Abstract of Ph.D. Thesis

"Control of Unified Power Quality Conditioner for Grid Connected and Standalone Renewable Energy Interfaced AC Systems"

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ABSTRACT

This thesis presents an advanced control strategies for a unified power quality conditioner (UPQC) renewable energy-based AC systems, addressing both grid-connected and standalone operational modes. As renewable energy sources (RES) become increasingly integrated into modern power systems, maintaining power quality remains a critical challenge due to their intermittent nature. The increasing integration of renewable energy sources, such as solar photovoltaic (PV) array systems and hydro power generations, into electrical grids poses significant challenges related to power quality (PQ). The UPQC, a combination of series and shunt compensators, offers an effective solution to mitigate power quality issues such as voltage sags, harmonics, and reactive power imbalances. In grid-connected mode, the UPQC is designed to enhance power quality by compensating for grid voltages disturbances and ensuring smooth integration of RES. In standalone mode, it ensures the stability and reliability of the microgrid by maintaining voltage and frequency stability, even under variable load conditions. This research work aims to address the capability of voltage and current qualities improvement through an adaptive control algorithm, which dynamically controls the operation of the UPQC.

The control strategies integrate advanced techniques such as enhanced second-order generalized integrator (ESOGI) control method for a grid-integrated UPQC with a solar PV system. This approach eliminates the need for voltage sensors on the grid side, effectively mitigating DC offsets and estimating fundamental elements to compute reference signals. A double-stage solar PV array integrated UPQC is developed for a three-phase three wire and four-wire distribution networks. The system effectively addresses multiple PQ issues, including neutral current and harmonics, through two four-leg voltage source inverters connected via a common DC bus. Performance analysis confirms the system's capability to maintain high PQ levels under diverse operational conditions.

The thesis also investigates the applications of a damped ratio adaptive second order generalized integrator (DRASOGI) control and model predictive control (MPC) method in standalone systems driven by pico-hydro turbines to enhance the performance of the UPQC. The proposed system is validated through extensive simulation and experimental studies, demonstrating its effectiveness in improving power quality and system stability in both grid-connected and standalone modes. Experimental validation through hardware prototypes further confirms the system's ability to follow the IEEE-519, IEEE-1159, IEC 61727 standards. The results indicate that proposed UPQC control approach provides a reliable and efficient solution for mitigating power quality issues in renewable energy-based AC systems, making it a valuable contribution to the development of more resilient and sustainable power systems.