Synopsis

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To overcome the issue of global warming, today's power system moves rapidly towards maximum utilisation of green power sources like wind,solar and biomass. There has been a resurgence of interest in deploying renewable DGs since the mid-2000s, when global warming was at center stage, but in that period higher cost of energy generation was one of the reason for relatively latent deployment of renewable DGS [1].

With advancement in technology, the advance digital and power electronics devices have been introduced in power system to make the system modern. The modern power system named as smartgrid has the large scope of accommodation of renewable energy sources but faces many challenges regarding economical, efficient, reliable and stable operation.The smart grid is introduced in 2004 in Europe and U.S [2]. The configuration of smart grid involves combination of distributed energy resources, energy storages devices, telecommunication technology, smart measurement system, bidirectional communication, advance control and managed demand. The one small part of the smart grid which is formulated to operate in independent mode or grid connected mode is known as micro-grid. It is semi autonomous grouping of generating sources and load [3]. There were 59 percentage addition in renewable energy sources worldwide till 2015 [4].

The distribution system of existing power grid is analogues to the microgrid in smart grid era. The microgrid structure should be such that it reducing congestion, counter-balance the need for generation, supplying local voltage support, enhancing stability or responding to rapid changes. Because of economical, technical and environmental profits,distributed generators are located near to load at distribution level but for that number of changes are required to make in the electric grid.The penetration of DG unit without appropriate planning in distribution network is introduced voltage rise, low voltage stability, power-fluctuation and high network losses [5]. The interest of researchers is increased to develop appropriate methodologies for optimal location and size of DGS associated with storage devices. The proper modelling of microgrid and distributed generator has been also made part of these study.

Here the aim behind integration of Distributed generators and storage device in microgrid is to locate proper size DG with storage devices for stable operation of grid. It has been reviewed that many factors with wide variety can be possible to include in the field of DG placement. The methodologies have been gradually advanced by inculcating the various factors separately and combined. These factor has been listed as technical, environmental and economical benefits in planning ,operation and control of powergrid[6].The numerous approach has been developed for optimal mix of variety of DGs and storage device in distribution system involving these factor. For developement of this approach, modelling of renewable DG with its uncertain nature, modelling of distribution system as autonomous microgrid or grid connected microgrid, methodologies for optimum planing and operation have been proposed and analysed.

The renewable and non renewable energy sources of small capacity are categerized under DG technology [7]. Study of current technology, new modeling tools and techniques help to asses clean power plan penetration and utilisation in power grid [8]. The clean power plan means asssesment of renewable energy sources like wind and solar. The output power generation of wind unit is based on uncertain nature of wind speed and wind turbine characteristics.The estimation of output power generation of wind based DG unit has been carried out using random behaviour of wind speed or wind speed statistics.The random behaviour of wind speed is modelled by Normal Distribution Function (NDF), Probability Distribution Function (pdf) or Cumulative Distribution Function (cdf)

The weibull pdf and Rayleigh pdf model are widely used for wind based DG in microgrid till today. The shape of the Weibull pdf is highly sensitive to the variation of shape index and scale index. These index can be determine from the historical data of wind speed of particular site.In [9] The probability distribution of wind speed has been obtained by determine Auto-regressive and moving average model of wind speed.The statical parameter like hourly mean wind speed "v_m" and standard deviation "v_{sd}" has been obtained from historical wind speed data of three different location. The common wind model has been developed on the basis of probability distribution curve for reliability evaluation. The output power has been estimated as per probability of specific wind speed using wind turbine parameters. In case of wind based DG planning,distinct number of small states of wind speed has been characterised by Rayleigh pdf for computation of probability of power generation [10]. The output power has been calculated as per turbine parameter. The the stochastic wind speed has been demonstrated by weibull pdf for siting and sizing of wind based DG in ieee 37 distribution system and hybrid DG in residual microgrid to improve voltage profile of the network [11] [12] [13].

The India is very rich country about solar energy. The assessment approach of the solar based DG unit is similar to the wind unit as the output power generation of solar unit depends on PV module characteristics. The series–parallel connection of multiple PV modules forms PV array. The solar irradiation and ambient temperature affect the output characteristics of the PV module. The output power of the PV array can be estimated using accurate solar irradiation forecasting method or best fitted probability distribution of the historical data. In the article [14], the output power of PV array has been predicted using forecasting model. A number of successful applications of solar forecasting methods for both the solar resource and the power output of solar plants at the utility scale level has been reviewed in [15]. The numerous probability distribution like Exponential Distribution, Normal Distribution, Weibull Distribution, Lognormal Distribution, Beta Distribution have been discussed to estimated best fitting probability distribution using the concept of the mean squared error (MSE) [16]. The modeling of random power generation can be decided in concern with objective and past data.The solar irradiation has been characterised by beta distribution in [6].[17] [18]

The Indian government polices as well as many countries around the world are encouraging the electrical market player to take interest in installation of Natural power small scale resources.Thus the power grid engineers has been inspired to advance the methodology which solve technic-economical and environment issues with maximum utilisation of Natural power distributed sources in mocrogrid.There are large number of technic-economical and environment issues while planing and managing microgrid in grid connected mode or autonomous mode.The grid losses, stability, reliability,unit commitment, operating cost, consumer unit cost, CO2 emission and many more can be listed in concern with operation and management of microgrid. The various algorithm have been developed by taking one or more issue as objective for betterment planning of integration of renewable/nonrewnwable DG in microgrid.

