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Simulation Analysis for Quasi Z-Source Inverter using Solar PV Systems by Implementing Sliding Mode Control

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ABSTRACT:DC-DC converter has an existing problem in balancing DC link, So to overcome the problem Quasi Z-Source inverter is used .Quasi-Z-source inverters (qZSIs) has advantages such as single-stage operation, lower component rating, and continuous input current and common dc rail it can suppress leakage current. Sliding mode control (SMC)-based controller for capacitor voltage regulation has been proposed to ensure a fast and dynamic response for wide variations in input voltage, output load, and reference controlled quantity. Solar PV based system for qZSI has a high voltage gain, High modulation index, Low switching stressing.

KEYWORDS*:* Quasi Z-Source Inverter, Sliding Mode Control, Solar PV System

I.INTRODUCTION

To overcome the above problems of the traditional V-source and I-source converters, this paper presents an impedance-source power converter and its control method for implementing dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion [1]. Because of its single-stage volt- age buck/boost properties, the ZSI can deal with input voltage fluctuation in a wide range, which is conventionally achieved by a two-stage dc–dc converter cascaded by dc–ac structure [2]–[4]. With the economic advantages and improved reliability due to the allowance of shoot-through state, ZSI gains increasing attention and was presented for use in several applications, such as DG, uninterruptible power system, fuel cell vehicles, PV or wind power conversion, and electronic loads [5]–[9]. Design guidelines of the impedance network are analyzed in terms of both steady-state and dynamic performances [10]-[11].

SMC was initially, introduced for a variable structure system [12]. SMC is well known for robustness towards variations in input, variations in output, and parameter. Because of the switching function, power converters are inherently variable structure systems. SMC is investigated in DC-DC converters to improve their dynamic response [13]. But because of the limitations of switching frequency of power converters, SMC cannot be applied ideally, [14]-[15]. SMC is employed for the control of capacitor voltage in qZSI. This paper presents the detailed analysis and demonstrates, the dynamics of the SMC based grid-connected single-phase qZSI

II. QUASI Z-SOURCE INVERTER

A Z-source inverter is a type of power inverter, a circuit that converts direct current to alternating current. It functions as a buck-boost inverter without making use of DC-DC Converter Bridge due to its unique circuit topology.

The voltage fed quasi z source inverter is derived from the Z source inverter. It includes all the advantages of Z source inverter like voltage buck and boost operation. Quasi-Z-source inverters (qZSIs) which has more advantages such as single-stage operation, lower component rating, and continuous input current and common dc rail it can suppress leakage current.

This kind of magnetic storage provides the boost voltages at the inverter output during operating states. By using qZSI DC link can be balanced easily compared to DC-DC converter. PV based system for qZSI has a high voltage gain, High modulation, Low switching index stressing.

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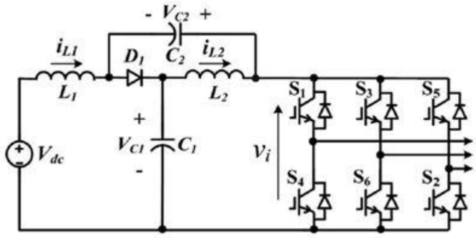

Fig.1.Quasi Z-Source Inverter

The qZSI has two operational states in continuous conduction mode, shoot-through state, and non-shoot-through state. Assuming that, the total switching cycle time is T , the shoot-through cycle time is $T_o$and the non-shoot through cycle time is T_1.Therefore, the shoot-through duty ratio is expressed as $D=T_o=T$. Also, for the modeling, the system presumes a symmetrical qZS network, (which means identical values of inductors L_1 and L_2, and capacitors C_1 and C_2. During the shoot-through state, the DC link terminal of the inverter is short-circuited through the upper and lower switches of the inverter. From shoot-through equivalent circuit,

$$V_{L1} = V_{C2} + C\ V_{in}$$
$$V_{L2} = V_{C1}$$
$$i_{C1} = - i_{L2}$$
$$i_{C2} = - i_{L1} \qquad (1)$$

