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A flexible Dual Winding Impedance Source Inverter for Renewable Energy Systems and Electric Vehicles

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Abstract: Inverters are used in a large number of power applications, the function of a T-shaped Impedance Source Inverter (ZSI)that we modelled is to convert DC power to AC power and buck-boost operation in a single stage. The T-shaped ZSI consists consist of T-shaped Dual Winding transformer and a capacitor connected such that a T-shape is formed, Hence the name T-shape ZSI has arrived. The simulation analysis of T-shaped ZSI carried out using MATLAB/Simulink and National Instruments Multisim. T-Source inverter has the Grid tie applications in hybrid Solar-Wind Power Systems and Electric Vehicle drives.

Keywords- T-shaped ZSI, Dual Winding ZSI, Buck-Boost DC-AC Converter, Renewable Energy Systems, E-Vehicles, Microcontrollers.

1. INTRODUCTION

The function of an inverter is to change a DC input to AC output of desired magnitude and frequency. By varying input DC voltage and maintaining the gain of the inverter constant can obtain a variable output voltage. Voltage source DC-to-AC inverters are desired to accept DC voltage source as input and produce either Single phase or Three phase Sinusoidal output voltage at a low frequency .These AC-to-DC inverters can make a smooth transition into the rectification mode, where the flow of power reverses to be from the AC side to the DC side Impedance Source (Z - Source) Inverter employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, Thus, providing unique features that cannot be obtained in the Conventional voltage-source (or voltage-fed) and current source (or current fed) inverters where capacitors and inductors are used Z - Source converter overcomes the conceptual and theoretical barriers and limitation of the Voltage Source Inverter (VSI) and Current Source Inverter (CSI) provides a novel power concept.
The T-source inverter (TSI) is one modified form of the basic ZSI topology, which is achieved by reducing the size of the Z-network. The two inductors are built together on one core to form a coupled inductor (or transformer) with low leakage inductance. Instead of having two capacitors, only one capacitor is used in the TSI.

2. METHODOLOGY

Magnetically coupled inductors and transformers find a niche in impedance networks to improve the voltage boost capability, as well as the modulation index. In addition, they reduce the number of passive components needed in the network, which improves the power density and reduces the cost of the system. The T-source inverter (TSI) is one modified form of the basic ZSI topology, which is achieved by reducing the size of the Z-network. The two inductors are built together on one core to form a coupled inductor (or transformer) with low leakage inductance. Instead of having two capacitors, only one capacitor is used in the TSI. In addition, the TSI has a common dc rail used between the dc source and the inverter bridges.

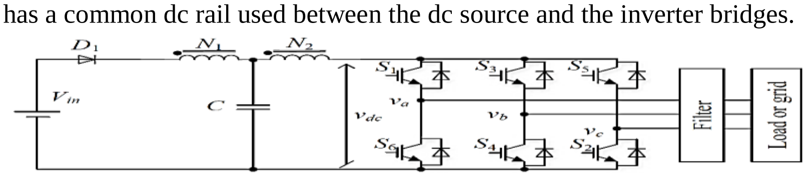

Fig. 2.1 Topology of T-Source Inverter

Furthermore, the most significant advantage of the TSI is the extended possibility of manipulation of inverter output voltage and ST duty ratio using a transformer turns ratio greater than one and reducing the voltage stress on the inverter switches. Figure 2.1 shows the topology of TSI, while the operation modes of TSI are displayed in Fig. 2.2.

