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An Advanced Res Based ZSPL Topology with Reduced Emi Problems

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Abstract—*In this paper a Power Factor Correction based ZSPL(zero switch power loss) Cuk converter fed Brushless DC Motor Drive using Solar PV is used. The Speed of the Brushless dc motor is controlled by varying the output of the DC capacitor. A Diode Bridge Rectifier followed by a Cuk converter based on ZSPL is fed into a Brushless DC Motor to attain the maximum Power Factor and reduce the switching losses. Here we are evaluating the three modes of operation in discontinuous mode and choosing the best method to achieve maximum Power Factor and to minimize the Total Harmonic Distortion. Here simulation results reveal that system is very effective and efficient compared to the RES based system with PI controllers, because of the steady state error is less and the stabilization if the system is better in it. The performance of the proposed system is simulated in a MATLAB/Simulink environment of the proposed drive is developed to validate its performance.*

Keywords — Brushless dc motor, ZSPL (Zero switch power less),Discontinuos input inductor mode , Discontinuous output inductor mode, Discontinuous intermediate capacitor mode ,Cuk converter, Power Factor Correction,Total Harmonic Distortion.

I. INTRODUCTION

Brushless Dc Motor is recommended for many low cost applications such as household application, industrial, radio controlled cars, positioning and aeromodelling, Heating and ventilation etc. ,because of its certain characteristics including high efficiency, high torque to weight ratio, more torque per watt , increased reliability, reduced noise, longer life, elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference(EMI) etc. With no windings on the rotor, they are not subjected to any centrifugal forces, and because the windings are
supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling purposes. The motor's internals can be entirely enclosed and protected from dust, dirt or any other foreign obstacles.

The two main factors that determine the power quality of a motor are the Power Factor (PF) and the total harmonic Distortion (THD). The Power Factor determines the amount of useful power being consumed by an electrical system. The term THD is defined as the ratio of the harmonic components of voltage (or current) to the voltage (or current) of the fundamental. So the Power Factor Correction (PFC) is the best method of improving the PF by making the input to the power supply purely resistive or else due to the presence of non linear loads the input will contain phase displacement which causes harmonic distortion and thus the power factor gets degraded.

The main aim of all papers is to improve the power quality according to the standards recommended ,But in the conventional schemes for example diode bridge fed Brushless Dc Motors due to the presence of huge capacitor value it draws a non sinusoidal current from the ac mains which increased the THD to 65% and power factor to 0.8.The other conventional schemes by using many of the converters fed BLDC motors like Sepic ,Buck, Boost ,Buck Boost etc. by using high frequency pulse width modulation increases the switching losses. Bridgeless configuration of these converters were also existed ,even though they reduces the switching losses ,the no of active and passive components were more which increases the complexity in designing the

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circuit and the overall cost. The Power Factor in these cases is very less and a high value of THD which reduces the power quality. In this paper we are using a Cuk converter for PFC correction to the maximum value and to attain a low value of THD using Solar PV.

There are some draw backs in using conventional Power Factor Correction Methods, By using a Boost converter in Discontinuous Current Mode leads to a high ripple output current. The Buck converter input voltage does not follow the output voltage in DCM mode and the output voltage is reduced to half which reduces the efficiency. In our proposed system front-end Cuk converter is used in both continuous and discontinuous mode because of its certain advantages like easy implementation of the transformer isolation ,protection against high inrush current ,low current ripple and also low electromagnetic interferences.

The two modes of operation for the front-end converter are continuous conduction mode and discontinuous conduction modes of operations. The current multiplier approach is used in continuous mode with low voltage and current stresses but which make use of three sensors(One voltage sensor and twocurrent sensors) and increase the cost. But in the case of discontinuous mode of operation we use voltage control follower with comparatively more voltage and current stresses but only one voltage sensor is used .

Cuk converter

The **Cuk converter** is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy.

Similar to the buck–boost converter with inverting topology, the output voltage of non-isolated Cuk is typically also inverting, and can be lower or higher than the input. It uses a capacitor as its main energy-storage component, unlike most other types of converters which use an inductor. It is named after Slobodan Cuk of the California Institute of Technology, who first presented the design.

Non-isolated Cuk converter

There are variations on the basic Cuk converter. For example, the coils may share single magnetic core, which drops the output ripple, and adds efficiency. Because the power transfer flows continuously via the capacitor, this type of switcher has minimized EMI radiation. The Cuk converter allows energy to flow bidirectional by using a diode and a switch.

