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MULTI MODE PV POWER SYSTEM USING INTERLEAVED CUK CONVERTER

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ABSTRACT: DC-DC converters inject harmonics to the power system when the input current ripple is present on the input side. This affects the components present in the module. The converters with low input current ripple and high efficiency are important in most common applications like dialysis machine, lift, electric vehicles etc., Compared to other converters, Interleaved CUK Converter (ICC) reduces ripple current on both input and output sides, reduces switching stress, improves transient performance and also improves efficiency. A multi-mode operation of an ICC for the single-phase Photovoltaic Module (PV) system is proposed. In this paper, the power from the PV panel can be continuously extracted using ICC and can be used in step up or step down applications. The Incremental Conductance(IC) which is based on Maximum Power Point Tracking (MPPT) algorithm is used to track maximum power from PV array and deliver the tracked power to the ICC. The converter's output voltage is connected to the single-phase induction motor through a single phase full bridge inverter. An ICC is designed and simulated in MATLAB /SIMULINK for 110 volt with an input of 12 volt.

KEYWORDS: ICC, Incremental Conductance algorithm, Single phase full bridge inverter, PV array, single phase induction motor.

1. INTRODUCTION

In today's scenario of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels were investigated. Global renewable energy capacity has been doubling since 2008. The solar and wind capacity installation in recent years is increased to about 25% today and it could reach 30% by 2022. Using PV panel the renewable energy from the sun is utilized. The efficiency of the PV system is low since it depends on irradiance and temperature variation. Therefore MPPT algorithm is employed to extract the maximum energy and to improve the efficiency of PV system.

MPPT algorithms are of many types such as fractional open circuit voltage, fractional short circuit current, neural networks, fuzzy logic, and Incremental Conductance method and Perturb and Observe (P&O) [2]. P&O algorithm cannot determine the optimal operating point under varying atmospheric condition but in normal condition it is reliable. To overcome this, IC algorithm is used to track maximum power under varying atmospheric conditions.

DC-DC converters are of many types such as buck, boost, CUK converter etc.., This paper deals with ICC since it reduces voltage and current ripple, improves efficiency, transient performance and also reduces switching losses.

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2. BLOCK DIAGRAM FOR PROPOSED SYSTEM

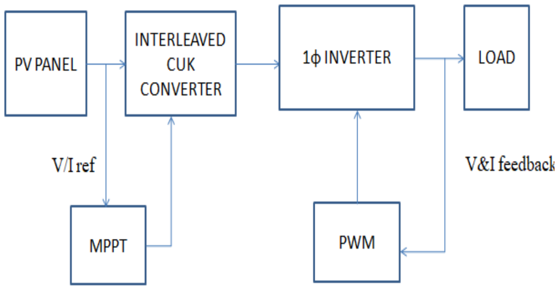

Figure 1.Block diagram of proposed system

A. PV PANEL

Electrical energy is produced by the PV by converting the sunlight. Based on the current and voltage requirement, the solar cells are connected in series and parallel. The sunlight falls on PV panel.

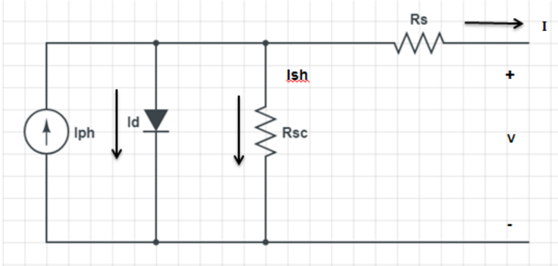

Figure 2. Equivalent circuit of single diode solar cell

The input of the solar panel is the solar irradiation and temperature. The solar cell is designed according to the mathematical formula as given below,

$I_{pv}=I_{ph}-I_p(e^{q(vpv+iRs)/NsKT})-V_{pv}+iR_s/R_{sh}$ where,

I_{pv} is the PV panel current (A), \`i\` is current of PV cells at the output terminals (A), V_{pv} is voltage of PV cells at the output terminals (V), I_p is current in series resistor (A), I_{ph} is photocurrent (A), K is Boltzmann constant (1.38×10^{-23} J/K), T-the ambient temperature (K), R_s and R_{sh}-Series and shunt resistance (Ω), q is the electron charge (1.60217×10^{-19} C), Ns is the number of cells in series[5][6].

