SERVICE RESTORATION WITH THE PRESENCE OF DISTRIBUTED GENERATION IN A DISTRIBUTION SYSTEM

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***Abstract*--**This paper studies the influence of distributed generation during service restoration and to identify the optimal network reconfiguration at the power distribution systems for loss reduction and voltage profile improvement under fault condition with the installation of distributed generation. It is assumed that after the occurrence of fault at particular section of a distribution network, the loads get disconnected and are left unsupplied. Service should be restored to the affected loads through a network reconfiguration procedure. The simulation was conducted by applying three phase fault at an identified location. In this study, network reconfiguration was implemented using the TOPO application in the power system simulation programme for planning, design and analysis of distribution system (PSS/Adept). This application determines the optimal sectionalizing-tie switch pairs based on minimum losses configuration and at the same time, all nodes are assured fopr the supply. The location of the distributed generation was identified by finding the minimum bus voltage. The results show that installing distributed generation at the suitable location with appropriate sizing has able to provide lower loss level and higher voltage profile in fault condition as compared to that obtained before installed distributed generation and network reconfiguration. The proposed study was conducted on the IEEE 69 bus distribution system.

Index terms - distributed generation, network reconfiguration, service restoration

1 Introduction

An electrical power system consists of three principle divisions namely generating stations, transmission lines and distribution systems. The distribution system is part of the system between transmission lines and the consumer service point. Distributed generation (DG) is defined as energy resources of limited sizes (15 MW or less) connected to the substation, distribution feeder or customer load levels. There are many technical issues to be considered when connecting distributed generation (DG) to the distribution system such as thermal rating of equipment, system fault levels, stability, reverse power flow capabilities of tap-changers, line drop compensation, steady-state voltage rise, power losses, power quality (such as flickers and harmonics) and protection [1]. However, depending on the system's operating condition and the DG's characteristics and location, DGs installation may impose either be positive or negative impact. Several techniques have been developed in determining the optimal location and sizing of DG as described in references [2] and [3] in order to minimize the total distribution losses and improve voltage profile in the system.

The unsuitable location and sizing of the DG unit will result in an increasing of power losses and in a reducing of reliability levels [4]. Forces and scheduled outages are commonplace in distribution system. The occurrence of fault will results in the isolation of some portion (branches) of the feeder downstream from the affected area. Therefore the service should be restored to these branches via network reconfiguration [5]. System reconfiguration problem concerns with identifying the suitable tie-line switches to be closed in replacement of opening sectionalizing switches. Distribution system reconfiguration can be considered as a combinatorial optimization problem, involving distribution system planning, loss minimization and supply restoration [6]. Many techniques have been proposed to find the suitable pair of switches (sectionalizing – tie) in order to achieve these objectives [6-8].

The objectives of this project are to minimize the power losses and improve the voltage profile during network reconfiguration with the installation of distributed generation (DG) and the presence of distributed generation (DG) under fault condition. The purpose also is to compare the network performance between distributed generation (DG) installation and network reconfiguration. The optimal sectionalizing – tie switch pairs were determined by the TOPO application available in the power system simulation programme for planning, design and analysis of distribution system (PSS/Adept). This application determines optimal sectionalizing – tie switch pairs based on minimum losses configuration and at the same time, all nodes are assured for the supply. The suitable location for distributed generator was determined by minimum bus voltage. Various locations of DGs were also tested in order to realize the effect of location of DGs in terms of loss minimization and voltage improvement during service restoration in the fault condition.

2 Network Reconfiguration

Network Reconfiguration of a power distribution system is an operation to alter the topological structure of distribution feeders by changing open/closed status of sectionalizing and tie switches. It is an operation problem which determines the switching operations that can give an optimal configuration of a distribution network. It is one of the feasible methods for reducing the distribution network loss in which the power flow in the distribution network is altered by opening or closing the appropriate switches on the feeders. During normal operating condition, networks are reconfigured to reduce the system real power losses and to relieve overloads in the network (load balancing) [9].

Normally, network reconfiguration is implemented by closing a single tie switch and opening a single sectionalizing switch to conserve the radial structure of the feeders. A switching-option is carried out between a tie and a sectionalizing switch. Multiple switching-options are possible for optimal or near optimal configuration where several tie and sectionalizing switches are simultaneously closed and or opened by the successive application of the proposed scheme. The best switching option to be implemented is chosen in each successive operation that minimizes losses the most, without violating the constraints, such as voltage constraints, capacity constraints of lines and transformers, and reliability constraints. Reference [7] to [10] presents different technique in determining optimal configuration during normal operating condition. Where as reference [5] presents a heuristic method to restore service to the isolated portions of a distribution system during fault condition. Several fault locations were pre-identified and the faults were isolated in order to analyze network reconfiguration. The corresponding tie-line switch was closed in order to maintain the radial configuration before the network is reconfigured.

