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Distributed generation (DG) integration on utilities distribution system: A survey

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Abstract
Distributed generation is one of the new trends in power systems used to support the increased energy-demand. Distributed generation is an electrical source connected to the power system, in a point very close to or at consumer's site which is small enough compared to the centralized power plants. Continuous demand for stable power supply by the end users of electricity necessitates the integration of DG directly to distribution system of a power network. If DGs are optimally sized and sited in the distribution network, power system reliability, stability and efficiency are guaranteed since they cut off losses associated with transmission system. Besides, more than 95% of total power generated can be effectively harnessed by the end users. This paper presents a comprehensive survey of DG integration on utilities distribution system of a power network with a view to measuring the extent of DG Integration on Nigerian Grid and to find out the most commonly used techniques for the optimal placement and sizing of DG problems. The results of this research paper shows that the work done on Nigerian radial distribution system is about 13.20% and this is largely due to scanty availability of Nigerian radial distribution system data. The most commonly used techniques for the optimal placement of DG are genetic algorithm and its variant which is about 25.71% in relation to other evolutionary algorithms based on the volume of paper reviewed.

Keywords: DG integration, DG sizing and sitting, DG technologies, distribution system, optimal placement, power network, radial distribution system

1. Introduction

With increase in emphasis on power system security nowadays, optimal placement of DG therefore becomes an alternative means of achieving maximization of power system reliability and stability [56]. Distributed Generation is a source of electrical power linked directly to distribution network or on the customer site of the meter and ranges in size from less than 1 kW to tens of megawatts (MW) [4]. The integration of DG in the distribution segment of power system in recent years receives growing interests due to its ability to mitigate issue of rise in system losses, decline in power quality, voltage fluctuation at the end of feeders due to nature of consumers' load [53, 40]. If optimally sized and sited in the network, the potential ability of distributed generation among others includes provision of primary power which could serve as backup and supplemental power. It serves as reactive power source for loss minimization and voltage profile enhancement, delay the imminent upgrade of the present system or the need to build newer infrastructure and lastly, it is more economical than running a power line to remote locations [56].

The objective problem formulations for DG integration in distribution power network ranges from single to multi-objectives. Generally, single objective functions entails minimization of any of the following; the total power loss, voltage deviations, DG capacity and voltage limit loadability among others. The approach in multi-objective formulations could either be multi- objective function with weights or goal multi-objective index. The former transformed multi-objective functions into a single objective function using the weighted sum of individual objectives while the latter transformed multi-objective formulations into a single objective function using the goal programming method [56, 54].

2. DG Technologies and Optimal Placement and Sizing Techniques

The two well-known DG technologies are Renewable (wind turbine, photovoltaic cell, biomass, geo-thermal, small hydro power) and Non-renewable (diesel engine, micro turbine, gas turbine and combined heat and power) [49, 13]. However, the general approaches for DG optimal placement over the last few years are analytical techniques, optimal power flow techniques and evolutionary algorithms. The distinguishing feature of analytical approach lies in its simplicity requires less computational time, lack of convergence and ease of calculations [21, 31]. Optimal power flow approach is another robust method for allocation and placement of DG in distribution system. It requires large memory, relatively long computation time due to the number of iterations required and it is hard to understand and implement. Evolutionary algorithms on the other hand are optimization techniques based on artificial intelligence; they have good convergence characteristics and efficient performance [31].

3. Review of Related Works

Akorede *et al*., (2010) proposed Genetic Algorithm hybridized with fussy logic controller to dynamically adjust crossover and mutation rate. The essence of this is to maintain proper population diversity during GA operation. The proposed approach was implemented on IEEE 6 and 30-bus radial distribution system. Simulation results demonstrated the robustness and accuracy of approach over the conventional GA techniques [6].

Hejazi *et al.,* (2010) presented application of Differential Evolution Algorithm (DEA) for a techno-economical multi-objective allocation for distributed generation. The optimal location, size and power factor of multiple DGs were determined so as to minimize the effect of probable faults on DG operation. The work demonstrated the effect of different assumptions in respect of DG price and technical aspects. The work concluded that considering the difference of energy purchase price significantly decreases the amount of DG installed compared to solely considering the technical issues [16].