B. MPPT

MPPT is a technique used to track the maximum power from the PV panel. Maximum Power Point (MPP) is a operating point at which the maximum power can be extracted from the system. The output of the solar module is a function of solar irradiance and temperature. Generally MPPT is installed in between PV module and load.

3. MPPT ALGORITHM

Incremental conductance

In the IC method, the Arduino UNO controller measures the incremental changes in PV array current and voltage (dI/dV) to predict the effect of a voltage change (dP/dV). By comparing the Incremental Conductance (I_Δ/V_Δ) to the array conductance (I/V), this method determines MPP. The IC method is based on the observation at the MPP dP/dV=0, and that P=IV.

When the Incremental Conductance dI/dV is greater than the instantaneous conductance I/V, then the MPP lies on the left side. When the Incremental Conductance dI/dV is lesser than the instantaneous conductance I/V, then the MPP lies on the right side. The PV panel will operate at the MPP when the Incremental Conductance is equal to the output instantaneous conductance [3].

Figure 3.Flowchart of Incremental Conductance algorithm

The IC algorithm consists of three iterations which includes voltage, current and power.

The basic equation of this method is as follows [7]:

$dP/dV\geq0$ left of MPP

$dP/dV\leq0$ right of MPP

$dP/dV=0$ at MPP

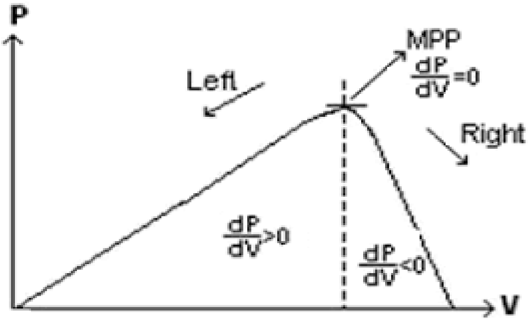

Figure 4.PV curve for solar module.

Advantages of incremental conductance

The IC algorithm can determine whether the MPPT has reached the MPP and it stops perturbing the operating point. Under varying atmospheric conditions, IC algorithm can rapidly track with higher accuracy than P&O algorithm. It has minimum iterations and maximum tracking time.

C. ICC

To overcome the disadvantage of CUK and interleaved boost converter, an ICC is preferred [1], since ICC reduces current ripples on both input and output sides, switching current stress and also improves the efficiency of the converter. It improves the transient performance. The circuit diagram of Interleaved CUK Converter is shown in fig 5 [8]. It consists of four inductors, four capacitors, two high frequency diodes, two switches and a load resistor. ICC operates in four modes. Switching stress is reduced compared to other converters since the duty cycle is limited to 50% [4]. It operates in four modes, in which mode 2 and mode 4 is similar

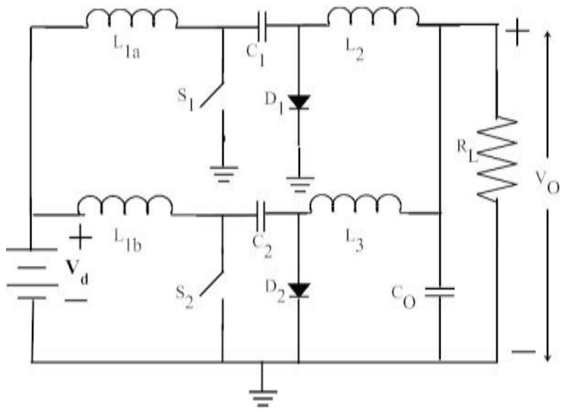

Figure 5.Circuit diagram for ICC

MODE 1- Switch S_2 ON and Switch S_1 OFF

The figure 5a shows the circuit diagram of mode 1, when switch S_1 is ON and switch S_2 is OFF. During this mode, the inductor L_3 charges and L_1 discharges. The energy stored in the inductor L_1 gets transferred to C_1 and it gets charged. The capacitor C_3 discharges through C_3, S_2, C_4, L_4, C_2, L_2 and R_L. The current through the load is considered as the constant and it flows in negative direction.

