Power loss minimization incorporating distributed generator in distribution system using Supervised Big Bang Big Crunch Method

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Abstract— Due to the vast expansion of electricity market the importance of distributed generators for loss minimization has been increased. The power which is generated should reach the consumers with minimum losses. But this is not happening there comes the issue of losses. It is important to reduce the losses. Installation of distributed generator at desired position can reduce power loss. This project implements, a method for the installation of distributed generators at suitable location which minimizes power losses by using Supervised Big Bang-Big Crunch method. An algorithm is proposed which deals with the optimization problems. The platform used is MATLAB@2009b and tested on 12 and 33bus.

Keywords: Distribution system, backward/forward sweep method, distributed generators, optimization, supervised big bang big crunch algorithm, analytical method, psi

I. INTRODUCTION:

The idea of installing small generating units in the power system attracted the attention in the last few years. Distributed generator is one of the main generating stations which are satisfying the growing power demanded. DG can be connected or disconnected easily from the network. This is the main advantage of DG and it has high flexibility. Best planning and operation of DG has many benefits as economic savings, power losses reduction, greater reliability and power quality high. Placing DG at proper location plays a major role in distribution system. Suitable location and size of DG's plays an important role in achieving the maximum benefits. In case, if the DG is placed at improper location in distribution system there is a chance of increase in losses .The optimization methods are classifies into analytical, numerical and fuzzy. 2/3 rule is an analytical method, was proposed for optimal installation of a single DG and two analytical methods for optimal location of one DG in radial and meshed power systems. An optimization method was developed for finding the locations and sizes of multiple DGs to achieve size and power loss reduction.

Optimization method is very useful for indicating the best solution for a given distribution network and it can be very useful for the system planning engineer when dealing with the increase of DG penetration that is happening now a days. Distributed Generation can be defined as an electrical power source connected directly to the consumer side meter .It may be simply stated as the small scale electrical market. In the presence of DG the planning of electrical system requires several factors such as the best technology to be designed to operate with the number of units and the capacity of the units, the best location etc. The effect of DG on operating characteristics of the system such as electric losses, voltage profile, stability and reliability needs to be assessed. Artificial bee colony algorithm was implemented for determining power factor, Dg size and its location for minimizing real power loss. Big bang big crunch method was firstly proposed by Errol and Eksin .In the proposed method, a supervised big bang big crunch method is used, which determines the optimal location and capacity of DGs which are connected to balance distribution system for power loss minimization without opposing system parameters. The DG in the algorithm is modeled as voltage controlled node with the flexibility to be converted to constant power node in case of reactive power violation. The big bang big crunch algorithm is implemented in MATLAB@2009b and tested on the 12 and 33bus feeder. The results obtained are compared with published results.

II. POWER SYSTEM

Power system consists of generation, transmission and distribution. While the power is being transmitted from one location to another there comes the issue of losses. The performance of any power system is evaluated through conducting load flow studies which calculates the power flowing through the lines of the system. There are different methods to determine the load flow such as Gauss Seidel, Newton Rap son method and the Fast Decoupled method. Since from the past few years, for finding digital computer solutions several developments had been taken place for power system load flows. Electrical losses in distribution systems are Technical losses and Non technical losses.

III .LOAD FLOW ANALYSIS

Load flow is the procedure used for obtaining steady state voltages at fundamental frequency. Efficient power flow solution requires fast evaluation time and less memory usage. Load flow studies are very important for all power system analysis, because these are used in planning and designing of power system network. There are many methods proposed for load flow studies but these methods are not applicable to the distribution system because of unbalanced loads, high X/R ratio and radial system. In this proposed method, we are using backward/forward sweep method because the network considering is radial distribution system. G.W. Chang proposed an Backward / Forward sweep load flow algorithm for radial distribution systems which includes the backward sweep and the forward sweep. Backward sweep uses KVL and KCL to obtain the calculated voltage at each bus. In this method, voltage values are assigned as per units starting from end node to source node. The ratio of specified voltage to the calculated voltage at first node is calculated at the end of backward sweep. The ratio which is obtained multiplied by the calculated voltage at each bus based on the linear proportional principle to update the voltage at each bus in the forward sweep. This backward/forward algorithm had been proved for its better convergence speed compared to the gauss method and new ton methods. Backward /forward sweep method has higher computational efficiency. Maximum voltage mismatch is checked and node voltages are adjusted to specified limits as proposed. The Forward Sweep is a voltage drop calculation, the source voltage used is the specified nominal voltage at the beginning of each forward sweep. The voltage is calculated at each bus, beginning at the source bus and to the end buses using the currents calculated in previous the Backward Sweep.

