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Article

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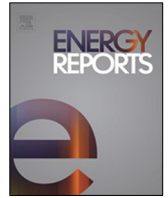
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Research paper

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.

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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.

$$P_{i_bus} = P_{0i_bus} \left(\frac{|V_{i_bus}|}{|V_{0i_bus}|} \right)^{\alpha_{i_bus}} \quad (1)$$

$$Q_{i_bus} = Q_{0i_bus} \left(\frac{|V_{i_bus}|}{|V_{0i_bus}|} \right)^{\beta_{i_bus}} \quad (2)$$

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.

$$P_{i_bus} = w_{i_bus_pi} \cdot P_{0i_bus} \left(\frac{|V_{i_bus}|}{|V_{0i_bus}|} \right)^{\alpha_{i_bus}} + w_{r_bus_pi} \cdot P_{0i_bus} \left(\frac{|V_{i_bus}|}{|V_{0i_bus}|} \right)^{\alpha_{r_bus}} + w_{c_bus_pi} \cdot P_{0i_bus} \left(\frac{|V_{i_bus}|}{|V_{0i_bus}|} \right)^{\alpha_{c_bus}} \quad (3)$$

$$Q_{i_bus} = w_{i_bus_qi} \cdot Q_{0i_bus} \left(\frac{|V_{i_bus}|}{|V_{0i_bus}|} \right)^{\beta_{i_bus}} + w_{r_bus_qi} \cdot Q_{0i_bus} \left(\frac{|V_{i_bus}|}{|V_{0i_bus}|} \right)^{\beta_{r_bus}} + w_{c_bus_qi} \cdot Q_{0i_bus} \left(\frac{|V_{i_bus}|}{|V_{0i_bus}|} \right)^{\beta_{c_bus}} \quad (4)$$

where, α_{i_bus} and β_{i_bus} are active and reactive exponents for industrial load model; α_{r_bus} and β_{r_bus} are active and reactive exponents for residential load model; α_{c_bus} and β_{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

limits. The following test cases are developed for optimal size and location of DG for constant and seasonal mixed load models for two objectives: (1) Real power loss (P_{Loss}) minimization; and (2) Apparent power intake (S_{int}) minimization. The types of DGs are as follows: Type 1 DG; Type 2 DG; Type 3 DG; and Type 4 DG. The parameters considered for study are as follows:

- (a) Number of voltage limit violations (NVLV);
- (b) Number of line limits violations (NLCLV);
- (c) Apparent power intake (S_{intake}), real power intake (P_{intake}), and reactive power intake (Q_{intake}) at bus 1;
- (d) Real and reactive power loss (P_{Loss} and Q_{Loss});
- (e) Apparent system power requirement (S_{system});
- (f) Power system performance indices (P_{L_index} , Q_{L_index} , VP_index , and LC_index , $SAID_index$, $CAID_index$).

2.2. Mathematical modeling of DG with NRLF

The formulation of DGP problem is proposed on the basis of two objective functions:

- (1) Real power loss (P_{Loss});
- (2) Apparent power intake (S_{intake}).

2.2.1. Minimization of real power loss

The objective function is total real power loss (P_{Loss}) in the system. The P_{Loss} in the system is represented by Eq. (7).

$$P_{Loss} = \sum_{i_bus, j_bus \in N_L} \frac{P_{i_bus, j_bus}^2 + Q_{i_bus, j_bus}^2}{|V_{i_bus}|^2} r_{i_bus, j_bus} \quad (7)$$

The P_{Load} is function of all system bus voltage (V_{i_bus}), line resistances (r_{i_bus, j_bus}), α (Alpha), and β (Beta). The total losses mainly depend on voltage profile.

2.2.2. Minimization of total power intake at substation

The objective function is apparent power intake (S_{intake}) at main substation. The P_{intake} is the sum of P_{Demand} and P_{Loss} , and represented by Eq. (8).

$$P_{intake} = P_1(V, P_0, Q_0, \alpha, \beta) = P_{Demand} + P_{Loss} \\ = \sum_{i_bus=1}^{N_B} P_{0i_bus} (|V_{i_bus}| / |V_{0i_bus}|)^{\alpha} + P_{Loss} \quad (8)$$

Similarly, the Q_{int} is the sum of QD and QL , and represented by Eq. (9).

$$Q_{intake} = Q_1(V, P_0, Q_0, \alpha, \beta) = Q_{Demand} + Q_{Loss} \\ = \sum_{i_bus=1}^{N_B} Q_{0i_bus} (|V_{i_bus}| / |V_{0i_bus}|)^{\beta} + Q_{Loss} \quad (9)$$

Apparent power intake at main substation is expressed as Eq. (10):

$$S_{intake} = [(P_{intake})^2 + (Q_{intake})^2]^{1/2} \quad (10)$$

And apparent power requirement for distribution system is expressed as Eq. (11):

$$S_{system} = [(P_{intake} \pm P_{DG})^2 + (Q_{int} \pm Q_{DG})^2]^{1/2} \quad (11)$$

where, based on terminal characteristic are as follows: $Q_{DG} = 0.0$ for Type 1 DG; $P_{DG} = 0.0$ for Type 3 DG; and $Q_{DG} = -ve$ for Type 4 DG.

It is observed that for a distribution power system as Eqs. (12)–(13).

$$\sum_{i_bus=1}^{N_B} P_{0i_bus} (|V_{i_bus}| / |V_{0i_bus}|)^{\alpha} \gg P_{Loss} \quad (12)$$

$$\sum_{i_bus=1}^{N_B} Q_{0i_bus} (|V_{i_bus}| / |V_{0i_bus}|)^{\beta} \gg Q_{Loss} \quad (13)$$

Thus the P_{intake} and Q_{intake} in Eqs. (8) and (9) respectively are largely decided by the load exponents α (Alpha) and β (Beta) not by P_{Load} and Q_{Load} .

The above objectives are subject to the following set of power flows, voltage limits, line power capacity limit, and DG size limit are expressed in Eqs. (14)–(20) respectively.

$$P_{i_bus} = \sum_{j_bus=1}^{N_B} |V|_{i_bus} |V|_{j_bus} [G_{i_bus, j_bus} \cos(\delta_{i_bus} - \delta_{j_bus}) + B_{i_bus, j_bus} \sin(\delta_{i_bus} - \delta_{j_bus})] \quad (14)$$

$$Q_{i_bus} = \sum_{j_bus=1}^{N_B} |V|_{i_bus} |V|_{j_bus} [G_{i_bus, j_bus} \sin(\delta_{i_bus} - \delta_{j_bus}) - B_{i_bus, j_bus} \cos(\delta_{i_bus} - \delta_{j_bus})] \quad (15)$$

$$P_{i_bus, j_bus} = |V|_{i_bus} G_{i_bus, j_bus} - |V|_{i_bus} |V|_{j_bus} [G_{i_bus, j_bus} \cos(i_busj_bus) - B_{i_bus, j_bus} \sin(i_busj_bus)] \quad (16)$$

$$Q_{i_bus, j_bus} = |V|_{i_bus} B_{i_bus, j_bus} - |V|_{i_bus} |V|_{j_bus} [G_{i_bus, j_bus} \sin(i_busj_bus) + B_{i_bus, j_bus} \cos(i_busj_bus)] \quad (17)$$

$$V_{min} \leq V_{i_bus} \leq V_{max} \quad (18)$$

$$S_{i_bus, j_bus} \leq CS_{i_bus, j_bus}^{max} \quad (19)$$

$$P_{DG} \leq P_{intake} \quad (20)$$

In this paper voltage limits and line power capacity limit are as follows: $V_{min} = 0.95$ p.u and $V_{max} = 1.05$ p.u. CS_{i_bus, j_bus}^{max} , for $i_bus, j_bus \in N_L$; Power capacity limits.

2.3. Power system performance indices to quantify the benefits of DG

The indices to quantify the benefits of DG are defined as follows (Singh et al., 2007a, b).

2.3.1. Real power loss index (P_{L_index})

The real power loss index is defined as Eq. (21):

$$P_{L_index} = \left(\frac{P_{L_WDG}}{P_{L_WODG}} \right) \times 100\% \quad (21)$$

The lower values of this index indicate better benefits in terms of real power loss reduction accrued due to DG location and size.

2.3.2. Reactive power loss index (Q_{L_index})

The reactive power loss index is defined as Eq. (22):

$$Q_{L_index} = \left(\frac{Q_{L_WDG}}{Q_{L_WODG}} \right) \times 100\% \quad (22)$$

The lower values of this index indicate better benefits in terms of reactive power loss reduction accrued due to DG location and size.

2.3.3. Voltage profile index (V_{P_index})

It is related to the maximum voltage drop between each node and root node. The lower values of this index indicate better performance of network. The V_{P_index} can be defined as Eq. (23):

$$V_{P_index} = \max \left(\frac{|V_{ref}| - |V_{i_bus}|}{|V_{ref}|} \right) \times 100 \quad (23)$$

2.3.4. Line capacity index (L_{C_index})

The power flows may diminish in some sections of the network and released more capacity with the power supplied near to the load. This index provides important information about the level of power flows/currents through the network regarding maximum capacity of distribution lines. Lower values of this index indicate more capacity available. This is defined as Eq. (24):

$$L_{C_index} = \max \left(\frac{S_{i_bus,j_bus}}{CS_{i_bus,j_bus}} \right) \times 100 \quad (24)$$

2.3.5. System average interruption duration index ($SAID_{index}$)

It is commonly referred to as customer minutes of interruption or customer hours and is designed to provide information as to the average time the customers are interrupted as Eq. (25).

$$SAID_{index} = \frac{\sum U_i N_i}{\sum N_i} \quad (25)$$

Here U_i is interruption duration at i th load point and N_i , is the number of customer at i th load point.

