ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

SPV Array Based PMBLDC Motor Controlled By MPPT Based Buck-Boost Converter

B.Swetha
Department of Electrical & Electronics Engineering,
St. Mary's College of Engineering & Technology,
Hyderabad, Telangana-502 319, India.

Thotakura China Durgarao
Department of Electrical & Electronics Engineering,
St. Mary's College of Engineering & Technology,
Hyderabad, Telangana-502 319, India.

Abstract:
In this paper, the change of vitality transformation productivity of the BLDC engine driven SPV exhibit is proposed. A Bu-Bo dc/dc converter is having favorable position of voltage control in the middle of PV cluster and 3-stage VSI. An incremental conductance (INC) MPPT calculation is utilized as a part of request to work the SPV exhibit at its ideal working point. An inbuilt Hall-impact position sensor of the BLDC engine is utilized to control VSI. The beginning, dynamic and consistent state exhibitions of the proposed SPV cluster based BB converter sustained VSI-BLDC engine pump framework has been checked by mimicking the conduct of BLDC engine pump under fluctuating insolation level of SPV cluster utilizing MATLAB/Simulink condition.

I. INTRODUCTION:

Sun based photovoltaic (SPV) vitality has developed as an option wellspring of power era having quantities of favorable circumstances. Additionally, the water pumping has turned into a practical use of SPV vitality now a days, particularly in remote areas and provincial zones [1-2]. A three-stage enlistment engine (IM) is generally utilized as a part of SPV exhibit nourished water pumping for water system and local purposes because of its reasonableness for applications in debased and secluded zones, minimal effort, unwavering quality and low support necessity [3]. A DC engine is additionally utilized as a part of [4-5], however inferable from a high upkeep prerequisite caused by the nearness of brushes and commutator, it is not favored for water pumping.

Notwithstanding, an entangled control of IM and high proficiency of a lasting magnet synchronous engine (PMSM) than an IM has propelled the analysts to utilize a PMSM drive where a powerful submersible water pumping framework is introduced [6]. A few endeavors in the range of SPV exhibit bolstered water pumping utilizing a synchronous hesitance engine (SRM) have been made in the writing. It has been watched that the SRM can run acceptable for a restricted scope of sunlight based insolation level. A ceaseless decrease in the cost of the sun powered photovoltaic (SPV) boards and the power gadgets has empowered the analysts and the businesses to use the sun oriented PV cluster produced control for various applications. Water pumping has picked up an expansive consideration as a critical and savvy use of the sunlight based PV exhibit created control [7].

A greatest effectiveness of the sun oriented PV exhibit is generally accomplished through a most extreme power point following (MPPT) calculation utilizing the DC-DC converters. Different DC-DC converters, for example, buck, support, buck-help, Cuk, SEPIC (Single Ended Primary Inductor Converter) have been utilized for MPPT in various sunlight based PV cluster based applications. The previously mentioned non-confined DC-DC converters are contrasted in [8] with locate a best arrangement suiting an application with MPPT.

Cite this article as: B.Swetha & Thotakura China Durgarao, "SPV Array Based PMBLDC Motor Controlled By MPPT Based Buck-Boost Converter", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 4, Issue 12, 2017, Page 89-98.

It has been presumed that the best choice of DC–DC converter in the PV framework is the buck– support DC–DC converter since it is equipped for accomplishing ideal operation paying little respect to the heap esteem. Then again, when the buck and lift converter is utilized for MPPT, the MPP is followed as though it is limited to inside the operation district. Other than that, because of the most noteworthy estimations of vitality stockpiling parts, the Cuk and SEPIC converters add to their principle downside [9].

II. BRUSHLESS DC MOTOR:

BLDC engine drives, frameworks in which a changeless magnet energized synchronous engine is bolstered with a variable recurrence inverter controlled by a pole position sensor [9]. There shows up an absence of business recreation bundles for the outline of controller for such BLDC engine drives. One fundamental reason has been that the high programming improvement cost brought about is not defended for their run of the mill minimal effort fragmentary/vital kW application territories, for example, NC machine apparatuses and robot drives; even it could suggest the likelihood of demagnetizing the rotor magnets amid authorizing or tuning stages.

