CHAPTER  2

LITERATURE SURVEY

The rapid depletion of fossil-fuel resources on a worldwide basis has necessitated an urgent search for alternative energy sources. A standalone solar photovoltaic, wind system and hybrid systems were more emphasized in literatures. The improvement of performance of renewable energy systems and their economical viabilities were dealt in more detailed manner. The renewable power generating systems are more reliable and environmentally clean. The hybrid power generation systems are reliable and satisfy the load demand very closely in all seasons and also minimize the size of the system components and hence reduce the total capital cost. The hybrid power generating systems are cost effective compared to standalone systems. A great deal of research has been carried out on solar photovoltaic, wind, biogas based diesel generator, bio-diesel generator and hybrid systems. Various works have been cited in the area of design of standalone solar and wind systems and exclusively on hybrid systems for power generation. However, the recent progress is mainly focussed on optimization of such systems considering the techno-economical aspects and operating characteristics. In the literature survey presented, some of the earlier works pertaining to the present work on standalone, hybrid power generation systems and optimization methodologies have been reviewed.

2.1 STANDALONE SOLAR PV SYSTEMS

The technical feasibility of a centralized charging system for solar photovoltaic lanterns for rural lighting system was studied by
Muhopadhyay et al (1993) and a comparative study was presented against a kerosene lantern for a life period of 25 years. This centralized charging system with solar PV provides self-employment and economical feasibility. A proper design and fabrication of the central charging station along with matching portable solar PV lantern has also been discussed in detail. This approach for central charging of the PV lanterns appears to be reliable and cost effective lighting to rural sectors especially in developing countries.

Lee et al (1994) have discussed about the design and implementation of hybrid air-electricity storage system for a PV system. This design gives a correct matching of the performance of PV, battery and air storage pump. The demonstration of the above system yields satisfactory results.

Gupta et al (1995) developed a model employing Graph Theoretic Modeling (GTM) for a standalone solar photovoltaic system. This is a unique model of a standalone photovoltaic powered system. However, the disadvantage of this model is that a system of equations are not developed and solved simultaneously. The model developed was demonstrated for a solar PV based ventilator and pumping system. Also the application of the above model can be much useful in incorporating into a software package for simulating the long term performance of PV powered systems.

Abhaya Swarup et al (1999) developed a model for energy management of PV based energy system. This model has been mainly proposed to raise the public awareness and education levels of solar systems in an interesting and entertaining way. The results indicate that the problems with PV systems were not due to PV array and instead it was due to the performance of the battery units. Also discussed in Barra (1984) and Clark (1984) about modeling of PV system.
A case study on the socio-economic aspects of implementing a rooftop photovoltaic system in Austria has been presented by Reinhard Hass et al (1999). It was observed from their study that the major limitation was the high initial cost of solar photovoltaic systems with the existing poor subsidies for implementing the program.

It is well known that the performance of the solar photovoltaic cells is strongly affected by dust depositions. The effect of wind velocity and airborne dust concentration on cell performance has been studied elaborately by Dirk et al (1999). The evolutions of the short circuit current, the open circuit voltage, the maximum power, the reduction of solar intensity received by the cells and the fill factor variation with increasing cell pollution were examined in their study. These results indicate that the wind velocity has an important impact on cell performance, since the drop in performance becomes larger in high winds than in low winds.

Martina et al (1999) have discussed about multilevel converters that are effectively used to connect single-phase grid with solar photovoltaic systems. An overview of different multi level topologies and the suitability for single-phase grid connected photovoltaic systems has also been presented.

Vivek Kapil et al (1999) have developed an Artificial Neural Network (ANN) model for designing PV systems for remote areas and presented the influence of various parameters on the design of PV systems. The results of ANN model showed a variation of ±5% as compared to other models with more reliability and accuracy.

The application of solar power is varied and the scope of PV systems being employed even in domestic applications appears to be bright.
Mishra et al (2000) have designed, tested and studied a solar photovoltaic powered system for a mini cathodic protection purpose.

