A Novel Zeta DC-DC Converter Based Closed Loop Control of BLDC Motor for SPV fed Water Pumping System

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Abstract: This paper pesents Novel zeta DC-DC Converter Based Closed Loop Control of BLDC Motor for SPV fed Water Pumping System Solar Photovoltaic (SPV) Array fed Water pumping System Utilizing Buck-boost DC-DC Converter in order to extract the maximum available power from Solar system. Solar energy has the greatest availability compared to other energy sources. For such solar PV systems, maximum power point tracking control is preferred for efficient operation. This concept is dealing with INC method which is one of the MPPT methods. This study deals with a buck–boost converter controlled solar photovoltaic (SPV) array fed water pumping in order to achieve the maximum efficiency of an SPV array and the soft starting of a permanent magnet brushless DC (BLDC) motor. The current sensors normally used for speed control of BLDC motor are completely eliminated. The speed of BLDC motor is controlled through the variable DC-link voltage of a voltage-source inverter (VSI). The VSI is operated by fundamental frequency switching, avoiding the losses due to high-frequency switching, in order to enhance the efficiency of the proposed system.

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INTRODUCTION

Severe environmental protection regulations, shortage of fossil fuels and eternal energy from the sun have motivated the researchers towards the solar photovoltaic (SPV) array generated electrical power for various applications [1]. Water pumping is receiving wide attention now a days amongst all the applications of SPV array. To enhance the efficiency of SPV array and hence the whole system regardless of the operating conditions, it becomes essential to operate SPV array at its maximum power point by means of a maximum power point tracking (MPPT)algorithm [2-4]. Various DC-DC converters have been already employed to accomplish this action of MPPT. Nevertheless, a Zeta converter [5-9] based MPPT is still unexplored in any kind of SPV array based applications. An incremental conductance (INC) MPPT algorithm [2] is used in this work in order to generate an optimum value of duty cycle for the IGBT(Insulated Gate Bipolar Transistor) switch of Zeta converter such that the SPV array is constrained to operate at its MPP. Various configuration of Zeta converters such as self-lift circuit, re-lift circuit, triplelift circuit and quadruple-lift circuit using voltage lift (VL) technique have been reported in aforementioned topologies have high voltage transfer gain but at the cost of increased number of components and switching devices. Therefore, these topologies of Zeta converter do not suit the proposed water pumping system. The PV inverters dedicated to the small PV plants must be characterized by a large range for the input voltage in order to accept different configurations of the PV field. This capability is assured by adopting inverters based on a double stage architecture where the first stage, which usually is a dc/dc converter, can be used to adapt the PV array voltage in order to meet the requirements of the dc/ac second stage, which is used to supply an ac load or to inject the produced power into the grid. This configuration is effective also in terms of controllability because the first stage can be devoted to track the maximum power from the PV array, while the second stage is used to produce ac current with low Total Harmonic Distortion (THD). BLDC motors are preferred over DC motors and induction motors due to their advantages like long operating life, higher efficiency, low maintenance and better speed torque characteristics. Stator windings of BLDC motors are energized in a sequence from an inverter. A bulkier DC link capacitor is connected in between the dc-dc converter and inverter to get a constant voltage at the input of inverter, thus to make the voltage ripple free. But the DC link capacitor is bulkier in size and its life time is affected by operating temperature. Moreover the cost is about 5-15% of overall cost of BLDC motor drive. As an attempt to reduce the cost of motor, DC link capacitor can be eliminated at the expense of torque ripple. Thus a new torque ripple compensation technique is proposed to compensate for the torque ripple associated with the elimination of the DC link capacitor. In this method, torque ripple compensation technique is proposed to a solar PV array fed DC link capacitor free BLDC motor. The permanent magnet brushless DC (BLDC) motor is employed to drive a centrifugal water pump coupled to its shaft. The BLDC motor is selected because of its merits [7,9] useful for the development of suitable water pumping system. This electronically commutated BLDC motor [9-11] is supplied by a voltage source inverter (VSI) which is operated by fundamental frequency switching resulting in low switching losses [12-15]. Suitability of the proposed SPV array fed water pumping system subjected to various operating and environmental conditions is demonstrated by satisfactory simulated results using MATLAB/Simulink environment. The existing literature exploring SPV array-based BLDC motor-driven water pump is based on a configuration shown in Fig.1. A dc–dc converter is used for MPPT of an SPV array as usual. Two phase currents are sensed along with Hall signals feedback for control of BLDC motor, resulting in an increased cost. The additional control scheme causes increased cost and complexity, which is required to control the speed of BLDC motor. Moreover, usually a voltage-source inverter (VSI) is operated with highfrequency PWM pulses, resulting in an increased switching loss and hence the reduced efficiency.