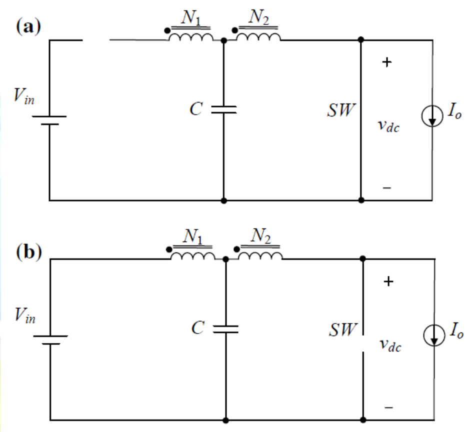

Fig. 2.2 Operation Mode of T-Source Inverter

I. Shoot Through State

II. Non-Shoot Through State

Similarly, with the z-source inverter (ZSI), the operation modes of TSI are also divided into shoot-through (ST) state and non-shoot-through (NST) state [1] . The TSI governing equations can be developed for the Fig. 2.2 using Kirchhoff's laws and voltage averaging. The average voltage through the coupled inductances should be equal to zero for the switching time period Ts. Both the capacitor voltage VC and dc-link voltage vdc are functions of the shoot-through duty ratio d = T0/Ts. Then the voltage across capacitor can be expressed as

$$V_C = \frac{1-d}{1-Kd} V_{\text{in}}$$

….. Eqn. (2.1)

where the winding factor K = (N1 + N2)/N2, and d satisfies a condition d <1/K. Hence, the maximum value of d for T-source inverter with K > 2 is smaller than for the ZSI and quasi-Z-source inverter (QZSI). From Fig. (2.2) and from (2.1), the amplitude Vdc of the dc-link voltage vdc during NST operational state can be derived as

$$V_{\text{dc}} = \frac{1}{1-Kd} V_{\text{in}}$$

….. Eqn. (2.2)

III. MODELLING OF RENEWABLE ENERGY SYSTEMS USING MATLAB/SIMULINK

The combination of renewable energy sources, wind & solar are used for generating power called as wind solar hybrid system [2]. This system is designed using the solar panels and small wind turbines generators for generating electricity. Wind and solar energy are complementary to each other, which makes the system to generate electricity almost throughout the year. The main components of the Wind Solar Hybrid System are wind aero generator and tower, solar photovoltaic panels, batteries, cables, charge controller and inverter [3]. The Wind - Solar Hybrid System generates electricity that can be used for charging batteries and with the use of inverter we can run AC appliances. Wind aero-generator is installed on a tower having a minimum height of 18 metres. from the ground level. Because of the height, the aero-generator gets wind at higher speed and thereby generates more power.The PV array consists of 86 parallel strings. Each string has 7 SunPower SPR-415E modules connected in series, the I-V and P-V characteristics of the selected module or of the whole array are given Fig. (3.1)

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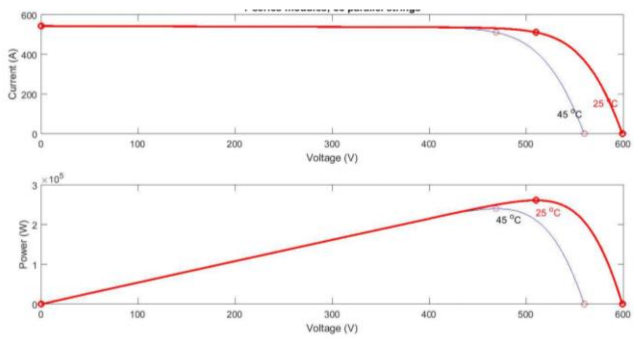

Fig. (3.1) I-V and P-V characteristics SunPower SPR-415E modules

The converter is modelled using a 3-level IGBT bridge PWM-controlled. The inverter choke RL and a small harmonics filter C are used to filter the harmonics generated by the IGBT bridge. A 250-kVA 250V/25kV three-phase transformer is used to connect the inverter to the utility distribution system.
The Maximum Power Point Tracking (MPPT) controller is based on the 'Perturb and Observe' technique. This MPPT system automatically varies the VDC reference signal of the inverter VDC regulator in order to obtain a DC voltage which will extract maximum power from the PV array.
VDC Regulator is used to determine the required Id (active current) reference for the current regulator.
Current Regulator is based on the current references Id and Iq (reactive current), the regulator determines the required reference voltages for the inverter. In our example, the Iq reference is set to zero.
PLL & Measurements is required for synchronization and voltage/current measurements.
PWM Generator is used to generate firing signals to the IGBTs based on the required reference voltages. In our example, the carrier frequency is set to 1980 Hz (33*60).
The wind turbine and the induction generator (WTIG) is shown in Fig. (3.2) and its stator winding is connected directly to the grid and the rotor is driven by the wind turbine. The power captured by the wind turbine is converted into electrical power by the induction generator and is transmitted to the grid by the stator winding.

