# DISTRIBUTED GENERATION PLANNING IN DISTRIBUTION SYSTEMS USING GENETIC ALGORITHM

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***Abstract: A combination of public policy, incentives and economics is driving a rapid growth of distributed generation in the electric power system. The majority of states/provinces now have renewable portfolio standards, with many requiring that over 20 percent of electricity sales by generated by renewable energy sources within the next five to fifteen years. The majority of these requirements will be addressed by adding significant amounts of wind energy and growing amounts of solar energy to the bulk power system.***
***Wind and solar power plants exhibit greater variability and uncertainty because of the nature of their "fuel" sources. Optimization is one of the tools that can be used to address concerns and costs around this variability and uncertainty. This paper discusses operational and optimal system impacts, provides background on what can be realistically expected from distributed generation power-output.***
***Distribution generation also includes more than wind resources: both established types, like run-of-river hydro and emerging varieties, such as wave energy. While the majority of attention in this report is on wind and solar generation, most varieties of distribution generation share similar characteristics (though to a different extent) since the variability is largely driven by weather or other non-anthropogenic phenomena. Similar optimization and integration approaches are also likely to apply to these distribution generation resources as well. In fact, because load is also influenced by the weather, demand and generation optimization may eventually come.***

***Index Terms— Distributed Generation (DG), Genetic Algorithm (GA), Distributed generation Planning.***

## I. INTRODUCTION

Today's economic environment changes rapidly for utilities and capacity options are expanding. Distributed generation (DG) is one new option being promoted for solving utility distribution system capacity problems. However, few utilities have experience in applying DG to planning rules in the case of new feeders and substations. To get a better understanding of when DG and other nontraditional expansion alternatives are economical, a better estimate of the costs must be computed. Then, the planner determines investment plans that minimize the total cost.

The pressure to consider DG options for capacity addition comes from a number of sources, including: Investment risk in competitive power markets, Regulatory agencies that require due diligence before approving major vestments such as new substations, and Availability of more cost-effective DG technologies. This Paper presents a planning process that considers DG as well as conventional and other nonconventional options. The basic process has its roots in utility generation planning and was adapted for smaller generators connected to utility distribution systems for an EPRI engineering handbook on DG and related planning software. The methodology continues to evolve with additional economic and engineering analyses to address such issues as power quality and system dynamics during islanding. There are many other planning frameworks that address this problem. The method described here is a relatively straightforward extension of familiar distribution planning concepts.

### ***A.*** *Distributed generation*

The distributed generation uses smaller-sized generators than dose the typical central station plant. They are distributed throughout the power system closer to the loads. The normal distribution system delivers electric energy through wires from a single source of power to a multiple of loads. Thus, several power quality issues arise when there are multiple sources. Will Distributed Generation improve the quality or will it degrade the service end users have come to expect.

The electrical power system, consisting of relatively small generators configured in isolated, used Distribution Generation. That model gave way to present centralized system largely because of economies of scale. Also, there was the desire to sequester electricity generation facilities away from population centre for environmental reasons to locate them closer to the source of fuel and water.

So we can say that Distributed generation is:

- Use of small generating units installed close to load centers
- Other terms:
    - ➢ Decentralized generation
    - ➢ Embedded generation
    - ➢ Disperse generation
- Trend: generators sized from kW to MW at load sites renewed interest for DG IEA lists five major factors
    - ➢ developments in distributed generation technologies,

- constraints on the construction of new transmission lines,
- increased customer demand for highly reliable electricity,
- the electricity market liberalization and
- Concerns about climate change.

***B.*** *Types of DG:*

The different types of traditional and non-traditional DGs are classified and described from the constructional, technological, size, and power time duration point of view. The DGs may also be grouped into four major types based on terminal characteristics in terms of real and reactive power delivering capability. Four major types are considered for comparative studies which are described as follows:

*Type 1:* This type DG is capable of delivering only active power such as photovoltaic, micro turbines, fuel cells, which are integrated to the main grid with the help of converters/inverters. However, according to current situation and grid codes the photovoltaic can and in sometimes are required to provide reactive power as well.

*Type 2:* DG capable of delivering both active and reactive power, DG units based on synchronous machines (cogeneration, gas turbine, etc.) come under this type.

*Type 3:* DG capable of delivering only reactive power, Synchronous compensators such as gas turbines are the example of this type and operate at zero power factors.

*Type 4:* DG capable of delivering active power but consuming reactive power, mainly induction generators, which are used in wind farms, comes under this category. However, doubly fed induction generator (DFIG) systems may consume or produce reactive power i.e. operates similar to synchronous generator.

**II. IMPACT OF DISTRIBUTED GENERATION ON DISTRIBUTION SYSTEM**

Distributed generation is an approach that employs small-scale technologies to produce electricity close to the end users of power. DG technologies often consist of modular (and sometimes renewable-energy) generators, and they offer a number of potential benefits. In many cases, distributed generators can provide lower-cost electricity and higher power reliability and security with fewer environmental consequences than can traditional power generators. Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from many small energy sources. Distributed generation reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed. In contrast to the use of a few large-scale generating stations located far from load centers-the approach used in the traditional electric power paradigm-DG systems employ numerous, but small plants and can provide power onsite with little reliance on the distribution and transmission grid. DG technologies yield power in capacities that range from a fraction of a kilowatt [kW] to about 100 megawatts [MW]. Utility-scale generation units generate power in capacities that often reach beyond 1,000 MW. Distributed generation takes place on two-levels: the local level and the end-point level. Local level power generation plants often include renewable energy technologies that are site specific, such as wind turbines, geothermal energy production, solar systems (photovoltaic and combustion), and some hydro-thermal plants. These plants tend to be smaller and less centralized than the traditional model plants. They also are frequently more energy and cost efficient and more reliable. Since these local level DG producers often take into account the local context, the usually produce less environmentally damaging or disrupting energy than the larger central model plants.

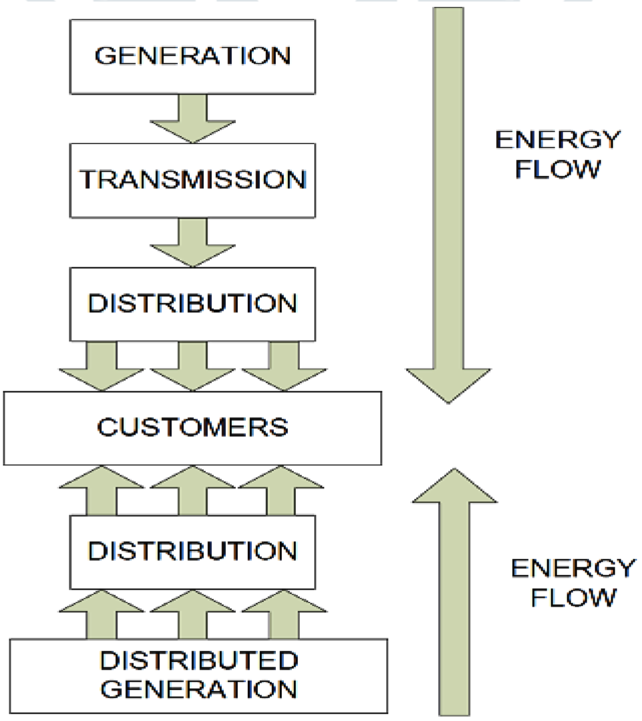


**Fig.1. New Industrial conception of Electrical Energy Supply**

***A.*** *Benefits of Distributed Generation:*

Consumer advocates who favor DG point out that distributed resources can improve the efficiency of providing electric power. They often highlight that transmission of electricity from a power plant to a typical user wastes roughly 4.2 to 8.9 percent of the electricity as a consequence of aging transmission equipment, inconsistent enforcement of reliability guidelines, and growing congestion. At the same time, customers often suffer from poor power quality-variations in voltage or electrical flow-that results from a variety of factors, including poor switching operations in the network, voltage dips, interruptions, transients, and network disturbances from loads. Overall, DG proponents highlight the inefficiency of the existing large-scale electrical transmission and distribution network. Moreover, because customers ‘electricity bills include the cost of this vast transmission grid, the use of on-site power equipment can conceivably provide consumers with affordable power at a higher level of quality. In addition, residents and businesses that generate power locally have the potential to sell surplus power to the grid, which can yield significant income during times of peak demand.

