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A Novel High Performance Flyback CCM Inverter Scheme for AC Module Application

Chinnu P Ravi, J Jency Joseph

Abstract—In a Grid Connected Photo-voltaic System maximum power is to be drawn from the PV array and has to be given to the Grid using suitable maximum power point tracking algorithms, converter topologies and control algorithms. Usually converter topologies such as buck, boost, buck-boost, sepic, flyback, push pull etc are used. In Flyback converter the source and load side are separated via a capacitor thus energy transfer from the source side to load side occurs through this capacitor which leads to less current ripples at the load side. Thus in this paper, a Simulink model PV panel with Flyback converter is being designed, simulated and for tracking the maximum power point the most common and accurate method called incremental conductance algorithm is used and the inverter control is done.

Keywords — Photovoltaic, Flyback Converter, Maximum power point tracking, Incremental conductance algorithm.

I.INTRODUCTION

Due to the increasing need for the electrical energy and due to the depletion of conventional sources of energy along with the rising cost of those, renewable energy resources are getting more importance. When solar energy is considered, electricity production from it, is very eco-friendly and available in plenty in nature. The high cost of PV panels and its low efficiency limited its use earlier but with the increase in technology the efficiency of solar cells are also getting increased which encourages the use of PV system in present days.Generation side of the PV system has to generate maximum power which is possible. Hence an efficient DC/DC converter is to be used for tracking the maximum power point. Thus here Flyback converter is used in between the PV panel and inverter.The most common algorithms for maximum power point are Perturb and Observe algorithm and Incremental conductance method.MPP is oscillating in perturb and observe method and this will lead to power loss.These disadvantages are eliminated in incremental conductance method, and hence this MPPT is used in this work.[1]

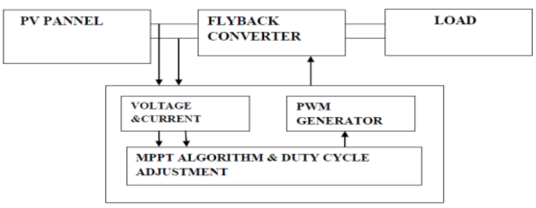

Fig 1: Block diagram

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II. PV SYSTEMS

Photovoltaics offer consumers the ability to generate electricity in clean, static and reliable way. Photovoltaic systems are comprised of photovoltaic cells devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from "photo", meaning light, and "voltaic", which refers to producing electricity therefore, the photovoltaic process is producing electricity directly from the sunlight. Photovoltaic are often referred to as PV.PV systems are being installed by Texans who already have grid supplied electricity but want to live more independently or who are concerned about the environment.

For some applications where small amounts of electricity are required, like emergency call boxes, PV systems are often cost justified even when grid electricity is not very far away. When applications require larger amount of electricity and are located away from existing power lines, photovoltaic systems can in many cases offer the least expensive, most viable options. In use today on street lights , gate openers and other low power tasks, photovoltaic s are gaining popularity in Texas and around the world as their price declines and efficiency increases .

PV cells convert sunlight directly into electricity without creating any air or water pollution .PV cells are made of at least two layers of semiconductor material one layer has a positive charge, the other has negative. When light enters the cell, some of the photons from the lights are absorbed by the semiconductor atoms, freeing electrons from the cells negative layer to flow through external circuit and back into the positive layer. This flow of electron produces electric current .To increase their utility, dozens of individual PV cells are interconnected together in a sealed, weatherproof package called a module. When two modules are wired in parallel their current is doubled while the voltage say constant. To achieve the desired voltage and current, modules are wired in series and parallel into what is called a PV array. The flexibility of the modular PV systems allows designers to create solar power systems that can meet a wide variety of electrical needs, no matter how large or small.

III.FLYBACK CONVERTER

The flyback converter is used in both AC/DC and DC/DC conversion with galvanic isolation between the input and outputs. More precisely, the flyback converter is a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation [2].

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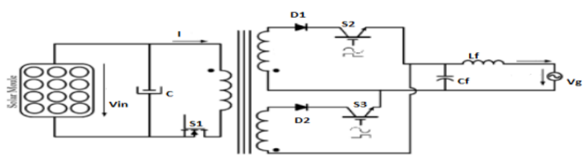

Fig 2.Flyback converter

IV. MATHEMATICAL MODEL FOR A PV MODULE

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation. The equivalent circuit of a PV cell is as shown in Figure 4.