Yammani *et al.,* (2011) used shuffled frog leaping algorithm for optimizing cost and optimal placement of DG with the aid of a simple vector based load flow technique. It was implemented on 38 bus radial distribution systems to reduce the real power losses and cost of the DG. The weighting factor was optimized which balanced the cost and the loss factors. The proposed approach outperformed other methods in terms of the quality of solution and computational efficiency [65].

Hidayatullah and Kalam (2011) discussed the impacts of distributed generation on Smart Grid technology, the work identified and determined whether the system remains stable or not after installing distributed generation into Smart Grid systems. To achieve this, the primary stability parameters of the system such as power angle, frequency and voltage were computed. The simulation result shows that the static var compensator (SVC) reduced system losses appreciably grid [17].

Ariyo and Omoigui (2012) carried out investigation of Nigerian 330 kV electrical network with distributed generation penetration. In the work, the Nigerian 330 kV electrical network was expended by incorporating wind, solar and small-hydro sources, the expected maximum currents was determined using Short-circuit analysis while the best economical operation for the proposed network was determined using transients stability and modal analyses on Nigerian 330kV 37 bus system with the aid of DIgSILENT version 14.1 [8].

Ariyo *et al.,*(2012) presented the transient stability analysis of the Nigerian Power Grid with the addition of DG at various levels of penetration. A transient fault was introduced at a particular bus based on load flow analysis and its effect on generator rotor angle and system frequency was determined at various levels of penetration. PV-curves were obtained to evaluate system voltage stability. Fuzzy Inference System, an artificial intelligent optimization technique was used to find the optimum location for DG added to the existing grid. The work concluded that for the Nigerian grid; a DG penetration level of 10% is the optimum. `There is no universal optimum penetration level that can be applied to any power network and lastly, the optimum level of DG penetration is actually a function of the power grid in consideration [9]

Galina *et al.,* (2012) described distributed generation concepts, applications and inherent challenges. Benefits and challenges are discussed and analyzed on a number of real life examples. Special considerations were given on ensuring security and dependability, as well as on protection, parameterization and coordination [14].

Shrivastava *et al.,(*2012) presented an overview, general backgrounds of research and development in the field of different solution methods for optimal placement of DG. The reviewed methods included analytical technique, optimal power flow methods (OPF) and evolutionary computational methods. Fifty-six papers were reviewed and logically presented on the basis of method of DG optimal placement. In all, it is clearly concluded that from the existing literature, there were different solution methods for finding optimal location and sizes of DG [56].

Mahesh, Nallagownden and Elamvazuthi (2012) gave an overview of methods of DG placement in radial distribution systems. Thirty-two literatures were reviewed, from the reviewed literatures; artificial intelligence techniques had the highest number of usage as compared to analytical and numerical methods. Lastly, the work raised the challenges and research issues that surrounded DG incorporation in a radial distribution system. DG incorporation causes the direction of power flow radial distribution system to become bidirectional and the main drawback raised in the work peculiar to renewable DG was uncertainty in its generation due to its prime sources, which ultimately affects the power quality [30].

Roy, Pota and Anwar (2012) proposed (DG) placement methodology based on reactive power loadability. The approach was implemented on distribution test system of Kumamoto area in Japan. The research investigated the sensitivity of the location of renewable energy based DG on voltage profile and stability of the system after which, a suitable location was identified for wind and solar installation separately in a bid to enhancing the stability margin of the system. The analysis showed that the proposed approach reduced the power loss of the system coupled with reduction in the size of compensating devices [50]

Gopiya, Khatod and Sharma (2012) discussed an overview of DG technologies, available capacity and their merits and demerits. The state-of-art-of literature on operational (network reconfiguration in the presence of DG) and planning (optimal sizing and sitting of DG, distribution system expansion planning with DG, and the DG-Capacitor placement) aspects in the presence of DG on the distribution networks were reviewed and presented. The work concluded that for complex problems hybrid of two or more approaches and artificial intelligent search techniques were suited compared to analytical approach [15]

MOHD (2013) used Particle Swarm Optimization (PSO) method on several cases. Without DG installed, varying number of particles such as 10, 30 and 50 were used to find the most optimal sizing and location of DG in distribution network. The proposed approach was tested on the standard IEEE-69 bus distribution network using MATLAB R2012a software. The results showed that the most optimized number of DG installed on distribution network was three DG with number of particle N=30, with this the power losses of the system decreased and voltage profile improved remarkably compared to other cases [35].