Bhattacharaya et al (2001) developed a simplified design approach and economic appraisal of a solar PV system. In this model, the PV array and battery bank sizes for a standalone PV system were estimated. Also a cost comparison of the standalone PV system with a PV diesel hybrid system was presented. The results indicate that the hybrid systems were cost effective than standalone systems for a given location. Similar to the above work, Kaushilka et al (2001) developed a knowledge based model for the design of standalone solar photovoltaic system. This approach combined both the site and array characteristics as a single parameter, referred to as an equivalent unit array output.

Hamid Marafia (2001) studied the feasibility of photovoltaic technology for power generation and presented comparative economic analysis of power generation with a conventional gas turbine. The results indicate that the solar photovoltaic systems are not economical as compared with a conventional gas turbine. However, it was concluded that PV systems could become economical when the system cost reduces to below $2.50 per peak Watt with conversion efficiency above 20%.

Mohanlal Kolhe (2002) has analyzed the economic viability of a standalone solar photovoltaic system with the most likely conventional alternative system i.e. a diesel powered system for energy demand through sensitivity analysis of life cycle cost computation. The analysis has been carried out for the energy demand for different key parameters, such as discount rate, diesel fuel cost, diesel system lifetime, fuel escalation rate, solar insolation, PV array cost and reliability. The result showed that the PV
powered systems could be a cost effective option at a daily energy demand up to 15 kWh even under unfavourable economic conditions.

Usha et al (2003) developed a model to optimize the size of PV panel and battery in a standalone photovoltaic powered system. Optimization of PV system was done based on the cell area, efficiency, cell power and array inclination. Hence this type of standalone PV power system can be more reliable, viable and acceptable. Similar work was also carried out by Philip (2003) on the studies of system design, installation and performance of a standalone wind-diesel power supply systems for remote applications. The result shows that the system performance was satisfactory.

2.2 STANDALONE WIND SYSTEMS

Aydogan et al (2001) have analyzed and presented a case study on wind energy utilization in a house in Izmir, Turkey. The developed model determines the number of batteries needed for continuous energy supply, for each wind turbine taking into account of the economical aspects. It was found that the wind battery hybrid system was not economical in the areas of low wind potential.

Baigarin et al (2001) have discussed about the potential of wind energy resources available in central Asia. The equations used for determining the distribution of wind energy output, energy density, energy cost and efficiency have been discussed in detail.

Suresh et al (2001) have developed a model to investigate the optimum sitting of wind turbine generators based on site and wind turbine type. The methodology of analysis was based on the accurate assessment of wind power potential of various sites. The analytical computation of annual
and monthly capacity factors has been carried out by using the weibull statistical model employing cubic mean cube root of wind speeds. A judicious choice of potential sites and wind turbine generator systems can be made using the model proposed.

Yang (2001) adopted the same principle for determining the power generation by a wind machine and discussed about the utilization of excess wind power for hydrogen storage and subsequent secondary power generation. Rogers et al (2002) studied experimentally the design requirements for a medium sized wind turbine for remote and hybrid power systems. Also, the operational problems of installing medium and large sized wind turbines at remote locations have been addressed.

2.3 OPTIMIZATION OF HYBRID SYSTEMS

In this literature survey various types of hybrid systems and modeling procedures, performance studies of hybrid systems, operating strategies, economical analysis and case studies were discussed in detail.

2.3.1 Solar photovoltaic wind hybrid system

Attempts have been made to optimize the array size of PV systems employed in hybrid power generation systems. Borowy and Salameh (1994) have suggested and developed a methodology for calculating the optimum size of a PV array for a hybrid PV-wind system. Probability density function of the wind speed and irradiance for each hour of a typical day in a month has been found. By using least square method, the best fit of the PV array and wind turbine for a given load has been determined and an algorithm has been developed to find the optimum size of the PV array. In hybrid power generation systems, the available energy from the PV-wind system decides
the size of the battery bank in such a way that the system will satisfy the load demand at any hour of a typical day.