2.3.6. Customers average interruption duration index ($CAID_{index}$)

It is the average time needed to restore service to the average customer per sustained interruption as Eq. (26).

$$CAID_{index} = \frac{\sum U_i N_i}{\sum \lambda_i N_i} \quad (26)$$

Here λ_i is the annual failure rate at i th feeder.

2.4. Multiobjective function for optimal planning of DG

The multi-objective function for optimal planning of DG in distribution power system from overall power system performance point of view as Eqs. (27)–(28).

$$F = \lambda_1.P_{L_index} + \lambda_2.Q_{L_index} + \lambda_3.V_{P_index} + \lambda_4.L_{C_index} + \lambda_5.SAID_{index} + \lambda_6.CAID_{index} \quad (27)$$

where

$$\sum_{m=1}^6 \lambda_m = 1 \quad (28)$$

The values of $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6$ are selected on basis of priority order of distribution power system performances such as real power loss, reactive power loss, voltage profile and line capacity indices. The above objective function can be optimized by employing artificial intelligence computational techniques such as GA, PSO, ANN, Fuzzy algorithm, ABC algorithm, ACS algorithm, SA algorithm, Hybrid algorithm etc. Such AI techniques are reviewed in taxonomical form in Section 3. The value of above weight factor such as $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6$ are given in Table 2.1.

3. Taxonomical reviews on DG planning from power system performances point of view

The taxonomical survey for the details of literature survey regarding with optimally placed DG in the distribution networks from the power system performance point of view presented in Table 3.1.

Table 2.1

Weight factor and its value on basis on priority.

Weight factors	Its value on basis of priority
λ_1	0.4
λ_2	0.3
λ_3	0.2
λ_4	0.05
λ_5	0.03
λ_6	0.02

4. Summary of paper

The summaries of paper are as follows:

4.1. Conventional methods

Table 4.1, shows the summary of this article from different conventional methods viewpoint.

Table 4.1, it is concluded that the conventional methods such as Eigen values method, Modal method, Added model method, Index method, OPF, PST, Monte-carlo method, Tradeoff method, LPF, Newton–Raphson are 2.9%, 27.94%, 19.11%, 9.5%, 20.5%, 3.68%, 2.21%, 3.68%, 8.09%, 2.21% respectively reviewed.

4.2. Artificial intelligence techniques

Table 4.2, shows the summary of this article from different artificial intelligence techniques viewpoint.

Table 4.2, it is concluded that the artificial intelligence techniques such as Genetic algorithms, Artificial neural network, Fuzzy logic, Particle swarm optimization, Ant bees colony, Gravitational search algorithms, tabu search, Simulated annealing, Heuristic algorithms, Kalman filter algorithms, Two stage planning algorithms, MMR algorithms, Evolutionary algorithms, Optimal algorithms, Immune system algorithms, Hereforced algorithms, Other are 37.64, 5.05, 5.05, 8.98, 16.29, 0.56, 1.12, 2.24, 8.42, 1.68, 0.56, 0.56, 1.12, 0.56, 0.56, 1.12, 8.42 respectively reviewed.

4.3. Optimization methods

Table 4.3, shows the summary of this article from different optimization methods viewpoint.

Table 4.3, it is concluded that the optimization methods such as Dynamic programming method, Linear programming method, Non-Linear programming method, Mixed integer non-linear programming method, Dual programming method, Other programming method are 20.22%, 11.23%, 34.83%, 24.71%, 2.80%, 6.17% respectively reviewed.

4.4. Hybrid intelligence techniques

Table 4.4, shows the summary of this article from different Hybrid intelligence techniques viewpoint.

Table 4.4, it is concluded that the hybrid artificial intelligence techniques such as FZ + GA, PSO + Model, OPF + Newton method, TS + SA, PSO + FZ, GA + BFGS, GSA + TS, GA + OPF, GA + PSO, FZ + HA are 35.29%, 5.88%, 5.88%, 5.88%, 11.76%, 5.88%, 5.88%, 11.76%, 5.88%, 5.88% respectively reviewed.

4.5. Others techniques

Table 4.5, shows the summary of this article from other techniques viewpoint.

Table 4.5, it is concluded that the others techniques such as Wind generation, Industrial Planning, Switching operation are 50%, 25%, 25% respectively reviewed.

Table 3.1

Taxonomical survey for the details of literature survey regarding with optimally placed DG in the distribution networks from the power system performance point of view.

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Pregelj et al.	2006	DG-1	Reliability	GA	IEEE 9 bus system	Static	Hybrid
Kansal et al.	2011	DG-4	Real power loss	PSO	IEEE 33 bus system	Static	Hybrid
Acharya et al.	2006	DG-2	Power loss reduction	GA	IEEE 33,37 bus system	Static	Hybrid
Ackermann et al.	2001	DG-1	Power loss reduction	LM	IEEE 15 bus system	Static	Hybrid
Pavlos et al.	2013	DG-1	ODGP Problem	GA	IEEE 69 bus system	Static	Hybrid
Shereen	2012	DG-1	Power loss reduction	GA	IEEE 33 bus system	Static	Hybrid
Huddleston et al.	1990	DG-1	Real power loss	OT	IEEE 33 bus system	Static	Hybrid
Georgilakis and Hatzigiorgiou	2013	DG-3	ODGP Problem	GA	IEEE 15 bus system	Static	Hybrid
Kashem et al.	2000b	DG-1	Loss	HA	IEEE33 bus system	Static	Hybrid
Rau and Wan	1994	DG-1	loss reduction	AP	IEEE 33,37 bus system	Static	Hybrid
Borozan and Rajakovic	1997	DG-1	Real power loss	OT	IEEE 37 bus system	Static	Hybrid
Ackermann et al.	2000	DG-4	Cost	AP	IEEE 9,69 bus system	Static	MOF
Khator and Leung	1997	DG-1	Power loss and Voltage	OT	IEEE 33,37 bus system	Static	Hybrid
Kim et al.	1998a	DG-4	Power loss	OPF	IEEE 33,37 bus system	Static	Hybrid
Ault et al.	2003	DG-1	Power loss and Voltage	OT	IEEE 37,69 bus system	Static	Hybrid
Griffin et al.	2000a	DG-1	Power loss + location	OT	IEEE 33,37 bus system	Static	Hybrid
Willis	2000a	DG-3	location	Model	IEEE 15 bus system	Static	Hybrid
Gray	1998	DG-2	Cost	OT	IEEE 33 bus system	Static	Hybrid
Zhu et al.	2006	DG-4	Reliability + efficiency	GA	IEEE 33,37 bus system	Static	Hybrid
Hoff and Shugar	1995	DG-1	Loss	GA	IEEE 37,69 bus system	Static	Hybrid
Kim et al.	1993	DG-1	Loss	ANN	IEEE 9,69 bus system	Static	Hybrid
Dugan et al.	2001	DG-1	Power loss and Voltage	OT	IEEE 9,33 bus system	Static	Hybrid
Ochoa et al.	2008c	DG-4	Time varying generation	Multi objective index	IEEE 15 bus system	Static	Hybrid
Kotari et al.	1996	DG-1	Location	PST	IEEE 37,69 bus system	Static	Hybrid
Wang and Singh	2008	DG-1	Reliability	Algorithm	IEEE 33,37 bus system	Static	Hybrid
Friedman	1998	DG-2	Cost	OT	IEEE 37 bus system	Static	Hybrid
Pavlos et al.	2013	DG-1	Power loss	OT	IEEE 33,37 bus system	Static	Hybrid
Porkar et al.	2011	DG-1	Loss+reliability	NLP	IEEE 69 bus system	Static	Hybrid
Brown and Freeman	2001	DG-3	Cost+location	OT	IEEE 9 bus system	Static	Hybrid
Khalesi et al.	2011	DG-3	Loss+reliability	Dynamic programming	IEEE 69 bus system	Static	Hybrid
Taleski and Rajcic	1997	DG-1	Real power loss	OT	IEEE 15 bus system	Static	Hybrid
Jabr and Pal	2009b	DG-1	Location+sizing	Ordinal optimization	IEEE 33,37 bus system	Static	Hybrid
Shirmohammadi and Hong	1989	DG-1	Real power loss	AP	IEEE 9,37 bus system	Static	Hybrid
Ramakumar	2001	DG-1	Cost+location	OT	IEEE 37,69 bus system	Static	MOF
Baran and Wu	1989b	DG-1	Loss	GA	IEEE 33 bus system	Static	Hybrid
Hegazy et al.	2003	DG-4	Voltage	Monte carlo method	IEEE 69 bus system	Static	Hybrid

(continued on next page)

Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Barker	2000	DG-4	Loss+capacity	OT	IEEE 37 bus system	Static	Hybrid
Ding and Girgis	2001	DG-1	Load+Loss	OT	IEEE 37 bus system	Static	Hybrid
Zhou et al.	1997	DG-1	Cost	ANN	IEEE 33,37 bus system	Static	Hybrid
Chiradeja and Ramakumar	2004	DG-1	Size+cost	Quantification method	IEEE 69 bus system	Static	Hybrid
Singh and Goswami	2009	DG-1	Siting+sizing	radial and networked	IEEE 15 bus system	Static	Hybrid
Broadwater et al.	1993	DG-1	Real power loss	AP	IEEE 37 bus system	Static	Hybrid
Peponis et al.	1995	DG-4	Real power loss	OT	IEEE 69 bus system	Static	Hybrid
Yokoyama et al.	1998	DG-2	Power loss+location	Probability security criteria	IEEE 9,37 bus system	Static	MOF
Harrison and Wallace	2005	DG-2	Size+loss	OPF	IEEE 69 bus system	Static	Hybrid
Civanlar et al.	1988	DG-1	Real power loss	GA	IEEE 33 bus system	Static	Hybrid
Tuba Gözel et al.	2009	DG-1	Sizing+sitting	radial systems	IEEE 15 bus system	Static	Hybrid
Ochoa et al.	2010	DG-1	capacity assessment	active networks	IEEE 33,37 bus system	Static	Hybrid
Goswami and Basy	1992	DG-1	Real power loss	AP	IEEE 37 bus system	Static	Hybrid
Kumarand and Gao	2010	DG-1	Location	NLP	IEEE 69 bus system	Static	Hybrid
Kashem et al.	1998	DG-1	Power loss	OT	IEEE 37 bus system	Static	Hybrid
Khoddr et al.	2010	DG-1	Location	OT	IEEE 69 bus system	Static	Hybrid
Brown et al.	2001	DG-1	Power loss and Voltage	AP	IEEE 37 bus system	Static	Hybrid
Hadjsaid et al.	1999a	DG-4	Loss	OT	IEEE 33 bus system	Static	Hybrid
Ault et al.	2002	DG-1	Power loss and Voltage	AP	IEEE 37,69 bus system	Static	Hybrid
Lasseter	1998	DG-3	Power loss	OT	IEEE 33,37 bus system	Static	Hybrid
Jabr and Pal	2009b	DG-1	Sizing	Ordinal optimization	IEEE 69 bus system	Static	Hybrid
Edwards et al.	2000	DG-1	Power loss,voltage	OT	IEEE 37 bus system	Static	Hybrid
Singh and Goswami	2010	DG-1	loss	Optimum allocation	IEEE 69 bus system	Static	Hybrid
Chao et al.	1999	DG-3	Capacity	GA	IEEE 9,33 bus system	Static	Hybrid
Lee and Park	2009	DG-1	optimal location+size	Kalman filter algorithm	IEEE 9 bus system	Static	Hybrid
Quintana et al.	1993	DG-1	Power loss and Voltage	Two stage-planning algorithm	IEEE 69 bus system	Static	Dynamic
Gonen and Ramírez-Rosado	1986	DG-1	Power loss+location	OT	IEEE 9 bus system	Static	Hybrid
Kim et al.	2002	DG-4	Location	Fuzzy+GA	IEEE 37,9 bus system	Static	Time varying load
Khan and Choudhry	2010a	DG-1	Feeder	Algorithm	IEEE 69 bus system	Static	Hybrid
Ault and McDonald	2000	DG-1	Location+capacity	TS	IEEE 37 bus system	Static	Hybrid
Rau and Wan	1994	DG-3	Location	OT	IEEE 37 bus system	Static	Hybrid
Willis	2000b	DG-1	Location+power loss	AP	IEEE 9,33 bus system	Static	MOF
Khan and Choudhry	2010b	DG-2	Feeder+load	Algorithm	IEEE 15 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Willis	1997	DG-1	Location	ANN	IEEE 69,9 bus system	Static	Hybrid
Thirault et al.	2002	DG-1	Cost	OT	IEEE 9 bus system	Static	MOF
Keane and O'Malley	2005	DG-1	Location	ABC	IEEE 69,37 bus system	Static	Hybrid
Raissi et al.	1997	DG-1	Power loss	AP	IEEE 9,69 bus system	Static	Hybrid
Lopez-Lezama et al.	2012	DG-4	Location+contract pricing	GA	IEEE 33,37 bus system	Static	Hybrid
Khattamet et al.	2004	DG-1	Cost+size	HA	IEEE 69,37 bus system	Static	Hybrid
Kellogg et al.	1998	DG-3	Cost+capacity	OT	IEEE 33 bus system	Static	MOF
Ochoa et al.	2008c	DG-2	Location	Multi objective index	IEEE 15 bus system	Static	Hybrid
Hadjsaid et al.	1999b	DG-4	Cost	OT	IEEE 33 bus system	Static	Hybrid
Rashid et al.	2010	DG-1	Size+Location	Intelligent Techniques	IEEE 69 bus system	Static	Hybrid
Nehrir et al.	2003	DG-1	Power loss+cost	OT	IEEE 9,37 bus system	Dynamic	Hybrid
Akorede et al.	2010	DG-1	Strategies	Optimal Placement	IEEE 15 bus system	Static	Hybrid
Kim et al.	1998	DG-1	Location	HRA	IEEE 69 bus system	Static	Hybrid
Lalitha et al.	2011	DG-1	Siting and Sizing	RCGA	IEEE 9,69 bus system	Static	Hybrid
Dugan and Price	2002	DG-4	Location+size	OT	IEEE 37,69 bus system	Static	Hybrid
Wang and Hsshem	2004	DG-1	Location	AP	IEEE 37,69 bus system	Static	Hybrid
Chiradeja and Ramakumar	1998	DG-4	Capacity+location	OT	IEEE 9,37,69 bus system	Static	MOF
Dugan and Mcdermont	2002	DG-1	Cost+size	OT	IEEE 37,69 bus system	Static	Hybrid
Scott	1998	DG-1	Power loss+location	OT	IEEE 933 bus system	Static	Hybrid
Sharma and Vittal	2010	DG-4	Allocation	HA	IEEE 9,69 bus system	Static	Hybrid
Rahman	2001	DG-1	Power loss+cost	AP	IEEE 9,37 bus system	Static	Hybrid
Kotb et al.	2010	DG-1	Siting+Sizing	GA	IEEE 69 bus system	Static	Hybrid
Price	2002	DG-1	Location + Size	OT	IEEE 69 bus system	Static	Hybrid
Singh et al.	2009a	DG-1	Load Models	Radial Distribution	IEEE 15 bus system	Static	Dynamic
Del Monaco	2000	DG-1	Location+cost+size	OT	IEEE 969 bus system	Static	Hybrid
Kuerasuk and Ongsakul	2006	DG-1	Optimal Placement	PSO	IEEE9,33 bus system	Static	Hybrid
Nara et al.	1992	DG-1	Loss	GA	IEEE 37,69 bus system	Static	Hybrid
Hien et al.	2013	DG-4	Location +loss +cost	OT	IEEE 9 bus system	Static	Hybrid
Rodrigo et al.	2005	DG-1	Size	OT	IEEE 69 bus system	Static	Hybrid
Zhu	2002	DG-1	Location	GA	IEEE 9,33 bus system	Static	Hybrid
Jabr and Pal	2009b	DG-4	Location +size	OT	IEEE 69 bus system	Static	Hybrid
Biswas and Goswami	2010	DG-1	Loss+voltage	GA	IEEE 37,69 bus system	Static	Hybrid
Ochoa et al.	2008a	DG-1	Load + Cost	OT	IEEE 9 bus system	Static	Hybrid
Kamel and Kermanshahi	2009	DG-1	Size+location+loss	OT	IEEE 37,69 bus system	Static	Hybrid
Silvestri et al.	1999	DG-1	Location	GA	IEEE 37 bus system	Static	Hybrid
Kashem et al.	2006	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Jain et al.	2010	DG-1	Siting+Sizing	PSO	IEEE 69 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Bernardon et al.	2005	DG-4	Loss+cost	GA	IEEE 15 bus system	Static	Hybrid
Hajizadeh and Hajizadeh	2008	DG-1	Planning	PSO	IEEE 9,33 bus system	Static	Hybrid
Dale	2002	DG-1	Location	OT	IEEE 37 bus system	Static	Hybrid
Amanifar and Golshan	2011	DG-1	Loss + voltage	PSO+Sensitivity Analysis	IEEE 9bus system	Static	Hybrid
Lopez et al.	2004	DG-4	Capacity	OT	IEEE 69 bus system	Static	Hybrid
Milligan and Graham	1996	DG-1	Location+cost	Probability simulation technique	IEEE 9,69 bus system	Static	Hybrid
Greene et al.	1997	DG-1	Voltage	Contingency analysis	IEEE 9,33 bus system	Static	Dynamic
Su	2010	DG-1	Voltage+location	OT	IEEE 9 bus system	Static	Hybrid
Ochoa et al.	2010	DG-1	Capacity	Analytical method	IEEE 69 bus system	Static	Hybrid
Caire et al.	2002	DG-4	Loss+ cost	GA	IEEE 37,69 bus system	Static	Hybrid
Ramakumar and Chiradeja	2002	DG-4	Location	OT	IEEE 9 bus system	Static	Hybrid
Yassami et al.	2011	DG-4	Reliability +loss	MOOA	IEEE 9,33 bus system	Static	Hybrid
Chiradeja and Ramakumar	2001	DG-3	Voltage+loss	Probabilistic approach	IEEE 37,69 bus system	Static	Hybrid
Rezaei and Vakilian	2010	DG-3	Location+loss	MPSO	IEEE 69 bus system	Static	Hybrid
Su and Lee	2003	DG-3	Location +loss +cost	Mixed integer programming	IEEE 9 bus system	Static	Hybrid
Kumar and Kumar	2011	DG-1	Voltage +loss	PSO	IEEE 30 bus system	Static	Hybrid
Merlin and Back	1975	DG-1	Loss	Spanning tree	IEEE 15 bus system	Static	Hybrid
Shirmohammadi and Hong	1989	DG-1	Loss	GA	IEEE 37 bus system	Static	Hybrid
Ramos et al.	2005	DG-3	Loss	Path based technique	IEEE 9,33 bus system	Static	Hybrid
Augugliaro et al.	2004	DG-3	Voltage+loss	OT	IEEE 69 bus system	Static	Hybrid
Mohammad and Nasab	2011	DG-3	Reliability +loss	GA	IEEE 9 bus system	Static	Hybrid
Glamocanin	1990	DG-2	Loss	OT	IEEE 33 bus system	Static	Hybrid
Taylor and Lubkeman	1990	DG-2	Loss+location	HA	IEEE 69 bus system	Static	Hybrid
Roytelman et al.	1996	DG-2	Location+loss+size	OT	IEEE 37 bus system	Static	Hybrid
Lalitha et al.	2010	DG-1	Loss	Algorithm	IEEE 9,33 bus system	Static	MOF
Das	2006	DG-1	Location+loss	FZ	IEEE 69 bus system	Static	Hybrid
Gil and Joos	2006	DG-1	Cost	Quantification	IEEE 37,69 bus system	Static	Hybrid
Conejo et al.	2002	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Gareth et al.	2007	DG-4	Cost	Trade off method	IEEE 9 bus system	Static	Hybrid
Paliwal and Patidar	2010	DG-4	Loss	Model	IEEE 69 bus system	Static	Hybrid
Chiang and Jean-Jumeau	1990b	DG-1	Loss+location	OT	IEEE 69,9 bus system	Static	Hybrid
Rezazadeh and Alavian	2009	DG-1	Sizing+Sitting	GA	IEEE 9,33 bus system	Static	Hybrid
Borges and Falcao	2003	DG-1	Location+size+voltage+loss	OT	IEEE 9,33 bus system	Static	Hybrid
Dent et al.	2005	DG-1	Capacity+voltage	OPF	IEEE 15 bus system	Static	Hybrid
Dent et al.	2010	DG-1	Capacity	ACOPF	IEEE 9,33 bus system	Static	Hybrid
Choi	2007	DG-1	Reliability	GA	IEEE 69,9 bus system	Static	MOF
Borazan et al.	1997	DG-4	Loss	FZ	IEEE 69 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Tong and Miu	2005	DG-4	Voltage	LPF	IEEE 9 bus system	Static	Hybrid
Carvalho et al.	2008	DG-1	Voltage	LPF	IEEE 69,9 bus system	Static	Hybrid
Ullah et al.	2009	DG-1	Cost+loss	OT	IEEE 9,33 bus system	Static	Hybrid
Fahim et al.	2001	DG-1	Impact	GA	IEEE 69,9 bus system	Static	Hybrid
Borozan et al.	1995	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Sarfi et al.	1994	DG-1	Loss	Analytical method	IEEE 9,33 bus system	Static	MOF
