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Study on the Strategies to Enhance the Efficiency of Parallel Inverters at Light Loads

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Abstract: *This paper presents the various paralleling methods and schemes to enhance the efficiency of parallel inverters at light loads.The various methods to improve the Conversion efficiency of inverters are discussed in the paper, which includes conventional Current Scheme, interleaved flyback converter andsoft switching scheme. These methods reducesthe switching and magnetizing losses and thereby enhancing the efficiency at light loads. Simulation results show that these schemes increase the efficiency of lightloads to a better range.*
Keywords: *Hybrid Switch, Parallel Inverters, Particle Swarm Optimization,Phase skipping mode*

I. Introduction

Increased amount of carbon dioxide and other gasses which causes environmental pollution havelead to the use of Nonrenewable energy resources which have very less impact on the surroundings. The various Non Renewable Resources include the Solar Energy, Wind Energy, Geothermal Energy, Tidal Energy etc. The commonly used type of Nonrenewable Energy in House hold applications include the Photovoltaic Generation system which uses single inverters. Due to the limitations of single inverter, they are replaced with the parallel inverters. The advantages of using the parallel Inverters are even if one of the inverterare not functioning or taken for maintenance, the other inverters can meet the demand.There are many types of paralleling schemes but the most commonly used one is the current sharing control.

II. Problem Definition

The efficiency of parallel Inverters are low at light loads. Generally, the efficiency of power-conversion circuits at heavy loads is determined by the conduction losses of semiconductor and magnetic components, whereas their light-load efficiency is primarily determined by switching losses of semiconductors, core losses of magnetics, and drive losses of semiconductor switches. A typical efficiency curve as a function of the load power shows a steep fall as the load is between 11percentage and 19 percentage of the full load, as illustrated in fig 1,whereas the switching and drive losses of semiconductor switches and core losses of magnetic components are almost independent of the load.

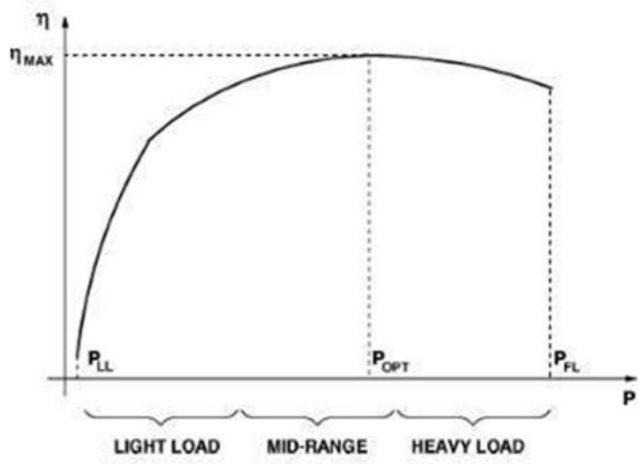

Fig1: Efficiency Curve

Furthermore, as the rated output power of the converter increases, larger semiconductor devices (or more devices in parallel) and larger magnetic cores are needed, which leads to increased switching and core losses, and an even steeper fall of efficiency at light loads.

Variable switching frequency control, bulk voltage reduction, phase-shedding, and burst-mode operation, have been introduced to make the power supply exhibit a better efficiency curve that meetcustomersexpectations, power management techniques. Although the described techniques have been shown to improve the partial load efficiency, they suffer from some major drawbacks that limit their area of application. For example, a major problem of reducing the switching frequency at light loads is an increased current ripple caused by the increased voltsecond product in the core of the output the inductor. This increase in the ripple current has an adverse effect on the efficiency because it increases the conduction loss. A major concern with bulk voltage reduction and phase-shedding techniques is the dynamic performance, especially their ability to restore full-power capability without output disturbance or other performance deterioration when the load suddenly changes from light load to full load. Finally, burst-mode operation is limited to very low power levels primarily due to acoustic noise. Light-load efficiency optimization is based on a simple observation that the minimization of power loss requires that the power converter is either always operated at the load power with the maximum efficiency or be completely turned off, i.e., by restricting the operation of a converter to one of these two operating points, the best possible efficiency can be achieved because when the converter is turned off, no loss is incurred, whereas when the converter is turned on it operate with maximum efficiency. Or it can be achieved by controlling the reference current of current sharing control technique. The various control strategies are discussed below.

