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Multi-Port DC-DC Converter for PFC Four-Switch Inverter-Based Induction Motor Drive

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Abstract: Single source boost converter fed drives may not be able to power continuously motor drive. Since PV power is not available at all times, one or more sources are proposed to reduce the effect of this condition. This paper presents a hybrid photovoltaic and permanent magnet synchronous generator (PMSG) wind-based multi-port dc-dc converter for a direct torque control (DTC) based induction motor drive. The proposed converter for PMSG wind ensures power factor correction to eliminate reactive power of the system, which improves the system's power quality. Further, the proposed drive shows lesser harmonics in the output, verified by measuring total harmonics distortion of drive current, THD is less in the range of 2%. Since more than one source is used to propose a multi-port converter that continuously supplies reliable power to a four-switch three-phase inverter. Then the hysteresis control also utilized to reduce the total harmonic distortion (THD %) values. The proposed multi-port converter-based four-switch three-phase inverter drive is simulated in MATLAB/Simulink environment. Results are presented to verify the merits of the proposed motor drive.

Keywords: Four Switch Three Phase Inverter, Direct Torque Control, Multiport DC-DC Converter, Power Factor Correction, and Induction Motor Drive.

1. Introduction

The multi-port power electronics converter has received particular attention to the four-switch three-phase inverter (FSTPI) drive. The proposed FSTPI technique reduces two main switches on one leg of the present six switches three-phase inverter (SSTPI) controlled by a modified Direct Torque Control (DTC) with the fuzzy logic controller. A multi-port power electronic converter with one or more sources, such as solar with maximum power point tracking based boost converter and PMSG wind-based three-phase single switch power-factor-correction boost rectifier, can reduce total harmonic distortion (THD).Literature [1] proposed a power management system using a multi-port dc-dc converter for renewable energy applications. It is a special converter which allocates power according to load, keeping available energy from PV and wind.[3] Presents a multi-port dc-dc converter, including hybrid power sources like PV, wind, and energy storage devices like a battery. Reference [4] proposed induction motor drive based on hybrid renewable energy resources using multi-port dc-dc converter. The multi-port DC-DC converter includes a DC-DC converter and a DC-AC inverter, in addition to the energy storage unit, and the proposed circuit includes many renewable energy sources through the incorporation of renewable energy sources [5]. When sources that have a statistical tendency to cancel each other out are employed, the impact of the intermittency can be considerably minimized [6].

The two-quadrant inverter topology based on multi-port DC-DC converters prohibits current passage from the AC to the DC. This step prohibits currents from passing across ports. Each two-quadrant inverter is programmed to extract the most incredible amount of electricity from its linked PV module. The suggested multi-port converter's research and operating scenarios are addressed [7]. Reduced size, cheaper cost, more efficiency due to a single power stage, faster reaction, and compact, centralized control benefit the converter [8]. The use of a four-switch three-phase inverter lowers the cost of the inverter, switching inefficiencies, the complication of the control algorithms, and the interface circuits required to provide six pulse width modulation (PWM) logic signals [9]. Multi-input converters (MICs) are highly regarded for integrating separate voltage sources in electric vehicles (EVs) and grid systems.

Consequently, multi-output DC-DC converters have sparked considerable interest in wearable electronics [10]. Because of the abrupt changes in load or speed circumstances, induction motor (IM) drives, notably three-phase IMs, are a nonlinear system that is difficult to describe theoretically. As a result, an improved controller is required to improve IM performance. Because of their simplicity and versatility, fuzzy logic controllers (FLC) are becoming increasingly prominent in the design of complicated IM control systems [11]. An accumulated current mode control technique is used to regulate the PFC converter's input current and control the DC-DC converters [12]. A number of solid-state DC-DC converters are proposed to enhance power quality in Power Factor Correction (PFC). These converters are designed to reduce Total Harmonic Distortion (THD) at both the input and output sides and synchronize the DC voltage in DC-DC converters that represent both Uni/Bi-Directional power flow [13]. Induction motors may self-start due to the rotor winding flux and the rotating magnetic field flux, creating a high rotor current when torque is increased. The architecture of a soft starter fed induction motor that regulated the applied voltage was given in this work [14]. Power electronics is approaching a special type of industrialization due to its relevance in power generation, aerospace, vehicle, energy storage, military, utility systems, traction, portable electronic devices, and systems integration and energy efficiency systems. According to recent innovations, power electronics will play an important role in improving energy efficiency, addressing global climate change concerns, and contributing to a more prosperous approach. [15].

