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Optimization and Validation of Converter Design Parameters of Brushless DC Motor for Electric Vehicle Application

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ABSTRACT: In order to overcome the disadvantage of conventional converters in Electric Vehicle like DC-DC Buck, DCDC Boost, DC-DC Buck-Boost converters, the SEPIC and the LANDSMAN converters are implemented. The SEPIC converter has high conversion efficiency and the LANDSMAN converter has good power factor maintenance. These converters have good efficiency when MPPT and PSO technique used as control signal generators. Since the Electrical Vehicle is to be hybridized, battery is used as a backup source. The PV fed converters along with brushless DC motor are analyzed in MATLAB SIMULINK software to get better efficient Electric Vehicle.

KEYWORDS: BLDC motor, LANDSMAN converter, PV-Module, SEPIC converter.

I. INTRODUCTION

The pollution free environment is the most debated topic in recent times. Vehicle emission is the major cause for pollution Which can be overcome by Electric Vehicle. EV's are the battery operated vehicle and they are controlled with controllers. Though, we can utilize renewable resources like Solar, Wind, etc., the hybrid vehicle emerged. The conversion of solar energy is carried out by PV-module which consists of 50 cell connected in series and the energy is bestowed to the converter. The MPPT technique is used to wrench out power from PV cells. The MPPT technique is subjected to track the highest voltage that can be produced and maintain the voltage constant with that highest value. Thus MPPT technique is used as pulse generator/control signals to DC-DC converters. The PSO [Particle Swarm Optimization] algorithm is an iterative methodused for producing control signals for the converters. The conventional converter such as Buck, Boost and Buck-Boost has a drawback of leakage in transformer since they are used as isolated converter. The other delimits are higherharmonics and higher distortion. The converters for the proposed vehicle are SEPIC and LANDSMAN where SEPIC has high energy conversion and LANDSMAN for better power factor. The SEPIC is abbreviated as Single-Ended- Primary- Inductor Converter is the boost converter with the inductor connected to the load side. This factor decreases the distortion and improvises converter efficiency [1]. The LANDSMAN converter increases the power factor quality by connecting capacitor in parallel. The BLDC motor is the best traction motor for electric vehicle application [5]. The entire system is analyzed by using MATLAB/Simulink software.

II. SYSTEM DESCRIPTION

The PV cells get energized by the sun's radiation which is bestowed to the DC-DC SEPIC boost converter. This converter step up the voltage required to match the DC bus. The ultra-capacitor connected to the output of the controller. The charge stored in the ultra-capacitor during regenerative braking is stepped up by DC-DC Buck- Boost converter required to the DC bus.

DC-DC Buck-Boost converter can also step down the voltage when the break is applied. These converters are provided with the control and drive signals by PSO and MPPT technique. This technique compares the present pulse and the required pulse to provide the necessary control signal to the converter.

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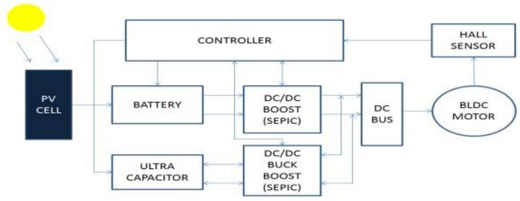

Fig.1.Basic block diagram of solar PV BLDC motor drive system.

Maximum Power Point Tracking (MPPT) [6] algorithms are typically used in the controller design that accounts factor such as variable irradiance and temperature to ensure that the system generates maximum power at all times. By using these techniques the pulse generations for the converter have reduced distortion and CCM can be easily achieved. Thus the BLDC motor runs efficiently.

III. ANALYSIS OF DC-DC CONVERTER

Based on the intensity of the solar radiation the solar PV cells voltage will fluctuate. In order to obtain the constant voltage required for the motor to run DC-DC converters are used. The DC-DC converters step up and step down the voltage by BUCK, BOOST, BUCK-BOOST converters. Since these converters have the above said drawbacks they are modified by the filters at their end or connecting capacitor in parallel, so these converters are named SEPIC and LANDSMAN. The performance of the converter with the brushless DC motor is analyzed.
The basic block diagram of SEPIC and LANDSMAN are shown as

