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High-Power Interleaved Flyback Microinverter Based on Perturb and Observe Maximum Power Point Tracking

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Abstract: Solar energy is the most widely used renewable energy in today's modern world due to its domestic applications and performance. But the energy obtained from the solar is comparatively lower, the cost of the installation is high and battery charging is high only at the zenith. So it is necessary to improve solar power obtained with lesser cost and greater performance. This proposal presents grid-synchronization of inverter for solar PV applications by designing a flyback converter which is operated in discontinuous current mode. In all the currently existing today's system grid synchronization is done with low power converter. Thus, the objective of this paper is to design a flyback converter for high power. Here the transformer is designed based on the panel ratings for converter operation and PV inverter is used thus synchronization conditions are matched and grid synchronization is done. Finally, a prototype at rated power is built and evaluated under the realistic conditions. To track maximum power, the maximum power point tracking (MPPT) of Perturb and Observe (P&O) algorithm is used. The efficiency of the inverter and the total harmonic distortion of the grid current are considered for the highest performance of the inverter. The performance of the proposed system is comparably higher to the commercial isolated PV inverters in the market.

Keywords: Flyback converter, PV inverter Maximum power point tracking, Total Harmonic Distortion

I. Introduction

Renewable energies are the most efficiently used energy generating technology in today's modern world. Such type of energy includes Biomass, Hydrogen, Fuel cell, Wind energy, Hydroelectricity, Solar energy, Piezoelectric energy, Tidal energy, Geothermal energy etc., Such type of energy are pollution less and eco friendly. One of the most widely used such renewable energy generation is solar from PV cells. In order to obtain the energy from PV cells it should be made clear that the energy obtained is efficient and is of less harmonic. Energy generated from solar is DC and one of the most important module in solar power usage is the conversion of the DC output to AC for using it to domestic and industrial applications. Here, The PV panel supplies DC power to the decoupling capacitor. This energy is then given to the Flyback converter where the energy is boosted and provided for further operation. The reference point to the inverter is given through of Zero crossing detector where the grid signal is taken through which the zeroth point is found. The unfolding inverter inverts the DC into AC and synchronizes this AC supply to the grid. The operation of the converter in the inverter block is controlled using a MOSFET driver. The driver controls the duty cycle of the MOSFET in the converter circuit thereby controlling the operation of the inverter. The MPPT algorithm obtains the maximum power from the PV panel and provides the value of duty cycle to the converter so that the grid voltage magnitude and inverter voltage magnitude can be made similar.Thus the synchronizing conditions are being satisfied and can be synchronized. This AC supply can be given to the load by stepping down the voltage based on the load used.