Loois et al (1994) have discussed the technical set-up and use of PV diesel systems for houseboats and barges. A detailed study on PV system coupled to an existing diesel system was carried out. The use of PV systems increased the reliability of energy supply, comfort and diminishes noise and air pollution. The parameters like average annual performance ratio and the average annual final yield were addressed.

Gomaa et al (1995) developed a model to design a hybrid solar photovoltaic and wind energy system and presented a case study for a location, Alexandria in Egypt. Hoque and Ahsan (1995) have investigated the potential and scope of wind turbine generator (WTG) and a photovoltaic generator (PVG) for power generation in an isolated area. Both reliability and cost aspects have been taken into account in the analysis. A temperature dependent probabilistic model for WTG and PVG was developed to compare their impact on the reliability and cost of generation with that of a conventional unit. The results indicated that the reliability of the system with the increase of installed capacity is low in the case of WTG and PVG.

Unlike the graphical method, a new technique using a three event probability method for optimizing the PV panel and battery banks for a hybrid system has been presented by Bagul et al (1996). This method uses long term data for wind speed, solar irradiance as well as the ambient temperature. The new technique provides more accurate results compared to the old methods. The three event probability method has been found to give increased accuracy as compared to the two event technique, as it closely represents the actual distribution of the daily surplus energy.
Borowy and Salameh (1996) developed a methodology for calculating the optimum size of a battery bank and PV array for a hybrid PV wind system. For a given load and a loss of power supply an optimum number of PV modules and batteries have been determined based on the cost analysis. They concluded that the optimum mix of PV modules and batteries depends mainly on the load of the particular site and reliability of the hybrid system.

Beyer et al (1996) developed a set of equations that linked the size of the hybrid system components namely the wind, photovoltaic and battery system directly with parameters that characterized the meteorological conditions at the respective site for a high level of reliability. But this approach is restricted to the case systems with a low loss of load probability.

A graphical construction method for optimizing the size of PV array and wind turbine has been demonstrated by Markvart (1996). The sizing has been made, using the data available from solar and wind sources by incorporating the daily energy balance, supply-demand level and seasonal analysis (like summer, winter, daily and hourly basis). The results indicate that the hybrid system is cheaper than the standalone PV array and wind turbines. Also the energy generated can be matched more closely to the load throughout the year.

Morgan et al (1997) have studied the performance of battery units in an autonomous hybrid energy system at various temperatures by considering the state of voltage (SOV) instead of state of charge (SOC). The algorithm developed by them, was able to predict the hybrid system performance at various battery temperatures. Also, the algorithm takes into account the non-linear behaviour of the low voltage controllers and temperature based batteries.
Elhadidy and Shaahid (1999) have studied the feasibility of wind-solar hybrid power system for Dhahran in Saudi Arabia. In the study, a 10 kW wind energy conversion system, 120 m² Photovoltaic panel together with a battery storage system and a diesel back-up were considered for the analysis.

Bhave (1999) studied the techno-economic feasibility of installing solar photovoltaic-wind hybrid system. This system uses electrical storage by lead acid battery and auxiliary power from AC mains. The result from the above study showed that 80% of the energy demand was satisfied by the solar photovoltaic wind hybrid system. But it was cost effective, only when the system cost was considerably reduced or the current electricity cost raised to a much higher level.

Habib et al (1999) have developed a model for optimizing the size of a hybrid photovoltaic wind energy system. The procedure was applied for the sizing of solar wind hybrid system designed to produce a constant load of 5 kW in the Dhahran area, Saudi Arabia. The analysis indicates that a hybrid system power output can be optimized to suit specific applications with variable or constant power loads.

