Boost Converter for PV Module Application

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Abstract—In this paper, a development of high efficiency boost converter for photovoltaic application is presented. The design aimed to create a completely self-contained unit capable of converting light energy from the sun into electrical energy. The initial goal was to build a device that could provide stable output, from a fluctuating direct current-linked input voltage from the photovoltaic array. The typical application of this boost converter is to provide a DC power supply for inverter either for grid connected or standalone system.

In recent years, interest in natural energy has grown in response to increased concern for the environment. Within the photovoltaic (PV) power-generation market, the ac PV module has shown obvious growth. Many kinds of inverter circuits and their control schemes for photovoltaic (PV) power generation systems have been studied. A conventional system employs a PV array in which many PV modules are connected in series to obtain sufficient dc input voltage for generating ac utility line voltage from an inverter circuit. However, the total power generated from the PV array is sometimes decreased remarkably when only a few modules are partially covered by shadows, thereby decreasing inherent current generation, and preventing the generation current from attaining its maximum value on the array. This converter achieves a high step-up voltage-conversion ratio; the leakage inductor energy of the coupled inductor is efficiently recycled to the load. These features explain the module’s high-efficiency performance.

This paper proposes a converter that employs a floating active switch to isolate energy from the PV panel when the ac module is OFF; this particular design protects installers and users from electrical hazards. This converter achieves a high step-up voltage-conversion ratio; the leakage inductor energy of the coupled inductor is efficiently recycled to the load. These features explain the module’s high-efficiency performance.

I. INTRODUCTION

IN RECENT years, growing concerns for the environment have led to increased interest in natural energy sources. Many kinds of inverter circuits and corresponding control schemes for photovoltaic (PV) power generation systems have been studied [1]. As shown in Fig. 1(a), a conventional system uses a PV array in which many PV modules are connected in series to obtain sufficient dc input voltage for generating ac utility line voltage from an inverter circuit. However, difficulty is encountered in avoiding shadows created by neighbouring buildings, utility poles, trees, and other obstacles that may partially cover some of the PV modules in the array. PV power-generation systems are becoming increasingly important and prevalent in distribution generation systems. A conventional centralized PV array is a serial connection of numerous panels to obtain higher dc-link voltage for main electricity through a dc-ac inverter.

The price of the PV modules were in the past the major contribution to the cost of these systems. A downward At the current growth rate, it is expected to reach 2% of the world’s electricity generation by 2020 and up to 5% by 2030. Today’s PV industry is being led by a handful of countries where incentive schemes are in place, for

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example, Germany, Japan, the U.S.A, Australia, and Spain, among others.

Initial grid-connected installations were rated up to a few kilowatts, but the trend is pushing for larger industrial-scale ratings of up to several megawatts.

The cost of the grid-connected inverter is, therefore, becoming more visible in the total system price. A cost reduction per inverter watt is, therefore, important to make PV-generated power more attractive. Focus has, therefore, been placed on new, cheap, and innovative inverter solutions, which has resulted in a high diversity within the inverters, and new system configurations.

A Photovoltaic System (informally, PV system) is an arrangement of components designed to supply usable electric power for a variety of purposes, using the Sun (or, less commonly, other light sources) as the power source.

PV systems may be built in various configurations:

- Off- grid without battery (array-direct)
- Off-grid with battery storage for DC-only appliances
- Off-grid with battery storage for AC and DC appliances
- Grid-tie without battery
- Grid-tie with battery storage

A photovoltaic array (also called a solar array) consists of multiple photovoltaic modules, casually referred to as solar panels, to convert solar radiation (sunlight) into usable direct current (DC) electricity. A photovoltaic system for residential, commercial, or industrial energy supply normally contains an array of photovoltaic (PV) modules, one or more DC to alternating current (AC) power converters (also known as inverters), a tracking system that supports the solar modules, electrical wiring and interconnections, and mounting for other components. The number of modules in the system determines the total DC watts capable of being generated by the solar array; however, the inverter ultimately governs the amount of AC watts that can be distributed for consumption. For example: A PV system comprising 11 kilowatts DC (kWDC) worth of PV modules, paired with one 10-kilowatt AC (kWAC) inverter, will be limited by the maximum output of the inverter: 10 kW AC.

The power capacity range of a single PV panel is about 100W to 300W, and the maximum power point (MPP) voltage range is from 15V to 40V, which will be the input voltage of the ac module; in cases with lower input voltage, it is difficult for the ac module to reach high efficiency [3]. However, employing a high step-up dc–dc converter in the front of the inverter improves power-conversion efficiency and provides a stable dc link to the inverter.

