International Journal on Applications in Electrical and Electronics Engineering
Volume 3: Issue 1: March 2017, pp 1 – 6 . www.aetsjournal.com ISSN (Online) : 2395 - 3527

HIGH SPEED BLDC MOTOR DRIVEN BY SOLAR ENERGY USING WITH ZETA CONVERTER

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Abstract— This paper deals with Single Phase BLDC Motor drive (IMD) using field oriented control (FOC) fed by solar PV array. Although the several researches have been carried out in the area of SPV array fed water pumping, combining various DC-DC converters and motor drives, the zeta converter in association with the permanent magnet brushless DC (BLDC) motor is still unexplored to develop such kind of system. BLDC motor is an ideal motor for low medium power applications because of its high efficiency, high torque/inertia ratio, low maintenance and wide range of speed control. Two stage PFC converters are widely in practice in which first stage is used for the power factor correction which is preferably a boost converter and second stage for voltage regulation which can be any converter topology depending upon the requirement. On the other hand, a zeta converter exhibits following advantages over the conventional buck, boost, buck-boost converter and Cuk converter when employed in SPV based applications. The operation is studied for a Zeta converter working in DICM (Discontinuous Inductor Current Mode) hence a voltage follower approach is used.

Keywords — SPV array, Zeta converter, INC-MPPT, BLDC motor, Electronic commutation.

I. INTRODUCTION

International concern of power quality (PQ) problems has prompted the use of power factor correction converters with a brushless DC motors (BLDCM) for numerous low power applications. Since, the BLDCMs are employed in low power applications due to features of high efficiency and wide speed range. Combining various DC-DC converters and motor drives, the zeta converter in association with the permanent magnet brushless DC (BLDC) motor is still unexplored to develop such kind of system. The BLDC motor has high reliability, high efficiency, high torque/inertia ratio, improved cooling, low radio frequency interference and noise and requires practically no maintenance [1].

The merits of the zeta converter mentioned above are Favorable for the proposed SPV array fed water pumping system. An incremental conductance (INC) MPPT algorithm is used to operate the zeta converter such that the SPV array always operates at its MPP and the BLDC motor experience a reduced current at the starting. BLDC motors are synchronous motors with permanent magnets on rotor & armature windings on stator [2, 3]. BLDC motors require lower maintenance due to the elimination of the mechanical commutator & they are more efficient due to the permanent magnets on rotor which results in lower rotor losses. The commutation in these motors is accomplished by solid state switches of three phase inverter. For proper commutation & motor rotation, the rotor position information is very important & with the help of this information only the electronic switches in the inverter bridge will be switched ON & OFF to ensure proper direction of current flow in respective coils [4].

II. BRUSHLESS DC (BLDC) MOTOR

Brushless dc motor is a permanent magnet synchronous motor, with permanent magnets on the rotor also with back EMF with trapezoidal shape. The rotor position determines the switching sequence. The [5] phase current of BLDC motor, is synchronized with the back EMF to produce constant torque at a constant speed. The electronic switches replaces the mechanical commutation of the brushed dc motor, which supply current to the motor windings which is a function of the rotor position. This kind of ac motor is called brushless dc motor, because it has similar performance as that of the traditional dc motor with commutations. These motors are usually controlled using a three-phase inverter, which requires a rotor position sensor which is

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required for starting and providing the proper commutation sequence to control the inverter. Hall sensors can be used as these position sensors, resolvers, or absolute position sensors.

A. Equations for designing

The duty ratio D for the Zeta converter (buck-boost) is given as

$$D = \frac{V_{dc}}{(V_{dc} + V_{in})} \quad (1)$$

Where V*dc* represents the DC link voltage of Zeta converter.

If the permitted ripple of current in input inductor Li and output inductor Lo is given as Δ_{iLt} and Δ_{iL0} respectively, then the inductor value Li and Lo are given as

$$L_i = \frac{D.V_{in}}{\{f_s.\Delta i_{Li}\}} \quad (2)$$

III. PROPOSED METHOD

In the proposed method, error correction code for single error and multiple errors using the code BCH will be generated. BCH code is a set of error-correction codes that can be used to detect and correct bit errors that can occur when computer data is moved or stored.BCH code is the most widely used in the embedded memory, since it provides low decoding latency with high code rate.BCH can be used to find large number of errors using codes such as (7,15) and (5,15).The parity bit is added with the data to encode the actual data to avoid the loss of data.

