



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

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International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 10, October 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.569



BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter

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ABSTRACT: This system proposes a simple, cost effective and efficient brushless DC (BLDC) motor drive for solar photovoltaic (SPV) array fed water pumping system. A zeta converter is utilized in order to extract the maximum available power from the SPV array. The proposed control algorithm eliminates phase current sensors and adapts a fundamental frequency switching of the Z source inverter (ZSI), thus avoiding the power losses due to high frequency switching. No additional control or circuitry is used for speed control of the BLDC motor. The speed is controlled through a variable DC link voltage of ZSI. An appropriate control of ZETA converter through the perturb and observer conductance maximum power point tracking (INC-MPPT) algorithm offers soft starting of the BLDC motor. The proposed water pumping system is designed and modelled such that the performance is not affected under dynamic conditions. The suitability of proposed system at practical operating conditions is demonstrated through simulation results using MATLAB Simulink followed by an experimental validation.

KEYWORDS: BLDC Motor, Converter, Water Pump

I. INTRODUCTION

The classic boost converter is not a good choice for the high step-up conversion due to following three reasons. Firstly, an extremely high duty-cycle must be used to obtain the steep conversion ratio, which causes serious losses on the power devices due to their parasitic parameters. Secondly, low on-resistance active switches and good performance diodes cannot be adopted due to the high voltage stress. Third, the reverse-recovery problem of the output diode is severe due to its short conduction time. All these three factors degrade the efficiency and limit the power level. So, after invention of power semiconductor devices these problems can be overcome. Consequently, a large number of inverters are invented but key components in all these power electronic devices. Particularly in hybrid, electric, and fuel cell vehicles, the Insulated Gate Bipolar Transistors (IGBTs), freewheeling diodes and advanced power module technology are used². After that a Novel PWM scheme was invented for controlling the output of an inverter with improved fundamental component value. The main advantage of this approach is that it adopts a consistent strategy for the entire range of modulation index i.e. it does not require any mode change and also causes exactly same number of switching per cycle³. The appreciable improvement in THD in the lower range of modulation depth attracts drive applications where low speed operation is required. Traditional VSI and CSI inverter are frequently used for speed control of machine.

The Z-source inverter system employs a unique LC network in the DC link and a small Capacitor on the AC side of the diode front end. By controlling the shoot-through duty cycle, the Z-source can produce any desired output AC voltage, even greater than the line voltage. The new Z-source inverter system provides ride-through capability during voltage sags, reduces line harmonics, improves power factor and reliability, and extends output voltage range.

The Z-source inverter based adjustable speed drive system has certain limitations and problems they are i) The Source network inductor has the limited value to guarantee the input current $I_n > 0$. In some applications, the inductance should be minimized in order to reduce cost, volume, and weight. The design of Z-source network inductor and system Z-source inverter based adjustable speed drive system. The DC-link voltage is increasing infinitely when the system is operated with light load. The DC-link voltage will be uncontrollable, and the system is unstable. The original Z-source inverter adjustable speed drive system cannot obtain the high performance due to its light-load operation limitation the

conventional 3- phase Pulse Width Modulation (PWM) inverter and a 3-phase PWM inverter with a dc-dc boost converter, which is also very popular in other applications. Because of the wide voltage range and limited voltage level of fuel cell stack, the conventional.

II. PROPOSED SYSTEM

The proposed PFC-based bridgeless ZETA (BL-ZETA) converter-fed BLDC motor drive. A single-phase Supply followed by a filter and a BL-ZETA converter is used to feed a VSI driving a BLDC motor. The BL-ZETA converter is designed to operate in DICM to act as an inherent power factor Pre regulator. This allows VSI to operate at fundamental frequency switching (i.e., electronic commutation of the BLDC motor) and hence has low switching losses in it, which are considerably high in a PWM-based VSI feeding a BLDC motor. The proposed scheme is designed, and its performance is simulated for achieving an improved power quality at ac mains for a wide range of speed Control and supply voltage variations. Finally, the simulated Performance of the proposed drive is validated with test results on a developed prototype of the drive.

