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PV BASED VOLTAGE FED BLDC MOTOR USING INTERLEAVED CONVERTER

1.T.Abirami, 2.S.Arunthathi, 3.G.Cathrine Prabha, 4.T.Malathi.

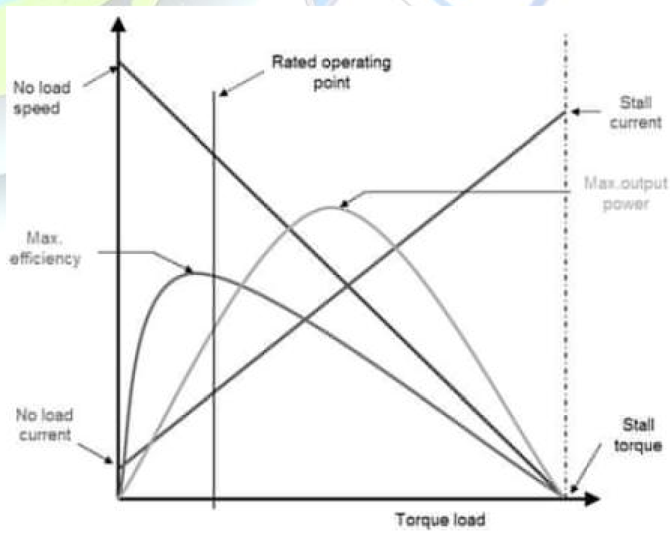
UG Scholar, Dept. of EEE, Jay Shri Ram Group of institutions, Tirupur, India

ABSTRACT- *Nowadays, BLDC motor are most popularly used in industrial application due to its reliability, low maintenance and low susceptibility. It has been progressively replacing conventional DC drives in various applications such as electrical vehicles and industrial automation. Solar photovoltaic is used to run the BLDC motor. The motivation of PV is to reduce system complexity, eliminate leakage ground currents and improve reliability. PV is followed by interleaved converter to boost the output of PV. The interleaved boost topology provides superior performance with low voltage and current stress and low individual component losses. Switching process is done by a three phase voltage source inverter. Finally, in Matlab/Simulink environment, performances of the proposed drive are simulated, which improved the efficiency and power factor*

Keywords:BLDC motor, Solar PV,Interleaved converter,Efficiency, Power factor correction.

1. INTRODUCTION

Brushless DC (BLDC) motors have become increasinglypopular in the past decade due to the advantages such as high efficiency, high power density, compact size, highruggedness, simple mechanical construction, easy maintenance, good reliability, simple rotor cooling,low maintenance requirements and theirimmunity to electro-magnetic interference (EMI) problems[1-3]. BLDC motor are more efficient compared to induction motor because of its good performance with longer life, low commutation and low copper loss . Brushless DC motors use a rotating permanent magnet in the rotor, and stationary electrical magnets on the motor housing. A motor controller converts DC to AC this design is simpler than that of brushed motors because it eliminates the complication of transferring power from outside the motor to the spinning rotor. The high-performance, small-diameter magnetic rotors reduce the inertia of the armature, allowing high acceleration rates, a reduction in rotational losses, and smoother servo characteristics.BLDC motor is a three phase synchronous motor having torque-speed characteristics of a DC motor [1-3]. It has three phase windings on the stator which are excited by a voltage source inverter (VSI) and permanent magnets on the rotor. It does not require any brushes and commutator assembly; rather an electronic commutation based on the rotor position as sensed by Hall Effect position sensors is used . Hence the problems such as sparking, wear and tear of brushes, EMI and noise interference are eliminated inthe BLDC motor



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There is a requirement of an improved power quality (PQ)as per the international PQ standard IEC 61000-3-2 which recommends a high power factor (PF) and low total harmonicdistortion (THD) of ac mains current for Class-A applications. A conventional BLDC motor drive using a front-end diodebridge rectifier (DBR) and a high value of DC link capacitordraws highly distorted peaky current which is rich inharmonics.It leads to a very low power factor of the order of 0.72 and high total harmonic distortion (THD) of supply current at AC mains. Improved power quality converters (IPQC) are used for improving the power quality at AC mainswhich also reduce EMI problems.Bridgeless converter configurations have gained importance in the past decade due to their high efficiency. The front end DBR is eliminated in these configurations which reduce the conduction losses associated in them

Filters are usually provided along with these converters for the correction of power quality and thereby reducing the total harmonic distortion level.The mode of operation of PFC converters are selected with great importance since it determines the cost and component ratings. Converters can be operated in both continuous conduction mode(CCM) and discontinuous conduction mode(DCM). DCM is mostly selecting in low power applications. This is because, for employing CCM it requires two sensors, one for sensing the inductor current and other for sensing the capacitor voltage. In DCM there requires only one sensor to detect the DC link voltage only. DC link voltage control cannot be selected in high power applications since it creates high stress on the switches.