Perhaps incongruously, DG facilities offer potential advantages for improving the transmission of power. Because they produce power locally for users, they add the entire grid by reducing demand during peak times and by minimizing congestion of power on the network, one of the causes of the 2003 blackout. And by building large numbers of localized power generation facilities rather than a few large-scale power plants located distantly from load centers, DG can contribute to deferring transmission upgrades and expansions-at a time when investment in such facilities remains constrained. Perhaps most important in the post-September 11 era, DG technologies may improve the security of the grid.

Environmentalists and academics suggest that DG technologies can provide ancillary benefits to society. Large, centralized power plants emit significant amounts of carbon monoxide, sulfur oxides, particulate matter, hydrocarbons, and nitrogen oxides.

Finally, DG can help the nation increase its diversity of energy sources. Some of the DG technologies, such as wind turbines, solar photovoltaic panels, and hydroelectric turbines, consume no fossil fuels, while others, such as fuel cells, micro turbines, and some internal combustion unit’s burn natural gas, much of which is produced in the United States. The increasing diversity helps insulate the economy from price shocks, interruptions, and fuel shortages.

***B.*** *Technologies used for distributed generation:*

The variety of end-use is to be related to an even greater variety in technologies. The range of technologies used for distributed generation and described by the International Energy Agency (2002) includes:

***a)*** *Reciprocating Engines:*

This technology uses compressed air and fuel. The mixture is ignited by a spark to move a piston. The mechanical energy is then converted into electrical energy. Reciprocating engines are a mature technology and largely spread thanks to their low capital investment requirement, fast start-up capabilities and high energy efficiency when combined with heat recovery systems. Most reciprocating engines run either on fuel or natural gas with an increasing number of engines running on biogas produced from biomass and waste. On the rolling year June 2007- May 2008, most of the reciprocating engines ordered were used as back-up or stand-by generators (45%), the remaining being divided between peaking generators (30%) and continuous generators (25%) (DGTW, 2008) Reciprocating engines perform, however, poorly in terms of noise, maintenance and emissions (IEA, 2002).

**Fig. 2. Reciprocating Engine**

**b)** Gas Turbines:

Gas turbines are widely used for electricity generation thanks to the regulatory incentives induced to favors fuel diversification towards natural gas and thanks to their low emission levels. Conversely to reciprocating engines, gas turbines ordered over the period covered by the survey were widely used as continuous generators (58%), 18% were used as standby generators and 24% as peaking generators (DGTW, 2008). Gas turbines are widely used in cogeneration;

**c)** Micro turbines:

Micro turbines are built with the same characteristics than gas turbines but with lower capacities and higher operating speed;

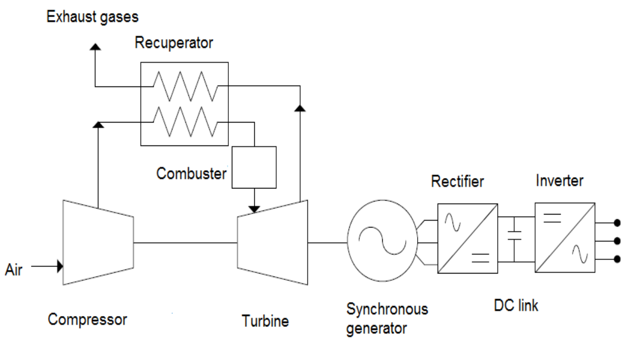


**Fig.3. Layout of Micro-Turbine**

***d)*** *Fuel cells*

Instead of converting mechanical energy into electrical energy, fuel cells are built to convert chemical energy of a fuel into electricity. The fuel used is generally natural gas or hydrogen. Fuel cells are a major field of research and significant effort is put in reducing capital costs and increasing efficiency which are the two main drawback of this technology;

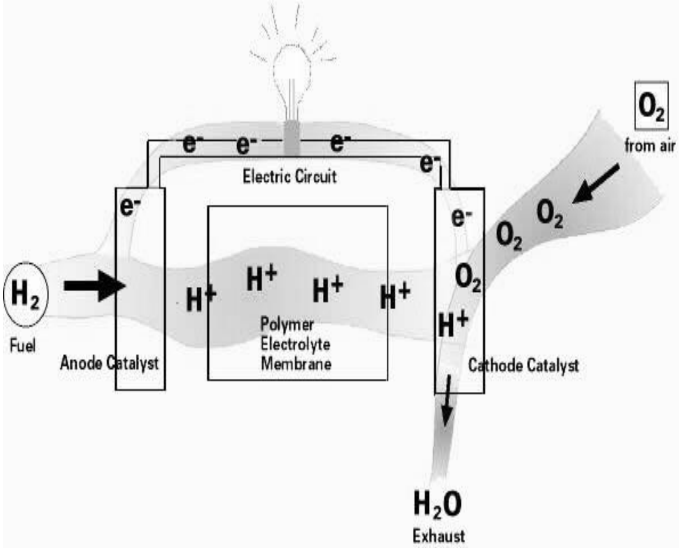


**Fig.4. Solar Photovoltaic (PV) Systems**

***e)*** *Renewable sources:*

Renewable technologies have been used as a way to produce distributed energy, Renewable sources range from photovoltaic technologies, wind energy, thermal energy etc. These sources qualify as distributed generation only if they meet the criteria of the definition which is not always the case. Distributed generation is therefore clearly distinct from renewable energy. For example, offshore wind farms do not qualify as distributed generation.

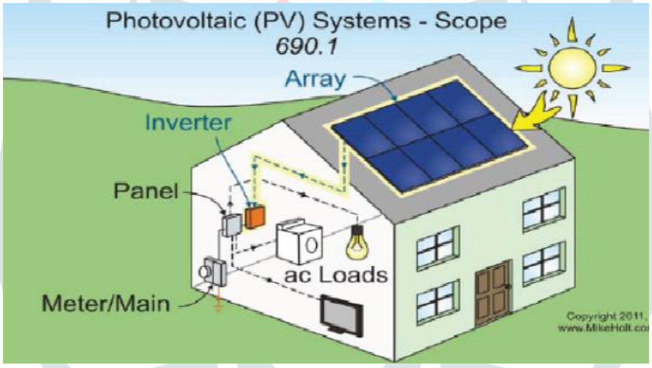


**Fig.5. Solar Photovoltaic (PV) systems**

## III. OPTIMAL LOCATION & SIZE OF DGS

***A.*** *Optimal Location:*

Placement of DGs is an interesting research area due to economical reason. Distributed generation systems (such as fuel cells, combustion engines, micro turbines, etc) can reduce the system loss and defer investment on transmission and distribution expansion. Appropriate size and optimal locations are the keys to achieve it optimal placement of DG (OPDG) in distribution network is an optimization problem with continuous and discrete variables. Many researchers have used evolutionary methods for finding the optimal DG placement.

In fact, three types of DG are considered which are as follows:

Type 1: DG is capable of supplying only real power

Type 2: DG is capable of supplying only reactive power

Type 3: DG is capable of supplying real power but consuming proportionately reactive power

In a Newton-Raphson algorithm based load flow program is used to solve the load flow problem. The methodology for optimal placement of only one DG type1 is proposed. Moreover, the heuristic search requires exhaustive search for all possible locations which may not be applicable to more than one DG.

There have been number of studies to define the optimum location of DG. The mathematical approaches on the optimum DG placement for minimum power losses are as follows:

Optimal load flow with second order algorithm method genetic algorithm and Hereford Ranch algorithm which can find optimum. Fuzzy-GA method, tabu search approach, the algorithm to determine the near optimal, 2/3 rule, which is often used in capacitor placement studies, and analytical approach in radial as well as networked systems. Particularly, reference demonstrates an analytical approach to determine exclusively the optimal location to place a DG in radial systems to minimize the total loss of the system. This study takes the size of DG as total load size and in respect of the size of DG obtains the optimal location of DG in radial systems without optimizing size of DG.

