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Design and Performance Analysis of Fly Back Convert for PV Application



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Abstract:

In recent years, the number of grid-connected systems using photovoltaic (PV) has increased considerably .The improvements of reliability, power conversion efficiency, lifetime and production cost of small power PV inverters have grown further concern. The new technology on this subject is the so-called "AC Module ranging. An AC Module is the integration of the inverter and PV module into one electrical device. It includes the possibility of an easy enlarging of the system due to the modular structure, and the opportunity to become a "plug-and-play" device. A fly back inverter suitable for AC Module has been proposed. The circuit is made up around a single-transistor fly back converter, with a high-frequency center-tapped transformer. To optimize the PV system performance, a Sensor less current MPPT method for the fly back inverter was presented although the fly back inverter is small and cost-effective, high-frequency switching mode transitions trend to decrease the actual efficiencies of the power conversion process.

I. INTRODUCTION:

Photovoltaic ac module (PV ACM), also named as micro-inverter, is a compact and modular structure for small power PV generation system applications. The PV ACM must meet a series of harsh requirement, such as THD and islanding protection demanded by standards of GT devices, maximum power point track (MPPT) and minimum power fluctuation demanded by PV panels, high efficiency, high reliability, long lifetime, low cost, and easy installation demanded by users Its major advantages include electric isolation, high power density, high efficiency, and high step-up ratio, which are based on the simple control loop and compact structure.

BCM is more preferred for PV ACM applications considering all the earlier research works. In the BCM with peak-current control, the output current iout is directly controlled by the reference current iref during each every switching cycle. The purpose of this paper is to analyze and propose an accurate mathematical model between iout and iref through theoretical derivation. Based on the proposed mathematical model, the relationship between fs and iref is also analyzed. Then, a novel control strategy of iref is proposed to decrease THD of iout. Moreover, the realization of MPPT based on this control strategy is also investigated. Finally, the control strategy is verified based on an improved fly back-inverter topology, which is described in. Both simulation and experiment results on this topology are shown in this paper. This results in high complexity and impossible to simulate large scale PV power systems using low cost platforms. Various step-up dc–dc converter topologies include a conventional boost and fly back converters witched- inductor converter, and switched capacitor converter as well as a transformer less switched capacitor types voltage-lift types capacitor–diode voltage multipliers , and boost types that are integrated with coupled inductors With increasing voltage gain, recycling the leakage inductance energy of a coupled inductor will reduce voltage stress on the active switch, which enables the coupled inductor and voltage multiplier or voltage-lift technique to realize high-voltage gain. The proposed SPO is shown in Fig. 2; its configuration is based on a high step-up dc–dc converter with an MPPT control circuit. The converter includes a floating active switch S and a coupled inductor T1 with primary winding N1, which is similar to the input inductor of a conventional boost converter capacitor C1, and diode D1 recycle leakage inductance energy from N1. Secondary winding N2 is connected to another pair of capacitors, C2 and C3, and to diodes D2 and D3. Rectifier diode D4 connects to output capacitor Co and load R.

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The duty ratio is modulated by the MPPT algorithm, which uses the incremental conductance method that is employed in the proposed SPO. It detects PV module voltage Vpv and current Ipv to determine the increase and decrease in the duty cycle of the dc converter. Therefore, the MPP can be obtained by comparing instantaneous conductance I/V and incremental conductance dI/dV. The algorithm is programmed into TMS320LF2407A, a digital signal microprocessor. The proposed converter has the following features:

1) its voltage conversion ratio is efficiently increased by using the switched capacitor and coupled inductor techniques;
2) the leak- age inductance energy of the coupled inductor can be recycled to increase efficiency, and the voltage spike on the active switch is restrained;
3) the floating active switch isolates the PV panel's energy during non operating conditions, thereby preventing any potential electric hazard to humans or facilities.

The MPPT control algorithm exhibits high-tracking efficiency; hence, it is widely used in the energy harvesting of PV systems. The rest of the paper is organized as follows. The operating principle and steady-state analysis of the proposed converter, respectively. Addresses the practical implementation and component selection of the proposed converter.

Tremendous efforts focus on MATLAB-SIMULINK based simulation platforms. These are generally based on specific applications and platforms therefore a generalized approach is needed for the efficient modeling and simulation which is applicable to long term operation of various photovoltaic power systems. iout and iref in BCM during half one cycle.

