CHAPTER-II

Literature review

2.1 Introduction

The increasing global demand for renewable energy sources increased the demand for the small-scale capacity of renewable distributed generation technology in the modern power system. In the form of small generating capacity, renewable distributed generation technology gives us the flexibility to generate power in a decentralized power generation system. Integration of renewable distributed generation technology with radial power distribution system is rapidly growing. In this thesis work, we worked on the optimal planning of renewable distributed generation system with some novel contributions. For this, government policy to boost this area, appropriate selection of a renewable distributed generation technology for installation region with the uncertainty of power generation and load demand has been studied in this thesis work.

The theoretical idea of installing renewable energy based distributed generation, namely renewable distributed generation, under uncertainty of load demand and power generation is a managerial strategic decision to cope up with demand and supply variations; nevertheless, its implementation is impaired by many practical difficulties till now. Evolution of smart grids supports optimal planning of renewable distributed generation. Analysis of investment region without storage systems is a very advance phase of modern power generation system which has been proposed in this thesis. Literature related to this is very scarce and we could not find any such literature. For this, we studied literature which supports whole project phases and issues.

The literature review of this thesis has been segmented in four subparts for specific work, which consists: (i) Selection of renewable distributed generation technology; (ii) Estimation of wind energy potential; (iii) Estimation of load demand distribution; and (iv) Optimal planning of renewable distributed generation. After going through the literature of respective work, research gaps have been identified.

2.2. Selection of renewable distributed generation technology

The modern power sector is moving towards adoption of renewable energy sources to overcome excessive carbon emissions and limitations of fossil fuels (Zangeneh et al., 2009; and Banos, 2011). In the form of renewable distributed generation, use of small-scale renewable energy based power plants is more cost effective with multiple advantages over the other modes of power generation systems (Hafez and Bhattacharya, 2012; Beccali et al., 2003; Wolsink, 2012; and Ochoa and Harrison, 2011). Renewable distributed generation system gives us the flexibility for installation of generating units in remote or rural areas, where transmission and distribution of power would not be feasible (Asrari et al., 2012; Atwa et al., 2010; and Rajanna and Saini, 2016). Kumar and Ravikumar (2016) identified hybrid technology to help needs of the urban building in India. On-site power generation from the renewable energy sources requires selection of the suitable renewable distributed generation technology for the installation region based on multiple criteria (S¸engu¨l et al., 2015; Barry et al., 2011; and San Crist´obal, 2011). In developing countries, selection of optimal renewable energy sources in the form of renewable distributed generation technology will give us the maximum payoff with the sustainable environment (Thiam, 2011; and Amer and Daim, 2011).

Renewable distributed generation technology selection initially requires the identification and elaboration of different decision criteria that will guide in the decision-making process. Different decision-making groups may choose different decision criteria for renewable distributed generation technology selection based on some factors which affect in decision-making process like most affected factors would be the power generation capacity and carbon emission. San Cristobal (2011) proposed a model that considers power, investment ratio, implementation period, operating hour, useful life, operation & maintenance costs, tons of CO_2 avoided factors for selection of suitable renewable energy based generating units in Spain. In recent work of Ahmad and Tahar (2014), they divided their sub-criteria under the major criteria of technical, economical, social, and environmental. Kahraman et al. (2009) divided their sub-criteria for the renewable energy planning into four technological, environmental, socio-political, and economic criteria. Based on the number of criteria, renewable energy planning will require the multi-criteria decision-making analysis.