III. Control Strategies

1) Interleaved Fly-Back Converter

The simple structure of the flyback topology and easy power flow control with high power quality at the grid interface are the main features of this type of converter compared to the other. The flyback converter is recognized as the lowest cost converter among the isolated topologies since it uses the least number of components. The advantage comes from the ability of the flyback topology combining the energy storage inductor with the transformer,whereas in other type of isolated topologies, the energy storage inductor and the transformer are separate elements. The combination of these two components in a flyback topology eliminates the bulky and costly energy storage inductor and therefore leads to a reduction in cost and size of the converter.

A flyback converter with a transformer that has large leakage flux and poor coupling will have poor energy transfer efficiency. For this reason, the flyback converters are generally not designed for high power. As a result, the flyback topology finds a role in photovoltaic applications only at very low power as a microinverter. In this practice, many AC PV modules are connected in parallel to get the desired power output. The maximum harvesting of solar energy in this method is the best since there is a dedicated maximum power point tracker for each PV panel.

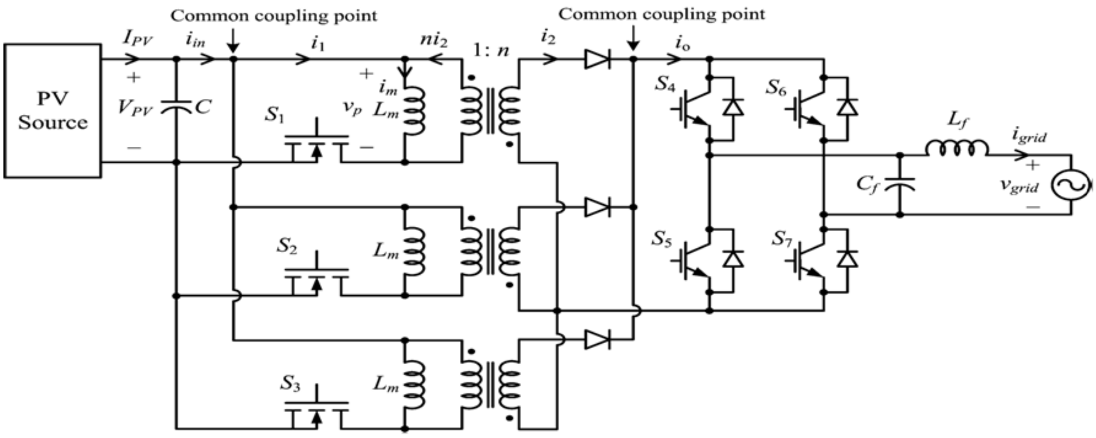

Fig:2 Circuit of an Interleaved Flyback Converter

Reference Current is given by the phase skipping schemes, it can be found using the equation below

$$\boldsymbol{i_{ref}} = \sin(\boldsymbol{wt}) \sqrt{\frac{2\, i_{out}\, V_o}{L_p f_s}}$$

Where i_{ref} is the value of reference signals,i_{out} is the output current, $v_o$is the output voltage,L_p is the value of primary induction of transistor, f_s is the switching frequency,P_o is the Output Power.