Francois Giraud (2001) analyzed a model for design of wind–photovoltaic system with battery storage for grid connected rooftop system. The system was designed to meet a typical load demand for a given loss of power supply probability. The various parameters like system reliability, power quality, loss of supply and effects of the randomness of the wind and the solar radiation on systems design have been studied. The results showed that the wind and solar systems were complementary to each other and resulted in improved reliability of the system.
Rajesh (2001) developed a simulation method for photovoltaic and wind energy utilization in small isolated power systems based on reliability/cost implications. This simulation method provides objective indicators to help system planners decide upon appropriate installation sites, operating polices, selection of energy types, sizes and mixes in capability expansion. In this model, cost and reliability are the main parameters to be considered as it has a significant impact on the design.

Celik (2002) developed a novel optimization technique for techno-economic analysis for autonomous small scale photovoltaic wind hybrid energy system. An optimum combination of the hybrid photovoltaic wind energy system could provide higher system performance than either of the single system. It was shown that the magnitude of the battery storage capacity has important influence on the system performance of a single PV and wind system.

Yang et al. (2003) have proposed an optimization technique following the Loss of Power Supply Probability model for a hybrid PV-wind system taking into account the reliability of the system. They demonstrated the utility of their model through a case study of a hybrid unit for a telecommunication system.

Celik (2003) has made a techno-economic analysis and optimization of a PV-wind hybrid system and reported a comparative study against a standalone solar and wind system for the same conditions of load, insolation and wind velocities. In the previous studies design was based on the worst month, which resulted in a costly and non-optimal system in terms of techno-economics. An alternative method was applied in the work by incorporating a third energy source into the system instead of increasing the
hardware sizes excessively for the worst month which facilitated a technoeconomically more optimum system.

Bitterlin (2005) developed a model for a reliable wind/PV/storage power system for remote radio base station, which explores the current practicalities of PV-wind hybrid power generation solution for the cellular phone base station. It is concluded that the application of PV is not technically or commercially viable for this application because a large capacity of PV modules and batteries are essential. Also it is concluded that wind power generation is technically viable and has some practical possibilities being integrated with the radio mast. The longer-term intermittence of the wind, demands a back-up power supply best provided by a diesel generator. The battery will minimize the start/run demand on the diesel engine, which in turn will minimize the required size of the battery storage capacity.

Tina et al (2005) developed a probabilistic model based on the closed form solution approach to convolute long term performance of a hybrid solar wind power system for both standalone and grid applications. For estimating the energy performance of hybrid system, the reliability analysis is performed by the use of the energy index of reliability. The model enables the study of range periods from one year to one hour, thus allowing the inclusion of time value of energy as appropriate in economical assessment. The model is validated by an illustrious numerical example and the results are compared to those resulting from the time domain simulation. A statistical approach alternative to a time step simulation is used for the evaluation of long-term average performance of a hybrid system.
2.3.2 **Solar photovoltaic diesel hybrid system**

An attempt was made to study the option of combining biomass with a PV system by Saha and Sathpathy (1989). They suggested a methodology for the design of such hybrid systems and presented a case study for a location in India. In this design, cost effective sizing ratio of principal power source and backup source were considered which can be applied to any combination of energy source of a hybrid system and also be used for low, medium and high load demands. This system is environmental friendly and the main fuel, i.e. biomass, is available in abundance at a cheap cost in many developing countries.

Seeling-Hochmuth (1997) had proposed an optimization strategy for sizing the PV diesel hybrid system by considering the design and operation parameters of PV system. The control setting and costing operation strategies for certain components together have also been taken into account. The response of battery units in a hybrid system strongly influences the effective utilization of power produced from a hybrid power plant.

Luiz et al (1998) have optimized the generation costs starting from a given load curve of photovoltaic diesel hybrid system and studied the techno-economic feasibility. The results were compared with conventional diesel system and it was found that the PV/diesel option could be more reliable and economical than the diesel system. Said (1998) has developed a model for sizing the photovoltaic diesel battery hybrid system. The sizing program developed can be used to size any PV diesel generator hybrid power system and the maximum number of battery storage days can be determined. The designed hybrid system can become more economical than a standalone system because of the minimization of array size and battery capacity required.
Muselli et al (1999) have developed a methodology for calculating the correct size of a Photovoltaic diesel hybrid system and optimizing its management. Various sizing configurations were simulated and the optimal configuration that meets the autonomy constraint was determined by minimizing the energy cost. A study on the effects of component lifetime on the economics of PV hybrid and PV standalone systems has shown that the battery size could be reduced by a factor of two in a PV hybrid system, as compared to a PV standalone system.

