An Approach of Power Quality Improvement in BLDC Motor Using Bridgeless LUO Converter

S. Arunkumar, N. MohanaSundaram

Abstract: BLDC motors are expected to be one of the fastest growing end product for household applications as well as irrigation purpose due to its electronic commutation feature, good running performance and overall efficiency. These motor drives, when combined with the use of power electronic converters poses challenges in power quality in terms of reduced supply power factor. In order to overcome these problem, it is proposed to employ a bridgeless LUO converter in BLDC Motor Drive system. The LUO converter possess high voltage transfer gain, high power density, reduced ripple voltage and current, thereby leading to improved power factor. The proposed scheme is modelled in MATLAB/Simulink platform and are simulated to find out the power factor and torque behavior.The results indicate the satisfactory performance of the proposed scheme in terms of power factor improvement and reduced ripple in electromagnetic torque waveform.

Keywords: BLDC Motor, Power Quality, LUO Converter, Torque Ripple, Irrigation, Power Factor

I. INTRODUCTION

Nowadays, agriculture sector is facing a severe challenge owing to frequent power cuts, reduced quality of power supply, increased power tariff.Hence, people are more interested in shifting to renewable based energy sources, especially solar based water pumping to improve the agricultural outcome.Since the solar energy is available in abundant with free of cost, it has become the most attractive choice in almost all fields.Though the initial setup cost is higher, it gives a good payback period [1].

In [2], the solar water pumping system employs a DC Motor and so it doesn't require any intermediate voltage conversion.But the presence of commutator and brushes in DC motor demands regular maintenance.The DC Motor is replaced with an induction motor in [3, 4] due to its reliability and ruggedness feature.

The control of induction motor is obtained using field oriented technique, which also requires intermediate voltage conversion and complex in implementing.The problems with these motors can be avoided by using BLDC motor [6, 7], which has appreciable features like small size, noiseless operation, long life, less maintenance.

The BLDC motor is conventionally fed with a combination of diode bridge rectifier and dc bus capacitor. The presence of capacitor draws highly distorted current from the supply.This leads to a very high total harmonic distortion of supply current at very low power factor [8].Hence, to meet the IEC61000-3-2 guidelines, Power Factor Correction (PFC) converters are proposed in [9].The PFC converters operate either in continuous or discontinuous conduction mode.The capacitor voltage and inductor current remains continuous or becomes discontinuous in these modes, respectively.The continuous conduction mode requires sensing of supply voltage, DC link voltage and input current, which offers BLDC motor drive employed with different multi-level inverter topologies.In [13], the BLDC Motor coupled with Cuk Derived converter is proposed for power quality improvement, but the cost and mode of implementation is complex.

II. PROPOSED SYSTEM

In the proposed scheme, the converter setup discussed above in the literature survey is replaced with a bridgeless LUO Converter.It is preferably used in DC-DC conversion, because it has good voltage regulation over a wide range of fluctuations and has high light load efficiency. Additionally, the frontend converter is powered with the help of solar energy source. Hall sensors are employed to detect the rotor position and aid in generation of PWM pulses.Maximum power from PV panel is obtained using MPPT technique. The overall block diagram of the proposed work is shown in Fig. 1.

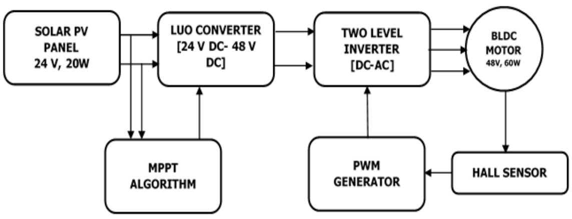

Fig. 1.Block Diagram Of The Proposed Work

III. SIMULATION MODEL

The overall simulation diagram of the proposed work is shown in Fig. 2.

