ANFIS CONTROLLER BASED ZETA CONVERTER FED BLDC MOTOR INTERTIE WITH SOLAR PV FED WATER PUMPING SYSTEM

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ABSTRACT: In this paper we propose an ANFIS controller based BLDC motor drive for solar photovoltaic (SPV) array fed water pumping system. A novel dc-dc converter like zeta converter is exploiting 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 voltage source inverter (VSI), 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 VSI. An ANFIS control of zeta converter through the incremental conductance maximum power point tracking (INC-MPPT) algorithm offers soft starting of the BLDC motor. The proposed water pumping system is designed and modeled 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.

KEYWORDS: ANFIS controller, zeta converter, BLDC motor, solar photovoltaic (SPV).

I.INTRODUCTION: The drastic reduction within the value of power electronic devices and annihilation of fossil fuels in near destiny invite to use the sun photovoltaic (SPV) generated electric strength for numerous programs as a ways as possible. The water pumping, a standalone utility of the SPV array generated power is receiving extensive attention now a day for irrigation in the fields, household packages and commercial use. Although several researches had been completed in a place of SPV array fed water pumping, combining various DC-DC converters and motor drives, the zeta converter in association with a permanent magnet brushless DC (BLDC) motor isn't explored precisely so far to broaden such sort of machine. However, the zeta converter has been utilized in some other SPV based totally programs [1-3]. Moreover, a topology of SPV array fed BLDC motor pushed water pump with zeta converter has been stated and its importance has been provided more or less in [4]. Nonetheless, an experimental validation is lacking and the absence of vast literature assessment and contrasts with the prevailing topologies, have concealed the technical contribution and originality of the stated paintings.

The merits of both BLDC motor and zeta converter can contribute to develop a SPV array fed water pumping device owning a capacity of operating satisfactorily underneath dynamically changing atmospheric situations. The BLDC motor has excessive reliability, excessive efficiency, and excessive torque/inertia ratio, stepped forward cooling, low radio frequency interference and noise and calls for nearly no protection [5-6]. On the other hand, a zeta converter famous following benefits over the traditional buck, enhance, greenback-increase converters and Cuk converter whilst employed in SPV primarily based applications.

Belonging to a family of dollar-enhance converters, the zeta converter can be operated both to growth or to decrease the output voltage. This assets gives a boundless vicinity for maximum power factor monitoring (MPPT) of a SPV array [7]. The MPPT may be finished with easy greenback [8] and improve [9] converter if MPP occurs within prescribed limits. This asset additionally enables the smooth beginning of BLDC motor unlike a boost converter which habitually steps up the voltage degree at its output, not ensuring gentle beginning. Unlike a classical dollar-increase converter [10], the zeta converter has a continuous output modern. The output inductors make the current continuous and ripple free.

Although along with equal quantity of additives as a Cuk converter [11], the zeta converter operates as non-inverting dollar-enhance converter unlike an inverting dollar-boost and Cuk converter. This belonging obviates a requirement of associated circuits for poor voltage sensing consequently reduces the complexity and chance of sluggish down the gadget response [12]. These deserves of the zeta converter are favorable for proposed SPV array fed water pumping device. An incremental conductance (INC) MPPT set of rules [8, 13-18] is used to operate the zeta converter such that SPV array usually operates at its MPP.

The existing literature exploring SPV array based BLDC motor driven water pump [19-22] is based on a configuration shown in Fig. 1. A DC-DC converter is used for MPPT of a 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 high frequency PWM pulses, resulting in an increased switching loss and hence the reduced efficiency. However, a Z-source inverter (ZSI) replaces DC-DC converter in [22], other schematic of Fig. 1 remaining unchanged, promising high efficiency and low cost. Contrary to it, ZSI also necessitates phase current and DC link voltage sensing resulting in the complex control and increased cost.

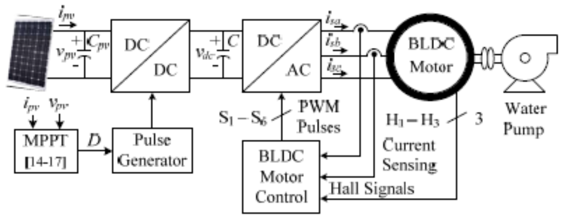


Fig. 1 Conventional SPV fed BLDC motor driven water pumping system [21].

