Chapter 1

Introduction

1.1 General

Over the last few decades, the world has attempted to develop the most cost-effective, simple, and best solution for natural power utilization in numerous technological fields to maintain the safety of our globe. All international leaders, legislators, industrialists, and researchers are working to limit carbon emissions and their impact on global warming. Several places around the world are abundant in these natural resources. As most remote areas face significant technical and economic challenges in obtaining national grid power, interest in integrating hydropower, biomass, solar panels, and the wind is growing. The cutting-edge technology and mathematical algorithm allow researchers and engineers to use natural power resources better. Many developed and developing countries are moving toward greater use of renewable energy sources while also attempting to find better and better technical ways to gain techno-economic advantages. With increasing deregulation and power demand in modern power system networks worldwide, power utilities face a significant challenge in locating and managing renewable energy resources along with power grid stability, security, reliability, and the security and economic issue of power supply.

According to the global status report [1], renewable sources contributed around 59 percent of global power capacity in 2014 with significant growth occurring all across the world. The market was dominated by wind, solar PV, and hydroelectricity, as renewable energy is a critical component of achieving carbon neutrality. Variable renewable is achieving high penetration levels in several countries' electricity systems. As a result, policymakers in certain jurisdictions have mandated that utilities alter their business models and grid infrastructure. The number of residential customers who produce their power has increased significantly in Australia, Europe, Japan, and North America. Major corporations and institutions worldwide have made substantial commitments to purchase renewable electricity or invest in their renewable generating capacity. More interest has been observed in solar PV and wind energy, which are starting to play a significant role in electricity generation due to rapidly falling costs. In terms of wind energy power systems, India was ahead of Spain in 2015. The principles for a clean energy plan have been reported in FERC staff paper [2]. Renewable generators are located near load at the distribution level due to economic, technical, and environmental benefits, and several changes to the electric system are required. The study of existing technologies, new modeling tools, and approaches aid in assessing a green power plan. According to [3], the high penetration of renewable power plants caused voltage increases, low voltage stability, power fluctuation, and substantial losses in distribution networks. The power sector has received the bulk of renewable energy policy attention. The policy drive for renewable and enabling technologies, such as energy storage, to be integrated into power systems remained focused on boosting power system flexibility, control and grid resilience. Policies to encourage VRE integration mainly focused on market design, demand-side management, transmission, and distribution system enhancements, grid interconnections, and support for energy storage [4]. As a result, several developed and developing countries have been modifying their technology for the placement, operation, and control of distributed generators during the previous few decades. The term "smart-grid" was introduced in 2004 to describe grid modernization in Europe and the United States, according to [5]. A microgrid is a well-known subset of a smart grid. It is a semi-autonomous grouping of generating sources and load. The main distinguishing feature of the microgrid is the distributed sources which are interconnected by micro source controllers [6]. A critical feature of the microgrid is its presentation to the surrounding distribution system as a single controlled system akin to a current customer or possibly a tiny generation source in load levels.

The micro-grid structure should be designed to reduce congestion, counterbalance the need for generation, supply local voltage support, enhance stability, or respond to rapid changes. Standard micro-grids are established by connecting small energy assets, such as MGT, small WT, DG, PV cells, and fuel cells, with programmable storage devices and loads, such as flywheels supercapacitors, and batteries, in low-voltage distribution systems [7]. These are possible with proper modeling, placement, sizing, and analysis of all these assets.

In the context of these trends, an overview of many studies and works on methodologies and models of green power Distributed Generators (DGs) for better placement and integration in power-grids/microgrids has been presented. Wind power generation and solar power generation are the primary natural resources under consideration for research. Proper green power source planning at the distribution level benefits the network regarding voltage profile, efficiency, reliability, and stability. Various scholars' methodologies for integrating conventional and Natural Power Distributed Generators (NPDG) in distribution systems, including technical limits, economic factors, and technological improvement, have been reviewed here.

