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DESIGN AND DEVELOPMENT OF QUASI-Z-SOURCE INVERTER WITH BATTERY

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Abstract: Alternate energy sources such as solar, fuel cell, and wind have a wide voltage change range due to the nature of the sources. Photovoltaic cell's voltage varies with temperature and irradiation. Fuel cell stack voltage drops greatly with current. And wind generator voltage varies with wind speed and control. The traditional voltage source inverter that has been the power conversion technology for these energy sources cannot cope with this wide voltage change nature and often requires additional voltage boost by additional dc/dc converter. The Z-source inverters can solve this problem. This single stage power conversion technology provides a great alternative with lower cost, higher reliability, and higher efficiency. System configurations, features and results are shown for advanced power conditioning of alternate energy systems.
Key Terms: PvArray, AC, DC.

I. INTRODUCTION

The photovoltaic PV system installation has played an important role worldwide as they are clean, environment friendly and secure energy sources [2]. In developing countries, where rural electrification is embryonic, the applications of PV systems are important. The concept of Z-Source inverter has become a future trend for three phase photovoltaic (PV) power systems [1]. Hence, this topology involves High frequency switching inverter, Z-Source, Filter circuit, Battery charge controller. The Z-source inverter employs a unique impedance network to couple the inverter main circuit to the power source, which provides a novel power conversion concept. By controlling the shoot-through duty ratio and modulation index, the Z-source inverter can step up and down the input voltage using passive components with improved reliability and reduced cost, thus providing unique features, such as ride-through capability during voltage sags, reduced line harmonics, improved power factor and reliability, and extended output voltage range.[3][4] The recent proposed quasi-Z-source inverter (qZSI) inherits all the advantages of the traditional ZSI and has several more advantages, including reduced passive component stress and continuous input current features[5]. Due to the above-mentioned features, the qZSI topology is very attractive for renewable energy sources interface application, such as photovoltaic panel, wind turbine and fuel cell. Usually, those renewable energy power systems require a battery to store the extra energy when the load is light or the source is abundant, and to supply the load power during the period without or shortage of the source [5][6]. So the inverter should have the function not only to charge the battery with the extra power, but also to feed the load from the battery when the energy is insufficient [3]

II. SYSTEM MODEL

A. Solar Pv Quasi Z- Source Inverter

The PV module is used to generate the input voltage for the inverter, photo voltaic cells are semiconductor devices, with electrical characteristics similar to a diode [7]; however, a PV cell is a source of electricity, rather than an electrical load when light energy, such as sunlight makes contact with it. A single PV module consists of 36 cells connected in series and parallel, encapsulated in glass and held together aluminum frame. Because these cells are connected in series, a typical module operates at around 12V DC and generates around 75W of power [7][8].

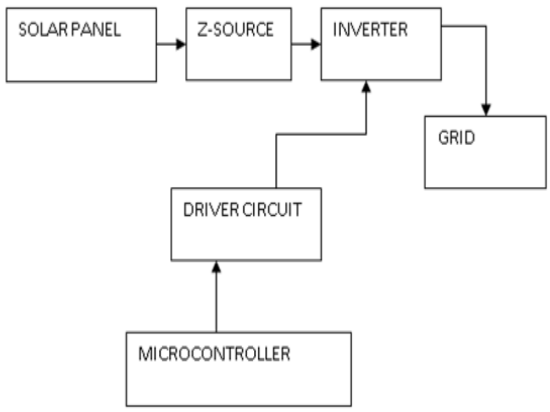

Fig. 1: Block Diagram of Quasi-Z-Source Inverter

This chapter gives information about various blocks, which constitute the design and development of QZSI. This project having following blocks: PV modules, Power Supply Unit, HF inverter, Z- source, AC filters [6][7] The block diagram of design and development of QZSI for solar PV system is shown in fig. 2.1