A combined method based on Genetic Algorithm (GA)and Intelligent Water Drops (IWD) and a Genetic Algorithm (GA) method combined with PSO have been proposed to find the place and capacity of DG in microgrid for optimizing network power losses with improving voltage regulation and rising the voltage stability within the system [19] [20]. An eagle strategy with particle swarm optimization has been implemented to allocate distributed generators in microgrids considering power system losses as objective function[21]. In the article[22], symbiotic Organism Search approach has been applied to determine the optimal number of Distributed Generators, and loss sensitivity factor has been used to locate the place of DG in the distribution system.PSO has resolved the multi-objective optimization problem as an optimal cost and dispatch strategy to integrate microgrids with renewable-based DG and natural gas DG [23]. The optimal planning and impacts of RE-based DG units, particularly wind power generation and solar units, have been addressed for techno-economic benefits. A new Harris Hawks Optimizer using Particle Swarm Optimization algorithm has been presented for the optimal allocation and sizing of RE-DG units in the distribution system. Uncertain behavior of wind power and solar power generation has been considered using appropriate probability distribution [24]. For strategically planning and operating renewable DG units along with an efficient usage of BES sources in distribution networks, the author has developed methodologies and implement its on 33-bus distribution network using load flow [6].

It has been observed through the literature survey that most of the proposed work regarding planning and management of microgrid including uncertain behaviour of renewable energy sources has used modified load flow or modified optimum power flow, modern heuristics optimization technique or combined heuristics/meta heuristics techniques, but the work has been divided in two part. In one part objective function included installation cost of DG, dispatch energy cost with DG capacity limits and grid losses to be minimised with equality and non equality constraints. The second part has been included with stability and reliability index. The focus on energy requirement from substation in case of uncertain condition of natural power resources has been neglected. The levelised cost of energy with stable operation of the system within predefined range of control variable has not introduced.

Here the work has been focused on maximisation of utilisation of natural Distributed generator with storage devices in microgrid using efficient, speedy and novel optimisation algorithm. To achieve the optimal value of variables,the incipient phase of work was analysis of the availability and potential of natural power resources like: solar and wind unit. For that historical data for the specific location of grid is prime factor. In this work natural power estimation of the site near gulf of Cambay has been selected. The wind speed and solar irradiation data has been of collected from the [25],[26] for the last three years. The statistic analysis of the historical data has been carried out to decide and justify the random nature of wind power and solar power generation.The probabilistic model has been used to estimate hourly average power generation of the discreet size of wind and solar power unit. It has been seen that the long term planning of renewable power sources are required season to season analysis of natural resources.

For wind power generation model using weibull pdf, shape parameter and scale parameter are basic factor which decided the power potential of the wind. The mean wind speed and the standard deviation has been considered for calculating these parameter. The shape parameter has high value when low variation in wind speed in any region for the given period.To get more accuracy in calculation of probabilistic power generation,the wind speed probability has been modelled for the state $v_m + 1.5v_{sd}$ to $v_m - 1.5v_{sd}$. The probable power generation has been estimated for the each state. The solar power generation has been modeled by characterised the solar irradiation by beta pdf. Same as the wind speed probability, solar irradiation has been modelled for the state $\mu_m + 1.5\sigma_m$ to $\mu_m - 1.5\sigma_m$. The probable solar power generation has been estimated for the each state.

The next step of this work has been concentrated on microgrid analysis and optimal planning and operation.For the analysis of microgrid, the mathematical model of the microgrid has been formulated considering radial distribution network. For grid-connected MGs, the bi-directional power flow between substation and microgrid has considered for the load analysis of microgrid. The substation and microgrid both has treated as generator and load as per availability of power sources. The load modelling is also the part of microgrid analysis. In the radial distribution system the load can be distributed along the lines or concentrated on the network buses. In this work the concentrated load has been modelled as constant power load.

The main body of this work is optimal integration of the wind and solar unit with/without storage device which can provide economical and stable operation of microgrid. This main work has been achieved by formulating multi objective problem in two stage. In the first stage, problem formation has been carried out without storage device and economical consideration. Only technical factor has been considered for the evaluation of optimal sitting of the DG without storage devices. The substation dependency factor of grid connected microgrid introduced and branch current loss approach has been involved as main objective in optimisation problem formulation, while the nodal voltage,branch current,discrete size of DG has been considered as constraints.The multi objective function has been converted into single objective using equal weight. The estimated power generation are considered as variable. In second stage, the objective regarding economical factor and effect of storage device have been included in function. In these part levelised cost of renewable energy sources, penalty on uncertainties of natural sources, cost on charging and discharging of storage devices have been added, while nodal voltage and phase angle of each bus has been considered as control variable. The storage device has been modelled as per [27].

The numerous methods have been referred for solving optimisation problem concern with DG [28]. The IEEE-13 node system has been considered to apply and verify proposed method. Here the optimal sitting of single renewable/non renewable DG unit and hybrid DG unit has been found by forward -backward load flow algorithm. The particle swarm optimisation algorithm has been developed for solving proposed optimisation problem. The enhanced PSO with levy-flight distribution [29] has been developed to achieve optimal planning of DG integration. The better and fast result has been obtained compared to the PSO.

The work in this thesis has been organized as follows:

Chapter-1 introduces the distributed generators (DG) along with its detail classification,concept and benefits of microgrid, challenges in microgrid planning and management. This chapter also presents 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. It also gives detailed description of forward -backward load flow, convention PSO and introduces Levy PSO method. 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 has analysed 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 has explored 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 avarage enegy 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 has investigated 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. The investigation 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.

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