IV. PROBLEM STATEMENT

The optimization problem can be described as

Present data: the input data consists of structure of distribution feeder, series impedances, mutual impedances, shunt capacitances, feeder loads values and load types.

Required: For finding the DG size and optimal DG location and for reducing the distribution feeder power loss as well as energy loss without violating the system parameters

Reduce the active power loss= $\sum_{f=1}^{N,f} P_{loss,f}$

Reduce the energy loss= $\sum_{h=1}^{f} P_{loss,f}$

Where f is feeder number, Nf is total number of feeders, P_{iossf} the power loss at certain feeder f,h is the hour number and P_{lossf} is the total system power loss at certain hour h.

The system constraints are as follows:

Voltage limits: voltage at each bus should be within a specified range usually

$$0.95 \leq V \leq 1.15$$

DG power limits: the active, reactive and complex powers of the DG units between minimum and maximum value and this range should not be opposed.

$$0 \leq P_g \leq P_g^{max}$$

$$Q_g^{max} \leq Q_g \leq Q_g^{min}$$

$$0 \leq S_g \leq \sum S_{load}$$

In this method, DG maximum active power is given as

$$P_g^{max} \leq \sum P_{load}$$

The previous relation is surrounded by the thermal capacity limit of the feeder line. Hence the reactive power is also bounded.

Thermal limit of the lines: it represents the line withstand capacity to maximum current at certain DG penetration. If this value exceeds the specified value, then it leads to melting of the line.

$$I_{flow} \leq Ithermal$$

Power balance: the sum of input power must be equal to the sum of output active power in addition to the real power loss. The input power may include the DG real power and the real power supplied by the station. The active output power is the sum of active power of the loads:

$$P_{substation} + \sum P_{dg} = \sum P_{load} + P_{loss}$$

Procedure: In order to solve the optimization problem supervised big bang big crunch method is applied for solving and then finding the suitable location and capacity of DGs in order to minimize the power losses which are connected to distribution system. The following are the problems faced by this method. They are

[1]Nature of the distribution system: Basically the Distribution system has a radial structure. Methods such as, Gauss seidal, Newton Rap son and fast decoupled are most widely used for transmission systems. These methods are not applicable for the distribution networks because distribution networks having high R/X ratio. Backward / forward sweep method is being used in distribution system for developing power flow and it involves limited matrix operations and no matrix inversions. This method is composed of two steps:

In the backward sweep, the branch current is calculated based on the node currents using KCL.

In the forward sweep, the voltages which are updated at all nodes are calculated using KVL.

[2] Modeling of voltage controlled Distributed generators: If the size of DG is small, then it cannot supply sufficient reactive power in order to control the output voltage which may leads to the generation node representing as constant negative load with current injection into the node. Distributed generators having more capacity can supply sufficient amount of reactive power. In this case, the generator node must be modeled as voltage controlled node. When generator node modeled as PV node, distributed generator function like as voltage dependent current source as the reactive current injection depends on the difference between the voltage magnitude of the PV node and the specified value. In case of reactive power violations, distributed generator in the algorithm is modeled as generator node with the flexibility to be converted to load node.

[3] Difficulty of the optimization problem: the big bang big crunch algorithm can be used to solve a non-linear optimization problem easily, where the function to be optimized is continuous, which depends on the system variables. The complexity of feeder branches and the mutual impedances between the phases makes the function as either power loss or energy loss.

