**Abstract of PhD Thesis**
**"Design and Development of PV-Small Hydro Hybrid Systems with Synchronization to Weak Grid"**
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This work presents the PV-BES-small hydro-wind hybrid system with synchronization to the weak grid, which operates in three modes like the grid synchronized mode, an islanded mode, and hydro generator mode. This system ensures reliable and uninterrupted power to the critical loads in rural, hilly, and coastal areas, where the grid is weak. The conventional grid tied solar inverters are shut down compulsorily at the outage of the grid due to safety concerns. The grid in the remote, hilly, and coastal areas are subjected to the grid voltage amplitude variations, grid voltage frequency variations, and frequent outage of the grid occurs. Thus, the electricity to the dedicated loads is ensured by diesel generators. The environmental and economic concerns of diesel generator set, its high-cost installation, operation, diesel transport to remote locations, emissions cause climate change due to global warming and other environmental issues because of release of the high amount of carbon dioxide and other toxic gases, have led to think on cost effective and pollution free energy. Moreover, fossil fuels are exhaustible and depleting, resulting in increased costs. These problems are mitigated by integrating the various renewable energy resources, and the battery energy storage (BES) accompanied to the efficient, accurate, and fast control strategy. The PV array generator is incompetent to ensure continuous electricity, while the PV array generation is low due to low irradiance than the load requirement at the outage of the utility grid. The BES stores energy at surplus generation from the PV array generator, and discharges to meet the load requirement, while deficient generation from the PV array at an islanded mode of operation. Moreover, the PV-BES system is controlled to function at variable grid power mode and preset grid power mode to ensure efficient utilization of the resources. The BES capacity required is large, moreover, BES needs replacement and frequent maintenance, thus, increases the cost of the installation and decreases reliability, especially, in remote hilly areas. The self-excited induction generator functions at single point of the saturation region of its magnetization characteristics is utilized to realize the hydro generator. The hydro generator accompanied to PV array generator feeds the load and charges the BES at the utility grid outage. This decreases the BES capacity requirement and BES loading. Wind power is abundant in coastal areas. The wind generator, realized from the permanent magnet synchronous generator is integrated at the DC link to reduce the dependency of the emergency load on the weak utility grid. The PV array generator, wind generator, BES, and hydro generator are integrated to efficiently utilize the available renewable resources. This PV-BES-small hydro-wind system is synchronized to utility grid for the exchange of powers. The utility grid tied mode control, an islanded mode control, and transition mode control algorithms are adopted for reliable control of PV-BES-small hydro-wind system. The PV-BES-small hydro-wind system is integrated to utility grid near the local loads rather than using a long transmission line for providing power to loads.
The increased concentration of the power converters in the residential load causes a serious power quality concern. The nonlinear load injects harmonics current to the utility grid, which leads to voltage distortion, causes mal operation of appliances, increased losses, and reactive power burden on the distribution network. The fast and accurate control algorithms are utilized to mitigate these harmonics current in the utility network current.
This investigation is focused on the design, development, and implementation of various single phase and three phase configurations of PV-small hydro hybrid systems with synchronization to the utility grid. All the topologies are simulated in MATLAB/ Simulink environment and validated on a developed laboratory prototype. These topologies ensure electricity to dedicated load with distribution grid power quality concern. The simulated and test results are utilized to analyse the utility grid synchronized mode, an islanded mode, and transition mode functions of various implemented configurations. The PV-BES-small hydro hybrid system configurations are classified based on their type of battery connection, type of utility grid (single-phase or three-phase), number of power conversion stages (single-stage or two-stage), and the renewable energy sources used. In the case of two stage power conversion stages, the first stage, which is a boost converter extracts the maximum power from the renewable sources. The remaining functions of power injection to the utility grid, harmonics current compensation, reactive power compensation of the non-linear load besides feeding the load are performed by the second stage, which is a utility grid interactive VSC. The bidirectional converter charges/ discharges the BES. In single stage conversion, all the function is performed by the VSC in the utility grid tied mode except BES charging and discharging, which is controlled by buck-boost converter. Whereas, in an islanded mode of single stage conversion, the bidirectional converter also tracks the MPPT. The VSC regulates the PCC voltage in an islanded mode in both the two-stage conversion and single stage conversion. The utility grid outage is common in rural, hilly, and coastal areas. Therefore, simple, accurate, autonomous, and intelligent control techniques for utility grid synchronized PV-BES-small hydro hybrid system, are developed such that the PV-small hydro-hybrid system is capable of operating under outage and recovery of the utility grid and at the outage and restoration of power generation from the renewable sources to ensure reliable and uninterrupted power to the end users.