This article describes the multi-port like solar and wind with MPPT technique. The converter and inverter are proceeded to convert the signal to the corresponding loads, the induction motor. This can be elaborately explained in further articles.

2. Proposed Topology

With a multi-port converter system, the proposed drive can operate with the presence of either input. A new multi-port dc-dc converter is implemented for DTC-based induction motor drive. DTC modified direct torque control algorithm is used to achieve smooth speed control with excellent torque characteristics. Figure 1 Shows an overall block diagram of proposed multi-port dc-dc converter fed induction motor drive. PV modeled using its single diode equivalent circuit and mathematical model of its characteristic equations. A permanent magnet synchronous generator-based wind energy system is used as one more input to the multi-port system.

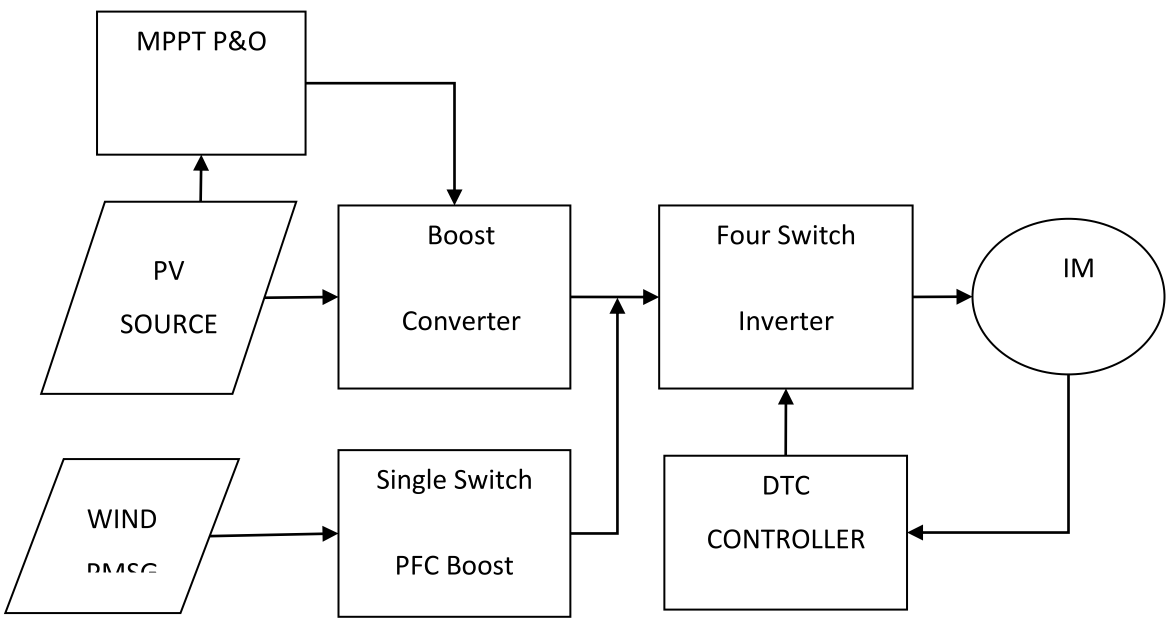

Figure 1: Block Diagram of Proposed multi-port converter fed Induction motor drive

On the wind side, a power factor corrected single switch three-phase boost rectifier is introduced. The inverter part of the drive is reduced as a four-switch three-phase inverter, which can be utilized to perform as same as a conventional six switch three-phase inverter.

