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Control of a Three-Port Converter Based on Interleaved-Boost-Full-Bridge for Hybrid Renewable Energy Systems

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***Abstract*— Control of a three-port (TPC) converter based on interleaved-boost-full-bridge with pulse-width-modulation and phase-shift control for hybrid renewable energy systems. In the proposed topology, the switches are driven by phase-shifted PWM signals, where both phase angle and duty cycle are controlled variables. The power flow between the two inputs is controlled through the duty cycle, whereas the output voltage can be regulated effectively through the phase-shift. The primary circuit of the converter functions as a interleaved boost converter and provides a power flow path between the ports on the primary side, while the third port provides the power balance in the system ports. The full bridge three port converter is designed and simulated using MATLAB/SIMULINK. The output parameters such as output voltage was obtained.**

Keywords*—*three port converter; interleaved boost converter; phase shift and duty cycle; renewable systems;

I. Introduction

In the recent years, the use of renewable energy such as solar, wind and hydrogen are used in the industries and academia [1],[2],[3]. Due to irregular intervals of these sources the energy storage units are necessary to balance the generation and consumption in the transmission system. In transmission system having high renewable energy interconnection. The system performances like decreasing cost, isolating energy sources from load fluctuations and enhancing the system dynamics are improved by using multiple energy source hybridization. These type of application are majorly used where the average power demand is low and load dynamics relatively high [4],[5]. As a result, merging the renewable energy source elements together as a hybrid power conversion system, as well as controlling the power flows effectively has become a topic of interest.

The advance power system has a large number of distributed generation (DG) units, including both renewable and nonrenewable sources A wide spread use of renewable energy sources in distribution networks and a high penetration level will be seen in the near future. In order to fulfill aforementioned objective, many hybrid system configurations and converter topologies have been proposed [3]. For the galvanic isolation application, there are basically two categories classified as: multiple-converter conversion and multiple-port conversion [6],[7].

A full bridge TPC with duty cycle and phase-shift control derived from an interleaved boost-full-bridge (BFB) and a bridgeless boost rectifier is presented in [8]. This topology reduces the input current ripple and current stress of the input ports because of the 180° phase-shift operation of the primary switching legs. The output port regulation is achieved through the phase-shift between the primary and secondary switches. Therefore, two extra active switches in the secondary side are necessary to control the output port power flow, both with high side driver requirements, which increases the circuit complexity. Moreover, the body diode of the secondary MOSFETs operate under hard switched current conditions generating reverse recovery losses.

The main work is to design a TPC topology for hybrid renewable energy systems. The major contribution of this paper is to analyze the relation between the two control variables, phase-shift and duty cycle, and the system dynamics based on the converter small-signal model. Based on the small-signal model, the power flow control is designed and the converter is tested under various operation modes, i.e. dual input (DI) mode, dual output (DO) mode and single input single output (SISO) mode.

II. Proposed Topology

The Fig. 1 consists of two input inductors, $L1$ and $L2$, an ac inductor Lac, four power MOSFETs $M1$ ~ $M4$, and a high frequency transformer with a turn ratio of 1: n. The ac inductor is the sum of the leakage inductance and the auxiliary inductance and it is the power interface element between primary and secondary sides of the transformer. Switches $M1$, $M2$ and $M3$, $M4$ are turn on and off by using gate signal. V1 and $V2$ are the input voltages; $iL1$ and $iL2$ are named as the input inductor currents.