During the non-shoot-through state (u D 0), and the inverter acts as a conventional voltage source inverter. The OFF state of single switch SH is represented as u D $_{0.}$

From the non-shoot-through equivalent circuit,

$$V_{L1} = - V_{C1} + V_i$$
$$V_{L2} = - V_C$$
$$i_{C1} = i_{L1} - i_{DC}$$
$$i_{C2} = i_{L2} - i_{DC} \qquad (2)$$

From (1) and (2)

$$V_{L1} = (-V_{C1} + V_{in}) + (V_{C1} + V_{C2})u$$
$$V_{L2} = (-V_{C2}) + (V_{C1} + V_{C2})u i_{C1} = (i_{L1} - i_{DC}) + (I_{dc} - i_{L1} - i_{L2})u i_{C2}$$
$$= (i_{L2} - i_{DC}) + (i_{DC} - i_{L1} - i_{L2})u \qquad (3)$$

III. SLIDING MODE CONTROL FOR QUASI Z-SOURCE INVERTER

SMC is well known for stability and robustness towards system input, output variation, and parameters uncertainties. SMC cannot be applied ideally, due to the limited switching frequency of power converters. So, SMC is used for power converters that act as quasi-sliding mode controllers (qSMC). There are many literatures, which propose the application of SMC, to control the output voltage of DC-DC converters such as buck, boost, and cuk converters. This basically, concerns with the selection of sliding coefficients for the desired dynamic properties. In renewable applications, where the DC input voltage of the converter varies in different circumstances, or DC voltage, which is fed to the inverter varies due to the load, qSMC seems to be suitable. SMC is best suitable for such applications, because of robustness towards system input and output load variation. In this paper, SMC is employed to control and regulate the DC output voltage of the grid connected qZSI impedance network.

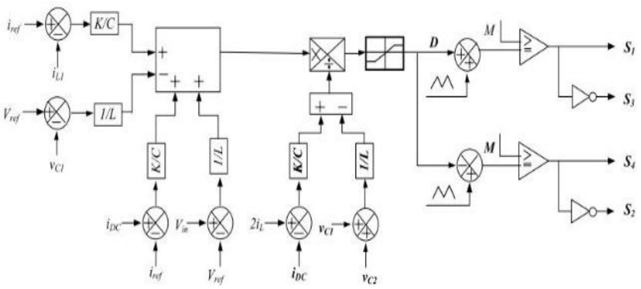

Fig.2.Sliding Mode control Modelling

IV. SOLAR PV MODELLING

A PV system directly converts sunlight into electricity. The main device of a PV system is a solar cell. Cells may be grouped to form panels or arrays. Power electronic converters are usually required to process the electricity from the PV device. These converters may be used to regulate the voltage and current at the load, to control the power flow in grid-connected systems, and for the maximum power point tracking (MPPT) of the device [16]

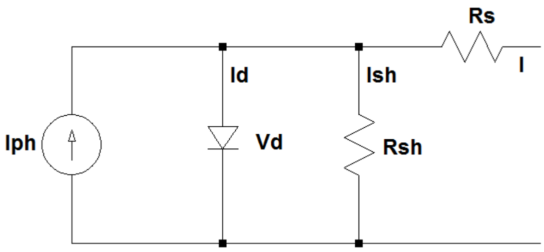

Fig.3. Basic diagram of Solar PV Cell

The solar cell is basically a semiconductor diode exposed to light. Solar cells are made of several types of semiconductors using different manufacturing processes [17]. The electrical energy produced by a solar cell at any time instant depends on its intrinsic properties and the incoming solar radiation [18]. The solar radiation is composed of photons of different energies, and some are absorbed at the p-n junction. Photons with energies lower than the bandgap of the solar cell are useless and generate no voltage or electric current. Photons with energy superior to the bandgap generate electricity, but only the energy corresponding to the bandgap is used. The remainder of energy is dissipated as heat in the body of the solar cell [19]. A single-diode PV cell model is considered in this paper, including the effect of the series resistance. The paper uses the equivalent circuit of a solar cell with its parameters as a tool to simulate in order to consider the irradiance and temperature change, the I-V characteristics of PV cell.

