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Optimal Placement Methods of Distributed Generation:A Review

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***Abstract*—Distributed Generation (DG) has been growing rapidly in power systems due to their potential solution for issues, like the deregulation in power system, to meet the power demand and the shortage of transmission capacities. Improper allocation of DG sources in power system would not only lead to increase power or energy losses, but can also jeopardize the system operation. The optimal placement of DG is necessary for the maximization of reliability and stability in power system. There are several research studies to solve DG placement problem by various objectives and their imposed constraints. However, the methodical principle for this subject is still an obscure problem. This paper presents an overview and general backgrounds of research and development in the field of different solution methods for optimal placement of DG found in the literature .This paper has reviewed some of the most popular methods including analytical technique, optimal power flow methods (OPF) and evolutionary computational methods. This paper provides useful guidelines for the future studies for those interested in the problem or intending to do additional research in this area.**

***Keywords*- Distributed generation (DG); optimal location; analytical methods; optimal power flow (OPF); evolutionary computational methods**

I. INTRODUCTION

Distributed power generation is a technology that could help to enable efficient, renewable energy production both in developed and developing world. Distributed generation (DG) is related with the use of small generating unit installed at strategic point of electric power system or locations of load centre's [1]. Distributed generation is an electric power source connected directly to the distribution network or on the customer site of the meter [2].DG can be used in an isolated way, supplying the customer's local demand, or integrated into the grid supplying energy to remainder of the electric power system. DG technologies includes engines, small wind turbines, fuel cells and photovoltaic system .DG technologies can run on renewable energy resources, fossil fuels or waste heat. Equipment ranges in size from less than a (kW) to tens of megawatts (MW). Despite their small size, DG technologies are having a stronger impact in electricity markets. In some markets, DGs are actually replacing the more costly grid electricity. DG can meet all or part of a customer's power needs. If connected to a distribution or transmission system, power can be sold to the utility or a third party. The main reasons for the increasingly widespread use of DG can be summed up as follows [1]:

- It may be more economic than running a power line to remote locations
- It provides primary power, with the utility providing backup and supplemental power
- It can provide backup power during utility system outages, for facilities requiring uninterrupted service
- It can provide higher power quality for electronic equipment
- For reactive supply and voltage control of generation by injecting and absorbing reactive power to control grid voltage
- For network stability in using fast response equipment to maintain a secure transmission system
- For system black-start to start generation and restore a portion of the utility system without outside support after a system collapse

The optimal placement of DG has attracted many researchers' attention recently due to its ability to obviate defects caused by improper installation of DG units, such as rise in system losses, decline in power quality, voltage increase at the end of feeders and etc [48]. Integrating DG sources within the network can improve both the reliability and efficiency of the power supply; release the available capacity of the distribution substation as well as reducing thermal stresses caused by loaded substations, feeders, and ancillary equipment; improve the system voltage profiles as well as the load factor; and delay the imminent upgrade of the present system or the need to build newer infrastructure. The extent of these benefits depends on how the DG is placed and sized in a system. In addition to supplying the system with the power needed to meet certain demands as an installation incentive, the real power losses could be minimal if the DG is optimally sited and sized. DG optimal allocation and sizing is an ongoing research area [55]. The exact solution of the DG allocation can be obtained by a complete enumeration of all feasible combinations of sites and sizes of DGs in the network [17].

Several methods have been proposed in determining the optimal location of DG [3-55]. The majority of DG placement objectives were power or energy losses in the network. In addition, other technical parameters like voltage profile, reliability of distribution network, line loadings, reactive power requirement, maximizing DG capacity, investment cost, operating cost, and etc have also been considered to form single or multi objective problem formulation in different studies.

Some authors [3-13] have used the analytical techniques for optimal allocation of DG in terms of different load types. The references [14-23] have applied power flow algorithms optimal DG placement at each load bus; such that DG can be placed at every load bus. Moreover, many authors have applied the evolutionary computational techniques for finding the optimal location and size of DG [23-53]. The Hereford Ranch Algorithm (HRA) [15,17], Genetic algorithm (GA) [24-35,37,41-42,52],Simulated Annealing (SA) [35-37], Evolutionary programming (EP) [38-40],Decision Theory [41,43], Fuzzy systems [42,44-45,51],Ant Colony optimization (ACO) [46-47,52],Particle Swarm optimization (PSO) [48-49,52],Tabu search (TS) [50-52],Differential Evolution [52], Immune algorithm based optimization (IA) [53] and Bee Colony optimization algorithm (BCO) [54] have come to be the most widely used tools for solving optimal DG allocation problem .

The proposed works aim to present the overview and key issues of previously considered methods for optimal siting and sizing in DG placement problem. No attempt is made here to prove the effectiveness of the solution technique applied by researchers for optimal allocation of DG.

II. REVIEW OF LITRATURE

This paper gives general backgrounds of research and development in the field of optimal placement of DG in power system network based on over 50 published articles. The following open literature presents the summary and application of each method for optimal placement of DG in power system network. The related assumptions made, strengths and weaknesses of each solution methods are highlighted.

In January 2000, Griffin, Tomsovic, Secrest and Law [3] presented an analytical approach to determine proper location of DG units on the power grid, with respect to system losses. The study shows the importance of placement for minimizing losses and maximizing capacity savings. The authors report that this method leads to a 10% reduction of losses transmission system, with near optimal placement of DG units on the power grid. The authors have also investigated the system losses and sensitivities on Eastern Washington system as part of the larger WSCC system. Still, the analysis here suggests that the net thermal losses arising from different placement varies greatly, and further, that one must consider both transmission and distribution effects when determining appropriate locations.

In July 2000, Willis [4] described analytical methods and rules of thumb methods to solve the DG placement problem. The first method is “zero point analysis” that focuses on the point on the feeder (if it exists) where power flow is zero, due to the DG unit output. The author report that the closer the zero point is to the substation, the greater the potential T&D capacity requirement reduction wrought by the DG, but the greater the potential for significant and complicated impacts with operating dynamics and protection needs. The second technique for DG placement is “2/3 rule” that is often used for capacitor placement in radial distribution systems. The proposed method has been employed for minimizing the losses and voltage impacts and for using in feeders with uniform loads. For a feeder with a uniform kVAR load, this rule has presented that the best capacitor size is 2/3 of the kVAR load which is located at the 2/3 of the distance out the feeder.