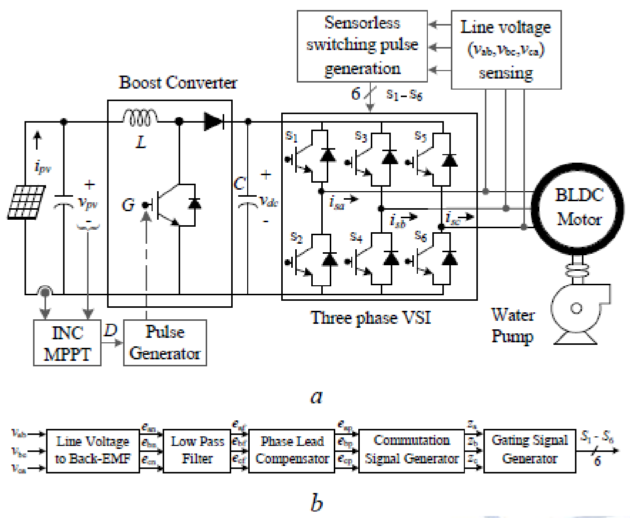


Fig. 1 Configuration of the conventional SPV array fed BLDC motor driven water pumping system
(a) Configuration, ***(b)*** Functional sequence of back-EMF zero-crossing based sensorless technique

SYSTEM MODELING

The various operating stages of the configuration shown in Fig. 1b such as the SPV array, the boost converter and the water pump are designed such that a satisfactory operation is always accomplished under any kind of change in solar isolation level. A BLDC motor of 1.3 kW rated power is selected and each stage of the proposed system are designed accordingly, as follows.

Design of SPV array

An SPV array of 1.5 kW peak power capacity, somewhat more than required by the motor, is selected so that the performance of the system is not affected by the losses associated with the converters and the motor. The parameters of the SPV array are estimated at the standard solar isolation level of 1000 W/m2. A PV module AP- 100, manufactured by Astro power Inc. [49] with peak power of 100 W, maximum voltage of 16.1 V and maximum current of 6.2 A is considered to design an SPV array of required capacity. First of all, the voltage of the SPV array at MPP is selected in view of the DC voltage rating of the BLDC motor same as DC-link voltage of the VSI. Selecting this voltage as *Vmpp* = vpv = 241.5 V, the other parameters are estimated as:

The current at MPP

$$I_{\text{mpp}} = i_{\text{pv}} = \frac{p_{\text{pv}}}{v_{\text{pv}}} = 1500/241.5 = 6.2\ \text{A}$$

where ppv = Pmpp = 1500 W is the peak power capacity.

Numbers of modules connected in series are as

$$N_s = \frac{V_{\text{mpp}}}{V_{\text{m}}} = 241.5/16.1 = 15$$

$$N_p = \frac{I_{\text{mpp}}}{I_{\text{m}}} = 6.2/6.2 = 1$$

where Vm and Im are voltage and current of a module at MPP.

Design of ZETA CONVERTER

The proposed converter is based on DC-DC converter to maintain the constant output voltage. The sixth DC-DC converter that we will study now was developed at the end of the 1980s, separately by Kazimierczuk, under the name of Dual SEPIC, and Barbi, under the name of Zeta converter (from the sixth letter of the Greek alphabet, to correspond to the "sixth" converter). Zeta is a fourth order DC-DC converter. Zeta converter will vary above or below the input voltage without change in output polarity. A Zeta is similar to a BUCK – BOOST converter but has advantages of having non-inverted output (the output voltage is of the same polarity as the input voltage). The inductors and the capacitors can also have large effects on the converter efficiency and ripple voltage. This converter transfers the energy between the inductance and the capacitance in order to change from the voltage to another. The transferred energy is controlled by switching device S (MOSFET).