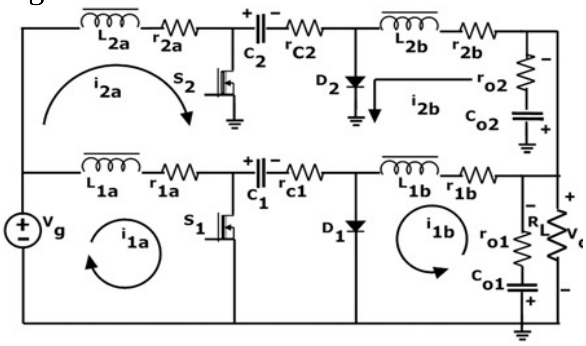

Figure 5a.Circuit diagram of mode 1

MODE 2 - Switch S_1 OFF and Switch S_2 OFF

The figure 5b shows the circuit diagram of mode 2, when both switches S_1 and S_2 are OFF. During this mode, both the inductors L_1 and L_3 discharges and the energy stored in these inductors gets transferred to the capacitors C_1 and C_2. At this stage, C_1 starts to charge the two inductors L_2 and L_4. The inductor L_4 discharges and the stored energy in this inductor is transferred to the load.

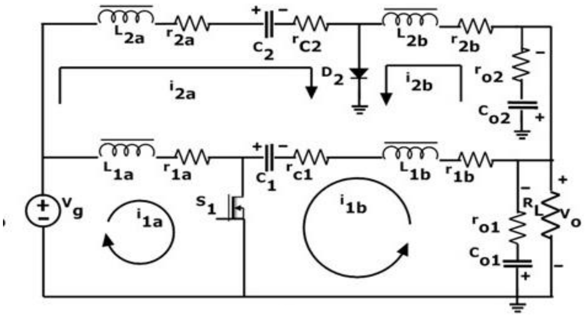

Figure 5b.Circuit diagram of mode 2

MODE 3 - Switch S_2 OFF and Switch S_1 ON

The figure 5c shows the circuit diagram of mode 3, when switch S_2 is OFF and switch S_1 is ON. During this mode, inductor L_1

charges and L_3 discharges and transfers its energy to C_3 and also it gets charged.
The capacitor C_1 discharges through C_1, S_1, C_2, L_2 and R_L thereby transferring the energy stored in the capacitor to the load.

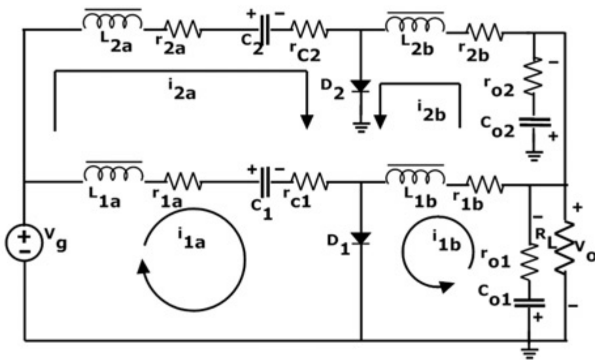

Figure 5c.Circuit diagram of mode 3

MODE 4 - Switch S_2 OFF and Switch S_1 OFF

The figure 5d shows the circuit diagram of mode 4, when switch S_2 is OFF and switch S_1 is OFF. Mode 4 operation is similar to that of operation of mode 2. During this mode, both the inductors L_1 and L_3 discharges and the energy stored in these inductors gets transferred to the capacitors C_1 and C_2.
At this stage, C_1 starts to charge the two inductors L_2 and L_4. The inductor L_4 discharges and the stored energy in this inductor is transferred to the load.