Making decision is an integrated part of human life, which is coming from the history of the mankind. Multi-Criteria Decision Making (MCDM) technique is the most famous technique for decision making in the recent world. Some authors like Zimmermann (1996) have divided MCDM into two categories; one is multi-objective decision making (MODM), and another one is multi-attribute decision making (MADM). However, both are used to represent the same class of MCDM models. The major difference between the two groups of methods is the selection process of the alternatives. In the MODM method, which is also known as multi-objective programming problem, instead of predetermined alternatives, we have a set of optimization objective functions for a set of constraints. In the MADM method, alternatives are predetermined, and a set of alternatives would be evaluated for the given set of attributes. Selection of the best alternative is based on the comparisons between each alternative on given criteria or attributes (Kahraman et al., 2009). In renewable energy projects like wind farm projects, solar projects, geothermal projects or biomass projects, MCDM methods have been widely used in these areas. For deciding the optimum mix of renewable-based distributed generation technology with various sectors like central power generation system, MODM methods have been used (Zangeneh et al., 2009a; Hafez and Bhattacharya, 2012; Kaya and Kahraman, 2010; Beccali et al., 2003). In the work of Borges and Antunes (2003), renewable energy economic planning is showing the interactions between technical and economic parts of the system. Amongst the number of decision-making techniques, Decision Support Systems, MODM, MADM (mainly AHP, PROMETHEE, ELECTRE, TOPSIS and Multi-attribute utility theory), and Fuzzy programming is the most applied MCDM technique in renewable energy projects.

For an application of the AHP method, the structure of a multiple criteria problem is hierarchically and breaking down the problem into smaller consistent parts (Saaty, 1990). In this system, the objective becomes at the top of the hierarchy whereas criteria and sub-criteria become at the levels, and sub-levels of the hierarchy and decision alternatives become at the bottom of the hierarchy. Selection of the suitable alternative depends on the comparison between the different alternatives on each criterion. Multiple authors are using AHP method for the renewable energy planning projects (Zangeneh et al., 2009b; Ahmad and Tahar, 2014; Kahraman et al., 2009; and Cobuloglu and B¨uy¨uktahtakın, 2015). Other kinds of decision-making methods used in renewable energy investment projects are Fuzzy programming to evaluate the selection of renewable energy alternatives (Kahraman et al., 2009; and Kahraman and Kaya, 2010), Decision Support Systems based on fuzzy decision support model for the energy-economy planning (Borges and Antunes, 2003; and Ma et al., 2014), a methodology of Geo-spatial multi-criteria analysis used to set up the wave energy farm (Nobre et al., 2009), and a linear programming optimisation methodology in the form of energy flow optimisation model (EFOM) is used for the regional energy planning with renewable energy sources and environmental constraints (Cormio et al., 2003).

Taking into consideration of the decision makers' preferences, multi-attribute utility theory (MAUT) is developed to help decision-makers allocate utility values to get outcomes from the evaluation of these utility values regarding multiple attributes and obtained the overall utility measures by combining these individual assignments (Keeney and Raiffa, 1993). Jones et al. (1990) used this method in the planning of renewable energy sources for their respective work and Golabi et al. (1981) used this theory in the work of solar energy project portfolio selection. For the discrete nature of criteria in both quantitative and qualitative term, the ELECTRE method provides complete ordering of the alternatives. This method chooses a set of alternatives that are preferred for most of the criteria, and that will not cause an unacceptable level of discontent for any of the criteria. ELECTRE method gives graphs for strong and weak relationships based on a concordance, discordance indices, and their threshold values. With an iterative procedure, we can have a ranking of alternatives from the graph of strong and weak relationships. Georgopoulou et al. (1997) and Beccali et al. (2003) used this method in their renewable energy project. Other MCDM method is PROMETHEE method, which uses the outranking principle to rank the alternatives and combined with ease of use to reduce the complexity. The PROMETHEE method performs a pair-wise comparison of alternatives for the ranking of the alternatives on a given number of criteria. In the work of geothermal project Goumas et al. (1999), Goumas and Lygerou (2000), Haralambopoulos and Polatidis (20003), for the utilisation of parabolic solar cookers in India Pohekar and Ramachandran (2004) and selection of location for hydro power plant Mladineo et al. (1987) used the PROMETHEE technique in their respective work.

