Optimal Allocation of DG to Radial Distribution Using GA. Overview of Different Approaches

Ravi Kumar Soni
M.tech Scholar, JaganNath University, jaipur

Deepesh Agarwal
Assistant Professor, Vivekananda institute of technology, jaipur

Parmeshwar kumawat
Associate Professor, Vivekananda Global University, jaipur

Abstract-This paper presents an overview of different approaches (Conventional, Analytical, heuristic and meta-heuristic) for proper placement and sizing of distributed generators in distribution network. . Power Sector moving towards deregulation has changed the traditional mission and mandates of power utilities in complex ways, and had large impacts on environmental, social, and political conditions for any particular country In this work it is found that objective functions have different weights in different situation and the Genetic Algorithm is used for find solution of above problem. If an electric utility is required to place distributed generator than the optimal placement and sizing is different and if a bulk customer wants to place distributed generator, than place and size is different. It is also found that in any of the above case, distributed generation is economic and plays a very important role in improving performance of a distribution network.

Key words: Distributed generator (DG), Genetic Algorithm (GA), Continuous Power Flow (CPF), Objective Function (OF), Improved Analytical (IA) method, Cumulative Voltage Deviation (CVD), Voltage Stability Margin (VSM)

I. INTRODUCTION

Electricity has been part of our daily life. It has brought many things that surely have made many wonders and life would seem so hard without it. The use of electrical power categorized such as residential sector includes private households and apartment buildings where energy is consumed primarily for space heating, water heating, air conditioning, lighting, refrigeration, cooking, and clothes drying, commercial sector, education sector, transportation etc Distributed generation (or DG) generally refers to small-scale (typically 1 kW – 50 MW) electric power generators that produce electricity at a site close to customers or that are tied to an electric distribution system. Distributed generators include, but are not limited to synchronous generators, induction generators, reciprocating engines, micro turbines (combustion turbines that run on high energy fossil fuels such as oil, propane, natural gas, gasoline or diesel), combustion gas turbines, fuel cells, solar photovoltaic's, and wind turbines.

The conventional energy sources which are being used to generate electricity from the very beginning are limited. Therefore the whole world is very keen to exploit non conventional energy sources to generate electricity. Because these are non-conventional energy sources are unending and freely available. These non-conventional sources are wind energy, solar energy, bio mass, geo thermal energy etc. [9]

In distributed generators (DG), non-conventional energy is used for the generation of electricity and hence it creates no pollution problem. Hence distributed generation is eco-friendly and is not a threat for human being, animals as well as plants and trees.

By the use of more and more distributed generators in distribution network, we will save more and more conventional sources of energy (i.e. gas, coal, diesel etc.) for future. [11]

Many advancement come in generation technology. DGs are increasing in our distribution network rapidly. This is because of the fact that photovoltaic cell (PV) which is solar cell and are being used for generation of electricity getting technically advance day by day and also getting cheap day by day.

Some of the facts related to PV and solar energy are given below encouraging the scientist of the whole world to exploit solar energy.

(1) The can sun provide energy to earth for another five billion years. Hence, it is an unlimited energy.
(2) The energy emitted by sun during 1/816000 second is sufficient to generate electricity required for one year.
(3) The energy given by sun is clean, green and sustainable form of renewable energy with a sound financial decision.
(4) If solar energy is used as an alternative of coal and gas, air pollution reduces drastically without spending a single rupee. [9] [11]

By the use of DGs, voltage profile of the transmission as well as distribution network improves and hence line losses reduce. Not only line losses, transformation losses in transformers at different levels also reduce. [10]

Every electric utility has to have about 20% extra generating capacity [6] Just to meet load demand at peak hours. This 20% extra generation is needed for at the most 10% of whole operation time during 24 hours. This involves huge amount of investment for a very short period of extra power supply. If DGs are added in our distribution network, this extra generation capacity needed for a short period can be avoided or reduced.

Particularly in developing countries, like India, there is a big gap between supply and demand of electricity. Hence power cut is a routine part of our distribution system in rural areas. Even in big cities power cut is required during peak summer season, which is a big challenge. [9]The installation of DGs in distribution network can greatly reduces this power cut problem. The installation of DG's in the system also makes customers self dependent. Now days, number of bulk customers are installing DG's in their premises. The aero-generators, solar panels etc sufficiently support for electricity supply to geysers, lighting etc. Even small individual customers are using solar cookers, getting energy from solar cell and also using solar water heaters. Also in rural areas street lights and illumination of public places is being provided by solar panels. Therefore DG's make rural areas self dependent in power sector.