1.2 State-of-the-Art

The good benefits of NPDS can be obtained by determining its optimal size and placement in the primary grid or microgrid. Microgrid planners and researchers face the challenging task of maximizing profitability from NPDG integration. Many research papers connected to these subjects have been reviewed to establish a solution path; thus, they are described here. The study has been separated into two sections. The first section presents an optimization strategy for Distributed generator placement and size. The second portion of the study presented a renewable distributed generator deployment and modeling of their intermittent nature.

1.2.1 Optimisation Approach for the Placement of DG

This study presents optimization problem on the basic and modified approach associated with optimization methodologies. The main five approaches have been reviewed and listed in this section:

1. Analytical approach(solve with optimal power flow or load flow)
2. Numerical Approach (solve with Iterative approach/optimal power flow)
3. Evolutionary Computational based approach
4. software-based approach

5. Hybrid approach

Most researchers have developed expressions based on various technical factors in the analytical approach. Analytical techniques based on the "2/3" rule have been proposed for installing DG at 2/3 of line length for 2/3 of incoming generation capacity. It is only allowed for radial feeders with uniformly distributed loads; it is ineffective for non-uniformly distributed loads. [8]. The expression based on the exact loss formula has been proposed for the placement of a single DG with optimum size to minimize network losses. That proposed formula has been tested & validated for three various distribution systems in [9]. The distribution systems have developed a loss sensitivity factor based on equivalent current injection. The developed sensitivity factor has been used to determine the optimal size and placement of distributed generation, to minimize the total power losses. The analytical method would not require the usage of an admittance matrix, inverse admittance matrix, or Jacobian matrix [10]. The analytic expression based on the exact loss formula has also been proposed for deciding the optimal size and power factor of DGs capable of delivering only real power and also for both real and reactive power. The proposed analytical expressions are based on improving the previously listed method to DG type. The load flow has been conducted to obtain the greatest possible loss reduction in distribution networks [11]. An improved analytical (IA) expression has been suggested to compute the optimal size of four different DG variants to determine their location, along with their capability of producing both real and reactive power. A technique for obtaining the ideal power factor and loss reduction has been described in [12]. In addition, the loss sensitivity factor (LSF) and exhaustive load flow (ELF) approaches have been included. Three alternative analytical expressions have been developed and solved using optimal power flow for evaluating the optimum sizes, best location, and operating strategy of distributed generation (DG) units considering power loss minimization [13]. The integration of dispatchable and non-dispatchable renewable distributed generation (DG) units for minimizing annual energy losses has been proposed in [14] by developing an analytical expression to identify the size and power factor of DG. The exact solution approach using the enumeration method, which enumerates the solution for every possible combination, is used in article[15] to solve optimum installation of DG using backward-forward load flow applied.

For determining the location and size of DG, the objective problems have been developed based on numerical methods like deterministic approach, graphical construction, linear/non-linear programming, quadratic programming, and solved on iterative approaches like optimal power flow by researchers. The existing distribution network should be utilized and developed optimally to accommodate a new type of embedded generation. A new technique has been developed using linear programming to determine the optimal allocation of embedded generation concerning EG constraints [16] and energy harvesting [17]. In the paper [18], A dynamic programming search method has been presented for locating and sizing DGs to enhance voltage stability and reduce network losses simultaneously. A mixed-integer non-linear programming (MINLP) technique has been applied for optimal allocation of either single wind DG units [19] or different types of DG units [20]. They considered a discrete probabilistic generation-load model, reduced into a deterministic model to decrease annual energy loss. The MINLP is employed for optimum allocation of various DG units to minimize cost and maximize total system benefit (TSB) [21] for evaluation of the DG placement model based on real power nodal price and real power loss sensitivity index, as an economic and operational criterion in hybrid electric market [22], and for planning to a developed integrated model for distribution network with DG [23]. This integrated model reduces DG's investment and operating expenses, total payments toward compensating system losses over the planning period, and various expenditures based on the available alternative scenarios. A multi-objective framework as non-linear programming (NLP) has been proposed in the formulation of the objective function for optimal placement and sizing of DG units to minimize the number of DGs and power losses as well as maximize voltage stability margin in [24]. The network capacity has been determined and analyzed to accommodate DG using optimal power flow [25]. A multi-period AC optimal power flow (OPF)-based technique for evaluating the maximum capacity of a new variable distributed generation able to be connected to a distribution network has been proposed in [26]. The same technique has been used to minimize energy losses of the network, including an innovative control strategy [27]. The effect of DG placement has been analyzed for achieving minimization of losses, and maximization of reliability with time-varying loads [28]. In contrast, the exhaustive Search approach [29] has been deployed for contingency assessment.

