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Solar Photovoltaic Array Powered BLDC Motor Drive Using LUO Converter with MPPT

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Abstract - *Luo converters are a series of new DC-DC step-up converters which were developed using voltage lift technique. This paper deals with the solar-powered BLDC motor simulation with luo convertor as associate intermediate dc-dc boost convertor. Among dc-dc boost converters, luo converters are best matched for application in solar power as they provide higher power density, higher productivity and easy structure with low ripples. The BLDC motor is employed with Voltage Source Inverter (VSI) performing at first harmonic therefore avoiding the frequency shift losses. The progressive electrical phenomenon (Incremental Conductance) rule is employed for tracking the point of maximum power (MPPT). This whole system is displayed in MATLAB/Simulink and results are lodged.*

Keywords— Solar PV Array, IC Algorithm, Luo Converter, VSI, BLDC Motor.

1. INTRODUCTION

Solar energy is associated in nursing simply accessible and out there supply of energy for overseeing end of the day in crisis of energy. The shortage of fossil fuels and a lot of energy consumption cause emphasis on alternative energy. An electrical device is power generating unit that consists of the many solar PV modules and array [1]. The potency of the cell lies on the quantity of daylight that falls on the panel and also the electrical characteristics of the load. Because the status changes the quantity of daylight varies throughout the day, the load characteristic which supplies the best power transfer potency changes. Thus, once the load characteristics modifies it ought to keep the ability transfer at its highest potency [2]. This characteristic of the load is named a maximum power point (MPP) and also the MPPT is employed for extracting the most power at a selected point of your time. The foremost unremarkably used methodology for MPPT includes perturb-and observe (P&O), constant current, constant voltage, incremental conductance (IC) [3]. An IC methodology is employed during this system so as to urge the specified price of the duty cycle for the MOSFET switch of luo converter. In IC the increment power is compared with increment voltage (current) for two consecutive samples then the MPP voltage is decided [4]. There are various types of luo converter which include the re-lift circuit, quadruple lift circuit, self-lift circuit, and triple lift circuit [5]. The above-mentioned techniques have high voltage transfer gain however thanks to use of a variety of parts and switching devices their prices are high and that they aren't appropriate for this method. The elementary luo converter is employed during this project for obtaining the highest power from the solar array. A luo converter is dc-dc boost device that may convert the positive input dc voltage to a positive output dc voltage. Luo converter will provide higher output with less quantity of ripple. Luo converter is almost like standard boost device however has smoothened output current not like sort of a conventional boost device [6-9]. The output of luo convertor is fed back to voltage supply electrical converter that turns it into the ac and this output is given to the permanent magnet brushless dc (BLDC) motor. The VSI is operated by the change basic pulses that are leading to low change losses. The potency of the BLDC motor is around 80-85% whereas the traditional brushed motors have 65-75%efficiency [7]. BLDC motors are appropriate for terribly high-speed application functions. These motors have smart speed management. BLDC motor is employed for devices that need high responsibility and speed like refrigerators, laundry machines, water pumping, etc. The in-operation condition of the model is simulated by MATLAB /Simulink. The planned system is through an experiment verified on a 60 W, 24 V_{dc} BLDC motor drive.

2. PROPOSED SYSTEM

The projected system using electrical device fed BLDC motor drive victimization luo convertor is bestowed in Fig.1.
The system consists of solar battery feeding power to the system, BLDC motor drive with associate in encoder for electronic commutation, luo converter, a three-phase voltage supply electrical converter for providing power to

the drive, IC MPPT and PIC controller. Once MPP is reached to the ultimate level duty ratio is generated by the INC MPPT and this duty ratio is turned back to change pulse by examination with the high frequency saw tooth signal and this signal is given to the MOSFET. Operating of every stage of the planned system is explained within the following section. Design of proposed of system different stages of proposed system which is shown in Figure 1 like a solar array, luo converter, MPPT, BLDC motor drive and their modeling and working of each are explained in this section.