Oshevire, Oladimeji and Onohaebi (2013) examined the prospects and possible applications of Smart Grid Technology to the Nigeria Power System. The study showed that incorporation of different sources of DG on the smart grid system will make the present network more efficient and reliable [41].

Shilpa, Ganga and Aashish (2013) presented an analytical approach based on Two Port Transmission Equations for Multiple Distributed Generators (DG) allocation in Distribution Systems for any input load conditions. The proposed approach was tested on IEEE 33-bus radial distribution system. Voltage Stability Index was used to determine the limit of number of the DG units which can be installed in the available capacity of the system. The result of the analysis showed that the proposed method requires less computational equations; gave greater accuracy as verified by the exhaustive load flow and improved analytical (IA) method and it was concluded that the approach was well suited for an on-line execution in an energy control center [55].

Abbagana, Bakare and Mustapha (2013) proposed Differential Evolution approach to find the optimal location and size of DG unit. The feasibility and effectiveness of the proposed approach was demonstrated on IEEE 33-bus radial distribution system using MATPOWER and MATLAB software for simulation. The simulation results revealed that the system losses reduced by 47.39 percent for the installation of one DG. The nodes violating the voltage limits reduced to 3 from 18 and the sum of square of voltage error dropped to 0.02968 from 0.1369 p.u [1].

Linh and Dong (2013) presented artificial bee's colony algorithm (ABC) for the placement and size of DG in the radial distribution system. The proposed method was tested on standard IEEE 33 bus test system. The results proved that the ABC algorithm was simple in nature than GA and PSO so it took less computation time. The total power loss of the system reduced drastically and the voltage profile of the system improved appreciably compared to PSO and GA [28].

Manafi *et al.*,(2013) used PSO and improved direct evolutionary algorithms for optimum placement of DG in radial distribution systems. These approaches were used to minimize distribution system real power losses by the least possible injected power from distributed generations. To assess different PSO and DE algorithm capabilities, simulations were carried out on two IEEE 33-bus and 69-bus standard RDS. Lastly, the authors of the work believed that a combination of PSO and DE techniques for DG placement problem yielded greater success in terms of system loss minimization [33].

Vukobratović, Nikolovski and Marić (2013) presented a solution for optimal DG placement by selecting the right terminal and power of DG using hybrid of Genetic Algorithm (GA) and Artificial Neural Network (ANN). The method was tested on a part of Croatian distribution network. The results of hybridized approach were compared with the analytical approach. A wide margin was observed in voltage profile improvement and active power losses reduction and this confirmed the usefulness of the combination of the ANN and the GA for providing fast and accurate optimization solutions in RDS [64].

Sneha *et al.*, (2014) proposed optimal placement of different types of DGs unit using PSO and DE. The optimal locations and size of the DG's were determined by minimizing the power distribution losses. The authors proposed different types of DGs supplying real and reactive power at different buses on 33-bus RDS. The results of PSO and DE technique were compared with the analytical approach. PSO approach not only reduces the line losses but also minimized the sizes of DGs with satisfaction of the permissible voltage limits than the analytical methods [59].

Oyedepo, Agbetuji and Odunfa (2014) presented a systematical reviews and analyses of transmission grid extension using solar and wind energy sources as DG. They also presented an overview of implications, effect and mitigation measures of DG integration as a tool for grid extension. Their work identified major challenges with the use of Solar and Wind as their output was uncontrollable just like other conventional generation sources unlike gas power plant whose output is controllable as occasion demands [43].

Vincent and Yusuf (2014) proposed a smart grid model for the Nigerian power sector with DG integration. The work suggested integration of small-Hydropower, Wind, Solar Radiation and Biomass (Fuel Wood, Animal Waste and Crop Residue) into the existing national grid as a mean of ensuring constant power supply to the end users. The author concluded that integration of renewable energy into the national grid is one of the most important areas for infrastructure upgrades [63]

Khosravi, Legha and Mirzaei (2014) proposed a population based Genetic Algorithm (GA) to solve DG placement problem and quantifying the total line loss reduction in distribution system. Simulations were carried out on power network of Kerman Province, Iran. The simulation results showed that the inclusion of DG, marginally reduced the losses in a distribution system [23].

Shareef and Kumar (2014) presented an overview of the state of the art models and methods applied to the optimal placement of distributed generators (OPDG), analyzing and classifying current and future research trends in this field. The solution methodologies found in the reviewed papers for OPDG problems were analytical, numerical and heuristic methods. However, GA and various practical heuristics algorithms were found to be commonly used in the 63 papers reviewed [54].