The Proposedinterleaved converter feeding a BLDC motor based on the concept of constant dc link voltage and PWM-VSI for speed control which has high

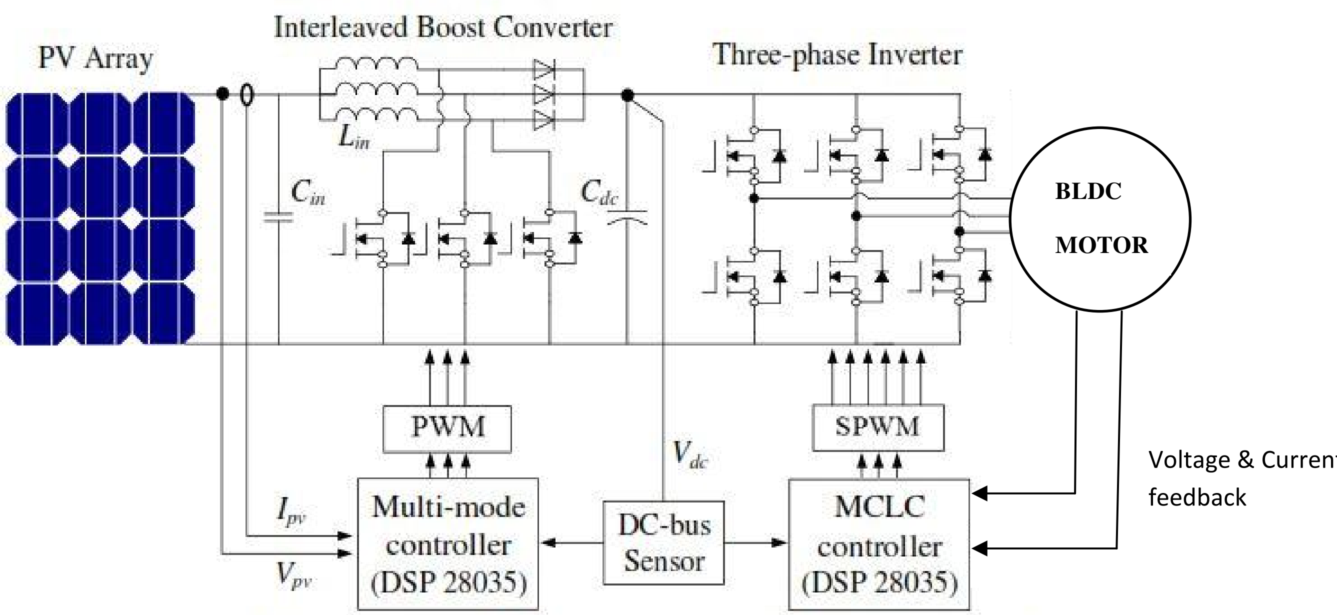

Fig 1 BLDC motor drive fed by a Interleaved converter

Switching losses.Interleaved converters are popular for converting low DC voltages into high DC voltages. When the power demands increases, a single power stage in converter is insufficient. When compared to the single-boost converter, the interleaved boost converter approach provides efficiency, size and cost advantages in both analytically and empirically.

2. SOLAR PHOTO VOLTAIC ENERGY

The renewable energy source, such as the Photovoltaic (PV)power system, has been rapidly developed in order to reducethe fossil fuel usage and carbon dioxide emission [4].However, the unpredictable environmental conditions,suchas irradiation or temperature, bring negative impacts to outputcharacteristics of PV arrays. Therefore, developing aneffective maximum power point tracking (MPPT) converterto improve the efficiency of PV power system is necessary.Usually, the boost converter is used as the front-end MPPTconverter for PV power systems because of its input currentlinearity [4]. Moreover, the interleaving technique,which can increase the input power rating but decrease thecurrent ripple, has been adopted for PWM converters [4]. For an m-phase interleaved boost converter, the current of each phase is only 1/m times of the total current. In otherwords, the current stresses and the power losses of the powerswitches can be reduced. Also, the total current ripple can bereduced significantly because of the cancellation betweendifferent phase currents. It can improve the accuracy of theMPPT as well as increase the total output power of the PVsystem. Eventually, the boost converter with interleaved operation is adopted for high power system to achieve highpower conversion efficiency and better MPPT performance.