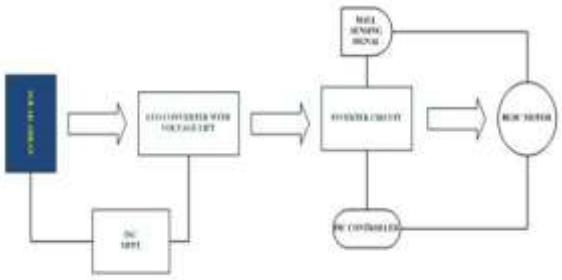

Figure 1. Proposed system

3. DESIGN OF PROPOSED OF SYSTEM

Different stages of proposed system which is shown in Fig.1 like a solar array, Luo converter, MPPT, BLDC motor drive and their modeling and working of each are explained in this section.

3.1 Solar PV Array and MPPT Tracking

Solar energy falls on the world and this energy is transformed into electrical energy by photovoltaic. The PV panels are made up of semiconductor material. These PV panels give a maintenance-free, safe and reliable, environment friendly power supply for an extended time. A basic photovoltaic cell is a P-N junction diode. The diode current equation is given by:

$I_D = I_S [e^{(q_{\blacksquare} v/KT)D} - 1]$ ..... (1)

An I_D is diode current, I_S is diode saturation current, v is voltage of the diode, k is Boltzmann constant and t is temperature dependent on I_S. The equivalent circuit of a photovoltaic cell is shown in Figure 2. The circuit consists of a current supply, a diode, series resistance Rs and Rsh the shunt resistance.

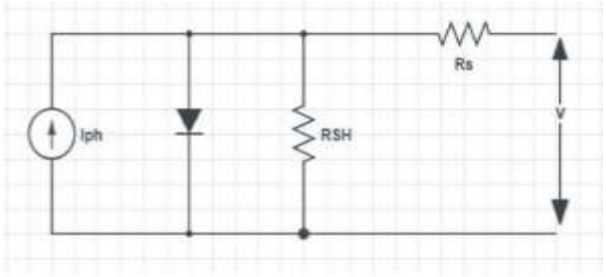

Figure 2. Diode model of PV cell

The PV cells created approx. 1W, they ought to be connected in series-parallel combos to get enough power. The Simulink model of star PV array is shown in Figure 3.

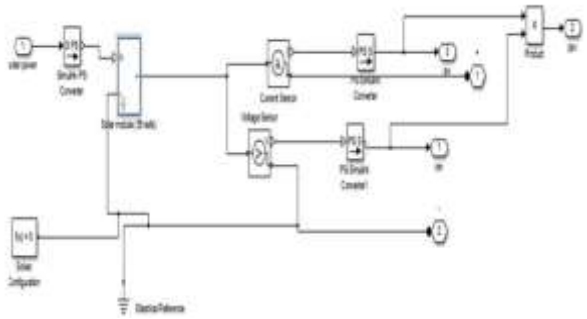

Figure 3. Solar PV array Simulink

3.2 Incremental Conductance MPPT

The principle of incremental conductance is that progressive power is compared with increment voltage for two consecutive samples then the MPP voltage is set. It is established on the fact that the slope of the curve power vs voltage of PV array is zero at the MPP, positive at its left and negative at its right

$\Delta V/\Delta P = 0 (\Delta I/\Delta P = 0)$ at the MPP..... (2)
$\Delta V/\Delta P < 0 (\Delta I/\Delta P > 0)$ on the left..... (3)
$\Delta V/\Delta P > 0 (\Delta I/\Delta P < 0)$ on the right..... (4)

In the IC methodology, how briskly the MPP is reached depends on the scale of the increment reference voltage. A major advantage of MPPT is that they extract the power in low light as well and the main downside of this can be that the fast shift of the irradiation can amend the MPP. The flow chart of IC is shown in Figure 4.