By and by, recursive prototyping of both the engine and inverter might be associated with novel drive arrangements for progress and concentrated applications, bringing about high formative cost of the drive framework. Enhanced magnet material with high (B.H), item likewise helps push the BLDC engines market to several kW application regions where authorizing blunders turn out to be restrictively expensive [7]. Displaying is along these lines basic and may offer potential cost funds. A brushless dc engine is a dc engine turned back to front, so the field is on the rotor and the armature is on the stator. The brushless dc engine is really a perpetual magnet air conditioning engine whose torque-current qualities emulate the dc engine. Rather than commutating the armature current utilizing brushes, electronic recompense is utilized.

This disposes of the issues related with the brush and the commutator plan, for instance, starting and destroying of the commutator-brush course of action, consequently, making a BLDC more rough when contrasted with a dc engine. Having the armature on the stator makes it simple to lead warm far from the windings, and if wanted, having cooling course of action for the armature windings is considerably less demanding when contrasted with a dc engine.

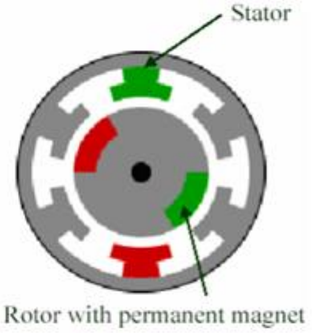

Fig.1: Cross-section view of a brushless dc motor

Basically, a BLDC is an adjusted PMSM engine with the alteration being that the backemf is trapezoidal as opposed to being sinusoidal as on account of PMSM. The "recompense locale" of the backemf of a BLDC engine ought to be as little as could be expected under the circumstances, while in the meantime it ought not be so limited as to make it hard to commutate a period of that engine when driven by a Current Source Inverter. The level consistent part of the backemf ought to be 120° for a smooth torque creation. The position of the rotor can be detected by utilizing an optical position sensors and its related rationale. Optical position sensors comprise of phototransistors (touchy to light), spinning screens, and a light source. The yield of an optical position sensor is generally a Logical flag.

Principle operation of Brushless DC (BLDC) Motor:

A brush less dc engine is characterized as a lasting synchronous machine with rotor position input. The brushless engines are for the most part controlled utilizing a three stage control semiconductor connect.

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International Journal & Magazine of Engineering, Technology, Management and Research
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The engine requires a rotor position sensor for beginning and for giving legitimate substitution succession to turn on the power gadgets in the inverter connect. In light of the rotor position, the power gadgets are commutated consecutively every 60 degrees. Rather than commutating the armature current utilizing brushes, electronic compensation is utilized thus it is an electronic engine. This kills the issues related with the brush and the commutator course of action, for instance, starting and destroying of the commutator brush game plan, accordingly, making a BLDC more tough when contrasted with a dc engine.

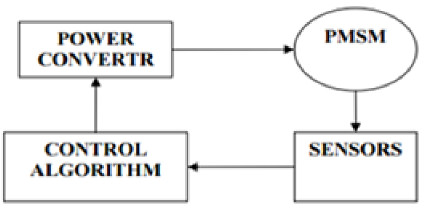

Fig.2: Basic block diagram of BLDC motor

The essential piece chart brushless dc engine as indicated Fig.4.2.The brush less dc engine comprise of four fundamental parts control converter, lasting magnet-synchronous machine (PMSM) sensors, and control calculation. The power converter changes control from the source to the PMSM which thus changes over electrical vitality to mechanical vitality. One of the notable elements of the brush less dc engine is the rotor position sensors ,in view of the rotor position and summon signals which might be a torque order, voltage charge ,speed charge et cetera the control calculations decide the entryway flag to every semiconductor in the power electronic converter.

The structure of the control calculations decides the sort of the brush less dc engine of which there are two fundamental classes voltage source based drives and current source based drives. Both voltage source and current source based drive utilized with lasting magnet synchronous machine with either sinusoidal or non-sinusoidal back emf waveforms .Machine with sinusoidal back emf (Fig.2.4) might be controlled in order to accomplish about consistent torque.

Be that as it may, machine with a non sinusoidal back emf (Fig.2.3) offer diminishes inverter sizes and decreases misfortunes for a similar influence level.