Akorede *et al* (2014) proposed a model based on Fuzzy Genetic Algorithm to determine the optimal capacity and location of DG unit in a radial distribution network. Fuzzy controller was to adjust the crossover and mutation rates dynamically so as to maintain the proper population diversity during GA operation. With this premature convergence problem of the simple GA was overcome. A multi-objective function was formulated which included maximization of cost savings arising from energy loss, minimization of voltage drops across all lines, and maximization of the transfer capability of the system. The proposed model was tested on 30, 33 and 69-bus RDS. The results of the analysis showed high computational efficiency and faster computation time when compared to ordinary GA [5]

Musau (2014) proposed a hybrid evolutionary algorithm based on the combination of bacterial foraging and direct evolutionary algorithms called hybrid bacterial foraging direct evolutionary (HBFDE) to obtain the optimal configuration of radial distribution systems with the objective function of power loss. The simulation results showed the effectiveness of HBFDE algorithm. The author concluded that a stochastic approach led to a more efficient utilization of energy in the distribution systems and permitted decision makers to select the possible actions to cope with the wind uncertainty in the modern power system [36].

Ishak *et al.,* (2014) proposed a voltage stability index as a fast assessment tool for identifying weak buses with small active power margins in a power system. The optimum distributed generator placement and size for improving voltage stability were determined using voltage stability index and backtracking search algorithm. The optimization problem was successfully solved considering minimization of real power loss and voltage stability improvement [19].

Tang, Zhang and Huang (2014) proposed a coordinating control method of reactive power optimization in distribution power system with distributed wind energy. The problem of reactive power output/absorption of adjustable compensating capacitor and wind turbine (WT) was formulated as constrained conditions; differential evolution algorithm (DE) and integrating depth-first search were developed to effectively obtain optimal solutions. The proposed algorithm was applied to a practical test system and the results obtained showed that the proposed approach was computational efficient [62].

Pradeepa *et al.,* (2015) used Particle swarm optimization (PSO), genetic algorithm (GA), Differential Evolution (DE) and hybrid Genetic Algorithm (GA) / Particle Swarm Optimization (PSO) to compute the optimum placement and size of DGs source in a bid to minimizing active power loss and improve voltage stability indices. A multi -objective function consisting of power loss reduction, increasing voltage stability index and load balancing was formulated and implemented with the proposed algorithms on 61 bus Hamedan radial distribution systems. The authors concluded that GA/PSO algorithm was very efficient in finding the optimal distributed generation sitting and sizing when compared to GA, PSO and DE algorithms [45].

Abbagana, Bakare and Mustapha (2015) presented Differential Evolution approach to find the optimal location and size of a Distributed Generation (DG) unit. The DG sources were added to the network to reduce the power losses and improve the voltage profile by supplying a net amount of power. The feasibility and effectiveness were demonstrated on IEEE 33 bus RDS consisting of 32 sections. The results revealed that the system losses reduced by 47.39 percent for the installation of one DG. The nodes violating the voltage limits reduced to 3 from 18 and the sum of square of voltage error dropped to 0.02968 from 0.1369p.u [2].

Khamis et al., (2015) presented optimal load shedding scheme based on backtracking search algorithm. A multi-objective function that handled linear static voltage stability margin and amount of load curtailment was formulated. The proposed approach was tested on IEEE 33-bus RDS incorporating 4 DG units and implemented in MATLAB environment. The results of the proposed approach was compared with GA, BSA outperformed GA in terms of the set objectives [22].

Abd-rabou, Soliman and Mokhtar (2015) proposed GA techniques to find optimum location for three different types of distributed generation such as synchronous generator, wind turbine and photovoltaic cell. The proposed approach was implemented on IEEE 13 bus RDS and the simulation results obtained were compared with that of PSO, GA produced better result in term of voltage profile improvements and power loss reduction. Synchronous DG type produced the highest grid performance while lowest performance was observed with photovoltaic DG [3].

Prabha and Jayabarathi (2015) used Invasive Weed Optimization algorithm to find optimal sizing of DG on IEEE 33 and 69 bus radial distribution system with a view to minimizing real power loss, the simulated result of the proposed approach gave good performance when compared to PSO and GA [44].