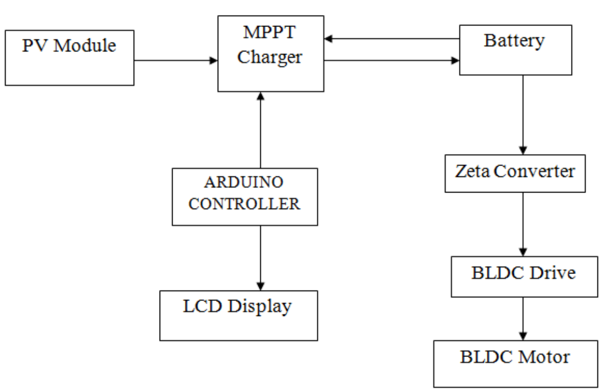

Fig.1 Block Diagram

A. Design of PV array A PV array of 3KW power rating, which is more than the power required by the BLDC motor, is selected in order to compensate the losses associated by DC-DC converter, VSI and motors. Estimation of all the parameters of PV array is done using Standard Insulation level of 1000 W/m2 . PV module is formed by connecting [6]. Table I gives the information about the various parameters to design a PV array of appropriate size.

B. MPPT Charger

Design of PV array A PV array of 3KW power rating, which is more than the power required by the BLDC motor, is selected in order to compensate the losses associated by DC-DC converter, VSI and motors. Estimation of all the parameters of PV array is done using Standard Insulation level of 1000 W/m2 . PV module is formed by connecting [1]. Table I gives the information about the various parameters to design a PV array of appropriate size.

IV. OPERATION OF THE PROPOSED SYSTEM

Although considering the differences in importance in memory, modified ECC ideas have been proposed to strongly protect the HOB data bits in the embedded SRAM memories of the DSPs. Although the tradeoff between the error correction performance and area overhead is considered in the approaches, since the ECC schemes are focused on low-latency decoding, area overhead due to large parity bits and increasing decoder complexity are still very expensive.

This brief presents a novel low-complexity and low-latency unequal-error-protection ECC (UEEP-ECC) for the embedded SRAM memories inside the DSPs. In the proposed ECC scheme, by efficiently merging repetition code over the Bose Chaudhuri Hocquenghem (BCH) code, the UEEP-ECC offers stronger error corrections on HOB parts without large area overhead due to parity bits and decoder complexity.

An efficient ECC generation algorithm with low area and low-latency hardware architecture is also presented to achieve the minimum power consumption of memory core and ECC encoder or decoder.

A. Working

The Power point tracker is a high frequency DC to DC converter. They take the DC input from the solar panels, change it to high frequency AC, and convert it back down to a different DC voltage and current to exactly match the panels to the batteries. Maximum Power Point Tracking is electronic tracking - usually digital. The charge controller [7] looks at the output of the panels, and compares it to the battery voltage. It then figures out what is the best power that the panel can put out to charge the battery. It takes this and converts it to best voltage to get maximum AMPS into the battery. In modern MPPT's is around 93-97% efficient in the conversion.

B. ZETA CONVERTER

The Zeta converter has the capability of getting low or high voltage of output referred to the input value. This converter offers high efficiency compared to the SEPIC Converter and synchronous rectification can be easily implemented in this converter.

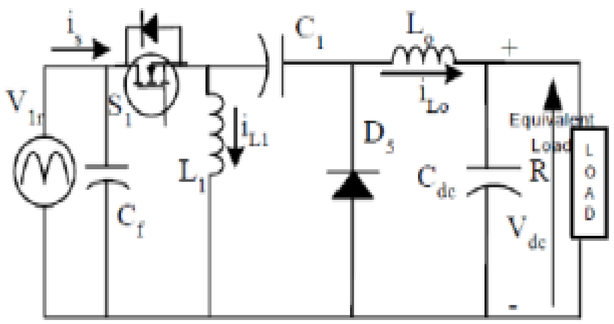

Fig.2: Circuit diagram of Zeta Converter

This converter operates in three modes and are as follows

Mode 1: The switch 'S' is turned ON. The source energy is transferred to the inductor L1 and output inductor L0 through capacitor C1 in turn the iL0, iL1 are increases linearly. During this mode the output voltage is in DC value.