The above literature has proposed a framework to integrate distributed generators in distributed power systems to meet various goals, including minimizing energy losses in terms of loss index, loss sensitivity index, and annual network losses, improving voltage stability and maximizing reliability. Reviewed literature has focused on the planning of DG placement without considering its nature and type, such as renewable or non-renewable except [19] and [20]. The optimization problems have been formulated with an analytical and numerical approach in the above study. The problems were solved using load flow of optimal power flow which consumes more time. A review of these works has motivated us to do research in two areas.

- Development of novel methodologies like evolutionary computational, software-based approach, and Hybrid approach for solving the optimization problem in the power system field
- Develop optimization problem including a model of non-renewable renewable DG considering its type, characteristics, availability, and nature of its sources to determine location, size, and the number of DGs.

Today's Power sector, which grows towards expanding the existing distribution network (DN), transforming DN into a microgrid, and developing new microgrid and smart-grid, needs robust and efficient planning.

A variety of meta-heuristic and heuristics algorithm such as Genetic Algorithm (GA)[30], [31], [32], [33], [34] Particle Swarm Optimization (PSO) [35],[36],[37],[38],[39], [40], [41]. Artificial Bee Colony (ABC) algorithm [42], Ant colony optimiser (ACO) [43], and Harmony search Optimization [44] have been proposed for planning of DG in the distribution network/microgrid. Many other Evolutionary Computational based approaches like Modified Teaching-Learning Based Optimization (MTLBO), Simulated Annealing (SA), Differential Evolution (DE), Practical Heuristic Algorithms,Tabu Search (TS) etc have been reviewed in [45],[46], and [47].

A hybrid approach combines two or more of the above methods. In recent years the application of the hybrid approach has been more favorable for planning DG placement and sizing. A hybrid GA and OPF, GA and fuzzy goal programming, GA and decision theory, and hybrid GA and PSO have been studied in [46]. Matrix real-coded genetic algorithm (MRCGA) corporate with dynamic capacity adjustment algorithm has been applied to solve optimization problem based on the analytical function to allocate DG in microgrids.[48]. The optimal sites and corresponding sizes of distributed generators and structural modifications for autonomous micro-grids have been obtained using particle swarm optimization, and genetic algorithm-based optimization techniques [49]. A combined genetic algorithm (GA)/particle swarm optimization (PSO) has been presented for optimal location and sizing of DG on distribution systems in [50], [51]. A methodology based on a combination of Genetic Algorithm (GA) and Intelligent Water Drops (IWD) has been proposed to find the location and capacity of DG in Microgrids. [52]. The below Table:1.1 shows a detailed study of the above meta-heuristic, heuristics algorithm, and hybrid approach.

Table 1.1: Details of meta-heuristic, heuristics and hybrid Optimisation Algorithm (OA)

OA Type	**Objectives**	**Description of optimisation problem**	**System on which algorithm applied**	**Ref.**
GA	Evaluate allocation and sizing of DG impacts on system reliability, losses and voltage profile	fitness function includes relation between benefits by installing DG,investment and operation cost. The reliability indices are evaluated based on analytical methods modified to handle multiple generations.	Brazilian distribution system	[30]
GA	Minimize the average of locational charges for unit real power at buses	fitness function has been evaluated by considering voltage dependent load models to allocate DG	13-Bus radial feeder and IEEE 6-bus networked system	[31]

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Table 1.1 – *Continued from previous page*