II.LITERATURE REVIEW

1) A Photovoltaic Panel Emulator Using A Buck-Boost DC/DC Converter and A Low Cost Micro-Controller:

So as to encourage the plan and testing of photovoltaic (PV) control frameworks, a PV emulator which models the electrical normal for a PV board or array is required. Among various ways to deal with demonstrating PV trademark, specifically the I– V curve, bend fitting is a well known methodology. Despite the fact that a solitary high-request polynomial condition may precisely speak to the I– V curve, the procedure of induction and usage is fairly mind boggling. This paper thus proposes the utilization of piecewise direct methodology which is simpler to determine and actualize in a minimal effort miniaturized scale controller. A two-switch buck-boost DC/DC converter is chosen as the PV emulator and is examined. Test results on an equipment model of the proposed PV emulator are accounted for to demonstrate the viability of the methodology.

2) power factor correction in bridgeless-luo converter-fed bldc motor drive

This paper proposes a power factor correction (PFC) based bridgeless-Luo (BL-Luo) converter brushless DC (BLDC) motor drive. A single voltage sensor is utilized for the speed control of BLDC motor and PFC at AC mains. The voltage adherent control is utilized for a BL-Luo converter working in discontinues inductor current mode (DICM). The speed of the BLDC motor is constrained by a methodology of variable DC connect voltage, which permits a low frequency exchanging of voltage source inverter (VSI) for electronic substitution of BLDC motor; along these lines offers diminished exchanging misfortunes. The proposed BLDC motor drive is intended to work over a wide scope of speed control with an improved power quality at AC mains. The power quality lists in this way acquired are under the prescribed furthest reaches of IEC 61000-3-2.

III.PROPOSED METHOD:

The SPV exhibit creates the electrical power requested by the motor pump. This electrical power is sustained to the motor pump by means of a zeta converter and a VSI. The SPV exhibit shows up as a power hotspot for the zeta converter as appeared in Fig. 2. In a perfect world, a similar measure of intensity is exchanged at the yield of zeta converter which shows up as an info hotspot for the VSI. By and by, because of the different misfortunes related with a DC-DC converter [23], marginally less measure of influence is exchanged to bolster the VSI. The beat generator creates, through INC-MPPT calculation, exchanging beats for IGBT (Insulated Gate Bipolar Transistor) switch of the zeta converter. The INC-MPPT calculation utilizes voltage and present as input from SPV exhibit and creates an ideal estimation of obligation cycle. Further, it creates real exchanging heartbeat by contrasting the obligation cycle and a high frequency carrier wave. Along these lines, the Max power extraction and consequently the proficiency improvement of the SPV exhibit is cultivated.

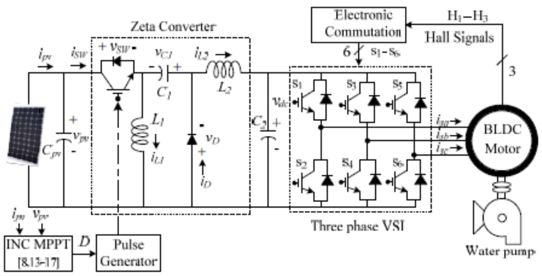


Figure 2.Proposed diagram

The VSI, changing over DC yield from a zeta converter into AC, encourages the BLDC motor to drive a water pump coupled to its pole. The VSI is worked in principal recurrence exchanging through an electronic substitution of BLDC motor helped by its implicit encoder. The high frequency switching losses are subsequently wiped out, contributing in an expanded effectiveness of proposed water pumping framework.

Different working stages appeared in Fig 2, are appropriately structured so as to build up a compelling water pumping framework, equipped for working under questionable conditions. A BLDC motor of 2.89 kW control rating and a SPV cluster of 3.4 kW top power limit under standard test conditions (STC) are chosen to structure the proposed framework. The general structure of different stages, for example, SPV exhibit, zeta converter and water pump are depicted as pursues.