In June 2003, Borges and Falcao [5] presented an approach for determining the impact of installation of DG units on electric losses, voltage profile and reliability of distribution network. The voltage profile and electric losses evaluation is based on a power flow method with the representation of generators as PV buses. The reliability indices evaluation is based on analytical methods modified to handle multiple generations. The authors have specified that the methodology may be used to determine the consequence of the location and the capacity of DG on these system performance characteristics for distribution generation expansion planning alternatives. The results obtained with the proposed methodology for test systems have been shown, revealing the applicability of the method.

In November 2004, Wang and Nehrir [6] presented analytical methods to determine the optimal placement of DG with unity power factor in radial as well as networked systems to minimize the power loss of the system. Firstly, placement of DG in a radial feeder is analyzed and the theoretical optimal site (bus) for adding DG is obtained for different types of loads and DG sources. Then, a method is presented to find the optimal bus for placing DG in a networked system based on bus admittance matrix, generation information and load distribution of the system. The proposed methods are tested by a series of simulations on radial feeders, an IEEE 6-bus test system, an IEEE 30-bus test system, and a subset of it. Simulation results have been given to verify the proposed analytical approaches.

In November 2005, Gozel, Hocaoglu, Eminoglu and Balikci [7] presented and evaluated an analytical method based on the effects of the load modeling for optimum size and location of DG in a radial system to minimize total power losses for the uniformly, centrally and increasingly distributed load profile. The optimal DG size and location which is determined by the analytical approach is validated against the results obtained by the classical grid search algorithm for each type of loads. The authors report that the radial feeder is simulated with different load types to examine the system loss and voltage profile. It is indicated that; optimal size and placement of DG are different for each distributed load profile; optimal size and location of the theoretical analysis are valid for constant power, current and impedance load models. It is found that while optimum size of the DG is heavily under influence of the load models, the optimum location does not change with the chosen model.

In February 2006, Acharya, Mahat and Mithulananthan [8] proposed an analytical expression to calculate the optimal size and an effective methodology to identify the corresponding optimum location for DG placement for minimizing the total power losses in primary distribution systems. The analytical expression and the methodology are based on the exact loss formula. The effect of size and location of DG with respect to loss in the network have been examined in detail. The proposed methodology have been tested and validated in three distribution test systems with varying size and complexity. The authors report that the results obtained from the proposed methodology are compared with that of the exhaustive load flows and loss sensitivity method and show that the loss sensitivity factor based approach may not lead to the best placement for loss reduction.

In February2006 Zhu, Broadwater, Tam, Seguin and Asgeirsson [9] discusses two criteria for the optimal placement of a DG for time-varying loads. First one is to maximize the reliability improvement, and the other is to minimize the power loss in the system. The authors have examined a three-circuit example for quantitative analysis. The results show that both reliability and losses vary as a function of loading or time. The authors have provided observations and recommendations concerning DG placement for optimum reliability and efficiency. Economic impacts have also been considered.

In June 2006, Payyala and Green [10] described a methodology for performing a combined Techno-Economic assessment of biomass-fuelled generators. It aims at calculating the optimal plant size and location that is justified in terms of economic as well as technical considerations. The economic aspects of the assessment involve determining the economically optimal size of a given biomass power plant depending on resource related costs and, in turn, the economic viability of the project. The technical aspects of the assessment check for the possibility that, in the given distribution network, the economically optimal plant might cause breaches of limits on line flow, voltage, fault current or power loss. A breach would lead to a curtailment of plant capacity in steps so as to avoid that breach. The curtailed plant sizes are reassessed for economic viability. In the case of line active power loss, the sensitivity of loss to each Distributed Generation (DG) plant location and size can be used to select candidate DG sites for curtailment. The suggested approach is tested on a realistic network model, a part of UK distribution network in East Anglia and the resulting DG placement solutions compared.

In June 2009, Gozel and Hocaoglu [11] described a loss sensitivity factor, based on the equivalent current injection, for the distribution systems. The formulated sensitivity factor has been employed for the determination of the optimum location and size of DG to minimize total power losses by an analytical method without use of admittance, impedance or Jacobian matrix for radial systems. The authors report that the proposed method is in close agreement with the classical grid search algorithm based on successive load flows.

In May 2010, Parizad , Khazali and Kalantar [12] presented two scenarios for distributed generation placement in a distributions system. The first scenario deals with minimization of the total real power losses in the system. The authors report that the optimal size and location have been obtained as outputs from the exact loss formula. In the next scenario voltage stability index has been considered to find optimum placement. In these scenarios different DG placements have been compared in terms of power loss, loadability and voltage stability index. To improve power transfer capacity, two line stability indices have been introduced. The proposed distribution power flow solution algorithm is based on the equivalent current injection that uses the bus-injection to branch-current (BIBC) and branch-current to bus-voltage (BCBV) matrices. These proposed scenarios are executed on typical 33 and 30 bus test system and yielded in improvement of voltage profile and reduction of power losses and may also permit an increase in power transfer capacity, maximum loading, and voltage stability margin.

In September 2010, Feng and Qi [13] presented the analytical approaches for optimal placement of DG with unity power factor in radial system to minimize power losses. The proposed approaches are not iterative algorithms, like power flow programs. Placement of DG in a radial feeder has been analyzed and the theoretical optimal site (bus) for adding DG has been obtained for different types of loads and DG sources. The proposed methods have been tested by a series of simulations on radial feeders to show the effectiveness of the proposed methods for determining the optimal bus for placing DG. The authors report that there is no convergence problems involved, and results can be obtained very quickly.

In November 1994, Rau and Wan [14] proposed a method to optimally allocate DG resources in a meshed network for maximizing the potential benefits .The benefit expressed as a performance index can be the minimization of network losses, var losses, line loadings, and reactive power requirement. The convergence properties of the proposed algorithm have been examined with a six bus test system. The results obtained for the reduced gradient method did not converge for small nodal injections. The authors report that the second order methods with proposed transformation of variables speedily yielded convergence to the global minimum. The computational requirements (memory and speed) to process a larger realistic system are the subject of future investigations.

In January 1998, Kim, Nam, Park and Singh [15] proposed a new method to optimally locate dispersed generation in a meshed network for minimization of losses using Hereford ranch algorithm (HRA). The proposed method has been tested for several sample power systems with 6, 14 and 30 bus types. The results of proposed method are compared with those of classical GA and conventional second-order method to show to show the effectiveness of the proposed method.

In July 2003, Khattam, Hegazy, and Salama [16] proposed a Monte Carlo based power flow algorithm that integrates the deterministic and the stochastic natures of the new structured, electrical distributed generation systems. The proposed algorithm incorporates the uncertainties in both the locations and the states (on or off) of the DG units with the Newton- Raphson solution of the power flow equations. The authors report that the Monte Carlo simulation is employed to perform the analysis of all the possible operation scenarios of the system under study and thus ensure the validity of the results. The proposed algorithm is employed to obtain the power flow solution for a typical DG connected system and the results obtained are presented and discussed.

