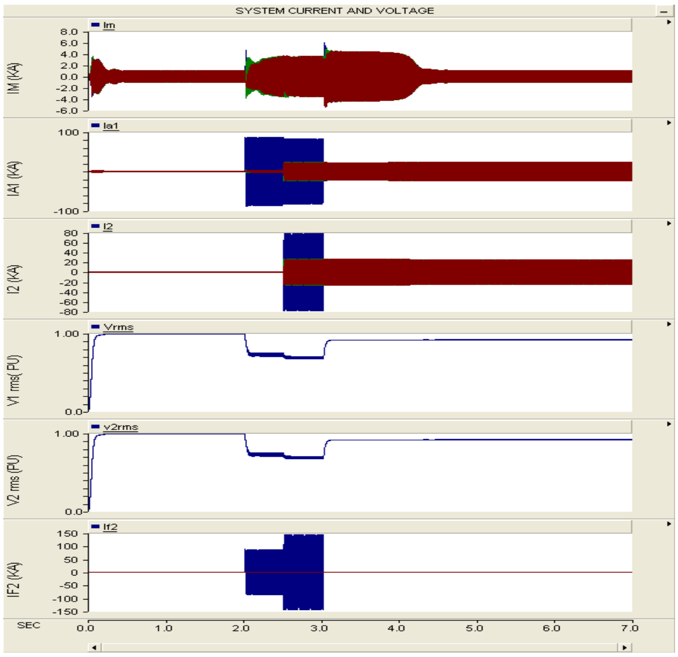


Fig. 2 Currents and voltages waveform under the influence of L-G fault and DG

Case II. In this case, initially both source and DG are connected in the system and a fault is simulated at 2.5sec. Here we have considered LL, LG and LLLG faults simulated at 0°, 45° and 90° inception angles.

Fig. 3 represents the waveforms of current drawn by the induction motor, current supplied by the source, current supplied by DG, RMS voltage of sending end, RMS voltage of receiving end and fault current under the influence of L-G fault during 2.5-3.5sec.

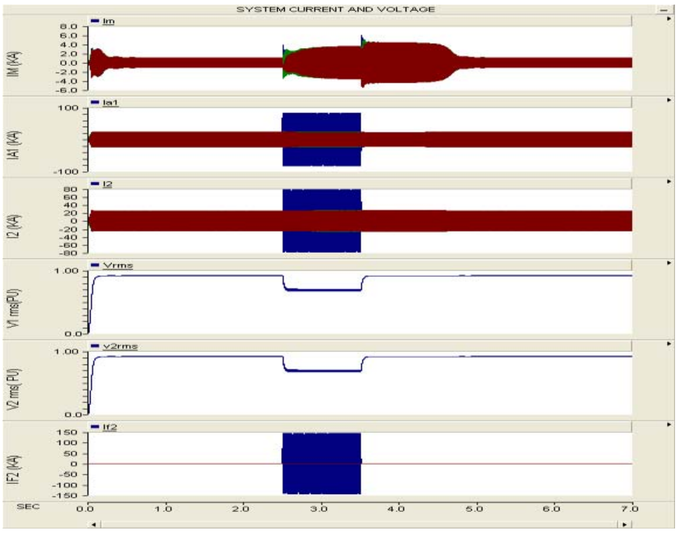


Fig. 3 Currents and voltages waveform of system with DG under the influence of L-G fault

Case III. In this case, the source is connected to the system with a fault occurring at 2.5sec for a duration of 1 sec. Here we have considered LL, LG and LLLG faults simulated at 0°, 45° and 90° inception angles. The system is facilitated with Overcurrent protection.

Fig. 4 represents the waveforms of current drawn by the induction motor, current supplied by the source, RMS voltage of sending end, RMS voltage of receiving end and fault current under the influence of L-G fault occurring at 2.5sec and operation of overcurrent protection.

