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Research paper

# A survey on enhancement of power system performances by optimally placed DG in distribution networks

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ABSTRACT

This paper presents a survey on enhancement of power system performances by optimally placed distributed generations in distribution networks. The distribution power system performances such as minimization of real power loss, minimization of reactive power loss, improvement of voltage profile, short circuit current capacity, system average interruption duration index (SAIDI), customers average interruption duration index (CAIDI), power system oscillations, available power transfer capacity of system, loadability of the system, reliability and security of the system, power system stability *etc.* are consider in this survey paper as major issue in distribution networks. Such power system performances can be enhance by conventional devices as well as planning of DG technologies such as fuel cell, biogas, wind turbine, photovoltaic, solar, geo-thermal, tidal and wave *etc*. This survey paper is very much useful for scientific persons, engineers, industrial persons and researchers regarding with enhancement of power system performances by optimally placed distributed generations in distribution networks.



## 1. Introduction

DG is an approach of small-scale electricity generation at a customer site, this approach is fairly new idea in the economics point of view about electricity markets, but the idea behind it is not new at all. In the starting days, DG was not used to the transmission, balancing demand and supply was partially done using local storage, i.e. batteries, which is directly coupled to the DC grid. Application of DG local storage is also coming in application, technology development, uses of AC grid allowed to electricity transmitted over a long distance and economic of generation electricity increase the power output according to demand. All this results with increased convenience and lower per unit costs a large electrical system were constructed, consisting of long distance transmission system with high capacity distribution grids and large generating plants to balancing demand and supply was done by the averaging effect.

According to Ackermann DG is defined as "Distributed generation is an electric power source connected directly to the distribution network or on the customer site of the meter". There are some other points of view to define the DG like real power, independent operation, capacity of generation etc. the DG basically classified in two category such as renewable and non renewable. The renewable DG such as wind power plants, solar power plants, solar cell power plants, biogas power plants, tidal power plants, wave power plant, ocean power plants, geo thermal power plants etc. and non renewable DG such as doubly fed induction generation, diesel engine, Internal combustion engine etc. the DG can be broadly classified on basis of real and reactive power delivered/absorbed as follows:

(i) ***DG Type 1:*** At unity power factor, the real and reactive power delivered by DG to the system, is known as type-1 DG such as wave energy source wind power source, and tidal energy source etc.
(ii) ***DG Type 2:*** At 0.8 to 0.99 leading power factors, only real power delivered by DG to the system is known as a type-2 DG such as fuel cell, photovoltaic system, and solar power plant etc.
(iii) ***DG Type 3:*** At zero power factor, only reactive power support provides by DG to the system is known as type-3 DG such as synchronous motor in over excited mode, phase modifier circuit or synchronous condenser etc.
(iv) ***DG Type 4:*** At 0.8 to 0.99 lagging power factor, provides real power support to the system and absorbs reactive power from the system by DG is known as a type-4 DG such as DFIG *etc.*

Several advantage of DG like minimization of the real power loss and reactive power loss, enhance voltage stability of the system, reduce power system oscillation, increase available power

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**Nomenclature**

| | |
|---|---|
| DG | Distributed generations |
| ODGP | Optimal distributed generations planning |
| DISCO | Distributed company |
| GA | Genetic algorithm |
| ANN | Artificial neural network |
| OPF | Optimum power flow |
| LPF | Load power flow |
| DFIG | Doubly fed induction generator |
| PSO | Particle swarm optimization |
| ABC | Ant Bee colony algorithm |
| ACS | Ant colony search algorithm |
| DLF | Decoupled load Flow |
| PST | Pole shifting technique |
| APF | Adaptive power flow |
| MOEA | Multi objective evolutionary algorithm |
| MPSO | Modified particle swarm optimization |
| SA | Simulated annealing |
| TS | tabu search |
| GSA | Gravitational search algorithms |
| HA | Heuristic algorithms |
| KFA | Kalman filter algorithms |
| HRA | Hereforced ranch algorithms |
| OT | optimization technique |
| LM | Load model |
| AP | Analytical approach |
| NLP | Non-linear programming method |
| MOOA | Multi objective optimization algorithm |
| MOF | Multi-objective function |

transfer capability, reduce pollution as it uses cleaner energy resources, increase loadability of the system, increase bandwidth of operation, hence more flexible operation, more social and economic benefits etc. besides this benefits, also the some limitation of DG like small power generation, subsidiary system to the main system, mechanical maintenance required, and choice of type of DG system greatly depend upon the environmental factors etc. the view of power quality, DG is used for reduction of harmonics, prevent voltage sag and voltage swell, to reduce the transient period, minimization of voltage fluctuation and power factor improvement. This development has led to the breaking up of investments (small generating units), emergence of new generation techniques with small ratings, ecological benefits, increased profitability, combined with heat generation, saturation of existing networks and the continuous growth of the demand.

The importance of DG is now being increasingly accepted and realized by power system engineers. The planning of DG is a feasible alternative for new capacity especially in the competitive electricity market environment and has immense benefits such as: short lead time and low investment risk since it is built-in modules, small-capacity modules that can track load variation more closely, small physical size that can be installed at load centers, and the existence of a fast range of DG technologies. Different schemes have been proposed in this paper, distribution network capacity expansion considering the options of adding new substations and connecting feeders. The drawbacks of DG are as follows: fuel problems in non renewable DG, and DG can be always using only at load center.

