Abstract

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Photovoltaic System Design and Control

Modern industrial society, increasing energy demands, and environmental issues have increased the need for new and clean renewable energy resources, among which photovoltaic energy has gained considerable interest. For best energy utilization, photovoltaic maximum power tracking and grid-integration aspects should be addressed. Generally, variable-step, incremental conductance maximum power point tracking technique has the merits of good tracking accuracy and fast convergence speed. Yet, the division processes in its algorithm create a computational burden. Also the conventional variable step-size encounters steady-state power oscillation and dynamic problems, especially under sudden irradiance changes. In this thesis, a division-free incremental conductance algorithm is proposed for photovoltaic maximum power tracking. It features a modified variable step-size and a direct converter control scheme. The proposed tracking technique does not only have the merits of superior steady-state and transient performance but also offers simple implementation and control. Thus, it can be practically implemented using low-cost microcontrollers, reducing overall system cost. Grid integration of photovoltaic systems using power electronic converters that vary in configurations, control loops and mandatory measured signals are investigated. A singlephase two-stage grid-interfaced photovoltaic system is presented in this thesis. It uses a boost chopper in the first stage for maximum power tracking and an H-bridge voltage source inverter in the second stage for grid interfacing. A novel DC-link voltage sensorless control technique is proposed for this topology. It eliminates the inverter outer DC-link voltage control loop, thus reducing system size, cost and control complexity. Additionally, system dynamics are enhanced during sudden changes. Single-stage based grid-tied photovoltaic power converters receive attention due to their merits of reduced footprint and losses, but at the cost of a limited degree-of-freedom. In this thesis, a single-phase single-stage grid-tied photovoltaic system is proposed. It adopts a single transformerless current source inverter to achieve photovoltaic maximum power tacking, whilst satisfying grid interfacing requirements. A proportional-resonant controller, associated with harmonic compensator units, is proposed for the inverter in order to limit injected grid current harmonics. Thus, a lower-sized inductor can be used in the inverter DC-link which enhances efficiency without sacrificing system performance. Simulation and experimental results validate all the proposed systems.