INTEGRATED HYBRID RENEWABLE ENERGY SYSTEM FOR OFF-GRID RURAL ELECTRIFICATION IN VILLAGES IN EAST INDIA

Ph.D. THESIS

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ABSTRACT

The increase in population, technology and per capita energy consumption results in an exponential increase in electricity demand. The conventional power generation alone could not meet the load demands due to inadequate investment policies, fuel constraints and high transmission and distribution losses. Off-grid Integrated Hybrid Renewable Energy Systems (IHRESs) can be a viable alternative for powering un-electrified villages, where the grid extension is not feasible and/or economical. Renewable Energy (RE) resources such as solar, wind, biomass and micro hydropower can be used to supply the electrical energy needs of isolated communities by constructing an off-grid Integrated Renewable Energy System (IRES). For a steady and cost-effective power supply, it is necessary to integrate one or two RE resources as well as batteries. A Diesel Generator (DG) can also be used to compensate for the inconsistency of RE resources. Demand-side management (DSM) can also be used to develop viable and efficient systems. In this regard, electricity generation using RE resources available in the study area is considered to be the best alternative.

The present study is planned with the objectives as (i) To identify the cluster of un-electrified villages which have the potential of RE resources, (ii) To assess the load demand and RE resources potential for the identified study area, (iii) To develop the mathematical models of different components of the IRES and IHRESs, (iv) To analyze the performance of an IRES, both with and without a DG using the effect of load variation, (v) To analyze the Life Cycle Cost (LCC) of the IRES with different battery technologies, both with and without a DG under different operating conditions and (vi) To optimize the LCC of the IRES by considering the Demand-Side Management (DSM), both with and without a DG.

In order to meet the aforementioned objectives, a study has been conducted to supply electricity and freshwater availability using an off-grid microgrid for a remote rural area in the Rayagada district of Odisha state in India. As per the data collected from TATA Power Southern Odisha Distribution Limited (TPSODL), it was found that there are 15 villages still un-electrified in the Rayagada district. A cluster of 5 un-electrified villages in the Muniguda block of Rayagada district is considered as the study area. A total of 1,213 people are living in the study area, with an average of 4 people living in a household for a total of 266 households. The study area is located 50 km away from the grid, which is located in the hilly terrain and in a high-density forest. Therefore, the extension of the grid is not feasible and

economical. This area is not yet electrified due to its remote location, so people still living in the lighting of candles, kerosene lanterns and solar lamps. These families are unable to connect to the conventional grid supply. Therefore, an off-grid microgrid is viewed as an alternate option for supplying electricity to these villages. The accessible RE resources in the study area are solar and biomass. The annual average solar energy in the study area is identified as 5.18 kWh/m^2/day and the annual average ambient temperature is 25.74^0 C. The estimated forest foliage is about 9 tons/year.

Under the present study, twelve different configurations have been modelled using the available RE sources and various battery technologies with their different depth of discharges (DODs) with and without a DG. Out of these six configurations are IRESs, whereas, the other six are considered for IHRESs. To find an optimal configuration out of these twelve configurations, the Salp Swarm Algorithm (SSA) has been proposed.

Based on the obtained results, it is found that the Ni-Fe battery-based IRES has resulted in a minimum LCC of $7,40,122, which is about 40% and 65% lower than the LCCs of LA (@80% DOD) and Li-Ion (@50% DOD) battery-based IRESs, respectively, as well as the Ni-Fe battery-based IHRES with LF strategy, obtained an LCC of $7,15,588, which is about 39% and 61% lower than the LCCs of LA (@80% DOD) and Li-Ion (@50% DOD) battery-based IHRES's LF and CC strategies, respectively. Finally, it is concluded that the Ni-Fe battery-based IHRES with LF strategy results in a minimum LCC of $7,15,588, which is about 3% lower than the LCC of Ni-Fe battery-based IRES.

In order to improve the performance of the system, the energy conservation-based DSM has been applied using high, medium and low-efficiency appliances usage-based scenarios. From the results, it is found that the Ni-Fe battery-based IRES with high-efficiency appliances usage-based scenario i.e. with DSM resulted in a minimum LCC of $5,30,603, it is about 44% and 17% lower than its low and medium efficiency appliances usage-based scenarios, as well as the Ni-Fe battery-based IHRES with LF strategy using high-efficiency appliances usage-based scenario i.e. with DSM has been found to have minimum LCC of $5,22,945, which comes out to be about 43% and 15% lower than its low and medium efficiency appliances usage-based scenarios, respectively. Finally, it is concluded that the Ni-Fe battery-based IHRES with LF strategy using LPRAHC based scenario resulted in a minimum LCC of $5,22,945, which is about 2% lower than the LCC of Ni-Fe battery-based IRES's LPRAHC based scenario.