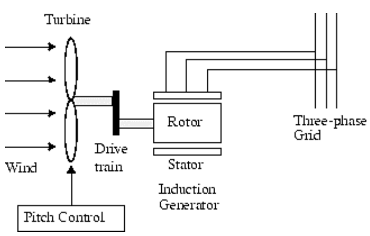

Fig. (3.2) Wind Turbine and the induction generator (WTIG)

The pitch angle is controlled in order to limit the generator output power to its nominal value for high wind speeds [4] [5]. In order to generate power, the induction generator speed must be slightly above the synchronous speed. But the speed variation is typically so small that the WTIG is considered to be a fixed-speed wind generator. The reactive power absorbed by the induction generator is provided by the grid.

The wind turbine model uses the Wind Turbine block of the Renewables/Wind Generation library in MATLAB. A Proportional-Integral (PI) controller is used to control the blade pitch angle in order to limit the electric output power to the nominal mechanical power. The Pitch angle control system block diagram is illustrated in Fig. (3.3) and Turbine Power Characteristics is shown in Fig. (3.4). The pitch angle is kept constant at zero degrees when the measured electric output power is under its nominal value. When it increases above its nominal value, the PI controller increases the pitch angle to bring back the measured power to its nominal value.

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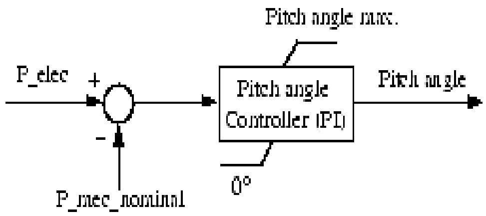

Fig. (3.3) Pitch Angle Control System

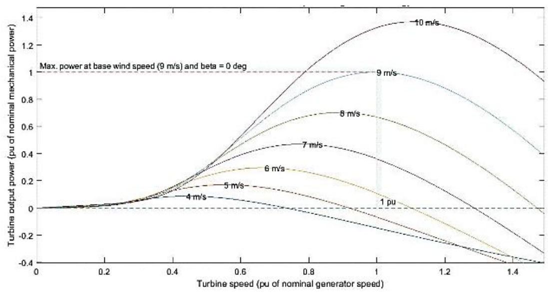

Fig. (3.4) Turbine Power Characteristics.

The mentioned Solar and Wind Power Systems are interconnected though a utility grid using T-Source Inverter as shown in Fig. (3.5), modelled as a typical distribution grid. It included two 25-kV feeders, loads, grounding transformer and an equivalent 120-kV transmission system.

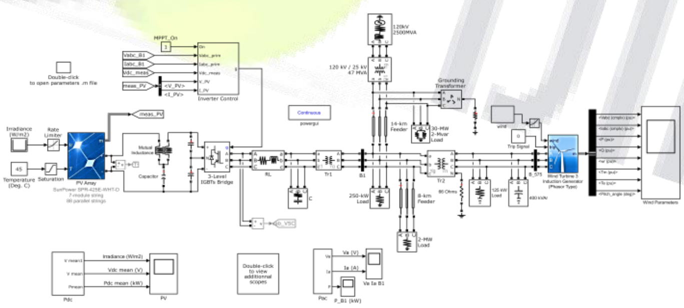

Fig. (3.5) Solar and Wind Power Systems are interconnected though a utility grid using the application of T-source Inverter.