Mode 2: The switch 'S' is turned OFF. The diode D starts conducting in this mode. The energy stored in the inductor L1 and L0 starts to supply to the output or load, meanwhile the capacitor Cdc maintains the voltage across the load.

Mode 3: This is freewheeling mode until the start of new cycle, in this mode neither switch 'S' nor diode 'D' conducts. The voltage across L1 and L0 are zero but their currents are constant until the new switching cycle begins.

V. DESIGN OF ZETA CONVERTER

Brushless dc motor is a permanent magnet synchronous motor, with permanent magnets on the rotor also with back EMF with trapezoidal shape. The rotor position determines the switching sequence. The phase current of BLDC motor, is synchronized with the back EMF to produce constant torque at a constant speed. The electronic switches replaces the mechanical commutation of the brushed dc motor, which supply current to the motor windings which is a function of the rotor position. This kind of ac motor is called brushless dc motor, because it has similar performance as that of the traditional dc motor with commutations.

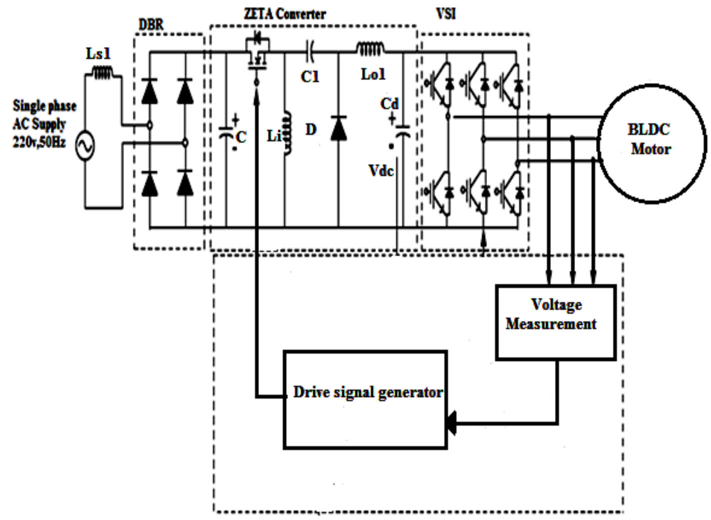

Fig . 3: Proposed zeta converter fed BLDC motor drive

The zeta converter design is to improving the power quality at AC mains and controlling the BLDC Motor. The design equations are as follows,

The output DC voltage of zeta converter is given by

$$v_d = \left(\frac{n_2}{n_1}\right) v_i \left(\frac{D}{1-D}\right) = 130\text{v}$$

Where, v_i = input voltage

$$v_i = \frac{2\sqrt{2}}{\pi} v_s$$

D = duty ratio

$\frac{n_2}{n_1}$ = turns ratio of HFT

The critical value of magnetizing inductor is

$$L_m = \frac{v_d^2}{P_i} \frac{1-D}{2Df_s\left(\frac{n_2}{n_1}\right)^2} = 250\ \mu\text{H}$$

fs = switching frequency

The output inductor is

$$L_o = \frac{v_{dc}(1-D)}{f_s K I_o} = 4.2\ \text{mH}$$

K = percentage ripple of the output current inductor i.e, 40% of inductor current

$$C_1 = \frac{v_{dc} D}{\eta\left(\sqrt{2}v_s + v_{dc}\right) f_s} \frac{P_i}{v_{dc}^2} = 0.44\ \mu\text{F}$$

η= allowable ripple voltage across C1and finally,

$$C_d = \frac{P}{v_{dc}} \frac{1}{2\omega(\eta v_{dc})} = 2200\ \mu\text{F}$$

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VI. PV CHARACTERISTICS

A PV module is a combination of series and parallel solar cells which generate voltage and currents. In darkness, PV cell only generates currents as it becomes a p-n junction diode [1].

In order to simulate the behavior of PV system a mathematical model has been developed based on the equivalent circuit of a solar cell. Figure 2 illustrates the equivalent circuit of a solar cell, where *Iph* is the photocurrent of the cell, *Vpv* and *Ipv* are the PV voltage and current respectively.