Ashari et al (2001) proposed an optimum operation strategy and economic analysis of photovoltaic-diesel-battery-mains. The system comprised of a photovoltaic system, battery and bi-directional inverter that was connected in parallel to the grid. The optimum operation strategy of the system was proposed for the diesel-connected mode, while the economic analysis was evaluated for the grid-connected mode. The optimum value has been obtained by comparing the cost of the diesel fuel consumption and the battery wear.

Park et al (2001) have investigated a PV-Diesel hybrid power generating system, used in a small ship having a load of 5 kW and proposed a simulation model considering the parameters like minimum and maximum battery terminal voltage, load pattern and operating modes (i.e. starting and stopping of DG set and charging and discharging of battery). The hybrid system was employed as a replacement option for the standalone photovoltaic power source due to change in solar radiation. The main objective was to maintain output of diesel generator constant so as to exploit the benefits of high efficiency and low fuel consumption of the diesel generator at constant load and to maximize the utilization rate of PV energy resource so as to minimize the capacity of the battery. It was found that the system with a large
PV array and a small battery lead to least utilization rate of PV energy resource.

A test facility has been developed by Wichert et al (2001) to evaluate the feasibility of a novel predictive strategy for photovoltaic diesel hybrid energy system. A quasi-random load profile, which closely resembles the statistical distribution of loads measured at several remote sites, was followed. The graphical control environment allows the implementation of complex, advanced dispatch strategies. The potential for the performance improvements of standalone renewable energy system, which can be achieved through the application of intelligent energy management strategies have been addressed.

Zahedi (2003) developed a new methodology for accurate sizing of the components of solar photovoltaic hybrid power systems. The size of each component in a photovoltaic hybrid system depends on the kWh per day required by the load and also the amount of solar energy received. The optimum sizing of the system ensures minimum capital and electricity cost. The proper designing of the above system offers all the benefits of photovoltaic system with respect to low operation and maintenance cost.

2.3.3 Wind diesel hybrid system

Nayar et al (1993) developed a new technology for an optimized performance of diesel-wind-battery hybrid system employing a microprocessor based control system and proposed a new parallel technology for diesel-sine wave inverter system. The economic analysis was also carried out and the results obtained signifies an optimal system efficiency, efficient operation of the diesel at all times and possibility of using smaller diesel generator set and battery bank.
Elhadidy et al (1999) have developed a strategy for optimal sizing of battery storage for wind diesel hybrid system. In this study the impact of battery storage system and diesel generator back up on the system performance was addressed. The results exhibit a trade-off between the size of storage capacity and diesel generator to cope up with the daily load demand. An economic analysis was performed to optimize the battery storage, number of hours of operation of diesel system, storage capacity and number of days of autonomy. The result showed that the variation of battery capacity, storage and number of days autonomy had led to variation in hours of operation of the diesel generator.

2.3.4 Solar photovoltaic wind diesel hybrid system

Ramakumar et al (1995) developed a model for designing integrated renewable energy systems. In this article, some typical design scenarios and the formulation of designs using the knowledge based design tool with the aid of KAPPA-PC development tools have been widely addressed. This software can handle multi-inputs and multi-outputs of renewable energy systems under many design constraints.

Barley and Winn (1996) developed a model for optimizing the dispatch strategy for photovoltaic wind diesel hybrid system for remote locations. Dispatch strategy is the aspect of control strategy that pertains to energy flows among components. In these systems, both battery and diesel generator dispatch strategy affects the life cycle cost through both the fuel usage and the battery life. Dispatch strategies have been compared using an analysis of cost trade offs, quasi-steady-state time series model and a more sophisticated stochastic time series model. Dispatch strategies for the operation of solar photovoltaic-diesel-battery hybrid power system using set points have been analyzed by Ashari and Nayar (1999). The site load power,
PV output, battery terminal voltage, DG operating power level and inverter operating power level have been considered to determine the optimum value of set points for the operation of DG in order to minimize the overall system costs.