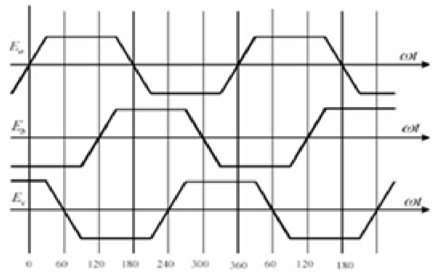

Fig.3: Trapezoidal back emf of three phase BLDC motor

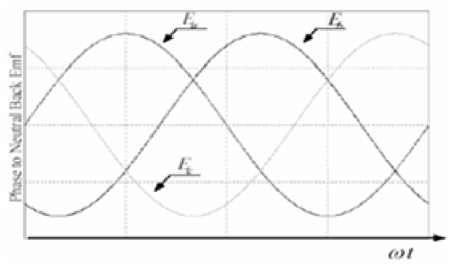

Fig.4: Sinusoidal phase back emf of BLDC motor

III. SYSTEM CONFIGURATION:

Fig.5 demonstrates the arrangement of the proposed SPV exhibit BB converter sustained BLDC engine drive coupled to a water pump. A SPV cluster goes before the BB converter which is associated with a VSI encouraging the BLDC engine pump. Utilizing a MPPT calculation, MPP of the SPV cluster is followed by working the IGBT (Insulated Gate Bipolar Transistor) switch of the lift converter.

An extra voltage control is given at the contribution of buck converter which produces the exchanging beats for the IGBT switch of the buck converter. An inbuilt encoder on the BLDC engine creates the Hall Effect signals which are additionally decoded to produce the exchanging beats for the VSI by the alleged electronic compensation of BLDC engine. The plan and working standard of each phase of the design are expounded in the accompanying segments.

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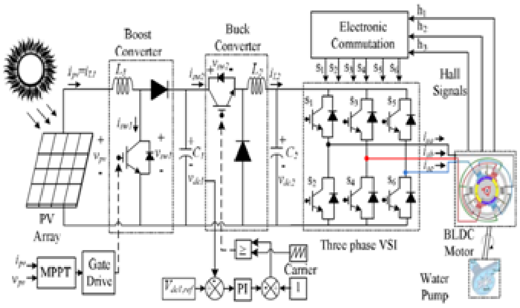

Fig.5: Configuration of the SPV array - BB converter fed BLDC motor driven water pumping system

IV. WORKING PRINCIPLE OF PROPOSED BB CONVERTER:

Fig. 6(a) represents the SPV array fed BB converter connected to the VSI fed BLDC motor pump. All the four of BB converter are considered for elaboration of the operation and working principle. According to the position of switches, the operation of the converter is categorized in two modes; (i) synchronized control mode and (ii) combined control mode. (i)When the position of both the switches is same i.e. both the switches are either on or off, the converter operates in the synchronized control mode. (ii) When the position of both the switches is different i.e. one is on and other is off, the converter operates in combined control mode.

