MATLAB SIMULATION OF BLDC MOTOR DRIVEN SPV ARRAY FED WATER PUMPING SYSTEM EMPOLYING ZETA CONVERTER WITH GRID CONNECTED

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ABSTRACT

The paper produces a cost effective solution for low power consuming using Solar Based Photovoltaic (SPV) array supplied water pumping framework using zeta converter as an interconnected DC to DC converter to get more power from solar panel. The zeta converter's controlled using Incremental Conductance, Maximum Power Point Tracking (INC-MPPT). This is used to smooth running of brushless direct current machine connected to centrifugal water pump connected through shaft. Smooth running i.e. which reduces starting machine drawing the high current is reduced in windings of the BLDC machine. The switching frequency of the voltage source inverter is controlled by electronic commutation of brushless direct current machine reduces the VSI losses of high switching frequency. The DC link capacitor is connected across the VSI. The project designed such that operate under variable conditions like irradiation, voltage, power. Here the model is produced new modification approach for the improved version of the system. It is synchronized with grid supply; grid is a bus which connects two or more power house, power networks with same frequency, phase sequence, terminal voltage. It is designed using matlab/simulink software

Keyword: *SPV array, Zeta converter, INC-MPPT, BLDC motor, Electronic commutation, Grid*

1 .INTRODUCTION

This paper presents the insight on the present scenarios in SPV power generation systems and BLDC motor. It gives the motivational factors for taking up the project. Objectives and literature survey carried out for the project are described.

Nowadays, the scope of conventional energy sources for the generation of electricity is getting vast due to its considerable advantages. It is evident that the standalone SPV systems are replacing conventional energy sources. Drastic reduction in the cost of power electronic devices and annihilation of the fossil fuels in near future invite to use the Solar Photovoltaic (SPV) generated electrical energy for various applications as far as possible. Water pumping, a standalone application of the SPV array generated electricity is receiving wide attention now a days for irrigation in the fields, household applications and industrial usage. 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. However, the zeta converter has been used in some other SPV based applications. The merits of both

The BLDC motor and zeta converter can contribute to develop a favourable SPV array Fed water pumping system possessing the potential of operating satisfactorily under the dynamically changing atmospheric conditions.

1.1 Paper Organization

This paper is organized as follows. Configuration of the proposed system is illustrated in section 1. Operation of the proposed system is illustrated in section 3. The control techniques used are briefly described in section 4. Finally, the performance of the proposed system is evaluated using the simulated results in section 5, followed by the concluding remarks in section 6.

2. CONFIGURATION OF THE PLANNED SCHEME

The formation of the planned Solar PV array supplied BLDC machine driven Water pumping framework utilizing a zeta converter is appeared in Fig.1.

Fig-1 :Configuration of proposed SPV array-Zeta converter fed BLDC motor drive for water pumping system without grid connection

As appeared in Fig.1, the planed framework comprises of the Solar-PV exhibit, the zeta converter, the VSI, the BLDC motor and the centrifugal water pump. The BLDC motor has an inbuilt encoder. The pulse originator is utilized to work the zeta converter. The regulated operation of the projected framework is accounted for in the accompanying segment in suitable element.