In all of the studies, cited above the loads are the loads are generally modeled as constant power or constant current types of loads. Since most of the distribution system loads are uncontrolled, effects of this type of load models on optimum sizing and location s should be questioned.

***a) DG Location:***

The optimal location of the distributed generation unit is determined based on the value of the stability index. The stability index is calculated using at every node in the system. The DG is installed at the bus with the highest stability index. The size of the DG is determined using an optimization technique which can be implemented for stability index minimization or system losses minimization as given below.

***b) Minimum stability index:***

The branch corresponding to the maximum value of the stability index Lis called the weakest branch where the voltage collapse normally starts from it. The margin of voltage stability can be obtained according to the deviation between 0.0 at no load and the critical value of 1.0 when the system collapses.

***c) Genetic Algorithm:***

A powerful class of optimization methods is the family of GA. The GA become particularly suitable for the problem posed here. GA based energy loss optimization technique is proposed for finding size and site for DG to place in power systems. For a given distribution system network wherein all branches between nodes are known and therefore evaluation of the objective function depends only on the size and location of DG units.

- The GA is employed to designate optimization algorithms that perform a kind of approximate global search such that: They rely on the information obtained by the evaluation of several points in the search space. Each “current point” is called an individual, and the set of “current point” is called the population. The algorithm keeps this set of “current points”, instead of keeping a single “current point” as would be the case of in most optimization algorithms.
- The population is expected to coverage to optimum (or near optimum) through sequential applications, at each iteration, of genetic operators.

Preparatory steps are the basic version of genetic programming. The human user communicates the high levels statement of the problem to the genetic programming system by performing certain well-defined preparatory steps. The preparatory steps are the human supplied input to the genetic programming system. The computer program is the output of genetic programming system. Genetic algorithm that yields good results in many practical problems is composed of three operators:

**a)** *Crossover:* The individuals, randomly organized pair-wise, have their space locations combined, in such a way that each former pair of individuals gives rise to a new pair.

**b)** *Mutation:* Some individuals are randomly modified, in order to reach other points of the search space.

**c)** *Selection:* The individuals, after mutation and crossover, are evaluated. They are chosen or not chosen for being inserted in the new population through a probalistic rule that gives a greater probability of selection to the “better” individuals.

The advantages in using GA are that they require no knowledge or gradient information about the response surface; they are resistant to becoming trapped in local optima and they can be employed for a wide variety of optimization problems. A GA search is done by examining at the same time a set of possible solutions, instead of a single one. This strategy allows a better exploration of the solution space during the search for the global optimum. Also, it reduces the probability of being stuck in a local optimum. The success of the optimization process depends on the appropriate design of a fitness function for the problem. The fitness values of individuals in a given population are employed to drive the evolution process. These characteristics enable the GAs to present excellent results even when optimizing complex or discontinuous functions. In most of the cases, it is very difficult to achieve analytic relationship between sensitivity of simulated power system and the parameters values to be optimized. GA don’t need this kind of information, hence it is suitable in our optimization task. An evolutionary strategy needs to be adopted in order to generate individuals for the next generation. The individuals are arranged by their fitness and only the best of them are taken unchanged into the next generation. In this way good individuals are not lost during a run. Other children come from crossover and mutation. The aim of the fitness function is to numerically represent the performance of an individual. In order to end the evolution of the population we choose certain termination criterion. The final result of the GA optimization is the best individual of the last iteration.

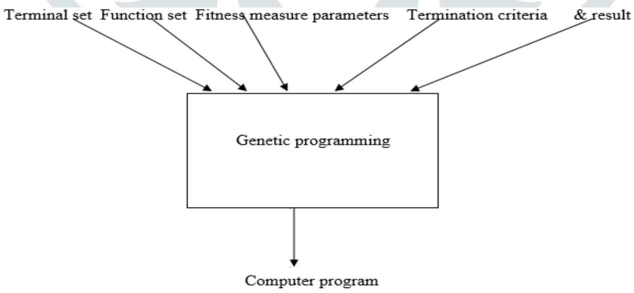


**Fig.6. Preparatory Steps of Genetic Algorithms**

***d) Problem formulation:***

DG sources are normally placed close to load centres and are added mostly at the distribution level. They are relatively small in size (relative to the power capacity of the system in which they are placed) and modular in structure A Common strategy for sizing and placement of DG is to minimize system energy loss of the power systems. The voltage at each bus is in the acceptable range and the line flows are within the limits. These limits are important so that integration of DG into the system does not increase the cost for voltage control or replacement of existing lines. The formulation to determining the optimal size and location of DG in a system is as follows:

Formulation for system energy saving

Min. [ $E_{loss}$ ]

Annual system energy loss

$$\left[E_{loss}\right] = \left[\Sigma P_{loss}\left\{DG\left(i, size\right)\right\} * t\right] * D \quad (1)$$

System power loss

$$P_{loss} = \sum_{line(i,j)=1}^{m} P_{line(i,j)} \quad (2)$$

Line power loss

$P_{line}(i,j) = P_i - P_j$ (3)

Subject to

Real power injected at $j_{th}$bus is the difference of total real power generated with DG of a particular size and real power load at $I_{th}$ bus. i.e

$$P_i = DG(i,size) - P_{di} = |V_i|\sum|V_k|\left[G_{ik}\cos(\theta_i-\theta_k)+B_{ik}\sin(\theta_i-\theta_k)\right] \quad (4)$$

Reactive power injected at $I_{th}$ bus is the difference of total reactive power generated with DG of a particular size and reactive power load at $I_{th}$ bus but reactive power generation is zero in DG. i.e

$$Q_i = -QD_i = |V_i|\sum|V_k|\left[G_{ik}\sin(\theta_i-\theta_k)+B_{ik}\cos(\theta_i-\theta_k)\right] \quad (5)$$

$$V_i \max \geq V_i \geq V_i \min \quad (6)$$

$$P_{line}(i,j)\min \leq P_{line}(i,j) \leq P_{line}(i,j)\max \quad (7)$$

The important operational constraints are addressed by Eqns. (6) and (7).

Annual system energy saving is the difference of annual system energy loss without penetration of DG and annual system energy loss with DG. i.e.

$$E_{saving} = \left[E_{loss}(noDG) - E_{loss}(withDG)\right] \quad (8)$$

In the above formulation ithe location which ranges from bus 2 to $n$, bus 1 being the slack node or the feeder node and n being the total number of buses in the system. DG size is also considered as variable that varies from 0 to 0.63 p. u. An operating time for particular load t ranges from 0 to T hours in any day. D is number of days in a year. The variables $P_i, Q_i, V_i$ and $\theta_i$ are real power, reactive power, bus voltage and power angle at $i_{th}$ bus. $G_{ik}$ And $B_{ik}$ are the shunt branch conductance and shunt branch susceptance between the bus $i$ and $k$. They are usual terms in power flow studies. *PDi* and *QDi* are the real and reactive load at bus $i$. The eqns. (4) and (5) are the real and reactive power balance equations for a particular bus $i$. The saving in energy given in eqn. (8) is the difference in losses of the system with and without DG.

***e)*** *Sizing & placement of DG using GA:*

The problem related to the placement and size of a DG can be formulated on the basis of energy loss minimization approach. The optimal placement of a DG requires finding the strategic locations for it according to the minimum energy loss so that overall system operation may be economical. Penetration level of the DG is the percentage of total demand supplied economically by it. The problem statement is to find the economically viable location and corresponding size for various types of DGs like reciprocating engine, mini gas turbine, fuel cell, etc. Proper placement of DG in power system is important for obtaining their maximum potential benefits. The goal is to find out proper size and optimal location for a DG in distribution systems and assure that the voltage Vi in every bus are in the acceptable range, 1 + 0.05 or 1-0.05 p. u. and transmission lines are loaded under specified MVA limits.