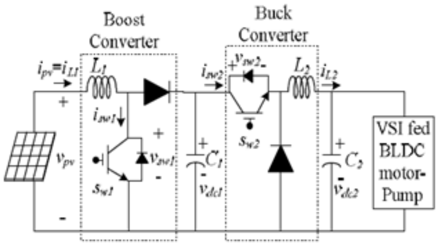

Fig.6 (a): SPV array fed BB converter

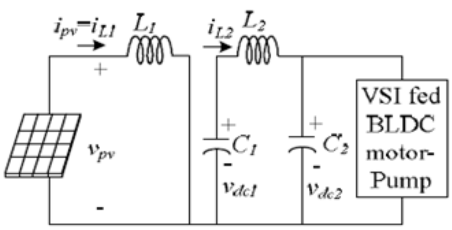

Fig.6 (b): When sw1 and sw2 are on

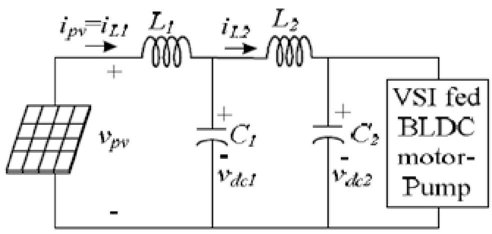

Fig.6 (c): When sw1 is off and sw2 is on

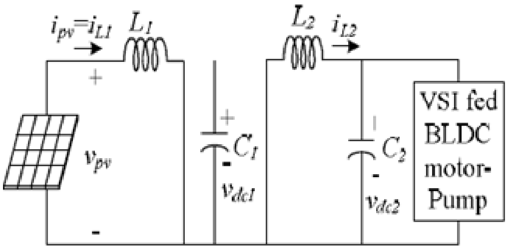

Fig.6 (d): When sw1 is on and sw2 is off

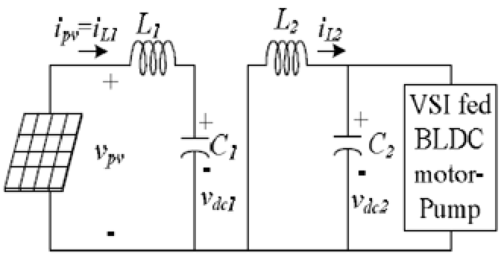

Fig.6 (e): When sw1 and sw2 are off

Both the switches can be controlled freely. Figs. 5.2(b-e) demonstrate the two mode operation of the BB converter, where, L1, L2, C1 and C2 are the info inductor, yield inductor, middle of the road capacitor and the yield capacitor of BB converter separately. Figs. 5.3(a-b) demonstrate comparing waveforms of the converter factors, where, sw1, sw2, vL1, iL1, vdc1, vL2, iL2 and vdc2 are the switch position of the lift converter, switch position of buck converter, voltage crosswise over L1, current coursing through L1, voltage crosswise over C1, voltage crosswise over L2, current moving through L2 and voltage crosswise over C2 separately. vpv is the voltage of SPV cluster. To get all the four blends of exchanging states, it is viewed as that the exchanging recurrence of the lift converter, fsw1 and the exchanging recurrence of the

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buck converter, fsw2 are not equivalent. For straightforwardness, it is likewise viewed as that the obligation cycle of the lift converter, D1 and the obligation cycle of the buck converter, D2 are equivalent and the BB converter works in nonstop conduction mode.

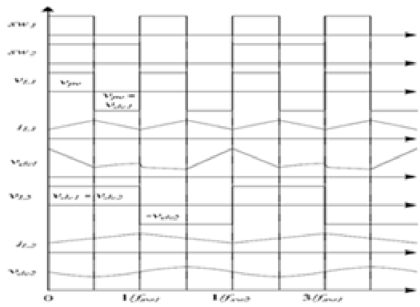

Fig.7: BB converter variables illustrating its two mode operation, (a) When the switching starts with sw1 on

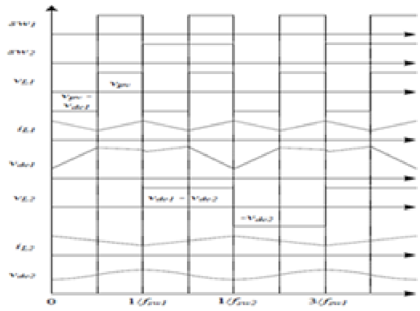

Fig.7 (b) when the switching starts with sw1 off

Fig.7 (a) speaks to the waveforms when the exchanging of the BB converter begins with the on condition of sw1 (independent of the condition of sw2). At the point when the converter works in synchronized control mode and both the switches are on as appeared in Fig.7 (b), L1 and L2 store vitality provided by the SPV cluster and streams iL1 and iL2 rise while C1 releases and shows up as a voltage hotspot for the buck converter, in this way vdc1 falls. Presently, when sw1 is off however sw2 is still on as appeared in Fig.6 (c), the converter works in joined control mode; L1 exchanges some measure of the put away vitality to C1 and remaining vitality to the heap by means of the buck converter, thus vdc1 increments gradually in light of the fact that the rate of charging of C1 lessens; iL1 falls andiL2 still ascents. Next, when sw1 is on however sw2 is off as appeared in Fig.6 (d), L1 stores vitality bringing about the ascent of iL1. L2transfers the put away vitality to the heap, bringing about the fall ofiL2; vdc1 diminishes gradually in light of the fact that C1 is disengaged to the circuit and the rate of releasing of C1 decreases. At the point when both the switches are off as appeared in Fig.6 (e), the converter again enters in synchronized control mode; L1 exchanges the put away vitality to C1. L2 exchanges the put away vitality to the heap and thus iL1 and iL2 fall yet vdc1 rises. This distinction in the conduct of vdc1 is in reality due the distinction in the position of switches at the beginning.