Singh and Bondriya (2015) presented an effective method based on PSO to recognize the switching operation plan for feeder reconfiguration and optimum value of DG size simultaneously. Their work aimed to reduce the real power loss, reactive power losses and enhanced bus voltage profile without violation of all the distribution constraints. The proposed approach was implemented on 33-bus RDS incorporating four distributed generation. The authors concluded based on the analysis and results of simulation that the PSO surpassed GA in term of fast computation time, lesser number of iterations, appreciable power losses reduction and the optimum value of DG sizing [58].

Mahmoudabadi, Moghadam and kazemipoor (2015) proposed a modified shuffled frog leaping algorithm (MSFLA) for allocating DGs with a view to reducing losses and improve voltage profile of power networks. A multi-objective function of Voltage Profile Improvement Index (VPII) and Line Loss Reduction Index (LLRI) was formulated and implemented on IEEE-34 bus radial distribution to compute the line losses and voltage profiles. The simulations results revealed that MSFLA techniques performed better than the shuffled frog leaping algorithm (SFLA) method [32]

Chidanandappa, Ananthapadmanabhab and Ranjith (2015) presented the implementation of Genetic Algorithm to predict optimum reconfiguration plan for power distribution system with multiple PV generators. A multi-objective and a multi-constrained optimization approach were used for the analysis. Forward backward load flow method with time varying load condition was considered. The algorithm developed predicted the switching pattern for reconfiguration at minimum loss and minimum voltage deviation and it reduced the number of switching operations without violating the defined limit constraints [12].

Hlaing and Swe (2015) proposed an analytical technique to determine the optimum location for Distributed Generation placement. The proposed approach was implemented on IEEE 17 bus test feeder with different sizes of DG to validate the effectiveness of the approach. The authors concluded that the average real and reactive power loss reduced after DG placement with proper sizing and the corresponding voltage profile values also improved after DG allocation with the optimal sizing [18].

Becerra, Riaño and Pisco (2015) presented a modified water cycle algorithm (WCA) to find the location and size of distributed generation (DG). A single objective function of power loss minimization was formulated and implemented on 33-node and 69-node RDS. The simulation results of the proposed method were compared with Bat Algorithm (BA), Particle Swarm Optimization (PSO) and Harmony Search Algorithm (HSA). The authors concluded that the modified WCA found the minimum power losses after locating and sizing distributed generators as compared with what was obtainable with BA and HAS. The algorithm converged faster than BA, PSO and HSA for all case studies [11].

Rajaram, Kumar and Rajaskar (2015) proposed a modified plant growth algorithm incorporating DG in a bid to minimizing real power loss. A single objective function was formulated and implemented on IEEE 33 bus radial distribution system. The results of the analysis showed that the proposed approach was efficient and suitable for real time application [46].

Osman and Amen (2015) proposed non-dominated sorting genetic algorithm (NSGA-II) for solving DG allocation problem in distribution systems taking into consideration technical and economic aspects. The proposed algorithm was implemented on IEEE 69- bus system. The authors concluded that certain bus (buses) in the system may be preferable for DG applications irrespective of the considered objectives [42].

Sudabattula and Kowsalya (2016) proposed an effective technique based on the cuckoo search algorithm to determine optimal allocation of wind based distributed generators in the distribution system. A single objective function of power loss reduction for a distribution system was formulated and tested on IEEE 69 bus RDS test system. The simulation results obtained with this approach were compared with other methods for validation. The authors concluded that the approach was computationally efficient with quality solution [60].

Sangwan and Ravi (2016) proposed Differential Evolution technique for optimal positioning and sizing of DG units on IEEE 14 bus RDS with a view to minimizing real power loss and improve system voltage profile. The simulation results of the proposed approach were compared to NSGA algorithm. DE gave better results in terms of real power loss and voltage profile enhancement [52]

Muthukumar and Jayalalitha (2016) used Hybrid Harmony Search Algorithm approach to minimize real power losses and enhanced voltage profile in RDS networks with optimal placement of DG and shunt capacitors. In their work, Artificial Bee Colony algorithm was used to overcome the premature and slow convergence of Harmony Search Algorithm. The proposed hybrid approach was tested on 33 and 119 node test systems and the results were compared with the other techniques. The simulation results revealed the efficiency of the proposed hybrid algorithm in obtaining optimal solution for simultaneous placement of distributed generators and shunt capacitors on the test systems [37].