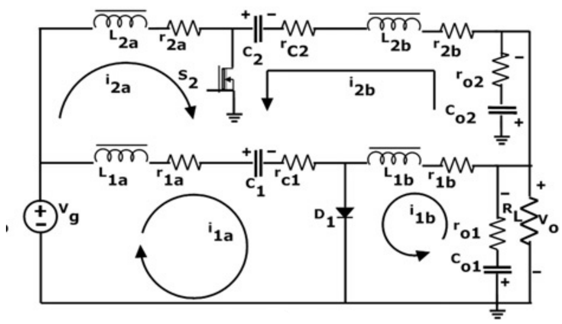

Figure 5d.Circuit diagram of mode 4

4. DESIGN OF INTERLEAVED CUK CONVERTER

The design equations of the ICC are as follows
Duty cycle calculation
$V_{out}= (D/1-D)\, V_{in}$
Ripple current
$I_{L1}=Pin/Vin$
$I_{L2}=P_{in}/V_0$
Formula for inductors
$L_1=(V_{in}\times D)/(F_{sw}\times \Delta I_{L1})$
$L_2=(V_{in}\times D)/(F_{sw}\times \Delta I_{L2})$
Formula for ripple voltage
$V_{c1}= V_{in}/(1-D)$
Formula for capacitor
$C_1=(I_{in}\times(1-D)/F_{sw}\times\Delta V_{c1})$
$C_2=I_o(6\times\omega\times\Delta V_o)$
Conduction loss
$P_{CON}=R_{DS(ON)}\times V_{out}/V_{in}(I^2_{out}+I^2_{RIPPLE}/12)$
Switching loss
$P_{SW}=V_{in}\times I_{out}\times F_{sw}\times(Q_{GS2}+Q_{GD})/I_G$
Efficiency
$Efficiency=(P_o/(P_{in}+LOSSES)) \times 100$

5. DESIGN COMPARISON FOR CONVERTERS

COMPONENT	CUK	SEPIC
L_1	0.9mH	4.41mH
L_2	2.1mH	2.2mH
C_1	4.6µF	58.32µF
C_2	0.3µF	35.34µF
ΔI_{L1}	3.8A	6.6A
ΔI_{L2}	1.68A	3.6A
ΔV	64.5V	145.8V
Switching losses	907.2	972
Conduction losses	136.74	139.73
Efficiency	64.485	53.77

D. INVERTER

An inverter converts the DC voltage into an AC voltage. The inverters are of two type namely single phase and three phase inverter. In addition, they are widely used in the switched mode power supplies inverting. The inverter may be built as standalone equipment for applications such as solar power, or to work as a backup power supply from batteries which are charged separately. There are different types of inverters based on the shape of the switching waveform. These have varying circuit configurations, efficiencies, advantages and disadvantages.
An inverter provides an ac voltage from dc power sources and is useful in powering

electronics and electrical equipment rated at the ac mains voltage. The circuits are classified according to the switching technology and switch type, the waveform, the frequency and the output waveform. In this project, single phase full bridge inverter is used. The inverter shown in fig 6 consists of four switches. In this project, MOSFET is used as the switch. A driver circuit is used to trigger the MOSFET. The inverter converts the direct current voltage of the converter 110 volt into 230 volt of alternating voltage. By providing pulses to the inverter with the help of pulse with modulation (PWM) technique, the MOSFET switch is driven.

The inverter consists of four switches namely S_1, S_2, S_3 and S_4 are unidirectional, i.e. they conduct current in one direction. During mode 1,when the switches S_1 and S_2 are turned on simultaneously for a duration $0 \le t \le T_1$, the input voltage (V_{in}) appears across the load and the current flows from point a to b.

$Q_1 – Q_2$ ON, $Q_3 – Q_4$ OFF => $V_o = V_s$

During mode 2, when the switches S_3 and S_4 are turned on for a duration $T_1 \le t \le T_2$, the voltage across the load is reversed and the current through the load flows from point b to a.