***i).*** *Algorithm for system annual energy loss minimization:*

*Step 1:* Randomly generate size-location pairs of distributed generation system in a predefined range of sizes and the buses. Set k = 1. Enter the maximum number of iteration m.

*Step 2:* Run power flow and calculate system annual energy loss of the system for each size-location pair under time-varying loading condition, and record the system annual energy loss and its corresponding size location pairs.

*Step 3:* Check whether the voltage limits and transmission line MVA limits are satisfied for all the buses for each of the size-location pairs.

*Step 4:* If all the voltages and MVA limits are in acceptable range for a particular size-location pair, accept that pair for next generation population. Else reject the size-location pair which does not satisfy criteria given in step 3 in the next generation. Obtain the size-location pair with minimum annual energy loss (min $E_{loss}$ size location (k)). If min $E_{loss}$ size location (k) has not changed for last m iteration STOP. Else, If k = m, the corresponding size and location pair is the optimum-size location pair. STOP and END the program.

*Step 5:* Use the available population of size-location pair (parent population) for cross-over and mutation for obtaining new generation of (offspring) population. If population size after step 4 is zero go to step 1.

*Step 6:* Use the newly generated population size i.e. off springs and parents as new generation. Go to step 2. A data file having all the previously searched options is created and is used in step 1, thus the new populations generated is checked and if already searched are excluded from the population. It can be seen from the algorithm that if the objective function do not change for large number of iteration the solution is taken as optimum otherwise algorithm allowed to run for maximum of m iteration and the results obtained are taken as minimum. The problem posed here is a combinational one wherein large numbers of combination of size-location pairs are to be solved using non-linear power flow equations.

***f)*** *Loss sensitivity factor method*

The loss sensitivity factor method is based on the principle of linearization of the original nonlinear equation (loss equation) around the initial operating point, which helps to reduce the amount of solution space. The loss sensitivity factor method has been widely used to solve the capacitor allocation problem. Its application in DG allocation is new in the field and has been reported in Loss Sensitivity. The real power loss in a system is given by Equation:

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}\left[\alpha_{ij}(PiPj+QiQj)+\beta ij(QiPj-PiQj)\right]$$

$$\alpha_{ij} = \frac{r_{ij}}{ViVj}\cos(\delta i-\delta j), \beta_{ij} = \frac{r_{ij}}{ViVj}\sin(\delta i-\delta j) \quad (9)$$

Where $r_{ij} + jx_{ij} = z_{ij}$ are the $ij_{th}$ element of $Z_{bus}$ .The sensitivity factor of real power loss with respect to real power injection from DG is given by

$$\alpha_i = \frac{\partial PL}{\partial Pi} = 2\sum_{i=1}^{N}(\alpha_{ij}Pj - \beta_{ij}Qj) \quad (10)$$

Sensitivity factors are evaluated at each bus, firstly, using the value obtained from the base case power flow.

***g)*** *Indices:*

There are various technical issues that need to be addressed when considering the presence of distributed generators in distribution systems. Computed several indices in order to describe the impacts on the distribution system due to presence of distributed generation during maximum power generation

- Real Power Loss Indices (PLI)
- Reactive Power Loss Indices (QLI)
- Voltage Profile Indices (VPI)
- Line capacity indices (LCI)

***i).*** *Real and Reactive Power Loss Indices (PLI and QLI):*

The real and reactive power loss indices are defined as

$$PL1 = \frac{[P_{LDG}]}{[P_L]} \quad (11)$$

$$QL1 = \frac{[Q_{LDG}]}{[Q_L]} \quad (12)$$

Where $P_{LDG}$ and $Q_{LDG}$ are the total real and reactive power losses of the distribution system after inclusion of DG. $P_L$ And $Q_L$ are the total real and reactive system losses without DG in the distribution system.

***ii).*** *Voltage Profile Index (VPI):*

One of the advantage of proper location and size of the DG is the improvement in voltage profile. This index penalizes the size-location pair which gives higher voltage deviations from the nominal ($V_1$=1.03 p .u). In this way, closer the index to zero better is the network performance. The VPI can be defined as follows*:*

$$VP1 = \max_{i=2}^{n}\left(\frac{V_1 - Vi}{V_1}\right) \quad (13)$$

***iii).*** *Line Capacity Index (LCI):*

As a consequence of supplying power near to loads, MVA flows may diminish in some sections of the network, thus releasing more capacity, but in other sections they may also increase to levels beyond distribution line limits (if line limits are not taken as constraints). The index (LCI) gives important information about the level of MVA flow/currents through the network regarding the maximum capacity of conductors. This gives the information about need of system line upgrades. Values higher than unity (calculated MVA flow values higher than the MVA capacity) of the index give the amount of capacity violation in term of line flows, whereas the lower values indicate the capacity available. It is define as

$$LCI = \max_{i=1}^{m}\left(\frac{\bar{S}_{ij}}{\bar{CS}_{ij}}\right) \quad (14)$$

## IV. RESULTS & DISCUSSIONS

In this section results are obtained for IEEE-38 Bus system. Four cases are taken for different types of DG viz. Type 1, 2, 3 and 4 and at different power factors. The load taken for study is Peak, medium and Low. Results are obtained without and with DG against different parameters.

The different cases which are taken for the system are as follows:
Case 1: Taking DG of Type T1 at unity power factor
Case 2: Taking DG of Type T2 at variable power factor
Case 3: Taking DG of Type T3 at zero power factors
Case 4: Taking DG of Type T4 at negative power factor

*Case 1:* Taking DG of Type T1 at unity power factor:

From Table I MVA intake Power and $P_{loss}$ are reduces with DG in comparison to without DG for different type of load. The Percentage reduction in MVA intake and $P_{loss}$ are 48.05 & 45.36, 13.02 & 43.13, 44.12 & 42.72 for Peak, medium and Low load respectively

*Case 2:* Taking DG Type T2 of variable power factor:

From Table II MVA intake Power and $P_{loss}$ are reduces with DG in comparison to without DG for different type of load. The Percentage reduction in MVA intake and $P_{loss}$ are 68.27 & 69.36, 67.55 &69.31, 43.97& 67.09 for Peak, medium and Low load respectively

*Case 3:* Taking DG Type T3 of Zero power factor:

From Table III MVA intake Power and $P_{loss}$ are reduces with DG in comparison to without DG for different type of load. The Percentage reduction in MVA intake and $P_{loss}$ are 1.2 & 30.86, 12 & 31.82, 12.7 & 27.27 for Peak, medium and Low load respectively

*Case 4:* Taking DG Type T4 of Negative power factor:

From Table IV MVA intake Power and $P_{loss}$ are reduces with DG in comparison to without DG for different type of load. The Percentage reduction in MVA intake and $P_{loss}$ are 32.07 &35.2, 31.64 & 35.59, 31.55 & 34.23 for Peak, medium and Low load respectively

Table 1 Performance Parameters for DG of Type T1 at Unity Power Factor

| **Load** | **Without/with DG** | **DG Size $P_{dg}$ (per unit)** | **Total Active Power** | **Power Factor** | **MVA Intake Power(p.u)** | $P_{loss}$ | $Q_{loss}$ | **Location** | **Percentage Reduction** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **MVA Intake** | $P_{loss}$ |
| **Peak** | Without DG | 0 | 0 | 0 | 3.9039 | 1.889 | 1.8890 | | 48.47 | 45.36 |
| | With DG | 2.5654 | 2.6543 | 1 | 1.2468 | .97329 | .70010 | 6 | | |
| **Medium** | Without DG | 0 | 0 | 0 | 3.1650 | .0880 | .05914 | | 13.02 | 43.13 |
| | With DG | 1.7690 | 1.7569 | 1 | 1.8630 | .04664 | .03354 | 6 | | |
| **Low** | Without DG | 0 | 0 | 0 | 2.5137 | .0557 | .03714 | | 44.12 | 42.72 |
| | With DG | 1.2556 | 1.2453 | 1 | 1.5635 | .02982 | .02133 | 6 | | |