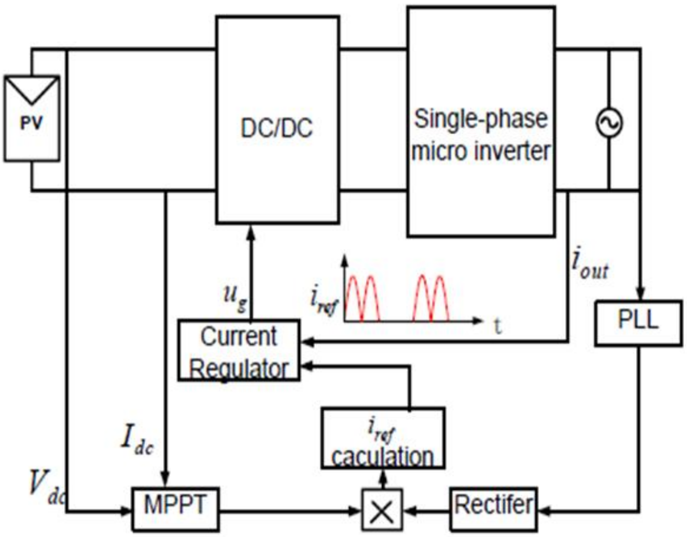

Fig: 3 Control Diagram

Fig. 3 shows the control block diagram with Phase Locked Loop (PLL) and MPPT block of the interleaved flyback inverter with the proposed control. The control blocks are implemented by Freescale DSP MC56F8257. When the output power of PV modules is inferior to the point of setting, the micro-inverters operate in phase skipping mode. Otherwise, conventional control method is employed. In this way, the proposed strategy can keep the system operating at highest efficiency point to a greatest extent when the load and irradiance condition changes.

2) Hybrid Switches

The use of a parallel IGBT-MOSFET switch combination, referred as hybrid switch, can be used for efficiency improvement at light load conditions.Since the power inverter will operate at light loads mostof its operation life in the stand alone residential applications, improved light load efficiency will result in more efficient use of limited sources and considerable energy savings. For example, this will mean hydrogen savings for fuel cell powered residential systems and less solar panel area for solar powered residential systems. It is shown that light load efficiency can be improved with hybrid switch use. IGBT–MOSFET combinations for reducing switching losses of the IGBT switch. Mainly, the faster response of MOSFET to switching signals compared to IGBT is used for minimizing IGBT turn-off losses. Analysis of conduction-loss of a parallel IGBT–MOSFET switch combination has been shown that MOSFET-based configurations have lower conduction losses at light loads. In this study, instantaneous load current feedback is used to control the hybrid switch for the first time. Only one of the switches in the hybrid switch is going to be active at any moment. The switching logic is shown in Figure 4.

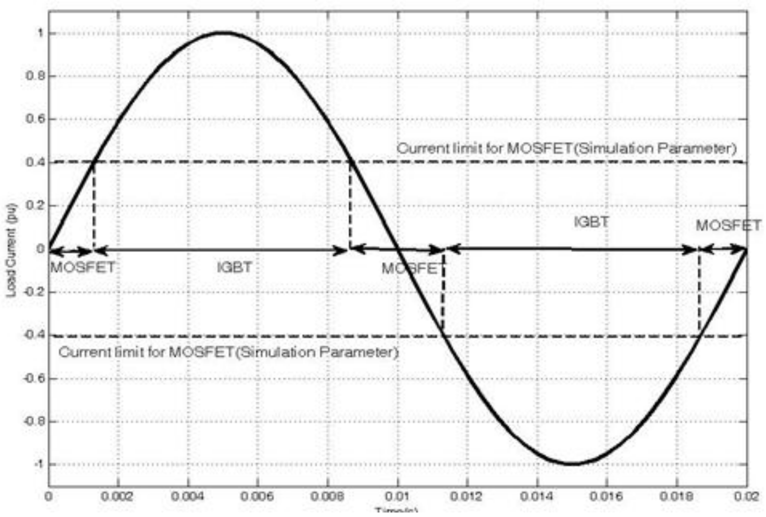

Fig. 4: Switching logic for the hybrid switch control based on instantaneous load current feedback

Since MOSFETs have faster switching characteristics which do not have on state voltage drop on conduction, both switching and conduction losses will be lower at low currents compared to IGBTswitch. Thus, when the load current is low, using MOSFET switch will provide efficiencyimprovement. It should be noted that maximum MOSFET current limit can only be the rated currentfrom the MOSFET datasheet.

3) Particle Swarm Optimization Algorithm

Fig. 5 illustrates control block diagram for the current-sharing control of parallel inverters. The rated powers of every single inverter in the parallel inverters are added up to meet the peak power of the load. The phase locked loop (PLL) is used to ensure the consistency between the frequency and phase of the output voltage. The current-programming control center acquires the total output current to define the reference current of each inverter. The average current-sharing control is commonlyused for parallel inverters with same rated output power. It means that each inverter have the same power and current.