OA Type	Objectives	Description of optimisation problem	System on which algorithm applied	Ref.
GA	Minimize the power loss	fitness function has been evaluated on the basis of single-distributed generation and multiple-distributed generations separately considering system subjected to no voltage violation at any of the buses to place DG	13-Bus radial feeder and IEEE 6-bus networked system	[32]
GA	Multi-objective performance index (IMO)such as real and reactive power loss index, voltage profile index, MVA capacity index	fitness function has been evaluated by considering different load models like industrial, commercial and residential to install DG	16-bus and 37-bus distribution system	[33]
GA	Least cost network investment that satisfies load growth requirements without violating any system and operational constraints	the problem is formulated as a cost function in terms of loss cost and the cost involved toward installing DG to locate and size DG	33-bus system,67-bus system	[34]

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Table 1.1 – *Continued from previous page*

OA Type	Objectives	Description of optimisation problem	System on which algorithm applied	Ref.
PSO	Minimise system costs which includes equipment cost, cost of load curtailment, manufacturing cost of microgrid , Power sale income to main grid with respect to constraints like Loss Factor Index	the objective function has been solved by considering solar system model, battery model,Fuel Cell model with reliability and wind model with uncertainty	choose best combination of DGs	[35]
PSO	Minimize real power losses	problem formation has been done into two sub-problems: the DG optimal size (continuous optimization) and location (discrete optimization) by adopting a radial power flow algorithm to satisfy the equality constraints	10-bus radial distribution system,69-bus power distribution system	[36]

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Table 1.1 – *Continued from previous page*

OA Type	Objectives	Description of optimisation problem	System on which algorithm applied	Ref.
PSO	Minimize losses	fitness function has been evaluated for placement of DG in numerous microgrid such as Microgrid with DG supplying real power only, Microgrid with DG supplying reactive power only, Microgrid with DG supplying real power and consuming reactive power, Microgrid with DG regulating the bus voltage, Microgrid with four different types of DGs : Photovoltaic, wind generation, and biomass generator, synchronous condenser, Island microgrid	69-bus power distribution system	[37]
PSO	Multi-Objective performance Index (MOI)such as real and reactive power loss index, voltage profile index, MVA capacity index and Short-circuit level index	fitness function has been evaluated by considering different load models like constant load, industrial, commercial and residential load and mixed load to install DG	38-bus radial test system and the IEEE 30-bus mesh test system	[38]

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Table 1.1 – *Continued from previous page*

OA Type	**Objectives**	**Description of optimisation problem**	**System on which algorithm applied**	**Ref.**
PSO	To achieve maximum penetration level of Inverter based and synchronous based DG	non linear problem has been formulated by considering power balance constraints, bus voltage limits, total and individual harmonic distortion limits, over-current relay operating time limits, and protection coordination constraints	IEEE-30 bus looped distribution network with ten load and DG scenarios	[39]

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Table 1.1 – *Continued from previous page*

OA Type	**Objectives**	**Description of optimisation problem**	**System on which algorithm applied**	**Ref.**
PSO	Minimizing the power distribution loss	The problem has been evaluated for determining optimal location,power factor and size of different types of DGs such as DG capable of injecting real power only, like photovoltaic, fuel cells etc, DG capable of injecting reactive power only, e.g. kvar compensator, synchronous compensator, capacitors etc, DG capable of injecting both real and reactive power, e.g. synchronous machines, DG capable of injecting real but consuming reactive power, e.g. induction generators used in the wind farms.	tested on 33-bus and 69-bus test systems	[40], [41].
ABC	Minimize the total system real power loss	the optimisation problem has been solved to determine the optimal DG-unit's size, power factor, and location	69-bus test systems	[42]

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Table 1.1 – *Continued from previous page*