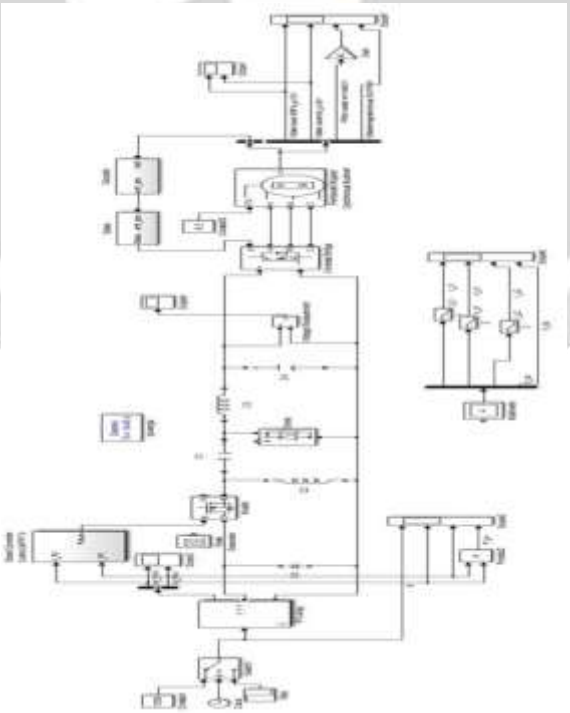

Fig -1I Matalab simulation circuit of BLDC machine drive SPV array fed Water pumping system without gird connection Name of the figure

3. OPERATION OF THE PROPOSED SYSTEM

The SPV array generates the electrical power demanded by the motor-pump system. This electrical power is fed to the motor-pump system via the zeta converter and the VSI. SPV array appears as the power source for the zeta converter as shown in Fig. 2. Ideally, the same amount of power is transferred at the output of zeta converter which appears as the input source for the VSI. In practice, due to the various losses associated with a DC-DC converter, slightly less amount of the power is transferred to feed the VSI. The pulse generator generates, through INC-MPPT algorithm, the switching pulse for the IGBT (Insulated Gate Bipolar Transistor) switch of the zeta converter.

The INC-MPPT algorithm takes the voltage and current variables as feedback from SPV array and returns an optimum value of duty cycle. Further, the pulse generator generates actual switching pulse by comparing the duty cycle with the high frequency carrier wave. In this way, the maximum power extraction and hence the efficiency optimization of the SPV array is accomplished. On the other hand, VSI converting the DC power output from the zeta converter into the AC power feeds the BLDC motor to drive the centrifugal pump coupled to its shaft. The VSI is operated by the fundamental frequency switching availed by the so called electronic commutation of BLDC motor assisted by its built-in encoder. The high frequency switching losses are thereby eliminated, contributing in the effective and increased efficiency operation of the proposed water pumping system.

Table -1:Electrical specifications the sun module plus sw280 Mono SPV section

Peak power, P_m(Watt)	280
Open circuit voltage, V_o(V)	39.5
Short circuit current, I_s(A)	31.2
Voltage at MPP, V_m(V)	9.71
Current at MPP, I_m(A)	9.07
Number of cells connected in series N_{ss}	60

3.1 MODIFIED BLDC MACHINE DRIVE SPV ARRAY FED WATER PUMPING SYSTEM WITH GIRD CONNECTION

The figure III shows the modified BLDC motor drive SPV array fed water pumping system which is similar to that of proposed system. Here SPV array is fed by irradiations which keep constant of 1000rad/sec, the SPV starts producing power or current in it. It is in DC supply is fed to zeta converter which controller measures the input output current & voltages interference recorders values. If these measures match then the INC-MPPT gives signals to trigger the MOSFET to control current which is passing through the capacitor, inductors, the output is kept constant so this circuit is called zeta converter which is similar to that of DC-DC, cuk, Buk-Boost, & SEPIC converters. The output of zeta converter filtered by capacitor the unwanted distortion in output voltage. The output voltage is fed to voltage source inverter to convert dc-ac then fed to BLDC machine. The BLDC is controlled by electronic commutation which is controls switching sequence operation one after another, here motor controlled by hall signals which are three hall signals controls six switches in the sequence order which is shown in above table I.