Nawaz *et al.,* (2016) proposed an efficient algorithm for network reconfiguration associated with DG allocation to minimize real power losses and enhanced voltage profile on radial distribution networks. A modified Binary Particle Swarm Optimization algorithm, called Selective Particle Swarm Optimization algorithm (SPSO) was used. A multi objective function was formulated and implemented on IEEE 33 bus RDS at three different load levels. The results were compared with that of HSA, HCACO, MPGSA, GA and RGA. The proposed approach was found better in all cases. The authors concluded that the proposed method can be easily applied and adapted to any large scale radial distribution networks [38].

Nweke, Ekwueand and Ejiogu (2016) presented an analytical method for the optimal sizing and placement of DG on the Nigerian power network for active power loss minimization. The effectiveness of the proposed method was tested on Nigerian 330kV, 28- bus system. The results of the simulation showed a 6.2% reduction in active power losses (i.e. from 92.7MW to 87.0MW). An appreciable voltage profile enhancement was noticed on six load buses whose voltages magnitude fell outside the statutory limit of $0.95 \text{ p.u} \leq Vi \leq 1.05 \text{ p.u}$ [39].

Reddy, Reddy and Manohar (2016) proposed Flower Pollination Algorithm for optimal placement of three types of DG units for compensating for real power loss. The approach was implemented on IEEE 15, 34 and 69- bus radial distribution system. FPA outperformed other algorithms that had been tested on the same test cases in terms of active power loss reduction and voltage profile enhancement [47].

Mohanty and Tripathy (2016) proposed teaching learning based optimization (TLBO) techniques for optimal location and sizing of DG units in a radial distribution system. Voltage stability index was formulated as the objective function. The proposed approach was simulated on IEEE 33 and 69 bus test system, the results obtained for the approach were compared with that of GA and PSO. TLBO proved superior in minimizing real power loss and enhancing voltage profile of the test case systems [34].

Liu *et al.,* (2016) proposed a new integrated planning method of the active distribution network while considering voltage control cost. Firstly, characteristics of decentralized and centralized voltage control methods were analyzed. The technical frameworks, voltage control strategies and economical models of different voltage control systems were put forward. Then, an integrated planning model with objectives to minimize the comprehensive cost and maximize clean energy utilization under the constraint of maintaining acceptable voltage was implemented. Simulations were made on IEEE 33-bus test systems using Multi-objective Differential Evolution Algorithm. The results demonstrated that the proposed approach was able to connect larger distributed generators and decrease the economic cost of Distribution Network Operators while maintaining voltage within the statutory limits [29].

Yuvaraj, Ravi and Devabalaji (2017) proposed a new approach to determine the optimal location and sizing of Distributed Generation(DG)and Distribution STATic COMpensator(DSTATCOM) simultaneously in the distribution network tested on IEEE12-bus, 34-bus and 69-bus RDS. Loss sensitivity factor (LSF) and Voltage Stability Index (VSI) were used to predetermine the optimal location of DG and DSTATCOM, respectively. Later, cuckoo search algorithm (CSA) was used to determine the optimal size of both DG and DSTATCOM, five different cases were considered during DG and DSTATCOM placement to access the performance of the proposed technique. The results of the proposed method were compared with other existing techniques and found to outperform other existing methods in terms of minimization of power loss and voltage profile [66].

Lalitha, Reddy and Reddy (2017) presented a new methodology using Fuzzy and Artificial Bee Colony algorithm (ABC) for the placement of Distributed Generators (DG) on the radial distribution systems to reduce the real power losses and improve the voltage profile. A two-stage methodology was used for the optimal DG placement. The authors used Fuzzy to find the optimal DG locations at initial stage and in the second stage, ABC algorithm was used to find the size of the DGs corresponding to maximum loss reduction. The proposed method was tested on standard IEEE 15, 33, 34, 69 and 85 Bus RDS respectively. The results of the simulation were compared with PSO and GA. The authors concluded that the proposed approach outperformed PSO and GA in terms of the quality of solution, computational efficiency and lesser computational time [25].

Kumar, Nallagownden and Elamvazuthi (2017) proposed optimal placement of probabilistic based solar power DG on the distribution system. A multi-objective function of power loss reduction and voltage stability index improvement were optimized. The non-sorting pareto-front based multi-objective particle swarm optimization (MOPSO) technique was implemented on standard IEEE 33 radial distribution test system. The authors concluded that the proposed model was best for integration of solar power DG into the radial distribution system compared to other algorithms [24].