As far as location and capacities of DG's are concerned there are number of classical [1], Analytical [2], heuristic [3] and meta heuristic approaches [5] which decide location and size of DG's to be installed.

However, if customers installed DG's, naturally customers will install in his/her primes and capacity as per his/her load requirement. So if a customer installed DG, no approach is applicable as the DG is not connected in the distribution network.

Rapid increase of load worldwide is a serious problem. For example, plug-in electric vehicle (PEV), and the plug-in hybrid electric vehicle (PHEV), are increasing unexpectedly throughout the world. On the other hand, millions of cars are already registered. Therefore, the increasing demand makes the existing power system saturated and it requires system upgrade. The DG's can provide an effective solution in solving the aforementioned problem with short construction time as well as it's quick response to the peak load. According to the studies of the electric Power research institute (EPRI) and natural gas foundation, it is expected that 30% of power generation in the U.S. will be supplied by DG's in the near future. In spite of their several benefits, installation of DG's to the power grid requires careful considerations for several factors such as stability, reliability, protection coordination, power loss, power quality issues etc. Besides no. of advantages there are some drawbacks with DG installation in distribution network.[4]

In both the above cases, installations of DG's are technically and financially feasible and have number of advantages.

Benefits of DG's :

1. No pollution.
2. Depletion of conventional sources of energy.
3. Advances in generation technology.
4. Improve voltage profile.
5. Reduce transmission and distribution line losses.

6. Reduction in on-peak operation cost.
7. A good alternative source for rural area where power cut is regular throughout the year.
8. DG's makes costumers self dependant.
9. Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy, distributed energy or district energy.
10. DG makes rural area self dependent in power sector.

Apart from transmission and distribution losses, transformation losses also reduced in power as well as distribution transformers [9] [10] [11]

II. CASE STUDY

Operation of power system with DG's benefits in terms of power loss reduction, improvement of voltage profile, system stability enhancement & improvement in system load ability. Installation of DG at non optimal place adversely affects the system performance. Hence the problem of installation of DG at optimal place has great importance followed by number and capacity of units and approach used.

Many of the scientists have worked on this problem and proposed number of approaches to find out the optimal location to maximize the benefits through DG's. Study of these approaches with boundary conditions (Constraints) shows improved results.

Objective of this paper is to compare these approaches in terms of computational time and accuracy in results with constraints.

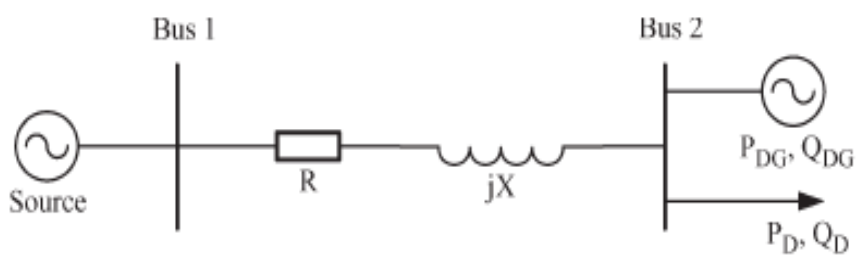

Figure.1: Sample distribution system with DG

1. FUZZY LOGIC

Masoud Esmaili et. al [3] has presented a novel approach to optimize selection of best location for DG using fuzzy logic. In this approach numbers of objective functions are fuzzyfied as describe below

$$\mathrm{ndg} = \sum_{i \in \mathrm{SB}} \frac{P_{\mathrm{DG}i}}{P_{\mathrm{DG}i} + \varepsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$P_{\mathrm{Loss}} = \sum_{i \in \mathrm{SB}} PG_i - \mathrm{PD}_{\mathrm{Total}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\mathrm{VSM} = \mathrm{VSM}_{\mathrm{BC}} + \sum_{i \in \mathrm{SB}} \frac{\partial \mathrm{VSM}}{\partial PG_i} P_{\mathrm{DG}i} + \sum_{i \in SB} \frac{\partial \mathrm{VSM}}{\partial QG_i} Q_{\mathrm{DG}i} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

From above mentioned objective functions which are to be fuzzified a common objective function is describe below which is to be maximized to get optimal solution.

$$\text{Maximise: } f = \omega_{ndg}\mu_{ndg} + \omega_{ploss}\mu_{ploss} + \omega_{vsm}\mu_{vsm} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

2. CLASSICAL APPROACH

E.Ettehadi, H. Ghasemi et. All have presented a classical approach for placement algorithm [1]. Model analysis and continuous power flow used in hierarchical placement algorithm.