II. BLOCK DIAGRAM

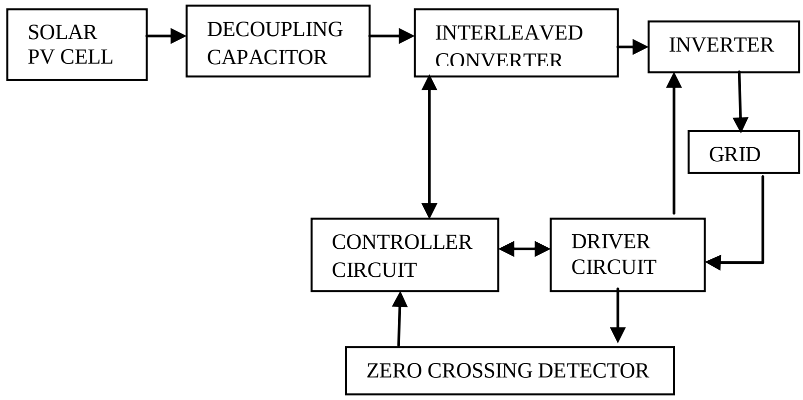

Figure no:1:Block diagram of the entire proposed system

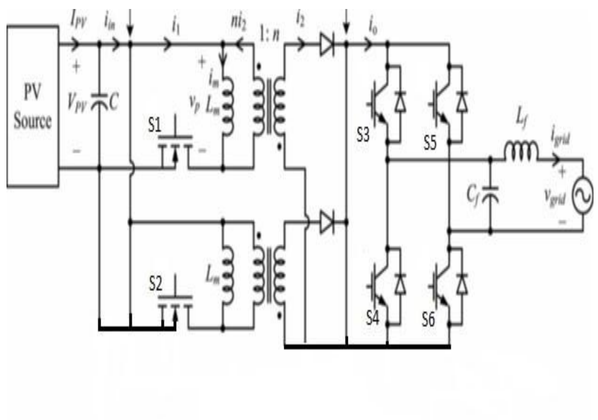

Figure no:2: Circuit diagram

III. SOLAR PV CELL AND MAXIMUM POWER POINT TRACKING

Photovoltaic generators are neither fixed current sources nor voltage sources but can be approximated as current generators with dependant voltage sources. It produces neither a current nor a voltage. A solar panel cell essential is a p-n semiconductor junction. When exposed to the light, a current is generated (DC).The generated current change linearly with the solar irradiance. It can be observed that the PV module's short circuit current highly depends on the radiation. High radiation leads to large short circuit current and the temperature impacts more on the open circuit voltage. High temperature leads to small open circuit voltage.

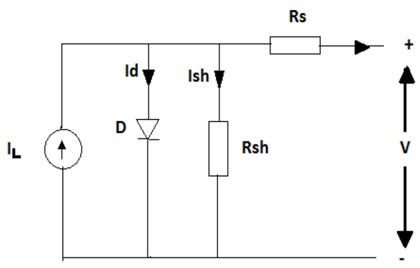

Figure no:3:Solar PV equivalent circuit

The current through diode is given by:

$I_D=I_O[\exp(q(v+I_{RS})/ KT))-1]$

while, the solar cell output current :

$I = I_L - I_D - Ish$

$I = I_L - I_O [\exp(q(v+I_{RS})/ KT))-1] - (v+I_{RS})/R_{Sh}$

I : Solar cell current (A)
I_L : Light generated current (A)
I_D : Diode saturation current (A)
V : solar cell output voltage (V)
Rs: Solar cell series resistance (Ω)
Rsh: Solar cell shunt resistance (Ω)

Polycrystalline silicon cells are also made from wafers of pure molten silicon. These structures are not as ideal as in the monocrystalline cells so the efficiency is lower, around 11-15% .Manufacturing processis cheap , so the lower efficiency is compensated. The surface needed to obtain 1 kW in STC is about 8m2. A maximum power point tracker is used for obtaining the maximum power from the solar PV module and conversion to the load. By varying the ratio of duty cycle the impedance of load as it appears by the source is varied and matched at the peak power point with the source so as to conversion the maximum power. Therefore maximum power point tracker methods are required to maintain the PV array's working at its MPP. In this paper the most popular of MPPT technique (Perturb and Observe (P&O) method is used. The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle. In this algorithm a slight perturbation is introduce to the system. If the power increases due to the perturbation then the perturbation is continued in the same direction. Once the peak power is reached the power at MPP is zero and then it decreases and after that the perturbation reverses. When the stable condition is arrived the algorithm oscillates around the peak power point. The technique is advanced in such a style that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts to transfer the operating point of the module to that particular voltage level. It is observed some power loss due to this perturbation also the fails to track the maximum power under fast changing atmospheric conditions. But remain this technique is very popular and simple.