At the point when the converter works in synchronized control mode and both the switches are off, L1 exchanges the put away vitality toC1 bringing about the ascent of vdc1. Presently, when sw1 is on however sw2 is still off, the converter works in consolidated control mode; vdc1 diminishes gradually in light of the fact that C1is disengaged to the circuit and the rate of releasing of C1reduces. Next, when sw1 is off yet sw2 is on, L1 exchanges some measure of the put away vitality to C1 and remaining vitality to the heap through the buck converter, henceforth vdc1increases gradually in light of the fact that the rate of charging of C1reduces. At the point when both the switches are on, the converter again enters synchronized control mode. C1discharges and shows up as a voltage hotspot for the buck converter, in this way vdc1 falls.

V. CONTROL OF PROPOSED SYSTEM:

The proposed framework comprises of a SPV exhibit, a BB converter, VSI and a BLDC engine coupled to a water pump. The segments of the SPV cluster, BB converter and the water pump are outlined according to the necessity of the water pump stack encouraged by the SPV exhibit. A BLDC engine of 4.4 kW control rating is chosen to drive a water pump and different parts of the proposed framework are composed agreeing explained in the accompanying areas. The work process diagram peruses as takes after.

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As shown in Fig.8, an additional voltage control feature is provided at the input stage of buck converter, so that the buck converter always experiences a constant voltage at its input, regardless of the variation in atmospheric condition. The reference input voltage, Vdc1,ref is compared with the sensed input voltage, vdc1 of the buck converter and error is passed through a proportional-integral (PI) controller. The output of the PI controller is compared with 1 which is the maximum possible value of a duty cycle. This comparison gives the duty cycle of buck converter, D2 which is further compared with the high frequency carrier wave to generate the switching pulses for the switch of buck converter.

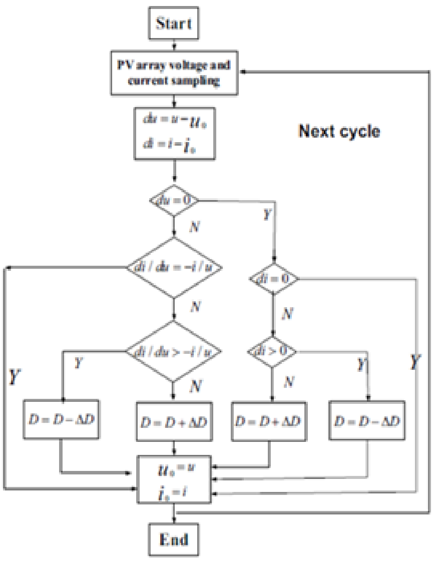

Fig.8: Flow chart of Incremental Conductance Method

An inbuilt Hall-effect position sensor of the BLDC motor senses the rotor position, 0on 60 degree span and generates 3 Hall signals which are decoded to generate the appropriate switching pulses for the IGBT switches of VSI by the electronic commutation of BLDC motor. Various parameters and ratings of the BLDC motor are given in Appendices. The switching sequence of the VSI is the state of switches for a particular rotor position of the BLDC motor as sensed by the Hall effect sensor. The turn on and turn off condition of the IGBT's is represented as '1' or '0', respectively.

VI. SIMULATION RESULTS:

The beginning, dynamic and unfaltering state exhibitions of the proposed SPV cluster based BB converter encouraged VSI-BLDC engine pump framework has been checked by reenacting the conduct of BLDC engine pump under changing insolation level of SPV cluster utilizing MATLAB/Simulink condition. The sun powered insolation level, S is arbitrarily shifted from 200 W/m2 to 1000 W/m2. An incremental conductance MPPT calculation is connected tooptimize the working purpose of the SPV cluster. Step size or aperturbation in the obligation proportion assumes a fundamental part in the operationof the proposed framework.

A higher estimation of step measure comes about inthe swaying around the most extreme power point. Subsequently, alow estimation of step measure, ΔD1 = 0.001 is chosen which increasesthe following time yet contributes in the delicate beginning of theBLDC engine. Fig. 7.1 demonstrates that when the MPPT algorithmis executed and MPP is followed appropriately, the SPV arrayvoltage, vpv achieves the voltage at MPP, Vmpp; SPV arraycurrent, ipv achieves the current at MPP, Impp and consequently the SPVarray control, Ppv comes to the MPP, Pmpp at 1000 W/m2.