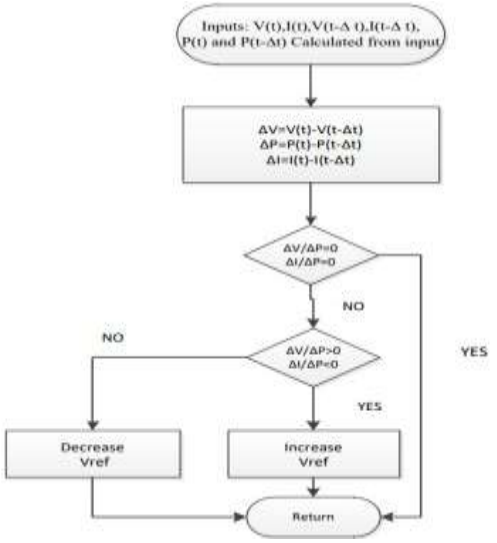

Figure 4. Flow chart of Incremental Conductance MPPT algorithm

3.3 Luo Converter Modeling

Luo converter is a dc -dc boost convertor it converts the positive input voltage to the positive output voltage. There are numerous sorts of luo converter, *viz.*, super lift, self-lift, re-lift, triple lift, and quadruple lift. These converters derived from the elementary circuit of luo converter. They provide the low switching losses and high potency among alternative dc-dc converters. Luo converters lay out an improved output current characteristic owing to the inductance within the output location. This configuration of the luo converter is effective for MPPT. The values of various parameters of luo converter are given in Table 1.

Table 1. Design values of luo converter

Parameters	Values
Input voltage, Vin	148 V
Output voltage, Vo	285 V
Duty ratio	0.5
Inductor, l	8.64 mH
Capacitor, c1=c2	524μF
Load resistance	180Ω
Switching frequency	10 kHz

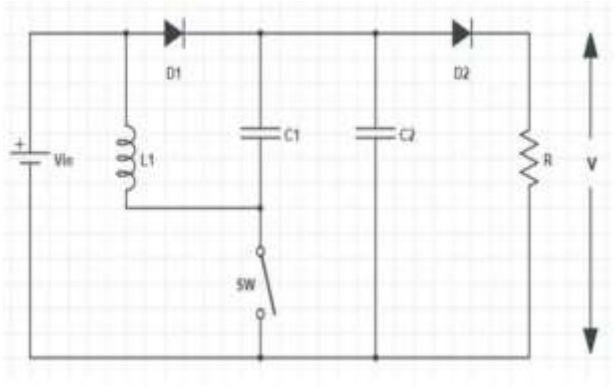

Figure 5. Elementary luo converter

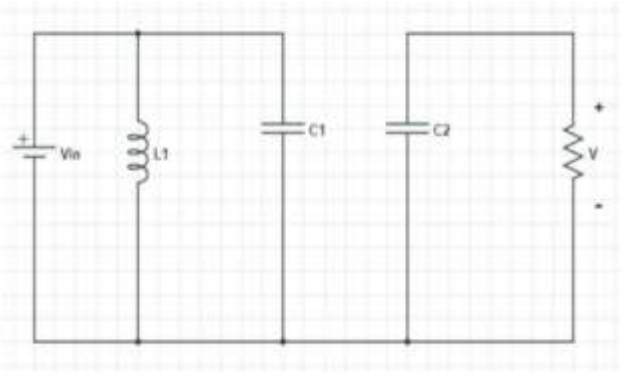

Figure 6. Closed switched operation

When the switch is closed, voltage across capacitor C is charged to V_{in}. The current i_{L1} will flow through inductor L and increase with voltage V_{in}.