V. SUPERVISED BIG BANG BIG CRUNCH METHOD

Errol and Eksin proposed a big bang big crunch algorithm, which is derived from nature. The origin of this method is from explaining the origin of the universe. The big bang big crunch algorithm consists of two steps: the first step is named as Big Bang phase consists of the creation of the initial solutions that are spread randomly all over the search space. The Big Bang phase is the followed by Big Crunch phase that huddle all the candidate solution at only one solution that is called the center of mass. Theories explaining the origin of universe are through Big Bang process which involves in dissipation of energy and formation of universe. The Big Crunch phase is the shrinks all the random points of the universe into singularity which is called as center of mass. The algorithm consists of a finite number of masses points uniformly distributed over the entire search space in the big bang step. In the Big Crunch stage, these points are shrunken to a single representative which is known as centre of mass. The coordinates of this center of mass are calculated based on the fitness function. The point's distribution depends upon the standard deviation chosen for normal distribution. With the

mass formed at the centre, new masses are taken at the start of next Big Bang. As the process goes on dispersion is small as the space contracts about a center of mass. Over repeated cycles of Big Bangs and Big Crunches, the overall search space forms as around the best solution.
Big Bang step: When energy is dissipated, the particles are randomly scattered. This is taken as reference for explaining the location of distributed generators in distribution system. It is same as that in the genetic algorithm. This formation of randomness is regarded as energy dissipation in nature causing disorders in an order.
Big Crunch step: The next is Big Crunch, which have disordered solutions and this moves to a single point called centre of mass. In order to obtain many points around the center are generated using a normal distribution this process aims to achieve the order which was lost during in the Big Bang phase.
To get the optimal solution with less effort and with rapid convergence the supervised Big bang big crunch algorithm is proposed. Fig. Shows the flow chart of the supervised BB-BC and it is presented in the following step by step procedure.
[1] Prepare the guidance table consists of x power intervals and the best location of distributed generators for each interval is chosen. Guidance table is divided accordingly to the DG active power range to x equal divisions. At each division the best location is estimated roughly by setting the DG active power to the middle value for each division and then finding the optimal location which can achieves the minimum real power loss.

$$0 \le P_g \le P_{gmin}$$

[2] Randomly the initial values of the DGs active power and DGs locations are generated.
[3] Calculate the active power loss for all initial DG locations and powers correspondingly by running the load flow studies.
[4] Chose the best DG location and power in order to achieve minimum active power loss.
[5] Obtain the DG location, and calling the active power for that location obtained from step [4].
[6] Compute the active power loss correspondingly to the active power determined from step [4] and recalled the DG location, and then compare this power loss pl_{rec} with the loss obtained from step[4]
[7] Verify the power loss at the recalled location, if its value is less than the power loss obtained from step [4], set the recalled location as the best location or otherwise set the best location as that obtained from step [4].
[8] Updating of the DG locations and powers is done using below equations and keeping the best DG location and power as a one of the new system variables of DG locations to the nearest integer. The new DG locations and powers are upper and lower bounded.

$$loc_{new} = loc_{best} + \frac{uploc \times randn}{it^2}$$

$$P_g^{new} = P_g^{best} + \frac{up_{p} \times randn}{it^2}$$

Loc_{new} and p_g^{new} indicates the new dg locations and active power.
[9] Repeat steps [4]-[8] until the convergence criterion is met. The criteria is met when more than50%of DG location and active powers are converged.

VI. ANALYSIS AND RESULTS

The proposed algorithm has been implemented in MATLAB@2009b and the following studies were done on the IEEE 12 bus and 33- bus feeder in order to evaluate the real and reactive power loss..
In the proposed method, IEEE 12 and 33 bus feeder are balanced feeders which are having constant active power loads and reactive power loads. The numbering of substation node starts from 0 as it taken as the reference node having a constant voltage of 1 per unit. The numbering of remaining nodes is done in ascending order.
The DG is modeled as generator node with the flexibility to be converted to load node in case of reactive power limit violation. Moreover, the DG model could be switched to PQ node only whenever required.
For a 12 bus system, the real power loss and reactive power loss are evaluated. The placement of Dg in 12 bus system is evaluated through power stability index.
Power Stability Index determines the optimal location of DG. The PSI value must be high in order to place a DG. Below figure shows the lay out of 12 bus radial system.