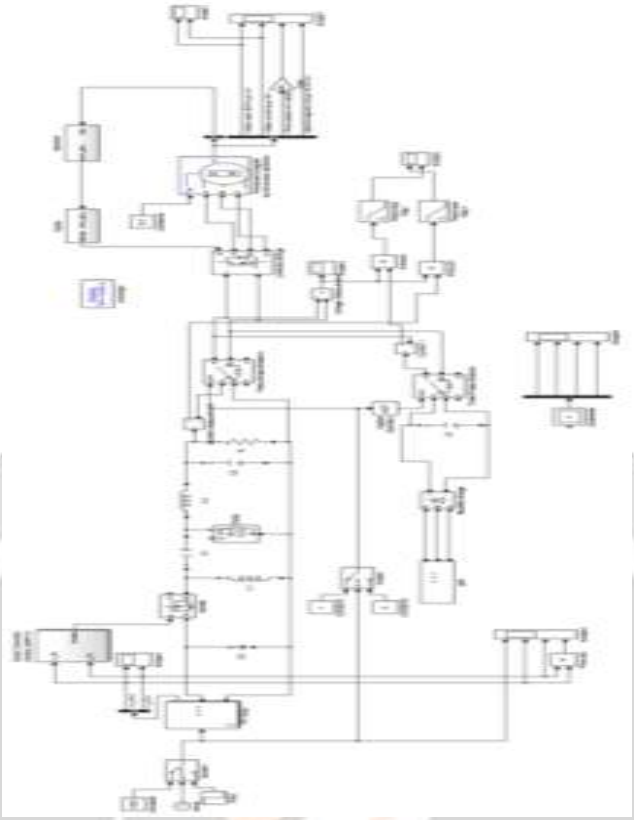

Fig –3: Modified BLDC machine drive SPV array fed Water pumping system with gird connection

4. CONTROL OF THE PROPOSED SYSTEM

The proposed system is controlled at two stages. These two control techniques namely; MPPT and electronic commutation are discussed in brief as follows.

4.1 INC-MPPT ALGORITHM

As was previously explained, MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array.

An efficient and commonly used INC-MPPT technique in various SPV array based applications is utilized in order to optimize the power available from the SPV array and to facilitate the soft starting of the BLDC motor. Selecting an optimum value of perturbation size ($\Delta D = 0.001$) not only avoids the oscillations around the MPP but provides the soft starting of the BLDC motor also. An intellectual agreement between the tracking time and the perturbation size is held to fulfil the objectives.

4.2 ELECTRONIC COMMUTATION

The BLDC motor is controlled by the VSI operated through the electronic commutation of BLDC motor. 6 switching pulses are generated as per the various possible combinations of 3 Hall-effect signals.

Table -1I: Switching sequence of brushless DC motor for electronic commutation based on the virtual hall signal

θ^0	Hall Signal			Switching Sequence					
	H_1	H_2	H_3	S_1	S_2	S_3	S_4	S_5	S_6
NA	0	0	0	0	0	0	0	0	0
0-60	0	-1	+1	0	0	0	1	1	0
60-120	-1	+1	0	0	1	1	0	0	0
120-180	-1	0	+1	0	1	0	0	1	0
180-240	+1	0	-1	1	0	0	0	0	1
240-300	+1	-1	0	1	0	0	1	0	0
300-360	0	+1	-1	0	0	1	0	0	1
NA	0	0	0	0	0	0	0	0	0

inbuilt encoder according to the rotor position. A particular combination of the Hall-effect signal is produced for specific range of rotor position. The electronic commutation provides fundamental frequency switching of the VSI, hence the losses associated with the high frequency switching is completely eliminated. TETRA 115TR9.2, a BLDC motor of motor power company with inbuilt encoder is selected for the proposed system and its detailed data are given in Appendix C.

The above table shows the switching sequence using hall signal angle of switching done in two modes 60^0 angle & 120^0 angle mode. When hall signal h_c is high the switch S_4-S_5 conducts similarly sequence is S_4-S_5, S_2-S_3, S_2-S_5, S_1-S_6, S_1-S_4 and S_3-S_6. This first logically designed and the implemented in the circuit.

A three-phase BLDC motor requires three Hall sensors to detect the rotor's position. Based on the physical position of the Hall sensors, there are two types of output a 60° phase shift and a 120° phase shift. Combining these three Hall sensor signals can determine the exact commutation sequence

5. RESULTS AND DISCUSSION

BLDC motor driven water pumping system employing zeta converter is carried out using simulated results in MATLAB/Simulink. The proposed system is designed, modelled and simulated considering the random and instant variation in solar irradiance level and its suitability is demonstrated by testing the starting, steady state and dynamic *behaviour*.

