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Resonant Converter Design for Solar Application

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***Abstract*— This paper presents design criteria for solar fed resonant converter for PV battery charging system. The model of solar PV module is designed using MATLAB/Simulink. The output of solar PV is fed to the resonant converter to get constant voltage by maintaining and regulating the battery voltage. But the input parameters for solar module like irradiance and temperature are variable, which affects the battery input terminal voltage. Hence, aim is to maintain and regulate the constant battery voltage under variable weather condition. The MPPT technique like Hill climbing algorithm is proposed for solar module fed resonant converter. In this paper the solar powered resonant converter with and without MPPT control technique are designed and analyzed using MATLAB/Simulink, under constant and variable weather condition.**

***Keywords*— solar PV; Resonant converter; MPPT technique; hill climbing algorithm;**

I. INTRODUCTION

The recent studies says that solar energy is the renewable energy source which gains popularity among other renewable energy sources like wind, ocean, geothermal, tidal and thermal energy etc. The solar power is noiseless source and large energy can be utilized when compared with conventional sources and this energy source is feasibly extracted and consumed. It is one of the important sources among renewable energy sources and are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy and convert it into useful power for consumption.

The solar Photovoltaic module can be designed using MATLAB/ Simulink software. PV module parameters have been selected according to the variation with irradiation and temperature, then current voltage (I-V) and power voltage (P-V) characteristics are obtained. It is tested under standard test conditions which is also suitable for various other weather conditions. To model the solar PV module, the inputs required are irradiance and temperature and the output obtained are voltage and current [1]. The analysis and design of CLL resonant converter for solar panel-battery systems with DSP based Fuzzy logic controller for solar panel to battery charging system fed with drive was developed in earlier researches. The converter performances are estimated under variable load conditions and TMS320F2407 DSP was used to implement the controller to get the constant output voltage under various load and supply disturbances [2]. This paper presented the practical design consideration for LLC resonant converter. Here there is no possibility of load independent operation and output voltage regulation.[4].

Zero current switching for all switches and Zero Voltage switching for all diodes on high voltage sides are achieved using DC-AC-DC Converter with transformer isolation operating without switching power dissipation.[5].A DC Boost converter consider using an auxiliary resonant circuit for implementation of soft switching technology to reduce switching losses in the converter [6].To reduce the switching loss some kinds of soft switching techniques is to be used to operate under high switching frequency this is achieved by loaded resonant converter[7] This paper deals with resonant converter design for solar application as a first step and then the resonant converter have been designed in open loop. Then the output from solar panel is 24 V which is fed to the resonant converter as input, to get the higher voltage level of 230V as output. Second step mostly battery failure is the major

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drawback in the solar application in order to overcome this controller circuit has to be added. The controller circuit will control the charging and discharging of battery and MPPT control technique added by this maximum power has been achieved. . [3] presented a brief outline on Electronic Devices and Circuits which forms the basis of the Clampers and Diodes.

II. Solar PV Module Design

Photovoltaic module consists of number of PV cells which are connected in series and parallel, produce electricity using solar energy and this model is simulated using MATLAB/Simulink model. The characteristics of photovoltaic module will differ accordingly on the basis of model and environmental condition. Now the designed model is used to determine PV characteristics for wide range of irradiation and temperature values. For wide range of inputs, the output power, voltage and current of the PV module can be determined rom the results obtained. Here is a simplified PV equivalent circuit with diode is designed as model. In addition, all the results of MATLAB simulation are verified with theoretical calculation.