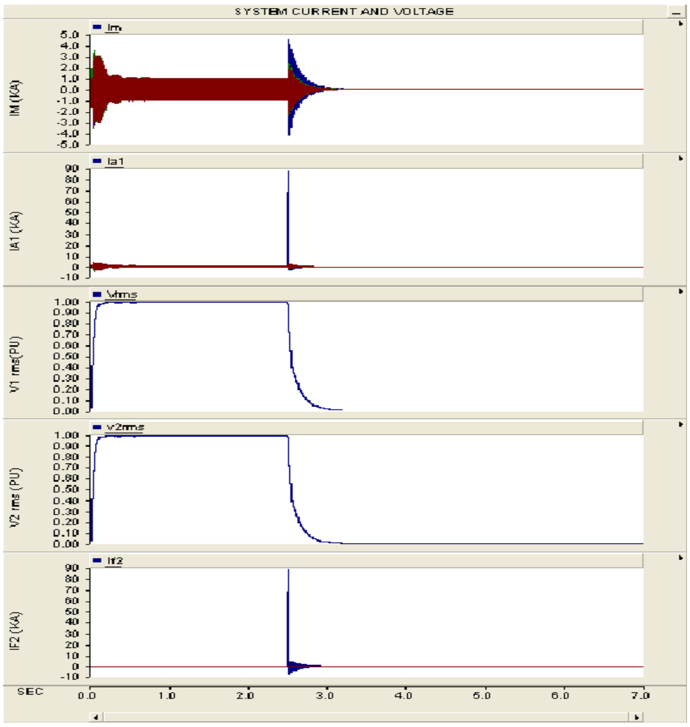


Fig. 4 Currents and voltages waveform of system under the influence of L-G fault and overcurrent protection

Case IV. In this case, initially both source and DG are connected in the system and a fault is simulated at 2.5sec. Here we have considered LL, LG and LLLG faults simulated at 0°, 45° and 90° inception angles.

Fig. 5 represents the waveforms of current drawn by the induction motor, current supplied by the source, current supplied by DG, RMS voltage of sending end, RMS voltage of receiving end and fault current under the influence of L-G fault occurring at 2.5sec and operation of overcurrent protection.

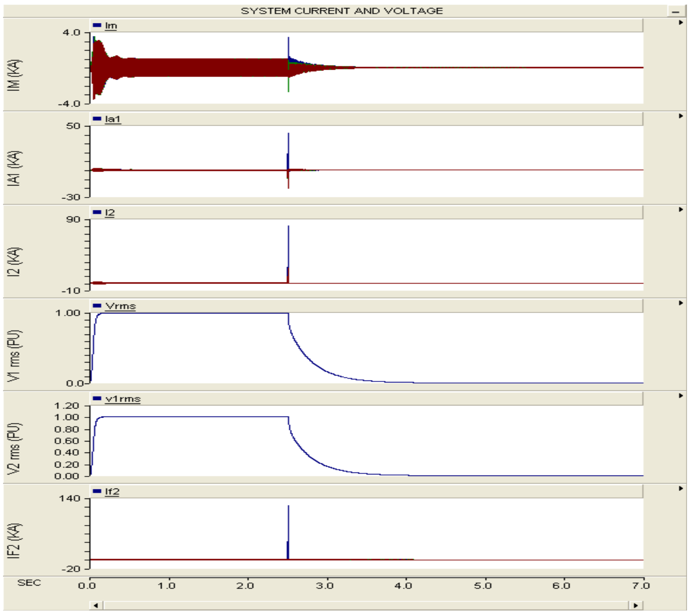


Fig. 5 Currents and voltages waveform of system with DG under the influence of L-G fault and overcurrent protection

Case V. In this case initially the only source is connected in the system with a fault occurring at 2sec for a duration of 1 sec and DG (wind generation) is inserted at 2.5sec. Here we have considered LL, LG and LLLG faults and DG is inserted at 0°, 45° and 90° instant of blue phase close to 2.5sec instant. A resistive fault current limiter of 5Ω is inserted in series with the source and DG.

Fig. 6 represents the waveforms of current drawn by the induction motor, current supplied by the source, current supplied by DG, RMS voltage of sending end, RMS voltage of receiving end and fault current under the influence of L-G fault during 2-3sec and resistive FCL of 5Ω.