Remha, Chettih and Arif (2017) solved the problem of optimal DG unit placement and sizing in radial distributed network using firefly algorithm to minimize the total active power losses. Simulations were performed on IEEE 33 bus radial distribution system. The effectiveness and robustness firefly algorithm were validated with particle swarm optimization algorithm (PSO) implemented on IEEE 33 bus radial system. The obtained results clearly revealed the effectiveness of the proposed algorithm in total active power losses minimization compared to PSO algorithm [48].

Jegadeesan and Venkatasubbu (2017) proposed a new hybrid method to solve cost reduction by finding optimal location and size of multiple DGs and capacitors simultaneously on IEEE 33 and 69 bus radial distribution systems. The combined GA and ABC algorithms were used to find optimal location and size of multi-DGs and capacitors. The simulation results of combined GA-ABC algorithm was compared with results of separate GA and ABC. The hybrid technique showed the efficiency of the proposed method in terms of loss reduction and economic savings [20].

Sultana *et al.,* (2017) presented a Grey Wolf Optimizer (GWO) approach for optimal placement and sizing of multiple DG with a view to reducing active and reactive energy losses in the distribution system. Power system constraints, such as voltage magnitude limits and current boundaries were as well considered. The GWO technique, Particle Swarm Optimization (PSO) and Gravitational Search Algorithm (GSA) were tested on IEEE 15 and 33 bus RDS. The numerical results obtained using these methods were compared, with the best performance recorded via the proposed GWO method in terms of not only active and reactive energy loss but also voltage profile and convergence characteristics [61].

Amini and Kazemzadeh (2017) proposed determination of the appropriate sizing and placement of DGs on unbalanced distribution network. The appropriate sizes of DGs were obtained using probabilistic methods while the convenient location was selected using weighted multi-objective IPSO algorithm. Simulations were done on IEEE 37 bus unbalanced distribution network implemented with MATLAB software. The results obtained indicated that network power losses and voltage unbalance factor were reduced. Voltage profile of each phase was improved and significant profit was obtained for distribution companies [7].

Samajpati and Ganguly (2017) presented an intelligent approach for loss minimization and reactive power management of radial distribution systems by optimal placement of DGs and on-line load tap changers (OLTC) connected to low voltage (LV) bus using genetic algorithm (GA). The approach was tested on IEEE 69-node RTS. Optimization result showed that the proposed approach reduced power losses and at the same time kept the voltages within required limit. The authors concluded that the proposed technique was suitable for integration into energy management scheme under smart grid concept [51].

Singh et al., (2017) proposed a new technique to determine optimal location and size of DGs for power loss reduction and improvement in voltage profile. Distribution System Voltage Stability Index (DSVSI) based approach was carried out to identify critical buses and allocation of different types of DGs supplying real and reactive power. The proposed method was tested on 33-bus radial distribution system with a single DG to multiple DG units. The authors concluded that placement of multiple DGs of small capacity were found more beneficial than single DG of huge capacity [57].

Lawal, Mohammed and Abarshi (2017) presented Particle Swarm Optimization algorithm for optimal planning of Distributed Generator (DG) connected to the distribution networks. PSO was implemented in MATLAB and tested on the IEEE 34-bus and validated with the IEEE 33-nodes feeder. The authors concluded that GA sited at bus number 31 has the best location with a maximum DG size of 2534kW. The power loss was reduced to 117.72kW as against the initial value of 221.27kW with a reduction also in voltage deviation to 1.3816V from 1.4651V at an objective function of 0.7376. This was compared with other algorithms and the results proved to be superior [27].

Guan *et el*., (2017) proposed quantum particle swarm algorithm (QPSO) based wind turbine generation unit (WTGU) and photovoltaic (PV) array placement and sizing approach for real power loss reduction and voltage stability improvement of distribution system. Performance modeling of wind and solar generation system were described and classified into PQ\PQ (V)\PI type models in power flow. The proposed method was tested on IEEE 33-bus radial distribution systems to demonstrate its performance and effectiveness in view of the stated objectives. The simulation results showed that proposed method was very helpful for optimizing placement and sizing of wind/solar based DG sources in distribution system [15].