II. MPPT CONTROLLER:

For maximum power transfer, the load should be matched to the resistance of the PV panel at MPP. Therefore, to operate the PV panels at its MPP, the system should be able to match the load automatically and also change the orientation of the PV panel to track the Sun if possible (Sun tracking is usually left out of most systems due to the high cost of producing the mechanical tracker). A control system that controls the voltage or current to achieve maximum power is needed. This is achieved using a MPPT algorithm to track the maximum power.

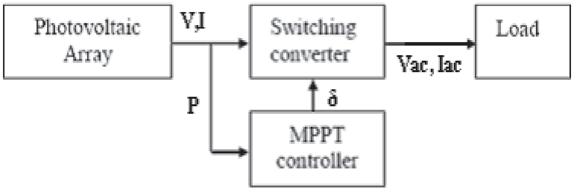

Fig:1. Basic MPPT system

A controller that tracks the maximum power point locus of the PV array is known as a MPPT controller. There are several algorithms to track the MPP and a few common maximum power point tracking algorithms have been reviewed. For optimal operation, the load line must match the PV arrays MPP locus and if the particular load is not using the maximum power, a power conditioner should be used in between the array and the load. Some of the frequently discussed MPPT techniques in the literature are as follows:

- Fractional short circuit current (Isc), a current based MPPT
- Fractional open circuit voltage (Voc), a voltage based MPPT
- Perturb and Observe (P&O) /Hill climbing
- Incremental Conductance Technique (ICT)
- Constant Reference Voltage(CRV)

Advantages of the MPPT approach :

» Only one ac current sensor is required to sense ac inverter current output for MPPT purpose in a balanced three-phase system.
» No dc sensors required, nor multiplier required revealing the power in digital control. This simplifies algorithm and computation.
» Since no voltage (no power) measurement is required, this avoids additional software filtering for the oscillating PV voltage.
» For a three-phase system, a sensor of smaller rating is required compared to the conventional method as whole dc power is not measured, instead ac current in one of the phases (which reflects ac power) is sensed, which is small.
» This method is based on the measurement periodically of the PV short circuit current, which is approximately linear to the current maximum power point
» Experimentally, k2 is a constant between 0.78 and 0.92. Once the constant k2 is known, IMPP is computed. The PV array needs to be shorted periodically to measure Isc.

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Similarly, the Fractional open-circuit voltage is based on the linear dependence between array voltages at maximum power VMPP with its open circuit voltage Voc. k1 is a constant between 0.71 and 0.78. Voc is measured by shortly shutting down the power converter. Implementations of those methods are simple and cheap but here is excessive power loss and the efficiency of the PV is very low due to the inaccurate determination of the constant k1 andk2. The power loss is caused by the necessity to open and close the circuit for measurement.

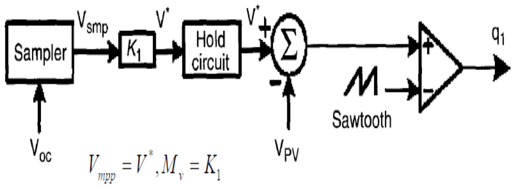

Fig.2: Conventional MPPT controller using open circuit voltage Voc

This is the one of the most conventional, but it is considered to be a fast, practical and powerful method for MPP estimation without the need for a powerful DSP. It is based on the observation that the MPP voltage (Vmpp) can be approximated by a linear function of the open circuit voltage (Voc).These algorithms are based on the measurement of the PV module output voltage and current. Then, it calculates the PV power and determines if the control parameter needs to be increased or decreased. The control parameter could be a reference signal (voltage or current) for a controller or it can be the duty ratio for the switching signal DC/DC converter. The advantage of MPPT with searching algorithm is easy to implement, it does not require previous knowledge of the PV module characteristics. However, it is necessary to choose the dc link capacitor correctly, the switching frequency and the step size used in changing the control variable. The performance of MPPT algorithm can be affected from those parameters. Among MPPT algorithms methods are Perturbation and observation (P&O), Hill climbing and Incremental conductance.P&O and Hill climbing use the same fundamental strategy. The duty ratio is the perturbation in hill climbing, while the voltage of the PV module is the perturbation for the P&O. Changing the value of the duty cycle causes a change to the current and as consequence, perturbs the voltage array. In Fig.3, the voltage and current are measured and the MPPT controller determines the voltage reference. The input for the regulator PI is the difference of the Vref and Vpv. The voltage regulated generates the PWM for the converter.