Mcgowan et al (1999) have summarized the recent progress on wind PV diesel hybrid system. They mainly concentrated on system configurations, hardware design, modeling tools used and recent applications. It was concluded that more concentration was required on component reliability, accurate documentation, monitoring system performance and cost effective improvements on system components.

Elhadidy et al (2000) carried out a parametric study on wind solar diesel hybrid generating system. In their study, hourly wind speed and solar radiation were taken from meteorological monitoring station of Dhahran, Saudi Arabia. The impact on parameters such as PV array area, number of wind machines and battery storage capacity on the operation of hybrid system to satisfy the annual demand were studied. However, the cost aspects have not been taken into account for optimization.

Elhadidy (2002) analyzed and studied the performance of hybrid system consisting of different rated power wind farms, photovoltaic arrays and storage capacities together with a diesel backup. The result indicates a small decrease in diesel-generated energy associated with a large increase in photovoltaic system capacity and in an economic point of view, the photovoltaic systems are not cost effective because of their high initial cost. Elhadidy (2003) studied and analyzed a PV-wind-diesel-battery hybrid system for Dhahran location at Saudi Arabia and reported the performance of the integrated system against the load variations.
Jose et al (2006) developed Strength Pareto Evolutionary Algorithm to the Multi-Objective design of isolated hybrid systems. The design is posed as an optimization problem, whose solution allows obtaining the configuration of the system as well as the control strategy that simultaneously minimizes both the total cost through the useful life of the installation and the pollutant emissions. Model explains a PV wind diesel system for two different load profiles.

2.4 GENERAL STUDIES

Anna Mani (1989) measured and recorded the solar radiation and wind climatology of various parts of India. Various parameters related to solar and wind energy has been discussed and the potential areas in India have been identified. Treble (1992) discussed the international standard for photovoltaic system and addressed the performance measurement and testing of systems carried out internationally. Gupta (1979) and Mani (1980) and Mani (1996) discussed about solar radiation.

Jorge et al (1995) studied the performance of lead-acid batteries in photovoltaic system for rural field electrification. Major problem in solar photovoltaic systems is the battery maintenance, which decides the performance of the total system. The complete discussion of the various parameters that affects the performance of battery and maintenance methods of lead acid batteries has been presented.

Scheer (1995) discussed the solar energy’s economic and social benefits in detail. The depletion of conventional fuel, environmental problems and research and development on solar energy and social benefits has been addressed. David et al (1996) developed a model to determine the ultimate service lifetime of a vented lead-acid battery for photovoltaic applications.
This model requires normally and readily available data only and can be used for different types of battery. This analysis is very much useful for selecting the battery and determining the life cycle cost of the battery.

Kruangpradit et al (1996) developed a program on design, implementation and evaluation of hybrid renewable energy system for remote village electrification. Three different types of hybrid systems namely PV/Microhydro/Diesel/Battery, PV/Diesel/Battery and PV batteryless grid connected power station have been discussed. Methodologies used in systems design, operation of systems have been given in detail.

Castro et al (1996) developed a dedicated computer program for assessment of stand alone and integrated renewable energy systems. The program can be used to assess close to the real time performance, the different energy mix scenarios involving both renewable and conventional power plants. Nayar (1997) had discussed in detail about the operation of a solar-wind-diesel hybrid system with battery backup developed in Australia for remote area applications. It was found that diesel generators could be operated at nominal capacity for a short period, while inverters peak to double of its capacity.

Peterson et al (1999) reported the operational experiences acquired with a photovoltaic hybrid system installed as a line extension alternative at a residence located in northern Newyork state. Detailed analysis have been presented on the energy flow through the system and all losses caused by battery storage, round trip, rectifier and inverter conversions, non-optimum operation of the generator and PV array have been considered in the study.