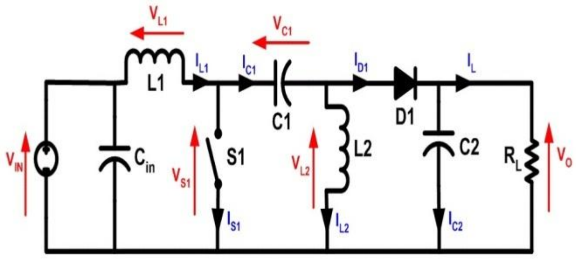

Fig.2.SEPIC Converter

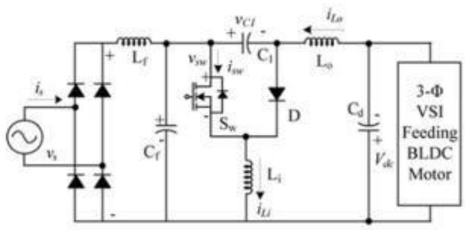

Fig.3.LANDSMAN Converter

A.OPERATION OF SEPIC CONVERTER
The SEPIC is the type of DC-DC converter that allows voltage at its output greater than, lesser than or equal to that at its input. The output of SEPIC is controlled by duty ratio of control switch.
The duty ratio of SEPIC converter for ideal and practical conditions is calculated as [1],

$$D_{ideal} = \frac{V_{dc}}{V_{in}+V_{dc}}$$

$$D_{practical} = \frac{V_0+V_d}{V_{in}+V_0+V_d}$$

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Here $V_{dc}$and V_{in} are the output and the input voltage of SEPIC. $V_{mppt}$is the maximum peak voltage of PV panel.V_d is diode voltage drop and D is the duty ratio of the converter. So the inductance and the capacitance of the SEPIC converter is given by [1],

$$L_2=\frac{(1-D)*V_{dc}}{f*\Delta I_{L1}}$$

$$L_1=\frac{D*V_{PV}}{f*\Delta I_{L1}}$$

$$C_1=\frac{D*I_{out}}{f*\Delta V_{c1}}$$

Based on the above equation the diagram of the SEPIC converter is described as

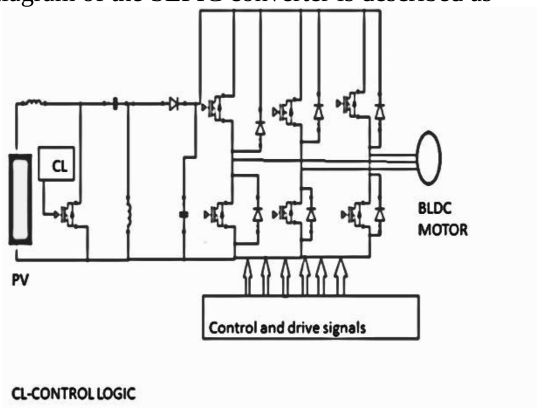

Fig.4.Block diagram of SEPIC converter fed PV BLDC system.

Based on the above inductance and capacitance, the SEPIC converter work in a continuous conduction mode of operation. If switch is ON inductor L_1 and L_2 starts charging by V_{dc} andV_{c1}, when switch is OFF the capacitor C_1 and C_2 starts discharging byL_2.

B.OPERATION OF LANDSMAN

The LANDSMAN converter provides a positive output from the input voltage. The LANDSMAN converter is configured from buck controller that drives MOSFET. LANDSMAN converter is an option for regulating an unregulated input power supply.

The main operation of the LANDSMAN converter is to optimize the output of the source and to give smooth and secure operation.

If switch is ON the diode of LANDSMAN converter gets reverse biased and its supply input flows through the switch. If V_{c1}>V_{dc}, the capacitorC_1 discharges through the switch and input supply gets to the load.

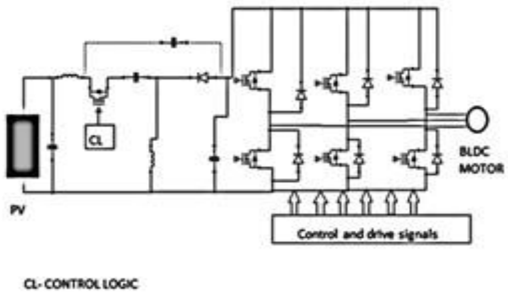

Fig.5.Block diagram of LANDSMAN converter fed PV BLDC system.