3 Methodology

3.1 Test System

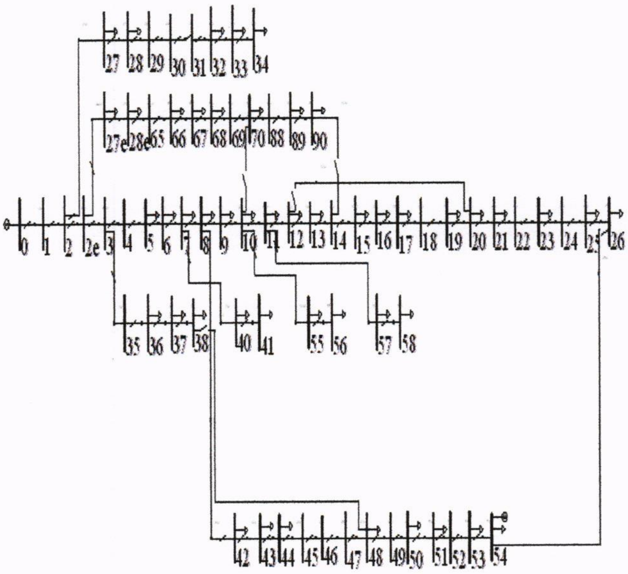


Figure 1: IEEE 69 bus test system

	Sending Bus	Receiving Bus	Tie Lines	
			R (ohm)	X (ohm)
Line TL1	10	70	0.500	0.500
Line TL2	12	20	0.500	0.500
Line TL3	14	90	1.000	1.000
Line TL4	38	48	2.000	2.000
Line TL5	26	54	1.000	1.000

Table 1: Tie Line switches connection

3.2: Load Flow Analysis and Network Reconfiguration

Figure 2 shows the flowchart for the methodology involved in this project.

