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A New three-port Interleaved Boost Full Bridge Converter Fed Induction Motor Drive

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ABSTRACT

A systematic single-stage power conversion method is achieved through a Full Bridge Three-Port DC- DC Converter (TPC) suitable for Industrial Drive applications. In the proposed topology, the switches are driven by phase-shifted PWM signals, where both phase angle and duty cycle are the 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-side MOSFETs can achieve Zero-Voltage-Switching (ZVS) operation without additional circuitry. Additionally, due to the ac output inductor, the secondary-side diodes can operate under Zero-Current-Switching (ZCS) conditions. Here, the effective power management is done through the three modes of operation depending on the utmost due to merging of multiple energy sources. Also, in order to decouple the multi-inputs and to regulate the output voltage accurately, duty cycle of the

power switches and the phase-shift angle between the midpoints of the full

bridge are considered as decoupled control variables to allow separate controller design for the three-port converter. Simulation was carried out to validate the effectiveness of the TPC.

I. INTRODUCTION:

Sustainable energies have now become the recent trend and the driving force for almost all applications, so as to achieve environment-friendly objectives. However, they are strongly dependent on location and weather conditions, and therefore are intermittent and unpredictable. For this reason, hybridization of multiple energy sources with energy storage units are needed in order to balance the electricity generation and consumption within a power system having a high renewable energy penetration and also in order to ensure

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reliable and constant power to the load, especially for industrial drive applications where safety margins are the utmost due to merging of multiple energy sources to provide power flows effectively.

To combine several input power sources, two approaches are usually adopted: multiple converter systems and multi-port converter. The advantages of multi-port converter over multiple-converters like reduced component count, enhanced power density, compactness and centralized control. Many topologies are proposed and they can be broadly classified into three groups, non-isolated, fully-isolated and partially-isolated multi-port topologies. Among these, fully-isolated multiple-port converter adopts the magnetic coupling method, where various input power sources can be coupled with transformer windings or independent transformers [1], [2]. Thus, it has been increasingly needed in many applications such as hybrid electric vehicles, fuel cell systems, UPS and photovoltaic systems due to the use of high frequency transformer and galvanic isolation. Therefore, the multi-port converter can be constructed from the basic high frequency switching cells, including the half-bridge (HB), full-bridge (FB), boost-half-bridge (BHB) and their combinations, according to the system constraints imposed by the features of the input power sources. Based upon this principle, a number of three-port (TPC) bidirectional dc-dc converters, which can fully isolate the various power ports and control the power flows into/out of each port [3].

The proposed scheme introduced in this paper is suited for Industrial Drive application area. This is derived by replacing the active clamp capacitor in the ZVS circuit with the second voltage source in the ZVS HB inductive dc-dc converter [4], [5]. The rectifier diodes achieve zero-current switching (ZCS) at turn-off avoiding reverse recovery losses. Additionally, the voltage across the diodes is inherently clamped by the output capacitor C_o, therefore, voltage rings caused by the stray inductance can be eliminated. Moreover, this converter is superior to its LLC counterparts due to lower complexity of the modulation and control [6]. The operating principleof the proposed system and simulation results are provided to validate the proposed scheme.

II. PROPOSED SYSTEM

The design, modeling and control of a three-port (TPC) isolated dc-dc 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 side MOSFETs can achieve zero-voltage switching (ZVS) operation without additional circuitry. Additionally, due to the ac output inductor, the secondary side diodes can operate under zero current switching (ZCS) conditions.

III.THREE PORT CONVERTER TOPOLOGY

A three-port energy management system includes a primary source and storage, and. single-stage power conversion between any two of the three ports is possible. Having the two energy inputs, the instantaneous power can be redistributed in the system in a controlled manner, which results in improvement of system dynamics and reliability. Another advantage of using a three-port system is that the primary source only needs to be sized according to the average power consumed by the load, not necessarily to the peak power. This operation is economically beneficial since per watt cost of the primary source is usually high, and thus it makes sense to operate the primary source at the maximum power.

IV.PRINCIPLE OF OPERATION:

The TPC topology is based on the integration of a Full Bridge switching cell and a bidirectional converter, combined with a high frequency transformer, an ac inductor as the power interface between the primary and the secondary ports, and a bridge rectifier. It has phase-shifted PWM Technique and interleaved boost converter.

A. Circuit Description

Fig. 1 shows the schematic of the proposed TPC topology, where the renewable energy source is connected to the input port V_1, the energy storage element to the bidirectional port V_2, and the output port interfaces with a dc-ac

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inverter connected to the grid.