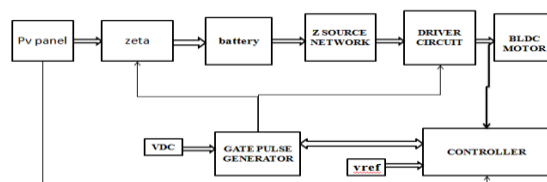


Fig 1. Block diagram of proposed system

A. Arduino UNO R3 Microcontroller

The Arduino Uno R3 is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. Revision 2 of the Uno board (A000046) has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.

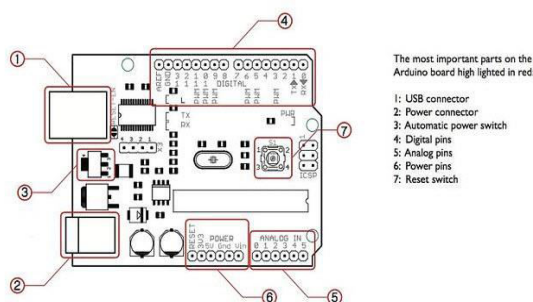


Fig 2. Arduino UNO R3 microcontroller

B. Relay

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another. Relays were used extensively in telephone exchanges and early computers to perform logical operations.



C. Solar Panel

Solar panel is a device which consists of combination of many photovoltaic cells. These photovoltaic cells are used to convert the solar energy (or) sun light into direct current electricity. These cells use photons to have electricity. The cells in the panel are connected one another in series to the desired voltage and they also connected in parallel to increase amps. The performance of the solar panel is based on the time of day. Difference in current and voltage may affect the performance of the solar panel. Solar panels are used in wide variety such as telecommunications, remote sensing. The power in the solar panel is drawn from the battery to the inverter which converts the dc current to ac current. Solar panel gives clean renewable energy to the users. The solar panel consist of different layers such as silicon, phosphorous and boron. Phosphorous that provides the negative charge and Boron provides the positive charge. The photovoltaic effect is the main process of the solar panel to generate the electricity. Here the photons from the sun striking the surface of the solar panel which allows the electrons to pass through the panel. Solar panels produce enough electricity to supply all of its power.

D. Voltage-Source Inverter

The three-phase voltage-source inverter structure. A dc voltage source supported by a relatively large capacitor feeds the 3-phase inverter circuit. The dc voltage source can be a battery, fuel-cell stack, diode rectifier, and/or capacitor. Six switches are used in the main circuit each is traditionally composed of a power transistor and an ant parallel (orrecwheeling) diode to provide idirectional current flow and unidirectional voltage blocking capability. It has certain limitation of the voltage source inverter. The ac output voltage is limited below and cannot exceed the dc voltage. The v-source inverter is a buck (step-down) inverter for dc-to-ac power conversion. The upper and lower devices of each phase leg should not be gated on simultaneously because a shoot-through would occur and destroy the devices. The shoot-through problem by electromagnetic interference (emi) noise's misstating-on is a major killer to the converter's reliable

E. Variable Reluctance (V_r) Wheel Speed Sensors

This kind of sensor is used to measure position and speed of moving metal components, and is often referred as a passive magnetic sensor because it does not need to be powered. It consists of a permanent magnet, a ferromagnetic pole piece, a pickup coil, and a rotating toothed wheel, as Figure illustrates. This device is basically a permanent magnet with wire wrapped around it. It is usually a simple circuit of only two wires where in most cases polarity is not important, and the physics behind its operation include magnetic induction.

III. SIMULATION

MATLAB (Matrix Laboratory) is a special-purpose computer program optimized to perform engineering and scientific calculations. It is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB is a multi-paradigm numerical computing environment and fourth-generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.

MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java.