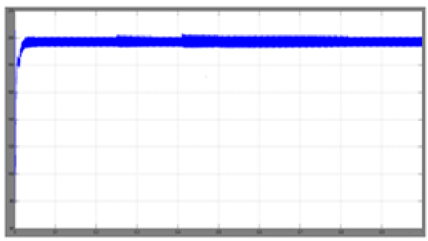

Fig.9: PV array voltage

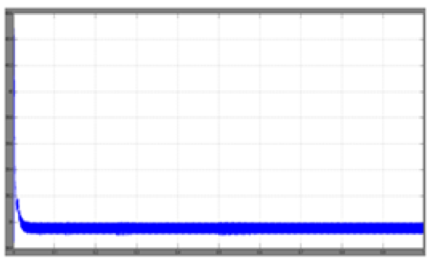

Fig.10: PV array current

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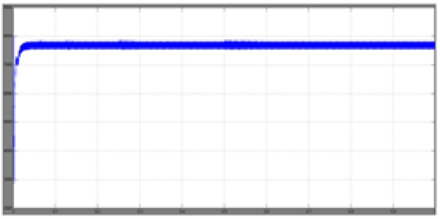

Fig.11: PV array Power

The BB converter is utilized as a middle of the road DC-DC converter between the SPV cluster and VSI so as to fulfill the elements of MPPT and delicate beginning of the BLDC engine with voltage control highlight at the contribution of the buck converter. The BB converter is constantly worked in ceaseless conduction mode as appeared in Figs. 7.2 and 7.3 individually at 1000 W/m2 and under the arbitrary variety in sun powered insolation level. A nonstop current moving through the info inductor, iL1 is the current of the SPV cluster.

The information inductor, L1 makes iL1, persistent and practically swells free. The estimation of yield voltage of the lift converter, vdc1 shows up as the pinnacle extent of the voltage over the switches of the lift converter and buck converter, vsw1 and vsw2 individually. In any case, the obligation cycles of both the switches are extraordinary. Correspondingly, the estimation of iL1 shows up as the pinnacle size of the present moving through the switch of the lift converter, isw1. Least conceivable weight on the switch is seen because of the nonstop conduction mode operation of the converter.

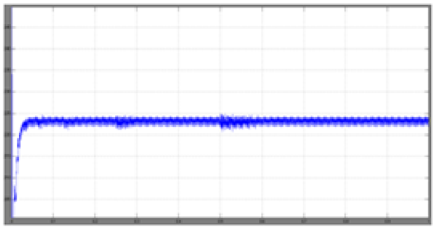

Fig.12: Boost converter output capacitor voltage

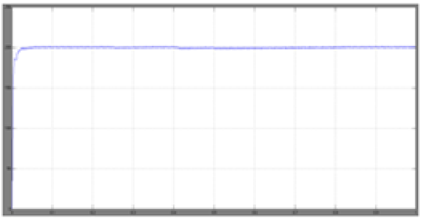

Fig.13: Buck converter Output capacitor voltage

The yield voltage, vdc1 which shows up as the information voltage for the buck converter is kept up at 225 V in perspective of better switch use of both the lift and buck converters. The switch usage relies upon the obligation cycle for the lift converter, switch use increments when the obligation cycle, D1 goes down, though for the buck converter, switch use increments when the obligation cycle, D2 goes up. The yield voltage, Vdc1 = 225 V brings about a lower estimation of D1 and a higher estimation of D2 as portrayed in the segment – IV(B) which gives the better switch usage of both the lift and buck converters. Expanding the estimation of Vdc1 decays the switch usage as well as builds the voltage weight on both the switches too.

The estimation of consistent current moving through the yield inductor, iL2 shows up as the pinnacle size of the present moving through the switch of the buck converter, isw2. The DC interface voltage, vdc2, containing an immaterial measure of swell, worries of both switches vsw1 and vsw2 are steady for each sun based insolation level in light of the fact that these rely upon Vdc1 which is constantly kept up at a consistent esteem. Other converter factors differ as indicated by the variety in sun powered insolation level.