DTC controller: DTC is an improved AC drive control technique in which inverter switching regulates the motor variables flux and torque directly. Motor current and voltage are the measured input values to the DTC control. The voltage is determined by the DC-bus voltage and the position of the inverter switches. Every 25 microseconds, the voltage and current signals are fed into an accurate motor model, which generates a precise value of stator flux and torque. Two-level motor torque and flux comparators compare real data to reference values generated by torque and flux reference controllers. These two-level controllers' outputs are updated every 25 microseconds and indicate whether the torque or flux must be adjusted.The switching logic immediately finds the optimal inverter switch locations based on the outputs of the two-level controllers. As a result, each voltage pulse is determined independently at the "atomic level." The position of the inverter switches determines the motor voltage and current, which impact the motor torque and flux, and the control loop is closed.

3. Simulation Results and Discussion

Figure 2 shows the results of the suggested multi-port solar and wind-based DTC induction drive, which was developed in the MATLAB/Simulink platform. The simulation is designed using Simscape, whereas the solar PV and wind is a main source with maximum power point tracking algorithm to extract maximum power from the sources. Then the solar PV is connected to the boost converter to step up the voltage. In boost converter the MOSFET is used as a switch. Then the switch is controlled by MPPT algorithm of P&O algorithm.

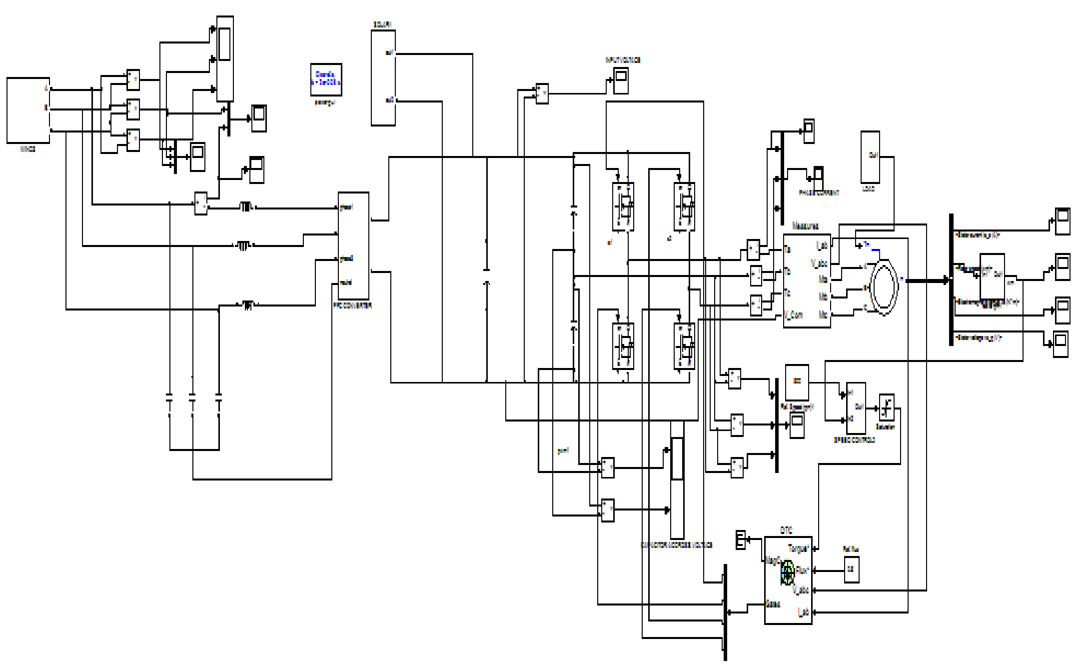

Figure 2: Simulation implementation of the proposed circuit

Then the wind system is designed with PMSG is used in variable wind speed generator. In wind systems there is a three blades which captures the kinetic energy coupled to a generator. Mainly, gearbox is used to transform the slower to higher of wind turbine rotation speed on generator side. This produces the output, which is maintained by DTC controller.

