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Adaptive Over-Current Protection for Distribution System with Distributed Generation

Nikhil Ashok Bari[1], S D Jawale[2], B T Deshmuikh[3]

M.E (EPS), Department of EEP, Jawaharlal Nehru Engineering College, Aurangabad, Maharashtra, India [1]

Asst. Professor, Department of EEP, Jawaharlal Nehru Engineering College, Aurangabad, Maharashtra, India[2]

Professor, Department of EEP, Jawaharlal Nehru Engineering College, Aurangabad, Maharashtra, India[3]

Abstract: The exponential growth of population has resulted a significant increase in power demand. Moreover the consumer area is vastly dispersed. Thus, the generation of electricity at the consumer side is gaining more popularity. The main problem associated with the generation of electricity at consumer side i.e. distributed generation is the failure of coordination between various protective devices employed in the system. Because after the integration of DG with the grid, the conventional radial distribution network is changed to interconnected mesh network. Therefore the existing protection system will not work satisfactorily in this case. This necessitates the modification of existing protection system or implementation of newer one. This paper recapitulates the impacts of DG on line losses, voltage profile, short circuit power levels of the network and presents a smart and adaptive methodology for protection of distribution network with distributed generation.

Keywords: distribution network, distributed generation, short circuit level, over-current protection.

I. INTRODUCTION

The population of the world is increasing day by day leading to the increasing demand of electrical energy. The existing transmission systems are working at their exhaustive limit as of now and the stiff constraints for installation of new transmission lines have bulged the necessity of electricity generation nearer to the consumers. Besides integration of local distributed generation with the grid assures security of supply, better voltage profile, an enhanced reliability of the system. Furthermore distributed generation indulges utilization of the diversity of resources to generate electricity. Distributed generation plants are of various types viz; solar PV plant, wind power plant, fuel cell plant, gas turbine operated plant, etc. Most of these power plants offer cleaner and quieter operation.[8], [9]. Conventionally the power flow was unidirectional i.e. from central generating power plant to the distribution system through a transmission network. On the other hand after integration of local distributed generation power plants the energy flow becomes bidirectional. Likewise the structure of distribution system, before addition of distributed generators was radial but after addition the distribution system becomes interconnected mesh network.. In this typical distribution network distribution feeder is fed from grid as well as local DGs. The direction of power flow depends on the ratings of DGs and load.

II. IMPACTS OF INTEGRATION OF DG

A. Voltage regulation of distribution system

There are various methods for regulating the voltage of distribution system such as shunt compensation, using boosters, OLTCs etc. In most of the cases after connecting DG the line voltages are slightly increased hence the amount of shunt compensation or the tap settings of OLTCs should be changed accordingly. Impacts on voltage regulation are imperceptible for small scale DGs. However for large scale DGs this effect should be taken into consideration [4].

B. Line losses

Line losses mainly depend on thermal characteristics and current carrying capacities of the lines for the feeders bearing significantly higher losses, addition of DG can offer great support. However this can have adverse effects too in case when DG rating is high as in comparison with thermal characteristics and current carrying capacity of the line [4],[5].

C. Harmonics in the system

Most of the DGs employ power electronic converters which are the great source of harmonics. Harmonics when exist in the system distort the pure sinusoidal waves affecting source side as well as load side too. Thereby causing problems like excessive heating of motors connected as a load, generation of vibrational torque, production of humming sound, saturation of the core, etc. [4],[7].

D. Protection schemes

No electrical distribution system can be visualized without faults. In the presence of DG if the fault occurs in the distribution network as the power flow is bidirectional the existing protection system will not work satisfactorily. Hence the directional unit must be added to the protective relaying devices. The fault currents are considerably higher if DG connected in the system has high percentage share of the load. Besides this will increase the short circuit current levels of the network. The rise in short circuit current levels may cause maloperation [1]-[6].