A detailed cost analysis considering the life cycle cost of a photovoltaic generator, kerosene generator and diesel generator was presented
by Koner et al (2000). The parameters considered for calculation of the unit cost of energy were the discount rate, inflation rate, loan facility by Indian Renewable Energy Development Agency (IREDA) to promote PV, operation and maintenance cost of PV, fuel generator set and associated fuel cost. It was observed that the PV energy could become cheaper if load shedding per year is less than 500 hours.

Iniyan et al (2000) developed an optimal renewable energy mathematical (OREM) model that allocates the renewable energy for the year 2020-2021. The main objective of the model was to minimize the cost/efficiency ratio subject to the constraints of social acceptance, reliability factor of renewable energy systems, potentials and energy demand for different end uses.

Bhargava (2001) presented an overview of photovoltaic technologies in India, feasibility, research and development activity, the Indian programme on photovoltaic, government policies and commercial market development efforts. Nagayoshi et al (2001) designed an effective combination of Photovoltaic-battery systems for obtaining high combined peak cut function. They also addressed the methods to improve the life of the battery and other components of the system.

Hiroyuki et al (2001) developed a new formula for calculating irradiation on to an arbitrary orientation-inclined plane. The results of this work demonstrate that an algorithm associated with the Perez model could estimate the in-plane irradiation. Riza Muhida et al (2001) have developed a model for optimization of Photovoltaic-micro hydro hybrid system. Photovoltaic system forms the primary source in the hybrid system, while the micro hydro system supports the PV system during slack periods. The
theoretical analysis reveals the performance of the system and it matches closely with the experimental results cited.

El-Kordy et al (2002) has analyzed the cost of electricity generated from different systems by considering external emission costs for the conventional and renewable energy systems. The life cycle analysis for each system was performed using the present value criteria. The comparative results showed that the wind energy generation has the lowest cost followed by combined cycle natural gas fired system. The photovoltaic system is comparatively expensive for electricity generation even when external emission cost is considered for capital cost of PV systems. To be economically competitive the capital cost of PV is to be reduced by about 60%.

Ghosh et al (2003) have made comparative studies of hydrogen storage with diesel generator in a PV-Wind hybrid system. Critical fuel cost has been calculated depending on the seasonal solar and wind energy difference and the actual fuel costs were compared with that of the critical fuel cost. It was concluded that hydrogen storage was not cost effective as compared to the diesel generator based system.

Jorge Islas et al (2004) has compared “BAU” (Business as usual) and transudation scenario over three decades by incorporating a simulation method and concluded that the annual average CO₂ reduction potential of 8.2million tons between the considered period. Which are accumulated terms corresponds to a 29% reduction of BAU scenario.

Lund (2006) developed a model for optimizing integration of PV, wind and wave power for electricity supply. Electricity supply is expressed in terms of the ability to avoid excess electricity production. The different sources are analyzed in the range of an electricity production from 0 to 100%
of the electricity demand. The excess production is found from detailed energy system analyses on the computer model Energy PLAN. The optimal mixture seems to be when onshore wind power produces approximately 50% of the total electricity production from RES. Meanwhile, the mixture between PV and wave power seems to depend on the total amount of electricity production from RES. When the total RES input is below 20% of demand, PV should cover 40% and wave power only 10%. When the total input is above 80% of demand, PV should cover 20% and wave power 30%.

2.5 SUMMARY

The literature review revealed the following:

- Reviews and optimization models developed by various researchers on standalone solar photovoltaic, wind and hybrid systems were reviewed.

- The various influencing parameters on design of PV hybrid system were identified.

- It is observed that most of the models were based on probability and reliability of the hybrid system without considering the cost.

- Future demands were also not considered in many models.

- Excess power generated were not considered in previously developed systems.

- Deficiency of power supply probability and cost were not considered simultaneously for optimization of hybrid system.