Another distance-based MCDM method is the TOPSIS method, which determines a solution of the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution, but its drawback is it does not give information of the relative importance between these two distances (Yoon, 1987; and Lai et al., 1994). Kaya and Kahraman (2011a) used modified fuzzy TOPSIS method for the selection of best energy technology. Comparative analysis between TOPSIS and VIKOR is shown in the article by Opricovic and Tzeng (2004). Both the VIKOR and TOPSIS methods developed as an alternative to ELECTRE method are based on an aggregating function or closeness to the ideal, and that originates in the compromise programming method. Both the VIKOR and TOPSIS methods introduce different forms of aggregating function for the ranking of alternatives and perform different kinds of normalization procedure for the elimination units of the criterion function (Opricovic and Tzeng, 2004). The VIKOR method uses linear normalization technique and the normalized values, which do not depend on the assessment unit of each criterion. The TOPSIS method uses vector normalization for a particular criterion, and the value of normalization could be different for a different evaluation unit. As regards of the aggregating function, VIKOR method uses an aggregating function that will represent the distance from the ideal solution, will consider the relative importance of all the criteria, and will have a balance between total and individual satisfaction. On the other side, TOPSIS method uses an aggregating function that will include the distances from the ideal point as well as from the negative-ideal point without having their relative importance. However, the reference point could play a major role in the decision-making process, and to have near of the ideal point is the justification of human choice (Opricovic and Tzeng, 2004).

This work has shown that the use of the Compromise Ranking Method also known as the VIKOR method in the selection of the renewable distributed generation technology. Along with VIKOR method, we used AHP technique for assigning the weights to have relative importance between each attribute. Similar approaches can be found in San Crist´obal (2011), who applied the same method for the selection of renewable energy alternative in Spain, or in Kaya and Kahraman (2011b), who applied the VIKOR method along with AHP under fuzziness for the renewable energy planning with a case of Istanbul. Multiple authors have suggested in their work, a combination of these two will allow the decision-makers to methodically allocate the values of relative importance to the attributes or criteria based on their preferences. This work assumes that each alternative is evaluated according to all the criteria, and the compromise ranking would be performed by comparing the computation of closeness to the ideal solution F*. From the use of Lp-metric in compromise programming method, the merit of multi-criteria for compromise ranking has been developed by Yu (1973) and Zeleny (1982). The compromise solution was established for a problem with conflicting criteria and it can be helping the decision makers to reach a final solution. The compromise solution is a feasible solution, which is the closest to the ideal, and compromise means an agreement established by mutual concessions.

VIKOR is a multi-attribute decision making technique which has a simple computation procedure that allows simultaneous consideration of the closeness to ideal and anti-ideal alternatives. In the literature, there are many studies which handle VIKOR method in a comparative manner: Opricovic and Tzeng (2004) conducted a comparative analysis of VIKOR and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) methods with a numerical example. Tzeng et al. (2005) also compared the two methodologies to determine the best compromise solution among alternative fuel modes. Opricovic and Tzeng (2007) made a comparison of VIKOR with PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations), ELECTRE (Elimination and Choice Expressing Reality) and TOPSIS approaches. Chu et al. (2007) provided a comparative analysis of SAW (Simple Additive Weighting), TOPSIS and VIKOR, which demonstrated the similarities and differences of these methodologies in achieving group decisions.

The VIKOR method was developed for multi-criteria optimization of complex systems. It determines the compromise ranking-list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial (given) weights. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multi-criteria ranking index based on the particular measure of ‘‘closeness’’ to the ‘‘ideal’’ solution (Opricovic, 1998).

Ranking by VIKOR may be performed with different values of criteria weights, analyzing the impact of criteria weights on proposed compromise solution. The VIKOR method determines the weight stability intervals, using the methodology presented in Opricovic (1998). The compromise solution obtained with initial weights (w_i, i = 1; . . . ; n), will be replaced if the value of a weight is not within the stability interval. The analysis of weight stability intervals for a single criterion is performed for all criterion functions, with the same (given) initial values of weights. In this way, the preference stability of an obtained compromise solution may be analyzed using the VIKOR program.