In September 2005, Gandomkar, Vakilian and Ehsan [17] illustrated the implementation of Hereford Ranch Algorithm (HRA) to determine optimal site and size of DG in distribution feeders to minimize the distribution power losses under the condition that number of DGs and total capacity of DGs are known. HRA uses sexual differentiation and selective breeding in choosing parents for genetic string. The proposed method has been tested for 34-node IEEE distribution test feeder. The results prove that the proposed algorithm performs better than the individuals SGA, in terms of both solution quality and number of iterations.

In October 2005, Momoh and Boswell [18] developed an approach for coordinating DG on a grid/micro-grid and solve the resource allocation problem in the framework of a voltage stability constrained optimal power flow. Continuation Power Flow (CPF) was used to determine weak voltage nodes that are vulnerable to voltage collapse as well as determination of the voltage stability margin (VSM). The impact assessment of DG is computed in terms of the added value to the Locational Marginal Price (LMP) differentials between neighboring network nodes as well as across area boundaries. LMP was used to compute the market implications of installing DG sources. The value of DG (or its detrimental impacts) is monitored and the corresponding Available Transfer Capabilities (ATC) of critical interfaces was determined. The feasibility of the developed approach for value-based DG implementation was tested on a 30-bus 330kV high voltage system model.

In May 2006, Khattam, Hegazy, and Salama [19] presented a novel algorithm that incorporates the deterministic and the stochastic natures of electric distribution systems, including DG systems in analyzing their steady-state performance. The algorithm incorporates Monte Carlo simulation with the traditional Newton–Raphson method to cover all possible operation conditions of the systems. The uncertainties in the locations, exported penetration level, and the states (on or off) of the DG units constitute the random parameters of the studied systems. The proposed algorithm is employed to obtain the hourly power flow solution for a typical DG connected system. Furthermore new hourly steady-state operating system parameters are evaluated to describe the system behavior under the DG random operation. The results obtained are presented and discussed.

In December 2006, Gautam and Mithulananthan [20] presented two new methodologies for optimal placement of distributed generation (DG) in an optimal power flow (OPF) based wholesale electricity market. The problem of optimal location and size of DG has been identified for social welfare as well as profit maximization problem. The candidate locations for DG placement have been identified on the basis of locational marginal price (LMP). Obtained as lagrangian multiplier associated with active power flow equation for each node, LMP gives the short run marginal cost (SRMC) of electricity. Consumer payment has been evaluated as a product of LMP and load at each load bus, is proposed as another ranking to identify candidate nodes for DG placement. The authors report that the proposed rankings bridges engineering aspects of system operation and economic aspects of market operation and act as good indicators for the placement of DG, especially in a market environment. In order to provide a scenario of variety of DGs available in the market, several cost characteristics have been assumed. For each DG cost characteristic, an optimal placement and size has been identified for each of the objectives. The proposed methodology has been tested in a modified IEEE 14 bus test system.

In January 2010, Ghosh, Ghoshal and Ghosh [21] presented a simple search approach determining for optimal location and size of DG using Newton Raphson method of load flow study. The multiobjective optimization covers optimization of both cost and loss simultaneously. The proposed technique has been examined with modified IEEE 6 bus, IEEE 14 bus and IEEE 30 bus systems. The authors report that the paper also focuses on optimization of weighting factor, which balances the cost and the loss factors and helps to build up desired objectives with maximum potential benefit.

In May 2011, Khanabadi, Doostizadeh, Esmaeilian and Mohseninezhad [22], discussed optimal distributed generation (DG) sizing and placement in order to eliminate power system's congestion based on AC optimal power flow (ACOPF) with binary variables and is solved by using mixed integer programming (MIP). . DG's have nonlinear impacts on the power system characteristics such as, the power transmitted between two locations of the network. A procedure is proposed, which uses ACOPF to completely capture the impacts of installing DG on system's variables. The IEEE-14 bus test system results showed that with optimal DG's sizing and sitting, total operation cost can be decreased and transmission congestion can be totally relieved. These results lead to lower energy prices for loads and consequently improve social welfare. Also, DG's operations in electricity market become economical and losses across the system have been decreased significantly.

In March 2011, Tang and Wu [23] proposed a new method of DG optimal placement based on load centroid based on of the analysis of the influence of the site and capacity of DG on power loss and voltage distribution. This method avoids the complicated process of traditional optimization algorithms. The authors report that the district DG supplied has been thought as an irregular shape load block and the load size has been thought as quality. When the DG is installed in the load centroid of its power circle, the radius of DG power supply area is decreased, and the power loss of the distribution network is reduced. The proposed method avoids the complicated process of traditional optimization algorithms. The method is proved to be effective and accurate through the simulation example.

In September 1999, Silvestri, Berizzi, and Buonanno [24] presented a new technique, based on GA, for the optimal sizing and siting of distributed generation resources (DG) in MV distribution networks. Different objective functions have been used, in order to account for the different benefits of DG (minimization of the cost of power losses, network reinforcements and energy production cost). The proposed technique has been tested on two networks of 43 and 93 busses to show the efficiency of the proposed technique.

In May 2001, Celli and Pilo [25] proposed a new software procedure, based on a GA to establish the optimal distributed generation (DG) allocation on an existing MV distribution network, considering all the technical constraints, like feeder capacity limits, feeder voltage profile and three-phase short circuit current in the network nodes. The authors report that the power losses cost during a prefixed period of analysis can be minimized and investments for grid upgrades can be put off. In order to show the capability of the proposed methodology, an area of the real MV Italian network has been considered.

In September 2004, Mithulananthan, Oo and Phu [26] presented a GA based distributed generator (DG) placement technique in a distribution system for minimizing the total real power losses in the system. The GA toolbox gives both optimal size and the locations as outputs. The results have been verified using two popular power flow analytical tools for distribution system load flow. The proposed technique also evinces the importance of selecting the correct size and suitable location or minimizing the system losses.

In May 2005, Celli, Ghiani, Mocci and Pilo [27] proposed a multiobjective (MO) formulation for the siting and sizing of DG resources into existing distribution networks by minimizing different functions related to the cost of energy losses, the cost of service interruptions, the cost of network upgrading, and the cost of energy purchased. Such objectives should be met subject to the network power flow equations as well as to the limits on the bus voltages, steady state current and short circuit currents. The implemented technique is based on a GA and a ε-constrained method that allows obtaining a set of non-inferior solutions. The results obtained by the application of the methodology are deeply discussed to highlight the usefulness of the MO approach.