Operating principle

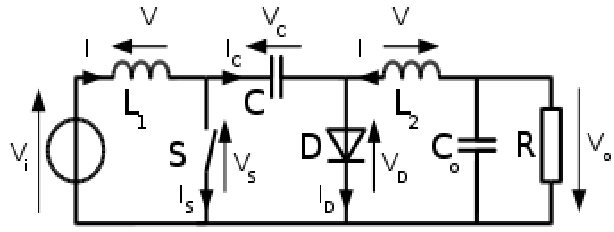
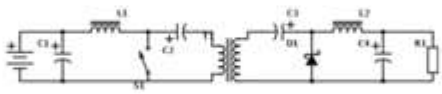
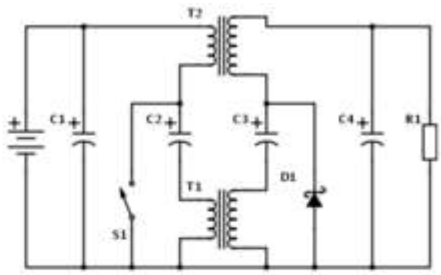


Fig 1: Schematic of a non-isolated Cuk converter.

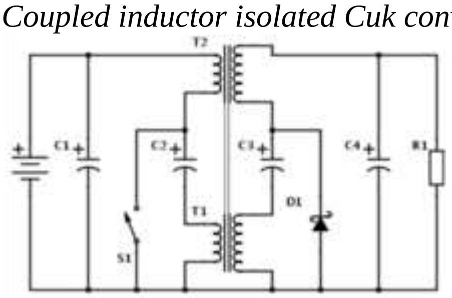
Isolated Cuk converter



Isolated Cuk converter with gapless AC transformer in the middle



Coupled inductor isolated Cuk converter



Integrated magnetics Cuk converter

The Cuk converter can be made in an isolated kind. An AC transformer and an additional capacitor must be added.

Because the isolated Auk converter is isolated, the output-voltage polarity can be chosen freely.

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As the non-isolated cukconverter, the isolated Cuk converter can have an output voltage magnitude that is either greater than or less than the input voltage magnitude, even with a 1:1 AC transformer.

Power factor

POWER FACTOR is the ratio between the useful (true) **power** (kW) to the total (apparent) **power** (kVA) consumed by an item of a.c. electrical equipment or a complete electrical installation. It is a measure of how efficiently electrical **power** is converted into useful work output. The ideal **power factor** is unity, or one.

Solar Photovoltaic

Solar cells, also called photovoltaic (PV) cells by scientists, convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage), which is called the PV effect.

A large silicon solar array installed on the roof of a commercial building.

Traditional solar cells are made from silicon, are usually flat-plate, and generally are the most efficient. Second-generation solar cells are called thin-film solar cells because they are made from amorphous silicon or nonsilicon materials such as cadmium telluride. Thin film solar cells use layers of semiconductor materials only a few micrometers thick. Because of their flexibility, thin film solar cells can double as rooftop shingles and tiles, building facades, or the glazing for skylights.

Third-generation solar cells are being made from a variety of new materials besides silicon, including solar inks using conventional printing press technologies, solar dyes, and conductive plastics. Some new solar cells use plastic lenses or mirrors to concentrate sunlight onto a very small piece of high efficiency PV material. The PV material is more expensive, but because so little is needed, these systems are becoming cost effective for use by utilities and industry. However, because the lenses must be pointed at the sun, the use of concentrating collectors is limited to the sunniest parts of the country.

Photovoltaic (PV) materials and devices convert sunlight into electrical energy. A single PV device is known as a cell. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. To boost the power output of PV cells, they are connected together in chains to form larger units known as modules or panels. Modules can be used individually, or several can be connected to form arrays. One or more arrays is then connected to the electrical grid as part of a complete PV system. Because of this modular structure, PV systems can be built to meet almost any electric power need, small or large.

