Modified Z-Source Inverter Based Three Phase Induction Motor Drive for Solar PV Applications

Vani Vijay, Shruthi K. J., P. Giridhar Kini, C. Viswanatha and M. Siddhartha Bhatt

***Abstract*--Various converter topologies have been developed from many years for the effective operation of solar photovoltaic (SPV) systems. Induction motor application using SPV source requires an efficient converter which can produce higher value of AC voltage output from the PV input and also implement v/f control with reduced losses and wide range of speed control. Here a modified Z- source inverter for V/f control of induction motor driven from a Solar PV system is presented. Using Z source network, voltage levels higher than the input value can be obtained without requiring a boost converter. This can be utilized in SPV applications for obtaining required DC voltage for the inverter. An improved PWM inverter with HERIC topology combined with Z source network is presented for the induction motor application. The new topology is found to have better performance with reduced switching losses compared to the conventional inverters. The topology is evaluated for variable speed applications and it is found to give satisfactory results compared to conventional v/f control especially for low speeds**

***Index Terms*—Z source network, HERIC converter, Solar PV Induction Motor drive.**

[1] INTRODUCTION

DUE to the rising energy crisis, the importance of renewable energy sources is increasing day by day. Solar Photovoltaic (SPV) system which is the most important renewable energy source, is finding its application in various areas of electrical utility. Standalone solar modules are commonly used for house hold lighting, street lighting etc. Large scale solar generating stations are being installed for supplying power to utility grid. Motor drive systems based on SPV source can bring about energy saving to a great extent.

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Out of various types of motors used in industrial and commercial sectors, induction motors are most popular because of high robustness, reliability, low price and high efficiency. Scalar and vector controls are used for speed control of induction motors, out of which scalar or v/f control is simple, cheap and stable. Sources such as solar and wind have a wide voltage variation range due to the nature of these sources depending upon temperature and radiation changes for photovoltaic cell and with wind speed and control for wind generator. The conventional inverter technology cannot provide satisfactory results for such voltage variations and demands requirement for voltage boost converter. This will increase cost, system complexity, and power loss. Z- Source Inverter (ZSI) is a single stage power conversion topology which can provide a solution to this problem with low cost, high reliability, and high efficiency [1-5].

Other problems to be addressed in inverter applications are the harmonics and switching losses. The output AC is desired to be pure sine wave for most of the applications. Multilevel inverters of various topologies have been developed to tackle this problem [9-14]. Large number of research and technical papers for minimization of THD and losses have been reported for various multilevel topologies of sine wave inverters. Here a combination of Z-source network and three phase inverter based on HERIC topology and the integration in SPV system is presented. The utilization of the system for v/f control of three phase induction motor is presented.

[2] SOLAR PV BASED IM DRIVES

Various types of solar PV based induction motor drives have been developed for specific applications. The proposed ZSI based SPV fed induction motor drive system has the following components: PV module, Z-source network, three-phase inverter with controller and a three-phase induction motor. The system setup is shown in figure 1. ZSI delivers the function of boost converter providing a conditioned DC input voltage for the converter.

The inverter is sinusoidal pulse width modulated to obtain nearly sinusoidal output. Very high levels of multilevel inverters have been developed by analysis using simulation softwares. But in practical hardware implementation, level

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higher than three is very difficult to obtain [1-3]. Moreover, in most of the cases, the switching losses are increased to a great extent with increase in number of levels. The proposed topology of a single level inverter with reduced switching losses is presented which can be modified to multi level. The controller shown as in the block diagram includes both the modified inverter control logic and v/f controller for the motor

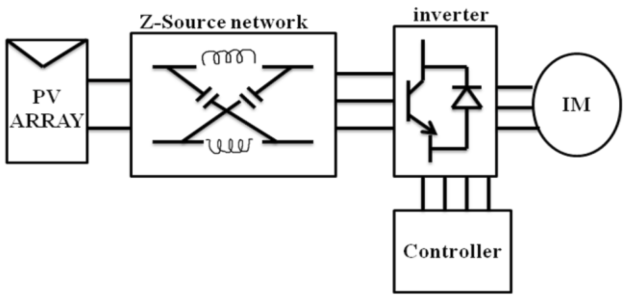

Fig. 1. General block diagram of the proposed system consisting of PV array as the voltage source, Z source network, Three phase inverter and controller for speed control of induction motor.

and generates the required gate signals for the inverter according to the required reference speed.