III. PREVIOUS METHODS OF PROTECTION

In reference [2] Pukar Mahat and co-authors concluded that behavior of existing protection system is changed in the presence of DG. If DG is operating in islanded mode then for low penetration of DG short circuit current levels are lower than short circuit current levels of distribution system having no DG. However for high penetration of DG these levels are significantly higher than that of the distribution network having no DG. Hence [2] suggests the algorithm for detecting the various states of the system i.e. intentionally or nonintentionally islanded, grid connected, etc. By detecting the state of the system the tripping characteristics of the relays are updated and the technique detects the faulted part of the system. The relay settings are defined once and are fixed according to the mode of operation i.e. either grid connected or islanded. The drawback of this method is that it can be applied to a specific distribution system and after the application the distribution system shall remain unaltered. Ref [5] considers the simple system of single DG connected to grid and at the feeder side SFCL units were connected. The function of SFCL is to hold coordination in protection system. The main constraint in this scheme is the resistance of the SFCL which is altered according to the fault. Application of SFCL to the simulated system seems to work satisfactorily. However the problems may occur to apply this scheme to an actual real life system as the resistance of SFCL [5] is changed by adding the shunt resistance to it which is quite difficult to happen in fraction of seconds. According to the reference [6] the distributed system interconnected with distributed generators is divided into number of zones so that in case of any abnormal conditions the defective zone is disconnected only. But this action demands the automation of the distribution system equipped with the master computer. The algorithm or the scheme takes data from distribution automation system. Furthermore the drawbacks of this scheme is that it hardly respond to the series type faults and increase in number of DG necessitates installations of significantly large number of breakers as there is significant increase in number of zones.

IV. PROPOSED METHOD OF PROTECTION

The ideal situation for any protection scheme is to isolate only the faulted section from the system. The best approach is to divide the system into zones as shown in Fig. 3. A zone should be formed such that it has a reasonable balance of load and DG, DG capacity being a little more than the load. In addition to this, at least one DG (usually the biggest in the zone) should have load frequency control capability.

A. Formation of zones

In the particular interconnected mesh network whole system is demarcated into various zones as shown in fig. 3[1]. Each zone should have uniform load and DG. The DG supplying power in a specific zone should have slightly more size than the load in that zone. Each zone is protected by a separate breaker. Among all the circuit breakers and relays, the relay in largest zone should be digital assisted relay. This relay should be able to log voluminous information about the system parameters. The communication of this relay with other relays in system can also be accomplished by WSN technology.

B. Monitoring

Once the demarcation has been done the prerequisite thingis to monitor all the current vectors of the system along with their directions from various buses. After collection of this data, the next step is to carry out load flow analysis which can be performed using the software tools.

C. Tasks to perform offline

After load flow analysis, the short circuit levels at each point are calculated. Using all these values a look up table is structured. This table comprises short circuit current contribution from each DG as well as grid. The fuse melting characteristics can be used to find the safe time before the fuse melts. The look up table is crucial for realizing faults and their nature.

D. Online Detection of fault and its location

TablesFor detection of fault and its type continuous monitoring of current vectors from the grid and DGs is performed. During steady operation without any fault, addition of all these vectors will be equal to the addition of all the loads in

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the network. During any abnormal condition, the addition of all the current vectors will be far greater than the actual load.

E. Fault clearing and reclosing

All Not all types of faults exist permanently in the system. Some of the faults may be temporary too. It can be checked whether the fault is temporary or permanent by sending an actuating signal to the recloser. If the fault is temporary, the addition of all the current vectors will be equal to the whole load. If this condition is violated then there is a permanent fault which may require human interference to clear that fault. The flow chart for this methodology is shown in fig.1.