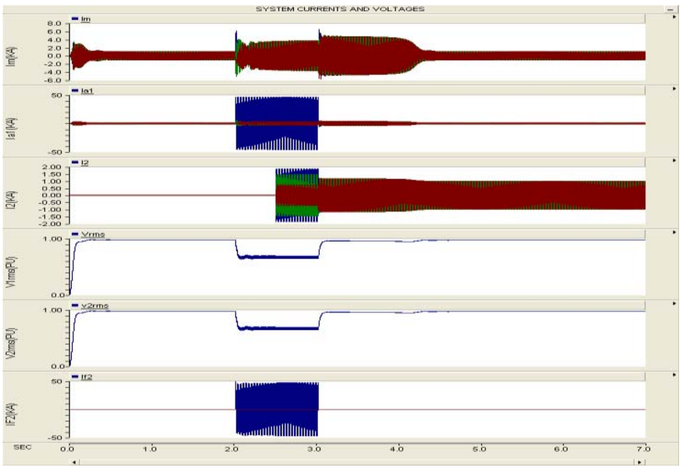


Fig. 6 Currents and voltages waveform under the influence of L-G fault, DG and resistive FCL of 5Ω

Case VI. In this case, initially the only source is connected in the system with a fault occurring at 2sec for a duration of 1 sec and DG (wind generation) is inserted at 2.5sec. Here we have considered LL, LG and LLLG faults and DG is inserted at 0°, 45° and 90° instant of blue phase close to 2.5sec instant. A resistive fault current limiter of 10Ω is inserted in series with the source and DG.

Fig. 7 represents the waveforms of current drawn by the induction motor, current supplied by the source, current supplied by DG, RMS voltage of sending end, RMS voltage of receiving end and fault current under the influence of L-G fault during 2-3sec and resistive FCL of 10Ω.

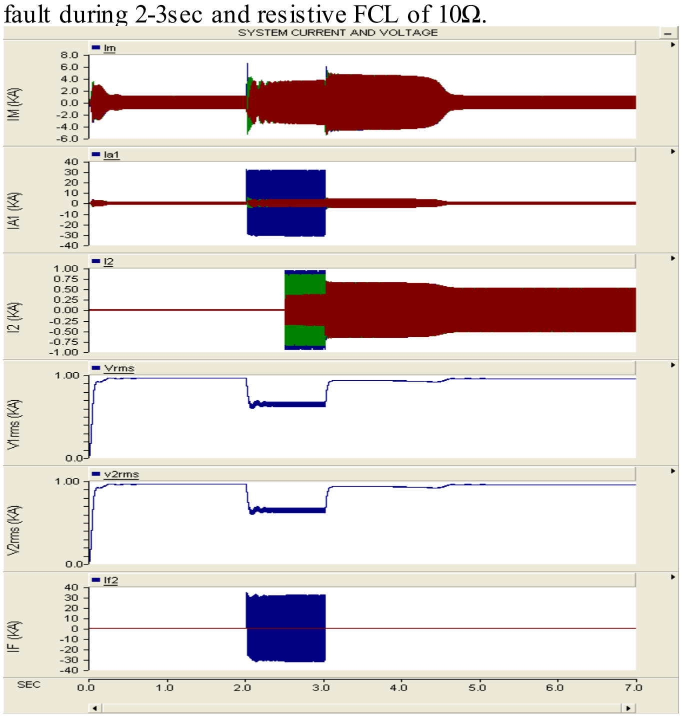


Fig. 7 Currents and voltages waveform under the influence of L-G fault, DG and resistive FCL of 10Ω

Comparison of fault currents magnitude without fault current limiter and with resistive fault current limiter of 5Ω and 10Ω under the influence of LG, LL and LLLG faults is shown in the following table.

TABLE I
Comparison of fault currents in case I, V and VI

| Types of Fault | Current in Previous Cases | | |
|---|---|---|---|
| | ***Fault Currents without FCL (Peak Valve in KA )*** | ***Fault Currents with5 ohm FCL (Peak Valve in KA )*** | ***Fault Currents with 10 ohm FCL (Peak Valve in KA)*** |
| LG fault | 88.62 | 48.71 | 34.75 |
| LL fault | 79.79 | 34.27 | 22.41 |
| LLLG fault | 89.14 | 40.22 | 27.07 |

Case VII. In this case, initially both source and DG are connected in the system and a fault is simulated at 2.5sec. Here we have considered LL, LG and LLLG faults simulated at 0°, 45° and 90° inception angles. A resistive fault current limiter of 5Ω is inserted in series with the source and DG.

Fig. 8 represents the waveforms of current drawn by the induction motor, current supplied by the source, current supplied by DG, RMS voltage of sending end, RMS voltage of receiving end and fault current under the influence of L-G fault during 2.5-3.5sec and resistive FCL of 5Ω.