Matching MCDM methods with classes of problems would address the correct applications, and for this reason the VIKOR characteristics are matched with a class of problems as follows (Opricovic and Tzeng, 2007):

• Compromising is acceptable for conflict resolution.

• The decision maker (DM) is willing to approve solution that is the closest to the ideal.

• There exist a linear relationship between each criterion function and a decision maker’s utility.

• The criteria are conflicting and noncommensurable (different units).

• The alternatives are evaluated according to all established criteria (performance matrix).

• The DM's preference is expressed by weights, given or simulated.

• The VIKOR method can be started without interactive participation of DM, but the DM is in charge of approving the final solution and his/her preference must be included.

• The proposed compromise solution (one or more) has an advantage rate.

• A stability analysis determines the weight stability intervals.

In brief, we can say that VIKOR method works on ranking and selection of the alternatives from the given one in the existence of conflicting criteria. It gives a compromise solution that will be accepted by the decision makers because of its maximum group utility for the ‘‘majority’’, and of the minimum individual regret for the ‘‘opponent’’. By the use of linear normalization, this method representing the closeness to the ideal solution based on aggregating function. Where, in TOPSIS method, use of vector normalization and two reference points does not consider the relative importance of the distances. From the group utility measures, PROMETHEE method ranks the alternatives with a linear preference function similar to the ranking of VIKOR method. Also, ELECTRE II gives similar value like VIKOR method from the linear surrogate criterion functions.

2.3. Estimation of wind energy potential

In recent years, efforts have been made around the world to generate electricity from renewable energy sources. This is due to the infinite availability of their prime movers and reduced harmful emissions into the environment. One of electricity generation source among these sources is wind turbines that convert the kinetic energy in a mass of moving air into electricity.

Globally, wind energy is the major contributor to the generation of electricity and helping to reduce carbon emissions. In wind energy case, now we can harness electricity at the offshore area or low wind speed region. The contribution of wind energy in the energy sector is growing rapidly over the worldwide. Now, total world's wind power capacity reached at 432,419 MW on December 2015, as per GWEC Global Wind Statistics (2015) report, and with the rapid expansion of wind energy, it has been reached around 4.7% contribution of total electricity usage over worldwide (The World Wind Energy Association Half-year Report 2016). Countries like China, USA, Germany, India, Spain, and Denmark are contributing majorly in wind energy sector with China (145,362 MW), United States (74,471 MW) and Germany (44,947 MW) are ahead of India. India (25,088 MW) is in fourth position as per Global Wind (2015) Report. Less installation period of wind turbines and functioning make this more favorable in India and a form of renewable distributed generation technology wind energy also helps to enhance reliability and performance of power distribution system(Khare et al., 2013). In a report of the expert group on 175 GW renewable energy by 2022, the MNRE set the target of 60 GW for wind power generation capacity to be achieved by the year 2022. Here in Figure-2.1, we can see the annual capacity addition of renewable energy and wind energy in Indian energy sector. Where x-axis represents samples of last six years and y-axis represents every year total installed capacity of renewable energy and wind energy in megawatt unit. We can see in Figure-2.1 the potential growth rate of renewable energy and wind energy in India for the past six years. We can analyze in last few years installation capacity of wind energy has significantly increased. In 2011 capacity addition of wind energy in India was record highest 3 GW of new installation capacity (Global Wind 2015 Report). In this sector, Indian states like Tamilnadu, Gujrat, Rajasthan and Maharashtra are contributing majorly.