B. Solar Panel

A photovoltaic PV generator is the whole assembly of solar cells, connections, protective paths, supports etc[4]. In the present modeling the focus is only on cell/module/array. Solar cells consist of a p-n junction fabricated in a thin wafer or layer of semiconductor (usually silicon). In the dark the I-V output characteristics of the solar cell has an exponential characteristic similar to that of a diode [2][4]. When solar energy hits the solar cell, with energy greater than the band gap energy of the semiconductor, electron or knocked loose from the atoms in the material, creating electron hole pairs. These carriers are swept apart under the influence of the internal electric fields of the p-n junction and create a current proportional to the incident radiation [7]. When the cell is short circuited, this current is shunt internally by the intrinsic p-n junction diode. Large and small scale PV power systems have been commercialized in many countries due to their potential long term benefits, generous fed in tariff schemes and other attractive initiatives provided by various governments to promote substantial green energy[8]. In PV power generation due to the high cost of modules, optimal utilization of the available solar energy has to be ensured. This mandates an accurate and reliable simulation of designed PV systems prior to installation [7][8].

C. Effect of Temperature and Solar Irradiation

A method to include these effects in the PV array modeling is included in our project. According to this method, for a known temperature and solar irradiation level, a model is obtained and then it is modified to handle different cases of temperature and irradiation levels [5]. Let (1) be the benchmark model for the known operating temperature Tc and known solar irradiation level Sc as given in the specification. When the ambient temperature and irradiation levels change the cell operating temperature also changes, resulting in a new output voltage and new photo current value. The solar cell operating temperature varies as a function of solar irradiation level and ambient temperature [4]. The variable ambient temperature Ta affects the cell output voltage and cell photocurrent. These effects represented in the model by the temperature co-efficient CTV and CTI for cell output voltage and cell photocurrent, respectively as shown in below equations 2.1 and 2.2

$CTV = 1+\beta T\ (Ta - Tx)$ ………2.1

$CTI = 1 + (\gamma T / Sc) * (Tx-Ta)$ ……2.2

Where BT=0.004 and Yt= 0.06 for the cell used and Ta=273K is the ambient temperature during the cell testing. This is used to obtain the modified model of the cell for another ambient temperature Tx. Even if the ambient temperature does not change significantly during the day time, the solar irradiation level changes depending on the amount of sunlight and clouds[6][7]. A change in solar irradiation level causes a change in the cell photocurrent and operating temperature, which in turn affects the cell output voltage. If the solar irradiation level increases from SX1 to SX2, the cell operating temperature and the photocurrent will also increase from TX1 to TX2 and from Iph1 to Iph2 respectively. Thus the change in the operating temperature and in the photocurrent due to variation in the solar irradiation level can be expressed via two constants, CSV and CSI, which are the correcting factors for changes in cell output voltage Vc and photocurrent Iph respectively

$Csv = 1 + \beta T\ \alpha s\ (Sx- Sc)$ …….2.3

$CSI = (1 / Sc)* (Sx - Sc)$ …….2.4

Where Sc is the benchmark reference solar irradiation level during the cell testing to obtain the modified cell model. Sx is the new level of the solar irradiation. The temperature change ΔTc occurs due to the solar irradiation level and is obtained using

$\Delta Tc = \alpha s\ (Sx- Sc)$ ……….2.5

The constant αS represents the slope of the change in the cell operating temperature due to change in the solar irradiation level and is equal to 0.2 for the solar cell used [2]. Using correction factors CTV, CTI, CSV and CSI, the new values of the cell output voltage Vcx and photocurrent Iphx are obtained for the new temperature Tx and the solar irradiation Sx as follows in the equations

$Vcx = CTV\ CSVVC$ …………..2.6

$Iphx = CTI\ CSI\ Iph$ ………..2.7

Vc and Iph are the benchmark reference cell output voltage and reference cell photocurrent, respectively.

D. Z-SOURCE

The normal distribution describes a theoretical distribution of values that follow a specific mathematical formula [3][4]. Although normal distributions may have different means and standard deviations, all normal distributions are "bell-curve" shaped, symmetrical with a peak at the mean (see Figure 1 for examples). Tails of a normal distribution are asymptotic, indefinitely decreasing but never touching the x-axis. The total area under the standardized normal curve sums to 1.00 (i.e., 100%). [5]