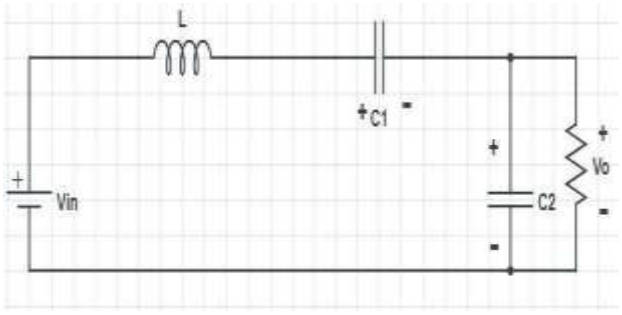

Figure 7. Luo converter with open switch

In Figure 7 when the switch is open, the inductor current decreases with voltage $(V_o - 2V_{in})$. The Simulink model of luo converter is shown in Figure 8

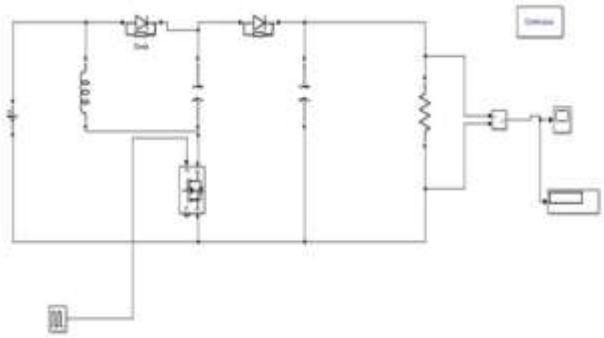

Figure 8. MATLAB Simulink model of luo converter

3.4 Mathematical Modeling of BLDC Motor

Permanent magnet brushless motor drive (BLDC) is employed for this system. Electronic commutation of a motor is completed by three-phase VSI in 120° conduction mode employing six switching pulses generated in accordance with the rotor position of the motor. The intrinsically encoder within the motor senses the rotor position every on 60° span and generates the set of three hall signal and in their accordance the switching sequence of VSI is generated. The model of armature winding of the BLDC is given below.

$Va = R*ia + l.(dia/dt) + ea$ ..... (5)

$V_b = R*ib + l.(dib/dt) + eb$ ..... (6)

$V_c = R*ic + L.(dic/dt) + ec$ ..... (7)

L is the armature self-inductance (h), r is the armature resistance (Ω), V_a, Vb, Vc, are terminal voltages (v), *ia, ib, ic* are motor input currents (a) and *ea, eb, ec* are back EMF (v) of the motor. The back EMF is a function related to the motor position and the back EMF of each phase has a difference of 120° phase angle. The torque equation of the BLDC motor is given below.

$$T_e = \frac{ea*ia+eb*ib+ec*ic}{w} \quad \text{..... (8)}$$

$$T_e - T_1 = j\frac{dw}{dt} + Bw \quad \text{..... (9)}$$

T_e is the overall torque output (N.m), T1 is that the load torque (N.m), j is that the inertia of the rotor and b is that the fraction constant. The MATLAB Simulink model of the projected system is shown within the Figure 9

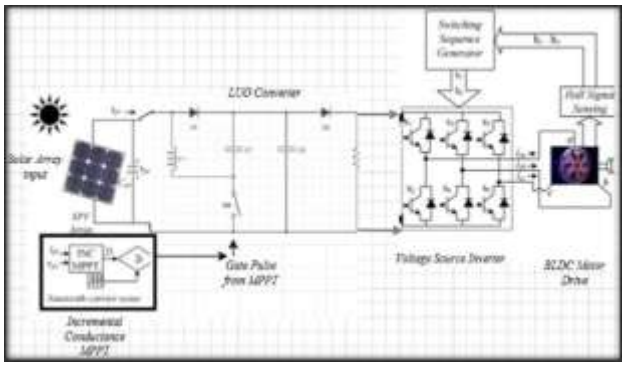

Figure 9. Proposed system

4. SIMULATION RESULT OF SYSTEM

The system gives the output speed of 750 rpm when simulated for the designed system. The converter output voltage obtained is 280 V. Output power is also obtained. These are the results of a theoretical simulation.

Practical implementation can be changed due to the variation in the environmental condition. Figure 10 shows the output current of Luo converter,

where y-axis is current in ampere and x-axis is time in seconds.

