Optimal placement and sizing of DG and DSTATCOM in a Radial Distributed Systems Based on Analytical Technique

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Abstract - *For rapid growing demand,employment of technologies like smart grid and Distribution generation technology can be a potential solution. Generally, the distribution system is planned for radial power flow, but with the installation of a Distributed Generation, thesystem's flow of powerbecomes bidirectional. Many factors affecting DG allocations are the availability of natural resources, types of DG technologies, distribution system, capacity, and quantity of DG units. Distribution Generations can be beneficial in many ways when integrated into a distribution network, depending upon their location and size. The placement of DSTATCOM is fast growing technology to improve the system with sustained power flow to the consumers. It will enact as a loss reducer in the modern era. This paper focuses on using the Power Stability Index(PSI) method for optimal position and optimal capacity of DGs and D-statcomin the distribution network. The proposed analytic technique is validated by applying it to the IEEE33 bus system for single and multiple DG units and D-statcom. Programming is done by using Matlab software.*

Index Terms- *Distribution network, distribution generation (DG), Load flow, power stability index (PSI), DSTATCOM*

I. INTRODUCTION

Technological developments inpower electronics, renewable energy, mini-generators, and energy storage systems for intermittent back-up have also increased DG's integrationat the distribution level into power plants. The power industry has undergone a steady increase in the market for electrical power in recent years. Rising power consumption and the lack of generating and transmitting resources Set a trend towards sources of the Distributed Generation (DG). Still, the various meanings to become a significant holder of the current power scenario, the DG program must be linked to the existing grid system. This will trigger some technological, organizational integration, and effects on delivery structures [1]. Power grid challenges are Committed to giving customers good quality power and to preserve the stability of the Networking. Load flow studies are, therefore, beneficial for evaluating network output Wonderful. Comparison of Newton-Raphson (NR) efficiency features system and method Forward / Backward Sweep (FBS) with a variable load pattern. The case is based on the Results studies indicate that the FBS approach is ideal for the Distribution System [2]. The multi-objective technique for achieving the optimum size of the Distributed Generation (DG) units, taking into account both technology and the distribution system, has economic influences. The technological considerations include a lack of real power minimization of the load line and enhancement of the stress profile and economic factors like the optimal cost of investment by DG. A current sensitivity index based on sensitivity to the voltage, and it is proposed that apparent load power is used to identify optimal positions for DG placement [3]. The GOA technique is used to reduce the multi-objective optimization problem into a 1-objective optimization problem. The types of DG units to be used on the side of the delivery system are analyzed [4]. The optimal position of DSTATCOM in the firefly algorithm distribution network. This approach minimizes the problem of voltage deviation and harmonic distortion. This method is performed on the IEEE 16 bus system, and the results were compared with the functional swarm optimization and genetic algorithm [5].

The loss index is used to position D-STATCOM optimally in the distribution network, to Minimize losses, and boost conflict profile. It takes reactive power value to Obtain optimum DSTATCOM positioning by Power Loss Index (PLI) process [6]. A Particle Swarm Optimization algorithm is used to find the optimum position and scale of the DSTATCOM to minimize total power loss in combination with voltage Boost Radial Delivery Network profile [7]. The simultaneous optimal allocation of Distributed Generation (DG) and DSTATCOM is achieved by the bio-inspired Cuckoo Search Algorithm (CSA) for minimizing losses and improving voltage profile [8].

The objective is to identify the optimal location(s) and determine the optimal size(s) of DG units and Dstatcom in a distribution system. In this paper, an analytical approach to identify the optimal position and size of DG and DSTATCOM is described.

II. PROBLEM FORMULATION

The proposed work's main objective is to curtail the active power loss in a radial distribution system, which can be described as follows:

$$F_1(P_{Tloss}) = \sum_{i=1}^{N} P_{ilosses} \quad (1)$$

$$F_2 = \sum_{i=1}^{N} (Vi - 1) \quad (2)$$

$$F = Min(F_1, F_2) \quad (3)$$

where,

N= total buses present in the system

P_{Loss}= system active power losses

Subjected to the constraints

$$V_{min} < |V_i| < V_{max} \quad (4)$$

0.95 P.U ≤ $|V_i|$ ≤ 1.05 P.U ; where, V_i= Voltage at i^{th} node

$P_{DGmin} < P_{DGi} < P_{DGmax}$; where, P_{DGi}=DG size at i^{th} node

$Q_{DSTATCOMmin} \leq Q_{DSTATCOMi} \leq Q_{DSTATCOMmax}$;
$Q_{DSTATCOMi}$ = DSTATCOM size at i^{th} node

III. METHODOLOGY

Power Stability Index is employed to identify the locations and capacities of DG units and DSTATCOM to be installed in the system. Stability Index method is based on the fundamentals of linearization of actual nonlinear expression around the initial operating point, by doing this number of solution, space is reduced.

