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Optimal Placement and Sizing of Multiple DG in Microgrid Systems

M Salmani, J Pasupuleti, V K Ramachandaramurthy

Abstract: ***Micro grid (MG) has become popular due to its ability to disconnect from utility grid during disturbance and operate autonomously. MG typically consists of three main parts, which are Distributed Energy Resource (DER), Energy Storage System (ESS) and load. MG has several benefits and one of them is to enhance the power system reliability and flexibility by balancing the supply and demand. The scarcity of fossil fuel and environmental concern has contributed to the growth of Renewable Energy Source (RES), which is one of the main elements in MG. However, the RES integration into MG has led to multiple uncertainties due to their inherent intermittency. Therefore, optimal strategies are essential to be employed in MG to manage and control the dynamic uncertainty introduced by the renewable-based DER and variable loads. In this paper, a comprehensive review is presented on the optimal allocation of the multiple DER in MG. various optimization methods are also investigated to solve the problems in MG. Furthermore, advantages and drawbacks of each optimization method are also reported.***

Keywords: energy Resource, micro grid, renewable Energy

I. INTRODUCTION

In fact, the most critical challenge of a sustainable Micro grid (MG) is the optimum utilization of Distributed Generations (DGs) which are integrated into MG. This optimal utilization requires can be achieved due to availability of DG resources at the desirable location, accurate weather forecast and optimal sizing of RES and ESS. Such a procedure eventually, leads to a satisfactory response to load demand [1, 2]. This goal can be reached, while a variety of scattered resources are available in the right place, especially when these resources are equipped by ESSs. Using of storage system as part of MG provides several benefits such as energy cost reduction and power quality enhancement. Hence, optimal allocation of an ESS is another significant issue in MG [3].

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The increased penetration of non-conventional resources in different situations changes the configuration of the conventional Distribution System (DS) into micro-network systems known as MG, which are often supplied by green and recyclable resources [4].

Subject to the optimal use of Renewable Energy Sources (RES) including solar system, biomass, wind turbine (WT), several studies are conducted on existing network and its topology [5, 6]. Definition of DG locating is also provided by researchers, which are mainly related to climatic conditions, availability of fuel and energy sources as well as the topology of the power system.

Lately, the issue of optimal DG placement has become attractive among many researchers due to its numerous benefits. As an advantage, it can help DS operators to be able to regulate the voltage profile. Power quality increasing, peak demand shaving and eventually, system reliability are the other beneficial advantages of optimal DG allocation. On the other hand, DG configuration impacts crucially the environmental situation besides its operational benefits in power system [7]. Even though the optimal deployment and optimization of DGs in MG has been discussed, most often, the DS Operator has neither influence nor control about DGs operation, position and size. Hence, optimal sizing and location as well as monitoring should be taken into consideration [8].

The integration of RES into MG has led to multiple uncertainties due to their inherent intermittency. Therefore, to mitigate these uncertainties a general survey of DGs placement problem methods, optimization techniques and the various solution strategies with respective advantages and drawbacks are gathered in [8, 9]. Additionally, power quality improvement [5, 7] and voltage profile enhancement [6] are developed for optimum placement of DG in DS. In order to determine the size and number of DGs and ESSs in MG system [3, 10] had tried to demonstrate the comprehensive comparison of each optimization techniques to find an efficient method.

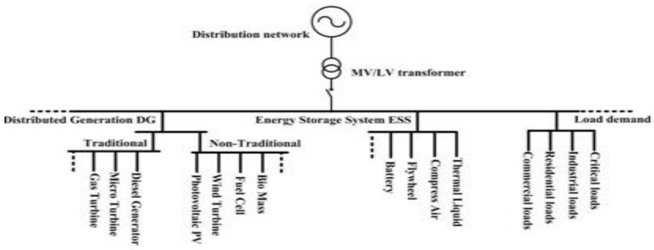

Fig. 1 Typical Distribution system encompasses DGs and ESSs

Comprehensive survey in micro grid reconfiguration had been reported in [11]. In this paper, several significant issues such as multi-objective functions, problem formulation, system constraints, and optimization methods of common renewable generation uncertainty had been considered. A review of DRE systems was accomplished in [12], various optimization methods such as Particle Swarm Optimization (PSO) is used for optimum placement and size of DGs in order to achieve a techno-economical optimization of MG. Meanwhile, several studies have been conducted to optimize both independent and grid-connected mode.