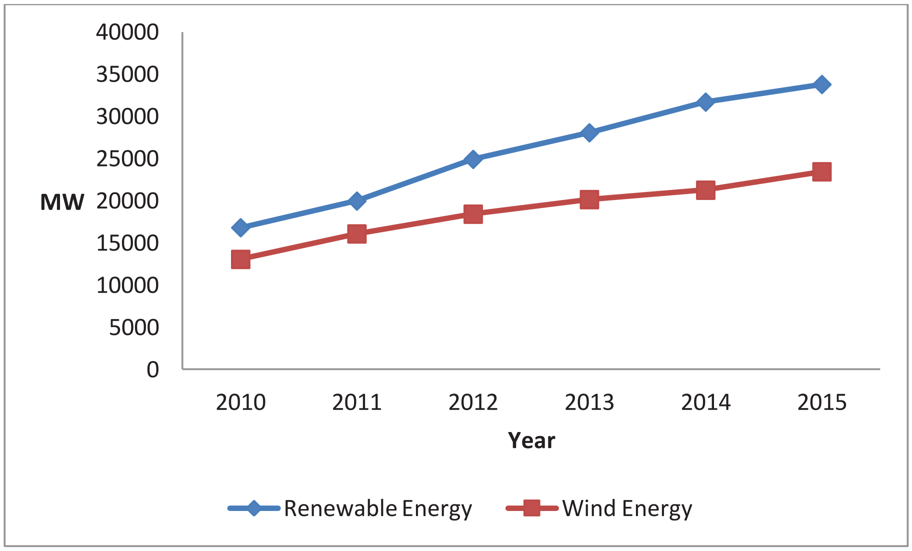

Figure 2.1: Annual installed capacity of renewable energy and Wind Energy in India

Wind power has been developed in India on 1986 with the first wind farms installation in coastal areas of Gujrat (Okha), Maharashtra (Ratnagiri) and Tamil Nadu (Tuticorin) with 55 kW capacities of Vestas wind turbines (Wind Power in India). Potential of the wind energy in India has been first analyzed by Dr. Jami Hossain (Hossain and Sharma, 2015) with the help of GIS system around of 3000 GW in the year 2011. In next year, analysis of Dr. Jami Hossain has been subsequently re-validated by Lawrence Berkley National Laboratory (LBNL), the United States in an independent study. With this study, the MNRE created a committee for the reassessment of the wind energy potential (Hossain and Sharma, 2015) and had announced a new estimation of the potential wind resource in India from 49,130 MW to 300,000 MW at 100 meter Hub height in a report of Estimation of Installable Wind Power Potential at 80 meter level in India. The analysis result of a demonstration project, sponsored by MNRE, has shown the increasing wind resource with increasing Hub heights.

In India, the interest in wind as a resource for electricity generation is receiving considerable support from stake holders. However, as a signatory to the United Nation Framework Convention on Climate Change (UNFCCC), the country has committed itself to the international community to reduce green house gas (GHG) emission. Given this, it is essential to have a reliable knowledge of the wind distribution in desired installation region. An understanding of the performance of a wind turbine power generation unit, in response to different wind speeds at a proposed site, is a prerequisite for the successful planning and implementation of a wind power project. Both the wind speed and its distribution influence the performance of a wind turbine. The turbine power curve operating parameters can be combined with the statistical wind distribution parameters of a given site to estimate the average power output of the turbine which will be used to determine the power generation potential. It reflects how effectively the turbine could harness the energy available in the mass of moving air. It also serves as a vital index for evaluating the economic viability of a wind power project. Various methods have been proposed in the literature for estimating the potential of power generation of a wind turbine.