A. Design of SPV Array

According to above dialog, the viable converters are related with different power misfortune also, the exhibition of BLDC motor pump is affected by related mechanical and electrical losses. To repay these misfortunes, the size of SV exhibit is chosen with.

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

B. Design of Zeta Converter

The zeta converter is the following phase of SPV cluster. Its structure comprises of an estimation of different segments, for example, input inductor, L1, yield inductor, L2 and middle of the road capacitor, C1. These segments are structured with the end goal that the zeta converter dependably works in CCM bringing about diminished weight on its segments and gadgets. An estimation of the duty cycle, D starts the structure of zeta converter which is assessed as,

$$D = \frac{V_{dc}}{V_{dc} + V_{mpp}} = \frac{200}{200 + 187.2} = 0.52$$

Where Vdc is a normal valu of yield voltage of the zeta converter (DC connect voltage of VSI)is equivalent to the DC voltage rating of the BLDC motor.

$$L_1 = \frac{DV_{mpp}}{f_{sw}\Delta I_{L1}} = \frac{0.52 * 187.2}{20000 * 18.16 * 0.06} = 4.5 * 10^{-3} \approx 5\,\text{mH} \quad (6)$$

$$L_2 = \frac{(1-D)V_{dc}}{f_{sw}\Delta I_{L2}} = \frac{(1-0.52) * 200}{20000 * 17 * 0.06} = 4.7 * 10^{-3} \approx 5\,\text{mH} \quad (7)$$

$$C_1 = \frac{DI_{dc}}{f_{sw}\Delta V_{C1}} = \frac{0.52 * 17}{20000 * 200 * 0.1} = 22\ \mu\text{F} \quad (8)$$

Where Fsw is exchanging recurrence of IGBT switch of the zeta converter Δ IL1 is the measure of allowed swell in current moving through L1, same as IL1 = Impp; ΔIL2 is the measure of allowed swell in the present moving through L2, same as IL2 =

Idc; ΔVC1 is allowed swell in the voltage crosswise over C1, same as VC1 = Vdc. Detailed data of the zeta converter are given in Appendix B.

C. Estimation of DC Link Capacitor of VSI

Another structure approach for estimation of DC connects capacitor of the VSI is exhibited here. This methodology depends on a reality that sixth symphonious part of the supply (AC) voltage is considered the DC side as a prevailing consonant in the three stage supply framework [25]. Here, the crucial frequencies of yield voltage of the VSI are evaluated relating to the appraised speed and the base speed of BLDC motor basically required to siphon the water. These two frequencies are additionally used to appraise the estimations of their comparing capacitors. Out of these two assessed capacitors, bigger one is chosen to guarantee a tasteful activity of proposed framework even under the base sun oriented irradiance level. The essential yield recurrence of VSI relating to the appraised speed of BLDC motor, ωrated is evaluated as,

$$\omega_{rated} = 2\pi f_{rated} = 2\pi \frac{N_{rated} P}{120} = 2\pi * \frac{3000*6}{120} = 942 \text{ rad/sec.} \quad (9)$$

$$\omega_{min} = 2\pi f_{min} = 2\pi \frac{NP}{120} = 2\pi * \frac{1100*6}{120} = 345.57 \text{ rad/sec.} \quad (10)$$

where frated and fmin are major frequencies of yield voltage of VSI relating to an evaluated speed and a base speed of BLDC engine basically required to siphon the water individually, in Hz; Nrated is appraised speed of the BLDC engine; P is various shafts in the BLDC engine. The estimation of DC connect capacitor of VSI at ωrated is as,

$$C_{2,rated} = \frac{I_{dc}}{6 * \omega_{rated} * \Delta V_{dc}} = \frac{17}{6*942*200*0.1} = 150.4 \ \mu\text{F} \quad (11)$$

Similarly, a value of DC link capacitor of VSI at *ωmin* is as,

$$C_{2,\min} = \frac{I_{dc}}{6 * \omega_{\min} * \Delta V_{dc}} = \frac{17}{6*345.57*200*0.1} = 410 \ \mu\text{F} \quad (12)$$

D. Design of Water Pump

$$K = \frac{P}{\omega_r^3} = \frac{2.89*10^3}{(2\pi * 3000/60)^3} = 9.32*10^{-5} \quad (13)$$

CONTROL OF PROPOSED SYSTEM

The proposed is controlled in two phases. These two control strategies, viz. MPPT and electronic compensation are examined as pursues.