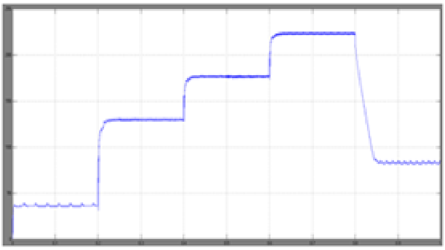

Fig.14: Boost converter output voltage

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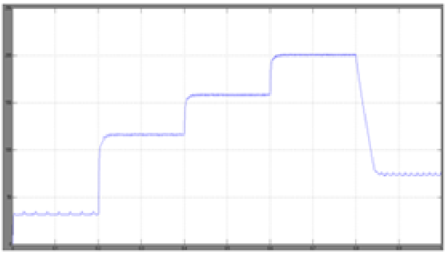

Fig.15: Buck converter output voltage

Performance of BLDC Motor - Pump at 1000 W/m2:

The starting and steady state performances of SPV array-BB converter fed BLDC motor pump system at the standard solar insolation level of 1000 W/m2 are shown in Fig. 7.4.The back EMF and the stator current of only phase 'a' are shown. In proportion to the DC link voltage of VSI, vdc2, the backs EMF of phase 'a,' ea increases and reaches the rated value at steady state condition.

The stator current of phase 'a,' is also increases and settles down at the rated value. The starting stator current of the motor is controlled within the acceptable limit. At 1000 W/m2, the motor runs at full load, hence the speed, N increases and reaches the rated value at steady state condition. At full load, motor develops the rated electromagnetic torque, Te to drive the water pump. A small pulsation in Te is reflected from the ripples present in the DC link current of VSI. Pump load torque, TL is equal to the electromagnetic torque, Te as an evidence of stable operation of the motor - pump.

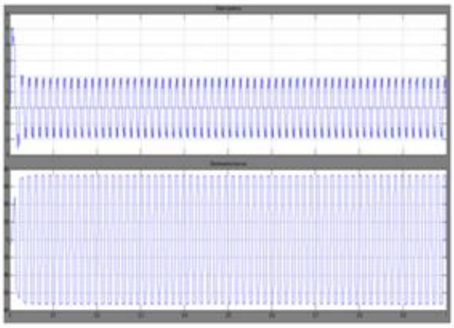

Fig.16: Stator current and EMF of PMBLDC motor (water pump)

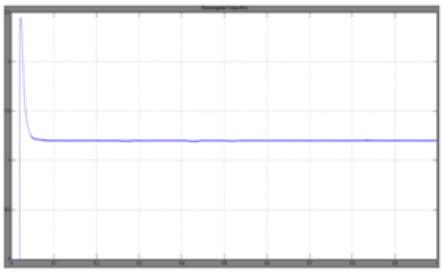

Fig.17: Torque of water pump

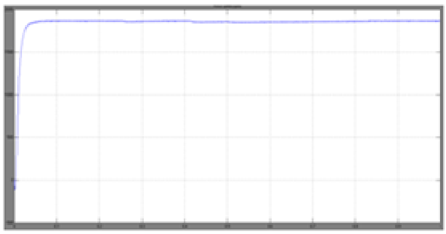

Fig.18: Rotor speed of water pump

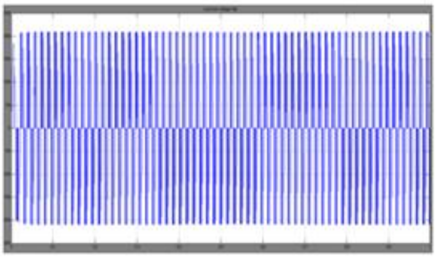

Fig.19: Input line-line voltage of PMBLDC motor

Dynamic Performance of BLDC Motor – Pump:

Fig. 7.5 demonstrates the dynamic execution of SPV cluster BB converter bolstered BLDC engine pump framework. A dynamic variety in the sun based insolation level is considered in 5 stages; 200 W/m2from 0 to 0.2 s., 600 W/m2 from 0.2 to 0.4 s., 1000 W/m2 from0.4 to 0.6 s., 800 W/m2 from 0.6 to 0.8 s. what's more, 400 W/m2 from0.8 to 1.0 s. The tasteful execution is confirmed under this substantial dynamic variety in climatic condition. The variety of the engine pump files, for example, the back EMF, ea, the stator current, isa, the engine speed, N, the electromagnetic torque, Te and the pump stack torque, TL as for the sunlight based insolation level, S are appeared in Fig. 7.6. Since all the engine pump lists are reliant of sunlight based insolation level, these change in extent to the sun powered insolation level as

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it were. The evaluated estimations of all the execution files are gotten amid the standard sun powered insolation level i.e. 1000W/m2. At the base sun powered insolation level of 200 W/m2, the execution records have their base esteems. Never the less, the speed of the engine is seen as 1107 rpm, adequate to direct some measure of the water.