OA Type	Objectives	Description of optimisation problem	System on which algorithm applied	Ref.
ACO	To maximize the distribution network reliability	Problem has been solved for optimal recloser location and DG placement	69-bus test systems and 394-bus test distribution system	[43]
HSA	To minimize real power loss and improving voltage profile	Network reconfiguration problem has been solved by identify location of (DG) with various loading scenario	33-bus radial distribution system	[44]
(MRCGA)	To minimise the cost function of the system	problem has been dealt with the non-smooth cost functions to find sets of optimal capacities and economic operation strategies of ESS and DG sources	Low Voltage MG system	[48]
Hybrid GA-PSO	To improve the voltage profile of the system, in reduction of real power	The methodology has been proposed to suggest novel sizing and siting strategies for distributed generators and structural modifications	To operate standard 33-bus distribution system as an autonomous	[49]
Hybrid GA-PSO	To minimize network power loss and better voltage regulation	solving the problem of optimal location and sizing of DG on distributed systems	33-bus distribution system 69 - bus distribution system	[50], [51]

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Table 1.1 – *Continued from previous page*

OA Type	Objectives	Description of optimisation problem	System on which algorithm applied	Ref.
GA-IWD	To minimize network power losses, improving voltage regulation and increasing the voltage stability	optimisation problem has formulated for solving the problem of optimal location and sizing of DG on distributed systems	69-bus and 33-bus Microgrids	[52]

Almost every published work in the literature on determining the size and location of DG in distribution systems has used a novel algorithm or addressed a modified optimization problem and demonstrated the efficiency of that technique. The achievement of a single or many objectives, such as network losses, voltage stability, and the cost of microgrid installation and operation, has been considered. A couple of these published works have talked about the DG model and type for installation. Renewable DG modeling is becoming crucial for proper microgrid design; further research into probabilistic models of Natural Power Distributed Sources (NPDS) is required to alter and manage the distribution grid as a microgrid. In this study, wind power distributed generators and solar power distributed generators have been chosen for the integration with microturbines in a microgrid.

1.2.2 Model of Renewable DG

There has been an enormous gain in wind power and solar utilization in the last two decades. The generation power of wind turbines depends on wind speed and wind speed characteristics. Several ways have been applied to determine the power output of wind generators as the probabilistic nature of wind. The mechanical design of the wind turbine, historical data on wind speed, generator characteristics, and wind speed forecasting are the foundations for wind turbine generator modeling. Thus, wind power generation is entirely dependent on wind speed for a given wind turbine. Wind speed prediction is vital for wind turbine electricity output. The majority of wind speed predictions are based on statistics or physical measurements. Most researchers employed statistical models to characterize the probabilistic nature of wind speed. The details of the wind mathematical model of wind speed are shown in Table:1.2.

Table 1.2: Details of wind speed model

Details of Wind speed model	**Objective**
Weibull probability distribution function.Power output has been estimated using co-efficient calculated from standard curve fitting technique	Integration of wind generator in micro grid with storage devices [47]
Rayleigh PDF which is a special case of the Weibull PDF	Optimal construction and planning for microgrid [53]
Wind speed statistics-SD (standard deviation) and mean value -µ of different areas for the period 8760 hours calculated	Optimal numbers of wind,solar ,diesel in stand-alone system [54]
Rayleigh PDF -case of the Weibull PDF has divided in wind speed states	Allocation of wind based DG unit in distribution system [19]
Weibull PDF, parameters were calculated for specific time segment	optimal allocation of renewable sources in smart distribution system [20, 55]
Real wind speed data for specific area has been used to obtain time series approach and corresponding PDF of three different wind speed regimes has been simulated.	determining the optimal DG sitting and sizing for different wind speed scenarios [56]
WeibullPDF was used to describe the wind speed, and parameters were estimated using curve fitting and maximum likelihood approaches.	optimal placement of energy storage system with wind penetration [57, 58]Sizing and analysis of renewable energy in distribution system[59]
Wind speed is modelled by Weibull PDF, scale index and shape index were calculated using mean and variance	evaluation of distribution system with wind and solar [60]

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Table 1.2 – *Continued from previous page*