In September 2005, Kamalinia, Afsharnia, Khodayar, Rahimikian, and Sharbafi [28] presented ratio questioning technique along with genetic algorithm (GA) and Analytic Hierarchy Process (AHP) are used as facilities to implement a strategic planning framework of DG placement and penetration level. The approach consists of GA for determining the best generation configurations of system by considering technical parameters that are included in the fitness function; and MADM techniques for ranking the selected plans regard to technical and economical attributes. The technical parameters of system, including total losses, buses voltage profile, lines capacity limits and total reactive power flow have been considered with appropriate priorities applied to each objective and the economical parameters are the emissions, congestion and capital cost. The proposed approach is illustrated by case studies on IEEE 30 bus distribution system which demonstrate significant improvement in optimization through this procedure.

In February2006, Borges and Falcao [29] presented a method for optimal DG units allocation and sizing in order to minimize the primary distribution network losses and to guarantee acceptable reliability level and voltage profile. The optimization process is solved by the combination of GA techniques with methods to evaluate DG impacts in system reliability, losses and voltage profile. The authors report that the fitness evaluation function that drives the GA to the solution is the relation between the benefit obtained by the installation of DG units and the investment and operational costs incurred in their installation. The losses and voltage profile evaluation is based on a power flow method for radial networks with the representation of DG. The reliability indices have been evaluated based on analytical methods modified to handle multiple generations. The present methodology was applied to three different distribution systems and results showed that the proposed method is robust, with moderate computer requirements, and produce solutions satisfying the imposed constraints and presenting a considerable improvement in the used optimization criterion.

In September 2007, Beromi, Sedighizadeh, Bayat and Khodayar [30] used GA as solving tool for the allocation of generators in distribution networks, in order to improve voltage profile and loss reduction in distribution network. Considering the sensitivity of the fitness values in GA, it is required to apply the load flow for a desirable decision making. . Load flow algorithm is combined suitably with GA, till the access to admissible results is obtained. The authors have used MATPOWER package for load flow algorithm and composed it with the GA. The suggested method is programmed under MATLAB software and applied ETAP software for evaluating of results correctness. The Khoda Bande Loo distribution test feeder in Tehran has been solved with the proposed algorithm and, the simple GA and illuminated the improvement of voltage profile and loss reduction indexes.

In October 2007, Jahromi, Farjah and Zolghadri [31] proposed a new procedure based on a GA to establish the optimal distributed generation (DG) allocation on a MV distribution network with respect to the voltage sag performance of the network. The GA method developed by the authors can be successfully applied in real size scenarios with several hundreds of nodes. In order to demonstrate the effects of DG allocation in a network, three indices have been examined. Average RMS (Variation) Frequency Index, SARFIx; which represents the average number of specified

RMS variation events that occur over the assessment period per customer served, the Overall Sag Performance (OSP) which is the number or percentage of buses experiencing voltage sag and the Overall Voltage Drop (OVD) which is basically a summation of all voltage drops in the distribution network under study. The first index reveals the effect of the positioning, on the end users, while the other two reflect the effect on the whole network. The most appropriate places for DG installation have been found to be the weakest parts of the network. The results show that the considerable improvements of power quality can be achieved simply by adding a number of DG units at the appropriate places.

In January 2010, El-Ela, Allam and Shatla [32] proposed an optimal proposed approach (OPA) to determine the optimal sitting and sizing of DG with multi-system constraints to achieve a single or multi-objectives using genetic algorithm (GA). The authors report that the linear programming (LP) is used not only to confirm the optimization results obtained by GA but also to investigate the influences of varying ratings and locations of DG on the objective functions. A real section of the West Delta sub-transmission network, as a part of Egypt network, has been used to test the capability of the OPA. The results demonstrate that the proper sitting and sizing of DG are important to improve the voltage profile, increase the spinning reserve, reduce the power flows in critical lines and reduce the system power losses.

In April 2011, Lin, Zhou and Wang [33] presented the optimal planning scenario when capacities of distributed generators (DG) when capacities are known at different locations. The methodology used is to build a multiobjective function model considering installation cost, power supply reliability and line loss rate, then to normalize and assign weight to the multi-objective function to build optimal objective function to minimize cost of distribution network, finally, to apply electromagnetism-like mechanism to resolve the function. The proposed method has also been compared to GA in optimizing placement of DG and the results yielded that the former has significant advantages in speed, accuracy and error tolerance.

In May 2011, Kalantari and Kazemi [34] presented GA based optimal placement of DG units and proper allocation of shunt capacitors in order to loss reduction and improvement of voltage profile in distribution systems. The authors report that the objective function has three important indices (active and reactive power losses and voltage profile). The power flow has been done using backward forward sweep method and simulation has been carried out on a 28 bus test system. The placement of DGs and capacitors has been done simultaneously in the test system. The proposed method yielded a significant reduction of losses and improvement of voltage profile with presence of DG unit and capacitors. The results can be more realistic if load models are voltage and frequency dependent, also if cost, MVA capacity and total harmonic distortion indices are considered in the objective function the better results can be obtained.

In May 2005, Gandomkar, Vakilian and Ehsan [35] presented a new algorithm based on integrating the use of genetic algorithm (GA) and simulated annealing (SA) methods to optimal allocation of distributed generation resources in distribution networks. The effectiveness of the proposed algorithm to solve the DG allocation problem is demonstrated through a IEEE 34-node distribution test feeder The results demonstrated the better characteristics of the GA-SA algorithm in comparison with the simple genetic algorithm (SGA) especially in terms of solution, quality and number of iterations.

In May 2006, Vallem, Mitra and Patra [36] described a method for siting of distributed energy resources (DER) units within the framework of an optimal microgrid architechture. An optimal microgrid architechture is characterized by minimum cost interconnection, sizing and siting of DER subject to stipulated global and local reliability criteria. The proposed method addressed the siting aspect of optimal microgrid architechture. Deployment costs, including the economic benefits of combined heat and power (CHP) comprised the objective function of this formulation. The problem is formulated as one of nonlinear programming and simulated annealing optimization (SA) is applied as a viable approach. The presented technique is tested using a six bus test system to highlight the usefulness of the approach.