Three phase diode rectifier is connected to three phase output terminals of PMSG. Rectifier converts the alternating current (AC) into direct current (DC).

Where as, the simulation parameters are enlisted in Table 1.

Table 1: Simulation parameters

Motor Parameters	
Resistance of the Stator Rs	0.09961 Ω
Inductance of the Stator Ls	0.000867 H
Resistance of the Rotor Rr	0.05837 Ω
Inductance of the Rotor Lr	0.03039 H
Mutual Inductance Lm	0.000867 H
Inertia J	0.4
Pole pairs	2

This diagram depicts the simulation-implemented circuit of the proposed converter and drive (Figure 3). This circuit is a PFC single switch boost rectifier circuit used for wind PMSG.

Furthermore, innovative PFC control approaches have been devised, driving the manufacture of commercial integrated circuits to implement them. Sinusoidal currents in the switch-mode front-end stage converters. Boost converters that operate on a constant current mode have grown in popularity as a result of reduced levels of electromagnetic interference are caused by it utilization.

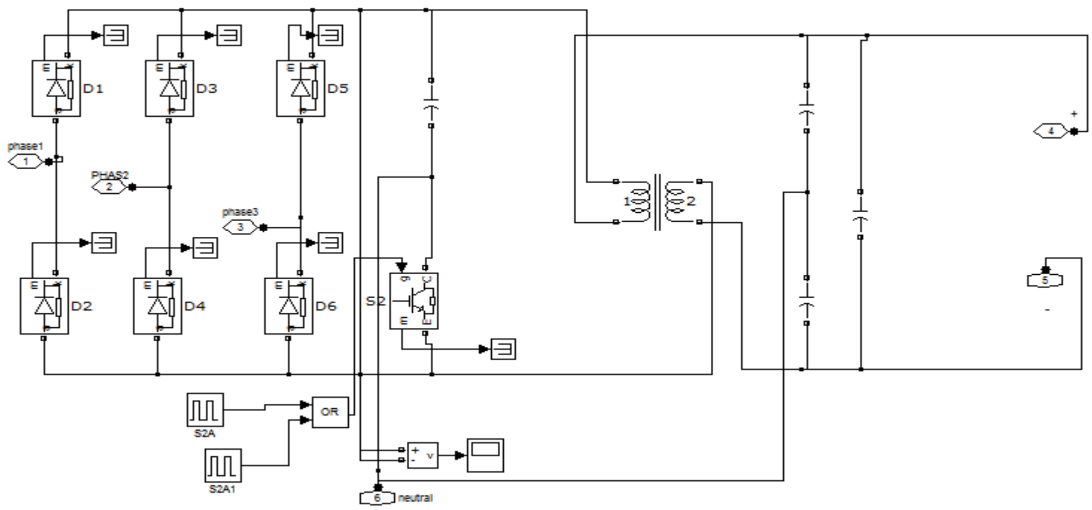

Figure 3: Circuit Diagram of PFC single switch-based boost rectifier

Using several dedicated control approaches, the boost architecture is fairly simple and enables for low-distorted input currents with almost unity power factor. Hysteresis control is a common technique.