This review paper presents a full overview of optimal DGs allocation (placement and sizing) as well as insight into the optimal sizing and siting of the ESSs. The most commonly previous methods which have used by authors are PSO, Moth Flame Optimization (MFO), Mixed Integer Linear Programming (MILP), Linear Programming (LP), Gravitational Search Algorithm (GSA) and Dynamic Programming, Fuzzy Logic Expert System, Genetic Algorithm (GA), Artificial Bee Colony, Tabu Search (TS), Efficient Analytical Optimal Power Flow (EA-OPF), Ant Colony Optimization, Evolutionary Programming Simulated Annealing, Sequential Quadratic Programming (SQP), Frog Jumping methods and Bat Algorithm (BA).

This paper consists of five sections. Next to the introductory of contents as first section, the second section provides a description of different uncertainty and problem statement. Section three provides a review of the methods which used to determine the optimal location and size of the DG and EES to overcome aforementioned uncertainty. The fourth section reports summary of the presented overview and give anticipation of expected trends, and eventually, conclusion is the final chapter.

II. PROBLEM AND UNCERTAINTY CLASSIFICATION

Some factors, such as floating electricity prices, intermittent and unpredictable production of renewable energy, and various types of variable loads, are the main uncertainty parameters in power grids. Since electricity generation from RESs which are WT, PV is inherently intermittent and unpredictable, therefore, their fluctuation have an impact on frequency and voltage profile, which can result in unfavorable voltage and Power Quality (PQ) [13]. According to PQ problems which caused by the penetration of DG and large amounts of unbalanced lines; these problems can be effectively solved by allocating the optimal DG placement and capacity through the use of proper optimization methods [5].

Newly, much attention has been paid to storage systems to mitigate the unbalanced line problem. In fact, in order to reduce the unwanted effects of RES in power systems including power quality and voltage stability, the ESS is introduced to solve these bugs. Furthermore, ESSs are able to store the generated energy at off-peak or when the energy costs are low and then, deliver the stored energy into the network at peak time. Due to aforementioned advantages and capability of MG which can be exploited as a separated remote power system in both island and grid-connected, it is very attractive for energy supplier to use RESs along whit ESSs [4, 14].

Siting the DGs and proper sizing of DREs almost always is the key points of MG configuration. In most cases, the problem of proper DG allocation cannot be solved by linearized minimization problem which its aim is to minimize the replacement cost of DGs, sum of the total capital as well as operational and maintenance cost. In case of the power exchange with utility, constraints such as system reliability, energy limits of each DG, voltage stability and appropriate sizing and location of DG units and choice the best interconnection point into the power grid is another significant matter which must taking into account. These types of problems can be solved by non-linear minimization techniques [12, 15].

High volume of RESs penetration in DS can cause voltage control instability due to the real power outputs. Some dynamic Static devices, such as Static Synchronous Compensator (STATCOM) and Static Var Compensator (SVC) could be used to improve the local control voltage in the network. So, the exact location of these compensators is also very important [16, 17].

In [18] different type of uncertainties in power systems is presented. Meanwhile, various handling models to mitigate the impact of these uncertainties are classified. Various types of problems which are the common uncertainties in the power system are depicted in Fig. 2.

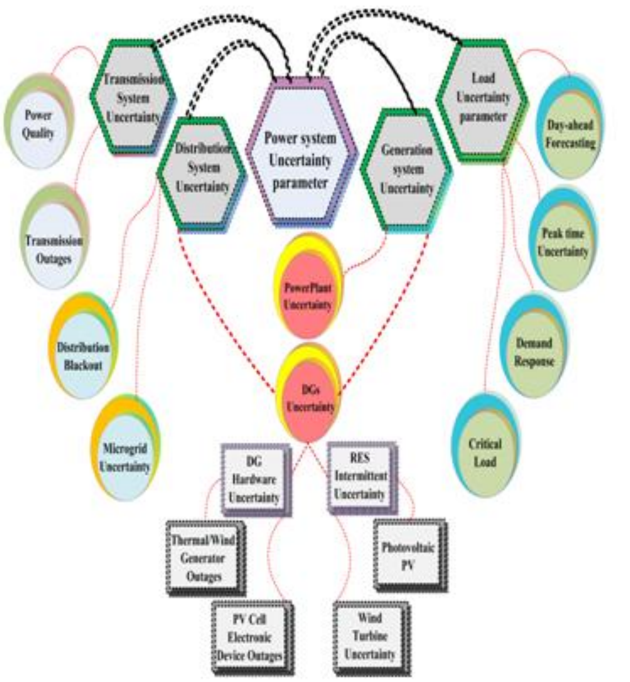

Fig. 2 The Uncertainty classification of Power system

Several optimization strategies had been investigated to achieve maximum efficiency, for instance, reconfiguration method is an operational technique in which, switching plays a key role. The topological structure of a grid is changed by opening and closing of switches. It means these switching let DS operators to decide whether network

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performance remains in radial or on the meshed mode. Reconfiguration is used to maximize the load balancing and to minimize power losses. In this regard, the proper reconfiguration creates a stable voltage profile throughout the system [19].