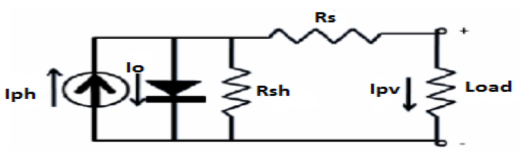

Fig 4 PV cell modeled as diode circuit

The current output of PV module is

$$I_{pv} = N_p \times I_{ph} - N_p \times I_0[\exp\{\frac{q \times (V_{pv} I_{pv} R_s)}{NsAKT}\} - 1] \quad \rightarrow (4)$$

Where,

V_{PV} Is output voltage of a PV module (V)

I_{PV} Is output current of a PV module (A)

T_R Is the reference temperature = 298 K

T Is the module operating temperature in Kelvin

I_{ph} Is the light generated current in a PV module

I_0 Is the PV module saturation current (A)

A = B Is an ideality factor = 1.6

K Is Boltzmann constant = 1.3805 × 10-23 J/K

q Is Electron charge = 1.6 × 10-19 C

R_S Is the series resistance of a PV module

I_{SCR} Is the PV module short-circuit current at 25 A and 1000W/ m^2 = 2.55A

K_i Is the short-circuit current temperature co-efficient

I_{SCR} = 0.0017A / ^0C is the PV module illumination (W/m2) = 1000W/ m^2

E_{go} Is the band gap for silicon = 1.1 eV

N_S Is the number of cells connected in series

N_P Is the number of cells connected in parallel

Table 1 Electrical Characteristics Data of Solar 36w PV Module

The current source Iph represents the cell photocurrent. Rsh and Rs are the intrinsic shunt and series resistances of the cell, respectively. Usually the value of Rsh is very large and that of Rs is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays. The photovoltaic panel can be modeled mathematically as given in equations [3].

Module photo-current:

$$I_{ph} = [I_{scr} + K_i(T - 298)] \times \frac{\lambda}{1000} \quad \rightarrow (1)$$

Modules reverse saturation current - Irs:

$$I_{rs} = \frac{I_{scr}}{[\exp(q \times V_{oc} / NsKAT) - 1]} \quad \rightarrow (2)$$

The module saturation current I varies with the cell temperature, which is given by

$$I_s = I_{rs}[\frac{T}{T_r}]^3 \exp([\frac{q \times E_{go}}{AK}][\frac{1}{T_r} - \frac{1}{T}]) \quad \rightarrow (3)$$

Parameters	Valı
Rated Power	37.08W
Voltage at Maximum power (Vmp)	16.56V
Current at Maximum power (Imp)	2.25A
Open circuit voltage (VOC)	2.24V
Short circuit current (ISCr)	2.55A
Total number of cells in series (Ns)	36
Total number of cells in parallel (Np)	1

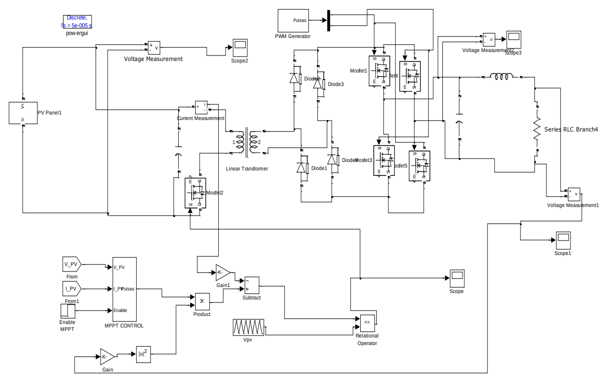
Figure 6 Entire Simulink Model

V CONTROL ALGORITHM

Maximum power point tracking (MPPT) is a technique that grid-tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve.

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And the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. Here incremental conductance method is used for control.

VI INCREMENTAL CONDUCTANCE ALGORITHM

In the incremental conductance method, the controller measures incremental changes in array current and voltage to predict the effect of a voltage change. This method requires more computation in the controller, but can track changing conditions more rapidly than the perturb and observe method (P&O). Like the P&O algorithm, it can produce oscillations in power output. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV). The incremental conductance method computes the maximum power point by comparison of the incremental conductance (ΔI /ΔV) to the array conductance (I / V). When these two are the same (I / V = ΔI / ΔV), the output voltage is the MPP voltage. The controller maintains this voltage until the irradiation changes and the process is repeated.
The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IC method. The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V. This relationship is derived from the fact that dP/dV is