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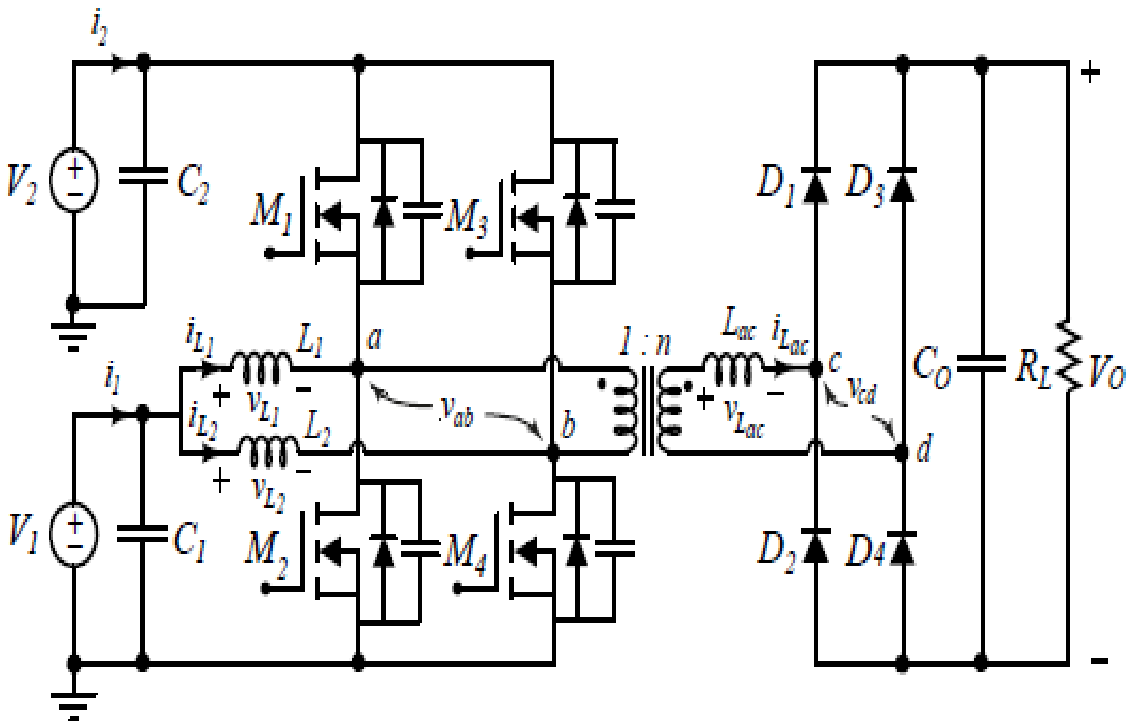

Fig1. Topology of the proposed TPC for hybrid renewable energy systems.

The bidirectional interleaved boost switching legs between the midpoints voltage is *Vab* and the secondary side winding current is *iLac*. *V*1 and *V*2 are the two inputs which is to be decouple and the output voltage can be regulate by using both the duty cycle and the phase-shift angle as the control variables. The power between the two independent sources are adjusted by using duty cycle and the output power flow is regulated by the phase shift angle between the midpoints of the full bridge.

The converter can be operated in three modes using the availability of the renewable energy source and the load through the phase shift with duty cycle control. In DI mode when the load is higher than the available power from the renewable energy source and the load gets the extra energy from the energy storage element. In DO mode the energy storage element balances the power when the power input is higher than the load power demand by storing the excess energy and in SISO mode when power transfers between the two inputs or from one of the inputs to the output port.