It consists of two input inductors, L_1 and L_2, an ac inductor L_{ac}, four power MOSFETs $M_1 \sim M_4$, and a high frequency transformer with a turn ratio of 1: n. The ac inductor, which is the sum of the leakage inductance and the auxiliary inductance, is the power interface element between primaryand secondary sides of the transformer. Switches M_1, M_2 and M_3, M_4 are driven with complementary gate signals with a deadband. i_{L1} and i_{L2} are defined as the input inductor currents; V_{ab} is the voltage between the midpoints of the bidirectional interleaved boost switching legs, and i_{Lac} is the current of the secondary side winding [8], [10].

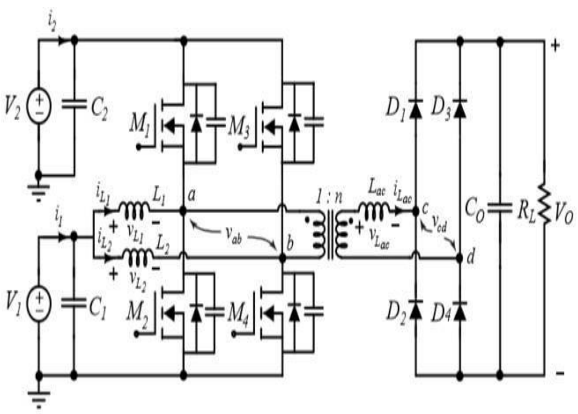

Fig. 1 Topology of the proposed TPC

In order to decouple the two inputs, V_1 and V_2, and regulate the output voltage accurately, both the duty cycle (D) and the phase-shift angle (Φ) are adopted as the control variables simultaneously. The duty cycle of the power switches is used to adjust the power among the two independent sources, and the phase-shift angle between the midpoints of the full bridge is employed to regulate the power flow to the output port.

Duty cycle plus phase-shift control mode:

Switches M_1 and M_2 are turned on and both of the inputs can deliver power to the load. In order to decouple the two inputs effectively as well as regulate the output voltage accurately, both the duty cycle and the phase-shift angle are used as the control variable. Therefore, the power flowing between the inputs and the power delivered to the load are controlled by D and Φ, respectively (Fig. 2).

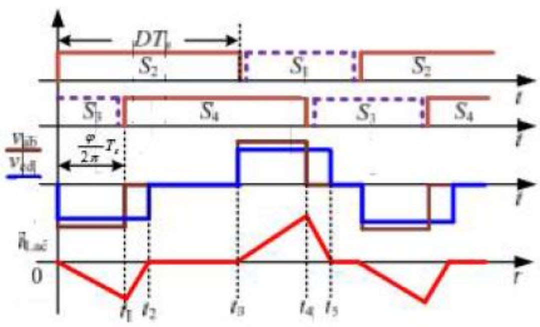

Fig.2 Operating waveforms in duty

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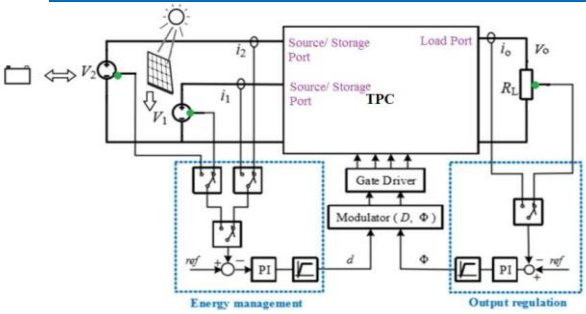

cycle plus phase shift control Completely demagnetized operation is the preferred mode since the output port voltage only depends on the phase-shift value, as shown in (1), for $\Phi < \min\ [D,\ (1-D)]$. Therefore, in completely demagnetized operation mode, the energy transferred to the output does not depend on the converter duty cycle [9].

$$V_o = \frac{nV_2}{k} . \Phi \left(-\Phi + \sqrt{\Phi^2 + 2k} \right) \quad (1)$$

Where,

$$k = \frac{2L_{ac}}{R_L T}$$

The relationship between V1 and V2is obtained as

$$V_2 = \frac{V_1}{(1 - D)}$$

Therefore, in the completely demagnetized operating mode the power flow from V_1 and V_2 to the output port will be entirely controlled by Φ.

V.CONTROL METHOD

The block diagram of the proposed system with power flow regulation and feedback regulators is as shown in Fig.3.