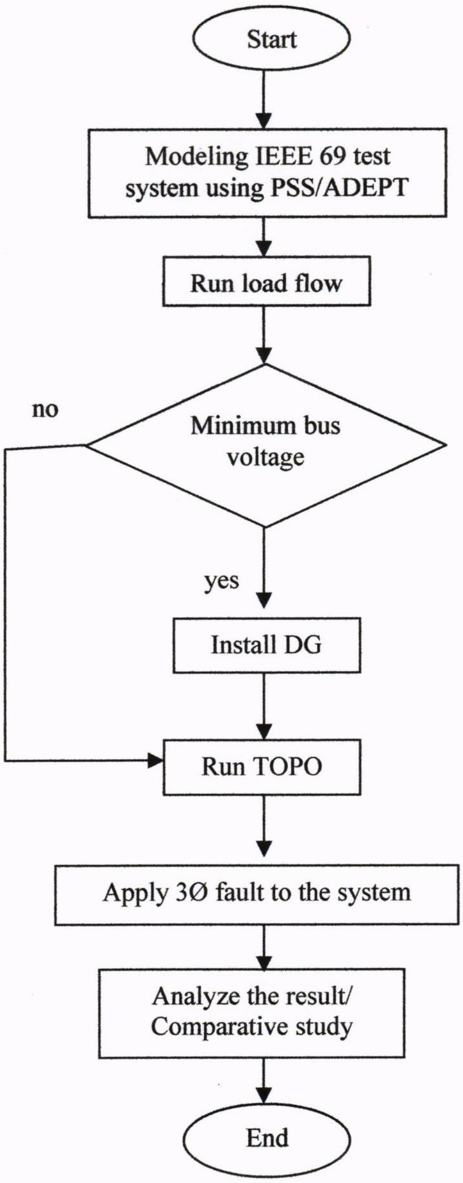


Figure 2: Flowchart for implementation the result

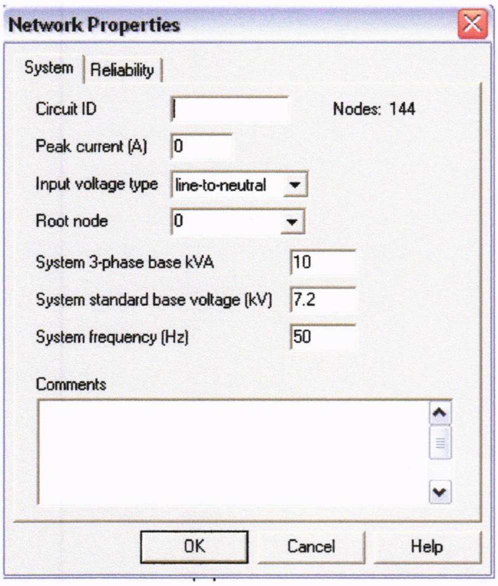
The load flow analysis and network reconfiguration will be determined using Power System Simulator and Advanced Distribution Engineering Productivity Tool (PSS/ADEPT) software. The PSS/ADEPT software was developed for engineers and technical personnel who design and/or analyze electrical distribution systems. PSS/ADEPT enables to graphically create, edit, and analyze power system models and diagrams.

PSS/ADEPT offers a full spectrum of design and analysis capabilities that can:

a) Create and modify power network models graphically.
b) Perform engineering analyses using multiple sources and unlimited nodes.
c) Display the results of engineering analyses on the network diagram.
d) Obtain output reports that display the results of a previously solved engineering analysis.
e) Define and update single and multiple system component data via property sheets.

Properties network model can be defined, including system base kVA, input voltage flag (line-line or line-neutral), node base voltage (kV), descriptive data, and default reliability data.

In order to set network property data:



Circuit ID

Nodes: 144

Peak current (A) 0

Input voltage type line-to-neutral

Root node 0

System 3-phase base kVA 10

System standard base voltage (kV) 7.2

System frequency (Hz) 50

Comments

Figure 3: Network Property Sheet: System Tab

In activating the PSS/ADEPT load flow analysis, it was determined for the properties components such as load, generator and bus. The results of the load flow analysis will be displayed on the diagram according to the results display options that specified.

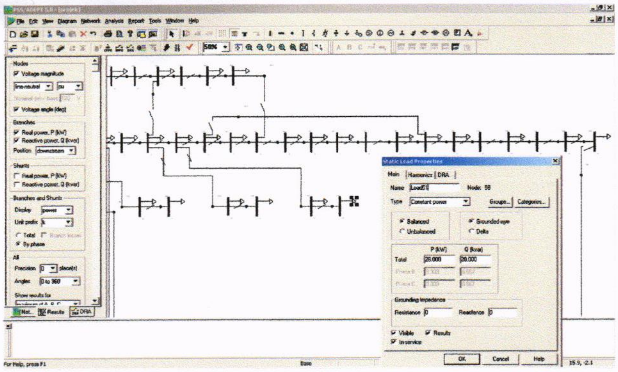


Figure 4: static load properties

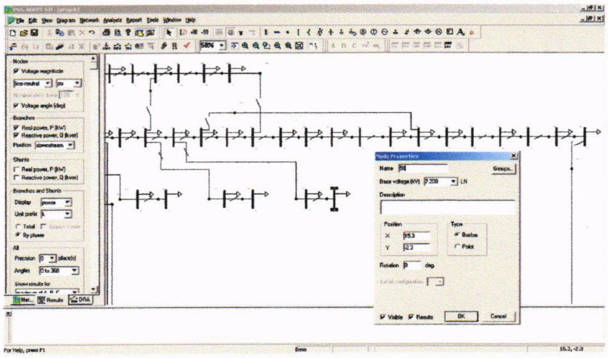


Figure 5: bus properties

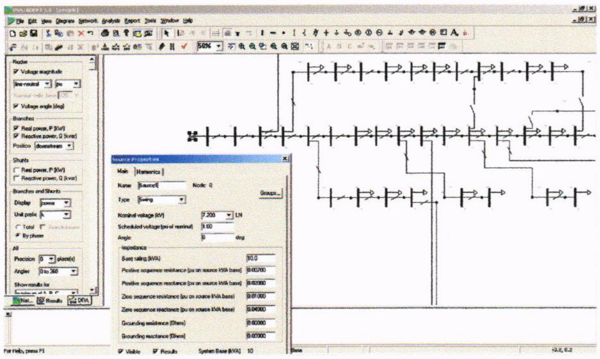
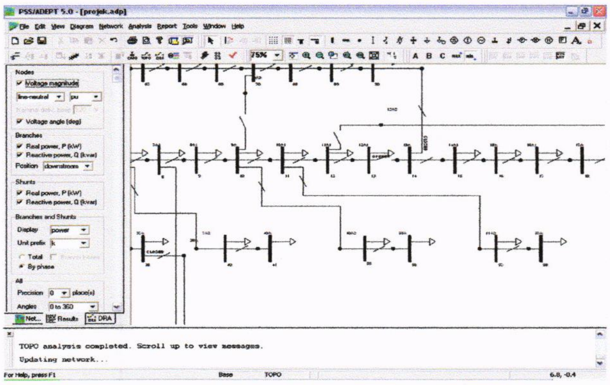


Figure 6: source properties

The purpose of a tie open point analysis is to determine the optimum system switch configuration that produces the minimal system loss. This is a special analysis activity that updates the diagram to indicate those switches that have changed from their original status.