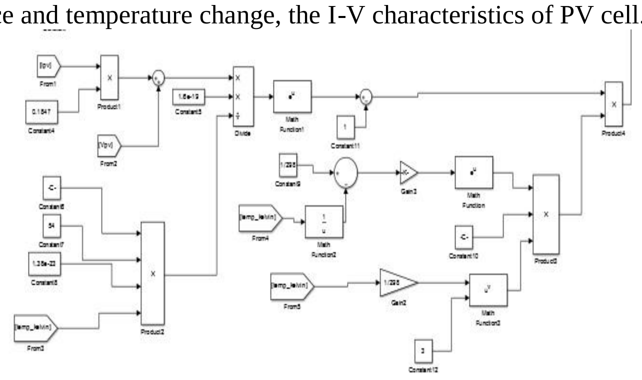

Fig.4. Modelling of PV Cell

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As mentioned previously, the solar cells are semiconductor with a p-n junction fabricated in a thin wafer or layer of semiconductors. When exposed to light a photo current proportional to the solar radiation is generated, if the photon energy is greater than the band gap. In the dark, the I-V characteristics of a solar cell have an exponential characteristic similar to that of a diode.In order to maximize the extracted output power from a PV power plant with the help of MPPT control, the understanding and modelling of PV cell is necessary. The following equations are used for modelling Solar PV cell;

$$I_{ph} = I_{sco}\left[\frac{G}{G_0}\right]\left(1+\alpha_1(T-T_0)\right) \tag{4}$$

$$I_{PV} = I_{ph} - I_0\left[\exp\left(\frac{V_{PV}+R_sI_{PV}}{n\left(\frac{\eta kT}{q}\right)}\right)-1\right]-\left[\frac{V_{PV}+R_sI_{PV}}{R_{sh}}\right] \tag{5}$$

$$I_o = I_o\left(\frac{T}{T_o}\right)^3 \exp\left[\left(\frac{qE_g}{\eta K_B}\right)\left(\frac{1}{T_o}-\frac{1}{T}\right)\right] \tag{6}$$

IV. Simulation Results and Analysis

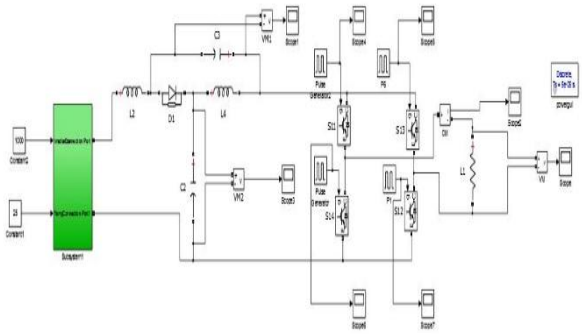

Fig.7. Simulink of Quasi Z-Source Inverter using SMC

The simulation results of Quasi Cascaded Multilevel Inverter by applying the SMC control to the single level inverter are presented. In above section-III SMC is explained and in section-I the reason for choosing the SMC control is explained, It has no switching losses mainly. Previously the three techniques which are used has high frequency and additional switching losses.