Peponis et al.	1996	DG-1	Cost+Size	OT	IEEE 69,9 bus system	Static	Hybrid
Sarfi et al.	1996	DG-1	Loss	GA	IEEE 69 bus system	Static	Dynamic
Harrison and Wallace	2005	DG-1	Location	OPF	IEEE 9 bus system	Static	Hybrid
Kuri et al.	2004	DG-4	Size+location	OT	IEEE 9,33 bus system	Static	Hybrid
Vovos et al.	2007	DG-1	Voltage	OT	IEEE 9,33 bus system	Static	Hybrid
McDermott et al.	1999	DG-3	Location+loss	HA	IEEE 69,9 bus system	Static	Hybrid
Murthy and Kumar	2013	DG-2	Allocation	Radial distribution	IEEE 9,33 bus system	Static	Hybrid
Lopez et al.	2002	DG-4	Loss	Dynamic programming	IEEE 9,33 bus system	Static	Hybrid
Wagner et al.	1991	DG-1	Loss	ANN	IEEE 69,37 bus system	Static	Hybrid
Alrashidi and El-Hawary	2009	DG-1	Loss	PSO	IEEE 9,33 bus system	Static	Hybrid
Del Valle et al.	2008	DG-1	Loss+voltage	PSO	IEEE 33 bus system	Static	Hybrid
Broadwater et al.	1993	DG-1	Loss+location	OT	IEEE 33,9 bus system	Static	Hybrid
Chiou et al.	2005	DG-1	Location +loss	Hybrid differential evolution	IEEE 9 bus system	Static	Hybrid
Su et al.	2005	DG-1	Loss	ABC	IEEE 9,33 bus system	Static	Hybrid
Reza and Hussain Shareef	2012	DG-1		Algorithm	IEEE 9,33 bus system	Static	Hybrid
Brian and Shin	1994	DG-2	Loss+location	HA	IEEE 9 bus system	Static	Hybrid
Niketut et al.	2011	DG-3	Loss +voltage	GA	IEEE 69,9 bus system	Static	Hybrid
Shenkman	1990	DG-4	Loss	Statistical techniques	IEEE 9,33 bus system	Static	Hybrid
Enrique et al.	2004	DG-1	Location+size	PSO	IEEE 9,33,69 bus system	Static	Hybrid
Merlin and Back	1975	DG-1	Loss	Spanning tree method	IEEE 9,33 bus system	Static	MOF
Etemadi and Fotuhi	2008	DG-1	Size+loss	OT	IEEE 9 bus system	Static	Hybrid
Ponnavaikko et al.	1987	DG-1	Location	MIPA	IEEE 9,33 bus system	Static	ANN
Hossain et al.	2011	DG-1	Placement+sizing	PSO	IEEE 9 bus system	Static	Hybrid
Coles and Beck	2001	DG-1	Cost	GSA	IEEE 9,69 bus system	Static	Hybrid
Chowdhury et al.	2003	DG-1	Location+Size	AP	IEEE 9,69 bus system	Static	Hybrid
Cebrian and Kagan	2010	DG-1	Loss+cost	GA	IEEE 9 bus system	Static	Hybrid
Walid et al.	2005	DG-1	Location	GA	IEEE 33,9 bus system	Static	Hybrid
Kuri et al.	2004	DG-1	Size+location	ABC	IEEE 33,69 bus system	Static	Hybrid
Ettehadi et al.	2013	DG-1	Cost	OT	IEEE 9 bus system	Static	Hybrid
Nara and Song	2002	DG-1	Location	HA	IEEE 37,69 bus system	Static	Hybrid
El-Khaltam et al.	2004	DG-1	Cost	OT	IEEE 37,69 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
M et al.	2011	DG-1	Size+location	ANN	IEEE 15 bus system	Static	Hybrid
Rau and Wan	1994	DG-1	Location	Undistributed planning	IEEE 9 bus system	Static	MOF
Chen et al.	1993	DG-1	Location+loss	PST	IEEE 33,69 bus system	Static	Hybrid
Hariri and Malik	1986	DG-2	Location+loss	FZ	IEEE 9,37,69 bus system	Static	Hybrid
El-Metwally et al.	1996	DG-3	Location+loss	FZ	IEEE 9,69 bus system	Static	Hybrid
Naik et al.	2013	DG-3	Loss	Model	IEEE 9 bus system	Static	Hybrid
Haque	1996	DG-4	Voltage	OPF	IEEE 69 bus system	Static	Hybrid
Mok et al.	2000	DG-1	Location	OPF	IEEE 37 bus system	Static	Hybrid
Fan et al.	1996	DG-1	Loss	OT	IEEE 9 bus system	Static	Hybrid
Abur	1996	DG-1	Location+loss	Modified linear programming	IEEE 69,9 bus system	Static	Hybrid
Das et al.	1995	DG-3	Loss+location	Dynamic programming	IEEE 37 bus system	Static	MOF
Abdel-Magid et al.	1997	DG-3	Location+loss	GA	IEEE 37,9 bus system	Realistic	Hybrid
Roger	1993	DG-1	Location+loss+cost	GA	IEEE 9,69 bus system	Static	Hybrid
Fraile and Zufiria	2005	DG-4	Loss+size	GA	IEEE 9,37,69 bus system	Static	Hybrid
Tinney and Hart	1967	DG-4	Loss	OPF + Newton's method	IEEE 9 bus system	Static	Hybrid
Stott and Alsac	1974	DG-3	Loss	FDLF	IEEE 33 bus system	Static	Hybrid
Tripathy et al.	1982	DG-2	Loss	Newton like method	IEEE 37 bus system	Static	Hybrid
Iwamoto and Tamura	1981	DG-1	Loss	OPF	IEEE 9,37 bus system	Static	Hybrid
Shirmohammadi et al.	1988	DG-1	Loss	OPF	IEEE 9,37 bus system	Static	Hybrid
Luo and Semlyen	1990	DG-1	Loss	OPF	IEEE 9,69 bus system	Static	Hybrid
Gopiya et al.	2013	DG-1	Loss	Allocation	IEEE 9,33 bus system	Static	Hybrid
Baran and Wu	1989a	DG-1	Location+size	OT	IEEE 69 bus system	Static	Hybrid
Chiang	1991	DG-1	Loss+size	DLF	IEEE 69 bus system	Static	Hybrid
Renato Cespedes	1990	DG-1	Loss+Location	OT	IEEE 33 bus system	Static	Hybrid
Roy and Hossain	2013	DG-1	Voltage	Wind generation	IEEE 15 bus system	Static	Hybrid
Borges and Falcao	2006	DG-3	Loss+voltage	OT	IEEE 9 bus system	Static	MOF
Abou El-Ela et al.	(2010)	DG-1	Cost	GA	IEEE 69,9 bus system	Static	Hybrid
Jasmon and Lee	1991	DG-1	Voltage	OPF	IEEE 37 bus system	Static	Hybrid
Liang et al.	2006	DG-3	Location+loss+cost	PSO	IEEE 9,37,69 bus system	Static	Hybrid
Soroudi et al.	2011b	DG-4	Cost+location	OT	IEEE 9 bus system	Static	Hybrid
Piccolo and Siano	2009	DG-4	Cost+size	OT	IEEE 9,37,69 bus system	Static	MOF
Salama and Chikhani	1993	DG-1	Reactive loss	LFT	IEEE 33,9 bus system	Static	Hybrid
Eminoglu and Hocaoglu	2005	DG-1	Voltage	OPF	IEEE 9,69 bus system	Static	Hybrid
Nara et al.	2001	DG-1	Location	TS	IEEE 69 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Huang et al.	2013	DG-1	Load	SVC	IEEE 9 bus system	Static	Hybrid
Vovos et al.	2005	DG-1	Size	OPF	IEEE 33 bus system	Static	Hybrid
Dommel and Tinney	1968	DG-1	Loss	OPF	IEEE 37 bus system	Static	Hybrid
Eberly and Schaefer	2002	DG-1	Voltage	OPF	IEEE 9,37 bus system	Static	Hybrid
Soroudi and Ehsan	2010	DG-1	Size+voltage	OT	IEEE 15 bus system	Static	Hybrid
Siano et al.	2009	DG-1	Cost	OT	IEEE 9,37,69 bus system	Static	MOF
Zangeneh et al.	2009	DG-4	Cost	OT	IEEE 9 bus system	Static	Hybrid
Santhilkumar and Raja	2008	DG-4	Loss	PSO	IEEE 33 bus system	Static	Hybrid
Wall	2001	DG-3	Loss	OT	IEEE 69 bus system	Static	Hybrid
Chin and Huang	2000	DG-3	Loss	OT	IEEE 9,37,69 bus system	Static	Hybrid
Kim et al.	1993	DG-4	Loss	ANN	IEEE 69,9 bus system	Static	Hybrid
Guimaraes et al.	2010	DG-1	Location+loss	GA	IEEE 9 bus system	Static	Hybrid
Lavorato et al.	2012	DG-1	Location +loss	OT	IEEE 9,33,69 bus system	Static	Hybrid
Goswami and Basu	1992	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Baran and Wu	1989b	DG-4	Loss	OT	IEEE 9 bus system	Static	Hybrid
Amany	2010	DG-1	Load	PSO	IEEE 9,33 bus system	Static	Hybrid
Kashem et al.	1999	DG-1	Load	OT	IEEE 9,37,69 bus system	Static	Hybrid
Hsiao and Chen	2001	DG-4	Loss+location+voltage	OT	IEEE 9,33 bus system	Static	Hybrid
Willis and Northcote	1985	DG-4	Loss	OT	IEEE 9 bus system	Static	Hybrid
Gonen and Ramirez-Rosado	1986	DG-4	Cost+location+size	OT	IEEE 9,33 bus system	Static	Hybrid
Jeon and Kim	2000	DG-1	Location	TS+Annealing	IEEE 9,33 bus system	Static	MOF
Lin et al.	2000	DG-1	Location	GA	IEEE 15 bus system	Static	Hybrid
Ghosh and Das	1999	DG-1	Load	OT	IEEE 9 bus system	Static	Hybrid
Bakirtzis et al.	2002	DG-1	Location	GA	IEEE 69,37 bus system	Static	Hybrid
Luan et al.	2002	DG-1	Loss+load	GA	IEEE 69 bus system	Static	Hybrid
Chang and Kuo	1994	DG-1	Location	Simulated annealing	IEEE 69,9 bus system	Static	MOF
Augugliaro et al.	1995	DG-4	Loss	Greedy approach	IEEE 9,33 bus system	Static	Hybrid
Morton and Mareels	2000	DG-2	Location	Brute-force solution	IEEE 9,33 bus system	Static	Hybrid
Yun et al.	2000	DG-2	Voltage	OT	IEEE 9 bus system	Static	Hybrid
Mutale et al.	2000	DG-3	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Carpaneto et al.	2006	DG-4	Loss+location	BC decomposition method	IEEE 9,33 bus system	Static	Hybrid
Swarup and Yamashiro	2002	DG-1	Size	GA	IEEE 37 bus system	Static	Dynamic
Hong and Ho	2005	DG-1	Location+cost+size	GA	IEEE 37 bus system	Static	Hybrid
Willis et al.	1995	DG-1	Loss	OPF	IEEE 9,33 bus system	Static	Hybrid
Boardman and Meckiff	1985	DG-1	Location	Branch method	IEEE 9 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Shaaban et al.	2013	DG-1	Power loss	OT	IEEE 69,9 bus system	Static	Hybrid
Fahad and El-Hawary	2011	DG-1	Allocation+sizing	ABC	IEEE 9,33 bus system	Static	Hybrid
Nara et al.	1994	DG-3	Size	AP	IEEE 9 bus system	Static	Hybrid
Ramírez-Rosado and Gönen	1991	DG-2	Size+cost	Pseudodynamic programming	IEEE 9,37,69 bus system	Static	Hybrid
Jóos et al.	2000	DG-3	Size	OT	IEEE 69,37 bus system	Static	Hybrid
Marei et al.	2004	DG-4	Voltage	OT	IEEE 9,37,69 bus system	Static	Hybrid
Hejazi et al.	2013	DG-4	Voltage stability	OT	IEEE 9,33 bus system	Static	Hybrid
Sedighzadeh et al.	2014	DG-1	Power loss	OT	IEEE 69,9 bus system	Static	Hybrid
Ramírez-Rosado and Bernal-Agustín	1998	DG-1	Cost+size	GA	IEEE 9,69 bus system	Static	Hybrid
Gómez et al.	2004	DG-1	Cost+location	ABC	IEEE 37,69 bus system	Static	Hybrid
Usaola	2009	DG-1	Voltage+location	LPF	IEEE 69,9 bus system	Static	Hybrid
Jabr and Pal	2009a	DG-1	Location	OPF	IEEE 9 bus system	Static	Hybrid
Ganjavi	2001	DG-1	Cost+location	OT	IEEE 9,33 bus system	Static	Hybrid
Paiva et al.	2004	DG-1	Cost	MI linear programming	IEEE 9,33 bus system	Static	Hybrid
Mithulananthan et al.	2004	DG-1	Loss	GA	IEEE 9 bus system	Static	Hybrid
Yang and Guo	2008	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
De Oliveira	2010	DG-4	Location+loss	OT	IEEE 15 bus system	Static	Dynamic
Jain et al.	2015	DG-3	Power loss	OT	IEEE 9,33 bus system	Static	Hybrid
Singh et al.	2015a	DG-3	Loss+cost	OT	IEEE 9,33 bus system	Static	Hybrid