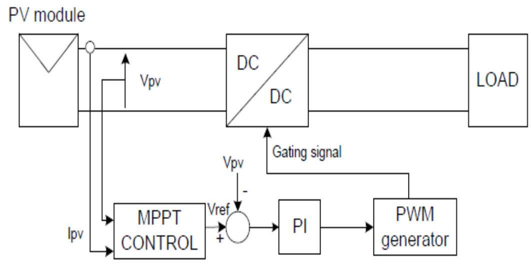

Fig.3: Block diagram of MPPT with P&O

For Hill climbing, there is no regulator, only the duty ratio controls the converter directly as shown in Fig.4.

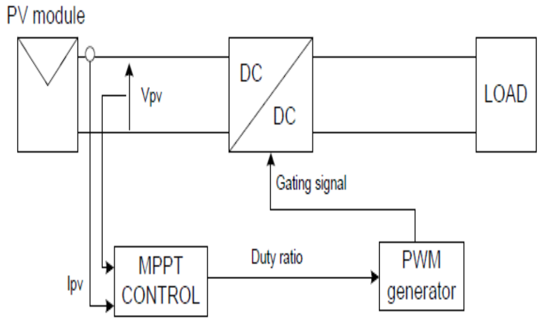

Fig.4: Block diagram of MPPT with Hill Climbing

In Fig.4 it can be observed that incrementing the PV voltage increases the power of the PV and decrementing the PV voltage decreases the power of the PV when operating on the left of the MPP. On the right of MPP, incrementing the voltage decreases the power and decrementing the voltage increases the power. This process will be implemented in the MPPT controller to extract the maximum power from the PV module.

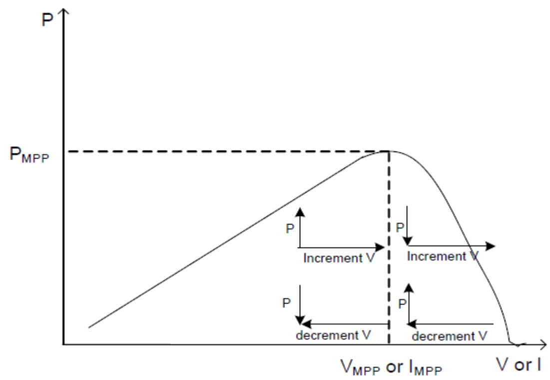

Fig.5: Principle of P&O

The system oscillates around the MPP with this method. The process of incrementing and decrementing can fail under rapid change in irradiation. The system diverges away from MPP if the irradiance increases suddenly.

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To remedies those problems, improved methods of perturb and observe are used: reduced perturbation step size, variable step size, three point's weights comparison methods and optimized sampling rate.Fig.5 shows the flow chart of perturb and observe method. First inputs are given are voltage and current and the power is calculated from these V & I. The sign of the power determines the duty cycle output of the MPP controller. Duty ratio is the control variable in simulation. Perturbing the duty ratio of the converter perturbs the PV array current Ipv and consequently perturbs the PV array voltage Vpv. The initial value of the duty cycle and PV power are given. The voltage and current of the PV array are measured first and then the power P is calculated. The calculated power is compared with the reference power and find out the difference. If the difference is positive then increment the duty ratio and update the new values of V, I, P and duty cycle and repeat the process. The range of the duty cycle is limited between zero and one to ensure that the boost will step up the input voltage within limit.