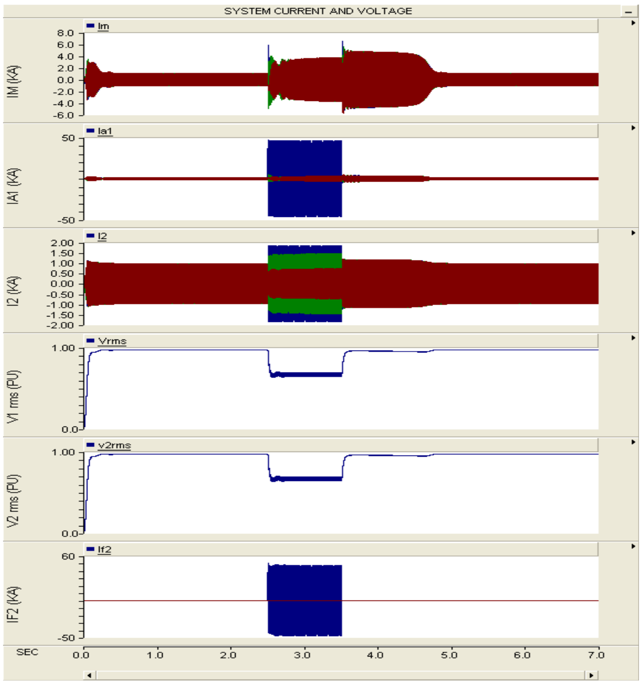


Fig. 8 Currents and voltages waveform of system with DG under the influence of L-G fault and resistive FCL of 5Ω

Case VIII. In this case, initially both source and DG are connected in the system and a fault is simulated at 2.5sec. Here we have considered LL, LG and LLLG faults simulated at 0°, 45° and 90° inception angles. A resistive fault current limiter of 10Ω is inserted in series with the source and DG.

Fig. 9 represents the waveforms of current drawn by an induction motor, current supplied by the source, current supplied by DG, RMS voltage of sending end, RMS voltage of receiving end and fault current under the influence of L-G fault during 2.5-3.5sec and resistive FCL of 10Ω.

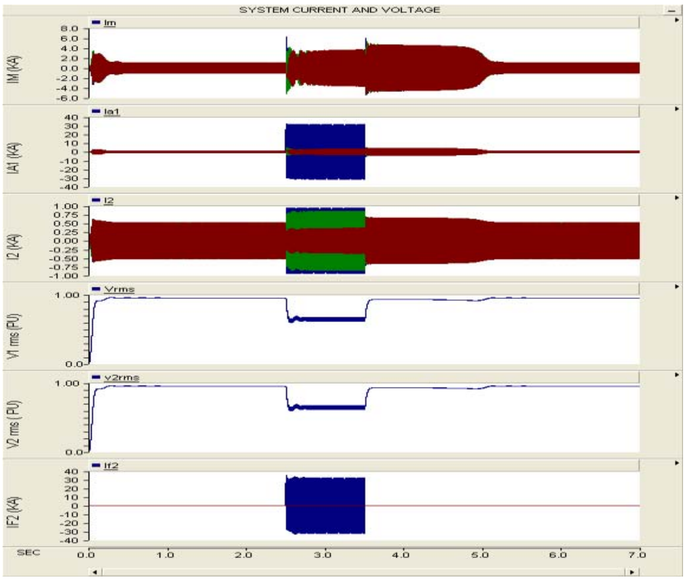


Fig. 9 Currents and voltages waveform of system with DG under the influence of L-G fault and resistive FCL of 5Ω

Comparison of fault currents magnitude without fault current limiter and with resistive fault current limiter of 5Ω and 10Ω under the influence of LG, LL and LLLG faults is shown in the following table.

TABLE II
Comparison of fault currents in case II, VII and VIII

| Types of Fault | Current in Previous Cases | | |
|---|---|---|---|
| | ***Fault Current without FCL (Peak Valve in KA )*** | ***Fault Current with5 ohm FCL (Peak Valve in KA )*** | ***Fault Current with 10 ohm FCL (Peak Valve in KA)*** |
| LG fault | 145.18 | 50.15 | 35.42 |
| LL fault | 134.95 | 35.40 | 22.80 |
| LLLG fault | 145.83 | 50.18 | 27.64 |

## VIII. CONCLUSION

The presence of Distributed Generation may cause higher fault currents that are over the breaking capacity of circuit breakers. Therefore, existing protection devices are exposed to more electrical stress than normal.