The various simulation outcomes of this mentioned model are arranged below for the reference

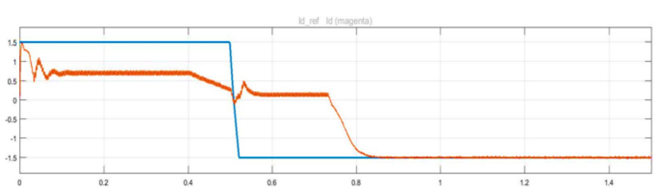

Fig. (3.6) Direct Axis Current (Id)

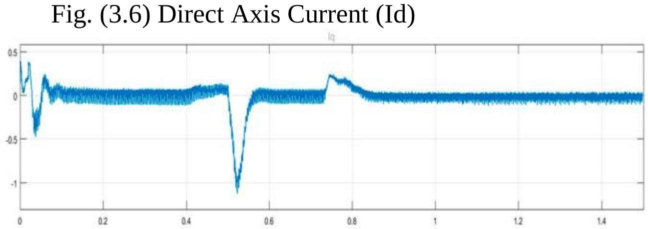

Fig. (3.7) Quadrature Axis Current (I_q)

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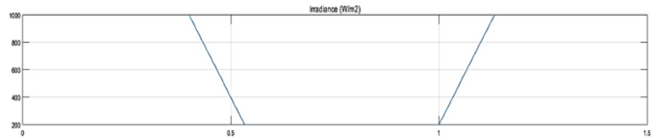

Fig. (3.8) Irradiance over Solar Panel

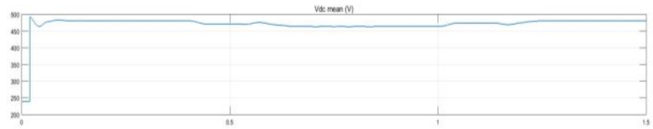

Fig. (3.9) Potential difference at the terminals of Solar Panel

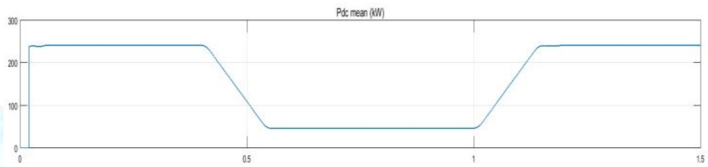

Fig. (3.10) Power delivered by the Solar Panel

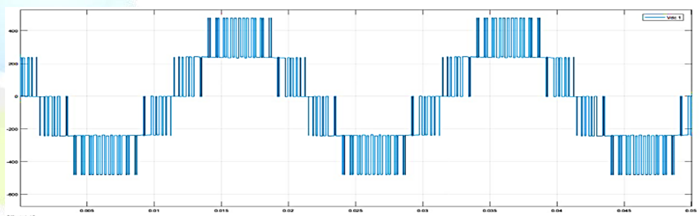

Fig. (3.11) Output Voltage of T-Source Inverter

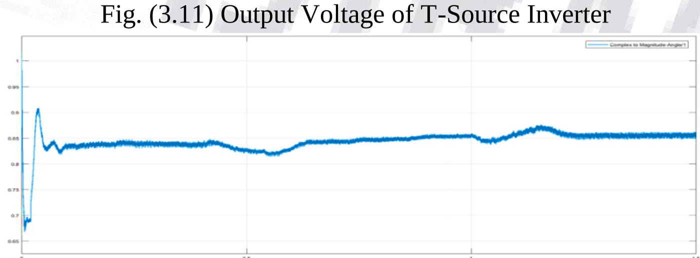

Fig. (3.12) Modulation Index of T-Source Inverter

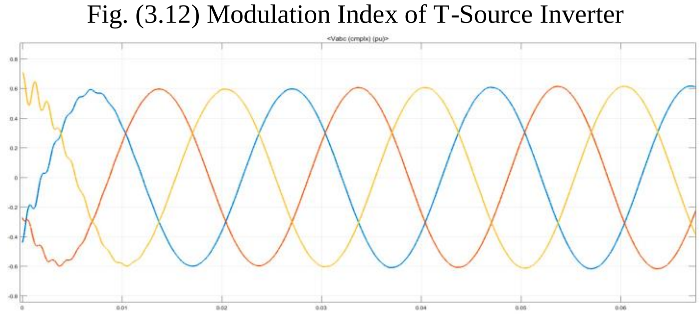

Fig. (3.13) Line to line Voltage observed at Wind Turbine's Doubly Fed Induction Generator.