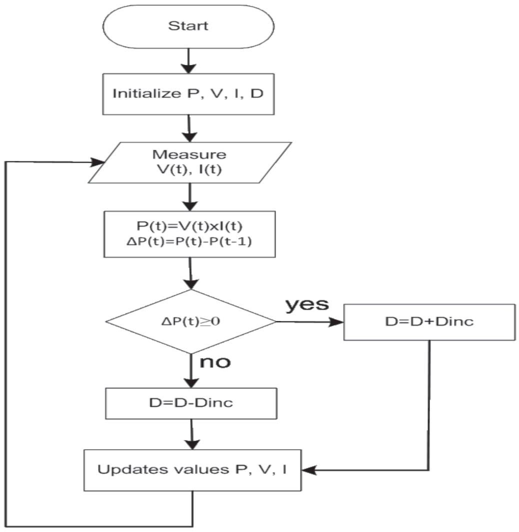


Fig.7: P&O flow chart

The performance of the P&O depends on the sampling interval and the duty-cycle perturbation of the algorithm. The accuracy, speed of the P&O depends on the above parameters. The duty cycle step must be chosen properly. The oscillations and steady state losses are reduced by reducing the duty cycle. But, under changes in atmospheric conditions this controller gives less efficiency.The sampling rate also effects in the algorithm, higher the sampling rate may cause instability. If the PV array samples the voltage and current too quickly then maximum power track will be missed. The sampling interval of the algorithm should be set as small as possible without causing oscillation of the system and the divergence away from the MPP. Otherwise, the instability will reduce the efficiency of the PV circuit diagram.

III. SIMULATION RESULTS:

A simplified single diode photovoltaic modeling approach is introduced to parameterization of PV cell models. The model implementation is provided with power interface topologies with intermediate DC link used as string inverts and single stage DC to AC conversion. The transformer with center-tapped secondary winding is no needed due to the independent GT inverter, which can reduce the difficulty of transformer design. The voltage stress of secondary switches is also decreased because of the GT inverter. The operations of the flyback inverter are the same during both the positive and negative half cycle of the grid voltage.

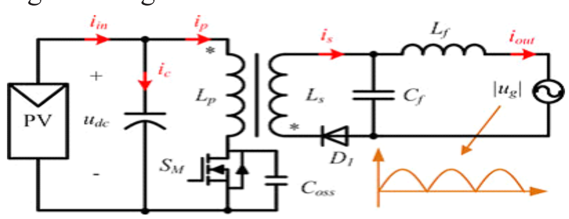


Fig.6. Equivalent diagram of a single flyback inverter

Therefore, the equivalent diagram for a single flyback inverter can be shown as Fig. 5.According to this figure, the output current iout is obtained by filtering secondary current is. When SM switches on, ip increases gradually in a linear relation with udc. Once ip equals to iref, SM is off and is decreases linearly with ug .

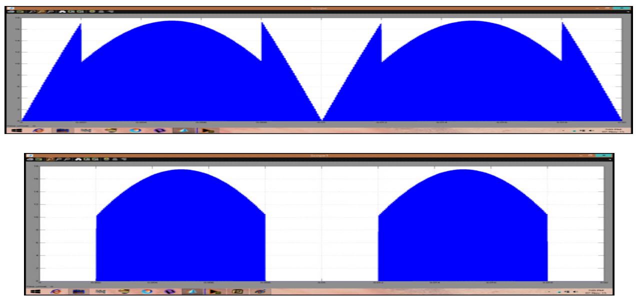
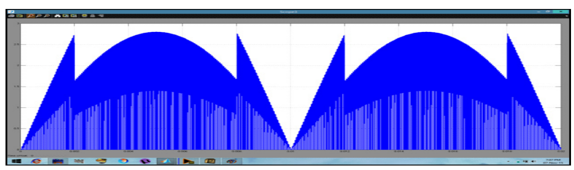


Fig.8: Primary currents of flyback 1 and 2.



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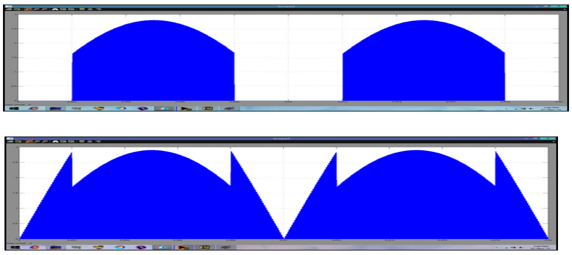

Fig.9. Secondary currents of flyback 1 and 2

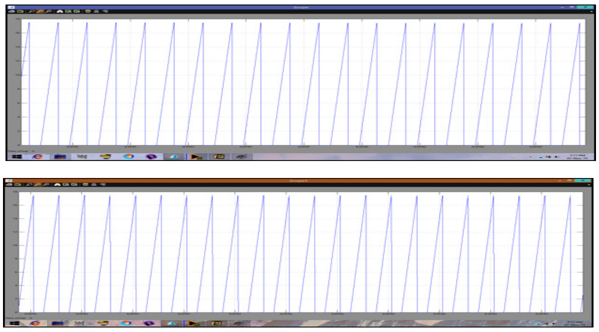

Fig.10. Details of primary currents.