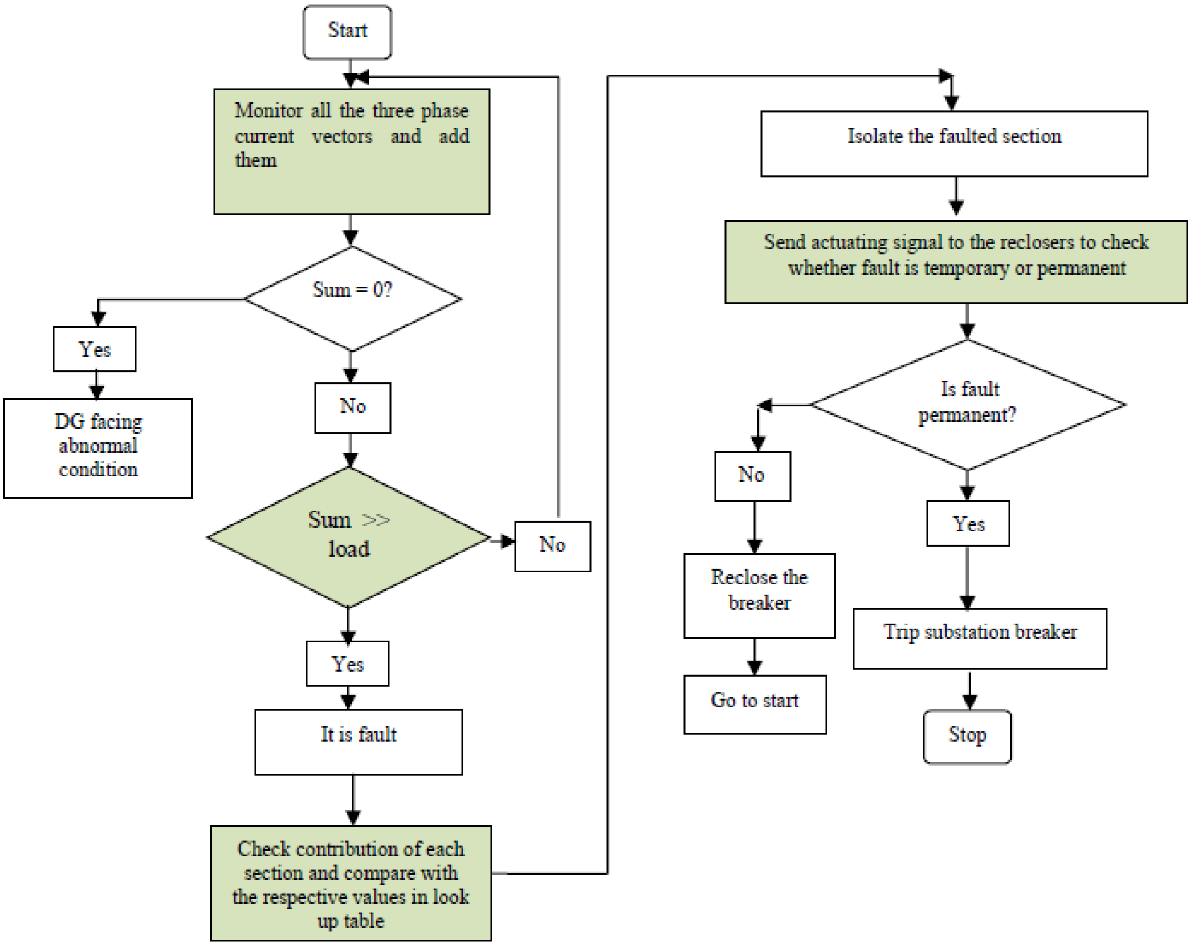

Fig. 1. Flowchart for suggested methodology

F. Actual prototype hardware model

The hardware model consists of three single phase inverters as DGs. The input to the inverters is given through the battery. The battery is having rating 12 volts 7.5 Ah capacity Three single phase inverters convert 12 volts dc output of a battery into 230 Ac output voltage. Considering the capacity of a battery only three small 5 watt bulbs are connected to the inverter output terminal. When the main switch is kept ON the three lamps glows normally. It is shown in figure. 2 When first DG is overloaded then DG waits for load to decrease and if the load is not reduced then the overload is shifted to the grid and power generation from DG is stopped. On DG1 overload condition is simulated in actual hardware model. When there is a short circuit fault on second DG then the current sensing