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Whenever the switch is OFF diode gets forward biased and inductor current flows through the diode and that can be calculated by [1],

$$\Delta i_{L1}=\frac{\Delta V_{c1}*T}{8L_1}$$

$$i_{c1}=\frac{\Delta V_{c1}*C_1}{(1-D)*T}$$

$$\Delta V_{c1}=\frac{(1-D)T*i_{L1}}{C_1}$$

From all the above equation it is found that
[1],

$$\Delta I_{L1}=\frac{(1-D)T^2*I_{L1}}{8C_1}$$

The duty ratio, inductance and capacitance can be derived as [1],

$$D=\frac{V_{dc}}{V_{dc}+V_{in}}$$

$$C_1=\frac{D*i_{dc}}{f*V_{c1}}$$

$$L_1=\frac{D*i_{dc}}{8f^2*\Delta I_{L1}*C_1}$$

$$L_2=\frac{D*V_{dc}}{f*\Delta I_{L2}}$$

Based on the above inductance and capacitance the LANDSMAN converter works in CCM of operation. The main advantages of CCM are the voltage gain is not depend on load and the repel component of inductor current is lower than average component.

The SEPIC and LANDSMAN converter are applied for correcting the power factor and to increase the conversion efficiency in both discrete and continuous mode.

IV. DESIGN OF BLDC MOTOR

Conventional DC motor use a stationary magnet with a rotating armature combining the commutation. In comparison, the brushless DC motor is reversed design; the permanent magnet is rotating whereas the windings are part of the stator and can be energized without requiring the commutator and brush system. The commutation of brushless DC motor is made electronically and can be done either by looking at the back emf of the motor or by using position sensor. So the BLDC motor is used for traction.

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PARAMETERS	VALUE
Winding type	Star
Hall effect angle	120^0
Insulation class	B
Ambient temperature range	- 20^0C→+50^0C
Insulation resistance	100M? Min 500VC DC
Dielectric strength	700V AC
Number of poles	4
Number of phases	3
Nominal voltage[VDC]	48
Rated speed [RPM]	3000
Rated torque [NM]	1
Rated current [A]	8.5
Output power [W]	314
Peak torque [NM]	3
Peak current[A]	25
Torque constant [NM/A]	0.131
Back Emf	13.7
Rotor inertia [Kg sq.mm]	120
Body length [mm]	80
Mass [Kg]	2.3

V. SIMULATION RESULTS

MATLAB allows testing algorithms immediately without recompilation. Itisused for simulation, optimation and statistics and data analysis. The main advantages of MATLAB over other software are easy implementation and testing the algorithms, easy debugging, external libraries and easy simulation videos.

S.NO	COMPONENTS	TYPE	SPECIFICATION
1.	Battery	Lithium Ion	48V,150Ah
2.	FET	P-MOSFET	0.1Ω
3.	Inductor	-	117.6μH
4.	Capacitor	-	470μf
5.	Motor	BLDC	48V,314W
6.	Regulating sequence	-	$01/10e^3$

Based on the above specification the components are used in SIMULINK. The design feature of SEPIC and LANDSMAN differs only by arrangement of MOSFET, Inductor and Capacitor as shown in fig

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SEPIC PV MODULE CHARACTERISTICS

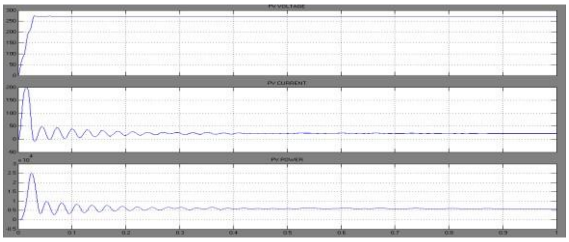

Fig.6.Voltage, Current, Power VS Time.