3. PROPOSEDINTERLEAVED CONVERTER FEEDING BLDC MOTOR DRIVE

As shown in Fig. 2, the PV source is applied to a threecell interleaved converterthrough a decoupling capacitor.Theconverter uses a metal–oxide–semiconductor field-effect transistor (MOSFET) for switching at the primary side,a transformer, and a diode at the secondary side. The
topology also has to employ a full-bridge inverter and a low-pass filter for proper interface to the grid. When the switches($S1$,$S2$) are turned ON, a current flows from the common point (the PV source) into the magnetizing inductance of the transformers, and energy is stored in the form of magnetic field. During the on time of the switches, no current flows to the output due to the position of the secondary side diodes therefore, energy to the grid is supplied by the capacitor Caandthe inductor $L1$.When the switches are turned OFF, the energy stored in the magnetizing inductances is transferred into the grid in the form of current. So, the inverter acts like a voltage-controlled current source.The converter is operated in DCM for easy and stable generation of ac currents at the grid interface. The DCM operation converter under open-loop control produces of triangular current pulses at every switching period. If sinusoidal pulse width modulation (SPWM) method is used for control, the inverter will regulate these current pulses into a sinusoidal current in phase with the grid voltage [5].

4. OPERATIONAL PRINCIPLES

The proposed PV power systemconsists of an interleaved boost converter with the MPPTfunction and a three-phase inverter with the fuzzy controller.The two-channel interleaved boost converter with low inputcurrent ripple can achieve better MPPT accuracy as well asincrease the PV system's total output power. Under lowisolation condition, one or two channels can be shut down toavoid unnecessary power losses at low PV power output.During the voltage sag period, the three-

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phase inverter canprovide maximum available reactive power by adopting the fuzzycontroller.Based on the quantity of thegenerated PV power and the allowable maximum activeoutput power of the inverter, the PV power system can beoperated in the MPPT mode.

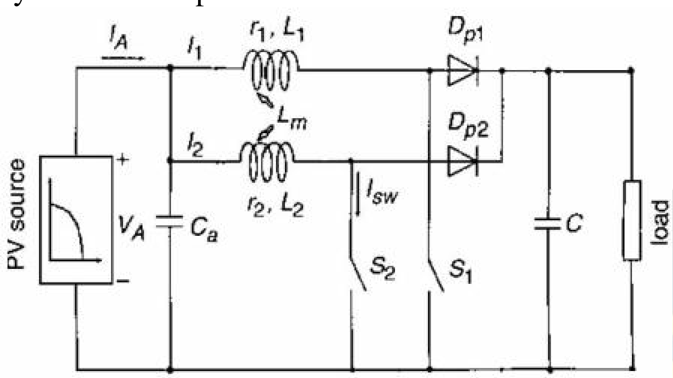


Fig 2Interleaved Boost Converter

(i)MPPT MODE

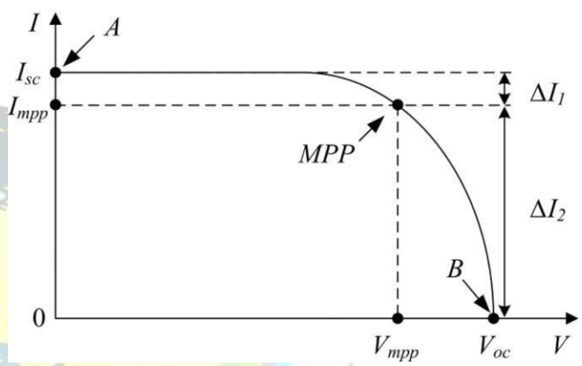
If the voltage of the ac mains is between 90% and 50% ofits normal value but the present active output power of thethree-phase inverter is lower than the allowable maximum value. The interleaved converter can remain its MPPT operation to harvest the maximumpower from the PV array. Thus, input reference currentcommand of interleaved boost converter remainsunchanged and is equal to its maximum power point (MPP)value under normal operation. That is given by