A. *INC-MPPT Algorithm*

A productive and normally utilized INC-MT procedure [8, 13] in different SPV exhibit based applications is used so as to advance the power accessible from SPV and to encourage a delicate beginning of BLDC engine. This method permits annoyance in either the SPV exhibit voltage or the obligation cycle. The previous requires a PI (Proportional-Integral) controller to produce an obligation cycle [8] for the zeta converter, which builds the unpredictability. Consequently, the immediate obligation cycle control is adjusted in this work. The INC-MPPT calculation decides the bearings of annoyance dependent on the incline of Ppv-vpv bend, appeared in Fig. 3. As appeared in Fig. 3, the slant is zero at MPP, positive on the left and negative on the privilege of MPP, i.e.

$$\left.\begin{array}{l} \frac{dP_{pv}}{dv_{pv}} = 0; \quad \text{at MPP} \\ \frac{dP_{pv}}{dv_{pv}} > 0; \quad \text{left of MPP} \\ \frac{dP_{pv}}{dv_{pv}} > 0; \quad \text{right of MPP} \end{array}\right\}$$

Since

$$\frac{dP_{pv}}{dv_{pv}} = \frac{d(v_{pv} * i_{pv})}{dv_{pv}} = i_{pv} + v_{pv} * \frac{di_{pv}}{dv_{pv}} \cong i_{pv} + v_{pv}$$

Therefore (14), can written as,

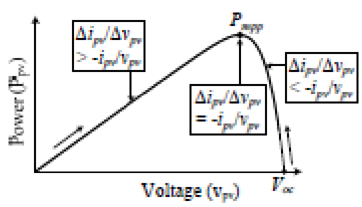


Fig .3 illusrtration of INC_MPPT with SPV array Ppv-Vpv characteristics.

$$\left.\begin{array}{l} \frac{\Delta i_{pv}}{\Delta v_{pv}} = -\frac{i_{pv}}{v_{pv}}; \quad \text{at MPP} \\ \frac{\Delta i_{pv}}{\Delta v_{pv}} > -\frac{i_{pv}}{v_{pv}}; \quad \text{left of MPP} \\ \frac{\Delta i_{pv}}{\Delta v_{pv}} < -\frac{i_{pv}}{v_{pv}}; \quad \text{right of MPP} \end{array}\right\} \quad (16)$$

Along these lines, in light of the connection between steady conductance and quick conductance, the controller chooses the course of bother as appeared in fig,3. What's more, expands/diminishes of the obligation cycle in like manner. For example, on the privilege of MPP, the obligation cycle is expanded with the fixed bother estimate until the bearing switches. In a perfect world, the bother stops once the working point achieves the MPP. Notwithstanding, practically speaking, working point sways around the MPP.

As the bother estimate decreases, the controller sets aside more effort to follow the MPP of SPV exhibit. A scholarly understanding between the following time and the annoyance estimate is held to satisfy the targets of MPPT and delicate beginning of BLDC engine. So as to accomplish delicate beginning, the underlying estimation of obligation cycle is set as zero. Likewise, an ideal estimation of annoyance measure (ΔD=0.001) is chosen, which adds to delicate beginning and furthermore limits motions around the MPP.

B. *Electronic Commutation of BLDC Motor*

The BLDC engine is controlled utilizing a VSI worked through an electronic recompense of BLDC engine. An electronic compensation of BLDC engine represents commutating the flows moving through its windings in a predefined succession utilizing decoder rationale. It symmetrically puts the DC input current at the focal point of each stage voltage for 120°. Six exchanging beats are produced according to the different potential blends of three Hall-impact signals. These three Hall-impact signals are delivered by an inbuilt encoder as per the rotor position.

A specific curve of Hall-impact signals is created for every particular scope of rotor position at an interim of 60° [5-6]. The generation of six exchanging states with the estimation of rotor position is organized in Table II. It is recognizable that just two switches lead at once, bringing about 120º conduction method of activity of VSI and subsequently the decreased conduction misfortunes. Other than this, the electronic replacement gives crucial frequency exchanging of the VSI, subsequently misfortunes related with high frequency PWM exchanging are killed. TETRA 115TR9.2, and motor control organization make BLDC engine [28] with inbuilt encoder is chosen for proposed framework and its nitty gritty determinations are given in Appendix C.