circuit sense the abnormal flow of current and hence the tripping action is taken and DG is isolated from the faulted section. Moreover as per given in previous case the power generation is also stopped. The scheme covers all types of faults normally occurring in a distribution system. In case of two simultaneous faults in the same zone (very rare), the relay will still trip the zone using the current direction signal from breakers, but will fail to detect the faulted section. . In case the faults occur simultaneously in different zones, after clearing one zone, the relay will still sense a fault. The accuracy of fault sensing and section detection depends mainly on the accuracy of sensing unit and on the relay algorithm. Greater the speed of algorithm lesser will be the time for protection scheme to act.

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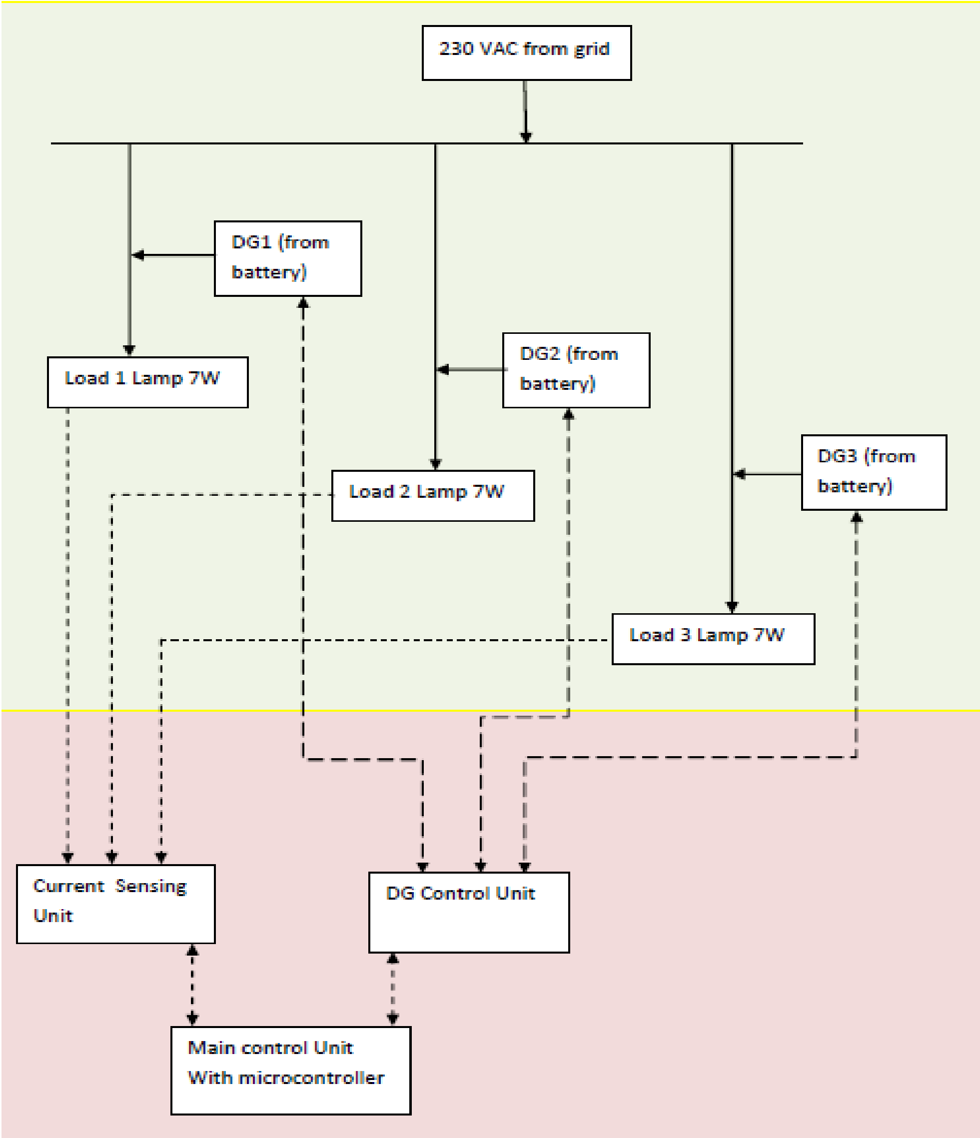