Table 2 Performance Parameters for DG of Type T2at Variable Power Factor

| **Load** | **With/without DG** | **DG Size $P_{dg}$ (per Unit)** | **Total Active Power (p.u)** | **Power Factor** | **MVA Intake Power (p.u)** | $P_{loss}$ | $Q_{loss}$ | **Location** | **Percentage Reduction with DG** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **MVA Intake** | $P_{loss}$ |
| **Peak** | Without DG | - | - | - | 4.5962 | .188 | 0.1250 | | 68.27 | 9.36 |
| | With DG | 2.4573 | 2.4573 | 0.8200 | 1.4584 | .0576 | 0.0453 | 6 | | |
| **Medium** | Without DG | - | - | - | 3.1651 | .0880 | 0.0590 | | 67.55 | 69.31 |
| | With DG | 1.7024 | 1.1882 | 0.8200 | 1.0267 | 0.0278 | 0.0219 | 6 | | |
| **Low** | Without DG | - | - | - | 2.5137 | .0550 | 0.0370 | | 43.97 | 67.09 |
| | With DG | 0.8557 | 0.6413 | 0.8200 | 1.4081 | 0.0181 | 0.0134 | 30 | | |

Table 3 Performance Parameters for DG of Type T3 at Zero Power Factor

| **Load** | **With/ Without DG** | **DG Size $P_{dg}$ (per unit)** | **Total Active Power(p.u)** | **Power Factor** | **MVA Intake Power(p.u)** | $P_{loss}$ | $Q_{loss}$ | **Location** | **Percentage Reduction** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **MVA Intake** | $P_{loss}$ |
| **Peak** | Without DG | - | - | 0 | 4.5962 | 0.1880 | 0.1250 | | 1.2 | 30.86 |
| | With DG | 1.2685 | 1.2655 | 0 | 4.0109 | 0.1341 | 0.0900 | 30 | | |
| **Medium** | Without DG | - | - | 0 | 3.1651 | 0.0880 | 0.0591 | | 12 | 31.82 |
| | With DG | 0.8817 | 0.8817 | 0 | 2.7735 | 0.0637 | 0.0427 | 30 | | |
| **Low** | Without DG | - | - | 0 | 2.5137 | 0.0550 | 0.0371 | | 12.7 | 27.27 |
| | With DG | 0.6954 | 0.6954 | 0 | 2.2093 | 0.0402 | 0.0269 | 30 | | |

Table 4 Performance Parameters for DG of Type T4 at Negative Power Factor

| **Load** | **Without/ with DG** | **DG Size $P_{dg}$ (per unit)** | **Total Active Power(p.u)** | **Power Factor** | **MVA Intake Power (p.u)** | $P_{loss}$ | $Q_{loss}$ | **Location** | **Percentage Reduction** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **MVA Intake** | $P_{loss}$ |
| **Peak** | Without DG | - | - | - | 4.5960 | .1880 | .1250 | - | 32.07 | 35.20 |
| | With DG | 2.2684 | 2.2684 | 0.99 | 3.1226 | .1159 | .0808 | 6 | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Medium** | Without DG | - | - | - | 3.1650 | .0887 | .0592 | - | 31.64 | 35.59 |
| | With DG | 1.5651 | 0.2230 | 0.99 | 2.1659 | .0549 | .0385 | 6 | | |
| **Low** | Without DG | - | - | - | 2.5130 | 0.550 | .0371 | - | 31.55 | 34.23 |
| | With DG | 1.2382 | 1.2382 | 0.99 | 1.7228 | 0.3472 | 0.0244 | 6 | | |

Table 5 Performance Parameters of Indices for DG of Type T1

| **Load** | **Without/With DG** | **PLI** | **QLI** | **VPI** | **LCI** |
|---|---|---|---|---|---|
| **Peak** | Without DG | 100 | 100 | 8.13495 | 99.641088 |
| | With DG | 55.589075 | 55.589075 | 4.599029 | 99.29383336 |
| **Medium** | Without DG | 100 | 100 | 5.564071 | 69.4266831 |
| | With DG | 52.551126 | 56.71288 | 3.19417474 | 69.41790077 |
| **Low** | Without DG | 100 | 100 | 4.4067 | 55.50678 |
| | With DG | 53.50672 | 57.43134 | 2.7417475 | 55.5033087 |