TABLE II
SWITCHING STATES FOR ELECTRONIC COMMUTATION OF BLDC MOTOR

Rotor position θ(°)	Hall Signals			Switching States					
	H_3	H_2	H_1	S_1	S_2	S_3	S_4	S_5	S_6
NA	0	0	0	0	0	0	0	0	0
0-60	1	0	1	1	0	0	1	0	0
60-120	0	0	1	1	0	0	0	0	1
120-180	0	1	1	0	0	1	0	0	1
180-240	0	1	0	0	1	1	0	0	0
240-300	1	1	0	0	1	0	0	1	0
300-360	1	0	0	0	0	0	1	1	0
NA	1	1	1	0	0	0	0	0	0

IV.SIMULATION RESULTS

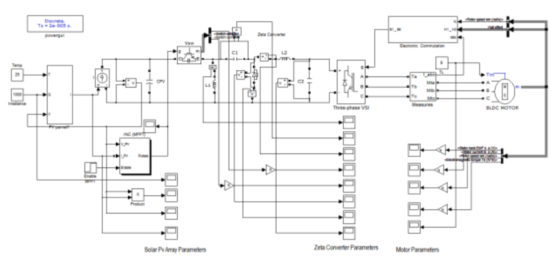
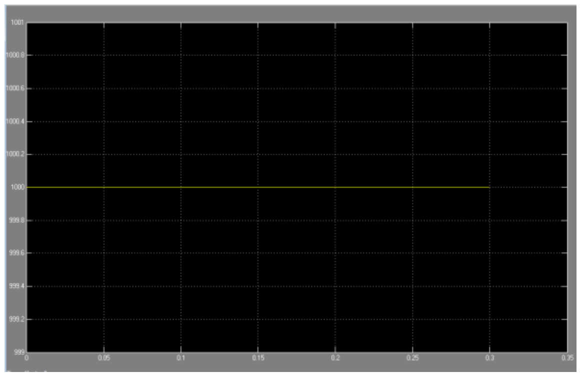
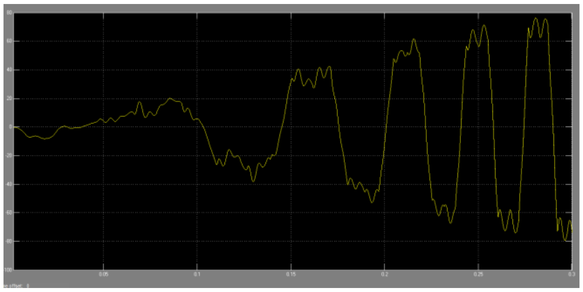


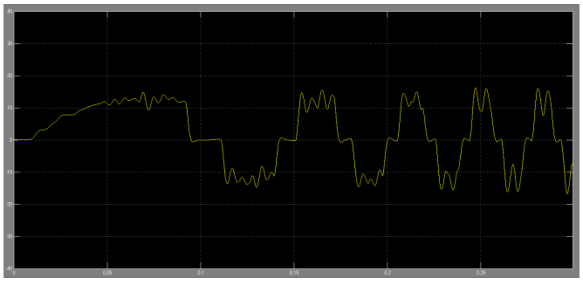
Fig. 2 Proposed SPV - Zeta converter fed BLDC motor drive for water pump with constant irradiation value