Costa and Matos	2015	DG-2	Loss	OT	IEEE 9,37,69 bus system	Static	Hybrid
Baran and Wu	1989a	DG-1	Loss	OPF	IEEE 9,37,69 bus system	Static	Hybrid
Jenkins et al.	2000	DG-3	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Hadsaid et al.	1999b	DG-1	Loss	OT	IEEE 9 bus system	Static	Hybrid
Shukla et al.	2010	DG-1	Size	Radial distribution	IEEE 9,33 bus system	Static	Hybrid
Zhang and Cheng	1997	DG-1	Size	Newton method	IEEE 9,37 bus system	Static	Hybrid
Augugliaro et al.	2001	DG-1	Size	Iterative method	IEEE 9 bus system	Static	Hybrid
Viswanadha Raju and Bijwe	2008	DG-1	Location+loss	HA	IEEE 9,33 bus system	Static	Hybrid
Khodr et al.	2009	DG-1	Location+loss	OPF	IEEE 9,66 bus system	Static	Hybrid
Kim and Hwang	2001	DG-1	Size	Analytical method	IEEE 9,33 bus system	Static	Hybrid
Usta and Redfem	2001	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
De Macêdo Braz and Alencar de Souza	2011	DG-3	Location+cost+loss	GA	IEEE 15 bus system	Static	Hybrid
Kuersuk and Ongsakul	2006	DG-2	Location	PSO	IEEE 9,33,69 bus system	Static	Hybrid
Xu and Girgis	2001	DG-1	Load	AP	IEEE 9,33 bus system	Static	Hybrid
Edwards et al.	2000	DG-1	Location	AP	IEEE 33,69 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Girgis and Brahma	2000	DG-4	Loss+fault	OT	IEEE 9 bus system	Static	Hybrid
Doyle	2002	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Brown	2002	DG-1	Loss	OT	IEEE 9,37,69 bus system	Static	Hybrid
Barker and De Mello	2000	DG-1	Impact	Radial distribution	IEEE 9,33 bus system	Static	Hybrid
Kersting	1991	DG-4	Loss	OT	IEEE 9,33,69 bus system	Static	MOF
Ciric et al.	2003	DG-1	Loss	General approach	IEEE 9,37 bus system	Static	Hybrid
Zhu and Tomsovic	2002	DG-1	Location	AFP	IEEE 9,33 bus system	Static	MOF
Meliopoulos et al.	1990	DG-4	Loss	PPFA	IEEE 9,37,69 bus system	Static	Hybrid
Hadjsaid et al.	1999a	DG-1	Impact	Dispersed generation	IEEE 9,33 bus system	Static	Hybrid
Walid et al.	2006	DG-1	Loss	Monte carlo method	IEEE 9 bus system	Static	Hybrid
Lopes	2002	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Celli and Pilo	2001a	DG-1	Location	GA	IEEE 69 bus system	Static	Hybrid
Kersting	2003	DG-4	Loss	OLF	IEEE 9,33 bus system	Static	Hybrid
Gupta et al.	2010	DG-4	Location+loss+cost	GA+ FZ	IEEE 9,37,69 bus system	Static	Hybrid
Chiang and Jean-Jumeau	1990a	DG-4	Location	Numerical analysis	IEEE 9,33 bus system	Static	Hybrid
Ochoa et al.	2006	DG-1	Loss+location	Index method	IEEE 69 bus system	Static	Hybrid
Brahma and Girgis	2004	DG-1	Location+fault	ANN	IEEE 37,69 bus system	Static	Hybrid
Ochoa et al.	2006	DG-1	Impact	multiobjective index	IEEE 9,33 bus system	Static	Hybrid
Abbey and Joós	2005	DG-1	Voltage	OT	IEEE 9 bus system	Static	Hybrid
Wenger et al.	1994	DG-3	Size	OT	IEEE 9,33 bus system	Static	Hybrid
Yiming and Miu	2003	DG-3	Reliability	Radial distribution	IEEE 33 bus system	Static	Hybrid
Kersting	1991	DG-3	Location+loss	Analytical method	IEEE 9,33 bus system	Static	Hybrid
Hugo and Geza	2006	DG-1	Cost	Quantification method	IEEE 9,33 bus system	Static	Hybrid
Kashem et al.	2000a	DG-1	Voltage	OT	IEEE 9,37 bus system	Static	Hybrid
Gomes et al.	2005	DG-1	Loss	HA	IEEE 9,66 bus system	Static	Hybrid
Zhu et al.	2006	DG-1	Location	OT	IEEE 9 bus system	Static	Hybrid
Warren et al.	2006	DG-1	Fault	OT	IEEE 15 bus system	Static	Hybrid
Singh et al.	2011	DG-2	Reliability	PSO + FZ	IEEE 37,69 bus system	Static	MOF
Kim et al.	2002	DG-2	Location	FZ+GA	IEEE 9,37,69 bus system	Static	Hybrid
Carpinelli et al.	2001	DG-2	Size+location	GA	IEEE 37,69 bus system	Static	Hybrid
Huang	2001	DG-1	Location+load	ABC	IEEE 9,37,69 bus system	Static	Hybrid
Salvatore et al.	2007	DG-1	Location +cost	ABC	IEEE 69 bus system	Static	Hybrid
Kotamarty et al.	2008	DG-1	Impact	Contingency analysis	IEEE 15 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Kim et al.	2002	DG-1	Location	FZ+GA	IEEE 37,69 bus system	Static	Hybrid
Wang and Nehrir	2002	DG-1	Location	AP	IEEE 9,33 bus system	Static	Hybrid
Gómez et al.	2004	DG-1	Loss	ABC	IEEE 9,37,69 bus system	Static	Hybrid
Concordia and Ihara	1982	DG-1	Stability	ABC	IEEE 9,33 bus system	Static	Hybrid
Philipson	2000	DG-1	Cost	OT	IEEE 9,39 bus system	Static	Hybrid
Carpinelli et al.	2001	DG-3	Location+size	ABC	IEEE 9,37 bus system	Static	Hybrid
Hsiao and Chien	2001	DG-2	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Vovos et al.	2007	DG-2	Voltage	Hybrid	IEEE 9,37,69 bus system	Static	Hybrid
Bala et al.	1997	DG-1	Loss	Analyzer recorder	IEEE 33,9 bus system	Static	Hybrid
Acharya et al.	2006	DG-1	Location	AP	IEEE 9,33 bus system	Static	Hybrid
Hobbs and Meier	1994	DG-4	Loss+location	OT	IEEE 9,37,69 bus system	Static	MOF
El-Hawary	1998	DG-1	Loss	FZ	IEEE 9 bus system	Static	Hybrid
Carrano et al.	2006	DG-1	Location+loss+cost	GA	IEEE 9,33 bus system	Static	Hybrid
Ramírez-Rosado and Bernal-Agustín	1998	DG-1	Location	GA	IEEE 9,33 bus system	Static	Hybrid
Teng et al.	2002	DG-1	Location	AP	IEEE 15 bus system	Static	Hybrid
Broadwater et al.	1994	DG-1	Fault	AP	IEEE 9,37,69 bus system	Static	MOF
Soroudi et al.	2011a	DG-3	Impact	GA	IEEE 9,33 bus system	Static	Hybrid
Pregelj et al.	2018	DG-1	Location	GA	IEEE 37,69 bus system	Static	Hybrid
Srinivas and Patnaik	1994	DG-4	Cost	GA	IEEE 9,69 bus system	Static	Hybrid
Wu et al.	2010	DG-1	Location +loss	OT	IEEE 9,33 bus system	Static	Hybrid
Carreno et al.	2008	DG-1	Loss	OT	IEEE 9,37,69 bus system	Static	MOF
Pregelj et al.	2006	DG-1	Location	OT	IEEE 9,33 bus system	Static	Hybrid
Parada et al.	2004	DG-3	Location	SA	IEEE 9 bus system	Static	Hybrid
Eduardo et al.	2007	DG-2	Size	Immune system algorithm	IEEE 9,33 bus system	Static	Hybrid
Teng and Liu	2003	DG-1	Location	ABC	IEEE 9,33 bus system	Static	Hybrid
Vlachogiannis et al.	2005	DG-1	Load	ABC	IEEE 9,39 bus system	Static	Hybrid
Merlin and Back	1975	DG-4	Loss	Spanning tree	IEEE 15 bus system	Static	Hybrid
Lee and El-Sharkawi	2002	DG-1	Loss	HA	IEEE 9,37,69 bus system	Static	Hybrid
Dorigo and Gambardella	1997	DG-3	Cost	ABC	IEEE 9,33 bus system	Static	Hybrid
Grenard and Strbac	2003	DG-1	Cost	OT	IEEE 9,39 bus system	Static	Hybrid
Heffner et al.	1998	DG-4	Cost	OT	IEEE 9,39 bus system	Static	Hybrid
Carrano et al.	2005	DG-1	Location	GA+BFGS	IEEE 9,39 bus system	Static	Hybrid
Miranda et al.	1994	DG-1	Location+cost	GA	IEEE 37 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Rizy et al.	1989	DG-1	Voltage	OT	IEEE 9,37,69 bus system	Static	Hybrid
Singh et al.	2007a	DG-1	Voltage+location	AP	IEEE 9,33 bus system	Static	Hybrid
Carvalho et al.	1998	DG-4	Size	Evolutionary convergence method	IEEE 9 bus system	Static	Hybrid
Willis et al.	1996	DG-3	Location	AP	IEEE 9,39 bus system	Static	Hybrid
Singh et al.	2009b	DG-1	Location+cost	AP	IEEE 9,37,69 bus system	Static	Dynamic
Ackermann et al.	2001	DG-2	Location	AP	IEEE 15 bus system	Static	Hybrid
Keane and O'Malley	2005	DG-1	Allocation	ANN	IEEE 9,39 bus system	Static	Hybrid
Gómez et al.	2004	DG-1	Location	ABC	IEEE 9,37,69 bus system	Static	Hybrid
Duan and Yu	2003	DG-1	Cost	OT	IEEE 9,39 bus system	Static	Hybrid
Salazar et al.	2006	DG-1	Loss	ANN	IEEE 9,37,69 bus system	Static	Hybrid
Song et al.	1997	DG-1	Loss	FZ	IEEE 9,33 bus system	Static	Hybrid
Shin et al.	2007	DG-3	Location	Optimal routing algorithm	IEEE 9,39 bus system	Static	Hybrid
Daly and Morrison	2001	DG-1	Cost	OT	IEEE 9,39 bus system	Static	Hybrid
Osborn	2004	DG-1	Cost	OT	IEEE 9,33 bus system	Static	Hybrid
EI-Khattam and Salama	2004	DG-3	Definitions	FZ	IEEE 9,37,69 bus system	Static	Hybrid
Lind and Karlsson	1996	DG-1	Voltage	OT	IEEE 9 bus system	Static	Hybrid
Venkatesh et al.	2000	DG-1	Loss+voltage	FZ	IEEE 9,33 bus system	Static	Hybrid
Jeon et al.	2002	DG-1	Size	SA	IEEE 9,37,69 bus system	Static	Hybrid
Joos et al.	2000	DG-3	Size	OT	IEEE 9,39 bus system	Static	Hybrid
Joos	2008	DG-3	Cost	Quantification method	IEEE 9,37 bus system	Static	Hybrid
Dobson and Lu	1992a	DG-1	Voltage	Bifurcation	IEEE 15 bus system	Static	Hybrid
Hasan et al.	2008	DG-1	Location	AP	IEEE 9 bus system	Static	Hybrid
Carpinelli et al.	2005	DG-3	Location+size	Double trade off method	IEEE 9,33 bus system	Static	Hybrid
Burke et al.	1988	DG-1	Location	Trade off method	IEEE 9,39 bus system	Static	Hybrid
Méndez et al.	2006	DG-1	Loss	OT	IEEE 15 bus system	Static	Hybrid
Ochoa et al.	2008b	DG-1	Location+cost	AP	IEEE 9, 39 bus system	Time varying	Hybrid
Hegazy et al.	2003	DG-2	Adequacy	Monte Carlo simulation	IEEE9,37 bus system	Static	Hybrid
Kataoka	2003	DG-1	Voltage	Probabilistic nodal method	IEEE 9,37,69 bus system	Static	Hybrid
Dobson and Lu	1992b	DG-3	Voltage	OT	IEEE 9,33 bus system	Static	Hybrid
Augugliaro et al.	1999	DG-4	Loss+location	GSA+TS	IEEE 9,39 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Zhu et al.	2006	DG-1	Location	AP	IEEE 9,39,69 bus system	Time varying	Hybrid
El-Khattam et al.	2005	DG-1		OT	IEEE 9 bus system	Static	Hybrid
Celli et al.	2005	DG-4	Location+size	Evolutionary algorithm	IEEE 9,37,69 bus system	Static	Hybrid
Ahuja et al.	2007	DG-1	Cost+size	Hybrid approach	IEEE 9,33 bus system	Static	Hybrid
Donnelly et al.	1996	DG-1	Stability	OT	IEEE 9,37,69 bus system	Static	Hybrid
Reza et al.	2003	DG-1	Stability	OT	IEEE 9,39 bus system	Static	Dynamic