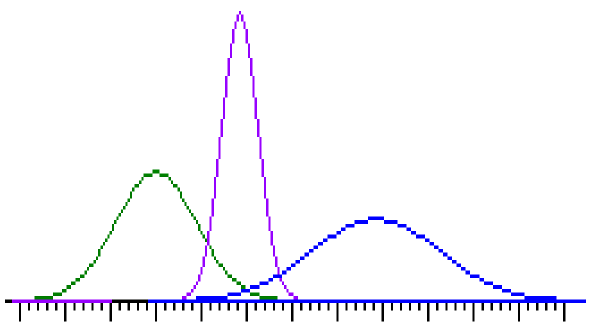

Fig. 2:The Bell curve for Z-Source

E. Three Normal Distributions

Some measurements in the natural world may approximate normal distributions (e.g., perhaps the weights of adult hippopotamuses, heights of palm trees, students' IQs, and people's happiness). The normal distribution may characterize distributions of individual data points in some populations of scores, a large sample drawn from such a population, or the theoretical distribution of sample statistics such as the mean. For more information on the normal distribution and its history [4][5].

- The normal distribution is important in inferential statistics because certain theoretical distributions, such as the distribution of possible means, can be very close to normal even when the population distributions are not normal[3].
- By using the areas underneath normal distributions, we can calculate probabilities of different outcomes, including how likely it is to obtain a mean within a certain range.

F. Standard Normal Distributions and Z Source

A normal distribution that is standardized (so that it has a mean of 0 and a *SD* of 1) is called the standard normal distribution, or the normal distribution of *z*-scores. If we know the mean *m* ("mu"), and standard deviation *s* ("sigma") of a set of scores which are normally distributed, we can standardize each "raw" score, *x*, by converting it into a *z* score by using the following formula on each individual score.

$$z = \frac{x - \mu}{\sigma} \quad \text{.........(2.8)}$$

A *z* score reflects how many standard deviations above or below the population mean a raw score is. For instance, on a scale that has a mean of 500 and a standard deviation of 100, a score of 450 would equal a *z* score of (450-500)/100 = -50/100 = -0.50, which indicates that the score is half a standard deviation.

III. SYSTEM CONFIGURATION AND ANALYSIS

The Fig. 3. 1 shows the system configuration of the proposed voltage-fed qZSI with battery. It consists of a voltage-fed quasi Z-source network, a battery energy storage unit, a three phase inverter, a variable input voltage source, a SM controller, a sinusoidal pulse-width modulator (SPWM) controller, and a switching logic controller [7]. The battery energy storage system is connected in parallel with the capacitor.

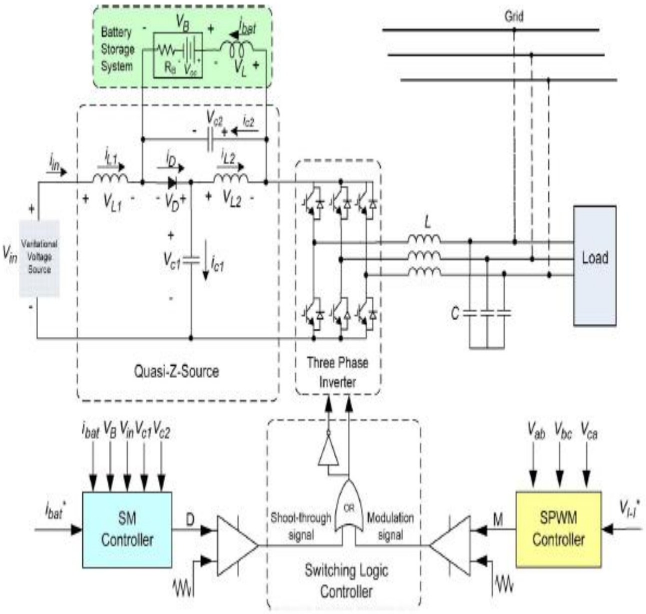

Fig. 3: Digital current control of QZSIs with battery

IV. SIMULATION RESULT

A. PV Array

Case 1:- Here the temperature of the surrounding is maintained at a constant value of 293K. And the solar irradiation level is varied. Thus the values are tabulated in the table

Table A- Variation of array voltage w.r.t solar irradiation Discussion.