Fig.3 Block diagram of Three-port converter with energy management and output regulation

There are two dc sources, which are connected to TPC and in turn to the load. The TPC converts dc to ac and step-up using transformer and again convert it ac to dc using rectifier. The output power is supply to the DC load. Also soft switching techniques ZVS and ZCS conditions are achieved at the primary and secondary sides of transformer operation without additional circuitry. Four different controllers are designed for the energy management of the renewable power system. At the renewable energy port, either voltage or current can be selected to be regulated depending on the type of the selected renewable energy source. At the energy storage port, constant voltage (CV) and constant current (CI) regulators are implemented, and at the output port,

voltage regulation is performed. In order

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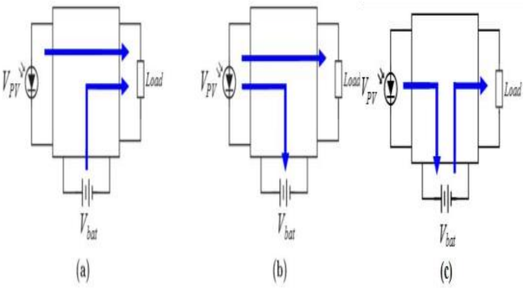
to control the power among the two inputs and the load and thereby balance the power between the different energy sources, two control loops are active at



any time. The output port regulation loop is employed to regulate the load voltage by the phase-shift angle Φ. On the other hand, assuming V_1 is the renewable energy source such as fuel cells or photovoltaic, the voltage or current is controlled by the duty cycle D. The power from the other input V_2 as an energy storage unit, for example a battery or a super-capacitor is controlled depending on the power at the renewable energy source and the output load power demand.

Through the phase-shift with duty cycle control, and according to the availability of the renewable energy source and the load demand, the proposed converter can operate in various operating modes (Fig. 4): Dual Input (DI) Mode: When the load demand is higher than the available power from the renewable energy source and the energy storage element delivers the extra energy to the load. Dual Output (DO) Mode: When the input power is higher than the load power demand and the energy storage element balances the power by storing the excess energy. Single Input Single Output (SISO) Mode: When power transfers between the two inputs or from one of the inputs to the output port.

Fig. 4 Operating modes of the proposed converter (a) DI mode (b) DO mode (c) SISO mode

The state-of-charge (SOC) of the energy storage element is always being monitored and when it is above or below its recommended values, the system is set to control the bidirectional port by performing CV or CI control, until the energy storage element SOC allows for a change in the operation mode.

VI.SIMULATION TEST RESULTS (MATLAB/ SIMULINK)

The feasibility of the proposed system is investigated for Industrial Motor Drive application, which is mostly used for obtaining a discrete precise positioning of objects with high resolution. For such an application, Induction motors can be used to attain it which has the advantages of providing precise positioning with each command electrical pulse input, speed control due to the precise increments of movement also allows excellent control of rotational speed, and maximum torque at low speeds, so they are a good choice for applications requiring low speed with high precision.