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TOPO analysis completed. Scroll up to view messages.
Updating network...
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Figure 7: TOPO Diagram Displaying New Configuration Result

3.3 Location and sizing of Distributed Generation

In order to obtain maximum benefit from the distributed generator, suitable location has to be determined before its installation. The location of distributed generator is determined by finding a bus which is having the lowest minimum voltage. The purpose is to improve voltage performance especially for this selected bus. The sizing of distributed generator is also important in order to obtain the maximum performance in distribution system. The power at distributed generator (Pdg) can be determined by using the equation 1 and reactive power (Qdg) can be determined using equation 2.

$$\sum Ps + \sum Pdg = \sum Pload + \sum Ploss \ldots \ldots \ldots 1$$

$$\sum Qs + \sum Qdg = \sum Qload + \sum Qloss \ldots \ldots \ldots 2$$

Where:
Ps = Real power source
Pdg = Real power of DG
Pload = total real power load
Ploss = total real power loss
Qs = Reactive power source
Qdg = Reactive power of DG
Qload = total reactive power load
Qloss = total reactive power loss

3.4 Fault Analysis

In order to study the effect of distributed generation (DG) to the system losses and voltage profile in the event of fault, various fault location were selected. The fault location selected including the fault near to the generator, fault far from the generator, fault near to the

DG and fault at the lowest load. The selected fault buses are as follows:

(a) Bus 5 (near to the generator bus)
(b) Bus 19 (at the lowest load bus)
(c) Bus 47 (near to the DG)
(d) Bus 50 (at the highest load bus)
(e) Bus 88 (far from the generator bus)

The fault was applied to the network individually with different location of distributed generation. The minimum losses and minimum voltage were identified after the network is reconfigured by closing/opening the corresponding tie-line and sectionalizing switches for service restoration.

The simulation was executed using a commercial load flow program called PSS/Adept. PSS/Adept or Power System Simulator and Advanced Distribution Engineering Productivity Tool, is a network simulation program for planning, designing and analyzing distribution system. PSS/Adept utilizes the Gauss-Seidel method for the solving load flow equations. In PSS/Adept, Tie Open Point Optimization (TOPO) is used to determine the network configuration with the lowest real power loss. TOPO algorithm uses a heuristic method based on optimum power flow. Starting with the initial radial system, TOPO closes one of the controllable switches to form a loop. An optimum power flow procedures is then done on the loop to determine the best switch to open to change the network back to radial. The process continues until the switch that is opened is always the one that was closed at which time TOPO has finished. The resulting network is the radial network with minimum real power loss. TOPO can work with multiple load snapshots; in which case a single network configuration is found which has the lowest real power loss over all snapshots. That is, the switch setting may not be optimum for any one particular load snapshot, but it will be for the combination of them. When doing the analysis with multiple snapshots, TOPO uses the real power loss from each snapshot weighted by its relative time duration. TOPO can consider branch overloads. If this option is chosen, and the initial network has no overloads, the optimized network will also have no overloads. If the initial system does have overloads, the procedure is slightly more complex. As TOPO is going through the optimization procedure, each time the network is restored to radial (by breaking a loop formed when a controllable switch was closed) all load snapshots are checked to see if they are any overloaded branches. If, at any time during the optimization procedure, a configuration is found with no overloads, then the final optimized network will have no overloads.

4 Result and discussions

A 69 bus IEEE radial test distribution system is used in all simulation tests. It could be notice that bus 54 is the minimum bus voltage; therefore it is chosen as the suitable location for the distributed generation (DG). Figure 8(a), 8(b), 8(c), 8(d), 8(e) and 8(f) show the comparison of total power losses before and network reconfiguration during normal condition and at various fault locations respectively. For each location, the fault is assumed to be isolated.