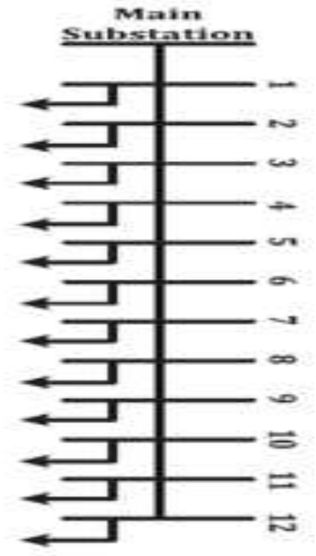


Fig:lay out of 12 bus

So the installation of DG at bus 9 will be the optimum place. The optimal sizing of DG is calculated by using analytical method based on psi and supervised big bang big crunch method.

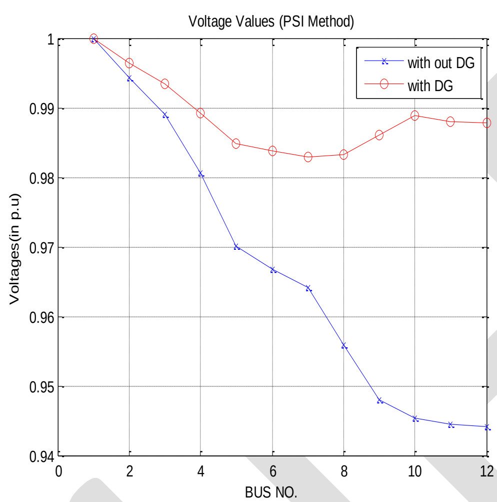


Fig: voltage profile of 12 bus with and without placing DG.

Number of buses=12

Number of slack buses=1

Number of PV buses=11

Number of PQ buses=0

For optimal placement of DG is at location 9.The red color indicates when DG is placed and blue color indicates without DG placement.

Cleary it is shown above, placement of DG at optimal location reduces losses.

Real power loss with DG: 10.760533

Reactive power loss with DG: 4.131653

Optimal size of DG: 220.325000

Elapsed time is 5.592575 seconds.

COMPARISON OF OPTIMAL LOCATION AND POWER OF DG CONNECTED TO THE IEEE 33-BUS FEEDER:

Feeder system	33Bus System	
Optimal Location	5	5
DG active Power	2575.3	2437.4
DG injected Reactive power	0	1704.1
Plossreduction	48.7	69.67%