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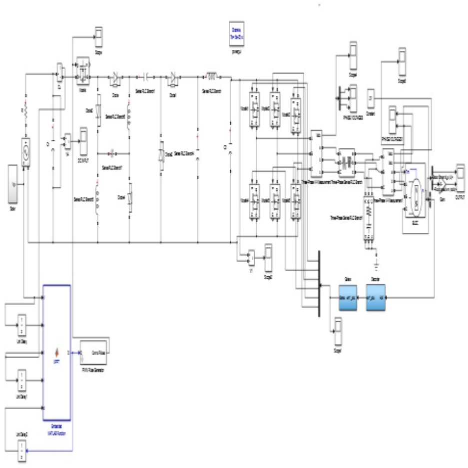

Fig. 2.Overall Simulation Diagram Of The Proposed Work

In this the switching pulses for the front end converter is obtained using MPPT technique.The rotor position sensed by the Hall Sensors is decoded into corresponding back EMF waveform.This acts as reference for PWM pulse generation, the details of which are shown in Table I.

Hall Signals			Back EMF			Switches Triggered
H_a	H_b	H_c	E_a	E_b	E_c	
0	0	0	0	0	0	-
0	0	1	0	-1	+1	Q4,Q5
0	1	0	-1	+1	0	Q2,Q3
0	1	1	-1	0	+1	Q2,Q5
1	0	0	+1	0	-1	Q1,Q6
1	0	1	+1	-1	0	Q1,Q4
1	1	0	0	+1	-1	Q3,Q6
1	1	1	0	0	0	-

Table Iswitching Pulse Generation For Two Level Inverter

At any instant, two switches are commutated, one from upper leg and another one from lower leg.When the back EMF becomes negative high, lower leg switches are conducted and when it reaches positive high value, upper leg switches are conducted.Each switch conducts for 1200 duration and each switch pair conducts for 600 duration.In total, six switching pairs are conducted for one full cycle. The sub system block for firing pulse generation from the hall sensor is shown in Fig.3 & Fig. 4.

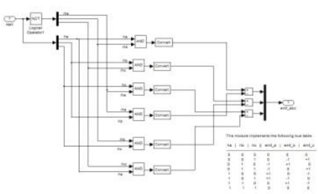

Fig. 3. Conversion Of Hall Sensor Signal To EMF Signal

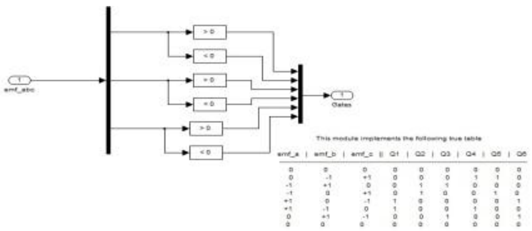

Fig. 4. Firing Pulse Generation From Back EMF Waveform

Parameters	Formula Used	Specifications
Input Voltage	-	24V
Output Voltage	-	48V
Frequency	-	20 KHz
Capacitor, C_1	$\frac{(1-a)}{\nabla VC} * Tl_1$	1000µF/250V
Capacitor, C_2	$\frac{(1-a)}{\nabla VC_1} * Tl_1$	1000 µF/250V
Capacitor, C_3	$\frac{(1-a)}{\nabla VC_2} * Tl_1$	1000 µF/100V
Capacitor, C_0	$\frac{(1-a)}{\nabla VC_3} * Tl_1$	1000 µF/100 V
Inductor,L_1	$\frac{(aTV_{in})}{\nabla IL}$	1mH
Inductor,L_2	$\frac{(aTV_{in})}{\nabla IL_1}$	1mH
Inductor,L_3	$\frac{(aTV_{in})}{\nabla IL_2}$	0.5mH
Inductor,L_0	$\frac{(aTV_{in})}{\nabla IL_3}$	0.5mH

Table II Luo Converter Design Parameters

The PV panel model for different irradiation is simulated separately as shown in Fig 5.

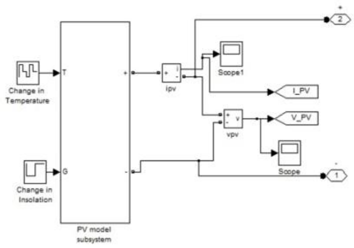

Fig. 5.PV Panel Model For Different Irradiation

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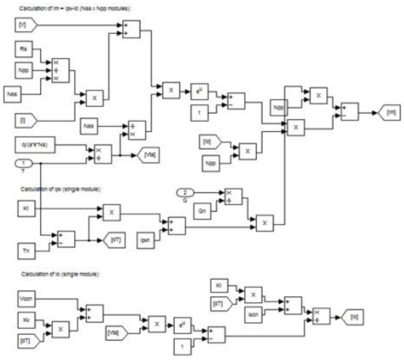

Fig. 6.Mathematical Model Of The PV Subsystem

The PV Panel output varies from time to time, because of time to time variation of solar irradiation.Hence Incremental conductance method is implemented in this scheme, to extract maximum power output from the PV array. The simulation diagram of MPPT block is shown in Fig. 7.