III. DG AND ESS: OPTIMAL SITE AND SIZING METHODS

Due to the fact that, the technological growth and transcendent economy is directly depends on the powerful, reliable and sustainable power system; development of the DG technology has grown in recent decade. Electricity production of DERs has significantly contributed to the power generation, especially in advancement nations. [1]. accordingly, sustainability and reliability of power system are essential concerns for the utility supplier to examine sustainability issues in MG control and operation. To reach these goals, positioning of DGs in MG is very important. Hence, various methods have been introduced to improve the reliability level of power system, whereas reliability is a significant parameter in optimal sizing and placement problem formulation of DG in power system [20-22].

There is different point of view to categorize the optimization methods based on optimal location and sizing. Nevertheless, optimization techniques are generally divided into two categories: mathematical and metaheuristic methods [23-25]. Table 1 summarizes significant features of several research which works on optimization method to address optimum DG size and location problem in power systems.

Table. 1 Brief description of the optimal methods of sizing and positioning DGs in power network

Ref.	Proposed approach	contributions	Optimal			Type of DGs	Optimization technique	
			site	size	ESS		Metaheuristic	math
[1]	CGSA	power loss reduction and reliability level enhancement	✓	✓		PV	✓	
[5]	GA SQP	Optimal allocation of ESS in unbalanced three-phase low voltage MG	✓	✓	✓	ESS	✓	
[6]	Novel Meta-heuristic	Power losses reduction and improvement of bus voltages	✓	✓	✓	PV, WT, Biomass, DSTATCOM	✓	
[7]	ANN, GA	Optimizing the total cost, reliability and voltage stability		✓		Multi-RES	✓	
[12]	PSO	Investment cost minimization	✓	✓		Multiple DGs	✓	
[26]	PSO FMCDM	Improvements in RES penetration, reduced DG locations/feeder configuration	✓	✓	✓	Multiple DGs, FESS	✓	
[27]	second order	To pave the way for using renewable resources as DGs in distribution networks	✓	✓		RES		✓
[28]	GSA	Multi-DG allocation to minimizing power loss				Multiple DGs	✓	
[29]	MFO	power system stability and reliability, improvement of power factor and voltage profile	✓	✓		Multiple DGs capacitor bank	✓	
[30]	PSO	power loss reduction and voltage profile enhancement	✓	✓		Multiple DGs	✓	
[31]	BPSO	Optimal DG reconfiguration, minimizing total cost and efficient power quality	✓	✓		Multiple DGs	✓	
[32]	VCS	To improve the reliability indices, this paper focuses on customer satisfaction and presents the comparison to other algorithms	✓			Multiple DGs	✓	
[33]	MILP GA	To minimize shed load, to find the best size, total investment costs minimization		✓		Multiple DGs	✓	
[34]	EA-OPF	Optimal commissioning of several DG technologies for power loss reduction	✓	✓		Multiple DGs	✓	
[35]	LP / GS	Investigating about the impact of the DGs and renewable sources on resiliency and reliability of distribution system	✓	✓		RES		✓
[36]	PSO	Optimum feeder reconfiguration, optimum DG size and to reduce the reactive and real power losses and enhance the bus voltage profile	✓	✓		Multiple DGs	✓	

Banumalar, et al. [1] presented a Clustered Gravitational Search Algorithm to solve multi objective problem for solar power generation. Authors believe that the high level of PV penetration can cause high level of risk in grid stability. This optimization model was accredited on radial 69-bus IEEE standard power grid. The effectiveness of this optimization method was compared with results of other available optimization method.

In [2] authors have highlighted the importance of ESS for renewable resources, the main constraints of ESS and RES, and the expected future for energy storage are also discussed.