In May 2010, Sutthibun and Bhasaputra [37] presented a model to determine optimal placement of distributed generation (DG) in order to minimize the electrical losses, emission, and contingency in which is solved using simulated annealing (SA) as the optimization tool by comparing with genetic algorithm (GA) and tabu search (TS). The proposed method has been tested on the IEEE 30 bus test system and yielded that the SA can find the optimal location and size with the less computing time than genetic algorithm (GA) and tabu search as well as the result of multi-objective problem can conclude that the DGs placing in the optimal location are indeed capable of obtaining higher quality solution efficiently comparing with single objective. The authors report that optimal placement of DGs in the system can reduce power loss upto 22%, emission upto 27.5% and system contingency upto 43% on compared with the system without DG.

In December 2004, Rahman, Rahim and Musirin [38] proposed a new method for determining the optimal location for embedded generator based on new sensitivity indices derived from voltage stability improvement with respect to changes in injected active and reactive power at a bus. The sensitivity indices were evaluated at every load bus and the bus with highest sensitivity index value was chosen to be the suitable location for the embedded generation. Evolutionary programming optimization technique has been developed in order to determine the optimal size of the embedded generation. The objective of the optimization was to minimize the losses in the network while maintaining the voltage profile at the acceptable level. The effectiveness of the proposed methodology was verified by the analysis on a 69-bus distribution system and the results showed a significant reduction in distribution losses and voltage profile improvement at various loading condition in the system with the implementation of the embedded generation at the suitable location and optimal sizing.

In August 2006, De Souza and De Albuquerque [39] presented an algorithm for the allocation and sizing of distribution generators (DGs) in radial distribution networks to minimize the load supply costs. In addition the operational schedule for each installed generator for all feeder load levels have been given. The evolutionary programming has been used as the optimization technique. The applicability of the method was evaluated using a feeder with high losses index and the proposed allocation provided a significant reduction on total costs. In order to improve the algorithm, it is being studied how to consider the load growth in the economical analysis. Besides, more efficient evolutionary programming operators are being tested, what will enhance the computational performance of the method.

In June 2010, Yasin, Rahman, Musirin and Rahim [40] presented a novel evolutionary programming inspired by quantum mechanics such as superposition and interference, called a quantum-inspired evolutionary programming (QIEP).The proposed algorithm is implemented to determine the optimal sizing of distributed generation (DG) for loss minimization at the optimal location. The location of the DG was identified using the sensitivity indices. The algorithm has been compared with conventional EP in terms of loss minimization and computation time. The comparison between single DG and multiple DG installation were also presented and the results revealed that multiple DG installation at optimal location produced better improvement in terms of loss minimization. The proposed study was conducted on the IEEE 69-bus test system.

In September 2001, Carpinelli, Celli, Pilo and Russo [41] presented a three step procedure, based on GA and Decision Theory to establish the best distribution generation (DG) siting and sizing on an MV distribution network, considering power production uncertainties and meeting technical constraints, like feeder capacity limits, feeder voltage profile and three-phase short circuit currents in the network nodes. Only the wind power production is considered, as an example of potentially large, renewable and environmentally-friendly source of energy. The proposed approach has been tested to an area of the actual MV Italian network which is constituted by 3 HV/MV substations, 148 nodes and 145 MV/LV trunk nodes. The results yielded that the DG presence significantly reduces the energy losses costs.

In July 2002, Kim, Lee, Rhee, Lee and You [42] presented a fuzzy-GA method for dispersed generator placement to reduce power losses of distribution systems and the constraints with the number or size of dispersed generators and the deviation of the bus voltage. This objective function and constraints are transformed into multi-objectives functions and modeled with fuzzy sets to evaluate their imprecise nature. The proposed method has been applied to the 12 bus and 11 branches sample system to demonstrate its effectiveness.

In May 2005, Khattam, Hegaz and Salama [43] presented a new integrated model for solving the distribution system planning (DSP) problem by implementing distributed generation (DG) as an attractive option in distribution utilities territories that identifies optimal sizing and siting of distributed generation to minimize DG's investment and operating costs, total payments toward compensating for system losses along the planning period, as well as different costs according to the available alternative scenarios. The authors report that these scenarios vary from expanding of an existing substation and adding new feeders to purchasing power from an existing intertie to meet the load demand growth. Binary decision variables have been employed in the proposed optimization model to provide accurate planning decisions without any need for rounding the solution. The present worth analysis of different scenarios is carried out to estimate the feasibility of introducing DG as a key element in solving the distribution system planning problem.

In October 2007, Cano [44] developed a fuzzy multi-objective optimization for distributed generation (DG) allocation for distribution systems. The author report that the methodology provides needed consideration for DG allocation and can handle uncertainties and imprecision using fuzzy set theory. Voltage drop reduction, short circuit capacity (SCC) augmentation, decrease operation cost and system losses reduction were considered as objectives for formulating fuzzy optimization. The proposed methodology has been tested through several numerical examples and compared with analytical algorithm and it was shown that the fuzzy optimization has technical and economic considerations neglected in other studies.

In March 2008, Haghifam, Falaghi and Malik [45] presented a strategy for the placement of distributed generation (DG) units in the distribution networks in an uncertain environment. The model considers a fuzzy explicit representation of the uncertainties associated with the future load, as well as a fuzzy representation of the uncertainties associated with the power flow in the feeders and substations, the network node voltages and the electricity market prices. The proposed approach is based on a multi-objective model in which the objectives are defined as minimization of monetary cost index (including investment, operation cost of DG units and cost of losses), technical risks (including risks of voltage and loading constraints violation because of load uncertainty) and economic risk due to electricity market price uncertainty. The max–min approach has been proposed to select the best Pareto-optimal DG placement solution. The new DG placement algorithm has been tested in a typical distribution network. The obtained results show that the suggested DG placement model is a powerful decision-making tool for risk management in distribution networks with DG installation and operation.

In May 2007, Favuzza, Graditi, Ippolito and Sanseverino [46] investigated the problem of reinforcement of distribution systems considering different scenarios and using DG units, in particular gas micro-turbines, instead of traditional means, such as cables and transformers. The comparison has been carried out trying to correctly evaluate the two possible alternatives also considering the possibility to couple them together in the same system. The results yielded that the installation and maintenance costs of the DG units are economically interesting as compared to traditional means because they give the opportunity to produce heat. The problem presented a large number of mixed-integer variables and is a typical dynamic optimization problem. Therefore, the authors have set up a modified version of the Ant Colony Search optimization (Dynamic Ant Colony Search algorithm) which can be used for dynamic optimization problems. The algorithm has proved to be robust and able to deal with large search spaces since it dynamically creates the search routes, such as real ants do. The algorithm is also a valuable tool to solve the same problem using different DG sources such as biomass, photovoltaic systems, as well as fuel cells or even a combination of these, and to make comparisons in order to find out general guidelines for the installation of DG sources and renewable in existing networks. The authors report that the algorithm can easily be modified to push the research towards exploration or towards exploitation by tuning the parameters.