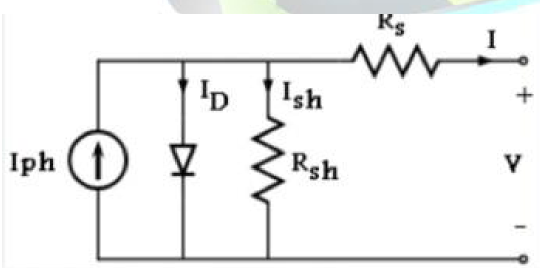
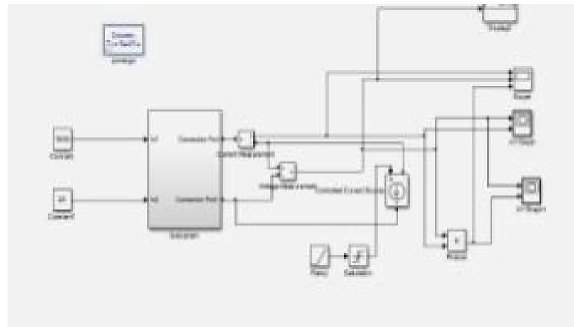


Fig 1. Equivalent circuit for solar cell

The output current I is obtained by following Kirchhoff's law:

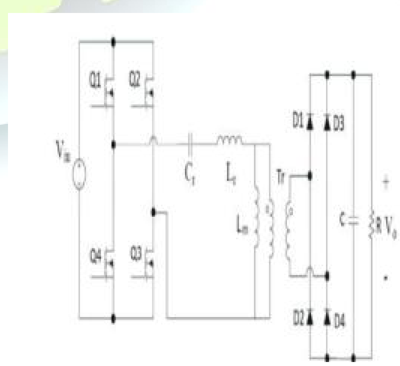
$$I_{pv} = I_{ph} - I_D - I_{shunt} \quad (1)$$

Here, I_{pv} is photovoltaic current I_{ph} is the phase current I_D is the diode currenthe Simulink model of PV shows



III. Proposed Model of LLC Resonant Converter

Resonant converter is also known as DC to DC Converter and the main function is to reduce switching losses in power electronic devices (MOSFET or IGBT) Resonant power conversion has many advantages over conventionally adopted pulse-width modulation, which has low electromagnetic interference, low switching losses. The output of resonant converter is filtered by using low pass filter. Here switching losses and noises can be reduced .The resonant converter are classified into series resonant converter and parallel resonant converter. In series resonant converter the rectified voltage is placed in series with L-C resonant network therefore series parallel resistance value will be always lesser than one. In parallel resonant converter the rectified voltage is connected in parallel by existing large amount of circulating current. Furthermore, the proposed converter has many applications in power electronic products.



A. *Parameter estimation for resonant converter*

The design methodology of LLC resonant converter has been estimated with certain equations. The resonant frequency is determined by the

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components such as Lr and Cr and other components such as Lm and load .The specifications of design are:

Input voltage =24V

Output voltage=230V

Transformer turns ratio (n) are calculated by

Np/Ns =

Where Mnom is considered to be a value for 1.Calculating resonant component value by quality factor ,resonant frequency and inductance ratio the equation shows that values are Q=0.4 , m=6.3 and the resonant frequency value Fr=100 k Hz.

Where Q is the quality factor and

M is the inductor ratio.

$$Q_{max} = \frac{\sqrt{Lr/Cr}}{Rac\_min} \quad [1]$$

Where

$$R_{ac\ min} = \frac{8}{\pi^2} \times \left\{ \left(\frac{N_p^2}{N_s^2} \right) V_{out}^2 \right\} / P_{0,max} \quad [2]$$

N_p and N_s are the number of turns in primary and secondary side of the transformer respectively.

$$Fr = \frac{1}{2\pi\sqrt{LrCr}} \quad [3]$$

$$m = \frac{Lr+Lm}{Lm} \quad [4]$$

Results:

Lr = 1.1238 micro H

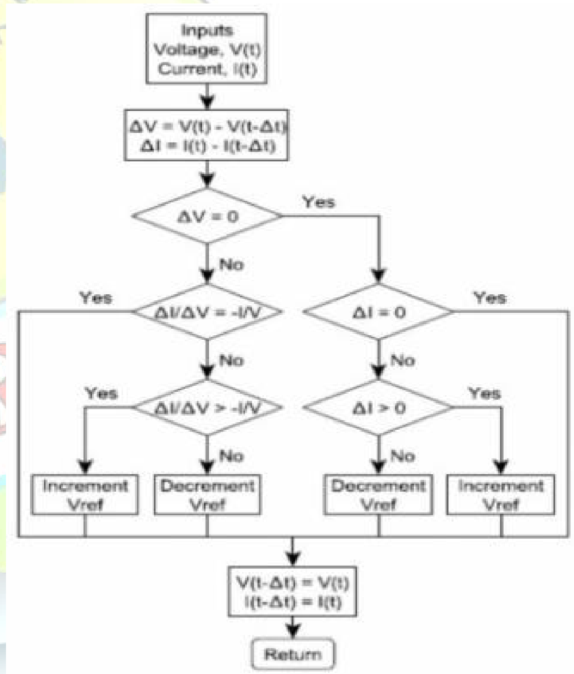
Lm = 5.95micro H

Cr=2.25micro F

V. MPPT CONTROLLER

Maximum Power Point Tracking (MPPT) is an algorithm used for extracting maximum available power from PV module under variable conditions. The maximum power varies with solar irradiance and temperature .Initially the output is determined and thereby the MPPT checks output of PV module, by comparing it or the existing output voltage and current to the previous voltage and the current values, then fix what can be the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current. This is achieved by changing the duty cycle for the power electronic devices accordingly to the output power. The MPPT is effective under this condition

MPPT is utilized to extract more power and if the state of charge in the battery is lower, then MPPT can vary the duty cycle and maintain constant output to the battery. For variations in the current – voltage characteristics of solar cell MPPT solar charge controller is used .The Hill Climbing Algorithm is the most commonly used method in MPPT. This includes Perturb & Observe method and Incremental conductance method to make the system to operate at the maximum point. Hill Climbing MPPT Technique increases the efficiency of solar panel. The MPPT technique has direct and indirect control algorithm.



VI. PROPOSED METHOD OF RESONANT CONVERTER WITH MPPT CONTROLLER

Direct control algorithm does not track maximum power accordingly to the recorded parameters. This controller directly control the duty cycle, which the above flowchart shows.

The PV system failure occur due to the storage battery system and cost .We cannot obtain constant

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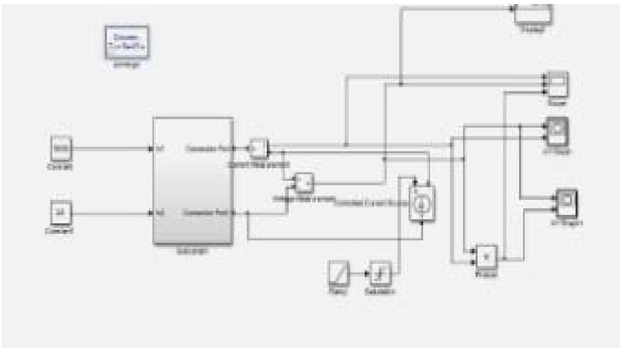
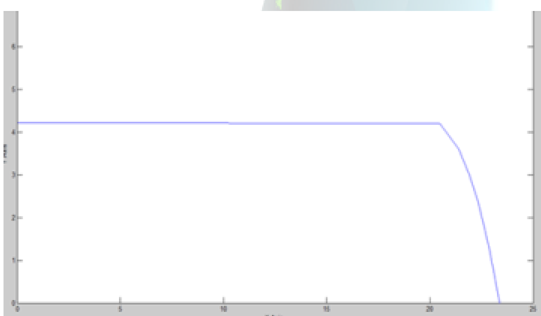
voltage due to change in input variables therefore LLC resonant converter with controller are used to maintain constant voltage it is designed and implemented with closed loop operation. The PV module result is as shown below.