Carpinelli, G., et al. [5] used sequential quadratic programming to model the genetic algorithm. This GA model has significantly reduced the identification process of subsets for the optimal location of ESS. However, DG location and sizing optimization and voltage profile is not considered. Ahmadian, et al. [7] also proposed the multi-objective GA method. The advantage of this method is that each objective can be evaluated independently. The total cost, reliability and voltage stability are different objectives which optimized in this paper.

Iqbal, et al. [6] proposed the combination technique which encompasses design, dispatch and operation of hybrid Generators in MG. Meantime, authors presented an optimal algorithm to minimize the yearly total operation cost which was developed for sizing the both PV and Battery ESS. In addition, this paper proposes the procedure to positioning the Battery ESS in order to minimize total system losses and increase the voltage profile across buses.

According to [12] the PSO method used to solve a optimum allocation problem which formulated by the non-linear integer optimization model in which performance of the MG in both Island and grid-connected had been evaluated. In this paper the significant key element including ESS did not play any role in DS which must be taken into consideration. In both papers [30, 36] the same meta-heuristic method are utilized. In these papers PSO has been applied in order to achieve minimum power losses and to improve voltage profile in the distribution networks.

The literature review [24] presents a summary of non-conventional models which is used to determine optimal size and optimal location of multiple DGs. The main purpose is to enhance the voltage profile and to decrease the real power losses. Furthermore, authors report the optimal application of some methods in which by determining the optimum position and proper cycle of charge/discharge of battery ESS.

A full review on optimal sizing, placement and control of ESS in distribution network has took placed in [22]. In this regard, various optimization approaches are also presented. Moreover, different type of ESS technologies and their respective benefits has been discussed. Amiryar, M. and K.J.A.S. Pullen [14] introduced a Flywheel ESS (FESS) into an embedded hybrid network which significantly enhanced the system reliability and allowed a much higher RESs penetration which reduced diesel fuel consumption.

The detailed study of DG definition, sight of current and future technologies for DGs, appropriate size and location of DG along with their advantages and drawbacks, optimizations methods and techniques has demonstrated in the literature [37]. In the similar sphere, Tan, et al. [38] attempted to readout the most prestigious DRE placement methods, including Analytical Methods, 2/3 Rule, MINL, OPF, Hybrid Intelligent System and different Artificial Intelligent optimization techniques.

Rasdi, et al. [28] present the optimal placement and optimal sizing of multiple DG in DS in order to achieve minimum power losses. This study applied developed GSA model as an optimization method. Also, results of evolutionary Programming (EP) were compared with result of proposed method in order to highlight its superiority.

According to [29] the optimal allocation of DG and capacitor bank in the electrical network can be led to improve sustainability and reliability of MG, power factor and voltage profile. This paper proposed the new MFO optimization techniques. This optimization technique is validated for power loss minimization in IEEE standard 33-buss and performed in the MATLAB R2015a software.

Rani, B. and A. Reddy, [31] developed Binary Particle Swarm Optimization algorithm for the best placement of DG in DS. In this work, location of DG was depended upon generation and load demand. The outcome also showed better convergence characteristics and better computational efficiency of the proposed method. Accordingly, the voltage profile, power losses, system stability have been improved. In this paper, ESS is not included as a part of MG component.

In review paper, [32] first of all, the impacts of DGs on the power system reliability was presented. Then, to determine the optimum allocation of DG units, VCS algorithm is applied to improve the reliability profile. The case study and simulation is accomplished on a IEEE standard 34-bus. The VCS optimization results are also compared with the results of several optimization algorithms such as genetic algorithm and PSO.

Li, B., et al. [33], presents an MINLP (mixed integer non-linear programming) model for 13-node modified network and Heat 14 nodes system, Gas 20 and IEEE 30. The main goal of this method is to attain the optimal operation for system, where the goal is to minimize shed load. On the other hand, in order to determine the proper size of DGs subject to the total investment costs minimization, the GA optimization algorithm is considered.

In Ref [34] authors used a simple Efficient Analytical method to accommodate suitable DG units to minimize power loss in DS. Then, to find a solution for the problem of optimal placement and sizing of multiple DG with different generation capacity, EA method was proposed. Moreover, the EA method has merged to the OPF algorithm to develop a new method, i.e., (EA-OPF), which effectively addresses overall system constraints. The success of the method was confirmed by testing on IEEE standard 33-bus and 69-bus system.