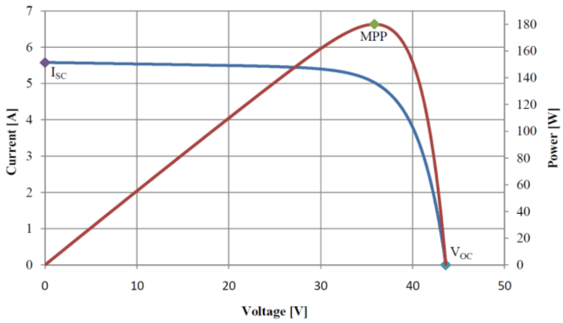

Figure no:4: MPPT tracking

IV. CONTROLLER

The controller used for obtaining the maximum power point tracking and for providing the gat pulses and duty cycles to the converter and inverter is dsPIC30F4011. Here initially the controller first tracks the maximum power point of the solar PV by maximum irradiation. This is don't by Perturb and Observe MPPT algorithm. Here the value of voltage and power obtained from the solar panel is tracked and compared with standard values or previous values by with a maximum power point is obtained. After this a particular value is generated by controller for obtaining the exact sine wave as that of the grid and for synchronizing all the conditions are satisfied. Initially the magnitude of the voltage is matched by the value generated with the help of controller and the phase difference is matched with the help of Zero crossing detector. This detects the zero of the grid sine wave and give the reference to the inverter so that the grid wave and inverter sine output has same phase difference. Also the frequency is matched. The controller also generates the duty cycle for MOSFET switches for the converter. The inverter operation is performed by the generation of PWM(Pulse Width Modulation) technique. By this the pulses are obtained and MOSFET switches are thus triggered. The driver circuit used here helps in providing suitable voltage to the MOSFET switches. Also it isolates the high power circuit and the low power circuit thus protecting the controller from any damage. The features of the controller are; Modified Harvard architecture ,C compiler optimized instruction set architecture with flexible addressing modes , 84 base instructions ,24-bit wide instructions, 16-bit wide data path ,48 Kbytes on-chip Flash program space (16K Instruction words) ,2 Kbytes of on-chip data RAM , 1Kbytes of non-volatile data EEPROM ,Up to 30 MIPs operation: - DC to 40 MHz external clock input - 4 MHz-10 MHz oscillator input with PLL active (4x, 8x, 16x) , 30 interrupt sources - 3 external interrupt sources - 8 user selectable priority levels for each interrupt source - 4 processor trap sources, 16 x 16-bit working register array. It used CMOS technology thus the advantages are Low power, high speed Flash technology, Wide operating voltage range (2.5V to 5.5V), Industrial and Extended temperature range, Low power consumption.

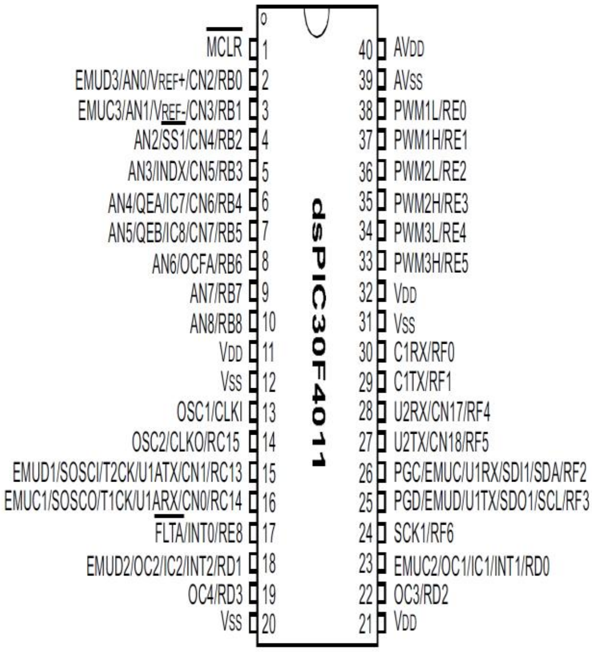

Figure no:3: PIN diagram of DSPIC30F4011

V. CONVERTER

The PV source is applied to an interleaved flyback converter through a decoupling capacitor. Each flyback converter uses a Metal Oxide Semiconductor Field Effect Transistor (MOSFET) for switching at the primary sideman flyback transformer, and a diode at the secondary side. When the flyback switches are turned ON, a current flows from the common point (the PV source) into the magnetizing inductance of the flyback transformers, and energy is stored in the form of magnetic field. During the on time of the switches, no current flows to the output due to the position of the secondary side diodes; therefore, energy to the grid is supplied by the capacitor Cf and the inductor Lf .When the flyback switches are turned OFF, the energy stored in the magnetizing inductances is transferred into the grid in the form of current. So, the flyback inverter acts like a voltage-controlled current source. The converter is operated in DCM for easy and stable generation of ac currents at the grid interface. The DCM operation of converter produces triangular current pulses at every switching period. In practice, a PV source is not an ideal voltage source; so any ac current that is supplied by it will cause variations at its terminal voltage. So, for good performance of the converter as far as the power utilization and output current distortion, the voltage variations (ripple) across the PV module terminals should be as small as practically possible. For this reason, a decoupling capacitor is placed at the flyback converter input and sized in such a way that both the low and the high frequency ac components are bypassed sufficiently and only the dc (average) component is allowed to be supplied by the PV source. Flyback transformer is designed in such a way that there is less air gap and the conversion ratio is higher.