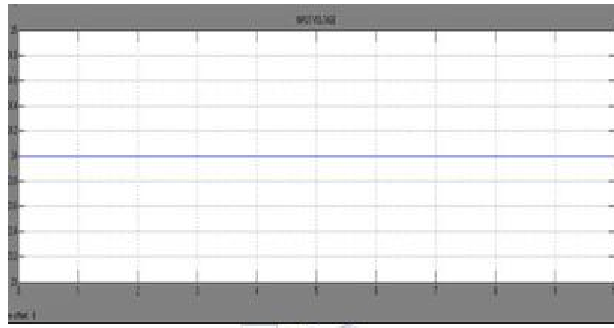
Here the inputs are given as per the Standard Test Condition (STC) taking irradiance and temperature value as 1000 m^2 and ℃ respectively, then output obtained is approximately 24V. While changing the inputs of the PV module as 200W/m^2 and ℃ then output obtained is 21.3V. Here the IV characteristics shown as

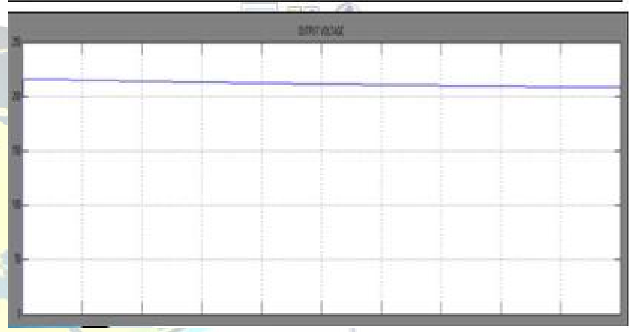


TABLE

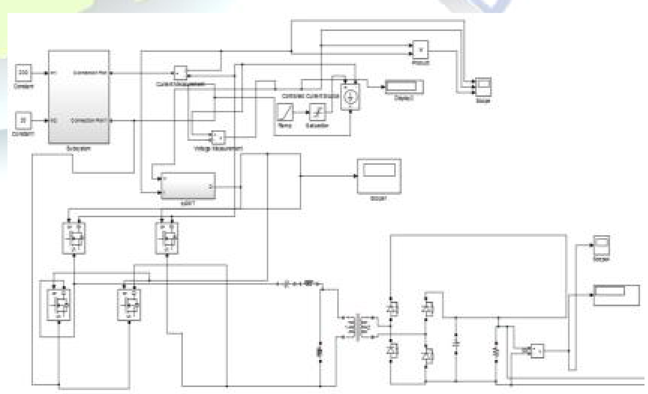
IRRDIANCE	TEMPERATURE	VOLTAGE
1000	25	24
200	30	21.3

This shows the comparison between the inputs and their respective outputs under different weather conditions. The simulation result of the resonant converter is as shown below.





THE PROPOSED MODEL OF RESONANT CONVERTER ALONG WITH MPPT CONTROLLER



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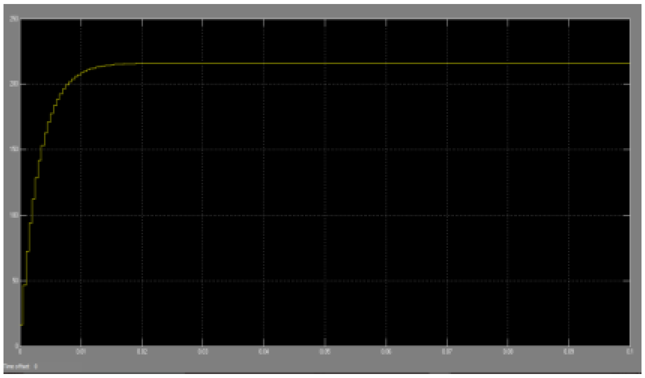
The simulation result from scope is as shown below which shows that the output voltage is around 216V



IRRADIANCE	TEMPERATURE	CONVERTER OUTPUT
1000	25	216
200	20	214.5

The above table shows that the converter output voltage doesn't vary very much and it is almost maintained constantly for variable environmental changes.

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