Photovoltaic Solar Energy Systems

PV modules and arrays are just one part of a PV system. Systems also include mounting structures that point panels toward the sun, along with the components that take the direct-current (DC) electricity produced by modules and convert it to the alternating-current (AC) electricity used to power all of the appliances in your home

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II OPERATION OF THE CONVENTIONAL SCHEME

A. PFC CUK CONVERTER FED BLDC MOTOR

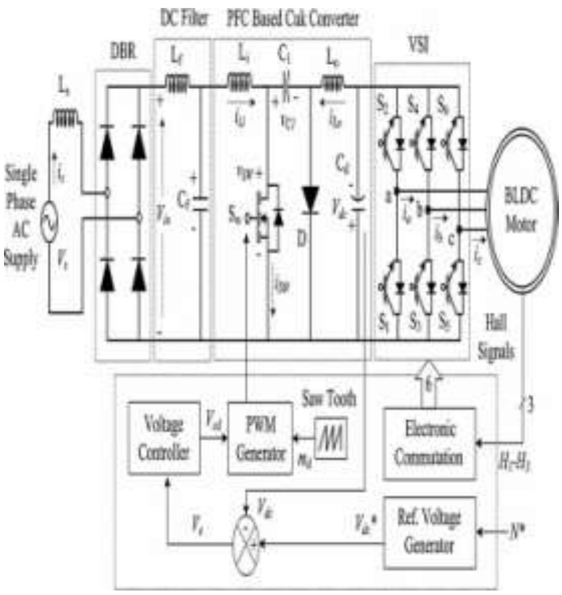

Fig.1.Conventional scheme using voltage follower approach

In this operation a diode bridge rectifier is used to convert the given ac source to a dc, which is fed into a Cuk converter to improve the Power Factor and THD. The Voltage follower approach is used to evaluate the scheme in three different discontinuous mode of operation. In the first method DICM (Li),the input inductor is made discontinuous while all other parameters are made continuous. In the DICM(Lo),the output inductor is made discontinuous while other parameters are continuous.In DCVM,the output capacitor is made discontinuous while the other parameters are continuous. The speed of the BLDC motor is sensed using the hall effect position sensors mounted on the shaft. Electronic commutation is used to trigger the switches in the inverter according to the information from the hall effect position sensors to turn on/off the switches with low frequency which reduces the switching losses. It means that proper switching of the VSI in such a way that asymmetrical current is drawn from the dc link capacitor for 120˚ and placed symmetrically. The output of the cuk converter(Vc) is feed back and compared with a reference voltage(Vf) to produce the voltage error(Ve) and is given to the PI controller .The proportional constant(kp) determines the reaction to the current error and the integral constant (ki) determines the reaction based recent error. The output of the PI controller is compared with the high frequency signals from the sawtooth generator to trigger the front-end Cuk converter switch

III PFC CUK CONVERTER FED BLDC MOTOR USING ARTIFICIAL NEURAL NETWORK

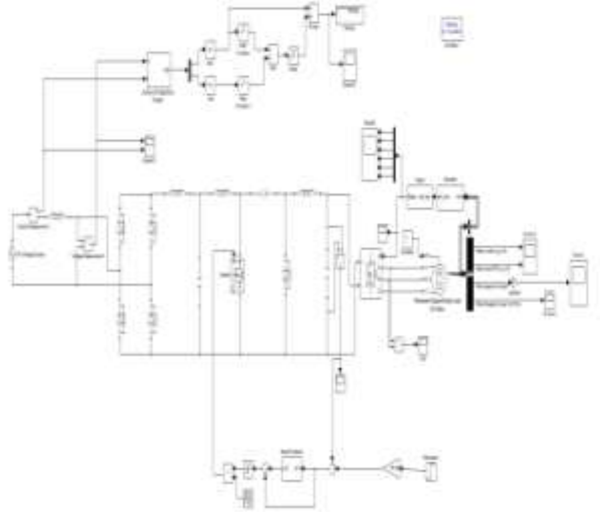

Fig.2.Proposed scheme using Artificial Neural Network

In this proposed scheme using Artificial Neural Network (ANN),The AC source followed by a diode bridge rectifier to convert AC source to DC is boosted or bucked using the switching pulse given to the MOSFET switch of a cuk converter is fed to a inverter fed Brushless DC motor. Here the power factor is made approximately to the unity by using the cuk converter. Here the speed is not sensed ,only the cuk converter output voltage is sensed and compared with the reference speed 2000rpm the output is given to a Artificial neural network which consist of two main functions Transig and Purelin. The error signal is given to the first layer Transig which removes the complex, imaginary minimized values and only allows the real values p. This p is given after a delay is given to various constant weights their product is given to a mux is compared with the biased value and produce the output a(1).This function a(1) is given to the next neural layer