III. Simulation and Results

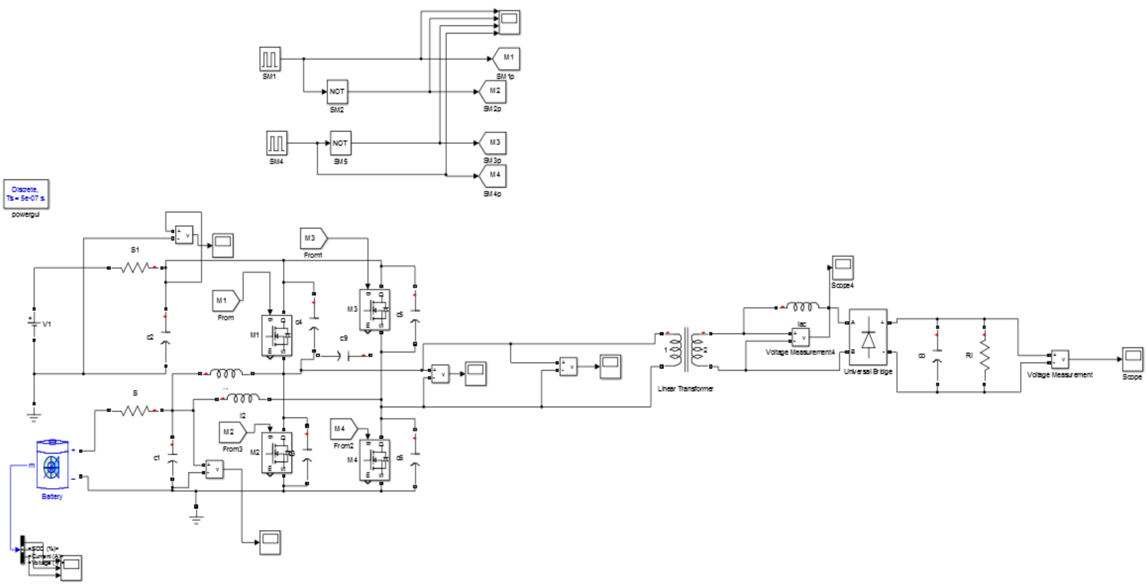

Fig 2. Simulink model of Three port converter for hybrid renewable energy systems.

Simulation of proposed TPC for hybrid renewable energy systems is carried MATLAB/Simulink.60V photovoltaic cell is given to the input of V2 and 150V battery is given to the input of V1. The input V1 is given to the interleaved boost converter and the input V2 is given to the full bridge converter. Four MOSFETS are used as switches and gating signals is given to the four MOSFETS to turning on and off the switches. The turns ratio of the transformer is 1: 6 is used. The secondary side operates as a bridgeless boost rectifier. The output port regulation is achieved through the phase-shift between the primary and secondary switches.

If the input voltage V1 is applied to the interleaved boost converter, output will be 120V and it is given to the input of the full bridge converter. If the input voltage V2 is given to the photovoltaic cell, the output of the full bridge converter will be 120V at the primary side winding. At the secondary side voltage is given to the bridge rectifier and finally at the output side 380V is obtained. Using this circuit, the three modes of operations to control the power flow among three port converters is analyzed.