The cases presented in this paper shows that by adding DG the current drawn by the induction motor is contributed by both source and DG. Also, the DG contributes to the fault so it is found that magnitude of fault current increases with the insertion of DG. By providing instantaneous overcurrent protection both source and DG are protected.

The presence of DG increases fault current levels and lead to protection problems. For solving these problems a solid state FCL is proposed to connect in series with DG. The main advantages of the proposed FCL are simplicity in structure and control, fast response. Also, this type of FCL has no effect on utility voltage and current at normal system operation

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## IX. APPENDIX

Configuration of system under study

| Component | Rating |
|---|---|
| Three Phase Source | 1500MVA, 69KV, 60Hz |
| Transformer (Δ –Δ) | 1500MVA, 69KV/12KV, 60Hz |
| Squirrel Cage Induction Motor | RMS Phase Voltage = 6.9282KV<br>RMS Phase Current = 0.7596KA<br>Angular Frequency = 376.99 rad/s<br>Rating of Motor = 18096hp |
| Distributed Generation (wind generation) | 12KV, 20MVA, 60Hz |

## X. References

[1] P.P. Barker and R.W.de Mello, “Determining the impact of Distributed generation on power systems: Part 1–radial distribution systems," in Proc. IEEE Power Engineering Society Summer Meeting, 2000, pp.1645-1654.

[2] T. A. Short, Electric Power Distribution Handbook. Boca Raton, FL: CRC Press LLC, 2004.

[3] IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, IEEE Standard 242-2001, June. 2001

[4] M.K.Donnelly, J. E. Dagle, D.J. Trudnowski and G.J. Roger “Impacts of the distributed utility on Transmission system Stability ” Power Systems, IEEE Transactions on, Volume: 11, Issue: 2, May 1996, Pages: 741 – 746

[5] G. Pepermans, J. Driesen, D. Haeseldonckx, R. Belmans and W. D’haeseleer, "Distributed generation: definition, benefits and issues," Energy Policy, vol. 33, issue 6, Apr. 2005, pp. 787-798.

[6] K. Kauhaniemi and L. Kumpulainen, "Impact of Distributed Generation on the Protection of Distribution Networks," in Proc. 2004 IET International Conference on Development in Power System Protection, vol. 1, pp.315-318.

[7] W.G. Hartmann, “How to Nuisance Trip Distributed Generation," in Proc. 2003 IEEE Rural Electric Power Conference, pp. C.5-1 –C.5-11.

[8] W. G. Hartmann,"How Not to Nuisance-Trip Distributed Generation,"in Proc. 2005 IEEE Technical Conference on Industrial and Commercial Power System, pp. 52-61.

[9] C.P. Lawrence, M. M. A. Salama, R. El. Shatshat "Studying the Effects of Distributed Generation on Voltage Regulation, "International Journal of Electrical Engineering Education, vol. 46, no. 1, pp. 11-29, Jan. 2009.

[10] G. Kaur and M. Vaziri Y., "Effect of Distributed Generation (DG) Interconnections on Protection of Distribution Feeders," in Proc. 2006 IEEE Power Engineering Society General Meeting, pp. 8.

[11] Zayandehroodi, Hadi, Azah Mohamed, Hussain Shareef, and Marjan Mohammadjafari. "Impact of distributed generations on power system

protection performance." International Journal of the Physical Sciences 6, no. 16 (2011): pp. 3873-3881.

[12] P. P. Barker, R. W. de Mello, “Determining the impact of Distributed generation on power systems: part1-radial distribution systems,” IEEE Trans. Power Delivery, vol. 15, pp. 486–493, Apr. 2000.

[13] P. Mahat, Zhe Chen and B. Bak-Jensen, "Review of islanding detection methods for distributed generation," in Proc. 2008 Electric Utility Deregulation and Restructuring and Power Technologies, DRPT. pp. 2743-2748.

[14] Wojciech Piasecki, Marek Florkowski, Marek Fulczyk, Pentti Mahonen and Wieslaw Nowak,”Mitigating Ferroresonance in Voltage Transformers in Ungrounded MV Networks,” IEEE Transactions on Power Delivery, vol.22,no.4,Oct’2007.