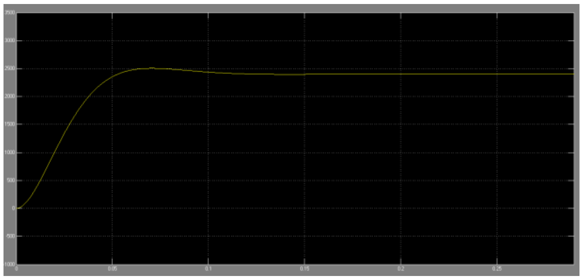
Variable irridance motor parameters



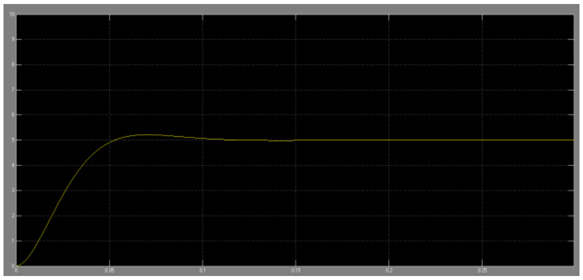
Ea



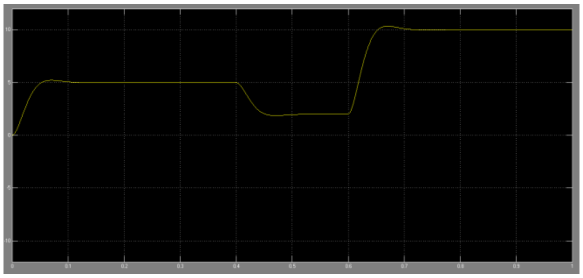
Ia



Speed

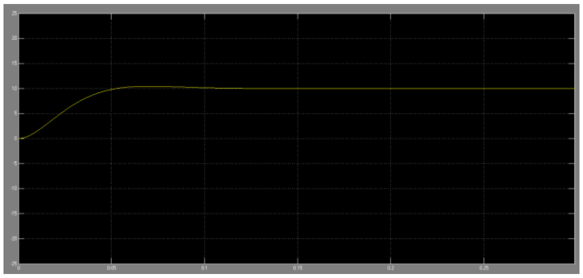


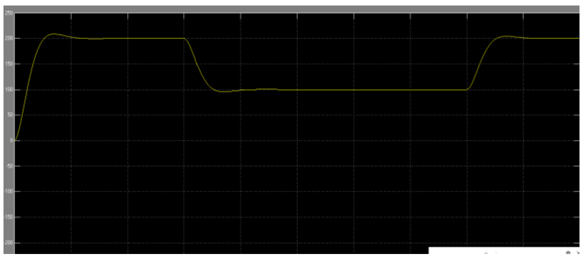
Torque



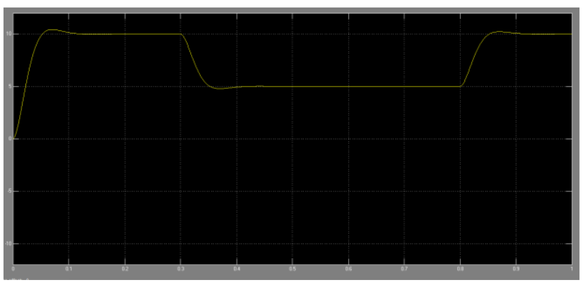
TL1

Zeta converter parameters

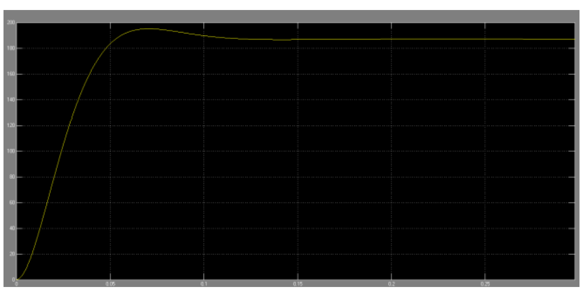




VC1



IL2



VDC

CONCLUSIONS

The SPV exhibit zeta converter fed VSI-BLDC motor pump has been proposed and its appropriateness has been shown through simulation results. The proposed framework has been designed and modeling properly to achieve the ideal destinations and approved to look at the different exhibitions under beginning, dynamic and unfaltering state conditions. The presentation assessment has defended the mix of zeta converter and BLDC motor for SPV exhibit based water pumping. The framework under examination has appeared wanted capacities, for example, MPP extraction of the SPV exhibit, delicate beginning of BLDC motor, fundamental frequency switching of VSI bringing about a decreased switching losses, speed control of BLDC engine with no extra control and an end of stage current and DC connect voltage detecting, bringing about the diminished expense and unpredictability. The proposed framework has worked effectively even under minimum solar irradiance.

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