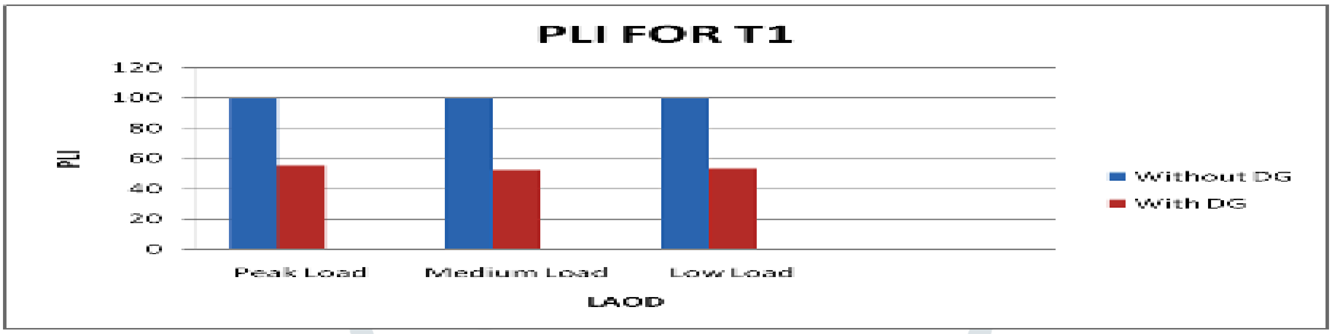


**Fig.7. PLI for DG of Type T1**

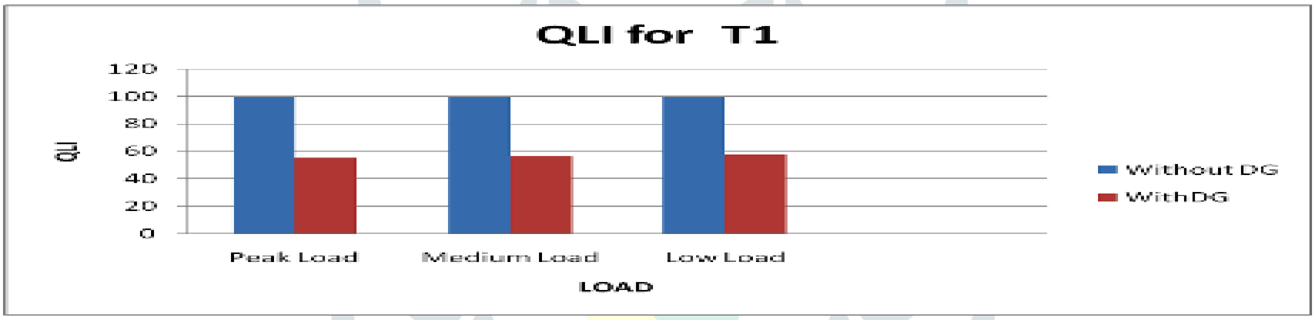


**Fig.8. QLI for DG of Type T1**

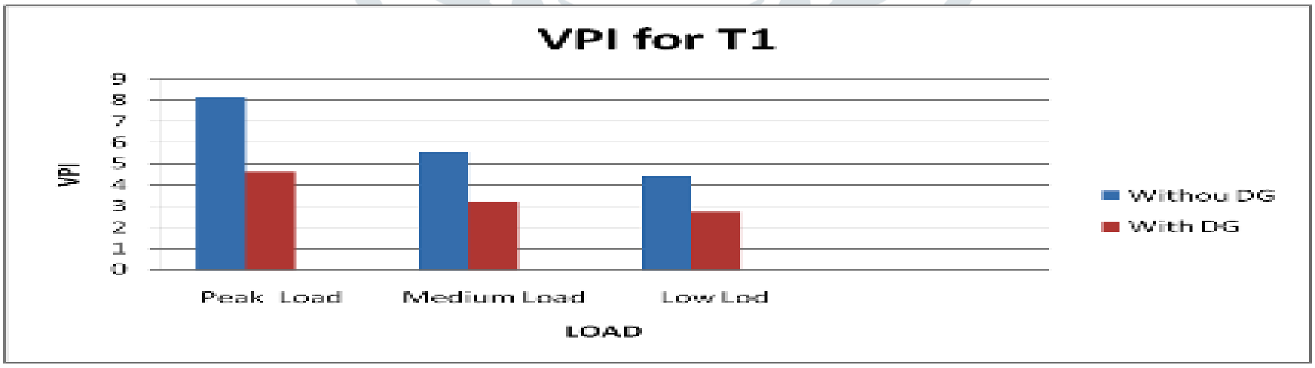


**Fig.9. VPI for DG of Type T1**

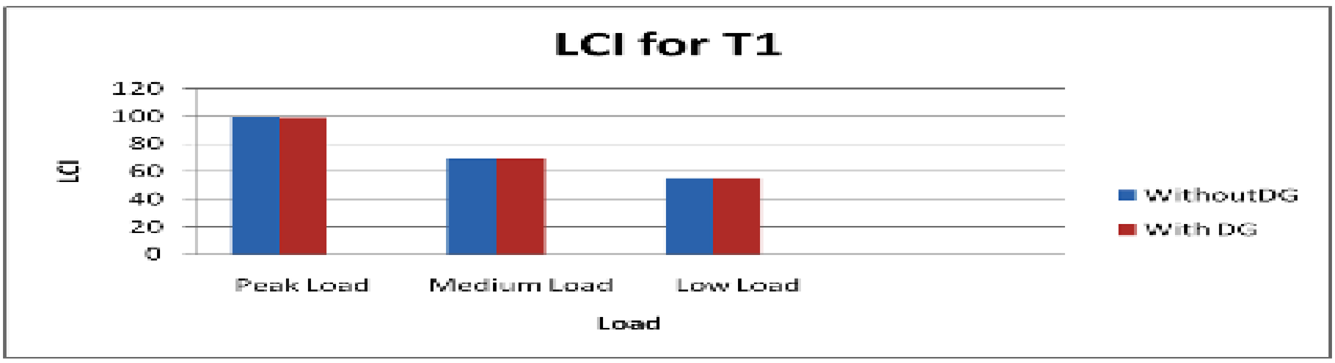


**Fig.10. LCI for DG of Type T1**

Table 6 Performance Parameters of Indices for DG of Type T2

| Load | Without/With DG | PLI | QLI | VPI | LCI |
|---|---|---|---|---|---|
| Peak | Without DG | 100 | 100 | 8.13495 | 99.641088 |
| | With DG | 30.52247 | 35.979676 | 3.25533 | 99.28322 |
| Medium | Without DG | 100 | 100 | 5.564071 | 69.4266831 |
| | With DG | 31.402816 | 37.0307744 | 2.2728155 | 69.413431 |
| Low | Without DG | 100 | 100 | 4.4067 | 55.50678 |
| | With DG | 33.183856 | 36.2950996 | 2.71067911 | 55.5033087 |