In November 2008, Wang and Singh [47] presented an ant colony system algorithm to derive the optimal recloser and DG placement by minimizing a composite reliability index for radial distribution networks. The authors report that the simulations have been carried out based on two practical distribution systems to validate the effectiveness of the proposed method. Furthermore, comparative studies with respect to GA are also carried out.

In December 2010, Sedighizadeh, Fallahnejad, Alemi, Arzaghi-haris and Omidvaran [48] presented a new advanced method for optimal allocation of DG in distribution systems to minimize active losses of feeders and improve voltage profile. PCLONALG technique has been utilized as a solving tool to acquire superior solutions which is a combination of Particle Swarm Optimization (PSO) and Clonal Selection Algorithm (CLONALG). The fitness values sensitivity in PCLONALG process have been considered load flow are applied for decision making. The feasibility of the proposed technique has been demonstrated for Khoda-Bande-Loo distribution test feeders of Tehran city. The experimental results illustrated that the PCLONALG method has a higher ability in comparison with PSO and CLONALG, in terms of quality of solutions and number of iterations.

In March 2011, Zonkoly [49] used PSO technique to find the best solution of the multi-objective problem of placing and sizing of distributed generation (DG) units in distribution system with non-unity power factor considering different types of load models. The proposed multi-objective function to be optimized includes a wide range of technical issues such as active and reactive power losses of the system, the voltage profile, the line loading, the MVA intake by the grid and a short-circuit-level parameter to represent the protective device requirements. The authors report that the analysis of continuation power flow to determine the effect of DG units on the most sensitive buses to voltage collapse has been carried out. The proposed algorithm has been tested using the 38-bus radial system and the IEEE 30-bus meshed system. The results showed that the proposed algorithm is capable of optimal and fast placement of DG units. The results clarified the efficiency of this algorithm for improvement of voltage profile, reduction of power losses, reduction of MVA flows and MVA intake from the grid and also increasing the voltage stability margin and maximum loading.

In January 2001, Nara, Hayashi, Ikeda and Ashizawa [50] illustrated an implementation of tabu search algorithm (TS) for optimal placement problem of distributed generators (DG) in order to minimize distribution loss at the demand side of the power system, under the conditions that number of DGs and total capacity of DGs are known. The locations and discrete capacities of each DG have been determined by nested use of the TS. The proposed algorithm has been tested using numerical examples and the calculation results of TS are better than those of simulated annealing method (SA).

In November 2004, Rosado and Navarro [51] presented a new possibilistic (fuzzy) model for the multiobjective optimal planning of power distribution networks that finds out the nondominated multiobjective solutions corresponding to the simultaneous optimization of the fuzzy economic cost, level of fuzzy reliability, and exposure (optimization of robustness) of such networks, using an original and powerful meta-heuristic algorithm based on Tabu Search. The proposed model determines the optimal location and size of the reserve feeders (location and size) that provide the best distribution network reliability at the lowest cost for a given level of robustness (exposure) and also substations in distribution networks. The model and the algorithm have been intensively tested in real distribution networks, to prove their practical application to large power distribution systems.

In October 2005, Niknam, Ranjbar, Shirani, Mozafari and Ostadi [52] presented the application of various evolutionary methods for solving the problem of optimal operation in distribution networks with regard to Distributed Generators (DGs). These methods are metaheuristic techniques such as the Genetic Algorithm (GA), differential evolution, Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and Tabu search (TS). The objective function in this problem includes cost of active and reactive electrical energy generated by DGs, electrical energy markets and capacitors. These methods are tested on IEEE 34 distribution test feeders and a practical distribution system and the performance of these algorithms was compared together.

In April 2009, Aghaebrahimi, Amiri and Zahiri [53] proposed an Immune Algorithm (IA) based optimization approach for solving the distributed generation (DG) placement problem in order to minimize power losses. In the proposed method, objective function (power losses) and constraints (bus voltage limits and line current limits) are represented as antigens. Through the genetic evolution, an antibody that most fits them antigen becomes the solution. In this IA computation, an affinity calculation process was also embedded to guarantee the diversity. The process stagnation can thus be prevented better. The Khoda-Bande-Loo distribution test feeder in Tehran has been solved by the proposed algorithm. The results showed a considerable effect on power losses reduction when DGs are installed in the network and a high speed of algorithm convergence is evident.

In June 2011, Sohi, Shirdel and Javidaneh [54] evaluated the problem of determining the optimal position, numbers, and capacity of distributed generators (DG) for loss reduction and line capacity improvement. The authors have utilized the heuristic Bee Colony optimization algorithm (BCO) as a solving tool. This algorithm is inspired of the intelligent behavior of bees during the nectar search process. The proposed algorithm has been applied for DG placement and sizing in IEEE 33 nodes test network and results showed that this method has a good convergence, and each time the program was run, a same output was received.

III. DISCUSSION

The strengths and weaknesses of different research studies to determine optimal placement of DG had been reviewed in this paper. Each technique has tried to solve the problem with various objectives and their imposed constraints. The effective comparisons for these solution methods are difficult however some objectives reduction in power losses in the network, cost minimization and improvement in voltage profile are common in most of them. Many conventional optimization techniques such as the linear programming, quadratic programming, gradient methods and dynamic programming has been employed to solve power system optimization problems in system planning, operation, control and pricing. Owing to the complexity of the problem, these methods may fail to find the global optimal solutions [53, 56]. Artificial intelligence techniques such as genetic algorithms, tabu search and ant colony optimization have come to be the most widely used tools for solving optimal DG allocation. [53].The optimal placement of DGs in the system can reduce power loss upto 22%, emission upto 27.5% and system contingency upto 43% on compared with the system without DG [37].

CONCLUSION

In this paper, an overview and key issues of different research studies for optimal placement of DG is presented. Improper allocation of DG sources in power system would not only lead to increase power or energy losses, but can also jeopardize the system operation. DG should be placed in the optimal location in order to provide maximum economical, technical and environmental benefits. The optimal placement of DG problem is quite complex. It is clear, from the existing literature, that there are different solution methods for finding optimal location and sizing of DG by various objectives and their imposed constraints. However, the methodical principle for this matter is still an unsolved problem. To maximize the DG placement profits, the provided helpful information and references for researchers can lead additional studies in this field.