$I_{pv,ref}=I_{mpp}$

On the other hand, the perturbation and observation (P&O)is adopted to achieve the MPPT feature. Although perturbingthe PV voltage is the most common approach for the P&Oalgorithm, the PV current is perturbed instead of the PVvoltage in this paper. It is because that the boost converter isimplemented with the interleaved feature, so the input currentfor each channel should be able to be controlledindependently to achieve the current sharing capability.In the meanwhile, the active power command, *Pcmd*, of thethree-phase inverter is equal to the one for MPPT operation*Pmpp*, under normal operation[5]. Thus, the reactive power command, *Qcmd*, which can provide themaximum reactive power because of the fuzzy controller during the voltage sag period, can be determined as

$P_{cmd}=P_{mpp}$

$Q_{cmd}=\sqrt{(S_{inv,max}^2-P_{mpp}^2)}$



ThetypicalI-VcurveofthePVarray.

It should be mentioned that the dc-link voltage will becontrolled by the three-phase inverter under the MPPT Mode.If the dc-link voltage, *Vdc*, is increased because of the increaseof the PV power, the output ac line current reference of thethree-phase inverter, *Iref*, should also be increased with acurrent regulation value, Δ*I*. On the contrary, if the dc-linkvoltage is decreased because of the decrease of the PV power,the output ac line current reference of the three-phase inverter,*Iref*, should also be reduced to maintain the power flowbalance. Otherwise, the current reference should remainunchanged. By adopting the phase-locked-loop (PLL), theoutput current command, *Iref*, will be changed at thebeginning of the ac mains cycle as soon as the dc-link voltageis higher/lower than the high/low voltage bound. However, alarge Δ*Id*value will lead to the frequently changed dc-linkvoltage and output currents, which will bring a negative impact to the power quality. A small Δ*I*value can mitigatethe ac line current variation but the response of the dc-linkvoltage regulation will be reduced. In order to minimize thechange of the

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input current variation, the optimal ac linecurrent regulation strategy is adopted in this paper to obtain the optimal Δ*I*.

5. THREE PHASE VOLTAGE SOURCE INVERTER

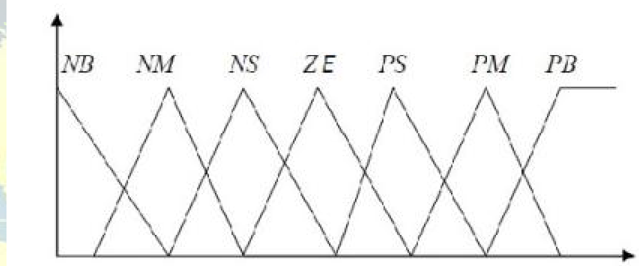
The full-bridge inverter is only responsible for unfolding the sinusoidally modulated dc current packs into ac at the right moment of the grid voltage. Since the switches of the inverter are operated at the grid frequency, the switching losses are insignificant. Only conduction losses are concerned. For this reason, the bridge can use thyristor or even transistor switches for lowercost. However, for easy control also the availability in the laboratory for fast prototyping, we prefer using insulated-gate bipolar transistor (IGBT) switches for this design. But, the final prototype will not use IGBTs. The low-pass filter after the IGBT inverter is responsible for supplying a current to the grid with low THD by removing the high frequency harmonics of the pulsed current waveforms.

6. FUZZY CONTROLLER

The Fuzzy controllers are designed by replacing the conventional PI and PID controller. The Fuzzy controller is implemented to improve performance of the system. The fuzzy inference of fuzzy controller is based on the fuzzy rule table set previously. So the algorithm of fuzzy inference is not complex[. The fuzzy rules are framed to vary the PI controller gains on line based on present error and change in error. The principle of designing fuzzy rules is that the output of the controller can make the system output response dynamic and static performances optimal. The fuzzy logic involves three steps; fuzzification, inference and defuzzification.