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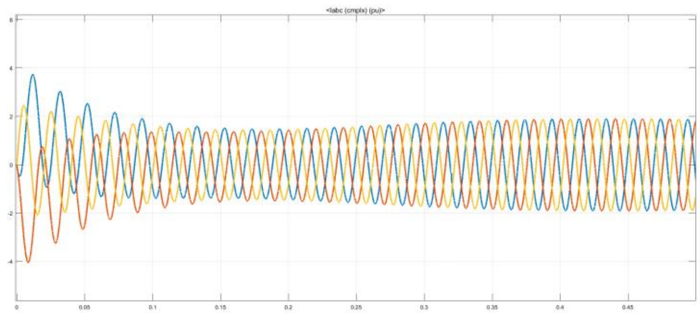

Fig. (3.14) Line Currents of Doubly Fed Induction Generator.

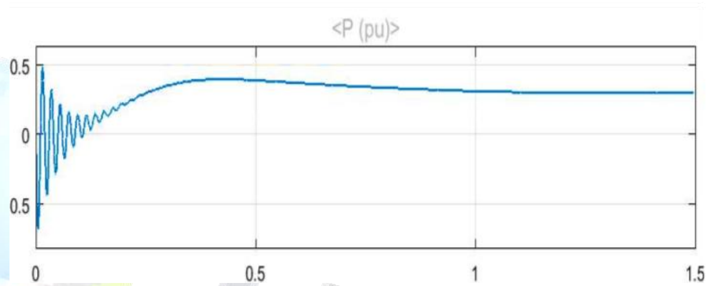

Fig. (3.15) Electrical Power Developed by Wind Turbine.

IV. MODELLING OF ELECTRIC VEHICLE DRIVES USING NI MULTISIM

A device that increases or decreases the voltage (AC or DC) of a power source depending on application. A converter that increases voltage is called a step-up converter and a converter that decreases voltage is called a step-down converter. In Electric Vehicles(EVS) /Hybrid Electric Vehicles (HEVs) step-up and step-down converters are combined into one unit. An application of a step-up converter is converting EV/HEV battery voltage (typically 180-300 volts) to about 650 volts to power the traction motor. An advantage of using a converter to increase voltage from the battery is a smaller and less expensive battery may be used while still utilizing an efficient high voltage motor. An application of a step-down inverter would be decreasing the high voltage direct current (DC 180-300 volts) from the HEV/EV battery to low voltage (12-14 volts) DC that can be used to charge the 12-volt auxiliary battery and operate light load devices such as lighting, radio, and windows. In this model based design, we use 48 V Battery as a source for T-Source inverter which is going to represent the electric vehicle drives for Buck-Boost operation in single stage.

Multisim™ software integrates industry-standard SPICE simulation with an interactive schematic environment to instantly visualize and analyse electronic circuit behaviour. A 3 phase squirrel cage induction motor is a type of three phase induction motor used in modelling of the electric vehicle, which functions based on the principle of electromagnetism. It is called a 'squirrel cage' motor because the rotor inside of it – known as a 'squirrel cage rotor' – looks like a squirrel cage used as a motor for the electric vehicle.

The Gating signals for the IGBTs are given accordingly with the reference sine wave and the carrier triangular wave. On the comparison of these two waves, output is driven as Pulse Width Modulated wave given to the six individual switches of the DC-AC Converter. The corresponding waveforms of the PWM are shown in Fig. (4.1)