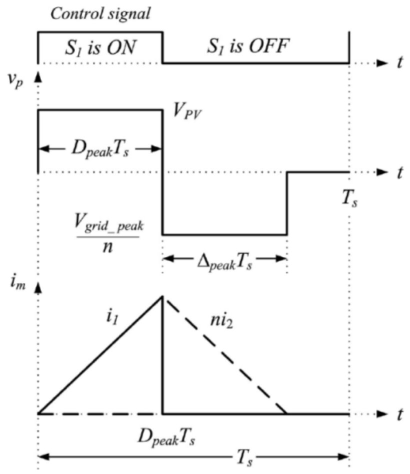

Figure no: : Control signal for flyback switch, flyback transformer primary voltage (vp), magnetizing current (Im)

VI. DECOUPLING CAPACITOR

The control system used in this design does not employ a feedback loop for the regulation of the output current. Therefore, the waveform quality of the grid current is greatly dependent on the quality of the dc voltage at the flyback converter input, which is also the voltage at the PV terminals. For that reason, a relatively constant dc voltage is required for synthesizing a sinusoidal current with low distortion under open-loop control. Otherwise, some low frequency harmonics appears at the grid current causing increased THD. In addition, the ripple at the PV voltage can create slight utilization losses at the PV power as reported in. So, low ripple is also preferred for perfect utilization of the solar power. The main reason that causes the voltage ripple in single-phase grid-connected PV inverters is the demand of the load by the PV source to deliver fluctuating power with a magnitude twice that of the average power and a frequency twice that of the grid frequency. As explained in Section II, the PV source is not an ideal voltage source, so the terminal voltage is significantly affected by the quality of the current delivered by the module. For that reason, employing a decoupling device is essential to bumper the instantaneous demands from the PV source. The decoupling capacitor works as buffer and provides the power balancing between the PV source and the grid. So, the major sizing criterion of the decoupling capacitor is the effectiveness in diverting the double line frequency component away from the PV source by creating a low impedance path and so maintaining a low ripple at the PV terminals. The following gives the peak to-peak voltage ripple across the decoupling capacitor.

$\Delta VPV = \Delta VC = XC\,\Delta IC$

where ΔVC is the peak-to-peak voltage ripple across, ΔIC is the current ripple through, and $XC = 1/2\pi fC$ is the reactance of the decoupling capacitor.

VII. INVERTER

The flyback inverter used here has two stages, the converter stage and unfolding H-bridge, while the conventional flyback inverterhas a single-stage power conversion system. The flyback inverter composed of two stages has some advantages to get higher power conversion efficiency due to its H-bridge based unfolding method, while the single stage configured flyback inverter is a cost effective solution for photovoltaic AC module systems. Thus, the total loss of transformer used in single-stage flyback inverter can be much larger than that in the two-stage flyback inverter.Whereas, the difference between the unfolding H-bridge and the conventional unfolding type is in the voltage stress of the secondary switching devices. In conventional method the maximum voltage of the secondary active switches is equal to 2Vpeak, Vpeak is the peak value of the grid voltage. Actually, the required voltage rating of the secondary active switches can be higher than 2Vpeak due to the oscillation or ringing of the secondary current. Unfortunately, higher voltage rating of the switching devices causes larger conduction losses. However, the maximum voltage of the unfolding switching device can be a half of that of the conventional unfolding stage. Thus, in the power conversion efficiency point of view, the unfolding H-bridge can be more useful solution. The output current of flyback inverter ig is,

$$Ig = \left(\frac{1}{Lf}\right) \int VLf\,dt = \left(\frac{1}{Lf}\right) \int (Vcf - Vg)dt$$