A.Fuzzification

This is the process to convert an input crisp set to a fuzzyset by using a membership function. Here a triangularmembership function is chosen. The input to the controller are“error(E)” and “change in error(CE)”. These twoinputs are fed to the controller which gives the output in formof reference current. The fuzzified E and CE signals consistsof 7 logic sets(levels) such as NB, NM, NS, ZE, PS, PM, PB.The fuzzy sets of E and EC are all defined as {NB, NS, ZO, PS, PB}, where NB, NS, ZO, PS and PB represent Negative Big, Negative Small, Zero, Positive Small and Positive Big respectively.The seven-level membership function is illustrated in Fig.



Seven leveled fuzzy membership function.

B. Fuzzy Inference

The programmer defines the rules (inferences) for howmuch to react for which level of input. Here the rules definethe level of reference current(Iqc) for the corresponding speederror(E) and change in error(CE) values. As both the input setsare of seven levels so a 7x7 rule table(look up table) is formed.

The rules are defined as follows

- If E is PB and CE is any, then Iqc is PB.
- If E is PS and CE is PS or ZE, then Iqc is PS.
- If E is ZE and CE is PS, then Iqc is PS.
- If E is ZE and CE is NS, then Iqc is NS.
- If E is NS and CE is NS, then Iqc is NS.
- If E is NB and CE is any, then Iqc is NB.

C.Defuzzification

The reference current levels can be obtained is in fuzzified state. To use these data itshould be

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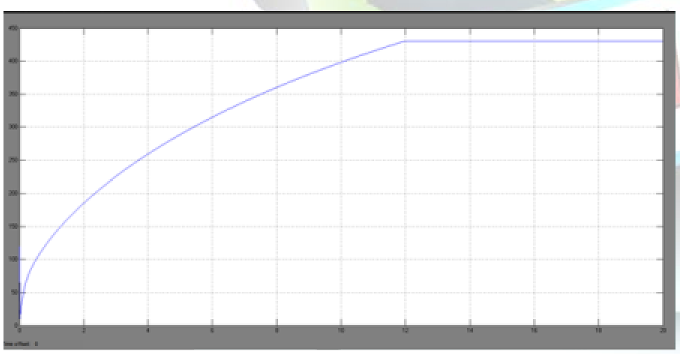
converted to crisp set. To obtain the crisp set we use the following methods

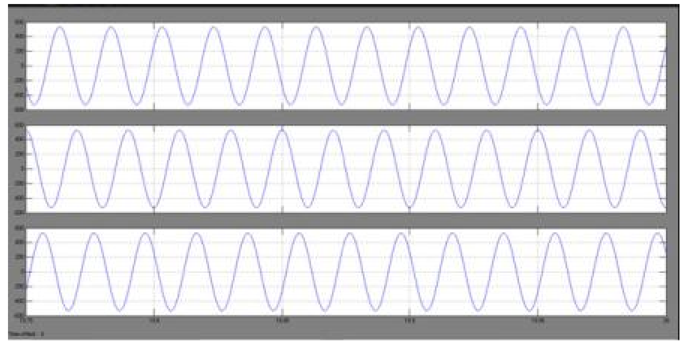
- Max criterion method
- Height method
- Centre of gravity method

7. EXPERIMENTAL RESULTS

The performance of proposed BLDC motor drive is simulated in MATLAB/Simulink environment using the Sim-Power-System toolbox. The performance evaluation of the proposed drive is categorized in terms of performance of BLDC motor, interleaved converter and the achieved power quality indices obtained at AC mains. The parameters associated with BLDC motor such as torque, power factor, efficiency are analysed for proper functioning of BLDC motor.



Waveform of Vdc



Three phase inverter output

8.COMPARATIVE ANALYSIS OF PROPOSED AND EXISTING SYSTEM

Thus the Proposed system shown an satisfactory performance and validity is proved.

Parameters	Existing System	Proposed System
Power factor	0.85	0.9
Duty cycle	0.5	0.9
Efficiency	85%	90%

Table: comparison between existing system and proposed system

9. CONCLUSION

This paper presents the simulation of bridgeless buck boost converter feeding a BLDC motor drive in low power applications. With this proposed converter the power quality can be improved at the AC mains. The power factor can be improved up to 0.99 with this arrangement. The speed control of the BLDC motor can be carried out by varying the DC bus voltage level. Electronic commutation will leads to the reduction of switching stress in the inverter. Speed can be controlled by the variation in DC link voltage. Future scope includes the introduction of any isolation network to control the undesired flow of electric current and a dynamic load change analyser can be used for detecting rapid load changes

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