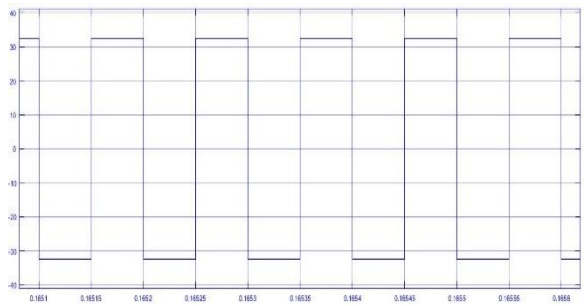

Fig.5. Output voltage of Quasi Z-Source Inverter using SMC

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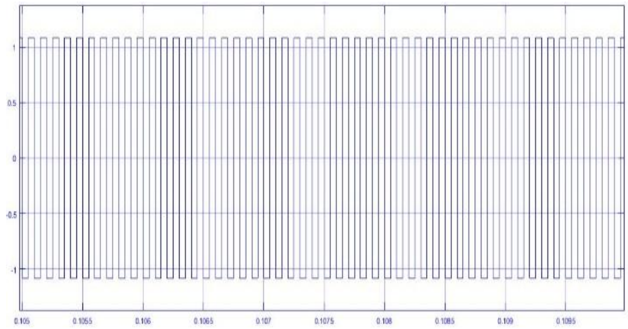

Fig. 6. Output current of Quasi Z-Source Inverter using SMC

Fig.5 and Fig.6 shows the output voltage and output current waveform. The output voltage of the Quasi Z-Source inverter is 48.2 volts and current is 1.3 Amps.

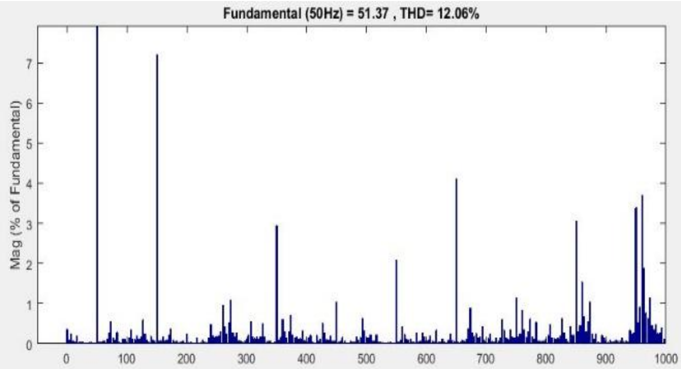

Fig.7. Voltage THD (%) with SMC

Table-I Harmonics description for Voltage

S.No	Type	THD(%)
1.	Without SMC	17.04%
2.	With SMC	12.09%

Table-I gives the detail explanation of voltage harmonics in the Quasi Z-Source Inverter by comparing without SMC technique and with SMC technique.

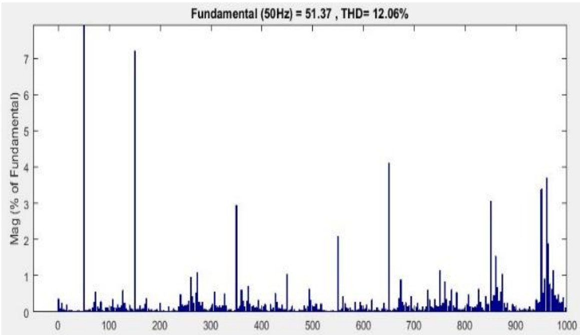

Fig.8. Current THD (%) with SMC

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Table-2 Harmonics description for Current

S.No	Type	THD(%)
1.	Without SMC	17.04%
2.	With SMC	12.09%

Table-2 gives the detail explanation of current harmonics in the Quasi Z-Source Inverter by comparing without SMC technique and with SMC technique.

V.CONCLUSION

The Quasi Z-Source has the following main features as: suppression leakage current, low component stress and shoot through immunity, a constant capacitor voltage can be achieved with an excellent transient performance which enhances the rejection of disturbance, including the input voltage and load current variations. By implementing SMC control the stability in output voltage waveform is increased, whereas the Total Harmonic Distortion (THD) is reduced in compare with normal PWM technique. Hence in future by designing the filter we can reduce the THD as per IEEE standards.

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