Details of wind speed model	**Objective**
ARMA time-series model has been used and Common wind model has been developed by Wind speed statistics-σ (standard deviation) and mean value -μµ of different sites for the period of three year	Evaluate reliability of power generation system with wind power [61, 62]
Auto regressive and moving average time-series model has been used	optimal allocation of energy storage system in distribution system with wind power penetration [63]
To model wind speed, cdf is utilised.	Analysis of droop –regulated microgrid with wind generation [64] .
Wind speed is subjected to NDF	Sizing and analysis of renewable energy in microgrid./cordinate with plug in vehicals in microgrid [65, 66]
Beta distribution parameter-ϕ,ψ has been used for real power value y with predicted value of power	DG placement and conservation voltage reduction interaction [67]

Output power generation of the solar system depends on physical factors like the area of the PV array, solar irradiance, and ambient temperature. Solar power generation for specified PV array can be modeled by solar irradiance and by statistical or physical measurement of latitude, altitude, seasonal variation, daily variation. "R. H. Inman, H. T. Pedro, and C. F. Coimbra," [68], "Y. D. Arthur, K. B. Gyamfi, and S. Appiah" [69], and M. Diagne [70] have studied several solar forecasting techniques for integration of solar energy sources. Mainly three methods have been adopted for the solar power model.
1) standard probability distribution, 2) Regression model 3) Artificial intelligence- Artificial neural network. The standard probability distributions for solar irradiance are as same as listed for wind. Among all these, Beta distribution function is widely used for solar power. Table:1.3 shows a summary of the solar irradiance model preferred by

different researchers.

Table 1.3: Details of solar irradiation model

Solar irradiation model	**Objective**
Solar irradiation has been modelled to follow beta distribution function	Integration of solar power generator in micro grid with storage devices [47], Optimal construction and planning for microgrid [53],
Solar irradiance is described by Weibull distribution function	Sizing and analysis of renewable energy in distribution system [59]
Solar irradiance statistics-SD (standard deviation) and mean value -μ of different areas for the period 8760 hours have been converted in to power generation using manufacturer specification	Optimal numbers of wind,solar ,diesel in stand-alone system [54]
Solar irradiation is characterised using beta PDF, parameters have been calculated for specific time sesgment	optimal allocation of renewable sources in smart distribution system [20, 55]
Clearness index PDF has been used for solar irradiance description for hourly analysis by analytical method and Monte carlo simulation	evaluation of distribution system with wind and solar [60]
Solar radiation depends on the solar panel tilt angle, and thus Meteonorm software was used to calculate the radiation at 30∘ tilted surfaces	Sizing and analysis of renewable energy in microgrid./coordinate with plug in vehicles in microgrid [66]
Beta distribution parameter has been used to analyse uncertainty of solar irradiation, Two parameters -ϕ and ψ have been used for prediction of real power value	renewable DG placement and conservation voltage reduction interaction [67]

1.3 Motivation

Prevalent research has been summarised in the form of state-of-art, and the study of the same revealed few gaps; hence same could be represented here.

- The articles which have been published presented research work in the context of accommodating renewable and non-renewable generators in the distribution system. The primary goal of these studies was to reduce losses and improve voltage stability. Reduced losses and improved voltage profiles can alter the distribution network's power drawn from the main grid. In the literature, this aspect has gained no attention.

- The problem of establishing the placement and size of DG has been solved by considering DG such as synchronous generators, biomass-based microturbines, solar, and wind independently. The impact of combined DG installation has not been extensively researched.

- Many papers assumed Weibull pdf and beta pdf parameters for wind speed and solar irradiation modeling. After obtaining this model, an examination of the influence of the NPDG was performed. The Weibull pdf and beta pdf parameters change over time.

- Only a few hybrid optimization algorithms have been addressed to install, plan, and operate microgrids with renewable and non-renewable DG. It motivates the development of a new hybrid strategy that provides robust operation and planning for renewable DG in the presence of uncertainty.

- The majority of work has been published to reduce microgrids' installation or operational costs using renewable and non-renewable DGs. The cost of under and overestimated natural resources were not considered when developing the cost function. This could be critical in the case of a microgrid powered by renewable energy.