5.1.WORKING OF SPV ARRAY

The performance of the maximized power SPV array used to feed the water pumping system is shown in Fig.6.1. The solar irradiance level, S is other variables such as the SPV array voltage, Vpv, SPV array current, Ipv and the SPV array power, Ppv are varied accordingly. The presented results manifest that the maximum power available from the SPV array is extracted regardless of the irradiance level and its dynamic variation. Since it is desired to achieve the soft starting of the BLDC motor, the MPP is tracked appropriately at the starting

5.2.PERFORMANCE OF ZETA CONVERTER

This converter is the latest type of single-stage input current shapers. It also uses single switching device and inherently provides an overload, short circuit, and inrush current protections. Since zeta converters behave as a resistive load to input AC mains, these converters are also called resistance emulators. Zeta converter is fourth order converters that can step down or step up the input voltage. The ZETA converters also have a series capacitor sometimes called a flying capacitor and two inductors. The ZETA converter topology gives a positive output voltage from an input voltage.

The Zeta converter has many advantages, such as buck-boost capability, and continuous output current, input to output DC insulation, so it can be used in high reliability system. This topology offer high efficiency, especially by using the synchronous rectification. The synchronous rectification can be easily implemented in this converter, because this topology, unlike the SEPIC converter, uses a low-side rectifier.

5.3. PERFORMANCE OF BRUSHLESS DC MOTOR

The day by day increasing demand for energy can create problems for the power distributors, like grid instability. In recent years brushless dc (BLDC) motors are widely used applications including appliances, automotive, aerospace, consumer, medical, automated industrial equipment and instrumentation because of their high starting torque, high efficiency, reliability, lower maintenance compared to its brushed dc motor. In a BLDC motor, the rotor magnets generate the magnetic flux, so BLDC motors achieve higher efficiency. Therefore, BLDC motors may be used in high end white goods (refrigerators, washing machines, dishwashers, etc.), high-end fans, and pumps and in other appliances which require high reliability and efficiency. BLDC motors have many advantages over brushed DC motors and induction motors, like higher efficiency and reliability, lower acoustic noise, smaller and lighter, greater dynamic response, better speed versus torque characteristics, higher speed range, longer life. Since the specific torque is higher it can be very useful in the applications were space and weight are critical factors. And also the BLDC motor is electrically commutated by power switches instead of brushes it has so many advantages such as no brushes/commutator maintenance, no brush friction to reduce useful torque, no mechanical limitation imposed by brushes or commutator, no arcs from brushes to generate noise, causing EMI problems.

The BLDC motor drive is fed from single-phase ac supply through a diode bridge rectifier (DBR) followed by a high value of smoothening capacitor at dc link which draws a pulsed current, with a peak higher than the amplitude of the fundamental input current at ac mains due to an uncontrolled charging and discharging of the dc link capacitor. This causes in poor power quality (PQ) at ac mains in terms of poor Power Factor (PF), high Total Harmonic Distortion (THD) of ac mains current and high Crest Factor (CF). Therefore, a Power Factor Correction (PFC) converter is inevitable for Brushless DC Motor Drive in order to improve the power quality.

Performance of the BLDC motor-pump is shown in below figures.. Following points are clearly observed from the presented simulation result

- The motor pump variables viz. the back EMF, e_a, the stator current, I_{sa}, the rotor speed, N, the electromagnetic torque, T_e and the pump load torque, TL are abide by the variation in solar irradiance.
- At the starting, the rate of rise of stator current is decreased as an evidence of soft starting of the BLDC motor.
- The motor-pump variables reach their rated values under steady state at 1000 W/m2, standard value of solar irradiance. However, it should be highlighted that the motor always attains a higher speed than minimum speed required pumping the water i.e. 1100 rpm (even at 200 W/m2) regardless of the solar irradiance level.
- The electromagnetic torque developed by BLDC motor is same as torque required by the centrifugal pump. This torque balance between the BLDC motor and the centrifugal pump irrespective of the solar irradiance variation verifies the stable operation of the proposed system.