This paper organized as follows: Section 2 presented the mathematical modeling of DG for optimal placement. Section 3 presented the taxonomical reviews on DG planning from power system performances point of view. Section 4 presented the summary of paper. Section 5 presented the conclusion and the future scope of work.

## 2. Mathematical modeling of DG for optimal placement

### 2.1. Mathematical modeling of static loads

The planning of different types of DG, for different load scenario i.e. summer day, summer night, winter day, and winter night loads, a IEEE-38 bus distribution system is adopted (Singh et al., 2007a, b). In this paper, the line impedances, load data and the line power limits are expressed in p.u. At the base voltage of 12.66 kV and base MVA of 10 MVA (Singh et al., 2007a, b). In conventional load flow analysis, the active and reactive power loads are assumed as constant power load whereas, in practice, the loads may be voltage dependent *i.e.* industrial, residential, and commercial loads which may be represented by models as described in (IEEE Task Force, 1993). The voltage dependent load model is a static load model that represents the power relationship to voltage as an exponential equation, and represented in following Eqs. (1)–(2) form.

$$P_{i\_bus} = P_{0i\_bus}\left(|V_{i\_bus}|/|V_{0i\_bus}|\right)^{\alpha lpha} \quad (1)$$

$$Q_{i\_bus} = Q_{0i\_bus}\left(|V_{i\_bus}|/|V_{0i\_bus}|\right)^{\beta eta} \quad (2)$$

where, $P_{i\_bus}$, $Q_{i\_bus}$, $P_{0i\_bus}$, $Q_{0i\_bus}$, $V_{i\_bus}$, and $V_{0i\_bus}$ are in per unit. Above Eqs. (1) and (2) neglect the frequency dependence of distribution system load, due to the fact that it is phenomenon which cannot be controlled locally and remain same for whole of the system. In practice, the load on each bus may be the composition of industrial, residential, and commercial which may vary with seasonal day and night. Therefore, in this paper the seasonal mixed load model at each bus is considered as described in Qian et al. (2011) and represented in following Eqs. (3)–(4) form.

$$\begin{aligned} P_{i\_bus} &= w_{i\_bus\_pi}.P_{0i\_bus}\left(|V_{i\_bus}|/|V_{0i\_bus}|\right)^{\alpha lpha_{i\_bus}} \\ &+ w_{r\_bus\_pi}.P_{0i\_bus}\left(|V_{i\_bus}|/|V_{0i\_bus}|\right)^{\alpha lpha_{r\_bus}} \\ &+ w_{c\_bus\_pi}.P_{0i\_bus}\left(|V_{i\_bus}|/|V_{0i\_bus}|\right)^{\alpha lpha_{c\_bus}} \end{aligned} \quad (3)$$

$$\begin{aligned} Q_{i\_bus} &= w_{i\_bus\_qi}.Q_{0i\_bus}\left(|V_{i\_bus}|/|V_{0i\_bus}|\right)^{\beta eta_{i\_bus}} \\ &+ w_{r\_bus\_qi}.Q_{0i\_bus}\left(|V_{i\_bus}|/|V_{0i\_bus}|\right)^{\beta eta_{r\_\_bus}} \\ &+ w_{c\_bus\_qi}.Q_{0i\_bus}\left(|V_{i\_bus}|/|V_{0i\_bus}|\right)^{\beta eta_{c\_bus}} \end{aligned} \quad (4)$$

where, $\alpha lpha_{i\_bus}$ and $\beta eta_{i\_bus}$ are active and reactive exponents for industrial load model; $\alpha lpha_{r\_bus}$ and $\beta eta_{r\_bus}$ are active and reactive exponents for residential load model; $\alpha lpha_{c\_bus}$ and $\beta eta_{c\_bus}$ are active and reactive exponents for commercial load model; $w_{i\_bus\_pi}$, $w_{r\_bus\_pi}$, and $w_{c\_bus\_pi}$ are the relevant factors for active industrial, residential, and commercial Load models at bus *i.*; $w_{i\_bus\_qi}$, $w_{r\_bus\_qi}$, and $w_{c\_bus\_qi}$ are the relevant factors for reactive industrial, residential, and commercial Load models at bus *i*.

The following condition expressed in Eqs. (5)–(6) must be satisfied for all buses except *buses without load* (BWL) (Bus 1 is slack bus and buses 34 to 38 are not having load).

$$w_{i\_bus\_pi} + w_{r\_bus\_pi} + w_{s\_bus\_pi} = 1 \quad (5)$$

$$w_{i\_bus\_qi} + w_{r\_bus\_qi} + w_{c\_bus\_qi} = 1 \quad (6)$$

The values for exponents of voltage for active and reactive component of summer day, summer night, winter day, and winter night load models are given in Qian et al. (2011). The relevant factor of each load model at each bus is (hypothetically generated) given in Payasi et al. (2013). In this study it is assumed that $w_{i\_bus\_p} = w_{i\_bus\_q}$, $w_{r\_bus\_p} = w_{r\_bus\_q}$, and $w_{c\_bus\_p} = w_{c\_bus\_q}$. The study is performed considering the situations of load, may be, in practice as follows: (1) each bus having mix of industrial, residential, and commercial load in certain proportion; (2) Loads vary with seasonal day and night. Apart from these situations, T1, T2, T3 and T4 are considered for comparative study. A 38 bus system is assumed to be supplying power to mix of industrial, residential, and commercial load without violating bus voltage and line capacity