$$B^2 - 4AC > 0$$

$$PSI(DG) = \frac{4R(P_{K+1} - P_{DG})\cos\theta}{[|V_K|\cos\theta - \delta]^2} < 1 \quad (5)$$

$$B^2 - 4AC > 0$$

$$PSI(STATCOM) = \frac{4R(Q_{K+1} - Q_{STATCOM})\sin\theta}{[|V_K|\sin(\theta - \delta)]^2} < 1 \quad \ldots\ldots(6)$$

The DG size can be calculated as:

$$S_{DG} = \sqrt{P_{DG}^2 + Q_{DG}^2} \quad (7)$$

The size of the DG in 'W' is given as:

$$P_{DG} = \frac{P_{1(k+1),eff} + \alpha . Q_{1(k+1),eff}}{1 + \alpha^2} \quad (8)$$

The size of the DG in 'VAR' is given as:

$$Q_{DG} = \frac{P_{1(k+1),eff} + \alpha . Q_{1(k+1),eff}}{\alpha + \beta} \quad (9)$$

where,

$$\alpha = \tan\delta = \frac{Q_{DG}}{P_{DG}}$$

$$\beta = \cot\delta = \frac{P_{DG}}{Q_{DG}}$$

δ is the Power factor for the compensating unit at an optimal location.

The D-Statcom size:

Q_D = conjugate (V_n * I_D)

V_n- new voltage after DSTATCOM injection

I_D – D-statcom

The procedure to find the optimal location and size of DG using LSF is described as follows:

1. Firstly, the quantities of DG units to be connected should be entered.
2. Base case steady-state system load flow is executed to determine the system losses and voltage profile.
3. Determine the optimal position and size of DG using the PSI. Arrange the buses in the descending order of the values of PSI's and identify the maximumPSI value bus.
4. Calculate the optimal size of the DG at the maximumPSI value bus that gives minimum losses
5. modify the load data after connecting the first optimal DG and now go for the second optimal DG allocation by following the steps 1-4.
6. Further, place the Dstatcom to enhance the voltage profile in the system.
7. Stop and store the optimal solutions for DG allocation.

Fig. 1 represents the flow chart of the proposed work.

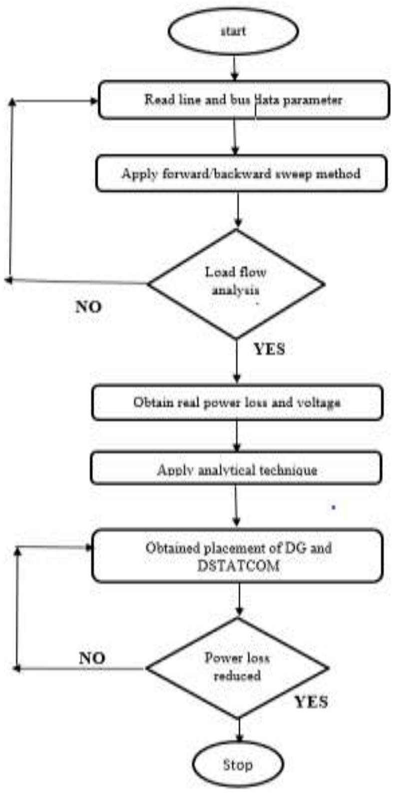

Fig. 1: Flow chart

IV. RESULTS

An IEEE 33- bus radial distribution system is considered for the proposed work. IEEE 33 –bus composed of 32 branches and 33 buses, and the base levels for that kind of network was 100MVA and 12.66kV at 0.85pf, while the total load demand - 3775kW and 2315KVAR. Fig. 2, Fig. 3, and Fig. 4 represent base case active power loss, Voltage magnitudes, and reactive power losses.

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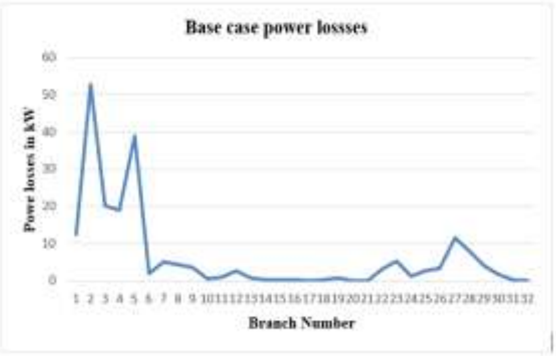

Fig.2: test system active power losses without and DG.