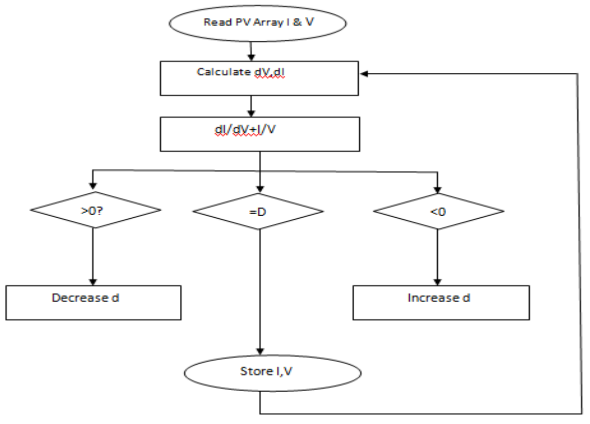

Fig 5 Flow chart (IC Algorithm)

negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe method.

VII SIMULINK MODEL WITH PV PANEL AND FLYBACK INVERTER

The overall simulink diagram has been given in Fig 6.The input to the flyback converter is given through PV panel.A capacitor is connected across the input to avoid the ripples.The flyback converter which is nothing but a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation.Then proper control algorithm is also used to get a controlled output.

VIII. CONTROL CIRCUIT

A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load. There are different algorithms to track maximum power here incremental conductance algorithms is implemented shown in Fig.7is implemented. In this method, incremental conductance and instantaneous conductance is added, to calculate the error.If the error exceeds 0.5 then a corresponding change is given for the duty cycle. The error is assumed to be in the range -0.2 to 0.2.[4]

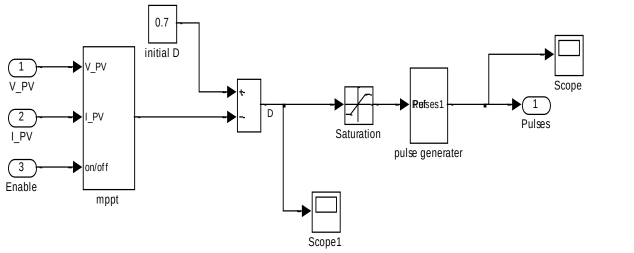

Fig 7 Incremental conductance algorithm

Incremental conductance algorithm as shown in Fig 8 is implemented for maximum power point tracking. In this method, incremental conductance and instantaneous conductance is added, to calculate the error.If the error exceeds 0.5 then a corresponding change is given for the duty cycle. The error is assumed to be in the range -0.2 to 0.2.

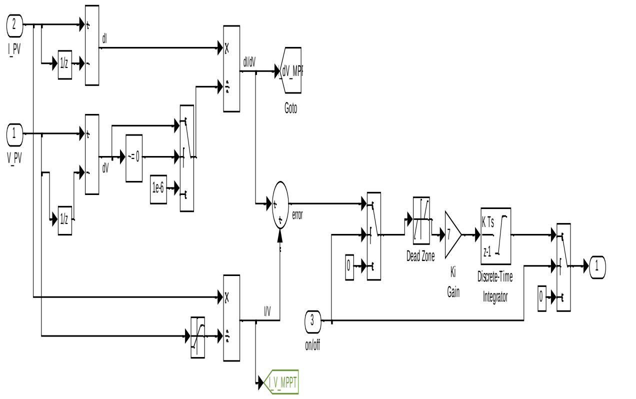

Fig 8 Sub circuit of MPPT

VIII. OUTPUT CURRENT SHAPING AND CONTROL

The two basic control requirements are: MPPT capability required by the PV application and output current shaping required by the grid connection. In a single-stage inverter, a dual-loop configuration is usually adopted, wherein a fast inner control loop tracks the line frequency waveform and a slow outer loop ensures operation at MPP. In order to prevent distorting the output ac current, the MPPT tracking speed is purposely designed to be slower than the line frequency. The performance of the implemented MPPT scheme in the outer loop does not, in general, depend on the inverter and the control scheme adopted. Therefore, it is not discussed in this work. The challenges of the inverter control for the proposed flyback CCM scheme lie in the output current shaping. The first challenge is due to the wide-ranging operating conditions of the inverter.

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Although designed to operate in CCM at rated power level, the inverter, in reality, would operate in a combined CCM/DCM mode, slipping into DCM operation around the zero-crossing instants of the ac cycle. Moreover, combined DCM/CCM operation even more complex. For instance, complete operation in DCM region alone can take place at low irradiation/power levels.