Cânizares	1998b	DG-1	Voltage	Bifurcation method	IEEE 9,39,67 bus system	Static	Hybrid
Chiang et al.	1995	DG-1	Stability	OPF	IEEE 9,39 bus system	Static	Hybrid
Rau and Wan	1994	DG-1	Location	OPF	IEEE 9,33 bus system	Static	Hybrid
Griffin et al.	2000b	DG-1	Loss	ABC	IEEE 9,39 bus system	Static	Hybrid
Celli and Pilo	2001b	DG-4	Location	AP	IEEE 9,37,69 bus system	Static	Hybrid
Sim and Sun	2003	DG-1	Size	ABC	IEEE 15 bus system	Static	MOF
Kim et al.	1998	DG-3	Planning	Algorithm	IEEE 9,39 bus system	Static	Hybrid
Cânizares	1998a	DG-1	Voltage	OT	IEEE 9 bus system	Static	Hybrid
Masters	2002	DG-2	Voltage	AP	IEEE 9,37,69 bus system	Static	Hybrid
Walling et al.	2008	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Löf et al.	1995	DG-4	Voltage	OT	IEEE 9,39 bus system	Static	Hybrid
Cânizares and Alvarado	1993	DG-1	Voltage	OT	IEEE 9,39,69 bus system	Static	Hybrid
Baran and El-Markabi	2007	DG-1	Voltage	Multiagent based technique	IEEE 9,33 bus system	Static	Hybrid
Carrano et al.	2006	DG-2	Location+loss	GA	IEEE 15 bus system	Static	Hybrid
Celli et al.	2005	DG-1	Location +size	MOEA	IEEE 9,37,69 bus system	Static	Hybrid
Greene et al.	1996	DG-1	Voltage	OT	IEEE 9 bus system	Static	Hybrid
Van	1991	DG-1	Voltage	LPF	IEEE 9,37 bus system	Static	Hybrid
Ramirez-Rosado and Bernal-Agustin	1998	DG-2	Power	GA	IEEE 9,33 bus system	Static	Hybrid
Blum and Dorigo	2004	DG-4	Location	ABC	IEEE 9 bus system	Static	Hybrid
Kuo and Wan	2007	DG-1	Location	AP	IEEE 9,39 bus system	Static	Hybrid
Bhowmik et al.	2003	DG-1	Penetration	Model	IEEE 9,39 bus system	Static	Hybrid
Chiou et al.	2004	DG-1	Location	Hybrid algorithm	IEEE 9,33 bus system	Static	Hybrid
Mendoza et al.	2007	DG-3	Voltage	GA	IEEE 15 bus system	Static	Hybrid
Singh et al.	2007	DG-1	Size	OT	IEEE 9 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Ochoa et al.	2006	DG-1	Impacts	Multi objective Index	IEEE 9,69 bus system	Static	Hybrid
Singh et al.	2009b	DG-1	Location	OT	IEEE 9,33 bus system	Static	Hybrid
Mutale et al.	2000	DG-1	Loss	OT	IEEE 9 bus system	Static	Hybrid
Haesen et al.	2005	DG-1	Location +size	GA	IEEE 9,37,69 bus system	Static	Hybrid
Kim et al.	2008	DG-1	Location	FZ+GA	IEEE 15 bus system	Static	Hybrid
Gao et al.	2001	DG-3	Stability+Voltage	GA	IEEE 9 bus system	Static	MOF
Kim et al.	1998	DG-4	Location	HRA	IEEE 9,39 bus system	Static	Hybrid
Hetzer et al.	2008	DG-3	Cost	OT	IEEE 9,33 bus system	Static	MOF
Shim et al.	2005	DG-2	Cost + location	OT	IEEE 9,37,69 bus system	Static	Hybrid
Cheng and Kou	1994	DG-1	Location	SA	IEEE 9,39 bus system	Static	Hybrid
Prasad et al.	2005	DG-1	Location	GA	IEEE 9,37,69 bus system	Static	Hybrid
Chiradeja and Ramakumar	2004	DG-1	Benefits	GA	IEEE 9,37,69 bus system	Static	Hybrid
Das et al.	1994	DG-2	Location	OT	IEEE 9 bus system	Static	Hybrid
Chis et al.	1997	DG-2	Location	HA	IEEE 9,37,69 bus system	Static	Hybrid
Vitorino et al.	2000	DG-1	Loss	OT	IEEE 15 bus system	Static	Hybrid
Chandramohana et al.	2010	DG-3	Cost	GA	IEEE 9,33 bus system	Static	Hybrid
Gomes et al.	2006	DG-1	Loss	OPF	IEEE 9,37,69 bus system	Static	Hybrid
Liu et al.	1988	DG-1	Loss	OT	IEEE 9 bus system	Static	Hybrid
Quezada et al.	2006	DG-1	Loss	GA	IEEE 37 bus system	Static	Hybrid
Nag et al.	2000	DG-4	Location	OT	IEEE 9 bus system	Static	Hybrid
Le et al.	2007	DG-1	Loss+cost	OT	IEEE 37,69 bus system	Static	Dynamic
Le et al.	2005	DG-1	Voltage	OT	IEEE 15 bus system	Static	Hybrid
Wang and Nehrir	2004	DG-1	Power	AP	IEEE 9,37,69 bus system	Static	Hybrid
Gözel and Hocaoglu	2009	DG-1	Location+size	AP	IEEE 9 bus system	Static	Hybrid
Vasebi et al.	2007	DG-1	Loss+cost	HA	IEEE 9,33 bus system	Static	Hybrid
Teng	2003	DG-1	Location+loss	LFT	IEEE 9,37,69 bus system	Static	Hybrid
Acharya et al.	2006	DG-4	Allocation	AP	IEEE 9 bus system	Static	Hybrid
Harrison et al.	2008	DG-3	Size	GA+OPF	IEEE 9,69 bus system	Static	Hybrid
Nagendra Rao and Ravishankar Deekshit	2006	DG-2	Loss	OT	IEEE 9,37 bus system	Static	Hybrid
Thomson	2007	DG-4	Loss	OPF	IEEE 9,37,69 bus system	Static	Hybrid
Dent et al.	2010	DG-1	Capacity	OPF	IEEE 15 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Borges and Falcao	2006	DG-1	Cost+location+voltage	OT	IEEE 9,33 bus system	Static	Hybrid
Jabr and Pal	2009b	DG-1	Location+size	OT	IEEE 15 bus system	Static	Hybrid
Popovic et al.	2005	DG-1	Location	OT	IEEE 9,37 bus system	Static	Hybrid
Vovos et al.	2005	DG-1	Fault	OPF	IEEE 9,37,69 bus system	Static	Hybrid
Ayed et al.	2009	DG-1	Loss	Model	IEEE 9 bus system	Static	Hybrid
Barker and De Mello	2000	DG-1	Loss	OT	IEEE 9,39 bus system	Static	Hybrid
Moradi and Abedini	2012	DG-4	Size+location	GA+PSO	IEEE 9,37,69 bus system	Static	Hybrid
Shirmohammadi et al.	1988	DG-1	Loss	OPF	IEEE 9,33 bus system	Static	Hybrid
Ochoa et al.	2010	DG-1	Capacity	Model	IEEE 9 bus system	Static	Hybrid
Soroudi and Ehsan	2011	DG-3	Loss	OT	IEEE 9,37,69 bus system	Static	Hybrid
Wang and Hsshem	2004	DG-3	Location	AP	IEEE 9,69 bus system	Static	Hybrid
Ochoa et al.	2008d	DG-2	Capacity	OT	IEEE 9,37 bus system	Static	Hybrid
Karki and Billinton	2004	DG-2	Cost	OT	IEEE 15 bus system	Static	Hybrid
Salameh et al.	1995	DG-1	Capacity	OT	IEEE 9 bus system	Static	Hybrid
Keane and O'Malley	2007	DG-1	Loss	OT	IEEE 9,33 bus system	Static	Hybrid
Keane and O'Malley	2006	DG-4	Power loss	OPF	IEEE 9,37,69 bus system	Static	Hybrid
Su	2010	DG-1	Voltage	Detailed distribution models	IEEE 9,37,69 bus system	Static	Hybrid
Delbem et al.	2005	DG-1	Loss	Evolutionary algorithm	IEEE 9,69 bus system	Static	Hybrid
Greatbanks et al.	2003	DG-1	Security and capacity	OT	IEEE 9 bus system	Static	Hybrid
Liang and Wang	2003	DG-1	Power +voltage	FZ	IEEE 9,33 bus system	Static	MOF
El-Khattam et al.	2004	DG-1	Cost	OT	IEEE 9 bus system	Static	Hybrid
Moshtagh et al.	2010	DG-4	Size+location	PSO	IEEE 9,39 bus system	Static	Hybrid
Khalesi et al.	2011	DG-1	Location+loss	Dynamic programming	IEEE 9,37,69 bus system	Static	Hybrid
Popovic et al.	2005b	DG-4	Security + Reliability	OT	IEEE 9,33 bus system	Static	Hybrid
Borges and Falcao	2006	DG-3	Voltage+ Losses+Location	OT	IEEE 9 bus system	Static	Hybrid
Liu et al.	2009	DG-1	Power +voltage	Switching operations	IEEE 9 bus system	Static	Hybrid
Boehme et al.	2007	DG-1	Load	OPF	IEEE 9,37,69 bus system	Static	Hybrid
Boehme et al.	2010	DG-1	Size	OT	IEEE 9,37,69 bus system	Static	Hybrid
Teng et al.	2007	DG-3	Reliability + cost	OT	IEEE 9,33 bus system	Static	Hybrid
Keane et al.	2011	DG-3	Voltage	PSO	IEEE9,37,69 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Park and Lee	2005	DG-1	Cost	PSO	IEEE 9,33 bus system	Static	MOF
Selvakumar and Thanushkodi	2007	DG-1	Cost	PSO	IEEE 9,37,69 bus system	Static	Hybrid
Su and Lee	2001	DG-1	Loss	OT	IEEE 9 bus system	Static	Hybrid
Chang	2008	DG-1	Loss	ABC	IEEE 9,37,69 bus system	Static	Hybrid
Carvalho et al.	2008	DG-1	Power +voltage	ABC	IEEE 9,33 bus system	Static	MOF
Haghifam et al.	2008	DG-1	Location	AP	IEEE 9,37,69 bus system	Static	Hybrid
Lee and Park	2009	DG-1	Location +size	Kalman filter algorithm	IEEE 9,37,69 bus system	Static	Hybrid
Abu-Mouti and El-Hawary	2007	DG-3	Loss	OPF	IEEE 9,33 bus system	Static	Hybrid
Basturk and Karaboga	2006	DG-3	Loss+cost	ABC	IEEE 9 bus system	Static	Hybrid
Mekhameer et al.	2002	DG-3	Loss	FZ+HA	IEEE 9,33 bus system	Static	Hybrid
Shukla et al.	2010	DG-1	Size	AP	IEEE 9,37,69 bus system	Static	Hybrid
Roy et al.	2010	DG-4	Impact	Wind generation	IEEE 9 bus system	Static	Hybrid
Sundhararajan and Pahwa	1994	DG-4	Loss	GA	IEEE 9,37,69 bus system	Static	Hybrid
Gallego et al.	2001	DG-1	Loss+location	OT	IEEE 15 bus system	Static	Hybrid
Akorede et al.	2011	DG-1	Location	OT	IEEE 9,33 bus system	Static	Hybrid
Zong	2009	DG-3	Location+loss	HA	IEEE 9 bus system	Static	Hybrid
Gonzlez-Longatt	2007	DG-1	Impact +loss	ABC	IEEE 9 bus system	Static	Hybrid
Wang and Singh	2008	DG-1	Location	ABC	IEEE 39 bus system	Static	Hybrid
Dan et al.	2006	DG-4	Reliability + Efficiency	Time-Varying Loads	IEEE 69 bus system	Static	Hybrid
Cözel and Hocaoglu	2009	DG-1	Size+location	OT	IEEE 9 bus system	Static	Hybrid
Ghosh et al.	2010	DG-4	Size+location	OT	IEEE 13 bus system	Static	Hybrid
Naresh et al.	2006	DG-1	Allocation	AP	IEEE 9 bus system	Static	Hybrid
Alarcon-Rodriguez et al.	2009	DG-1	Loss+cost	OT	IEEE 69 bus system	Static	Hybrid
Hamedi and Gandomkar	2012	DG-1	Location+loss	OT	IEEE 39 bus system	Static	Hybrid
Mendoza et al.	2009	DG-1	Loss+location+size	MMR Algorithm	IEEE 13 bus system	Static	MOF
Soo-Hyoung and Jung-Wook	2009	DG-1	Location +size	Kalman Filter Algorithm	IEEE 9 bus system	Static	Hybrid
Mardaneh and Gharehpetian	2004	DG-1	Location+size	GA+OPF	IEEE 9 bus system	Static	Hybrid
Senjyu et al.	2008	DG-1	Voltage	ABC	IEEE 13 bus system	Static	Hybrid
Zhang et al.	2008	DG-4	Loss	OT	IEEE 69 bus system	Static	Hybrid
Karaboga and Basturk	2007	DG-3	Location	ABC	IEEE 69 bus system	Static	Hybrid
Rao et al.	2008	DG-2	Loss	ABC	IEEE 13 bus system	Static	Hybrid
Keane et al.	2009	DG-1	Cost+location	OT	IEEE 39 bus system	Static	Hybrid
Jabr and Pal	2009b	DG-1	Location +sizing	Ordinal Model	IEEE 13 bus system	Static	Hybrid
Tuitemwong and Premrudeepreechacharn	2011	DG-4	Protection	OT	IEEE 9 bus system	Static	Hybrid