2.1. model analysis – It is a static approach, can discover the instability characteristics and can be used to find out best locations for DG's using linearized load flow equation:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{P\theta} & J_{PV} \\ J_{Q\theta} & J_{QV} \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \Delta V \end{bmatrix}$$

2.2 Continuous power flow approach is utilized to determine maximum loading to compute voltage profile up to collapse point. In successive approach power at the load increase continuously as shown below

$$P_L = \partial P_{LO}$$
$$Q_L = \partial Q_{LO}$$

Where P_{LO} and Q_{LO} base case load active and reactive power and ∂ is scaling factor

3. ANALYTICAL APPROACH

Doung quoc hung et. al [2] [8] have presented analytical approach to find out best location for DG.

3.1. IA expression: The optimal size of DG at each bus *i* for minimizing losses can be given by as follows

$$P_{DGi} = \frac{\alpha_{ii}(P_{Di} + aQ_{Di}) - X_i - aY_i}{a^2\alpha_{ii} + \alpha_{ii}}$$

$$Q_{DGi} = aP_{DGi}$$

4. GENETIC ALGORITHM

M.F. Kotb, K.M. shebl et. al [5] used genetic algorithm as optimization tool to solve above mentioned problem. Under genetic operation the fitness function is evaluated for reducing power loss and to increase the voltage stability margin or reducing cumulative voltage deviation.

With the objective of power loss reduction and voltage profile improvement the fitness function or objective function (OF) is selected as follows:

$$OF = W_p x P_L + W_q x Q_L + W_v x CVD \quad \ldots\ldots\ldots\ldots\ldots (6)$$

P_L & Q_L are determined by load flow program and to evaluate CVD:

$$CVD = [\sum_i F_i(1 - F_i)] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

W_P W_Q and W_V are objective function weights and these are evaluated as:

$$W_P + W_Q + W_V = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Algorithm for DG allocation in distribution system:

1. Generate random population of N_{POP} chromosomes.
2. Evaluate the objective function F(x) and fitness f(x) of each chromosome x in the population
3. Select the pairs of chromosome as parents from the population with giving a priority that the better fitness parents will get highest chance to be selected in the matting pool.
4. According to the matting pool parents are crossed over with a crossover probability and generate the offspring.
5. Now the crossed offspring are mutated with a mutation probability where the offspring locus is change slightly.
6. Consider the mutate offspring as a new population and use it for the next generation.
7. If the solution satisfied the end condition, then stop, and display the optimal solution.
8. Go to step 2

Solution Approach	System status	P_L (PU)	PLR (%)	Q_L (PU)	QLR (%)	CVD (PU)	CVDR (%)
Base load	No DG	0.123	41.46	0.089	30.34	1.0137	18.29
	With DG	0.072		0.062		0.8283	
With 5% increment	No DG	0.132	38.64	0.097	28.87	1.0499	17.71
	With DG	0.081		0.069		0.864	
With 10% increment	No DG	0.144	38.19	0.104	28.85	1.0862	17.18
	With DG	0.089		0.074		0.8997	
With 15% increment	No DG	0.157	38.22	0.111	28.83	1.1226	16.65
	With DG	0.097		0.079		0.9357	
With 20% increment	No DG	0.169	36.09	0.119	28.57	1.1592	16.17
	With DG	0.108		0.085		0.9717	