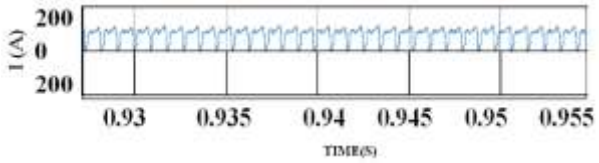

Figure 10. Output current of luo converter

The gating pulses for the switches 1, 3 and 5 are provided by the MPPT where y-axis is voltage and x-axis is time and is shown in Fig 11

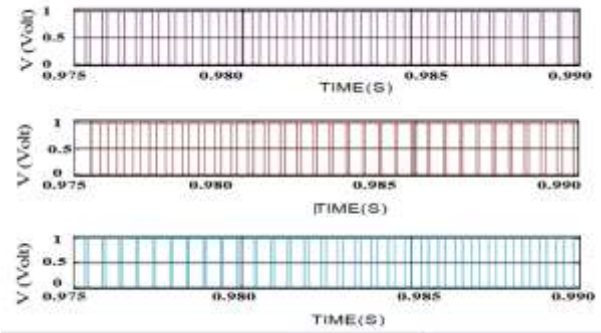

Figure 11. Gate Pulse

The gating pulses shown in Figure 11 are for upper switches of the voltage source inverter. These pulses are inverted and given to the lower switches for getting VSI operation. The other simulation results of voltage source inverter and BLDC motor drive are shown in the in the following figures.

The simulation results are shown in the following Figs, where y-axis is voltage in volts (line and phase respectively) and x-axis is time in seconds.

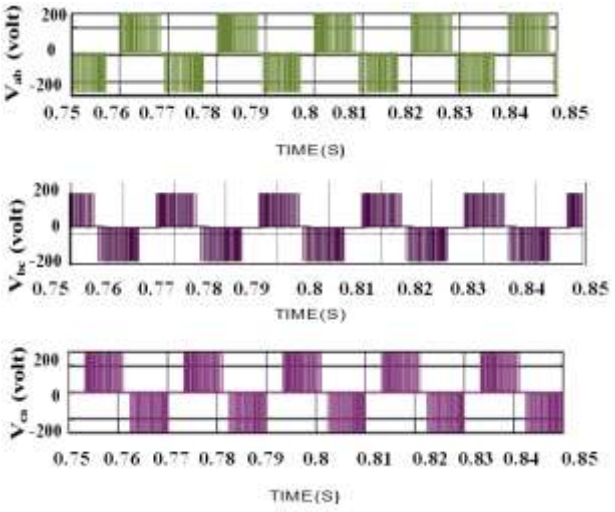

Figure 12. Line voltage of VSI inverter

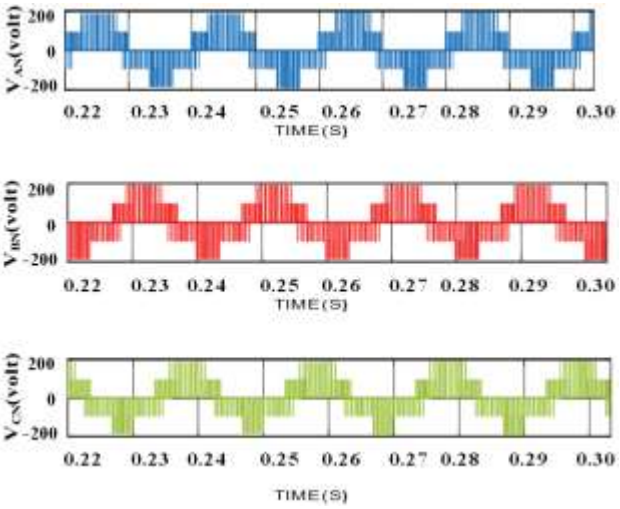

Figure 13. Phase Voltages

Figures 14 and Figure 15 show the various solar array indices like solar array voltage and solar array current, where y-axis is voltage and current respectively and x-axis is time in seconds.