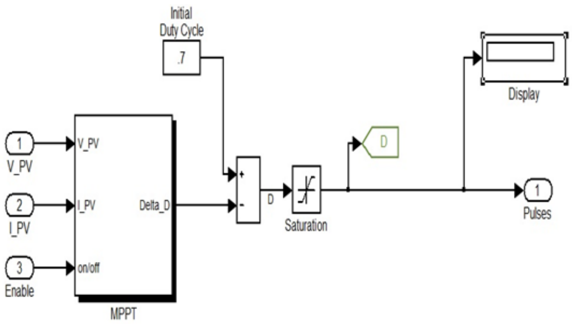

Fig. 7. Simulation Block For MPPT Implementation

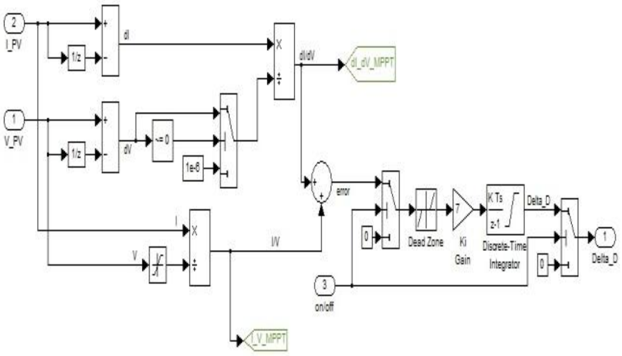

Fig. 8.Subsystem Block of MPPT Algorithm

IV. RESULTS AND ANALYSIS

To examine the behavior of the PV array with different irradiation condition, the repeating sequence stair is used which have both higher and lower values. For that the IPV curve decreases from the short circuit current value and VPV increases to open circuit voltage value. The output waveform for IPV& VPV is shown in Fig. 9 & 10.

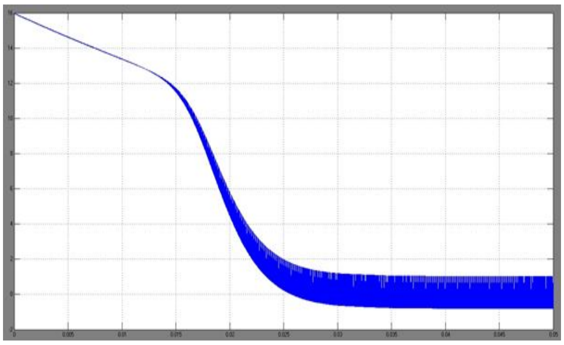

Fig. 9.I_{PV} Curve

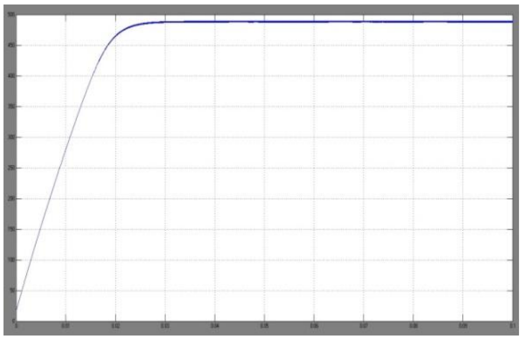

Fig. 10.V_{PV} Curve

The output of the PV is fed to the input to the LUO Converter. The LUO converter is excited by a stepped down voltage of 24 V.