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called Purelin with the same process as same as Transig layer.The only difference is that in Transig layer the weighted values are compared with many biased values.but in the case of purelin only 1 bias value is used for the comparison.From the purelin only the real values are permitted and removes all constants,imaginary,complex values etc.This output y(1) is compared with the feed back signal and the error signal is undergone a comparison with the repeating sequence to produce the gating signal for triggering the mosfet. The ANN controllers are very effective and efficient compared to the PI and Fuzzy controllers, because the steady state error in case of ANN control is less and the stabilization if the system is better in it. Also in the ANN methodology the time taken for computation is less since there is no mathematical model

VI OPERATING MODES OF THE PROPOSED CONVERTER

There are mainly three modes of Discontinuous operation:

A) DICM(Li)

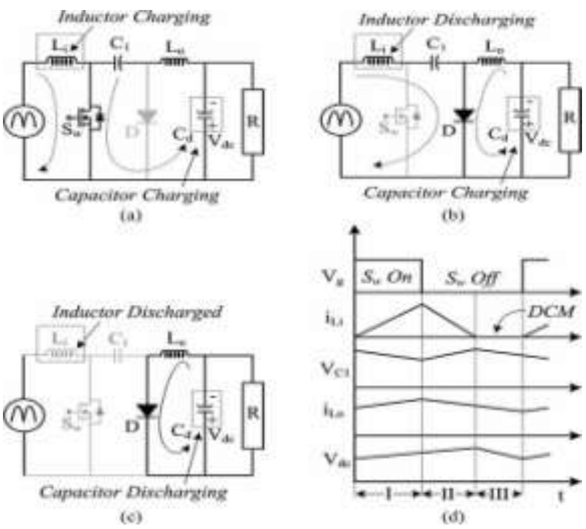

Fig. 4. Operation of the Cuk converter in the DICM (Li) during (a)–(c) different intervals of switching period and (d) associated waveforms. (a) IntervalI. (b) Interval II. (c) Interval III. (d) Waveforms.

Interval I The swithch Sw is turned on and the inductor Li will store energy and the capacitor Ci will start discharging through the switch Sw to the dc link capacitor Cd .So the voltage across the capacitor Cd will start increasing and the current iL1 will be decreasing in this interval.

Interval II The switch Sw is turned off and the energy stored across the inductor will start discharging through diode D to the dc link capacitor Cd.

Interval III At this moment no energy will be left back in the inductor and the inductor Lo will be in continuous conduction mode to transfer its energy to the Dc link capacitor.

B) DICM(Lo)

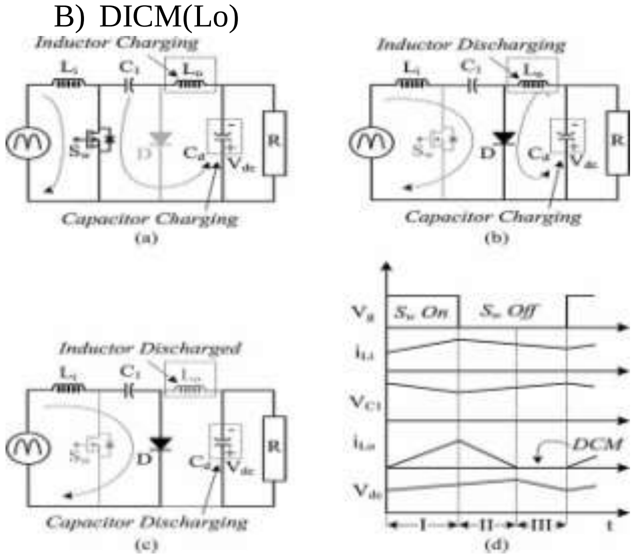

Fig. 5. Operation of the Cuk converter in DICM (Lo) during (a)–(c) different intervals of switching period and (d) associated waveforms. (a) Interval I.(b) Interval II. (c) Interval III. (d) Waveforms

Interval IThe swithch Sw is turned on and the inductor Li will store energy and the capacitor Ci will start discharging through the switch Sw to the dc link capacitor Cd .So the voltage across the capacitor Cd will start increasing and the current iL1 will be decreasing in this interval .

Interval II The switch Sw is turned off and the energy stored across the inductor Li and Lo will start discharging through diode D to the dc link capacitor Cd and capacitor Ci.