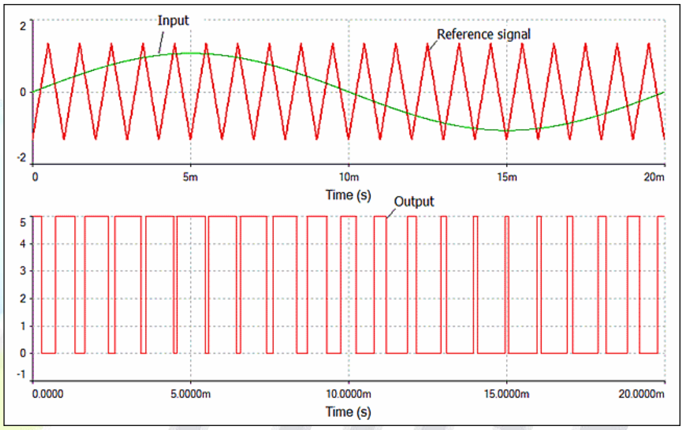

Fig. (4.1) Pulse Width Modulated signal generation

The mentioned modelling of electric vehicle drive using NI Multisim using T-Source Inverter is shown in Fig. (4.2)

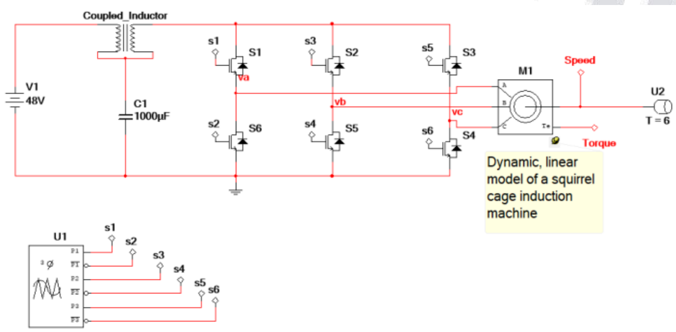

Fig. (4.2) Simulation of Electric vehicle drive using T-source Impedance Network.

The various simulation outcomes of this mentioned model are arranged below for the reference.

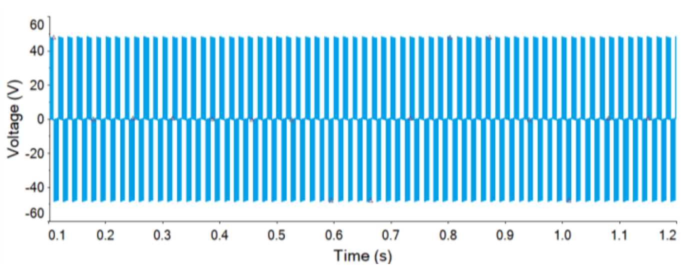

Fig. (4.3) Line to Line Voltage at motor terminals

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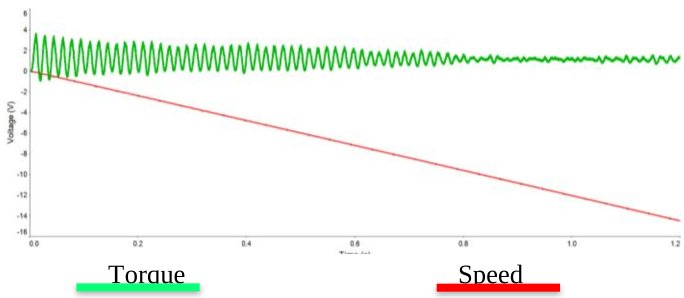

Fig. (4.4) Speed and Torque Characteristics of Induction Motor

V. FUTURE SCOPE

The proposed work, the electric motor drive is designed for fixed frequency and amplitude only, may in future may develop this topology as a variable frequency drive and designing the T-source Impedance Network with less leakage inductance of Coupled Inductor.

REFERENCES

[1] Hongpeng Liu, Zichao Zhou, Yuhao Li, Wentao Wu, Jiabao Jiang, Enda Shi - Impedance Source Inverters (2020, Springer).
[2] Mathworks Simulink Documentation.
[3] National Instruments Help Centre.
[4] D. Hemanand & N. Sankar Ram, "Performance of security algorithm against malicious nodes based wireless sensor network", Asian Journal of Information Technology, vol. 19, no. 15 pp 3687- 3692, 2016
[5] D. Hemanand, & N. Sankar Ram, "QoS Routing for Mobile ADHOC Network Environment", Research Journal of Applied Sciences, Engineering and Technology Vol. 11, no. 9, pp 1013-1018, 2015.