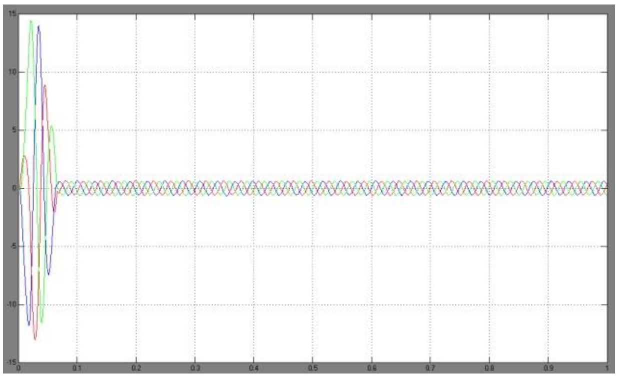

Fig.7.Stator current VS Time

Since BLDC motor is used, there will be a large inrush current. So, the initial current characteristics of stator are highly distorted but the converter brings the oscillation to the sinusoidal current waveform.

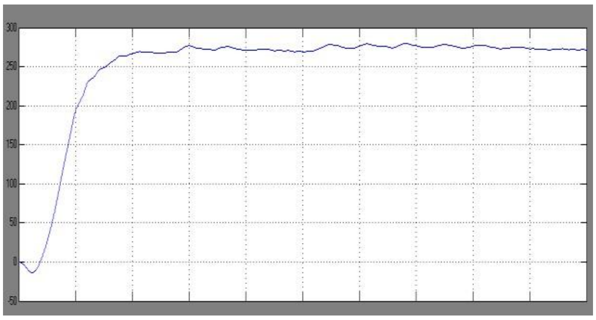

Fig.8. Torque VS Speed

The SEPIC converter along with the BLDC motor increases the torque slight linearly with respect to speed and remains constant.

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LANDSMAN PV MODULE CHARACTERISTICS

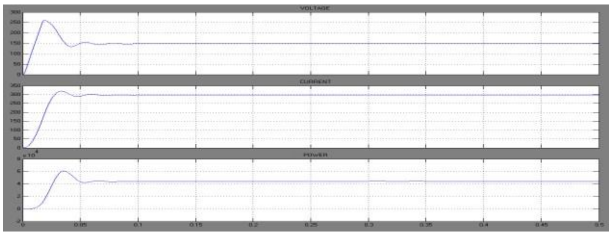

Fig.9. Voltage, Current, Power VS Time.

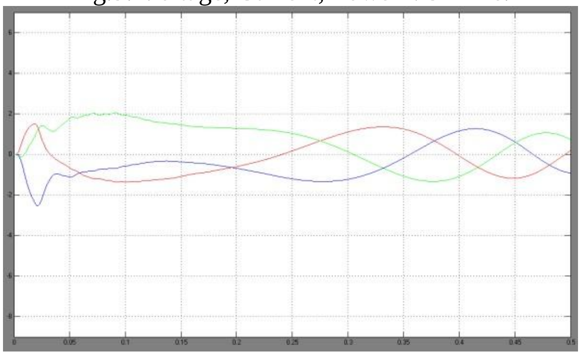

Fig.10. Stator current VS Time

Since BLDC motor is used, there will be a large inrush current. So, the initial current characteristics of stator are highly distorted but the converter brings the oscillation to the sinusoidal current waveform. The LANDSMAN reduces higher distortion than SEPIC converter [1].

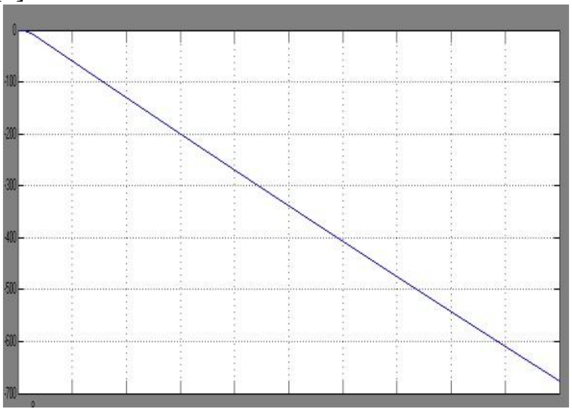

Fig.11. Torque VS Speed

The torque decreases linearly with speed then remains constant when LANDSMAN converter is used.
The Simulink output of the PV panel cum
SEPIC and LANDSMAN converter along with the motor is found.

VI. CONCLUSION

The comparative analysis of SEPIC and LANDSMAN with PV panel for brushless motor is done and the MATLAB SIMULINK results are given. From the analysis it is found that solar energy is efficiently converted by the SEPIC and the most suited brushless DC motor operates effectively with the above configuration.

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