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Design, Control and Implementation of 3.5 kW Bi-Directional Energy Harvester for Intelligent Green Energy Management System

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Abstract : Integration of distributed green renewable energy sources in addition with battery energy storage is an inevitable requirement in a smart grid environment. To achieve this, an Intelligent Green Energy Management System (i-GEMS) needs to be incorporated to ensure coordinated operation between supply and load demand based on the hierarchy of Renewable Energy Sources (RES), battery energy storage and distribution grid. A bi-directional energy harvester is an integral component facilitating Intelligent Green Energy Management System (i-GEMS) and it is required to meet the technical challenges mentioned as follows: (1) capability for bi-directional mode of operation (buck/boost) (2) reduction of circuit parasitic to suppress voltage spikes (3) converter startup problem (4) high frequency magnetics (5) higher power density (6) mode transition issues during battery charging and discharging. This paper is focused to address the above mentioned issues and targeted to design, develop and implement a bi-directional energy harvester with galvanic isolation. In this work, the hardware architecture for bi-directional energy harvester rated 3.5 kW is developed with Isolated Full Bridge Boost Converter (IFBBC) as well as Dual Active Bridge (DAB) Converter configuration using modular power electronics hardware which is identical for both solar PV array and battery energy storage. In IFBBC converter, the current fed full bridge circuit is enabled and voltage fed full bridge circuit is disabled through Pulse Width Modulation (PWM) pulses for boost mode of operation and vice-versa for buck mode of operation. In DAB converter, all the switches are in active state so as to adjust the phase shift angle between primary full bridge and secondary full bridge which in turn decides the power flow directions depending on modes (boost/buck) of operation. Here, the control algorithm is developed to ensure the regulation of the common DC link voltage and maximum power extraction from the renewable energy sources depending on the selected mode (buck/boost) of operation. The circuit analysis and simulation study are conducted using PSIM 9.0 in three scenarios which are - 1.IFBBC with passive clamp, 2. IFBBC with active clamp, 3. DAB converter. In this work, a common hardware prototype for bi-directional energy harvester with 3.5 kW rating is built for IFBBC and DAB converter configurations. The power circuit is equipped with right choice of MOSFETs, gate drivers with galvanic isolation, high frequency transformer, filter capacitors, and filter boost inductor. The experiment was conducted for IFBBC converter with passive clamp under boost mode and the prototype confirmed the simulation results showing the measured efficiency as 88% at 2.5 kW output power. The digital controller hardware platform is developed using floating point microcontroller TMS320F2806x from Texas Instruments. The firmware governing the operation of the bi-directional energy harvester is written in C language and developed using code composer studio. The comprehensive analyses of the power circuit design, control strategy for battery charging/discharging under buck/boost modes and comparative performance evaluation using simulation and experimental results will be presented.

Keywords : bi-directional energy harvester, dual active bridge, isolated full bridge boost converter, intelligent green energy management system, maximum power point tracking, renewable energy sources
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