S.No	Solar irradiation(Sc) (W/m²)	Voltage(V)
1.	700	16.71
2.	800	18.47
3.	900	20.23
4.	1000	21.99
5.	1100	23.75
6.	1200	25.5
7.	1300	27.26
8.	1400	29.02
9.	1500	30.78
10.	1600	32.54

Table B- variation of array voltage w.r.t temperature

S.No	Temperature(K)	Voltage(V)
1.	285	22.69
2.	290	22.25
3.	298	21.55
4.	303	21.11
5.	305	20.93
6.	308	20.67
7.	311	20.4
8.	313	20.23

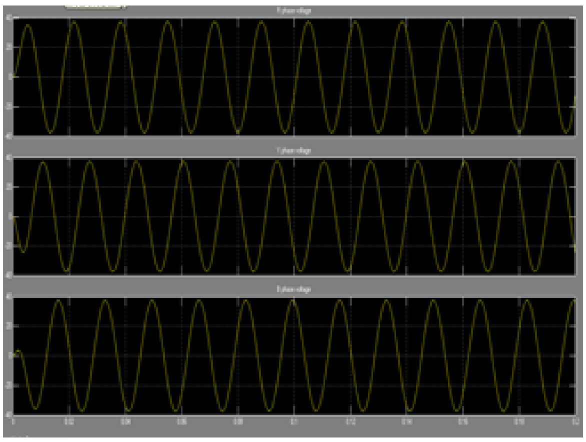

Fig. 4: Simulation Output Voltage

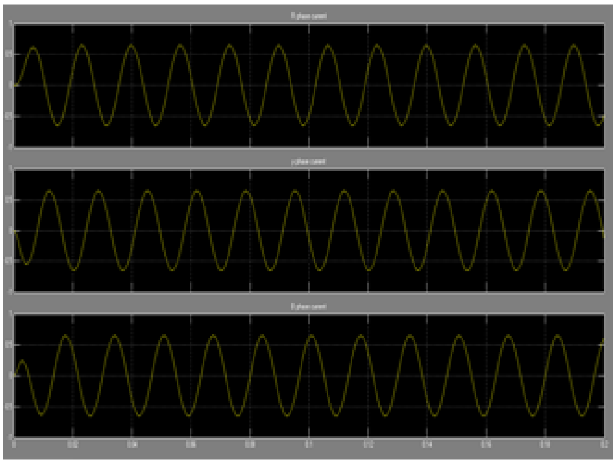

Fig. 5: Simulation Output Current

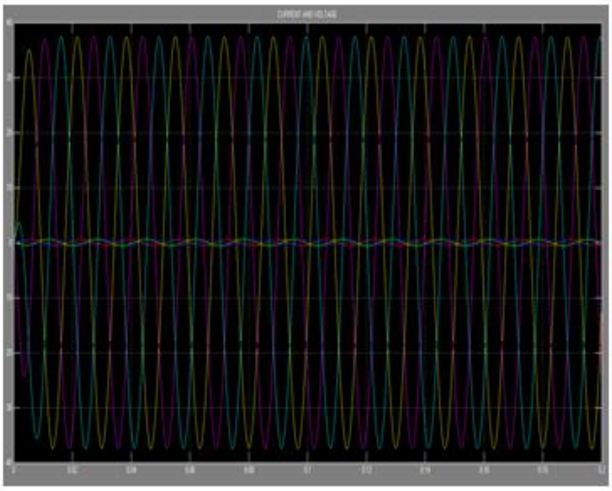

Fig. 6: Three Phase Out Put Wave Form

V. CONCLUSION

A simulation model of testing for a fast-response SM controller operating at a fixed frequency has been proposed for the voltage-fed quasi Z-source inverter with battery energy storage unit. Thus the proposed SM controller can achieve faster response, lower current ripple and better stability for qZSI when the supply and load variation is large and then the simulation model for testing the PV array under various conditions of temperature and solar irradiation level is developed. The variations of array output voltage with respect to solar irradiation and temperature is studied and it is tabulated. Which include the selection method of the sliding surface, the existence condition and the stability properties analysis, and the control parameters design? The proposed SM controller, the battery charging current of the qZSI has a faster response with a lower ripple over a wide range of operating conditions than the traditional PI controller. The achievements of a good charging current control accuracy and fast response for the qZSI with battery energy storage unit

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