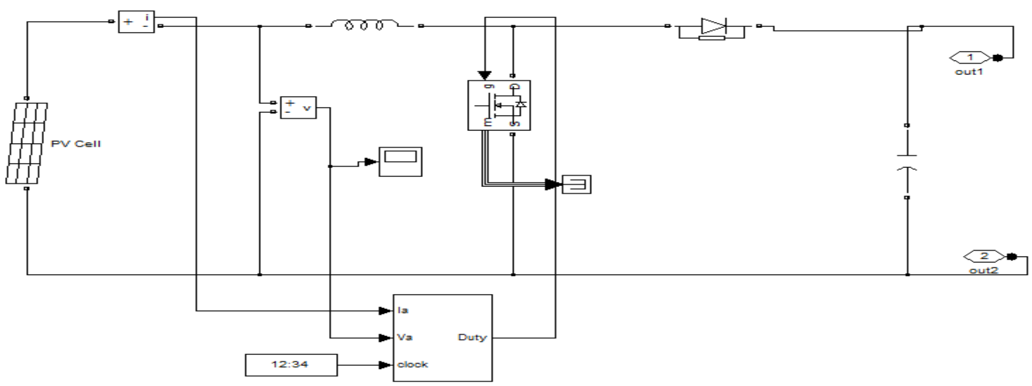

Figure 4: PV DC-DC boost converter

Figure 4 illustrates that the implemented boost converter circuit schematic for solar PV. The solar PV is designed with DC-DC boost converter to step up the solar PV voltage. This can be controlled by MPPT technique and the controller can regulate the pulse of MOSFET.

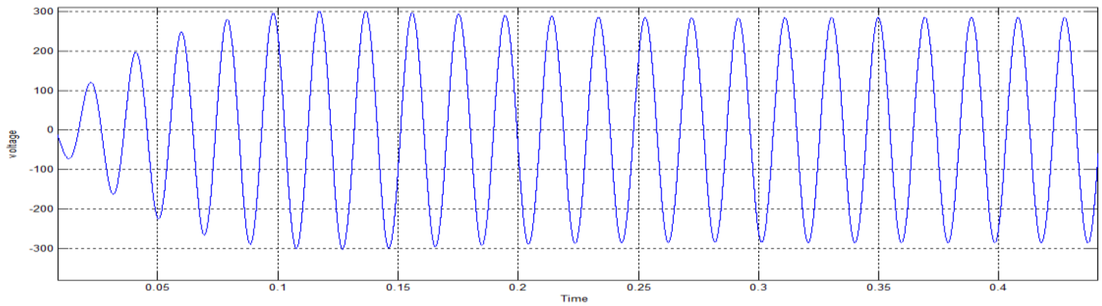

Figure 5: Response of PMSG wind

Figure 5 shows the PMSG wind response, the wind system's output voltage is 300V. The variable wind speed generator system can cause initial fluctuation then gradually stabilize the voltage at 0.1 sec.

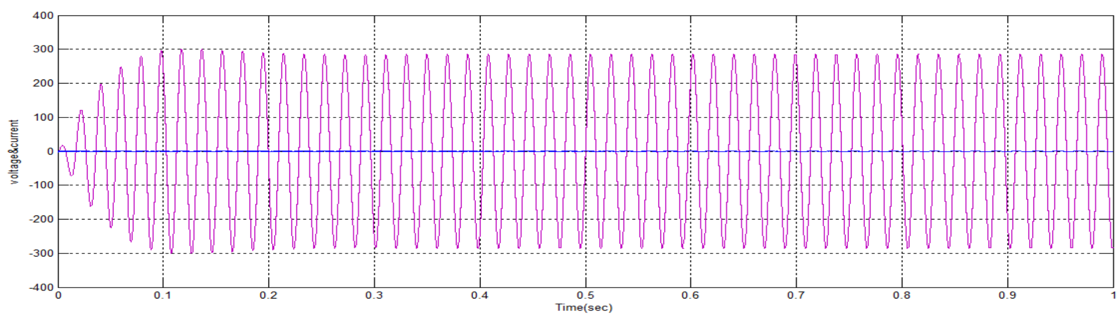

Figure 6: PFC output shows voltage and current in phase

Figure 6 shows the performance of proposed drive speed characteristics, power factor correction performance. The voltage is 300V and current is in phase (0A).