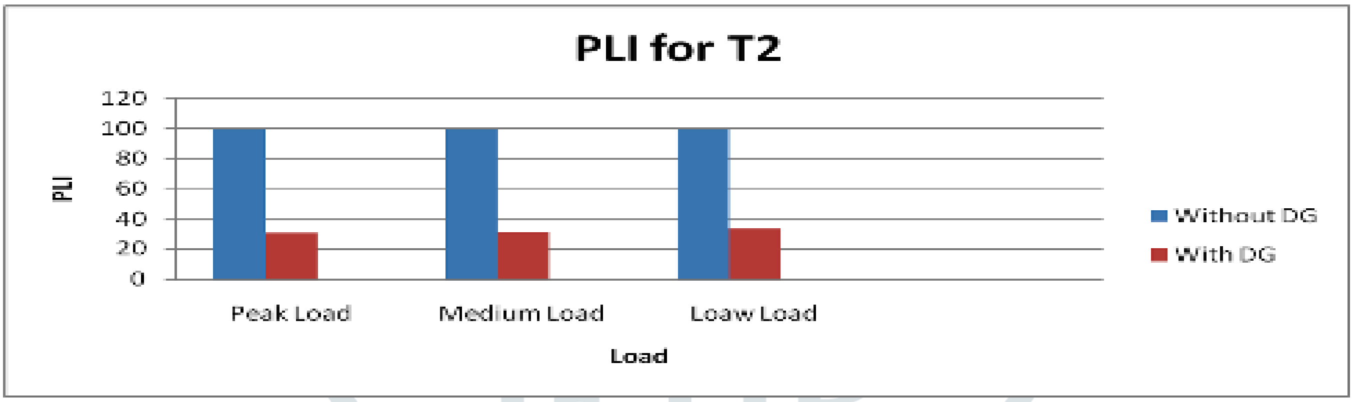


**Fig.11. PLI for DG of Type T2**

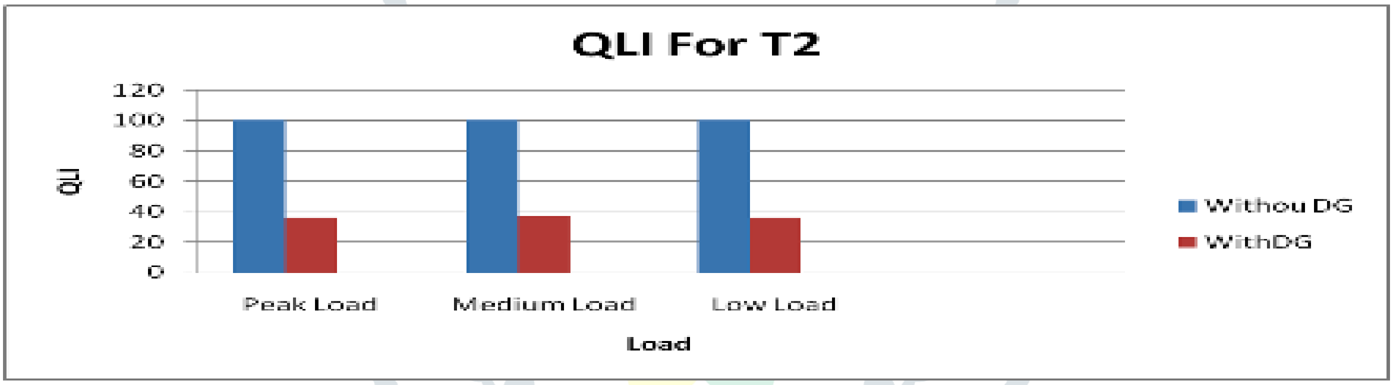


**Fig.12. QLI for DG of Type T2**

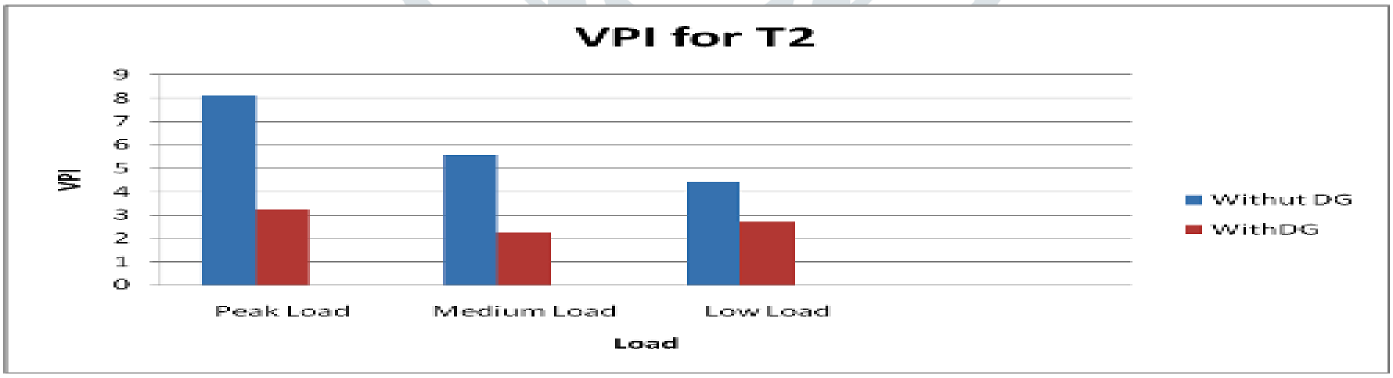


**Fig.13. VPI for DG of Type T2**

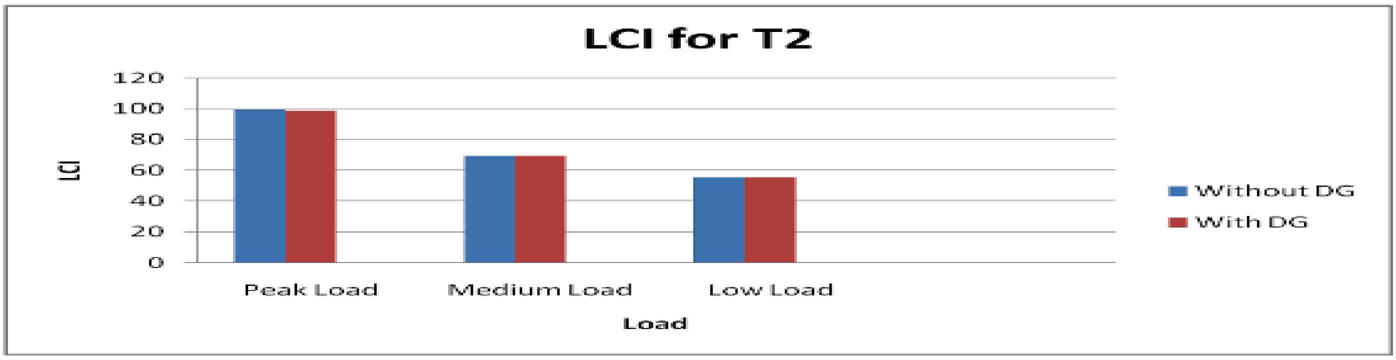


**Fig.14. LCI for DG of Type T2**

Table 7 Performance Parameters of Indices for DG of Type T3

| Load | Without/With DG | PLI | QLI | VPI | LCI |
|---|---|---|---|---|---|
| **Peak** | Without DG | 100 | 100 | 8.13495 | 99.641088 |
| | With DG | 71.03380 | 71.467132 | 6.97184460 | 99.315873152 |
| **Medium** | Without DG | 100 | 100 | 5.564071 | 69.4266831 |
| | With DG | 71.842253 | 72.3199 | 4.779611 | 69.42403278 |
| **Low** | Without DG | 100 | 100 | 4.4067 | 55.50678 |
| | With DG | 34.905829 | 39.876144 | 2.4262135 | 55.50148945 |