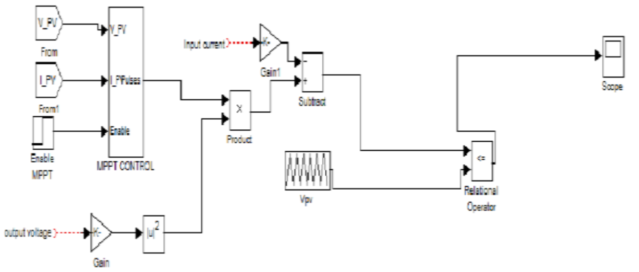

Fig 9 Output current shaping circuit

Another difficulty arises in CCM operation due to the non minimum phase nature of the flyback inverter, which shows up as an RHP zero in the linearized small-signal control to output current transfer function. This would greatly limit the achievable system bandwidth (BW). As indicated earlier, the system operating point varies widely; this would result in large changes in the RHP zero location. A controller designed to accommodate the worst-case (minimum) RHP zero, which occurs at the peak of ac voltage under maximum load, was found to result in unacceptably low BW (even lower than 100 Hz) when than operation changes to DCM at low instantaneous ac voltages. Thus, the widely varying RHP zero in CCM operation results in poor tracking performance in the DCM operating zone, and hence, unacceptable output power quality. In our approach this problem is avoided by sensing and controlling the primary switch current directly rather than the output current. The primary current reference signal's magnitude is determined by an external MPPT scheme and its shape is determined by the sensed instantaneous grid voltage by assuming input–output power balance based on in each switching cycle. As a result, the output current is controlled in an open-loop manner. The effect of the RHP zero is felt, in this case, only in the uncontrolled dynamics relating the output current to the input current.

IX. RESULTS

PV cell can be modelled as a current source in parallel with a diode.Power which depends upon irradiation and temperature. When irradiation increases power will also be increase. Also power will decrease when temperature increases. Figure shows the PV characteristics of the panel.

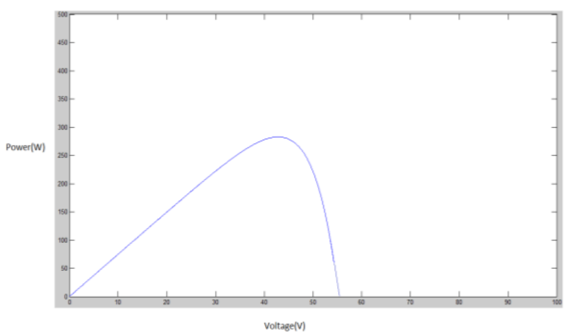

Fig 10 PV characteristics

When there is no light present to generate any current, the PV cell behaves like a diode. As the intensity of incident light increases, current is generated by the PV cell, as illustrated in Figure11.

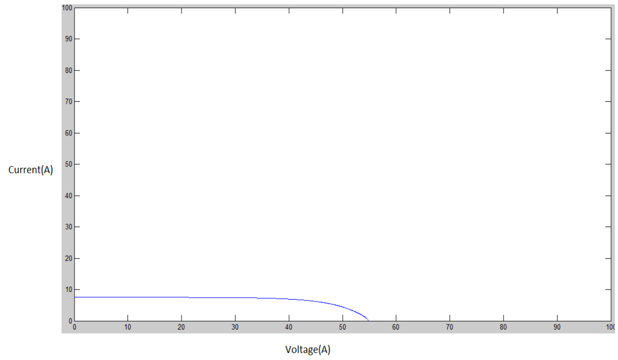

Fig 11 I V characteristics

The output voltage from solar panel is shown in figure12.We are giving this voltage output to the converter input.

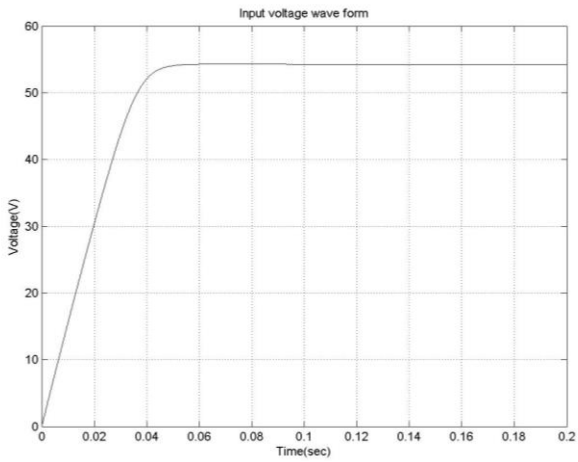

Fig 12 Input voltage waveform

Incremental conductance algorithm is used for maximum power point tracking. Here when there is any variation to maximum power point the duty ratio will change and according to that pulses will generate.