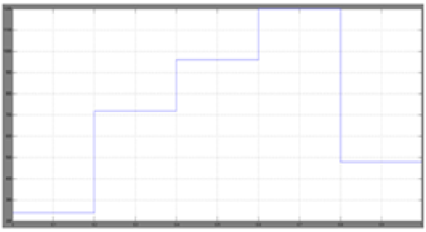

Fig.20: Solar irradiation

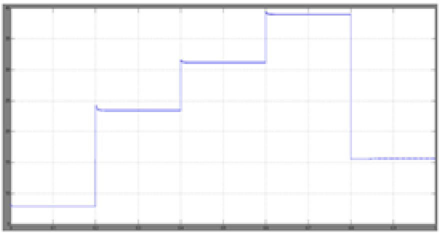

Fig.21: PV array current

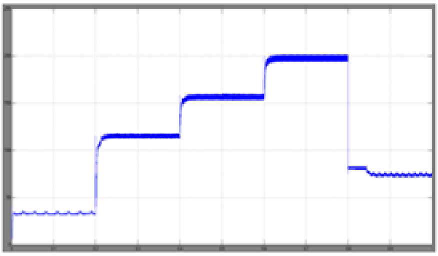

Fig.22: PV array voltage

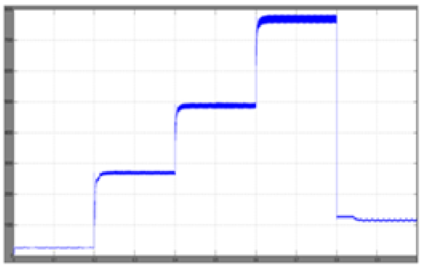

Fig.23: PV array power

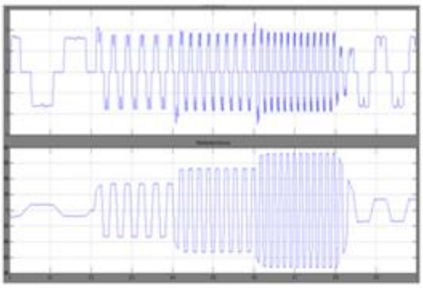

Fig.24: Stator current and EMF of PMBLDC motor (water pump)

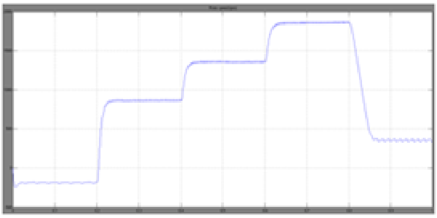

Fig.25: Rotor speed

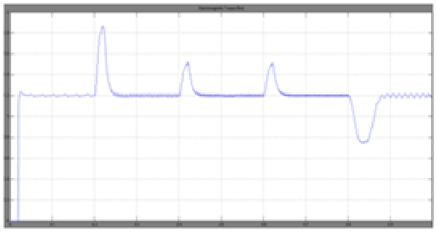

Fig.26: Torque of water pump

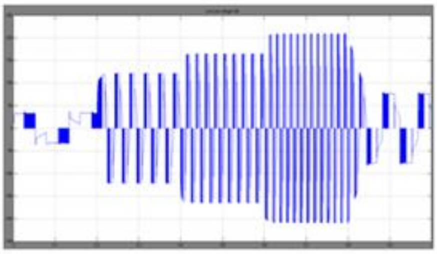

Fig.27: Line-line Input voltage of PMBLDC motor

VII. CONCLUSION:

The DC-DC support buck converter for SPV cluster nourished BLDC engine driven water pump has been proposed. The entire framework has been composed, demonstrated and recreated in MATLAB/Simulink condition and executed on a created equipment model. Using every one of the properties of both the lift and buck converters and interfacing these two converters in

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

a suitable way, another BB converter with the low esteemed parts has been planned and worked in CCM. Functioning as a non-transforming buck-help converter, the proposed BB converter has killed the downsides of the buck; lift and topologies of buck-support converters utilized as a part of SPV based applications. The water pumping has been achieved even at the base sun based insolation level and the beginning ebb and flow of the engine has been controlled inside the passable range. Also, key recurrence exchanging of the VSI has maintained a strategic distance from the high recurrence exchanging misfortunes. The displayed reenactment and trial exhibitions of the proposed framework at beginning, dynamic and enduring state have demonstrated its reasonableness for the SPV cluster based water pumping.

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