IV. SUMMARY AND FUTURE TREND

Although many studies have suggested different optimization methods relevant to the optimal location and sizing of multiple DGs in the MG system, results do not completely satisfactory. In this regard, the main bottleneck is complexity of optimization process, as well as lack of common procedure due to differentiation of each DG specification [39]. In fact, much more restriction must be considered synchronously, such as system reliability, power factor, power loss, load factors, operational cost, voltage profile, GHG emission, demand capacity, weather forecasting analysis. However, each methodology has been proposed to solve the multi-objective problems and restrictions.

Indeed, the practical evaluation and analytical comparison for these methods is difficult. Accordingly, just some objectives like pollution and power loss reduction are in common. Therefore, more researches are required to improve the performance of optimization methods which could be achieved by allocating the proper DGs in MG. Fig 3 demonstrates stochastic flowchart of the general optimization algorithm for optimal sizing and placement.

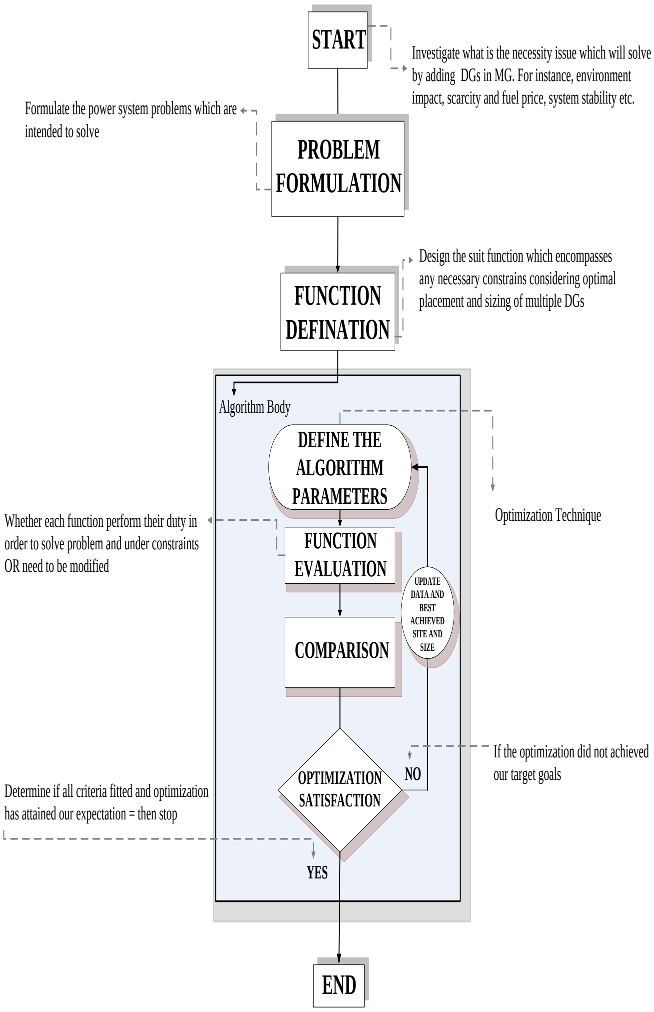

Fig. 3 Block diagram of the common placement and sizing algorithm

Since application of RES gradually will be become more universal, moreover, due to annual new demand in power system and subject to construction new power planet and transmission line, it will be expected which DG sources play a crucial role in supplying system in the future. Therefore, in order to maximize the efficiency of the MG system, the optimal allocation of DGs should be taking into account.

V. CONCLUSION

This study aims to provide a general review of the various approaches which are available to solve the problems of optimal sizing and placement of DG units in MG system. The goal of all optimization methods is to minimize the uncertainties caused by the RES's impact on the network. These objectives are: to minimize the destructive impact of dispersed resources, power losses, GHG emission, total operation and investment cost of power system. On the contrary, to enhance and improve voltage profile, power quality, system stability and reliability.

Many researches had been revealed that the "optimal site and sizing of DG" has various benefits in many fields, for instance; environmentally, technically and especially on the economic front. Hence, different optimization methods and the variety solution techniques with respective merits and demerits are given. In general, GA, PSO are the most applicable method which is applied to find the optimal size and site of DGs in MG. Nonetheless, some researchers added elitism to combine other algorithms or initializing cutting the edge techniques.

In the nutshell, since the future prospects of the global energy are moving towards the use of green energy sources, exploitation of ESSs along with the use of RESs will be inevitable. Furthermore, in this scope, as most of the previous research just has concentrated on one aspect, Therefore, the prospective trends for optimization procedure will be investigating for proper size and location of DG and EES simultaneously. It could be achieved by combination of non-conventional techniques.

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