Fig.11. Details of secondary currents.

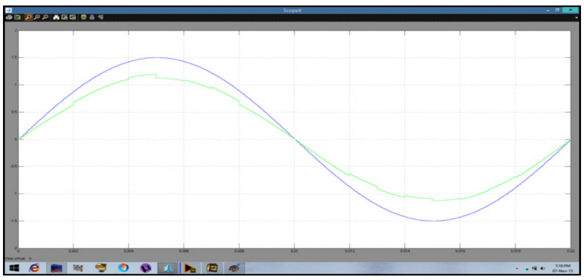

Fig.12. Output current of ACM and sampling of grid

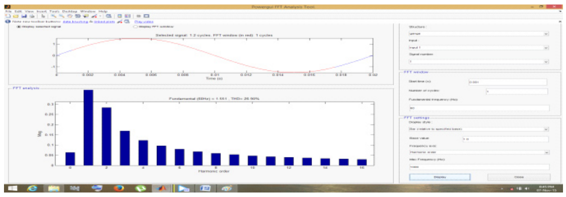

Fig.13. Spectrum of ACM's output current

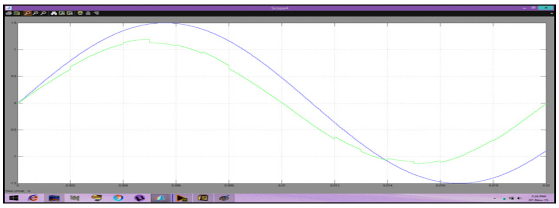

Fig.14. Waveforms of iref , iref .a , and iref .b .

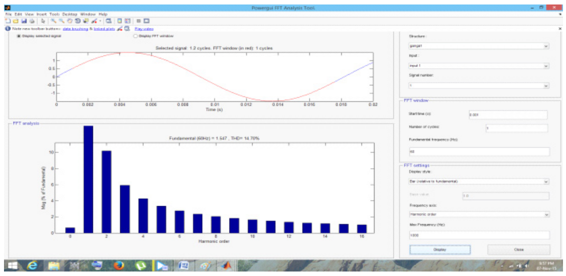

Fig.15. Spectrum of output current.

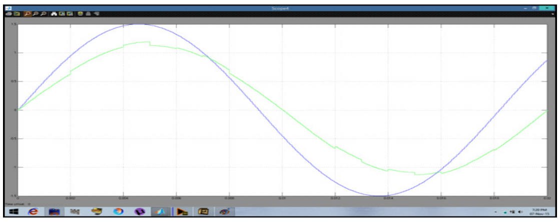

Fig.16. Output current of ACM

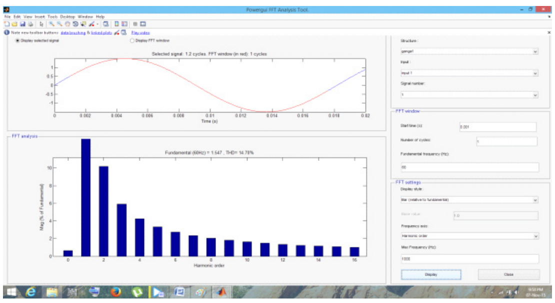

Fig.17. Spectrum of output current

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VI. CONCLUSION:

Flyback inverter is an attractive solution for photovoltaic ac module application. As a grid-connected device, flyback inverter should work as a current source and provides the sinusoidal output current that is synchronous with the grid voltage. Meanwhile, the flyback inverter should have high efficiency to satisfy user's demand. In this topology, BCM is more preferred compared to DCM and CCM, because of its higher power level, higher efficiency, and wider switching frequency bandwidth. However, the control of BCM is more complicated, due to its VSF. This also leads to the difficulty to get the accurate mathematical model between output current iout and reference current iref, which has a great influence on THD of iout . In this paper, the relationship between ACM output current iout and reference current iref of flyback inverter in BCM is investigated, and an accurate mathematical model is proposed through theoretical derivation. Then, a novel control strategy of iref is proposed to decrease THD of iout . Moreover, the realization of MPPT based on this control strategy is also investigated. Finally, simulations of an improved flyback-inverter topology are presented, which verifies the proposed control strategy.

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