Practically it is very important to analyze the variation of wind speed for optimizing the design of the systems, resulting in less energy generating costs. From the last few years, multiple researchers have conducted various studies to assess wind power worldwide. Previous works are showing the wind variation for a typical site represents the Weibull distribution (Mohammadi et al., 2016; Usta, 2016; Abdraman et al., 2016; Bilir et al., 2015; Shu et al., 2015; Kwon, 2010; Keyhani et al., 2010; Weisser, 2003). Some works have been done over comparative analysis between Weibull and Rayleigh distributions to predict wind speed distribution (Kose et al., 2014; Pishgar-Komleh et al., 2015; Olaofe and Folly, 2012; Togrul and Ertekin, 2011; Turk Togrul and Imas Kaizi, 2008; Celik, 2004). Some authors developed new distribution function and advocate other than conventional Weibull distribution for the estimation of wind speed distribution (Akgul et al., 2016; Harris and Cook, 2014; Kollu et al., 2012; Chang, 2011; Akpinar and Akpinar, 2009; Kantar and Usta, 2008; Akpinar and Akpinar, 2007). In these previous studies, the major consideration has been given to the two parameters (shape, and scale) Weibull distribution, because the previous study has shown the fitness of Weibull distribution with a wide collection of wind speed data. Despite having the major contribution of Weibull distribution for the estimation of wind speed distribution, multiple researchers identified more fitted probability distribution other than the Weibull distribution. Based on these studies, selection of conventional Weibull distribution without any comparative analysis may be a wrong choice.

2.4. Estimation of load demand distribution

The transformation of today's grid towards smart grid opens new perspectives on demand-side management as shown in Figure-2.3. First, a significant part of the generation in smart grid is expected to come from renewable energy resources such as the wind and solar. The unpredictability of these renewable energy sources makes power dispatch functions in a smart grid challenging (Broeer et al., 2014). The procedure of the prediction refers to a random variable x and predicts future events for x depending on the initial conditions or more precisely said on the initial conditions. A linear functional form is hypothesized for the postulated causal relationship, and functions parameters are estimated from the data. For prediction in a stochastic environment, explanatory variable values that are deemed relevant to future values of the dependent variable are input to the parameterized function to generate predictions for the dependent variable. Such a scenario necessitates the use of load control methodologies. Next, the operation of smart grid requires two-way communication between the central controller and various system elements. Tong et al. (2016) proposes the generalized extreme value distribution characteristic for household load data and then utilizes it to identify load features including load states and load events.

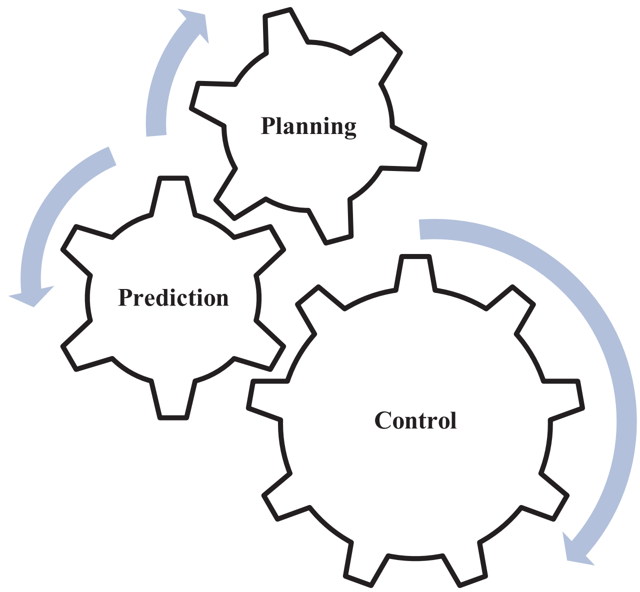

Figure 2.2: Demand side management in smart grid system

The developed demand side management system should, therefore, be able to handle the communication infrastructure between the central controller and controllable utilities. The last, but not the least, criteria for deciding the optimal load consumption can vary widely. The criteria could be maximizing the use of renewable energy resources, maximizing the economic benefit by offering bids to reduce demand during peak periods, minimizing the amount of power imported from the main grid, or reducing peak load demand.

This work presents a generalized hourly annual demand-side management strategy for the future smart grid. It uses demand uncertainty as for the primary technique that can be utilized by the central controller of the smart grid. The objective of the demand side management could be maximizing the use of renewable energy resources, maximizing the economic benefit, minimizing the power imported from the main distribution grid, or reducing the peak load demand. Smart grid manager designs an objective load curve according to the objective of the demand side management.