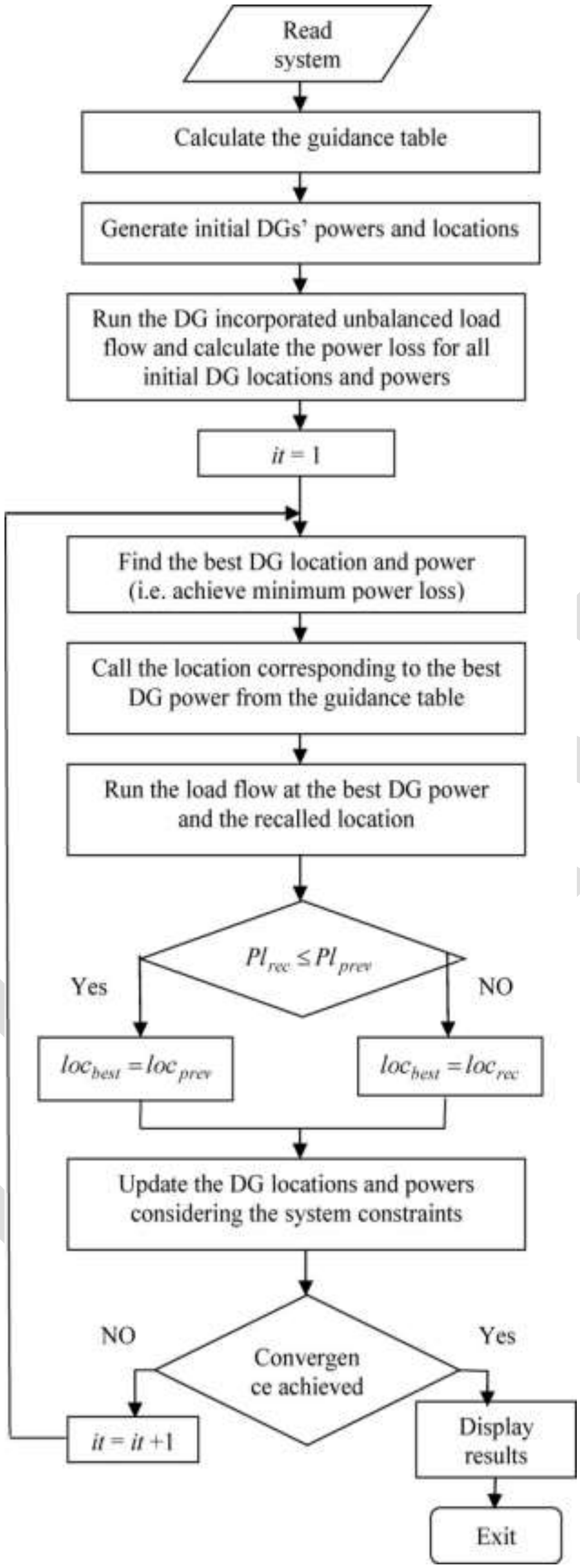
Table I: Comparison of losses with and without reactive power injection.

VII. COMPARATIVE STUDY

Validation of the supervised big bang big crunch Algorithm:

The algorithm is applied to the 33-bus feeder which uses analytical method for finding the optimal location, size of DG in order to minimize the power loss. Two case studies were conducted using this method: the first case was to find the optimal location and power of a dg unit, which is able to supply real power only. and the second case was for a DG that's able to supply active power and reactive power within the specified range. The comparison of results is presented in Table I where the optimal location of DG is 5. The algorithm is more efficient in finding the DG optimal location and power, where the power loss is much reduced. This algorithm not only evaluates the optimal DG active power but also evaluate the reactive power of DG within the specified range. This is able to keep the bus voltage at the specified voltage i.e.1 p.u. It is important to note that numbering of the IEEE 33- bus feeder starts from zero.

Flowchart of Supervised Big Bang-Big Crunch method is shown below:



Flow chart of supervised big bang big crunch method

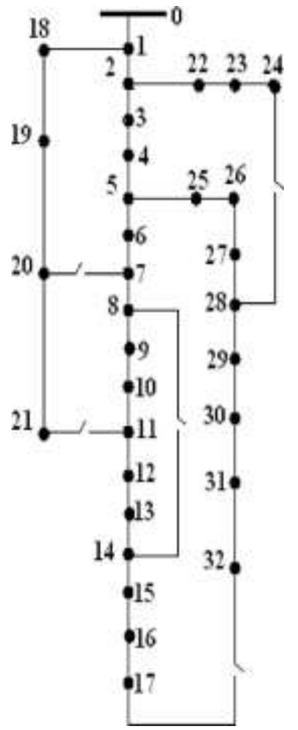


Fig: Lay out of 33 bus feeder

Validation of DG to the load flow:

Different sizes of DG's are connected to the system and comparing their results i.e. active power loss and reactive power loss. Proposed method, generates two variables one for locating the DG and other for size. The results are presented in table2. When DG is placed at node 25 and 29, the losses are reduced and there is an increase in voltage profile improvement.

Hence we can suggest the optimal placement of single DG at bus no. 25 and 29. The number of nodes for 33 bus is 33 and the branch numbers are 32.The voltage profile of the system waveform is shown below.

