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Optimum Placement and Sizing Determination of Distributed Generation and DSTATCOM Using Penguins Search Optimisation Algorithm

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ABSTRACT: A Penguin Search Optimization algorithm for finding the optimal location and sizing of Distributed Generation and Distribution STATic COMpensator (DSTATCOM) with the aim of reducing the total power loss along with voltage profile improvement of Radial Distribution System is proposed in this paper. The new-fangled formulation projected is inspired by the idea that the optimum placement of the DG and DSTATCOM can facilitate in minimization of the line loss and voltage dips in Radial Distribution Systems. A complete performance analysis is carried out on 14, 30 and 57 bus radial distribution test systems and each test system has three different cases**.**

I. INTRODUCTION

DISTRIBUTED GENERATION

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 sgenerators include, but are not limited to synchronous generators, induction generators, reciprocating engines, microturbines (combustion turbines that run on high-energy fossil fuels such as oil, propane, natural gas, gasoline or diesel), combustion gas turbines, fuel cells, solar photovoltaics, and wind turbines.

APPLICATIONS OF DISTRIBUTED GENERATING SYSTEMS

There are many reasons a customer may choose to install a distributed generator[2,7]

DG can be used to generate a customer’s entire electricity supply; for peak saving (generating a portion of a customer’s electricity onsite to reduce the amount of electricity purchased during peak price periods); for standby or emergency generation (as a backup to Wires Owner's power supply); as a green power source (using renewable technology); or for increased reliability. In some remote locations, DG can be less costly as it eliminates the need for expensive construction of distribution and/or transmission lines.

II. RELATED WORK

A Particle Swarm Optimization algorithm for finding the optimal location and sizing of Distributed Generation and Distribution STATicCOMpensator (DSTATCOM) with the aim of reducing the total power loss along with voltage profile improvement of Radial Distribution System is proposed in this paper. The new-fangled formulation projected is inspired by the idea that the optimum placement of the DG and DSTATCOM can facilitate in minimization of the line loss and voltage dips in Radial Distribution Systems. A complete performance analysis is carried out on 12, 34 and 69 bus radial distribution test systems and each test system has five different cases. The results analyzed using Loss Sensitivity Factor shows the optimal placement and sizing of DG and DSTATCOM in Radial Distribution System effectively improves the voltage profile and reduces the total power losses of the system**.**

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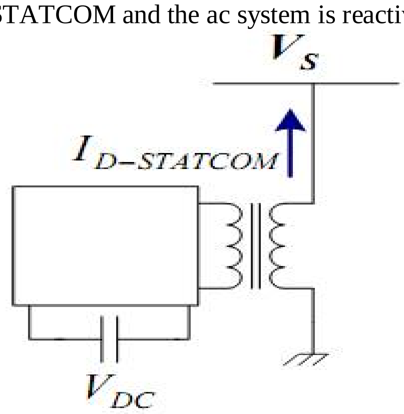
III. DSTATCOM (DISTRIBUTED STATIC COMPENSATOR)

D-STATCOM is a shunt device that injects or absorbs reactive current. It's diagram is shown in Fig. (b)[1,3]. For the steady-state application, D-STATCOM consists of a small dc capacitor and a voltage source converter and the steady-state power exchange between D-STATCOM and the ac system is reactive power (Fig. (b)).



(b)

(b), only reactive power exchange

Generally, voltage of buses in the system is less reactive power exchange than 1p.u. and it is desired to compensate voltage of interested bus (jV0) to 1p.u. by using D-STATCOM. The relationships between voltage and current can be written as:

$$V_{0j}\angle\alpha_0 = V_{0i}\angle\delta_0 - (R + jX)I_{0L}\angle\theta_0$$

Where:

$V_{0j}\angle\alpha_0$	voltage of bus *j* before compensation
$V_{0i}\angle\delta_0$	voltage of bus *i* before compensation
$Z = R + jX$	impedance between buses *i* and j
$I_{0L}\angle\theta_0$	current flow in line before compensation

As noted earlier, in this paper, D-STATCOM is used for voltage regulation in the steady-state condition and can inject only reactive power to the system. Consequently $I_{DSTATCOM}$ must be kept in quadrature with voltage of the system. By installing D-STATCOM in distribution system, all nodes voltage, especially the neighboring nodes of DSTATCOM location, and braches current of the network change in the steady-state condition. The schematic diagram of buses i and j of the distribution systems, when D-STATCOM is installed for voltage regulation in bus j, is shown in Fig. 4. Phasor diagram of these buses with D-STATCOM effects is shown in Fig. 5. Voltage of bus j changes from V_j to $V_{j\ new}$ when D-STATCOM is used. For the sake of simplicity, the angle of voltage V_i , i.e., δ is assumed to be zero in phasor diagram. It can be seen from Fig. 4 and Fig. 5 that:

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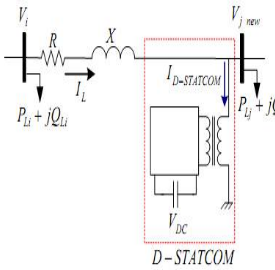

Fig. 4 Single line diagram of two buses of a distribution system with consideration of D-STATCOM

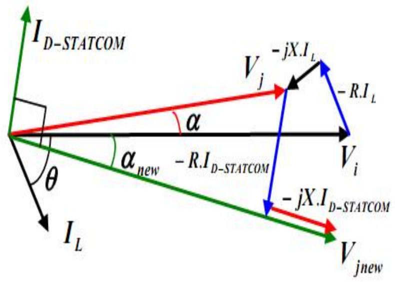

Fig. 5 Phasor diagram of voltages and currents of the system shown in Fig. 4

III. PROBLEM FORMULATION

The objective of DG and DSTATCOM placement in the distribution system is to minimize the power loss of the system, subjected to certain working constraints given below Mathematically, the objective function of the problem is described as:

$$\min f = \min(P_{Loss})$$

where PLoss is the total power loss of the RDS.

Constraints:

Equality Constraint:

Angle difference between Vjnew and I $_{D\text{-}STATCOM}$ =90.

To improve the power factor ID-STATCOM must be kept in quadrature with Vjnew.

Inequality Constraints:

Power constraints:

The bus real power is limited to:

$$P_{LOSS} + \sum P_{Dj} = \sum P_{DGj}$$

The real power generation at node 'j' by the installation of DG must be equal to the sum of the real power loss at that node to the actual real power demand at that node.

The bus reactive compensation power is limited to:

$$Q_j^c \leqslant \sum_{j=1}^{n} Q_{Lj}$$

where Qcj and QLj are the compensated reactive power at bus 'j' and the reactive load power at bus 'j', respectively. To maintain the power quality, Qcj must be less than or equal to QLj also voltage magnitude of each node and current through each branch must lie within the permissible range.

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Voltage constraints:

$$V_{j\min} \geqslant Vj \geqslant |V_{j\max}|, \quad j = 1, 2, \ldots, N$$

Current constraints:

$$|Ij| \leqslant |Ij\max|, \quad j = 1, 2, \ldots, N$$

where Vjnew is the voltage of bus 'j' after placement of DSTATCOM and $I_{DSTATCOM}$ is the current through the DSTATCOM. PLOSS is the real power loss. PDGj is the real power generation using DG at bus 'j', PDj is the power demand at bus 'j'. Vjmin and Vjmax are the minimum and maximum voltages of the jth bus respectively. Similarly Ijmax is the maximum value of the branch current.

IV. PENGUINS SEARCH OPTIMISATION ALGORITHM

The optimization algorithm based on the hunting behavior of penguins can be described in numerous ways[4]. While all methods agree to optimize their objective functions such as maximizing the amount of energy extracted from the energy invested, we propose to simplify the optimization function by using rules, described below, to guide the search strategy by the penguins:

Rule 1: A penguin population is made up of several groups.

Rule 2: Each group is composed of a variable number of penguins that can vary depending on food availability in a specific location.
Rule 3: They hunt in group and move randomly until they find food when oxygen reserves are not depleted. **Rule 4**: They can perform simultaneous dives to a depth identical.
Rule 5: Each group of penguins starts searching in a specifc position (hole "i") and random levels (levels "j1, j2, ...,jn").
Rule 6: Each penguin looks for foods in random way and individually in its group, and after rough number of dives, penguins back on the ice to share with its affiliate's, the location (represented by the level or depth of the dive) where he found food and plenty of it (represented by the amount of eaten fish). This rule ensures intra-group communication.
Rule 7: At one level, one can have from 0 to N penguins (penguin or any group) according to the abundance of food.
Rule 8: If the number of fish in a hole is not enough (or none) for the group, part of the group (or the whole group) migrates to another hole. (This rule ensures inter-group communication)
Rule 9: The group who ate the most fish delivers us the location of rich food represented by the hole and the level. In the algorithm each penguin is represented by the hole "i" and level "j" and the number of fish eaten. The distribution of penguins is based on probabilities of existence of fish in both holes and levels. The penguins are divided into groups (not necessarily the same cardinality) and begin searching in random positions. After a fixed number of dives, the penguins back on the ice to share with its affiliate's depth (level) and quantity (number) of the food found (Intergroup Communication). The penguins of one or more groups with little food, follow at the next dive, the penguins who chased a lot of fish.