Fig.1 Block diagram of actual protection system

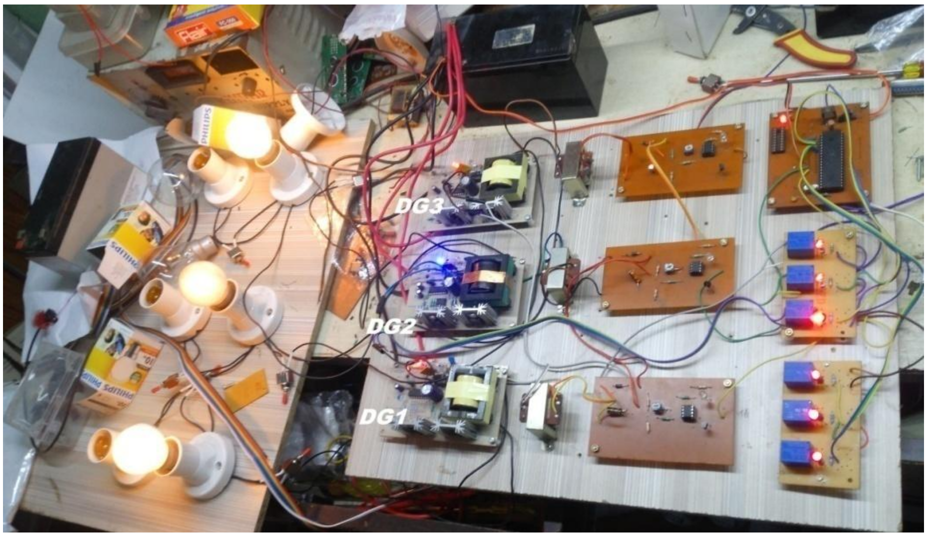

Fig. 3. Hardware model showing three single phase inverters as DGs

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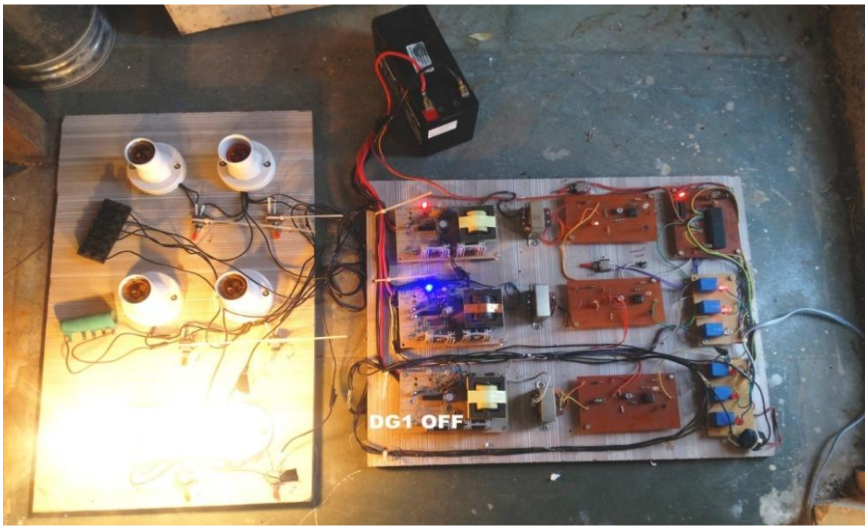