The proposed optimization algorithm aims to bring the theoretical load curve as close to the actual load curve as possible such that the desired objective of the demand side management strategy is achieved. For example, if the objective of the demand side management is to make a balance between demand and supply, a theoretical distribution curve will be chosen based on previous data to fit with supply.

According to the proposed architecture, the demand side management system receives the theoretical load curve as an input and calculates the required load control actions to fulfill the desired load consumption. Set up of smart grid for renewable distributed generation technology at any location necessitates good load demand estimation (Saber and Venayagamoorthy, 2012). With good estimation, we can optimize investment cost of the renewable distributed generation technology and deliver continuous power supply to the desired location with a minimum per unit cost. For this, there is a requirement of statistical analysis to find out the best-fitted probability distribution of given load demand data. There are multiple types of statistical distribution methods to estimate the load demand uncertainty.

Optimal power flow, between the renewable distributed generation and load demand integrated with the smart grid system, needs the prediction of the uncertainty of renewable energy sources like wind and solar energy and load demand variability.

2.5. Optimal planning of renewable distributed generation

Presently, a large number of research papers are available in the area of the optimal planning of renewable distributed generation (Mena et al., 2014; Kim et al., 2014; Tan et al., 2013; Khatod et al., 2013; and Amor et al., 2012). Brey et al., (2002) emphasised in their work Integration of renewable energy sources as an optimised solution for distributed generation. Robitaille et al., (2005) developed modeling of an islanding protection method for a hybrid renewable distributed generator. In Ochoa and Harrison, (2011), analytical methods are presented to determine the optimal allocation of renewable distributed generation in the radial network as well as smart grid system with the minimization of the network loss as the objective. Zeng et al., (2011) considering the present situation of renewable energy development under the smart grid, the work analyzes distributed generation of renewable energy and sets up the power project evaluation index. Then fuzzy synthetic evaluation model is applied to evaluate the index and consistency test and sensitivity analyses are made. The distributed wind power investment project is cited as a calculation example to verify that the index and model are fit for the project assessment of distributed renewable energy, and can contribute to investment decision-making for both investors and the government. In a work of Mohsenzadeh and Haghifam, (2012), the fuzzy multi-objective optimization is employed to determine the optimal placement of renewable distributed generation for loss reduction and voltage improvement in distribution systems. Mena et al., (2014) shows self-adaptable hierarchical clustering analysis and differential evolution for optimal integration of renewable distributed generation in their work. Yang et al., (2013) propose a framework for demand response in smart grids that integrate renewable distributed generators. Conti et al., (2012) presents an innovative generalized systematic approach and related analytical formulation to evaluate distribution system reliability in smart grids where islanded operation of microgrids helps to improve local and overall reliability. To do this, the analytical formulation involves the adequacy calculation of conventional and renewable distributed generators supplying microgrids by using probabilistic models. Adequacy is computed using a new general analytical expression which takes into account load shedding (user load disconnection) and curtailment (user load reduction) policies. Kim et al., (2014) propose a methodology to determine the optimal capacity of renewable distributed generation. The objective of their work is to maximize cost-savings of energy not supplied (ENS) as well as cost-savings of energy loss according to renewable distributed generation installation in a distribution network. Pegueroles-Queralt et al., (2015) presents a power smoothing system based on super capacitors for renewable distributed generation. Karabiber et al., (2013) presented an investigation of a hybrid DC/AC integration paradigm to establish microgrids by using a conventional three-phase local power delivery system. This approach adds DC power line to the local power distribution system to collect energy generated by distributed domestic renewable sources. The local renewable distributed generation works in conjunction with the conventional grid utility to reduce the power draw from the grid.