Normal condition:

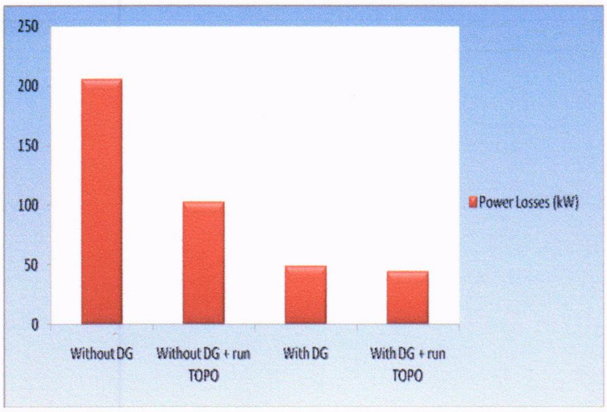

Figure 8(a): Comparison of total power losses before and after network reconfiguration in normal condition

From the graph shown in figure 8(a), it could be observed that the total losses in the system are reduced after network is reconfigured with and without the presence of distributed generation (DG) during normal condition.

Fault Locations:

1. Near to generator bus (fault at bus no. 5)

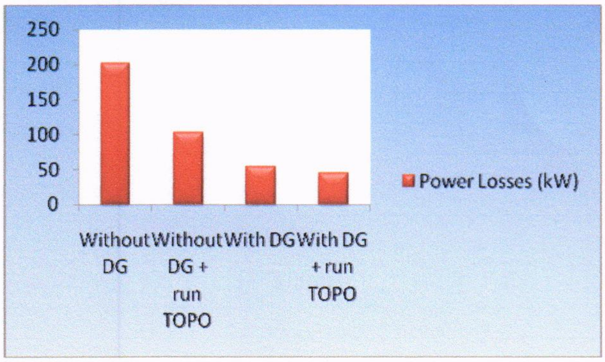

Figure 8(b): Comparison of total power losses before and after network reconfiguration since fault at bus no.5

2. Far from generator bus (fault at bus no. 88)

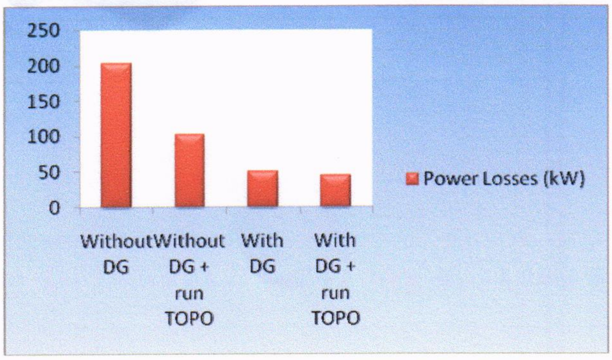

Figure 8(c): Comparison of total power losses before and after network reconfiguration since fault at bus no. 88

3. At the lowest load bus (fault at bus no. 19)

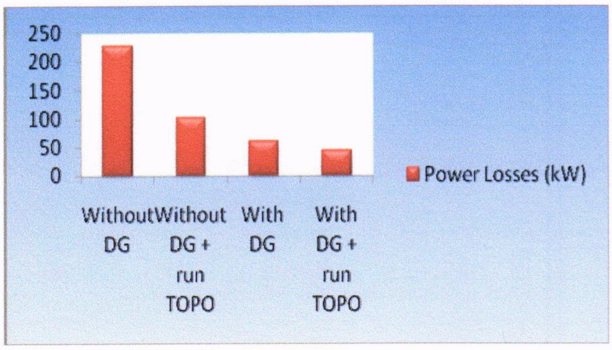

Figure 8(d): Comparison of total power losses before and after network reconfiguration since fault at bus no. 19

4. At the highest load bus (fault at bus no. 50)

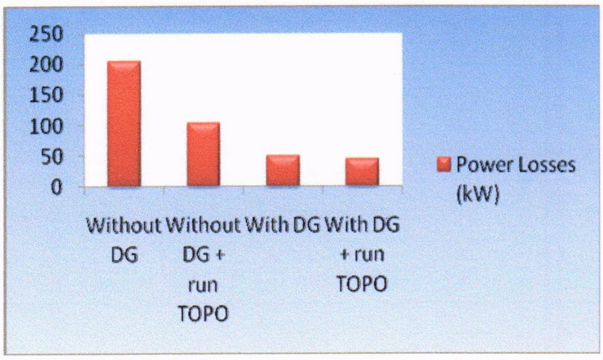

Figure 8(e): Comparison of total power losses before and after network reconfiguration since fault at bus no. 50

5. Near to DG (fault at bus no. 47)

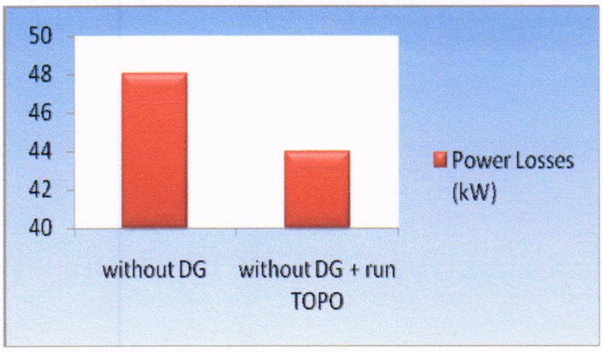

Figure 8(f): Comparison of total power losses before and after network reconfiguration since fault at bus no. 47

Figure 8(f) shows the analysis just after installation of DG only in order to find the effect of total power losses when fault occurred near to DG.