The thorough review of the existing study reveals a few missing elements, motivating the development of a new algorithm for optimal integration of Microturbine, wind generation +, solar generation +, and storage device utilizing a hybrid approach. The goal of integrating DGS and storage devices is to position DGS for cost-effective installation and operation of a distribution power system as a microgrid. The same has been stated here:

- Analyze available wind speed to develop a mathematical model of a single wind generation unit. Even though Gujarat's seacoast is relatively long, total wind power generation in Gujarat is low compared to wind availability. The site was chosen based on an analysis of wind resources across several sea-shore regions of Gujarat state. It has been determined to collect historical wind statistics to study wind potential and compute probable wind power at variable parameters, so that wind power generation may be estimated to plan a microgrid with DG.

- Develop a mathematical model of a single solar generation unit based on the available solar radiation and the geographical conditions of the chosen site. The following parameters are considered while estimating solar power generation: Location's longitude and latitude, type of solar panel, tracking technology of the solar panel, and the ambient temperature.

Because wind and solar power sources are changeable in nature, a statical analysis using a probability distribution function has been performed at the beginning. Regular interval analysis can help to reach accuracy. As a result, it is decided to determine the hourly average power generation of solar and wind units and incorporate it into the formulation of the optimization problem;

- Determine the model for the microgrid and load and the nodal voltages and losses, using backward forward load flow without the installation of DG. Place a single wind DG unit and a single solar DG unit on each node to determine the effect on branch losses, overall grid losses, nodal voltage, and power. Analyze the performance of a microgrid with and without storage devices. Determine the best location and amount of DG to minimize grid losses and maximize natural resource utilization.

- Develop algorithm for optimal placement and sizing of the combination of wind + solar generation + Microturbine with storage device through well-known particle swarm optimization algorithm. To very Propose methodology on 13 bus distribution system/ Rural distribution system. The formulation of the optimization issue comprised installation/operational costs and total grid losses, the use of natural power distributed generators, including the uncertainty cost component, the dependency of the microgrid on the main grid, and so on.

- To solve an optimization problem, one of the hybrid approaches such as Enhanced Velocity Differential Evolutionary Particle Swarm Optimization (EVDEPSO), Differential Differential Evolutionary Particle Swarm Optimization (DEEPSO), and LEVYPSO can be used.

1.4 Thesis Organization

chapter-1 discusses the dominance of renewable distributed generators (DG) in the power system, as well as their classification, the concept and benefits of microgrid, and the problems of microgrid design and management. This chapter also represents the state-of-the-art of application of Particle Swarm Optimisation (PSO), enhanced PSO for optimal placement of various types of DG, and the significance of microgrid management systems, modeling of wind and solar distributed sources. It discusses the prime factors that have the need to the emergence while planning the operation and control of microgrid with renewable and non-renewable DG and the motivation behind this work.

chapter-2 presents the analysis of the Weibull probability distribution function to develop a wind power generation model. The estimation of the output power generation of wind unit has been carried out based on pdf's shape and scale parameter. The historical data has been canalized to justify the selection of shape parameter to compute hourly average power generation for the given size of wind unit. The integration of wind speed probability for the discrete state has been done to develop a probable wind power generation model.

chapter-3 explores the methodology to determine the potential of solar power units per day on any selected site. The beta probability distribution function has been described to calculate the hourly average energy generated of a given solar unit. The integration of solar irradiation probability for the discrete state has been done to develop a probable solar power generation model.

The *chapter-4* finds the optimal sitting of single and hybrid DG units without a storage device for all combinations of placement using forward-backward load flow for minimum grid losses. It also gives a detailed description of forward-backward load flow. The finding has been brought out on IEEE-13 node distribution system. The objective function has been designed to achieve the technical benefits of the summation of natural power distributed generators. The PSO has been executed to solve optimization problem. The result of both methods has been compared regarding grid and substation dependency factor.

In *chapter-5*, The modification of optimization problem has been presented for the integration of distributed generators and storage devices in microgrid planning and operation. A levy flight PSO algorithm has been used to obtain the optimal value of variables and fulfill the objectives.

chapter-6, summarizes the contribution of the thesis and also provides a few suggestions for the future expansion of this work.