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Title: Power Management of Single-Phase Grid Connected Inverter

Abstract: The growing environmental concerns due to conventional power plants and increasing power demand has resulted in a transition towards renewable energy-based distributed generation (DG) systems. The photovoltaic (PV) installations are one of the largely adapted renewables with significant installation and high growth rates. But the volatile nature of PV resulted in high fluctuations at the output, and challenged the grid integration. To overcome this, methods to strengthen the electrical network are widely discussed in the literature. However, these methods had drawbacks with different modes of operation, implied high expenses, and the overall efficiency drops when the energy is transported over long distances. Among these, the drawbacks associated with the control of PV inverter in both standalone and grid connected modes, islanding detection and low voltage ride through mechanism for grid connected operation, and power management during transition between standalone and grid connected modes impacted both reliability and stability of the power transmission network and the utility.

In light of these drawbacks, this research formulates the objectives to develop efficient control strategies required for achieving energy management with the inverter and operate the systems individually or together with the main electrical grid. The performance parameters of the stand-alone transformerless PV inverter operation is assessed to develop a new control technique. Further, a novel transformerless inverter topology is proposed and its voltage and harmonics regulation control in standalone and grid-connected modes are investigated with the safety standards. Furthermore, a machine learning based islanding classification mechanism and an additional reactive active current control approach are proposed to achieve low voltage ride through control for the transformerless grid connected inverter topology. Finally, a power management approach is proposed for hybrid operation and transition of the inverter between grid connected and standalone modes.

The outcome of the thesis has identified that the developed intelligent control approach achieves voltage and harmonic regulation efficiently. The results are verified using numerical simulations under varying load conditions and the performance parameters like stability analysis, settling time, harmonic distortion, and efficiency are evaluated and compared with conventional techniques. Further, the proposed novel transformerless inverter topology achieves improved efficiency of the pre-existing inverter and reduces the total harmonic distortion (THD) for the voltage and current outputs. For the grid integrated operation of the inverter, the proposed islanding classification approach depicted improvement in robustness and performance when tested for various islanding and non-islanding conditions. Further, the proposed controller regulated the active and reactive power and achieved low voltage ride through (LVRT) within the time limits of grid standard and maintained the operation of the PV system under its nominal capacity by avoiding unwanted grid disconnection events. Furthermore, the proposed power management approach coordinates between the boost converter of PV, bidirectional DC-DC converter of the energy storage unit, and the full-bridge inverter based on the mission profile, battery state of charge, and the load profile such that the power balance is achieved in the network. Besides, the transition between standalone (SA) and grid connected (GC) modes is achieved by operating the controller according to the power flow between the utility and the PV system. The results showed that the developed control strategy efficiently handles the power management between various sources and the load and perform a smooth transition between SA and GC modes.

Keywords: Photovoltaic Inverters, Grid Connected Control, Islanding classification, Low voltage Ride Through, Power Management system.