Interval III At this moment no energy will be left back in the inductor Lo and the inductor Li will be in continuous conduction mode to transfer its energy to the intermediate capacitor.

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C) DCVM

Interval I The swithch Sw is turned on and the inductor Li will store energy and the capacitor Ci will start discharging through the switch Sw to the dc link capacitor Cd .So the voltage across the capacitor Cd will start increasing and the current iL1 will be decreasing in this interval.

Interval II The switch Sw is turned off ,the capacitor Cd will be completely discharged, The inductor Lo will give supply to the dc link capacitor Cd

Interval III At this moment Li will start charging the intermediate capacitor Ci and the inductor Lo will be in continuous conduction mode to transfer its energy to the Dc link capacitor.

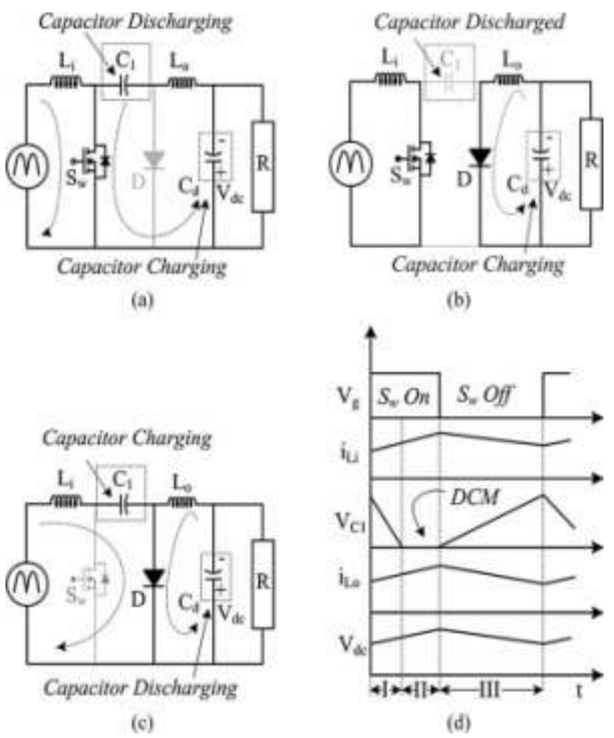

Fig. 6. Operation of the Cuk converter in the DCVM (C1) during (a)–(c) different intervals of switching period and (d) associated waveforms. (a) IntervalI. (b) Interval II. (c) Interval III. (d) Waveforms.

D) DESIGN PARAMETERS

TABLE I
SPECIFICATIONS OF A BLDC MOTOR

S. No.	Parameters	Values
1.	No. of Poles (P)	4 Poles
2.	Rated Power (P_{rated})	251.32W
3.	Rated DC link Voltage (V_{rated})	200V
4.	Rated Torque (T_{rated})	1.2Nm
5.	Rated Speed (ω_{rated})	2000rpm
6.	Back EMF Constant (K_b)	78V/krpm
7.	Torque Constant (K_t)	0.74Nm/A
8.	Phase Resistance (R_{ph})	14.56Ω,
9.	Phase Inductance (L_{ph})	25.71mH
10.	Moment of Inertia (J)	1.3×10^{-4}Nm/s^2

Table2 DESIGN PARAMETERS IN DIFFERENT MODES OF OPERATION

Specifications ↓	Values			
Supply Voltage (V_s)	Rated: 220V, (Universal Mains: 85-270V)			
DC Link Voltage (V_{dc})	Rated: 200V, (40V-200V)			
Power (P)	Rated: 350W, (70W-350W)			
Switching Frequency (f_s)	20kHz			
Operation ↓	L_i	L_o	C_1	C_d
CCM	2.5mH	4.3mH	0.66µF	2200µF
DICM (L_i)	100µH	4.3mH	0.66µF	
DICM (L_o)	2.5mH	70µH	0.66µF	
DCVM (C_1)	2.5mH	4.3mH	9.1nF	

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Table3
SWITCHING STATES OF VSI CORRESPONDING TO HALL-EFFECT ROTOR POSITION SIGNALS

Hall signals			Switching states					
H_1	H_2	H_3	S_1	S_2	S_3	S_4	S_5	S_6
0	0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	1
0	1	0	0	1	1	0	0	0
0	1	1	0	0	1	0	0	1
1	0	0	0	0	0	1	1	0
1	0	1	1	0	0	1	0	0
1	1	0	0	1	0	0	1	0
1	1	1	0	0	0	0	0	0