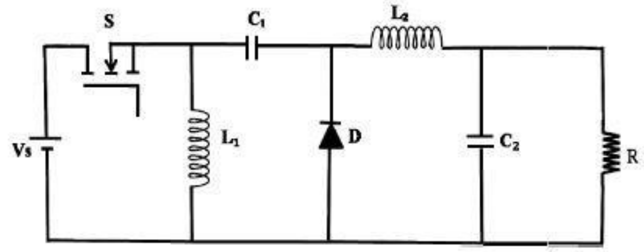


Fig.2.Schematic Diagram of Zeta Converter

OPERATION OF PROPOSED SYSTEM:

The SPV array generates the electrical power demanded by the motor-pump. This electrical power is fed to the motor pump via a zeta converter and a VSI. The SPV array appears as a power source for the zeta converter as shown in Fig.9. Ideally, the same amount of power is transferred at the output of zeta converter which appears as an input source for the VSI. In practice, due to the various losses associated with a dc–dc converter, slightly less amount of power is transferred to feed the VSI. The pulse generator generates, through INCMPPT algorithm, switching pulses for insulated gate bipolar transistor (IGBT) switch of the zeta converter. The INC-MPPT algorithm uses voltage and current as feedback from SPV array and generates an optimum value of duty cycle. Further, it generates actual switching pulse by comparing the duty cycle with a high-frequency carrier wave. In this way, the maximum power extraction and hence the efficiency optimization of the SPV array is accomplished. The VSI, converting dc output from a zeta converter into ac, feeds the BLDC motor to drive a water pump coupled to its shaft. The VSI is operated in fundamental frequency switching through an electronic commutation of BLDC motor assisted by its built-in encoder. The high frequency switching losses are thereby eliminated, contributing in an increased efficiency of proposed water pumping system.

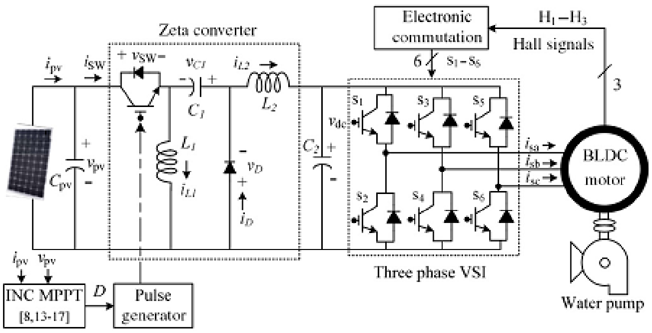


Fig.3. Proposed SPV-zeta converter-fed BLDC motor drive for water pump

SIMULATION RESULTS:

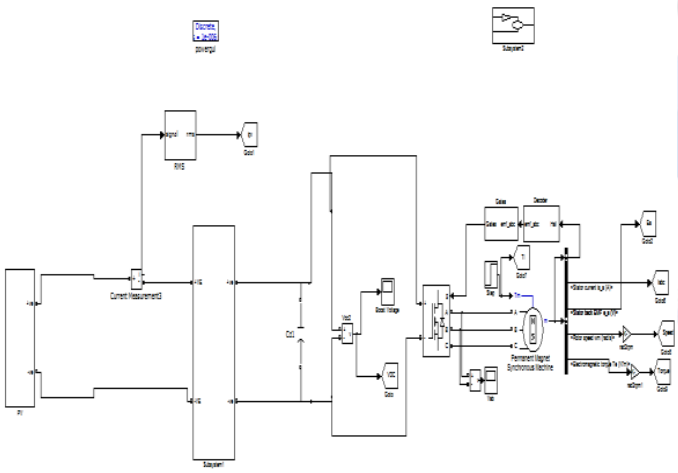
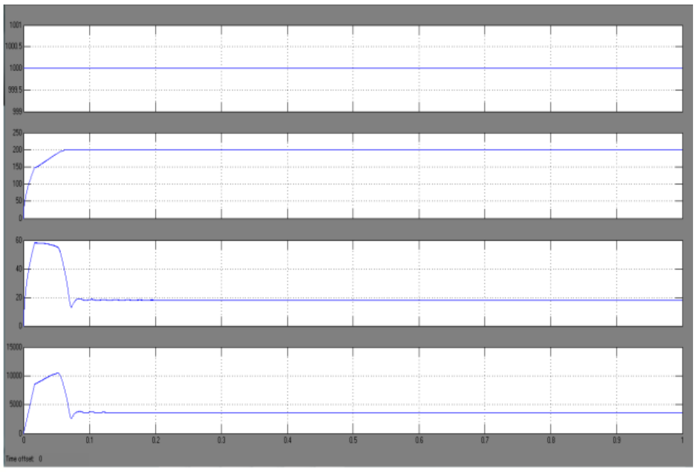
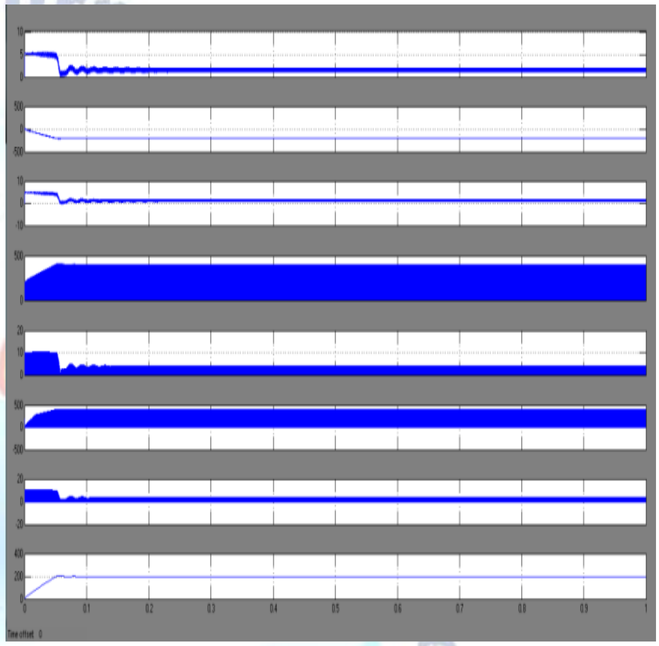


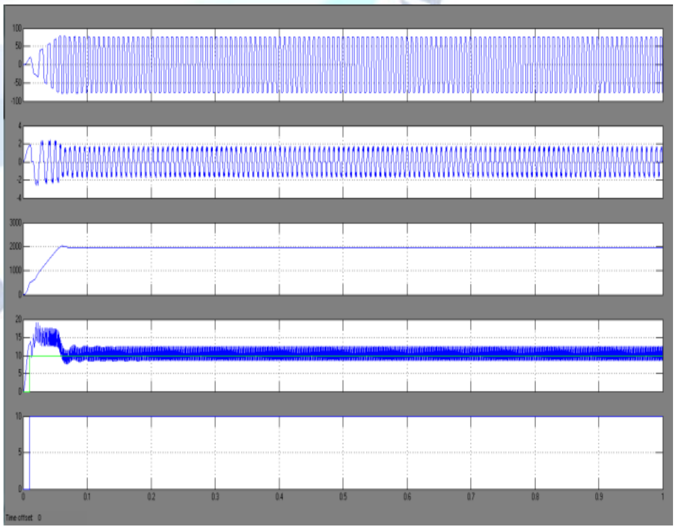
Fig. Fig 4 Matlab/Simulink circuit of Starting and steady-state performances of the proposed SPV array based zeta converter-fed BLDC motor drive for water pump



(a)



(b)



(c)

Fig.5 Starting and steady-state performances of the proposed SPV array based zeta converter-fed BLDC motor drive for water pump. (a) SPV array variables. (b) Zeta converter variables. (c) BLDC motor-pump variables.