where Lf is filter inductance, VLf is voltage of the filter inductor Lf and Vg is the grid voltage. During the positive period of grid voltage, the voltage of filter capacitor, Vcf, is equal to link voltage, VCs, due to the unfolding bridge operation. If the voltage drop of unfolding H-bridge is neglected, the Ig can be written as,

$$I_g = \left(\frac{1}{L_f}\right) \int (V_{cf} - V_g)\,dt$$

Consequently, it is obvious that the output current can be controlled by the link voltage, VCs, under the normal unfolding bridge operation.

VIII. FILTER CIRCUIT

Low pass filter are used in wide number of applications particularly in radio frequency applications. The filter depends on the properties of passive circuit elements. The low pass filters are made in their LC form using inductors and capacitors. They are used to filter out unwanted signals that are present in a band above the wanted pass band. The combination of inductor filter with the capacitor the ripple factor will become almost independent of the load filter. It offers high resistances of the AC components and allows DC components to flow through the load. By this way the ripples are rectified and a smooth DC is provided through the load. The low pass filter after the MOSFET inverter is responsible for supplying a current to the grid with low total harmonic distortion by removing the high frequency harmonics of the pulsed current waveform.

IX. GRID SYNCHRONIZATION PROTOTYE AND OUTPUT

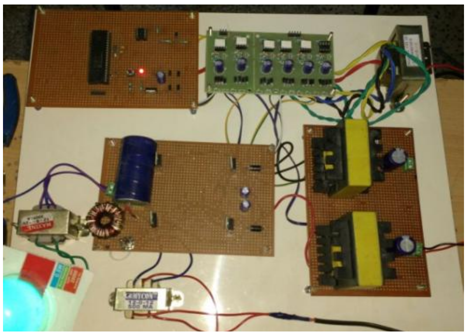

Figure no: :Grid Synchronization prototype model:

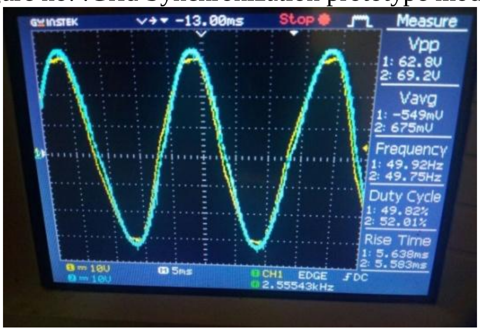

Figure no: : Output of DSO showing synchronization of inverter output and grid

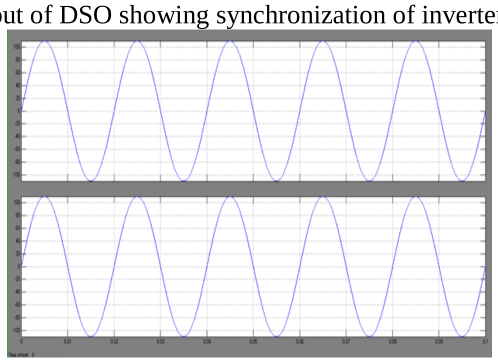

Figure no: : MATLAB simulation output of the inverter and the grid

X. ADVANTAGES

Solar PV system is more reliable, modular, durable and generally maintenance free. Advantage of Discontinuous Current Mode is very fast dynamic response better stability, No turn no losses and easy control. Passive components used is less thus small size. Low-power switch mode power supplies(cell phone charger, standby power supply in PC's). Low cost multiple output power supplies(e.g., main PC< 250W) High voltage supply for the xenon flash lamps, lasers, copiers, CRT in the Television and monitors etc,. Isolated Gate driver is used thus easy control.

XI. COLCLUSION

This paper has presented the design and simulation verification of grid-tied interleaved flyback inverter operated in DCM. The main design objective is to implement interleaved flyback inverter topology at high power. The study included analysis and simulation steps where the number of interleaved cell is determined. The two cell interleaving is optimum because it is low cost, small size and good performance. Here the perturb and observe algorithm used for MPPT. It is the optimum control method to track maximum power.

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