Lavudya (2017) presented Selective Particle Swarm Optimization algorithm (SPSO) to resolve network reconfiguration challenge. Allocation of DG units was achieved through sensitivity evaluation. The effectiveness of the proposed algorithm was tested on IEEE 33 bus radial distribution systems using three different load phases, particularly light, nominal and heavy loads. An improvement of 54.92% on network power losses was reported with this approach [26].

Arya, Kumar and Yadav (2017) applied VSI method on IEEE-

33 and IEEE-69 buses and obtained the location of DGs. Four optimal locations were identified for optimal sizing of DGs by a particle swarm optimization algorithm to minimize the total real power loss without violating the constraints. The approach was tested on 33 and 69 bus systems. By installing DG at optimal locations, the total power loss of the system reduced and the voltage profile of the system improved [10].

4. Discussions

Samples of open accessible literatures were reviewed from 2010 till date. The summary of the reviewed works is as shown in Figure 1. Evolution Algorithms were frequently used for DG placement and sitting. This frequent usage could be due to the fact that Artificial Intelligence methods are the current trends in solving both the simple and complex optimization problems. Artificial Intelligence methods are known to have good convergence characteristics and efficient performance.

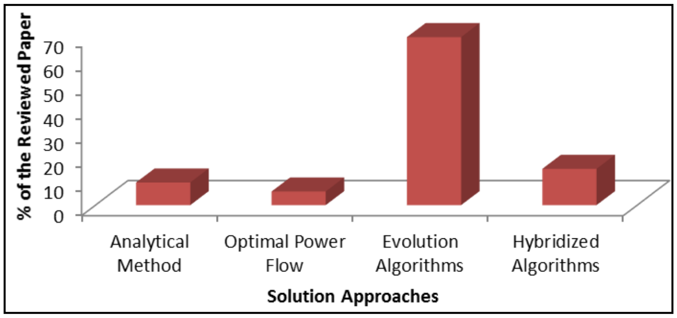

Fig 1: Solution Approaches for DG Optimal Placement and Sitting

Various types of evolution algorithms reviewed are presented in the Figure 2 below with a view to finding the frequently used algorithm(s) in solving DG optimal placement and sitting problems in a typical distribution system of a power network.

It evident that PSO and its variant enjoyed frequent usage in light of the papers reviewed. This perfectly agrees with the works of Shrivastava *et al.*, (2012) and Shareef and Kumar (2014) [1, 5].

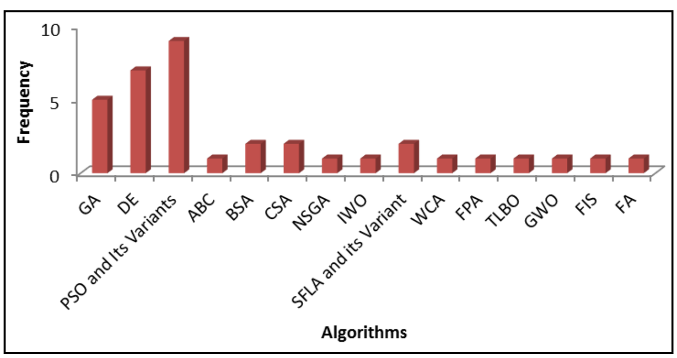

Fig 2: Shows different types of Evolution Algorithms

5. Conclusion

This work has presented an extensive review of Distributed Generation (DG) Integration on utilities distribution system of a power network. There are different solution approaches for finding optimal placement, sizing and sitting of various types of DG and their imposed constraints. It was observed that IEEE radial distribution systems were extensively exploited to validate the effectiveness and feasibility of many of the algorithms.

However, real life distribution systems were not sufficiently used to validate most of these algorithms. Going by the number of papers reviewed, lesser work has been done on Nigerian RDS in respect of DG integration. +This is largely due to scanty availability data compared to transmission systems. In respect of the volume of work reviewed, work done on Nigerian RDS was about 13.20% which was comparatively low.

Most commonly used techniques for optimal placement of DG solution are genetic algorithm and its variant, other newly developed population based optimization algorithms such Firefly Algorithm, Cuckoo search Algorithms, Fruit fly Algorithm and others are scantly exploited. The use of hybridized algorithms offer promising solutions as it involves trade off disadvantage of one and cooperatively harnessing the advantages of each other in searching for global solution in less iterations and shorter computational time.

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