[3] CONVERTER MODEL

[4] Z Source Network

Utilization of ZSI in industrial applications greatly increases the reliability by allowing only lower inrush current, lower harmonic injection and high immunity to EMI noises. In conventional voltage-source inverter (VSI), the switching of the same-phase leg switches at the same time will cause a short circuit or shoot through which will damage the device. This limitation can be overcome by ZSI. With the use of the

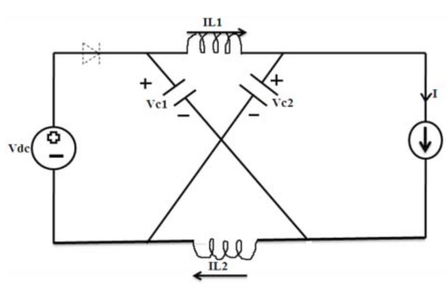

Fig. 2.a. Equivalent circuit of Z source inverter during Non- Shoot through state when the diode is conducting

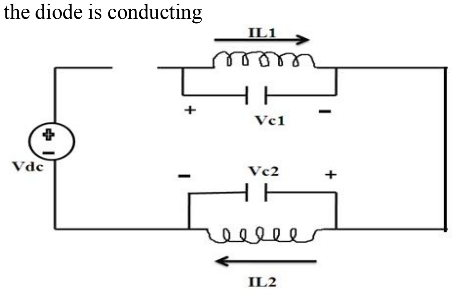

Fig. 2.b. Equivalent circuit of Z source inverter during Shoot through state when the diode is reversed biased

impedance source network in ZSI, there is no shoot through problem. Also voltage level higher than input voltage can be obtained which is not possible in conventional VSI without boost converter [4-7]. Figures 2. a and 2. b shows the equivalent circuit of ZSI when the diode is conducting state (Non- Shoot through mode) and the not conducting state (Shoot through mode) respectively [8-11]. The working equations at various conditions is shown below.

In shoot through mode as in fig 2.b., a diode placed at the input side is reverse biased and the capacitors charge the inductors and voltage across the inductor is:

$$V_{L1}=V_{C1};\ V_{L2}=V_{C2} \qquad (1)$$

It is assumed that the impedance network is a symmetric network ($C_1=C_2=C$ and $L_1=L_2=L$), it can be observed that $V_{L1}=V_{L2}=V_L$ and $I_{L1}=I_{L2}=I_L$ and the DC link voltage across the inverter bridge during shoot through interval is

$$V_i=0 \qquad (2)$$

The inductor voltages in two modes:
Shoot through mode: $V_L=V_C$ (3)

Non-shoot through mode: $V_L=V_{dc}-V_C$ (4)

The average inductor voltage over one switching period is zero.

$$V_L = \frac{T_0.V_C + T_1(V_{dc} - V_C)}{T} = 0 \qquad (5)$$

$$\frac{V_C}{V_{dc}} = \frac{T_1}{T_1 - T_0} \qquad (6)$$

V_L- Inductor voltage
V_C- Capacitor voltage
$T1$-Non- shoot through period
T_0- shoot through period
T- total switching period= T_0+T_1

[5] Inverter Topology

Inverter is the most important part of any PV based application. The inverter topology and controller logic are chosen based on the type of application. Inorder to obtain better sinusoidal waveform and lower harmonic content, various types of multilevel topologies are designed. Some of them are diode-clamped, cascaded H-bridge, multi cell, modified H-bridge etc [11-13]. These configuration have more number of switches and consequently the switching losses and leakage currents are increased. Inorder to avoid this, a combination of HERIC converter and Z- source network can be utilized.