Table: Results of Genetic Algorithm approach

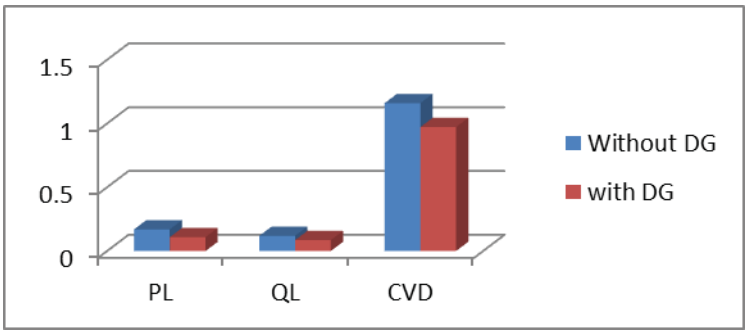

Fig.2: Graphical representation of loss reduction by genetic algorithm

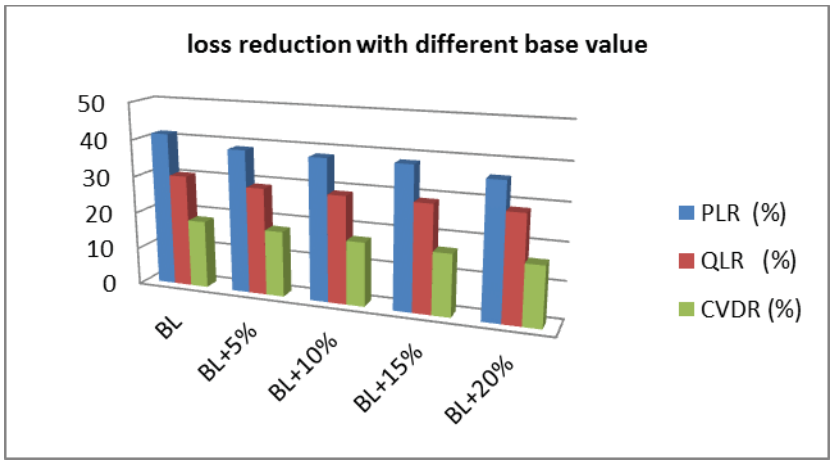

Fig.2: Graphical representation of loss reduction with different base value by genetic algorithm

5. CONSTRAINTS

In all above mentioned approaches, followings constraints are applied to get optimal solution.

5.1. Active and reactive loss constraints

$P_{LDG} \leq P_{LBC}$
$Q_{LDG} \leq Q_{LBC}$

5.2. Voltage constraints:

$V_{min} \leq Vi \leq V_{max}$

Vi = i bus voltage
V_{min} = minimum bus voltage
V_{max} = maximum bus voltage

5.3. DG size constraints

20% L ≤ DGs ≤ 80%L
L = load value
DGs = size of DG

s. No.	Approach	Constraints	Results		Remarks
			With DG	Without DG	
1	Fuzzy logic	P_L, Q_L, VSM	2.186 MW	0.879 MW	Saving 30.2% (P_L)
			0.862 PU	2.271 PU	112% increase in VSM
2	Classical	P_L, Q_L, VSM	-	-	Saving 29.12% (P_L)
			-	-	40.37% increment (VSM)
3	Analytical	P_L, Q_L, VSM	511.43 KW	161.49 KW	Saving 36.12% (P_L)
			0.86PU	1.27 PU	48% increment (VSM)
4	G.A.	P_L, Q_L, VSM	0.1085 MW	0.0471 MW	Saving 38.56% (P_L)
			0.0009 PU	3.1885 PU	99% increment (VSM)