Pseudocode of the algorithm PeSOA :

Generate random population of P solutions (penguins) in groups[5]. Initialize the probability of existence of fish in the holes and levels;
For i=1 to number of generations;
For each individual i € P do
While oxygen reserves are not depleted do
- Take a random step.
- Improve the penguin position using

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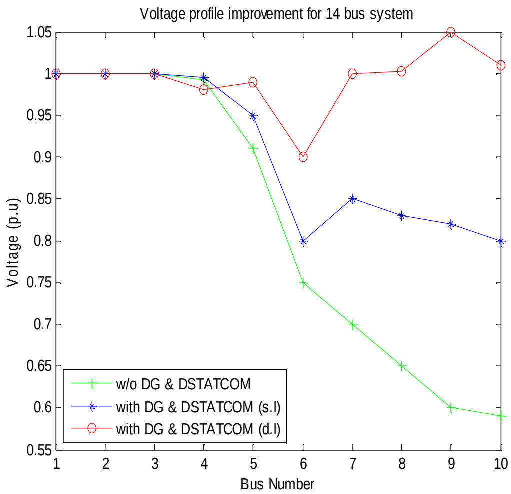
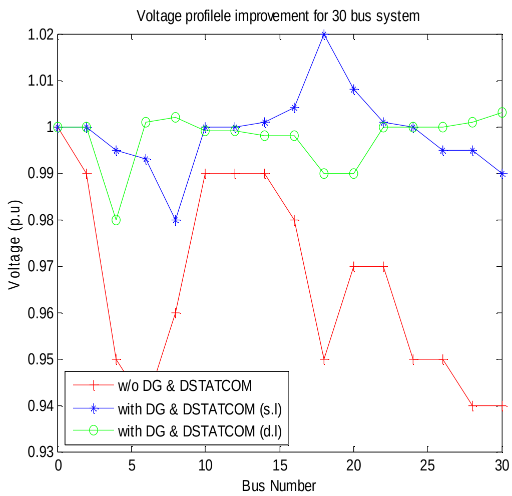
$$D_{new} = D_{LastLast} + rand() \, |X_{LocalBest} - X_{LocalLast}|$$

- Update quantities of fish eaten for this penguin.
End
End
- Update quantities of eaten fish in the holes, levels and the best group.
- Redistributes the probabilities of penguins in holes and levels (these probabilities are calculated based on the number of fish eaten).
- Update best-solution
End

V. SIMULATION RESULTS

The power of the PeSO algorithm to solve the OPF problem was tested using standard bus system. All simulations were performed on a personal computer (i3 3.1 GHz Intel Processor and 2 GB RAM running MATLAB 11a).





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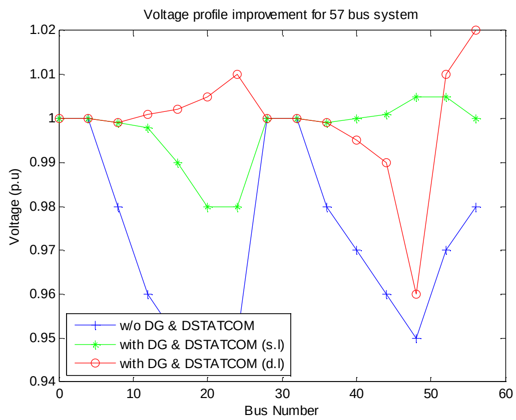

VI. CONCLUSION

In this paper, PeSO based DG and DSTATCOM placement and sizing in Radial Distribution System for three different test systems are carried out. The study is done with three different cases. For the future work the DG and DSTATCOM placement can be done by using LSF(Loss sensitivity factor) and the sizing can be done with PeSO or PSO, because LSF reduces the processing time[1]. From this research it is concluded that optimizing DG and DSTATCOM location and sizing the total power loss of the Radial Distribution System is reduced with voltage improvement using PeSO. Also it is suggested that both DG and DSTATCOM placement in same bus has provided the improved voltage profile, compared with the placement at different buses.

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