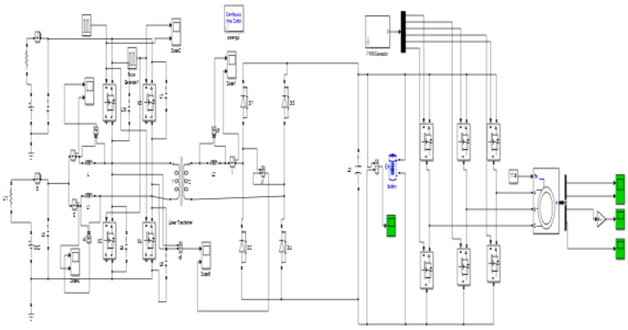


Fig 5 Proposed Simulation Circuit

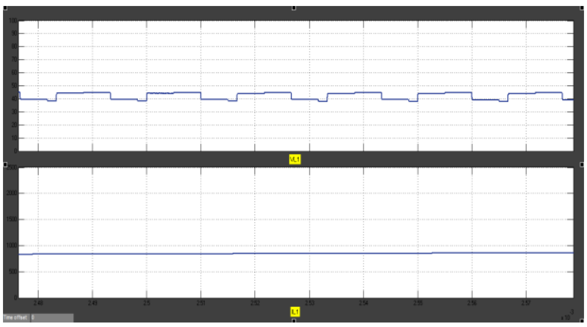


Fig 6 L1 Voltage & Current

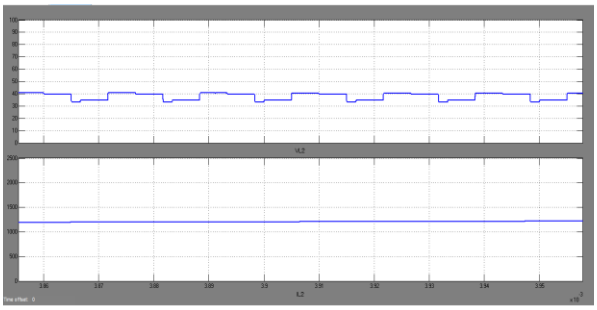


Fig 7 L2 Voltage & Current

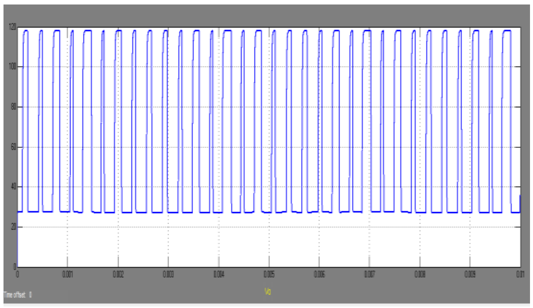


Fig 8 output Voltage

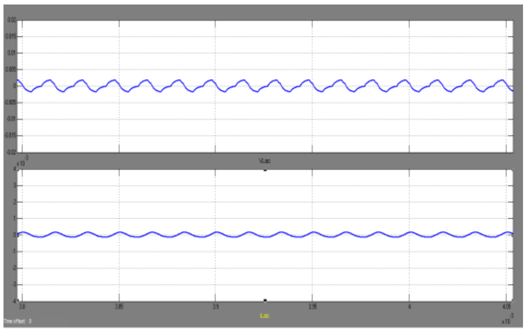


Fig 9 Lac Voltage & Current

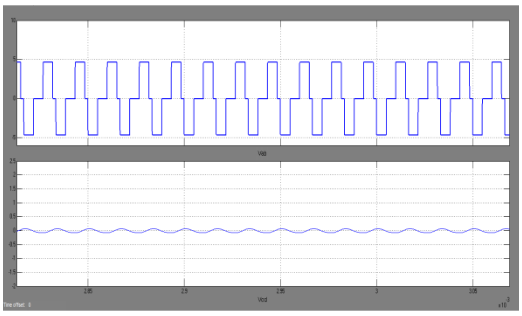


Fig 10 Voltage Vab,Vcd

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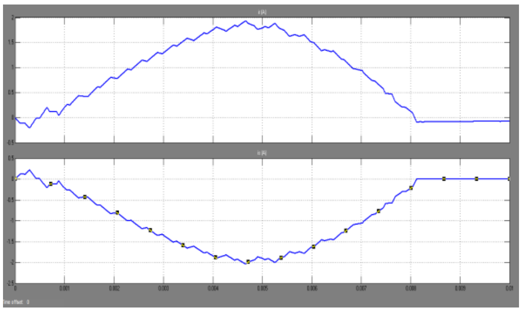

Fig 11 Ir ,Is Current

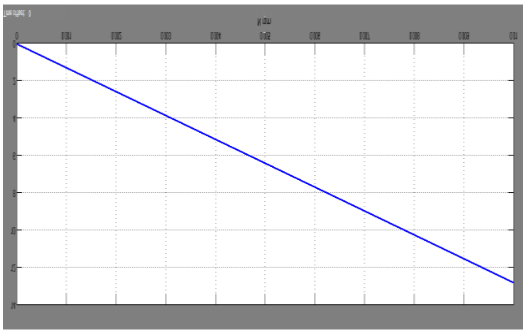

Fig 12 Speed

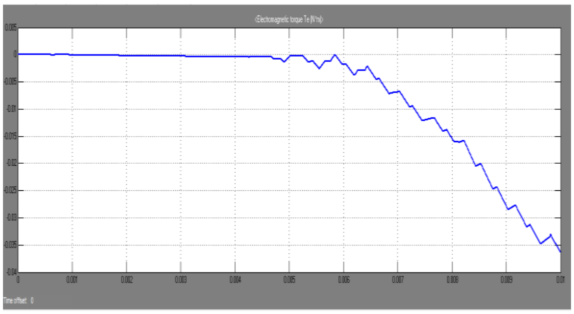

Fig 13 Torque

CONCLUSION

A Three port isolated dc-dc converter suitable for industrial drive application is proposed based on duty cycle and phase-shift control for hybrid renewable energy systems with energy storage unit as renewable energy alone is less efficient due to its intermittent nature. A detailed simulation for the proposed TPC with fixed input voltages in closed loop condition with induction motor load was obtained. The main objective of the proposed system is to investigate its feasibility in orbital satellite operation which is mainly used for precise positioning since safety margins are utmost in order to provide power flow effectively. The motor performance characteristics comprising theta showing the accuracy of positioning were obtained with a load torque 0Nm and zero voltage switching and zero current switching techniques were also evaluated without any additional circuitry.

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