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Table 3.1 (continued)

Author	Year	Different types of DGs	Objective function	Algorithms	Test system	Different types of load model	Future work
Harrison and Wallace	2005	DG-1	Capacity	GA	IEEE 69 bus system	Static	MOF
Keane and O'Malley	2005	DG-3	Allocation	Model	IEEE 13 bus system	Static	Hybrid
Acharya et al.	2006	DG-2	Allocation	AP	IEEE 69 bus system	Static	Dynamic
Kejun et al.	2011	DG-2	Allocation	GA	IEEE 38 bus system	Static	Hybrid
Payasi et al.	2013	DG-2	Voltage	GA	IEEE 38 bus system	Static	Hybrid
Singh et al.	2007b	DG-2	Loss+Voltage	GA	IEEE 38 bus system	Static	Hybrid
Singh et al.	2009c	DG-2	Loss+Voltage	GA	IEEE 38 bus system	Static	Hybrid
IEEE Task Force	1993	DG-2	Loss+Voltage	GA	IEEE 38 bus system	Static	Hybrid
Tiwari and Ghatak	2017	DG-2	Loss+Sizing	GA+DSTATCOM	IEEE 37 bus system	Static	Hybrid
Mishra and Singh	2017	DG-2	Loss+Sizing+Voltage	GA	IEEE 37 bus system	Static	Hybrid
Mahdi et al.	2016	DG-4	Loss+Sizing	PSO	IEEE -39 bus system	Static	Hybrid
Raju et al.	2016	DG-1	Loss+Sizing	Tabu Search Algorithms	IEEE -39 bus system	Static	Hybrid
Rajendran and Narayanan	2017	DG-3	Loss+Sizing+Voltage	Ant Bees Colony	IEEE 9 bus system	Static	Hybrid
Srivastava et al.	2016	DG-1	Loss+Sizing	PSO+GSA	IEEE 37 bus system	Static	Multi-task
Avyappa and Gaonkar	2016	DG-4	Loss+Voltage	GA	IEEE 9 bus system	Static	Multi-task
Singh et al.	2015b	DG-2	Loss+Sizing+Voltage	GA	IEEE 37 bus system	Static	Multi-task
Singh and Parida	2015	DG-2	Loss+Sizing+Voltage	PSO	IEEE -39 bus system	Static	Multi-task
Lu et al.	2018	DG-3	Loss+Sizing	ST	IEEE -37 bus system	Static	Multi-task
Herlambang et al.	2018	DG-2	Loss+Sizing+Voltage	GA	IEEE 9 bus system	Static	Hybrid