From figure 8(b), 8(c), 8(d), 8(e) and 8(f), it could be observed that the network reconfiguration with distributed generation (DG) produced minimum total power losses in the system for all fault location selected.

The minimum voltage is analyzed based on bus 54 only because of the lowest voltage compare the others. From the graph shown in figure 9(a), it could be observed that the minimum voltages in the system are increased after the network is reconfigured with and without the presence of distributed generation (DG) during normal condition.

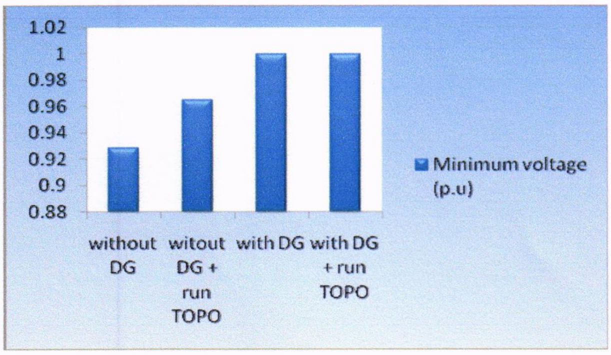

Figure 9(a): Comparison of minimum voltage before and after network reconfiguration in normal condition

Fault Locations:

1. Near to generator bus (fault at bus no. 5)

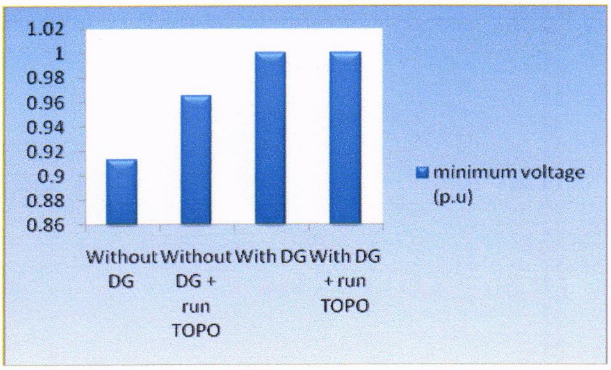

Figure 9(b): Comparison of minimum voltage before and after network reconfiguration since fault at bus no.5

2. Far from generator bus (fault at bus no. 88)

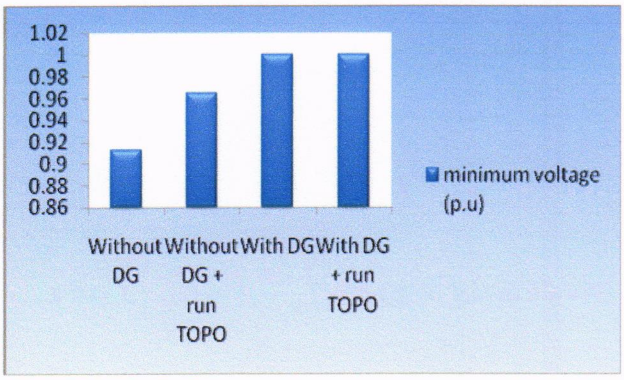

Figure 9(c): Comparison of minimum voltage before and after network reconfiguration since fault at bus no. 88

3. At the lowest load bus (fault at bus no. 19)

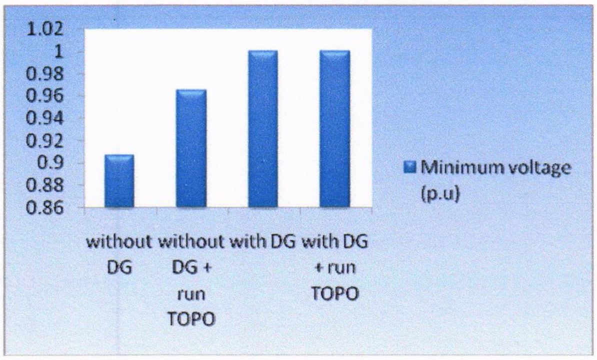

Figure 9(d): Comparison of minimum voltage before and after network reconfiguration since fault at bus no. 19