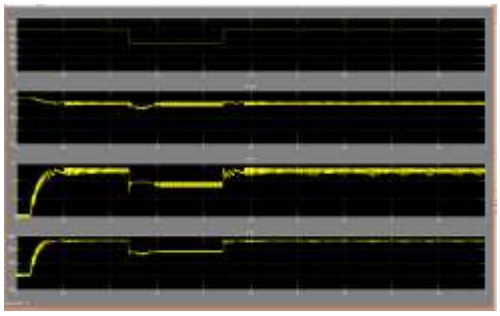

Fig-1: SPV array variable

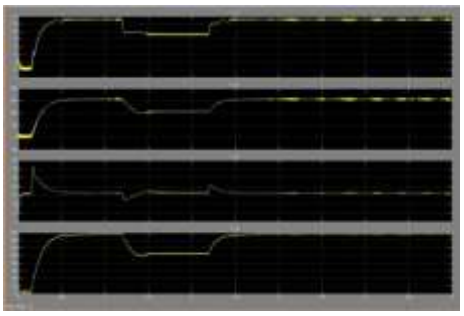

Fig-2: Exhibition of the zeta converter

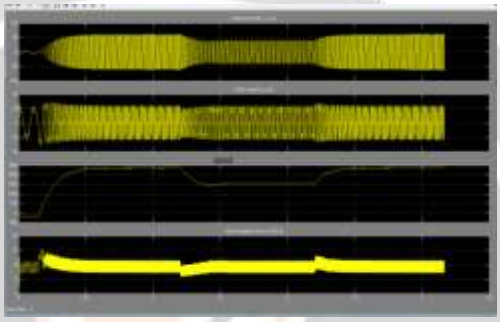

Fig-3: Output of modified system

Fig-3(a): Performance of the BLDC motor pump stator back EMF and current

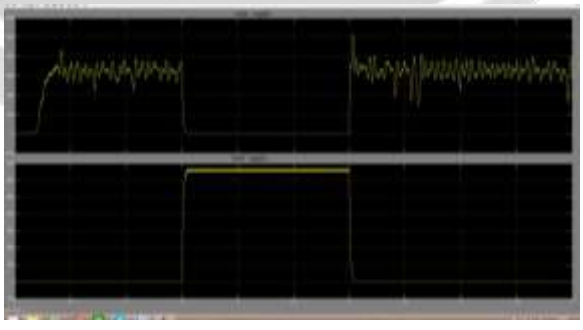

Fig-4: Solar supply & grid supply conduction wave form

4. CONCLUSIONS

The solar photovoltaic arrangement zeta converter supplied voltage source inverter-BLDC motor pump for water pumping has been proposed & modified are appropriateness have be verified by virtual results by means of Matlab/simulink and its sim power system toolbox.

- First the proposed system is designed logically to fulfil the various presentations under starting, dynamic, & steady state condition and also trial and error method.
- The performance evaluation has justified the combination of zeta converter and BLDC motor drive for SPV array based water pumping.
- The system under study availed the various desired functions such as MPP extraction of the SPV array, soft starting of the BLDC motor, fundamental frequency switching of the VSI resulting in a reduced switching losses, reduced stress on IGBT switch and the components of zeta converter by operating it in continuous conduction mode and stable operation.
- Moreover, the proposed system has operated successfully even under the minimum solar irradiance.
- Water pumping in villages or remote areas needs three phase supply which is not possible to supply continuously.
- So using these types of projects, we can supply the power with low cost low energy consumption motor with high speed response of the system.
- Here modified system is synchronized with grid supply which automatically connects to the gird when solar power is not available. Here it is easy to converter AC-DC & DC-AC and controlling because of low loss, low cost power electronic devices.

6. REFERENCES

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