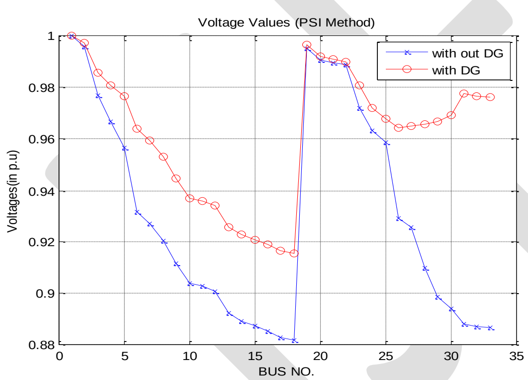


Fig: voltage profile of 33 bus

In the below, waveform, red color indicates there was a improvement in voltage profile when DG was placed. Whereas color blue indicates the voltage profile of 33 bus radial feeder when DG is not placed.

Dg connected to	Node 25	Node 29
Active power	2465KW	1700 KW
Reactive power	1527.67KVAr	1053.56KVAr
Dg capacity	2900kVA	2000KVA
Active power loss	62.877	66.5444
Reactive power loss	48.9547	48.9047
Minimum voltage	0.9637	0.9488
Maximum voltage	1.0006	1.0027

Table II .Comparison of losses when DG is connected to node25 and 29.
The active power schedule of a dg is connected to node 5 to achieve minimum energy loss in fig 2:

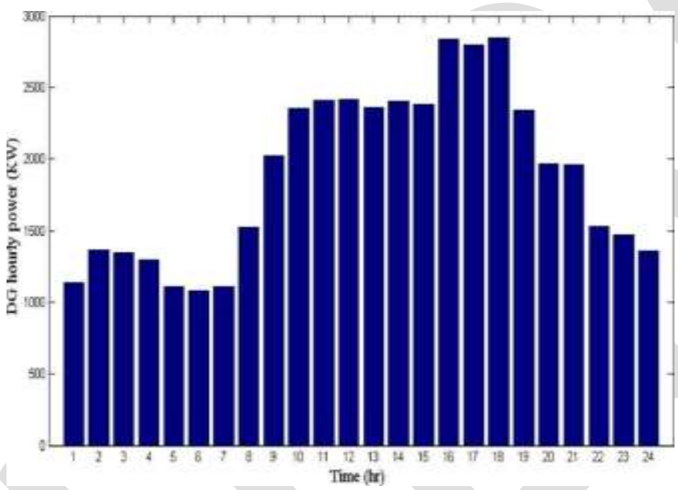


Fig: Daily active power schedule of DG connected to node5

As the number of DG's are increasing the percentage of loss reduction is going to be decreased. The supervised big bang big crunch method generates the variables randomly and it helps in finding the optimal location and size of distributed generators.
Below waveform shows when two dg's are connected to the distribution system, the active power loss and reactive power loss are compared with and without Dg placement.

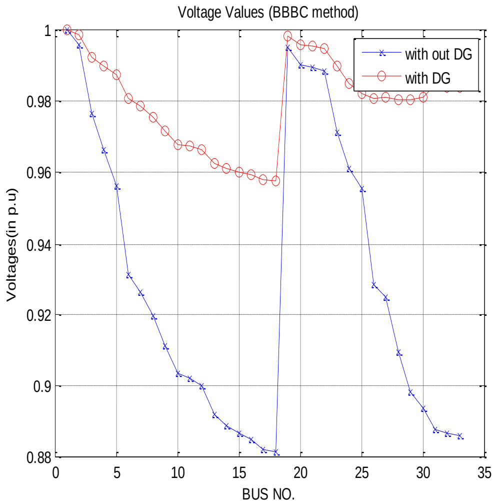


Fig: wave forms when two DG's are placed..

Real power losses without DG's = 40.3325

Reactive power losses without DG's =28.5912

Real power losses with DG's = 40.1630

Reactive power losses with DG's = 28.2059

Size of DG's = 1.0e+003 *1.9956 1.6630

Locations = 25 29

VIII. CONCLUSION

Supervised big bang big crunch method determines the optimal location of DG's in distributed system for power loss minimization. Placement of DG at suitable location is efficient in reducing both real and reactive power losses and thus improves the voltage profile. The results show that maximum power loss reduction is done by placing dg's in distribution system. This method has high speed of convergence and better in evaluating optimal location of distributed generator.

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