4. At the highest load bus (fault at bus no. 50)

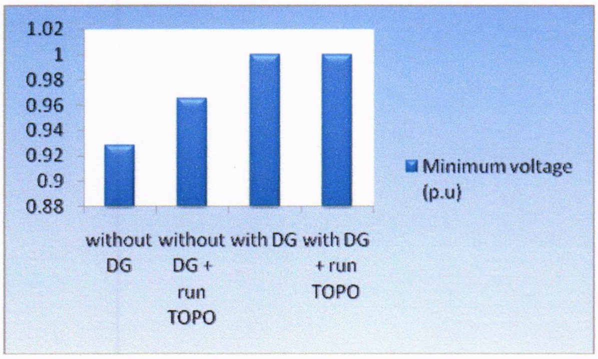

Figure 9(e): Comparison of minimum voltage before and after network reconfiguration since fault at bus no. 50

5. Near to DG (fault at bus no. 47)

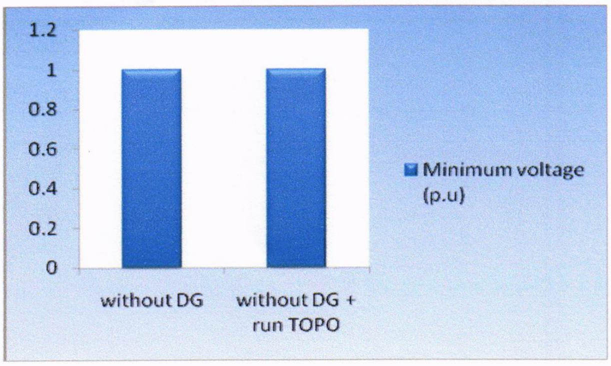

Figure 9(f): Comparison of minimum voltage before and after network reconfiguration since fault at bus no. 47

Figure 9(f) shows the analysis just after installation of DG only in order to find the effect of minimum voltage when fault occurred near to DG.

From figure 9(b), 9(c), 9(d), 9(e) and 9(f), it can be observed that the network reconfiguration with distributed generation (DG) increasing minimum voltages in the system for all fault location selected.

Figure 10(a), 10(b), 10(c), 10(d), 10(e) and 10(f) shows the comparison of power generator and power at DG in the system during normal condition and at all fault location selected.

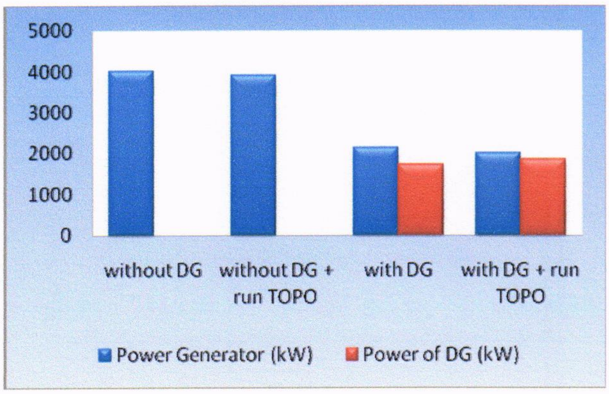

Figure 10(a): Comparison of power generator and power of DG before and after network reconfiguration in normal condition

Fault Locations:

1. Near to generator bus (fault at bus no. 5)

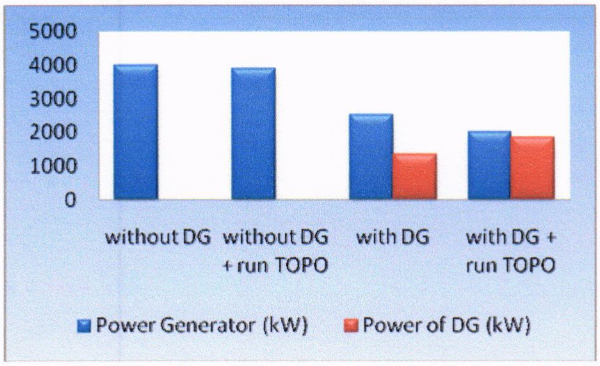

Figure 10(b): Comparison of power generator and power of DG before and after network reconfiguration since fault at bus no. 5