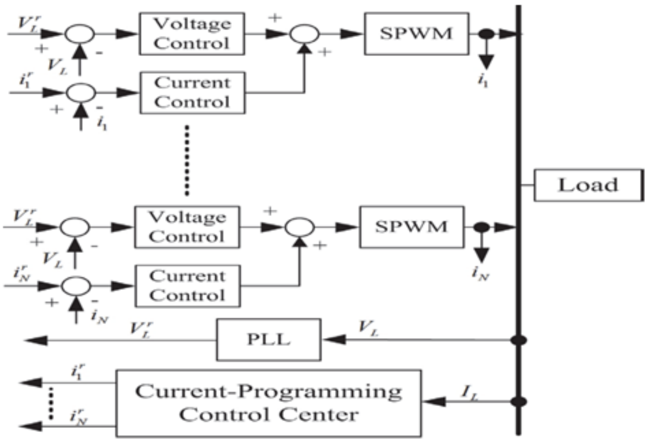

Fig 5: Control Block Diagram of Current Sharing Control

Since all parallel inverters operated by average current-sharing control are interconnected simultaneously to supply power to the load, the conversion efficiency of the parallel inverters operated simultaneously based on the current sharing at light loads is low. Therefore Particle Swarm Optimization Algorithm is used for finding the reference current. Microprocessor used in the current-programming control center, it is not suitable to calculate the current reference of each parallel inverter by a PSO-based algorithm in real-timeoperation.Therefore, an off-line computing and real-time application scheme is proposed in this scheme. The proposed off-line computing divides the rated output power of parallel inverters into several output-power segments and then calculates the current reference of each parallel inverter for each output-power segment during the night hours. Thus the improved control block diagram for the enhancement of light load efficiency is given in fig6.

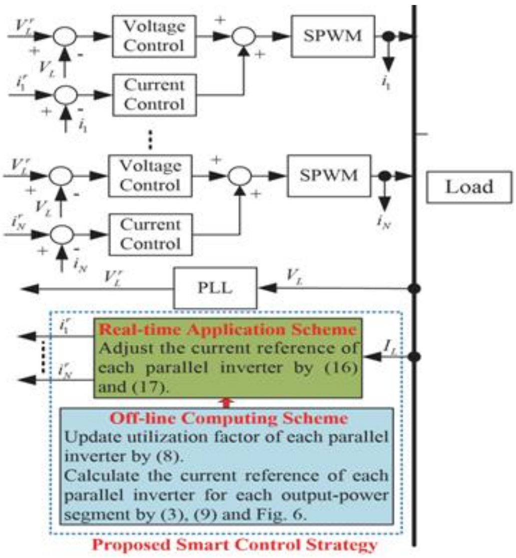

Fig6: Proposed Control Strategy

Fig. 6 shows the control block of the proposed smart strategy. It can be seen that the conventionalcurrent sharing control as illustrated in Fig. 5 is employed in the proposed control strategy. The current reference of each inverter is adjusted by the proposed off-line computing and real-time application scheme. When the output power, changes due to solar irradiance variation, the current reference for each parallel inverter can be adjusted immediately and the output power of each parallel inverter can be controlled by the control block diagram as shown in Fig 6.Thecumulative output energy of each inverter iscalculated by the current-programming centerconsequently. During the night hours, the off-linecomputing scheme will update the utilization factor of eachparallel inverter. The current reference of parallel inverter for each output-power segment can then beproposed off-line computing and real-time application scheme, both computing efficiency and conversion efficiency can be achieved.

IV. Conclusion

In this study various control schemes are studied that aims at improving the efficiency at light loads. Thus by improving the efficiency, the electricity demand as well as the cost can be reduced to a great extend in home applications.In this paper various commonly used control schemes are explained in detail.The flyback topology is selected because of its simple structure and easy power flow control with high power quality outputs at the grid interface.Whereas the smart control strategy to find the reference current using PSO algorithm is a bit troublesome. The Soft switching scheme is comparatively simpler and easy to perform digital implementation.

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