Table: Results of different approaches

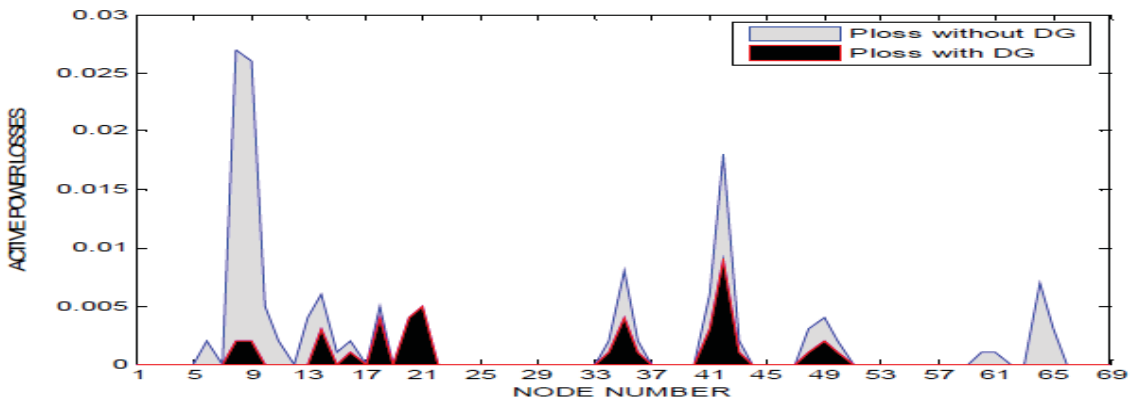

Fig.3: Graphical representation of loss reduction by installation of DG

III. CONCULISION

Installation of DG's in distribution networks has assumed a significant importance worldwide in the electric utilities during last few years. This is because of the fact that the efficiency of all the non-conventional energy operated electric generation is increasing sharply due to advancement in technology. Also cost of such generation is sharply decreasing and demand of electricity is going on increasing day by day worldwide. Hence researches round the clock are going all over the world to exploit non-conventional energy. Numbers of classical, conventional, heuristic and meta-heuristic approaches have been proposed by different scientists regarding placement & sizing of DG in the distribution network considering no. of constraints in order to achieve maximum benefits of DGs.

In this paper numbers of approaches are compared on the basis of their results. It is found that all approaches gives encouraging results. Power loss reduction, voltage profile improvement is achieved with all approaches.

While going through the table mentioning results of different approaches for optimal placement and sizing of DG's in distribution network. It is found that conventional and analytical approaches are also good enough to reduce power loss and improve voltage stability of the distribution network with proper placement and sizing of DG's. However their computational time is large.

Whereas, the heuristic and meta-heuristic (Genetic Algorithm) approaches are giving almost the same results as far as reduction in power loss and voltage stability margin is concerned, but the computational time required by these approaches is very less and hence these approaches are suitable for on-line application for complex distribution networks.

REFERENCES

[1] M. Ettehadi, H.Ghasemi, S. Vaez-Zadeh, "Voltage Stability-Based DG Placement in Distribution Networks," IEEE Transactions on power delivery, VOL. 28, NO. 1, JANUARY 2013,PP. 171-178.
[2] Duong Quoc Hung, Nadarajah Mithulananthan, "Multiple Distributed Generator Placement in Primary Distribution Networks for Loss Reduction," IEEE Transactions on industrial electronics, VOL. 60, NO. 4, APRIL 2013PP. 1700-1708.
[3] Masoud Esmaili, "Placement of minimum distributed generation units observing power losses and voltage stability with network constraints," IET Gener. Transm. Distrib., 2013, Vol. 7, Iss. 8, pp. 813–821 813 doi: 10.1049/iet-gtd.2013.
[4] In Primary Distribution Networks" IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 25, NO. 3, SEPTEMBER 2010
[5] M.F.Kotb, K.M.Shebl, M. El Khazendar, A. El Husseiny, "Genetic Algorithm for Optimum Sitting and Sizing of Distributed Generation," International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21, 2010, Paper ID 196.
[6] M. Alonso, H. Amarís, "Voltage Stability in Distribution Networks with DG" IEEE Bucharest Power Tech Conference, June 28th, 2009.
[7] Hasan Hedayati, S. A. Nabaviniaki, and Adel Akbarimajd, "A Method for Placement of DG Units in Distribution Networks" IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 23, NO. 3, JULY 2008.
[8] Duong Quoc Hung, Nadarajah Mithulananthan, R. C. Bansal, "Analytical Expressions for DG Allocation
[9] Subrata Mukhopadhyay, Bhim Singh, "Distributed Generation - Basic Policy" 978-1-4244-4241-6/09/2009 IEEE
[10] P. Chiradeja, "Benefit of Distributed Generation: A Line Loss Reduction Analysis" IEEE/PES Transmission and Distribution Conference & Exhibition, 2005.
[11] "Electricity Act 2003", Ministry of Power, Government of India, New Delhi, India, Jun. 2003.

[12] Subrata Mukhopadhyay, “Towards Electricity for All – Transmission Planning for the Growth of India's Power System”, IEEE Power & Energy Magazine, September/October 2007
[13] http://www.indiaenvironmentportal.org.in/files/Guidelines_for_Village_Electrification_DDG_under_RGGVY.pdf.