Table 4.1

The different conventional methods are reviewed in literatures for impact assessment of optimally placed DGs.

Conventional methods	No. of literatures reviewed out of 81	% of literatures reviewed out of 81
Eigenvalues method	4	2.9%
Modal method	38	27.94%
Added model method	26	19.11%
Index method	13	9.5%
OPF	28	20.5%
PST	5	3.68%
Monte-carlo method	3	2.21%
Tradeoff method	5	3.68%
LPF	11	8.09%
Newton–Raphson	3	2.21%

Table 4.2

The different Artificial intelligence techniques are reviewed in literatures for impact assessment of optimally placed DGs.

Artificial intelligence techniques	No. of literatures reviewed out of 188	% of literatures reviewed out of 188
Genetic algorithms	72	38.64
Artificial neural network	9	5.05
Fuzzy logic	9	5.05
Particle swarm optimization	20	10.64
Ant bees colony	29	16.29
Gravitational search algorithms	2	0.56
tabu search	2	1.12
Simulated annealing	4	2.24
Heuristic algorithms	15	8.42
Kalman filter algorithms	3	1.68
Two stage planning algorithms	1	0.56
MMR algorithms	1	0.56
Evolutionary algorithms	2	1.12
Optimal algorithms	1	0.56
Immune system algorithms	1	0.56
Hereforced algorithms	2	1.12
Other	15	8.42

Table 4.3

The different optimization methods are reviewed in literatures for impact assessment of optimally placed DGs.

Optimization methods	No. of literatures reviewed out of 178	% of literatures reviewed out of 178
Dynamic programming method	36	20.22%
Linear programming method	20	11.23%
Non-Linear programming method	62	34.83%
Mixed integer non-linear programming method	44	24.71%
Dual programming method	5	2.80%
Other programming method	11	6.17%

Table 4.4

The different hybrid intelligence techniques are reviewed in literatures for impact assessment of optimally placed DGs.

Artificial intelligence techniques	No. of literatures reviewed out of 18	% of literatures reviewed out of 18
FZ + GA	6	35.29%
PSO + Model	1	5.88%
OPF + Newton method	1	5.88%
TS + SA	1	5.88%
PSO + FZ	2	11.76%
GA + BFGS	1	5.88%
GSA + TS	1	5.88%
GA + OPF	2	11.76%
GA + PSO	2	11.76%
FZ + HA	1	5.88%

Table 4.5

The different other techniques are reviewed in literatures for impact assessment of optimally placed DGs.

Other techniques	No. of literatures reviewed out of 4	% of literatures reviewed out of 4
Wind generation	2	50%
Industrial Planning	1	25%
Switching operation	1	25%

5. Conclusions and future scope

5.1. Conclusions of papers

The following conclusions from this survey article A survey on enhancement of power system performances by optimally placed DG in distribution networks as follows:

- Improve power system security.
- Reduction of power system oscillation.
- Improve power system reliability.
- Improve the available power transfer capability capacity of system.
- System power factor Improvement.
- Bandwidth of operation increase.
- Enhancement of system voltage profile.
- Enhancement the loadability of system.
- Reduce the SSR problems.
- Improve power system stability.
- Reduction of real and reactive power losses of the system.

5.2. Future scope of paper

The future scopes of this work are as follows:

- Two or more DG can be used in hybrid manner to improve the power system performances.
- In future the type of DG such as DG-1, DG-2, DG-3 and DG-4 can be used for reactive power supporter in power distribution system for enhancement of voltage profile.
- The different type of Artificial intelligence technique such as PSO, Tabu search, search algorithm, Ant bees colony algorithm, Simulated annealing algorithm etc. can be use in future for the optimal placement of DG in distribution power system for enhancement of power system performances.
- Hybrid artificial intelligence technique such as combination of FZ + GA, PSO + Model, OPF + Newton method, TS + SA, PSO + FZ, GA + BFGS, GSA + TS, GA + OPF, GA + PSO, FZ + HA etc. can be use for the optimal placement of DG in distribution power system for enhancement of power system performances.
- Overall cost of per unit electricity is reduced due to minimization of real and reactive power loss of the system by using DGs.
- Practical implementations of these things are possible for benefits of society.

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