REFERENCES

[1] L.L.Lai and T.F.Chan, "Distributed Generation: induction and permanent magnet generators",Wiley,2007.

[2] T. Ackermann, G. Andersson and L. So¨der, "Distributed generation: a definition", Electric Power Systems Research,Elsevier, 2001.

[3] T. Griffin, K. Tomsovic, D. Secrest, A. Law, "Placement of Dispersed Generations Systems for Reduced Losses", Proceedings of the 33rd Hawaii International Conference on System Sciences, 2000.

[4] H. L. Willis, "Analytical Methods and Rules of Thumb for Modeling DG-Distribution Interaction", IEEE Power Engineering Society Summer Meeting, Volume 3, Issue, 2000, PP. 1643 – 1644.

[5] C. L. T. Borges, D. M. Falcao, "Impact of Distributed Generation Allocation and Sizing on Reliability, Losses and Voltage Profile", IEEE PowerTech conference 2003, Bologna, Italy.

[6] C. Wang, M. H. Nehrir, "Analytical Approaches for Optimal Placement of DG Sources in Power Systems", IEEE Trans. On Power Syst., Vol. 19, No. 4, November 2004; pp. 2068–2076.

[7] T.Gozel, M. H. Hocaoglu, U. Eminoglu, A. Balikci, "Optimal placement and sizing of distributed generation on radial feeder with different static load models", International Conference on Future Power Systems, 2005

[8] N. Acharya, P. Mahat and N. Mithulananthan, "An analytical approach for DG allocation in primary distribution network", Int. J. Electr. Power Energy Syst., 2006, 28, (10), pp. 669–746.

[9] D. Zhu, R. P. Broadwater, K. Tam, R. Seguin, H. Asgeirsson, , "Impact of DG Placement on Reliability and Efficiency With Time-Varying Loads", IEEE transactions on power systems, VOL. 21, NO. 1, February 2006, PP. 419-427.

[10] Payyala S.L., Green T. C., "Sizing of Distributed Generation Plant through Techno-Economic Feasibility Assessment", IEEE Power Engineering Society General Meeting, 2006.

[11] T. Gözel and M. H. Hocaoglu, "An analytical method for the sizing and siting of distributed generators in radial systems", Electric Power Systems Research, 2009, 79, pp. 912–918.

[12] Parizad A, Khazali A and Kalantar M, "Optimal placement of distributed generation with sensitivity factors considering voltage stability and losses indices ", 18th Iranian Conference on Electrical Engineering (ICEE), 2010

[13] Du Yun-Feng and Huang Qi, "Optimal Placement of Distributed Generation on a Radial Feeder", 6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM), 2010

[14] N. S. Rau, Y. H. Wan: "Optimal Location of Resources in Distribution Planning", IEEE Transactions on Power Systems, Vol. 9, No.4, 1994.

[15] J. O. Kim, S. W. Nam, S. K. Park and C. Singh, "Dispersed generation planning using improved Hereford Ranch algorithm", Electric Power System Research, 1998, 47, (1), pp. 47–55.

[16] Walid El-Khattam, Y. G. Hegazy, and M. M. A. Salama, " Stochastic Power Flow Analysis of Electrical Distributed Generation Systems", IEEE Meeting Power Engineering Society 2003, Vol. 1, pp. 141-143.

[17] M. Gandomkar,M. Vakilian, M. Ehsan, "Optimal distributed generation allocation in distribution network using Hereford Ranch algorithm", Proceedings of the Eighth International Conference on Electrical Machines and Systems, 2005.Volume 2, Issue , 27-29 Sept. 2005, pp. 916 – 918.

[18] J.A. Momoh, G. Boswell, "Value- based Implementation of Distributed Generation in Optimal Power Flow", Proceedings of the 37th Annual North American Volume , Issue , 23-25 Oct. 2005, pp. 27 – 33.

[19] Walid El-Khattam, Y. G. Hegazy, and M. M. A. Salama, "Investigating Distributed Generation Systems Performance Using Monte Carlo Simulation", IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 21, NO. 2, MAY 2006

[20] D. Gautam and N. Mithulananthan, "Optimal DG placement in deregulated electricity market", Electric Power Systems Research, 2007, 77, pp. 1627–1636.

[21] S. Ghosh, S. P. Ghoshal and S. Ghosh, "Optimal sizing and placement of distributed generation in a network system", Electric Power and Energy Systems, Elsevier, 2010.

[22] Khanabadi M, Doostizadeh M, Esmaeilian A and Mohseninezhad M, "Transmission congestion management through optimal distributed generation's sizing and placement ", 10th International Conference on Environment and Electrical Engineering (EEEIC), 2011

[23] Xiao-bo Tang and Xue-hong Wu , "A New Method of Distributed Generation Optimal Placement Based on Load Centroid ",Power and Energy Engineering Conference (APPEEC), 2011 Asia-Pacific

[24] A. Silvestri, A. Berizzi, S. Buonanno, "Distributed generation planning using genetic algorithms", International Conference on Electric Power Engineering, 1999. PowerTech Budapest 99, pp. 257.

[25] G. Celli, F. Pilo, “Optimal distributed generation allocation in MV distribution networks”, 22nd IEEE Power Engineering Society International Conference, 2001, PP.81-86.

[26] N. Mithulananthan, Than Oo, L. Van Phu, “Distributed Generator Placement in Power Distribution System Using Genetic Algorithm to Reduce Losses”, Thammasat Int. J. Sc. Tech., Vol. 9, No. 3, July-September 2004.

[27] G. Celli, E. Ghiani, S. Mocci, F. Pilo, “A Multiobjective Evolutionary Algorithm for the Sizing and Siting of Distributed Generation”, IEEE Transactions on Power Systems, Vol. 20, No. 2, May 2005.

[28] S. Kamalinia, S. Afsharnia, M. E. Khodayar, A. Rahimikian, M.A. Sharbafi, “A Combination of MADM and Genetic Algorithm for Optimal DG Allocation in Power System”. IEEE UPEC 2007, PP. 1031-1035.

[29] C. L. T. Borges and D. M. Falcao, “Optimal distributed generation allocation for reliability, losses, and voltage improvement”, Int. J. Power Energy Syst., 2006, 28, (6), pp. 413–420.

[30] Y. Alinejad-Beromi, M. Sedighizadeh, M. R. Bayat, M. E. Khodayar,“ Using Genetic Algorithm for Distributed Generation Allocation to Reduce Losses and Improve Voltage Profile”, IEEE UPEC 2007, PP. 954-959.

