Preface

Now a days, the trend in electric power generation is to employ power generation sources ranging from kW to MW near load locations rather than traditional centralised sources with larger MW and positioned far from the loads. The installation and operation of a portfolio of small, compact, and clean electric power generating units are key components of this electric power generation technology. The small, compact, and clean electric power generating units near to the load are known as Distributed Generators(DGs). The penetration of DG units must required appropriate planning in distribution network to face challenges such as high cost, high network losses, reliability, voltage rise, voltage stability, power-fluctuation. Use of renewable DG depends of availability of natural resources and geographical condition of location. The purpose of integrating Distributed Generators (DGs) and storage devices is to provide a solution to the issues of renewable and nonrenewable DG penetration by determining the optimal location and size for each. Integration of DGS and storage devices improves distribution system management as a grid connected or autonomous microgrid by considering their types and availability. Prevalent state-of-art reveals few missing links or research gaps, and the same could be presented as:

- The articles which have been published presented research work in the context of accommodating renewable and nonrenewable 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 power drawn from the main grid by the distribution network. 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 medelling. After obtaining this model, an examination of the influence of the NPDG has been performed. In fact, the weibull pdf and beta pdf parameters change over time.
- Only a few hybrid optimization algorithms have been addressed for the installation, planning, and operation of microgrids with renewable and nonrenewable 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 in order to reduce the installation or operational costs of microgrids using renewable and nonrenewable DGs. The cost of under and overestimation of natural resources was not considered when developing the cost function. This could be critical in the case of a microgrid powered by renewable energy.

The work in this thesis is organized in a chartered manner to alleviate and address the presented gaps, as

- **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 state-of-art of application of Particle Swarm Optimisation(PSO), enhanced PSO for optimal placement of various type of DG and significance of microgrid management system, modelling of wind and solar distributed sources. It discusses about the prime factors that have need to the emergence while planning the operation and control of microgrid with renewable and non renewable DG and motivation behind this work.
- **Chapter-2**, presents analysis of the weibull probability distribution function to develop wind power generation model. The estimation of the output power generation of wind unit has been carried out on the basis of shape and scale parameter of pdf. The historical data has been canalised 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 discrete state has been done to develop probable wind power generation model.

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

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

- In **Chapter-5** The modification of optimisation 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 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.

Key Findings

The findings of the work that has been carried out, has been summarized as follows: In chapter-2 the energy generation/day and power production/specific time period has been computed by four ways.

1. Assume fixed value of shape parameter- k by studying historical data of wind speed.

2. Choose Ray-leigh pdf means shape parameter- k =2.
3. find value of shape parameter- k for specific time slot/day by statical analysis of historical data of wind speed
4. consider power probability as per wind speed state and shape parameter- k has been calculated from wind statistics for a one quarter.

The identical result has been obtained from the method no:3 and 4. However, In the case of state-wise probability (method-4), the length of computational steps and time are less. As a research point of view, wind models with Shape parameter K=2 (Rayleigh) may not always be applicable to develop unique methods. As a result, a thorough analysis about wind speed and probable wind power has been carried out. This analysis has been used to plan the optimal installation, operation and control of the power grid, and scheduling of the power plant. This model is also useful for reducing estimation error in wind power forecasting and maximising natural resource utilisation in the power grid. The model which is discussed in chapter -2 is applied to plan summation of wind power resource with convectional DG in the microgrid.

The solar power generating model was established following a detailed analysis of the sun radiation at the chosen location-Town Cambay, along the seaside of Gujarat state. The solar radiation potential has been evaluated using beta pdf which is obtained on hourly basis. the solar energy generation/day and solar power production/specific time period has been computed by two way.

1. On the basis of hourly mean solar radiation.
2. hourly solar radiation is divided in four states.

When state-by-state probability is taken into account, the estimation of average solar energy generated per hour in first and second quarters is 25% greater. The probable energy produced per hour during the quarter-3 is less than that produced by the preliminary technique. During the fourth quarter period, the hourly average energy generated by both the way is the same. The result of estimation has been verified with the readily available solar power production tools.

The studies conducted in Chapter-5 reveals about Particle Swarm Optimization (PSO) for finding optimal summation of solar, wind and microturbine in microgrid.

A microgrid power flow analysis with backward forward load flow has been carried out to determine system losses and nodal voltage and phase angle. The development of an optimal problem strategy for determining the placement and size of NPDG and micro turbines in grid-connected microgrid has been presented in this chapter. The hourly average probable power generation of wind and solar units has been taken into account as the maximum power generation limit of that unit for the reliable operation of a distributed power system. In order to minimise losses and reliance on the main grid, the highest loaded node is the best optimum location for any DG having a maximum power generation limit. It is proved that the PSO method is far better to get value of fitness function regarding optimal integration of renewable and non renewable DGs in microgrid.

A novel approach, Levy flight Particle Swarm Optimization has been discussed in chapter-5 to solve optimisation problem on planning and operation of microgrid along with renewable and non renewable DGs. The fitness function has been developed by including in DG Levelized energy costs, grid losses, system restrictions, and microgrid reliance on the main substation. The average of G_best value has been obtained for IEEE 13 bus distribution test system. Hence, Levy flight Particle Swarm Optimization provides the optimum value of objective function.

Conclusion

The optimal planning and operation of microgrid on the basis of potential analysis of the renewable power resources has been carried out in this study. Estimation of wind and solar power generation have been investigated by collecting wind data of selected site (Town Cambay,Gujarat). The wind speed has been analysed using Weibull probability function, in which time slot wise shape parameter as well as fixed value of shape parameter have been utilised. The solar irradiation has been analysed using beta pdf in which parameters have been found hourly and state wise. From the wind speed statistics and the Weibull pdf, it is proved that in the periods- April to June and July to September, possibility of power production using wind turbine unit is good. Results of solar irradiation analysis shows good potential of the solar energy in most of the period. During the period July to sept low potential of solar energy. It is because of cloudy day in that period. The wind and solar power generation model have been developed based on natural source (wind speed and solar irradiation) analysis. It is used to determine location and size of renewable power unit in microgrid planning and operation. Optimisation problem has been designed and applied to the IEEE-13 node distribution system and found best location of wind, solar and microturbine DG for minimisation of network losses, cost and maximum utilisation of natural power sources, . The Particle Swarm optimisation and Levy Flight PSO has been utilised to solve optimisation problem. The Levy PSO is more efficient and gave best solution of proposed method in less time period without trapping.

0.1 Scope for Further Research

The following aspects are suggested for further research as a result of the analysis and investigations presented in this thesis.

(i) The findings in Chapters 2 and 3 were limited to the one chosen location. The idea can be analyzed for various sites near or off the coast. It can be used with a range of sizes and types of solar and wind power units.

(ii) The problem formulation can include voltage controller and AC/DC converter constraints. The same fitness function can be solved for real-time data of natural power supply or a variety of other situations not covered in this thesis.

(iii) In this study, the proposed strategy is applied to the IEEE-13 bus distribution system. The same can be tested on grid-connected commercial microgrid or residential microgrid. It can also be tested on an isolated microgrid.

(iv) In comparison to convectional PSO, the LEVY-PSO technique, which is explored and implemented in Chapter 5, is more efficient and faster. This method can be used to solve a wide range of optimization problems in order to address Smartgrid issues and identify solutions.