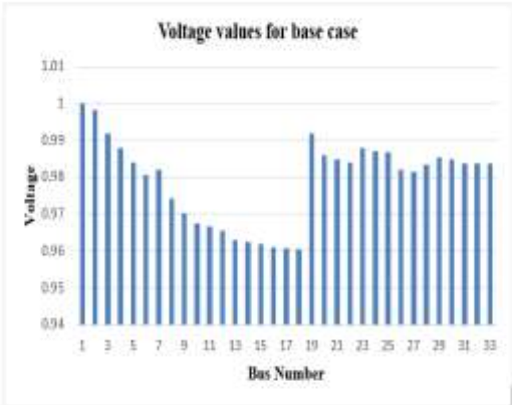

Fig. 3: voltage magnitudes of the test system

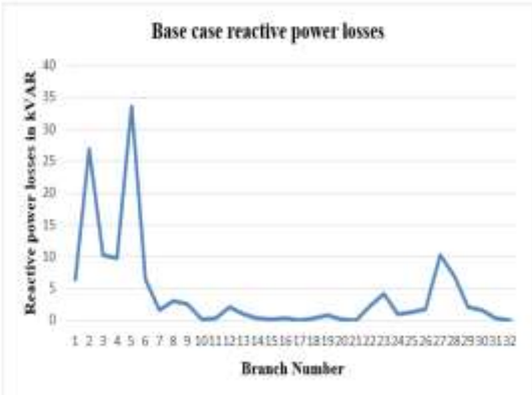

Fig.4: Base case reactive power losses

After calculating the stability index at all the buses and arranging in descending order. The bus bearing the Maximum PSI is 6th bus. Hence the optimal location obtained for placement of a single DG unit is bus number 6th with an optimal size of 557.045kW. After post of DG, the system loss reduced to 178.00kW from 207kW, Fig.5represents the active power losses after 1 DG placement.

Fig. 5: active power losses after1st DG placement

The optimal location obtained for placement of 2nd DG unit is at 30th bus with PSI value. After placement of DG the system loss reduced to 136.4704kW from 178.00kWas shown in Fig. 6.

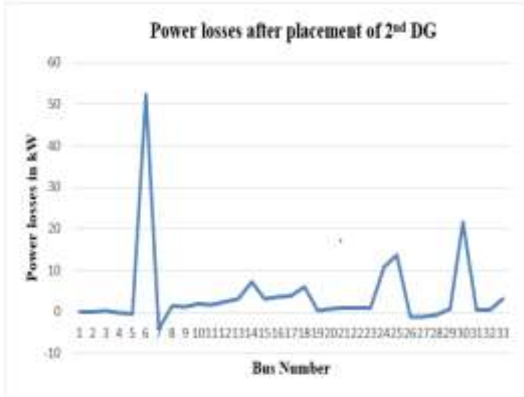

Fig.6: power losses after 2nd DG placement

For optimal placement of dstatcomthe highest values for $PSI_{DSTATCOM}$is at the 32nd bus to reduce the losses. The total losses after dgs and dstatcom is reduced to 115.27kW. Fig. 7 represents the voltage profile of all the 4 cases.

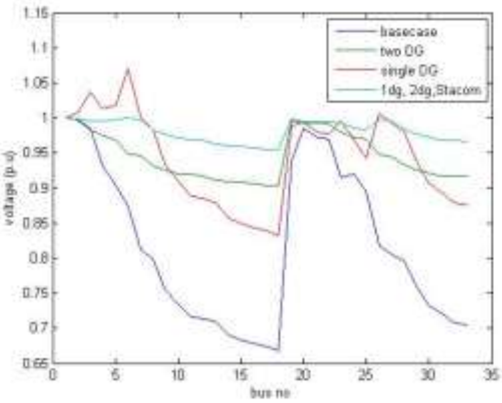

Fig.4.1: voltage values for 33 test bus system without DG, 1DG, 2DG and 1st DG,2nd DG and DSTATCOMS.

V. COMPARISON OF RESULTS

Table 1: Comparison of Results

Case Number	Voltage (min)	DG/DSTATCOM Placement (Bus Number)	DG/DSTATCOM Size	Real Power Losses
Case 1: Base Case	0.9024V	-----	------	206.732kW
Case2: 1st DG	0.9063V	6th	557.045kVA	178.00 Kw
Case3: 2nd DG	0.9546V	30th	1515.03kVA	136.4704kW
Case4: 1DG,2DG and DSTATCOM	0.9850V	6th,30th and 32th	557.045kVA 1515.03kVA 3.1279kVAR	115kW

VI. DISCUSSION

It can be observed from the results that both dg's forms have a large effect on the bus voltage profiles and system losses.

The comparison showed that the algorithm proposed is effective and can produce reasonable results for the optimum allocation of DG units.

At the other hand, most dg's are pollution-free, have lowered operating amount, the other forms of dg's will have major benefits while compare with them and must have to choose the better one. D-STATCOM placement would reduce power losses inside the network.

VII. CONCLUSION

An analytical method for evaluating the optimal placement and capacity of DG units in radial distribution systems based PSI, it is observed from the results that the optimal allocation of DG and Dstatcom reduces total power losses significantly and to raise the tension profile. The results were compared with placement in 1dg, 2dg and d-statcom and it can be clearly seen by optimally allocating Dstatcom the voltage profile of the system is significantly improved.

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