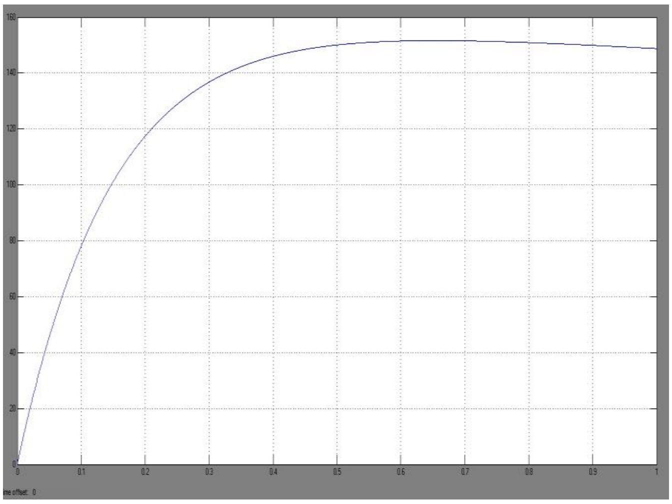

Fig 3. Input voltage V1

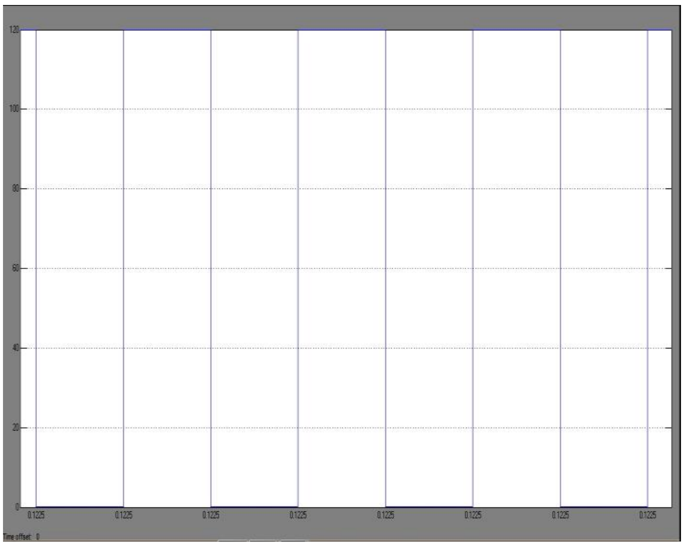

Fig 4. Output of interleaved boost converter

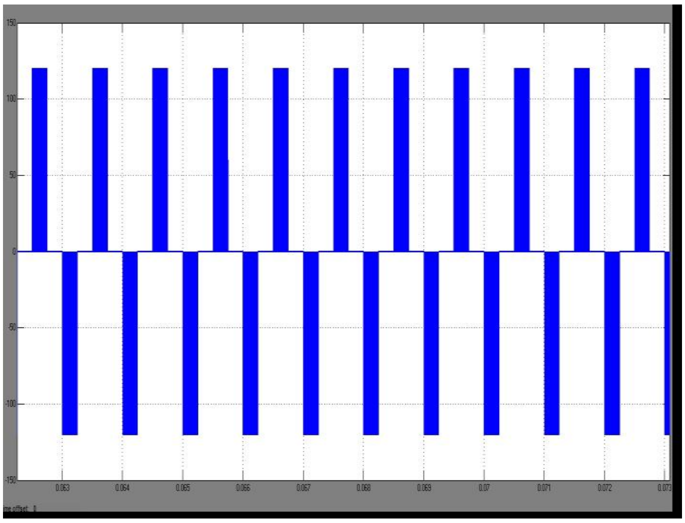

Fig 5. Voltage across the primary side of the transformer

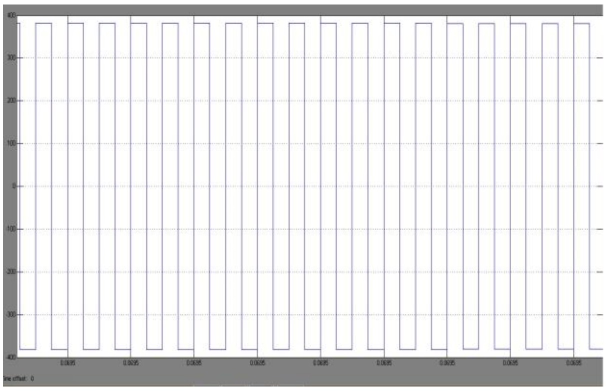

Fig 6. Voltage across the secondary side of the transformer

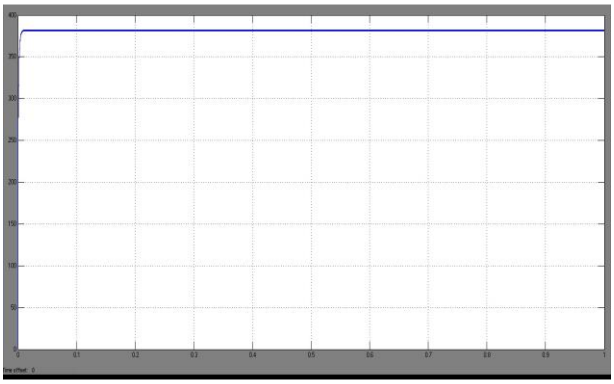

Fig 7. Output Voltage

IV. CONCULSION

In this paper, a three-port converter is interface with hybrid renewable energy systems is presented. In order to control the power flow between the different ports, a duty cycle and phase-shift control scheme is adopted. The duty cycle is used to control the power flow between the two independent sources, whereas the phase-shift angle is employed to regulate the output voltage. The advantage of the proposed topology is that it can be dynamically modeled as individual converters, which makes it possible to design a control strategy with totally uncoupled control variables. This fact makes this topology a very interesting solution in renewable energy applications where an energy storage element is required, since full reutilization of the converter primary side switches is achieved, without having a negative impact in the controllability of the converter. By selecting the renewable source and the energy storage voltages, $V1$ and $V2$, to require a duty cycle approximately to 0.5 the Phase-shift value range can be fully utilized.

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