[31] M. J. Jahromi, E. Farjah, M. Zolghadri, “Mitigating Voltage Sag by Optimal Allocation of Distributed Generation Using Genetic Algorithm”, 9th International Conference on Electrical Power Quality and Utilization, 2007, Barcelona, Spain.

[32] A. A. Abou El-Ela, S. M. Allam and M. M. Shatla, “Maximal optimal benefits of distributed generation using genetic algorithms”, Electric Power Systems Research, 2010, 80, pp. 869–877.

[33] Nan Lin, Buxiang Zhou and Xueyou Wang, “Optimal placement of distributed generators in micro-grid”, International Conference on Consumer Electronics, Communications and Networks (CECNet), 2011

[34] Meysam Kalantari and Ahad Kazemi, “Placement of Distributed Generation unit and Capacitor Allocation in Distribution Systems using Genetic Algorithm”, 10th International Conference on Environment and Electrical Engineering (EEEIC), 2011

[35] M. Gandomkar, M. Vakilian, M. Ehsan, “A Combination of Genetic Algorithm and Simulated Annealing for Optimal DG Allocation in Distribution Networks” IEEE CCECE/CCGEI, Saskatoon, May 2005.

[36] M. R. Vallem, J. Mitra, S. B. Patra,, “Distributed Generation Placement for Optimal Microgrid Architecture” ,PES TD ,May2006,pp. 1191-1195.

[37] Sutthibun T and Bhasaputra, “ P Multi-objective optimal distributed generation placement using simulated annealing”, International Conference on Electrical Engineering/Electronics Computer Telecommunications and Information Technology (ECTI-CON), 2010

[38] T. A. Rahman, S. A. Rahim, I. Musirin, “Optimal allocation and sizing of embedded generators,” in Proc. 2004 National Power and Energy Conference, pp.288-294.

[39] B. A. de Souza, J. M. C. de Albuquerque, “Optimal Placement of Distributed Generators Networks Using Evolutionary Programming”, Transmission & Distribution Conference and Exposition: Latin America, 2006.IEEE/PES, pp.1-6

[40] Z.M.Yasin, T.K.A.Rahman, I.Musirin and S.R.A.Rahim, “Optimal Sizing of Distributed Generation by using Quantum-Inspired Evolutionary Programming” 4th International Power Engineering and Optimization Conf. (PEOCO2010), Shah Alam, Selangor, Malaysia: 23-24 June 2010

[41] G. Carpinelli, G. Celli, F. Pilo, and A. Russo, “Distributed generation sitting and sizing under uncertainty,” in Proc. IEEE Powertech Conf., vol.4, Porto, Portugal, Sep. 10–13, 2001, pp. 376–401.

[42] K.-H. Kim, Y.-J. Lee, S.-B. Rhee, S.-K .Lee, and S. K. You, “Dispersed generator placement using fuzzy-GA in distribution systems,” in Proc. 2002 IEEE Power Engineering Soc. Summer Meeting, vol. 3, Chicago, IL, July 2002, pp. 1148–1153.

[43] Walid El-Khattam, Y. G. Hegazy, and M. M. A. Salama, “ An Integrated Distributed Generation Optimization Model for Distribution System Planning” ,IEEE transactions on power systems, VOL. 20, NO. 2, May 2005

[44] E. B. Cano, “Utilizing Fuzzy Optimization for Distributed Generation Allocation”, IEEE TENCON 2007, PP.1-4.

[45] M.-R. Haghifam, H. Falaghi and O. P. Malik, “Risk-based distributed generation placement”, IET Gener. Transm. Distrib.,2008, 2, (2), pp. 252–260.

[46] S. Favuzza, G. Graditi, M. G. Ippolito, E. R. Sanseverino, “Optimal Electrical Distribution Systems Reinforcement Planning Using Gas Micro Turbines by Dynamic Ant Colony Search Algorithm Power Systems”, IEEE Transactions on Power Systems Volume 22, Issue 2, May 2007 Page(s): 580 – 587

[47] Lingfeng Wang and Chanan Singh,“ Reliability-Constrained Optimum Placement of Reclosers and Distributed Generators in Distribution Networks Using an Ant Colony System Algorithm”, IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS—PART C: APPLICATIONS AND REVIEWS, VOL. 38, NO. 6, NOVEMBER 2008

[48] M. Sedighizadeh, M. Fallahnejad, M. R. Alemi, M. Omidvaran and D. Arzaghi-haris, “Optimal Placement of Distributed Generation Using Combination of PSO and Clonal Algorithm”,IEEE International Conference on Power and Energy (PECon 2010),Malaysia

[49] A.M. El-Zonkoly, “Optimal placement of multi-distributed generation units including different load models using particle swarm optimisation”, IET Gener. Transm. Distrib., 2011, Vol. 5, Iss. 7, pp. 760–771

[50] Nara, K, Hayashi, Y, Ikeda, K and Ashizawa, T, “Application of tabu search to optimal placement of distributed generators”, IEEE Power Engineering Society Winter Meeting, 2001, Volume: 2, PP.918 –923

[51] K.-H. Kim, Y.-J. Lee, S.-B. Rhee, et al., “Dispersed generator placement using fuzzy-GA in distribution systems”, Proc. IEEE Power Engineering Society Summer Meeting, Chicago, USA, 21–25 July 2002, pp. 1148–1153.

[52] T. Niknam, A. M. Ranjbar, A. R. Shirani, B. Mozafari and A. Ostadi, “Optimal Operation of Distribution System with Regard to Distributed Generation: A Comparison of Evolutionary Methods”, IEEE Industry Applications Conference, 2005, Vol. 4, pp. 2690 -2697

[53] M. R. Aghaebrahimi, M. Amiri and S. H. Zahiri, “ An Immune-Based Optimization Method forDistributed Generation Placement in order to Minimize Power Losses”, 1st International Conference on Sustainable Power Generation and Supply (SUPERGEN), Nanjing, China, April 6-7, 2009.

[54] Mohammad Falahi Sohi, Morteza Shirdel and Ali Javidaneh, “Applying BCO Algorithm to Solve the Optimal DG Placement and Sizing Problem”,5th International Power Engineering and Optimization Conference (PEOCO2011), Malaysia ,2011

[55] M. F. ALHAJRI, M. R. ALRASHIDI and M. E. EL-HAWARY, “Improved Sequential Quadratic Programming Approach for Optimal Distribution Generation Deployments via Stability and Sensitivity Analyses”, Electric Power Components and Systems, 38:1595–1614, 2010

[56] K. P. Wong, “Recent development and application of evolutionary optimization techniques in power systems”, Proceedings of International Conference on Power System Technology, 2002.