The series resistance (*Rs*), which is very small, and the shunt resistance (*Rsh*), which is very large, both can be neglected to simplify the model [16]. The PV Panel can be described as the following [17]:

$$I_{pv} = I_{ph} - I_{sat}\left[\frac{q(V_{pv} + I_{pv}R_s)}{AkT - 1}\right], \quad \textbf{(1)}$$

$$I_{ph} = \frac{\lambda}{1000}\left[I_{sc} + K_I(T - 25)\right], \quad \textbf{(2)}$$

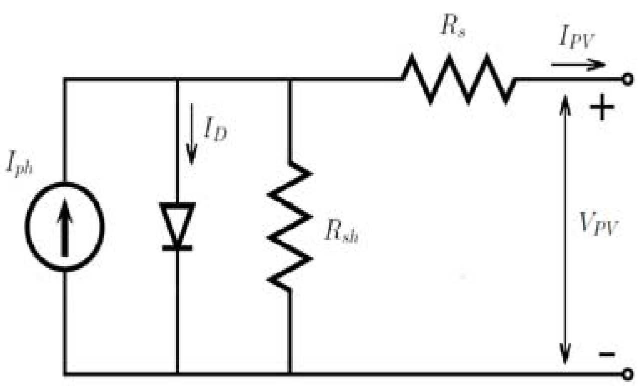

Fig.4: Equivalent circuit of a solar cell

where q is the charge of an electron (1.602 × 10−19*C*), λ is solar irradiance, *A* is the idealist factor of a p-n junction (1 or 2), *k* is the Boltzmans factor (1.381 × 10−23*J/K*), *T* is the temperature of the cell array and *Isc* and *KI* are the short-circuit current and the short-circuit current temperature respectively. The output power characteristics of the PV panel as functions of solar irradiance is shown in Fig.3.

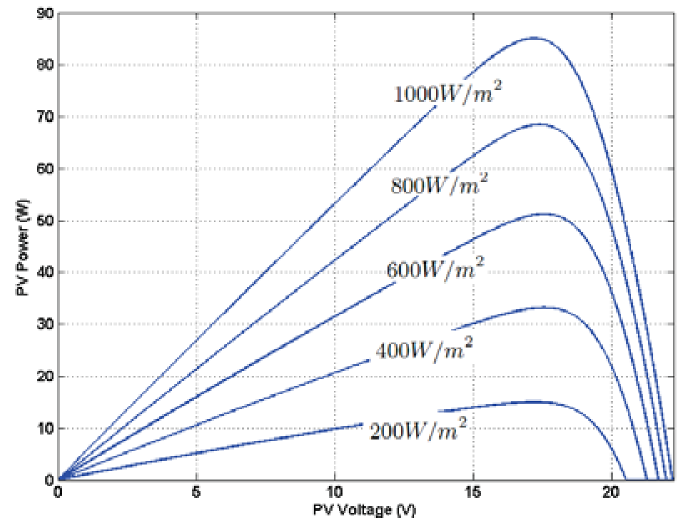

Fig. 5: P-V curve of the PV panel

VII. ARDUINO CONTROLLER

Arduino is an open-source physical platform based on microcontroller board having the ATmega32 series controllers and Integrated Development Environment for writing and uploading codes to the microcontroller. It has input and output pins for interaction with the outside world such as with sensors, switches, motors and so on. To be precise it has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller .It can take supply through USB or we can power it with an AC-to-DC adapter or a battery Arduino acts as the processing module of the system. It takes input from the LDR, process the data and gives the output to LEDS directly or through a relay and a transistor mechanism.

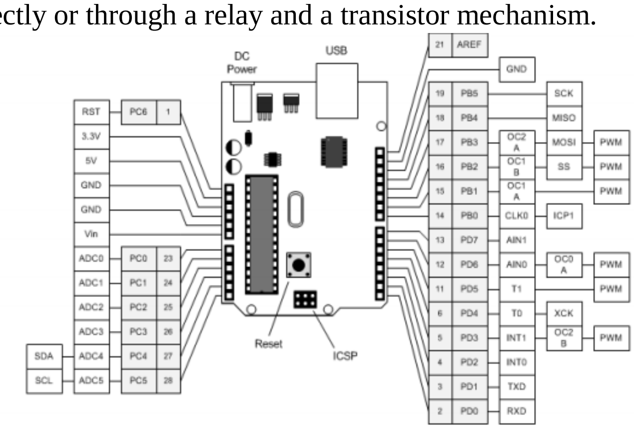

Fig.6 Architecture of Arduino UNO Controller

It has everything that is needed to support the microcontroller. Simply connect it to the computer with a USB cable to get started with the Arduino Uno board. It is flexible, easy to use hardware and software. Arduino Uno can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators.