V. SIMULATION RESULTS OF CONVENTIONAL SCHEME The simulation of the PFC Cuk converter fed BLDC motor drive is done in the environment of MATLAB/SIMULINK at a switching frequency 20khz.The input voltage 230V is given to a diode bridge rectifier where rectification process is done which convert AC to DC and fed to a Cuk converter which is used for power factor correction and to reduce the THD. The speed of the BLDC motor drive is controlled by using the dc capacitor voltage. Here Electronic commutation is used by sensing the rotor position by using the hall effect position sensors to trigger the low frequency IGBT switches of the Vol

V. SIMULATION DIAGRAM

Simulation Circuit

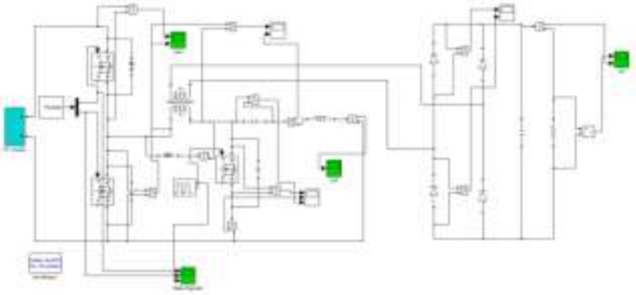

Fig.7. Matlab Simulation Circuit

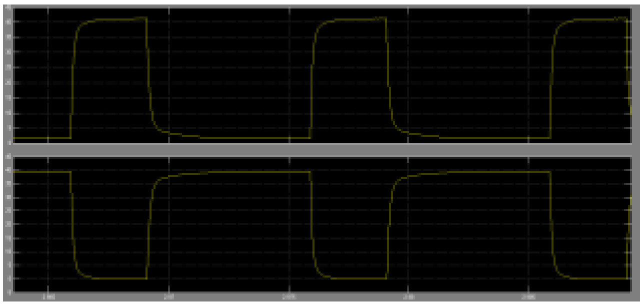

Fig.8. Vds - M1,M2 switches

Fig.9. Inductor Current (ILr)

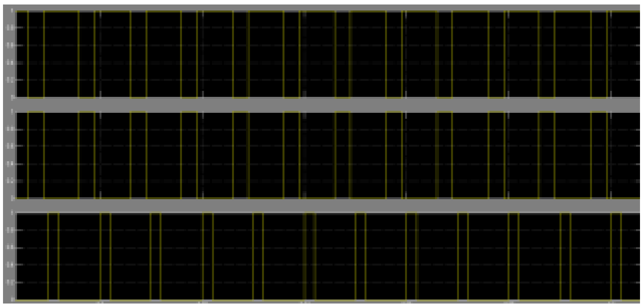

Fig.10. Gating Signals (Vgs) of M1,M2 &M3

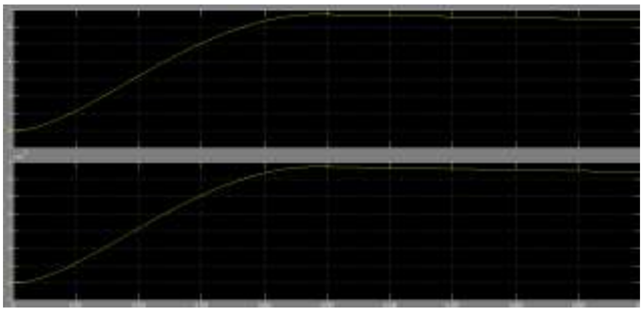

Fig.11. Output Voltage (V0) & Current (I0)

V1 CONCLUSION

A Power Factor Corrected Cuk converter fed BLDC motor using Solar PV is simulated in the environment of MATLAB. The three modes of Discontinuos DICM(Li),DICM(Lo),DCVM(Vco) is simulated at the given switching frequency 20Khz.The diode bridge followed by a Cuk converter is used here for maximum Power Factor Correction. . Here simulation results reveal that the PV ouput got constant dc output by using Cuk converter is very effective and because the steady state error is less and the stabilization of the system is better in it. Hence the system is suitable for Renewable energy interfaced applications with reduced losses(zspl) and improved power quality.

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