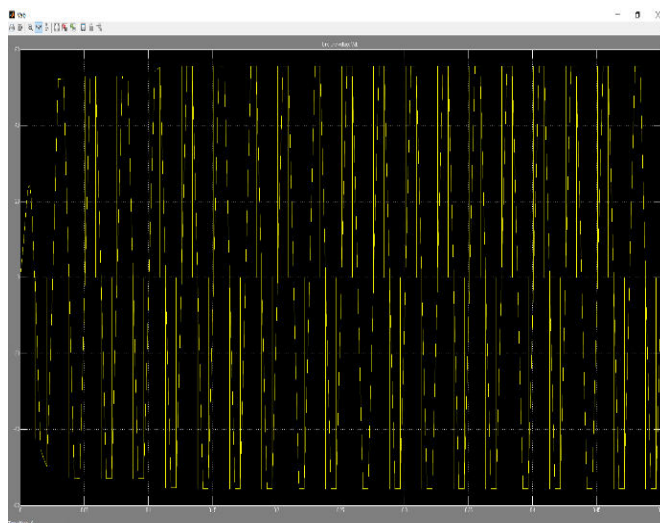


Fig 3. Line to Line Voltage

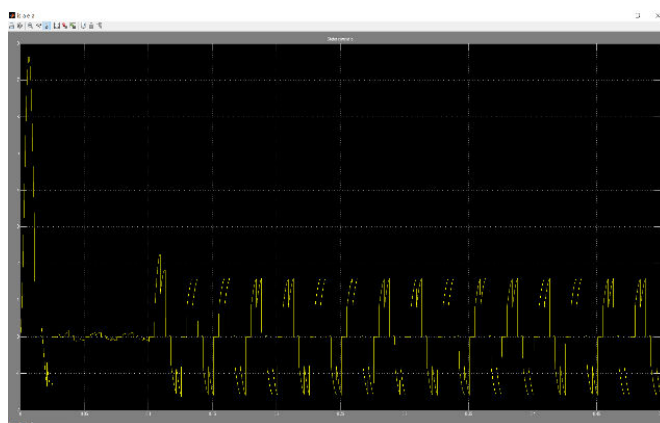


Fig 4. Stator Current

IV.HARDWARE IMPLEMENTATION

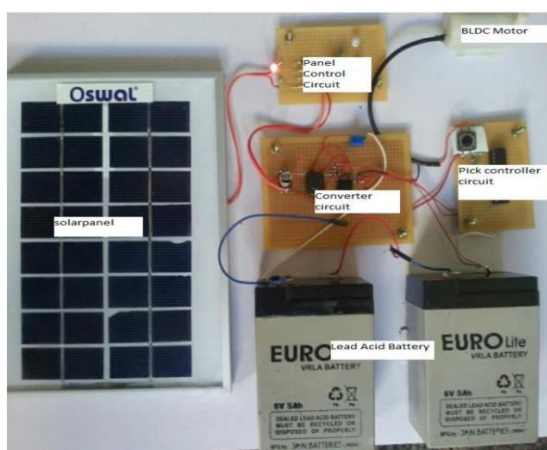


Fig 5. Hardware Setup



A zeta converter is utilized in order to extract the maximum available power from the SPV array. The proposed control algorithm eliminates phase current sensors and adapts a fundamental frequency switching of the Z source inverter (ZSI), thus avoiding the power losses due to high frequency switching. No additional control or circuitry is used for speed control of the BLDC motor. The speed is controlled through a variable DC link voltage of ZSI. An appropriate control of ZETA converter through the perturb and observer conductance maximum power point tracking (INC-MPPT) algorithm offers soft starting of the BLDC motor.

V. CONCLUSION

A PFC based BL-ZETA converter-fed BLDC motor drive has been proposed for a wide range of speeds and supply voltages. A single voltage sensor-based speed control of the BLDC motor using a concept of variable dc-link voltage has been used. The PFC BL-ZETA converter has been designed to operate in DICM and to act as an inherent power factor pre regulator. An electronic commutation of the BLDC motor has been used which utilizes a low-frequency operation of VSI for reduced switching losses. The proposed BLDC motor drive has been designed and its performance is simulated in MATLAB/Simulink environment for achieving an improved power quality over a wide range of speed control. Finally, the performance of the proposed drive has been verified experimentally on a developed hardware prototype. A satisfactory performance of the proposed drive has been achieved and is a recommended solution for low-power applications.

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