Significant research has been conducted in the areas of renewable distributed generation planning, which may assume many different sizes and forms. Karki et al., (2008) considers environmental implications of renewable distributed generation technologies in rural electrification. The adoption of renewable distributed generation technologies (especially wind and biomass gasifiers) provides no-regret options with significant CO_2emission mitigation potential when operated under the net-metering scheme. The results of Labis et al., (2011) show that optimally located renewable distributed generation is economical in the long run when factors of fuel costs and carbon dioxide emissions are taken into account. Abdullah et al., (2014) worked on the assessment of energy supply and continuity of service in the distribution network with renewable distributed generation. Continuity of electricity supply with renewable distributed generation is a topical issue for distribution system planning and operation, especially due to the stochastic nature of power generation and time-varying load demand. Amor et al., (2014) shows in their work implications of integrating electricity supply dynamics into life cycle assessment with a case study of renewable distributed generation. Amor et al., (2012) shows in another work, assessing of economic value of renewable distributed generation in the North-eastern American market. Their results are key to understanding the extent to which subsidies for renewable distributed generation can be economically sustainable when the latter are integrated into regional networks driven by centralized electricity production. Chowdhury et al., (2011) reports on the current UK scenario of islanded operation of active distribution networks with renewable distributed generators. Shenhang et al., (2010) shows, based on distributed renewable energy generation; an energy internet system is constructed, which enables the real-time, high-speed, bi-directional access of electric power data and the grid-paralleling of renewable energy sources. The energy Internet system consists of intelligent energy management system (IEMS), distributed renewable energy source, energy storage, converter and intelligent terminals, etc. Manditereza and Bansal, (2016) discussed the hidden challenges of renewable distributed generation from the protection perspective. The integration of distributed generation is transforming the traditional radial distribution system into a multisource system that requires protection that is capable of maintaining proper coordination under bidirectional and variable power flow conditions.

Tan et al., (2013) discussed on the installation of distributed generation at the non-optimal location can result in various problems such as an increase in system losses and costs, voltage rise and fluctuations, reliability and stability problems. Therefore, it is necessary to develop an optimization or heuristic technique based methodology to identify the optimal placement of distributed renewable generation for a given system that can provide economic, environmental and technical advantages. They reviewed some of the most popular distributed renewable generation placement methods, including 2/3 Rule, Analytical Methods, Optimal Power Flow, Mixed Integer Nonlinear Programming, various types of Artificial Intelligent optimization techniques and Hybrid Intelligent System. Each methodology has its features and potential for significantly promote the applicability of distributed renewable generation in power systems. An evolutionary programming (EP) based technique has been presented by Khatod et al., (2013) for the optimal placement of distributed generation units energized by renewable energy resources (wind and solar) in a radial distribution system. The correlation between load and renewable resources has been nullified by dividing the study period into several segments and treating each segment independently. To handle the uncertainties associated with load and renewable resources, probabilistic techniques have been used. An integration study of photovoltaics and wind turbines, distributed in a distribution network, is investigated based on the stochastic modeling using Archimedean copulas as a new efficient tool in a work of Haghi et al., (2010).

2.6. Research gaps identified

After going through the relevant literature of this thesis research topic, we identified research gaps in respective work areas which are listed below:

- Increasing adoption of renewable distributed generation technologies needs better managerial decision making. Selection of appropriate renewable distributed generation technology is more strategic and decisive area. This is a complex multi-criteria decision-making problem of having uncertain and conflicting factors.

- Amongst the number of available renewable energy sources, the role of wind energy source in the power sector is very important. Estimation of wind energy potential depends on statistical analysis of wind speed distribution, which will give us the best-fitted probability density function of the desired location.
- Optimal utilization of renewable energy sources and continuous electricity supply in any location needs statistical analysis to predict the random distribution of electricity load demand of the demand area.

Optimal planning of renewable distributed generation under uncertainty of load demand and power generation with minimization of the net project cost is the major challenging and complex work in the managerial decision-making process. Power sharing with the grid from the prosumers under smart grid technology is the new managerial challenge to get optimal utilization of renewable distributed generation.