CHAPTER 5

CONCLUSION

In the present scenario standalone solar photovoltaic and wind systems have been promoted around the globe on a comparatively larger scale. These independent systems cannot provide continuous source of energy, as they are seasonal. The solar and wind energies are complement in nature. By integrating and optimizing the solar photovoltaic and wind systems, the reliability of the systems can be improved and the unit cost of power can be minimized.

A PV-wind hybrid systems is designed for rural electrification for the required load at specified Deficiency of Power Supply Probability (DPSP). A new methodology has been developed to determine the size of the PV-wind hybrid system using site parameters, types of wind systems, types of solar photovoltaic system, number of days of autonomy of battery and life period of the system.

A primary model was developed to optimize PV-wind hybrid system for any specific location, by considering the parameters like DPSP and REPG. The developed model processes the input parameters pertaining to the wind velocity, solar insolation, environment temperature, load distribution, wind and PV system parameters like cut-in-speed, cut-off-speed, rated speed, rotor diameter, hub height, peak module power, capacity of the PV panel and wind systems. It computes the output parameters like PV capacity, array configuration, number of modules, tilt angle, inverter capacity, battery
capacity, charge controller capacity and wind machine capacity. The optimal size of the hybrid system is determined based on the calculated values of REPG for a specified DPSP. Thus the model suggests the optimum combination of the capacity of wind, PV and battery units of a chosen type that can generate power with a minimum REPG by the implementation of iterative technique.

A secondary model developed for optimizing techno economic aspects like LCC, LEC or LUC considering the parameters like life period of solar system, wind system, battery discount rate, escalation rate, cost of the module, wind machine, battery, inverter, BOS components and CO₂ mitigation cost for solar photovoltaic wind hybrid system.

In the developed model of PV-wind hybrid system the specific data related to the location of Ottapidaram (8°54’N, 78°1’E) are given as inputs by considering the parameter DPSP as 0.15, the wind velocity 5.1 m/sec, solar insolation 5.89 kWh/m², environment temperature of 32°C for a load of 72 kWh/day. Wind system parameters like cut-in-speed of 3 m/sec, cut-off-speed of 20 m/sec, rated speed of 12 m/s, rotor diameter of 20 m, hub height of 30 m, PV parameters like peak module power of 52W. The computed output parameters are PV capacity of 0.5 kW_p with 3 days of battery autonomy and wind machine capacity of 10 kW for a REPG of 0.07. Thus the model suggests the optimum combination of the wind capacity of 10 kW and PV capacity of 0.5 kW_p with 3 days of battery autonomy can satisfy the load requirement for a given DPSP of 0.15 with a minimum REPG of 0.07 for a minimum LUC of Rs.26.93.

The comparative cost of grid line extension energy source with PV-wind hybrid system is a vital parameter to decide the viability of installing a PV-wind hybrid system. It is evident from the study that, to meet out the
daily energy demand of 75 kWh a fixed life cycle cost of Rs.150 lakhs is required for a grid line extension of 50 km. This LCC does not vary even when the load demand is less than 75 kWh/day for the same grid line extension. But in the autonomous PV-wind hybrid system LCC is Rs.150 lakhs for a daily energy demand of 75 kWh, and for a load less than 75 kWh, the LCC proportionately reduces. In comparison with the grid extension, it is concluded that for a load less than 75 kWh per day and when the grid line is 50 km away from the load point then the PV-wind hybrid is economical. Also that when the grid extension distance is longer than 50 km and load demand is lower than 75 kWh/day the autonomous PV-wind hybrid system is economically viable.

Sensitivity analysis is carried out for various parameters of solar photovoltaic wind hybrid system for an economic evaluation. The analysis done is for life cycle cost of PV-wind hybrid system through the simulation analysis which determines how it varies for the key parameters such as discount rate, escalation rate, PV module cost, insolation, wind velocity, module efficiency and battery autonomy. When the module efficiency has been increased from 10% to 20%, the life cycle unit cost is reduced by 25%, for given module cost of Rs.200 per Wp. The life cycle unit cost decreases at higher module efficiency, lower module cost and also it decreases with increase in life period of the system. The life cycle unit cost of the system is much sensitive at life periods less than 20 years.

The model output data is compared with the real time output data, which is obtained for a hybrid plant installed at Chunnambar, Pondicherry (11.46° N, 79.46°E). The estimated value of energy generated by the model of solar system and wind system deviates by 6.22% and 7.18% respectively with the real time values. In the case of PV-wind hybrid system the deviation is found to be 6.66%. 
From the studies for a given energy to load ratio the capacity of the solar wind hybrid system is found for a given load demand. The study reveals that at the vicinity of 0.74 solar or wind energy to load ratio, the PV-wind hybrid system capacity converges to be optimum and also the life cycle cost is minimum. In the case of Ottapidaram the optimum combination is achieved with 7.8 kW$_p$ solar PV capacity and 8 kW of wind system for a annual average daily load demand of 72 kWh at DPSP of 0.02 and solar or wind energy to load ratio of 0.74. Also it is noted that this point corresponds to minimum life cycle cost of Rs.130 lakhs.

The case study carried out for an annual average daily load of 450 kWh at Poompuhar indicates that for a given DPSP of 0.2 the life cycle unit cost of energy for standalone wind, standalone PV and PV-wind hybrid systems are Rs.28, Rs.25 and Rs.23 respectively. It may be noticed that the hybrid system returns the lowest unit cost values to maintain the same level of DPSP as compared to standalone solar and wind systems in all cases.

After implementing the model in case studies, a thorough analysis is made and the results are obtained which highlights the following important conclusions.

- An optimum hybrid system ensures minimum REPG for a given DPSP for a specific location
- The optimum combination of solar PV-wind hybrid system lies between 0.70 and 0.75 of solar or wind energy to load ratio and the corresponding LCC is minimum
- Life cycle unit cost of power generation from hybrid system is less compared with standalone solar and wind systems. It lies between Rs.20 and Rs.30 per kWh
- Load demand less than 75 kWh per day and when the grid line of 11 kVA is 50 kms away from the load point, then the PV-wind hybrid is economical for the PV module cost of Rs.200 per Wp.

- When the module efficiency is increased from 10 to 20% then LUC is reduced by 25% for given module cost of Rs.200 per Wp.

- If insolation is increased by 65% the LEC decreases by 27%. Variation in LUC is meager after a life period of 20 years.

The PV-wind hybrid option is techno-economically viable for rural electrifications when the PV module cost is below Rs.100 per Wp and the efficiency of PV module is higher than 20%. The scope of implementing these systems in suburbs may possible in near future.

5.1 SCOPE FOR FUTURE WORK

The following aspects may be investigated as an extension of this work in future.

1. The optimization and reliability estimation for an hybrid combination of a photovoltaic (PV), wind energy conversion system and diesel system.

2. Optimization of hybrid system by considering maximum power point tracking, cost of externalities and future demands to minimize the capacity of battery and excess power generated.

3. Practical difficulties associated with the implementation of hybrid system in rural areas.