Fig.4. Overload on DG1 shifted to grid

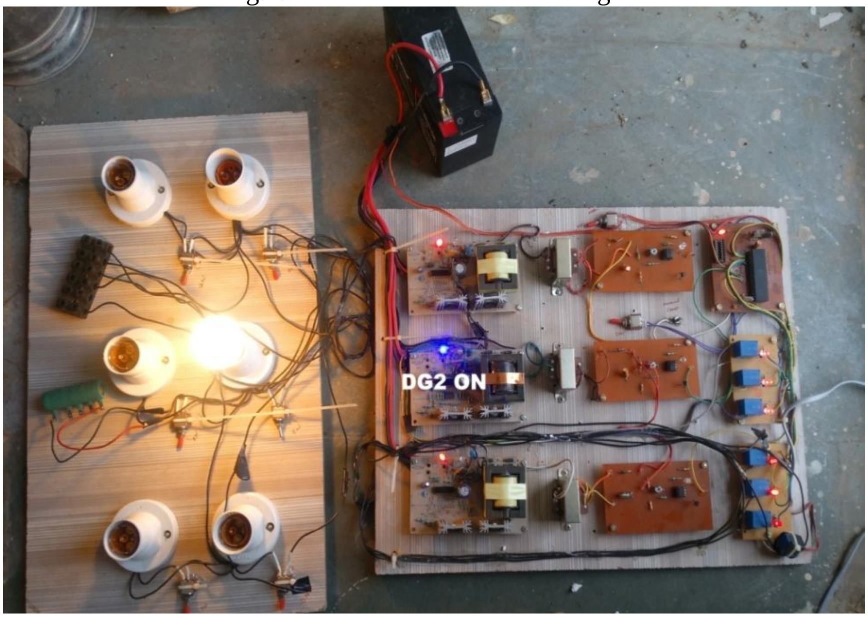

Fig. 5. DG2 during normal operation

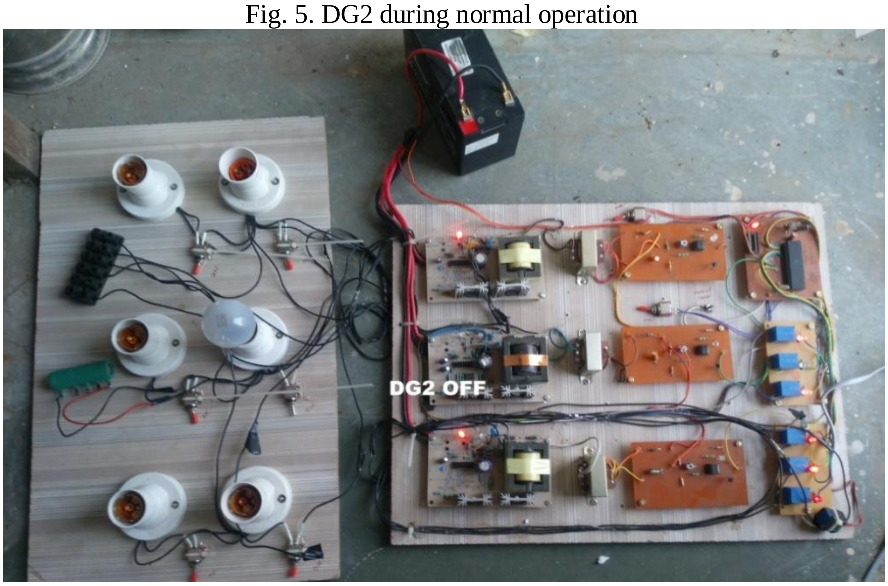

Fig. 4. Short circuit fault occurred on DG2

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V. CONCLUSION

Current trend and literature show that distributed generation is going to increase significantly in the coming years. The methods proposed in literature to solve the problem are not satisfactory from operational point of view. The scheme discussed here offers a practically acceptable solution to this problem that is independent of size, number, and placement of DG in the distribution system. The proposed scheme is adaptive to temporary as well as permanent faults in the distribution network.

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