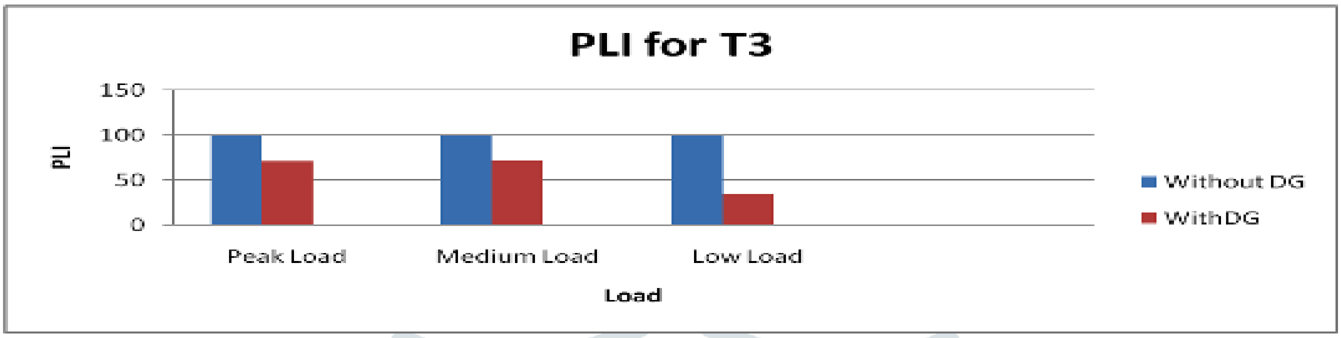


**Fig.15. PLI for DG of Type T3**

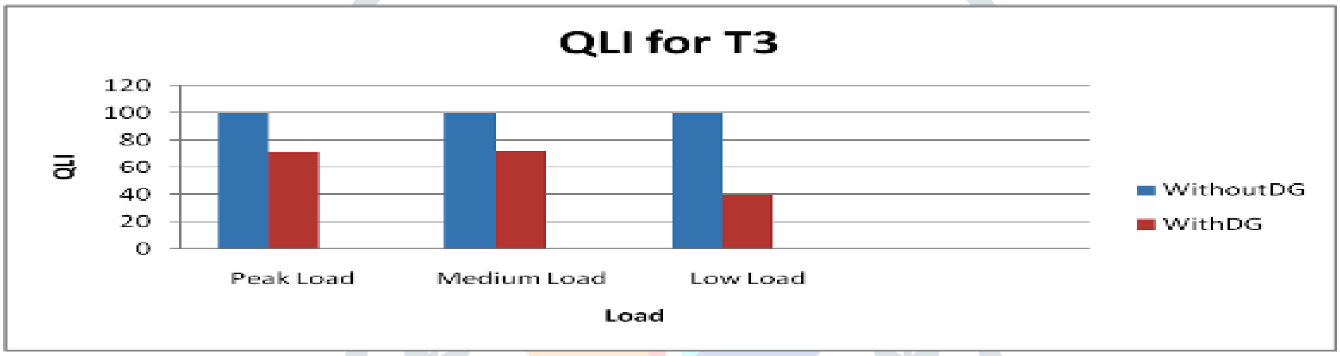


**Fig.16. QLI for DG of Type T3**

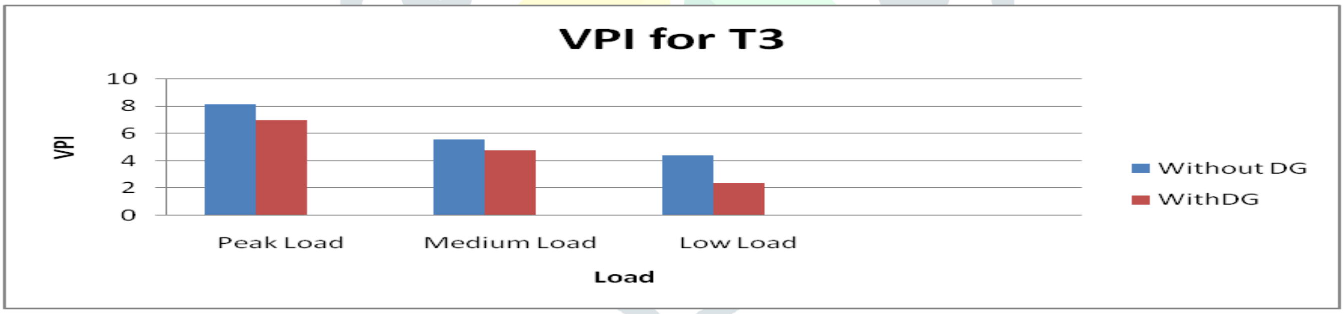


**Fig.17. VPI for DG of Type T3**

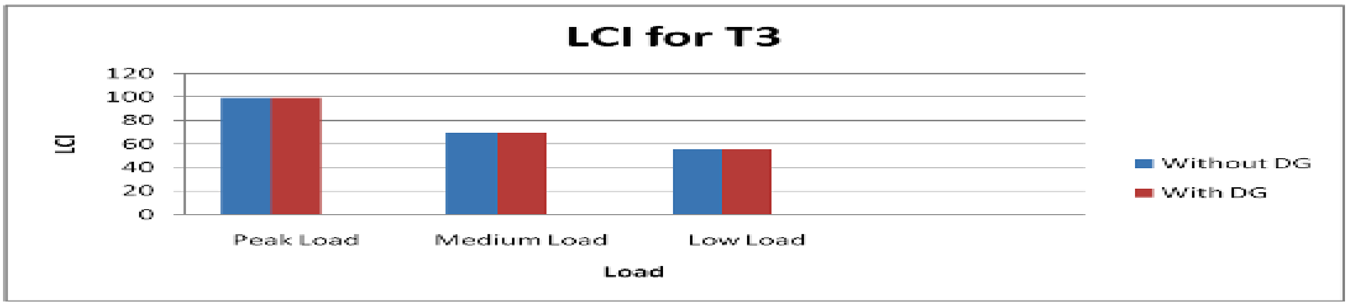


**Fig.18. LCI for DG of Type T3**

Table 8 Performance Parameters of Indices for DG of Type T4

| Load | Without/With DG | PLI | QLI | VPI | LCI |
|---|---|---|---|---|---|
| **Peak** | Without DG | 100 | 100 | 8.13495 | 99.641088 |
| | With DG | 60.891429 | 64.210860 | 5.285436 | 99.299967 |
| **Medium** | Without DG | 100 | 100 | 5.564071 | 69.4266831 |
| | With DG | 61.859154 | 65.251944 | 3.656310 | 69.418732 |

| | | | | | |
|---|---|---|---|---|---|
| **Low** | Without DG | 100 | 100 | 4.4067 | 55.50678 |
| | With DG | 62.278026 | 65.69736 | 2.91650 | 55.50413955 |

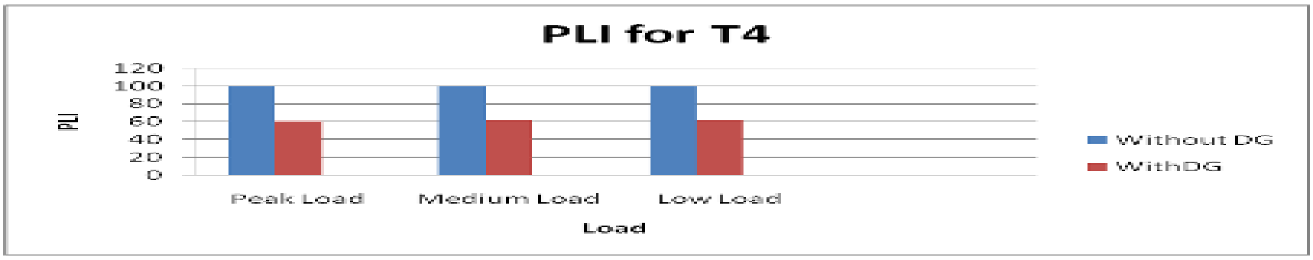


**Fig.19. PLI for DG of Type T4**

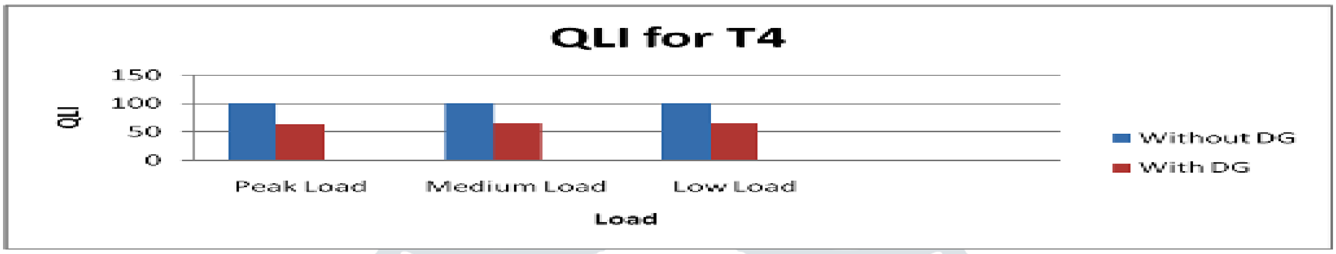


**Fig.20. QLI for DG of Type T4**

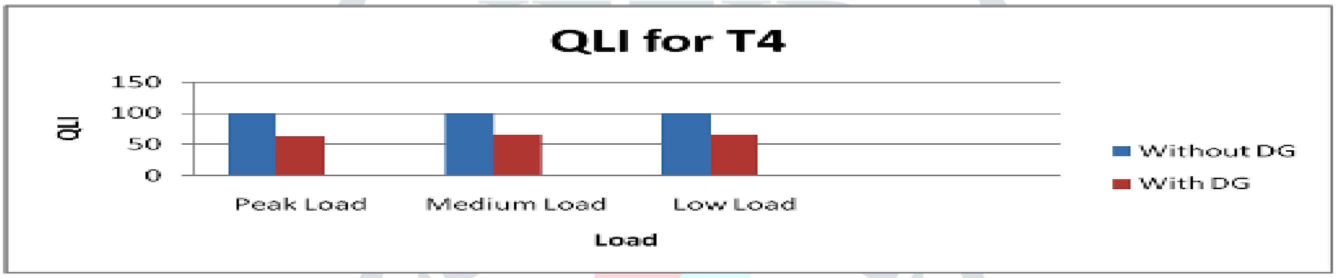


**Fig.21. VPI for DG of Type T4**

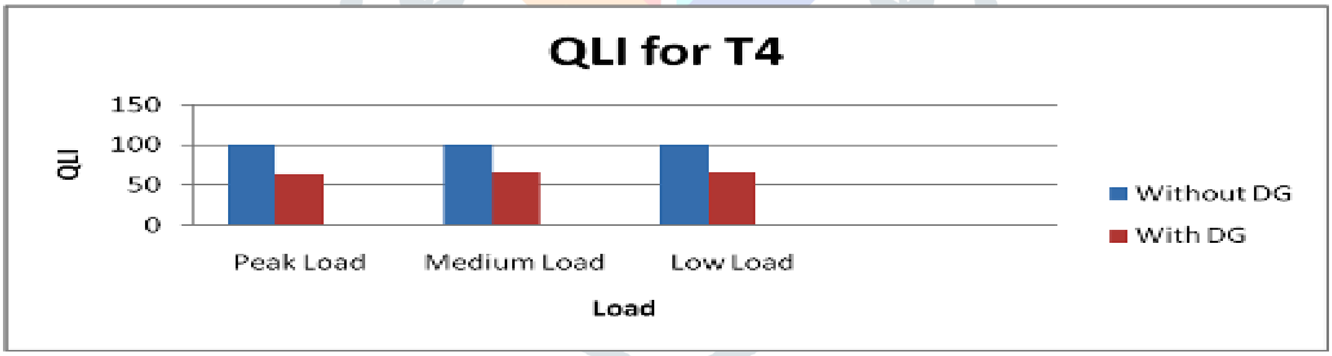


**Fig.22. LCI for DG of Type T4**

## V. CONCLUSIONS

To find the optimal location & size of different types of DG along with other relevant quantities corresponding to minimum power loss. The following conclusions have been drawn which are as follows;

- The location of DG is different for different types of DG.
- Real power loss is minimum for type 2 DG for all loading conditions.
- DG location for all loading conditions in case of type T1, T3 & T4 are same except type T2.

## VI. FUTURE SCOPE

In this paper optimal location & size of different types of DG are obtained using Genetic Algorithm. However, the scope of this work can be extended for

- Study can be done for 10% more load.
- For other system such as higher No. of buses can be taken.
- For any practical system it can be implemented.

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