CONCLUSION:

A solar photovoltaic array fed Zeta converter based BLDC motor has been proposed to drive water-pumping system. The proposed system has been designed, modeled and simulated using MATLAB along with its Simulink and simpower system toolboxes. Simulated results have demonstrated the suitability of proposed water pumping system. SPV array has been properly sized such that system performance is not influenced by the variation in atmospheric conditions and the associated losses and maximum switch utilization of Zeta converter is achieved. Zeta converter has been operated in CCM in order to reduce the stress on power devices. Operating the VSI in conduction mode with fundamental frequency switching eliminates the losses caused by high frequency switching operation. Stable operations of motor-pump system and safe starting of BLDC motor are other important features of the proposed system.

REFERENCES

[1]. Banaei, M.R., Ardi, H., Alizadeh, R., et al.: 'Non-isolated multi-input–single-output DC/DC converter for photovoltaic power generation systems', IETPower Electron., 2014, 7, (11), pp. 2806–2816

[2]. Singh, B., Shahani, D.T., Verma, A.K.: 'Neural network controlled grid interfacedsolar photovoltaic power generation', IET Power Electron.,2014,7,(3),pp.614–626

[3]. Kim, K.-T., Kwon, J.-M., Kwon, B.-H.: 'Parallel operation of photovoltaic power conditioning system modules for large-scale photovoltaic power generation', IET Power Electron., 2014, 7, (2), pp. 406–417

[4]. Bendib, B., Belmili, H., Krim, F.: 'A survey of the most used MPPT methods: conventional and advanced algorithms applied for photovoltaic systems', Renew. Sustain. Energy Rev., 2015, 45, pp. 637–648

[5]. Subudhi, B., Pradhan, R.: 'A comparative study on maximum power point tracking techniques for photovoltaic power systems', IEEE Trans. Sustain.Energy,2013,4,(1),pp.89–98

[6]. de Brito, M.A.G., Galotto, L., Sampaio, L.P., et al.: 'Evaluation of the main MPPT techniques for photovoltaic applications', IEEE Trans. Ind. Electron.,2013,60,(3), pp. 1156–1167

[7]. Bastidas-Rodriguez, J.D., Franco, E., Petrone, G., et al.: 'Maximum power point tracking architectures for photovoltaic systems in mismatchingconditions:areview', IET Power Electron., 2014, 7, (6), pp. 1396–1413

[8]. Tey, K.S., Mekhilef, S.: 'Modified incremental conductance algorithm for photovoltaic system under partial shading conditions and load variation', IEEE Trans. Ind. Electron., 2014, 61, (10), pp. 5384–5392

[9]. Killi, M., Samanta, S.: 'Modified perturb and observe MPPT algorithm for drift avoidance in photovoltaic systems', IEEE Trans. Ind. Electron., 2015,62,(9),pp.5549–5559

[10]. Espinoza-Trejo, D.R., Barcenas-Barcenas, E., Campos-Delgado, D.U., et al.: 'Voltage-oriented input–output linearization controller as maximum power point tracking technique for photovoltaic systems', IEEETrans.Ind.Electron.,2015,62,(6),pp.3499–3507

[11]. Faraji, R., Rouholamini, A., Naji, H.R., et al.: 'FPGA-based real time incrementalconductance maximum power point tracking controller for photovoltaic systems', IET Power Electron., 2014, 7, (5), pp. 1294–1304

[12]. Renaudineau, H., Donatantonio, F., Fontchastagner, J., et al.: 'A PSO-based global MPPT technique for distributed PV power generation', IEEE Trans. Ind. Electron., 2015, 62, (2), pp. 1047–1058

[13]. Sitbon, M., Schacham, S., Kuperman, A.: 'Disturbance observer-based voltage regulation of current-modeboost-converter-interfaced photovoltaic generator', IEEE Trans. Ind. Electron., 2015, 62, (9), pp. 5776–5785