2. Far from generator bus (fault at bus no. 88)

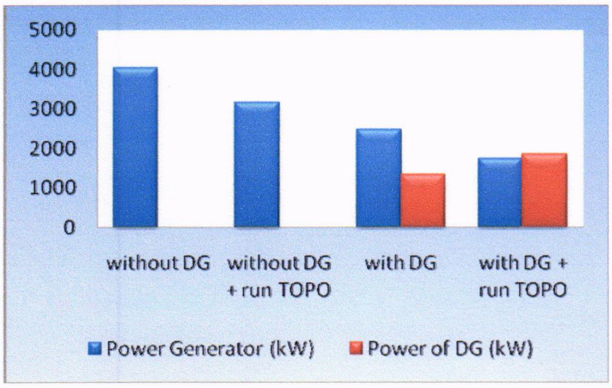

Figure 10(c): Comparison of power generator and power of DG before and after network reconfiguration since fault at bus no. 88

3. At the lowest load bus (fault at bus no. 19)

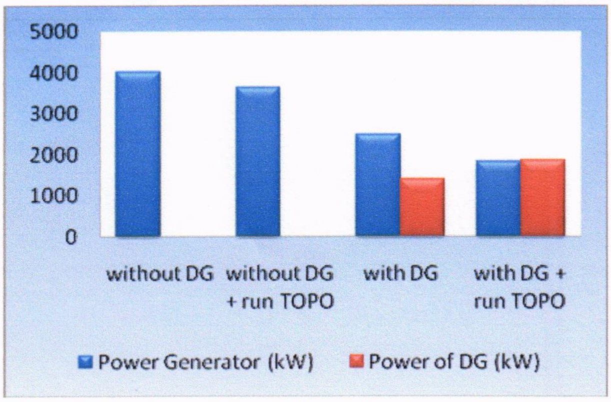

Figure 10(d): Comparison of power generator and power of DG before and after network reconfiguration since fault at bus no. 19

4. At the highest load bus (fault at bus no. 50)

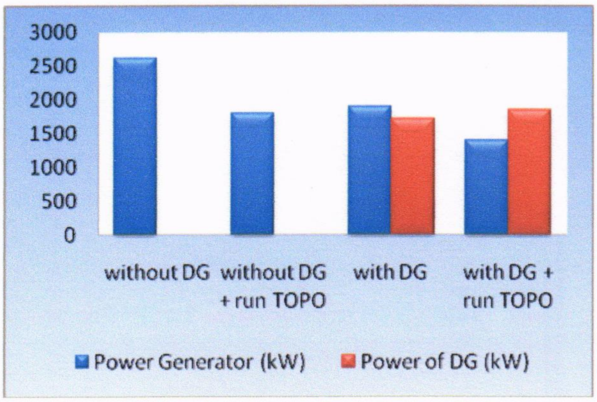

Figure 10(e): Comparison of power generator and power of DG before and after network reconfiguration since fault at bus no. 50

5. Near to DG (fault at bus no. 47)

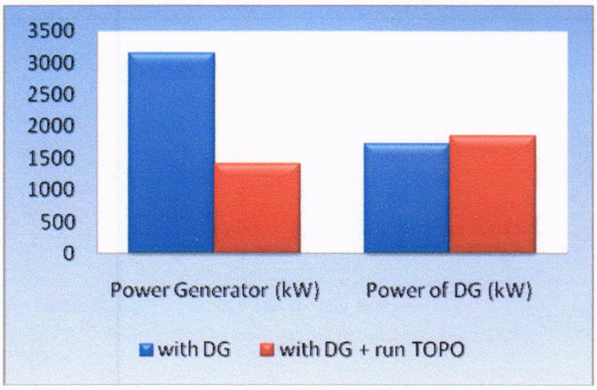

Figure 10(f): Comparison of power generator and power of DG before and after network reconfiguration since fault at bus no. 47

Figure 10(f) shows the analysis just after installation of DG only in order to compare of power generator and power at DG when fault occurred near to DG.

From the figure 10(a), 10(b), 10(c), 10(d), 10(e) and 10(f), it could be observed that the power generator are reduced after network reconfiguration with DG and without DG otherwise power at DG are increased.

5 Conclusions

In this paper, the benefit of implementing Distributed Generation (DG) in terms of minimizing the power loss and improving voltage profile under fault condition were analyzed. The DG was located at bus with minimum voltage. Five fault locations were selected for the analysis. Network reconfiguration was implemented after the occurrence of fault for service restoration. The simulation was carried out using software PSS/Adept with various location of the fault. The results of the existing configuration network were compared with the results obtained after the network is reconfigured. From the numerical simulation, the presence of distributed generation at the proposed location and sizing are able to produce the best results in terms of voltage profile improvement and power loss minimization after the network is reconfigured at various fault location.

6 Acknowledgements

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