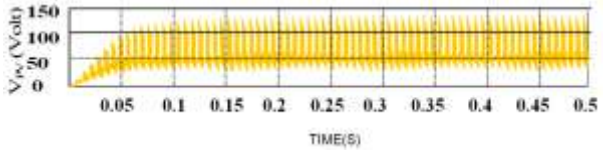

Figure 14. Voltage of solar array

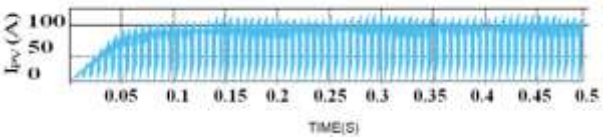

Figure 15. Current of solar array

Following figures show simulation results of BLDC motor drive like stator current, torque, speed and angle, where y-axis is current in Ampere, torque in Newton meter, speed in rpm and angle in radian respectively while x-axis is time in seconds.

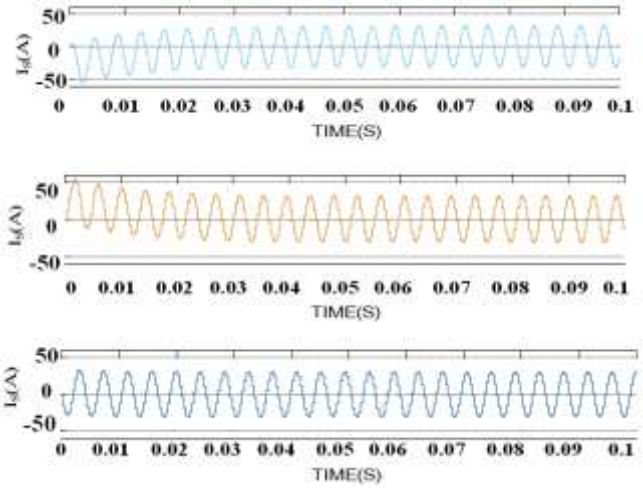

Figure 16. Stator Current

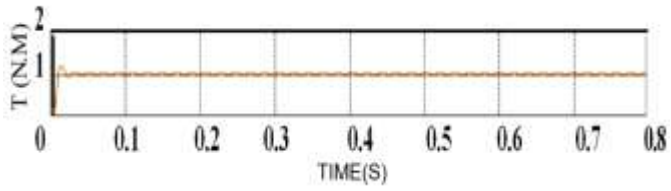

Figure 17. Torque of 1 Nm

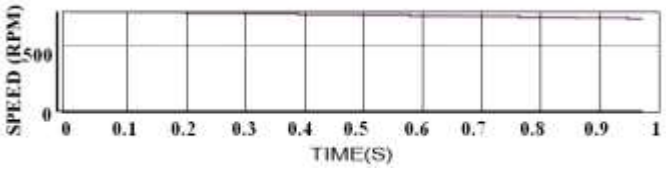

Figure 18. Speed of 750 rpm

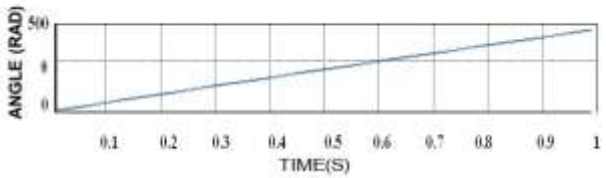

Figure 19. Angle

5. CONCLUSION

With the aid of a solar cell, solar energy is converted into electric energy. We use the solar array for large scale applications. We implement IC MPPT to get the maximum power from the solar array. This INC algorithm gives the pulses that switch of the luo converter switch. It is a dc-dc boost converter which gives the positive output voltage and this voltage fed into the voltage source inverter (VSI) which operates in 120°conductive mode and converts the dc voltage into ac voltage. It also reduces the losses caused by the operation of high frequency switches. In this proposed system we used the BLDC motor, which has high efficiency compared to other motor. This proposed system has many applications including water pumping, irrigation.

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