Wind turbine for solar system

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In this paper, a topology of a multi-input renewable energy system, including a PV system, a wind turbine generator, and a battery for supplying a grid-connected load, is presented. The system utilizes a multi-winding transformer to integrate the renewable energies and transfer it to the load or battery. The PV, wind turbine, and battery are linked to the transformer through a full bridge dc-ac converter and their energy supplied to a grid-connected single-phase inverter and loads. A phase-shift control technique is employed to control the power flow between the sources and loads and the grid. To control the power flow, simple PI controllers have been used. The operation details and control techniques of the system are presented and also validated by using numerical simulations.

Topology of the proposed hybrid renewable energy system including the multi-port phase-shift converter and grid-connected inverter

Structure of QAB converter as a part of the proposed hybrid renewable energy system

Simplified model of the QAB converter by simplifying the multi-winding transformer using cantilever model

Magnetizing inductance is neglected as it has no influence on the power flow. As can be seen, the resultant structure shows that the four-port converter topology can be decomposed in several dual active bridge converter. Therefore, the total power flows from each converter port can be obtained by summation of power flows to each individual port, referring to the simplified model in Fig. 3. The power flow equations in the proposed converter according to Fig. 3 can be written as

The waveforms of voltage and current of port one and four in the transformer winding for three cases of a v1 is lagging v4, b v1 and v2 are in phase and c v1 is leading v2 where duty cycle of v1 (D1) and phase-shift angle are presented

where Vi is the dc voltage in port i, Vj the dc voltage in port j, o the frequency of waveforms, Lij the summation of leakage inductance in windings i and j and D duty cycle in the waveform of port i as presented in Fig. 4a. The amount of leakage inductance in each port depends on the maximum power generated or is planned to be transferred from each of the PV, battery or wind turbine ports to the inverter port. Therefore, the range of power in each port should be taken into account. On the other hand, the power flow between the two ports such as PV or wind turbine to the battery port where both waveforms have duty cycle controlled can be presented as

where Di and Dj are the duty ratio of vi and vj and vi/Di = vj/nDj and n = Nj/Ni. The waveforms frequency is kept constant and the leakage inductance of the transformer windings are utilized as the main energy transfer elements [16, 42]. A dc conversion ratio can be defined between the converter ports as where Kp and Ki are the proportional and integral control coefficients and are set as 0.01 and 0.56, respectively. The power flow control in each converter port can be designed to regulate the voltage according to the provided reference signal. As voltage-type energy sources like wind turbine and PVs have a variable operating voltage, a power control strategy can be used as an equivalent of current control due to the slow change of the operating voltage of the source compared to the control bandwidth [16] and the dynamics of the power control loop is mainly determined by the port current.

The magnitude and phase Bode diagrams of the power control closed-loop transfer functions

a The control system for the grid-connected inverter and b current direction reference in the inverter output

The waveforms of the voltage and current in the multi-winding transformer a where duty cycle in both PV and wind turbine ports is not controlled and, b the duty cycle in the wind turbine port is controlled