VIII. SOFTWARE USED

The program is written in Arduino Integrated Development Environment (IDE) as shown in figure 6 . Here, the version used is 1.6.1.It connects to the Arduino hardware to upload programs. But before uploading the program there is a need to select appropriate Microcontroller so, "Arduino Uno" from the Tool menu has been chosen. And for proper communication with computer and Arduino Uno boards there is a need to select COM port from the Tool menu.

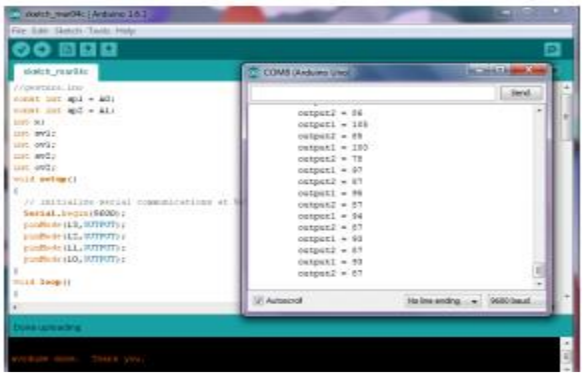

Fig.7: Arduino IDE

IX. SYSTEM CONFIGURATION

The proposed system consists of a solar PV array, dc-dc converter, voltage source inverter, BLDC motor and a pump load. Solar energy is tracked by the solar PV array whose efficiency is maintained by an MPPT system. The unregulated dc voltage at the output of PV system is made a regulated dc voltage by means of a dc-dc converter. Duty ratio of switch in the converter is controlled by MPPT technique. Switching pulses for inverter is generated according to back emf using a truth table. Switching pulse for buck- boost converter is generated by MPPT algorithm. DC link capacitor replaces a ceramic capacitor and a switch with anti-parallel diode between converter and inverter. This is done as a method to reduce the overall cost of BLDC motor drive with dc link capacitor.

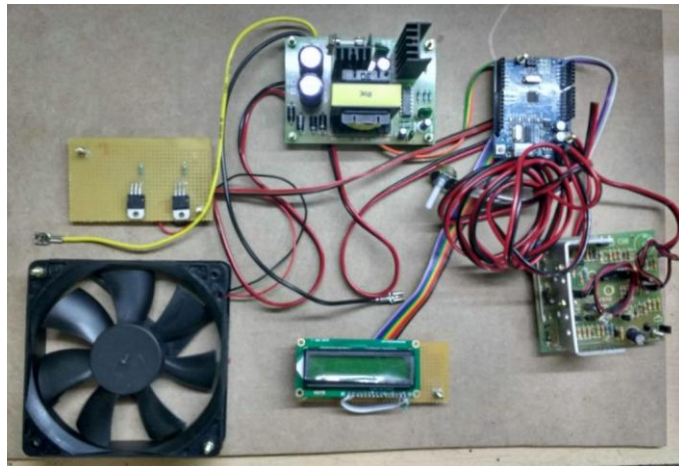

Fig. 8 Hardware Diagram of Zeta Converter based High Speed Motor

X. CONCLUSION

This project will be helpful in maintaining the power factor of an industry. By adopting this project, mutual benefit is gained over consumer and Electricity Board. This paper deals with advance method of power factor correction by using microcontroller. As Switching of capacitors are done automatically hence we get more accurate result, Power factor correction techniques makes system stable and due to improvement in power factor its efficiency also increases. Power factor correction scheme can be applied to industries, power systems as well as in house hold purpose. The project is economically beneficial one. Care should be taken for overcorrection otherwise the voltage and current becomes more due to which the power system or machine becomes unstable and the life of capacitor banks reduces.

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