HYBRID RENEWABLE ENERGY SYSTEM FOR A REMOTE RURAL AREA IN INDIA

Ph.D. THESIS

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ABSTRACT

The increase in population, technology and per capita energy consumption leads to an exponential increase in power demand. Due to fuel constraints, inadequate investment policies, high transmission and distribution losses, the conventional power generation alone could not meet the load demand. Increased emissions of pollutants and technological developments in solar and wind energy have paved the way for an alternative to electricity generation in the last decade. It is therefore, producing electricity from renewable energy sources become essential to meet the energy needs in the global scenario. In addition, the RERs are inexhaustible in nature and capable of addressing emission problems, thus encouraging the development of green energy-based power generation and technology. Therefore, renewable energy based power systems are acquiring more attention to provide cost effective and reliable power supply. The power generation using RERs can be utilized for grid connected/off-grid applications. Worldwide grid-independent hybrid renewable energy system (HRES) is an alternative option for powering the un-electrified villages where grid extension is not feasible.

For the development of off-grid HRES, the RERs such as solar, wind, biomass and small hydropower can be used to meet the electricity needs of remote areas. Off-grid rural electrification is considered as the most acceptable and economical approach. As RERs are intermittent and not reliable in nature, the required load demand of the remote rural area may not be supplied by a single RER. For reliable and cost effective power supply, it is imperative to combine two or more RERs. Moreover, batteries (BTs) and diesel generators (DGs) can also be used to confronting the irregularity of RERs. In-order to obtain feasible and efficient HRES, demand side management (DSM) can be implemented. In this context, electricity generation from available renewable energy resources is the right choice in the proposed isolated area.

Under this study, an extensive literature review has been performed and it is found that most of the studies were concentrated on single/two resources with BT/DG viz: photovoltaic (PV)/BT, wind turbine (WT)/BT, PV/WT/BT and WT/DG. However, quite limited studies on PV/WT/micro hydro (MHP)/DG/BT based HRES are reported in the literature. Most of the researchers focused on feasibility studies of HRES without considering the effects of different batteries and DGs on techno-economic and environmental parameters with and without scheduling. Several researchers carried out techno-economic analysis without taking into

account the impact of dispatch strategies such as load following (LF), cycle charging (CC) and combined dispatch (CD) on the techno-economic and environmental parameters of the stand-alone HRES. Very few researchers optimized the stand-alone HRES based on the comparison of different batteries like Lead Acid (LA) and Li-Ion. Keeping this in view, the present study on PV/WT/MHP/DG/BT hybrid system was proposed with the following objectives:

i. To identify a cluster of un-electrified villages having sufficient renewable energy resources and to estimate the load demand and potential of RERs.
ii. To assess daily and seasonally varying renewable energy resources and load demand for the selected cluster of villages.
iii. To analyze the effect of LA, Li-Ion batteries and with and without scheduling of DGs on HRES operating costs such as net present cost (NPC) and cost of energy (COE) of the HRES.
iv. To investigate the effects of various dispatch strategies such as LF, CC and CD on the techno-economic and environmental performance of the proposed LA and Li-Ion battery based HRES.
v. To perform sensitivity analysis for evaluating the impact of input variables on the COE and NPC of the proposed HRES under different dispatch strategies.
vi. To enhance the reliability and to decrease the operating costs through implementation of different DSM methods.

In order to satisfy the above mentioned objectives, a study has been carried out to provide power supply using the HRES for a remote rural area in Chikmagalur district of the Karnataka state in India. As per the data collected from Mangalore Electricity Supply Company (MESCOM), it was found that there are 49 villages still un-electrified in Chikmagalur district. A cluster of 13 un-electrified villages has been considered as the study area. Due to hilly terrain, households are scattered and about 297 households are not electrified in these villages. The conventional grid connection to these households is not feasible. Therefore, a HRES is considered the alternative option for the supply of electricity to these villages. Solar, wind and hydro are the available resources in this area. The integration of these RERs together with the DG is proposed to supply the required electrical power. In addition, to store the excess energy and to act as back-up, batteries have been proposed.

The effect of use of LA, Li-Ion batteries on the performance of HRES has been assessed considering four different configurations such as PV/MHP/BT, PV/MHP/WT/BT, PV/WT/BT and PV/WT/MHP/DG/BT in the present study. Out of these configurations, PV/MHP/Li-

Ion_BT HRES is found to provide the optimal feasible NPC and COE of the HRES. To find out the effect of DG scheduling, four different configurations have been considered as PV/WT/MHP/DG, PV/MHP/DG, WT/MHP/DG and MHP/DG HRESs respectively. A saving in NPC and COE of about 11% is found in all the four proposed configurations using with scheduling of DG than that of without scheduling. Further, the effect of LF, CC and CD strategies on LA and Li-Ion batteries with PV/MHP/BT and PV/WT/MHP/DG/BT configurations has been studied through HOMER Pro® simulation tool. For both LA and Li-Ion batteries based hybrid systems, the COE and NPCs are found to be minimum with CD strategy. Based on analysis, it has been found that COE was reduced by 34%, 25% and 37% under LF, CC and CD strategies in PV/MHP/BT_Li-Ion system in comparison of PV/Hydro/BT_LA hybrid system. Similarly, NPCs are also reduced by 35%, 34% and 35%. The results follow similar trends with the PV/WT/MHP/DG/BT HRES also. The effects of input parameters such as discount rate, PV system cost, battery cost, fuel cost, wind speed and design flow rate have also been investigated for sensitivity analysis. For the Li-Ion battery based system, the COE is found as 20%, 17% and 34% less than LA battery based system under LF, CC and CD strategies with ±20% variation of system input parameters, whereas, NPCs are reduced by 18.5%, 10% and 34%.

To improve the performance of the proposed PV/MHP/BT, PV/WT/MHP/DG/BT based HRESs, various DSM methods viz: Load shifting, Strategic conservation and Load shifting along with Strategic conservation have been implemented. Out of these three methods Load shifting with Strategic conservation method is found to give the optimal solution. Based on the comparison, it is found that number of components was saved substantially by implementing the DSM to the proposed HRES. The operating costs such as the NPC and COE are found to be saved by $2,71,884 and 0.004$/kWh respectively and pollutant emissions are reduced by 63%. Further, DSM enabled PV/MHP/BT_Li-Ion HRES under CD strategy offers the optimal operating costs such as NPC and COE respectively as $3,14,079 and 0.103 $/kWh. The optimal capacity of PV, MHP, and converters are found as 203 kW, 15.7 kW, and 81.9 kW along with 557 numbers of batteries for the considered area. This study can be useful to provide guidance to develop HRES models for supplying power to similar off-grid rural areas.

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