$Q_1 – Q_2$ OFF, $Q_3 – Q_4$ ON ==> $V_0 = -V_s$

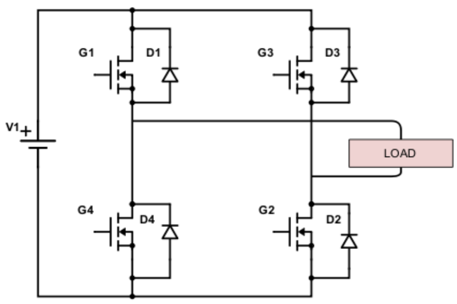

Figure 6.Circuit diagram of single phase full bridge inverter

The inverter output voltage of 230 volt is then finally fed to the load. In this paper, a single phase induction motor is used as the load. The single phase power system is most widely used than three phase system for domestic purposes, commercial purposes and some extent in industrial uses. Because, the single phase system is more economical than a three phase system and the power requirement in most of the houses, shops, offices are small, which can be easily met by a single phase system. The single phase induction motors are simple in construction, cheap in cost, reliable and easy to repair and maintain. Due to all these advantages, the single phase induction motor is used as the load.

6. SIMULATION RESULTS

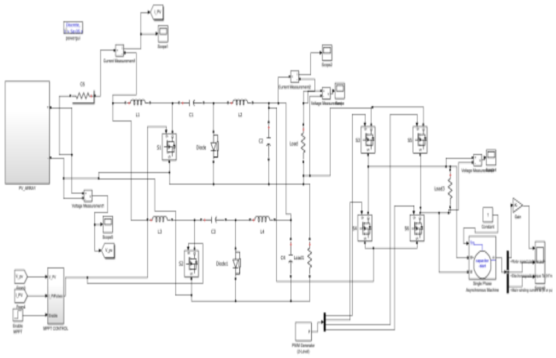

Figure 7a.Circuit diagram of ICC

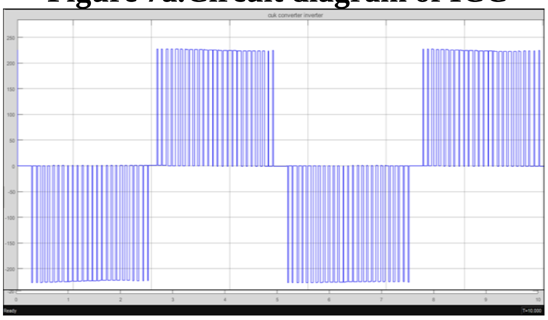

Figure 7b.Output of inverter

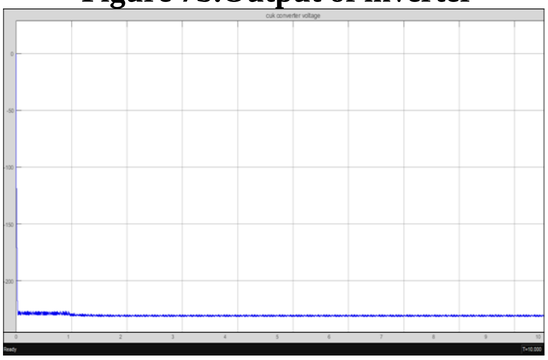

Figure 7c.Output of ICC

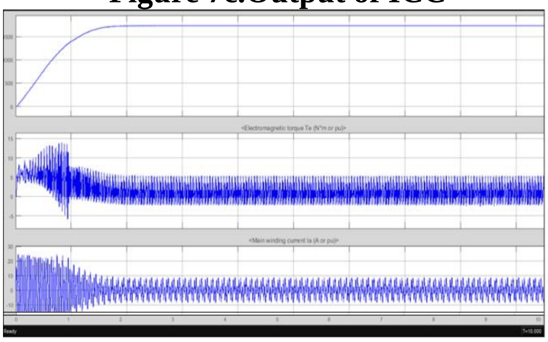

Figure 7d.Output of motor

CONCLUSION

In this project, the ripple current in continuous conduction mode is rejected by using the ICC. Therefore the switching stress and the voltage ripple is reduced, thereby increasing the efficiency of the converter.

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