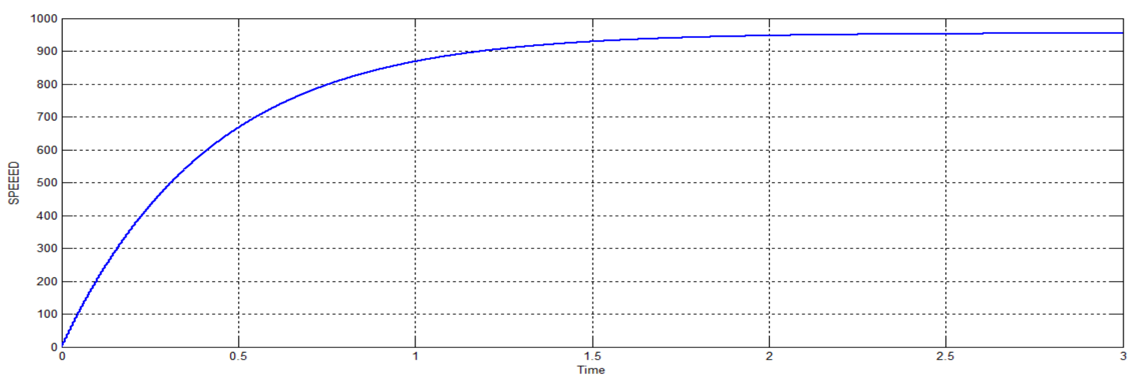

Figure 7: Speed performance of proposed IM drive

Figure 7 represents that the speed performance of the induction motor, this IM can be connected as the load. The rotation of the motor can be drive by the source, which is a converter to achieve high gain voltage, then it connects to the proposed inverter, then the supply can be attained to rotate an IM drive. Hence, the induction motor can rotate at 950 rpm.

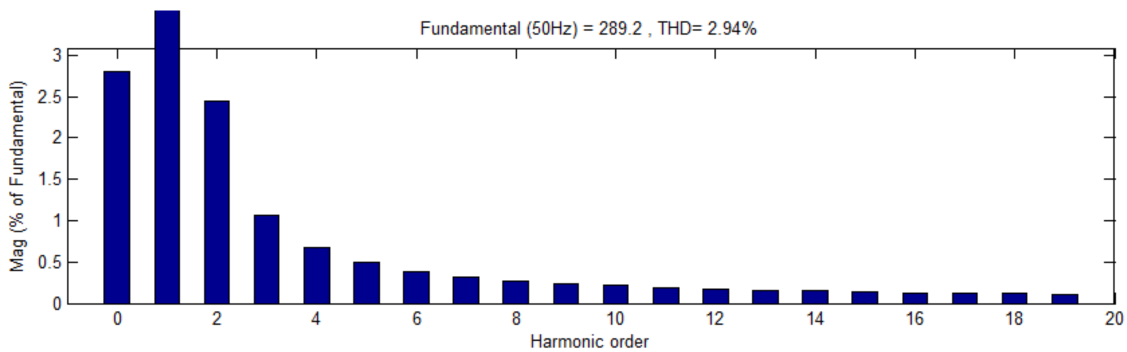

Figure 8: THD of the proposed system

Figure 8 illustrates that the THD of the overall proposed system, which is 2.94%. The THD shows that the system work at stable condition. According to IEEE standards the THD limitation is below 5%.

4. Conclusion

The multi-port, a multi-port converter, is used to provide the many input sources to the system, likea photovoltaic boost converter with a maximum power point tracking algorithm and PMSG wind energy. The wind energy system has asingle switch power factor corrected boost rectifier that has absorbed special attention in the four-switch three-phase inverter (FSTPI) drives. The proposed FSTPI and the control strategy of novel Direct Torque Control with a fuzzy logic controller are used to eliminate additional two switches of the conventional six switches three-phase inverter (SSTPI) and achieve active speed with reduced cost and system of the drive.The proposed drive shows lesser harmonics in the output, which is verified by measuring total harmonics distortion of drive current. THD is less in the range of 2%.The designed four-switch three-phase inverter drive is tested in the MATLAB/Simulink environment, and the results are provided to validate the effectiveness of the suggested drive.

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