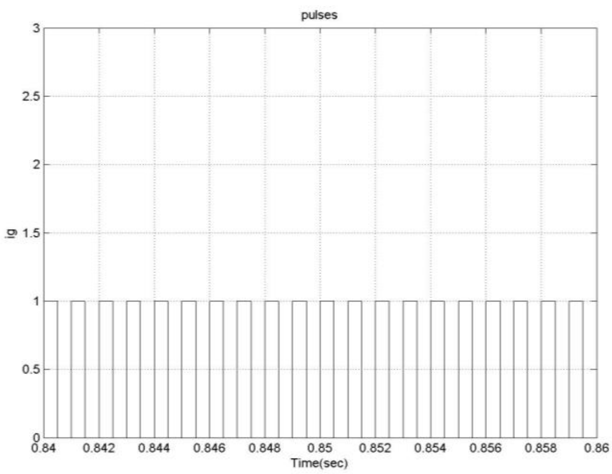

Fig 13 Gate pulses

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The overall voltage waveform is given in Fig 14.Here the output voltage is 230V Sinusoidal wave and having low amount of harmonics.

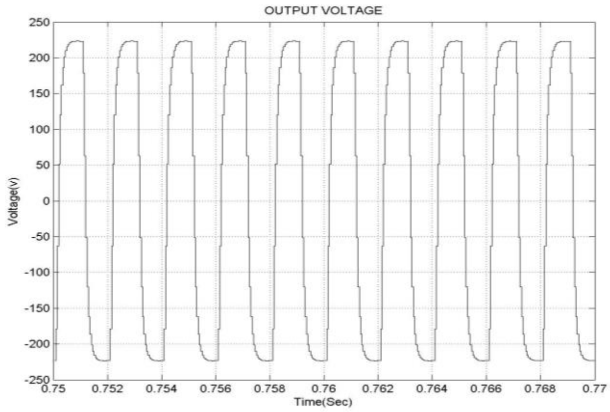

Fig14 Output voltage waveform

X. CONCLUSION

The step-by-step procedure for modeling the PV module is presented. This mathematical modeling procedure serves as an aid to induce more people into photovoltaic research and gain a closer understanding of I-V and P-V characteristics of PV module.

Here we can say that the flyback CCM scheme can be a viable solution for medium-power ac module application. Design issues, both for the power scheme and the control scheme, have been identified. The output power quality at rated power level is satisfactory.

REFERANCE

[1] A.Pradeep Kumar Yadav, S.Thirumaliah, G.Haritha(2012) “Comparison of MPPT Algorithms for DC-DC Converters Based PV Systems,” international journal of advanced research in electrical, electronics and instrumentation engineering Vol. 1, issue 1, July 2012

[2] A. C. Kyritsis, E. C. Tatakis, and N. P. Papanikolaou, “Optimum design of the current-source flyback inverter for decentralized grid-connected photovoltaic systems,” IEEE Trans. Energy Convers., vol. 23, no. 1,pp. 281–293, Mar. 2008.

[3] Pandiarajan and Ranganath Muthu (2011) “Mathematical Modeling of Photovoltaic Module with Simulink” In International Conference on Electrical Energy Systems.

[4] M S Syam, T.Sreejith Kailas,(2013) “Grid Connected PV System using Cuk Converter,” International Conference on Microelectronics, Communication and Renewable Energy (ICMiCR-2013).

[5] Yanlin Li, Ramesh Oruganti, (2012) “A Low Cost Flyback CCM Inverter for AC Module Application,” ieee transactions on power electronics, vol. 27, no. 3, march 2012.

[6] Araujo S. V., Zacharias P., And Sahan B. (2008) “Novel Grid-Connected No isolated Converters for Photovoltaic Systems with Grounded Generator,” In Proc.IEEE Power Electron. Spec. Conf. (Pesc), Pp. 58–65.

[7] Ji Y.-H, Jung D.Y, Kim J.H, Won C.-Y., And Oh D.-S.,(2010) “Dual Mode Switching Strategy Of Flyback Inverter For Photovoltaic Ac Modules,” In Proc. Int. Power Electron. Conf. (Ipec), Pp. 2924–2929.

[8] Kerekes T., Teodorescu R., And Borup U. (2007) “Transformerless Photovoltaic Inverters Connected To The Grid,” In Proc. 22nd Annu. IEEE Appl. Power Electron. Conf. (Apec), Pp. 1733–1737.

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