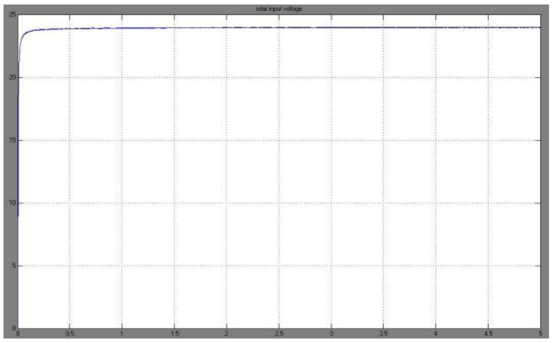

Fig.11.Input Voltage Waveform of LUO Converter

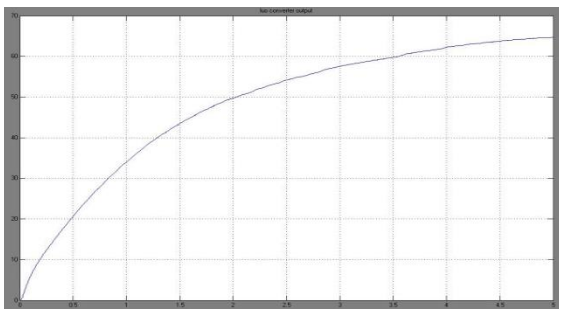

Fig.12.Output Voltage Waveform Ofluo Converter

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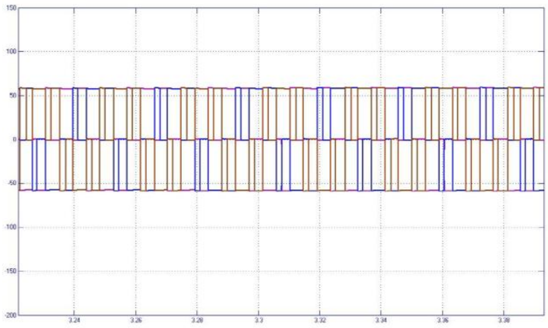

Fig. 13.Inverter Output Voltage Waveform

As seen in the Fig. 13, the inverter output is square in nature.Since this is used to excite the motor windings, the stator current is found to be distorted in nature, containing harmonics. When compared with other converter fed drives, the harmonics is minimum in this case.

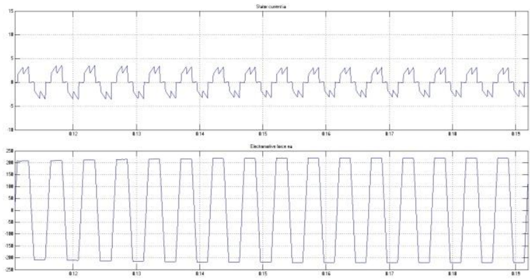

Fig. 14.Stator Current and Back EMF Waveform

As shown in Fig. 15, the speed increases linearly and settles to a reference value of 3000 rpm.The initial oscillations in the electromagnetic torque is very low and settles to a nominal value, in a short period.

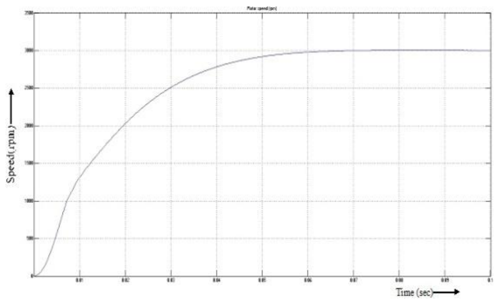

Fig. 15.Speed Response Curve

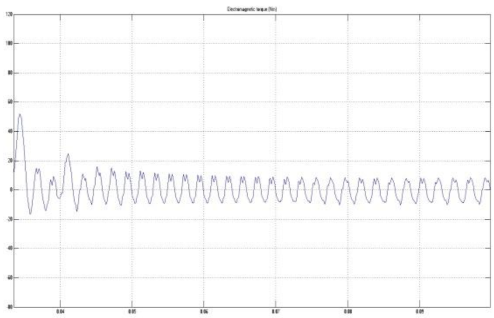

Fig.16.Electromagnetic Torque Waveform

V. CONCLUSION

In this work, the BLDC Motor is powered with PV fed LUO converter. In order to maintain output torque constant, closed loop speed control is employed.This setup is simulated and analyzed using MATLAB/Simulink platform.From the results it can be observed that this work provides satisfactory performance in terms of less harmonic content in stator current waveform, less electromagnetic torque ripple.This helps in improved power factor at supply mains. Because of this characteristic, this drive is more suited for solar based water pumping applications in agriculture as well as in domestic.

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