When installing the PV generation system during daylight, for safety reasons, the ac module outputs zero voltage [4], [5]. the solar energy through the PV panel and micro inverter to the output terminal when the switches are OFF. When installation of the ac module is taking place, this potential difference could pose hazards to both the worker and the facilities. A floating active switch is designed to isolate the dc current from the PV panel, for when the ac module is off-grid as well as in the non-operating condition. This isolation ensures the operation of the internal components without any residential energy being transferred to the output or input terminals, which could be unsafe.

The microinverter includes dc–dc boost converter, dc–ac inverter with control circuit as shown in. The dc–dc converter requires large step-up conversion from the panel’s low voltage to the voltage level of the application. Previous research on various converters for high step-up applications has included analyses of the switched-inductor and switched-capacitor types; transformerless switched-capacitor type; the voltage-lift type; the capacitor-diode voltage multiplier and the boost type integrated with a coupled inductor, these converters by increasing turns ratio of coupled inductor obtain higher voltage gain than conventional boost converter. Some converters successfully combined boost and fly-back converters, since various converter combinations are developed to carry out high step-up voltage gain by using the coupled-inductor technique.

The efficiency and voltage gain of the dc–dc boost converter are constrained by either the parasitic effect of the power switches or the reverse recovery issue of the diodes. In addition, the equivalent series resistance (ESR) of the capacitor and the parasitic resistances of the inductor also affect overall efficiency.

The proposed converter has several features:
1) The connection of the two pairs of inductors, capacitor, and diode gives a large step-up voltage-conversion ratio;

2) The leakage-inductor energy of the coupled inductor can be recycled, thus increasing the efficiency and restraining the voltage stress across the active switch; and 3) The floating active switch efficiently isolates the PV panel energy during nonoperating conditions, which enhances safety.

The immediate available solutions for a large DC gain are either the use of a high-frequency transformer (which implies leakage inductance’s losses, high voltage stress, reducing the efficiency, EM problems), or a cascade of boost converters (quadratic converter). As the practical applications do not require isolation in the power flow, the use of a transformer would not be a clever solution. In a cascade of power stages, the overall efficiency is a product of each stage’s efficiency, attracting important losses of energy.

A possible solution to integrate a switched-capacitor circuit with a boost converter is presented in . An alternative solution is presented here. The main idea is to use the capacitors only for transferring the energy. The regulation requirement is left for the classical boost stage. In such a way, one can exploit the full potential of the capacitors.

II. PROPOSED CONVERTER

![Circuit configuration of proposed converter.](image)

The proposed converter, shown in Fig. 3, is comprised of a coupled inductor T1 with the floating active switch S1. The primary winding N1 of a coupled inductor T1 is similar to the input inductor of the conventional boost converter, and capacitor C1 and diode D1 receive leakage inductor energy from N1. The secondary winding N2 of coupled inductor T1 is connected with another pair of capacitors C2 and diode D2, which are in series with N1 in order to further enlarge the boost voltage. The rectifier diode D3 connects to its output capacitor C3.

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III. AC MODULE

A solution for the future is believed to be the AC-Module. The AC-Module is the combination of a single PV-module and a matching inverter, which converts sunlight into electrical power when connected to the utility-grid. The main reason to deal with an integrated solution is the possibility to reduce the price per watt for the full system, while all parts must be manufactured in high numbers. It also overcomes the problems with the centralized MPPT and high DC-voltage. At the bottom-line, the AC-Module may become a “plug and play” device, which can be installed by everyone without any electrical education, and moreover makes further system-enlargement far easier than today.

It is accepted that, under these circumstances, an installation with PV ac-module inverters (low-power inverters attached at the back of each panel) yields more energy than an array of panels connected to a string inverter (see, for example, and ). In the latter case, for instance, when part of the solar array gets covered or shaded, the current drops, and because the panels are in series, the overall power also drops. In contrast, in a PV ac-module plant when a panel gets shaded, only that inverter will yield lower power, whereas the rest continue to perform at their optimum points. There have been several contributions in this area.

The inverters reported so far cover a wide spread in terms of power electronic configuration, control, cost, and efficiency. To date, however, only a few modular inverters have been taken to the market, and even these have had mixed success. One of the key drawbacks reported is reliability [12]. All electronic devices have a lifetime that greatly depends on the operating conditions.

![Installation of ac module inverter.](image)
In this system, a low-power ac utility interactive inverter is mounted on each individual PV module as shown in Fig. 3, and the inverter operates so as to generate the maximum power from the corresponding PV module. Each output terminal of the individual ac module inverter is connected to the utility lines, and the current generated by each inverter is injected into the utility line. Another advantage of this system lies in that the number of the parallel connected inverters, which is equal to the number of PV modules, can be selected in consideration of the dimensions of the roof on which PV modules are installed. This greatly improves the flexibility of the PV generation system. Furthermore, the ac module concept is expected to lower the manufacturing cost of the inverter, because of the effect of mass production.

However, employing a high step-up dc–dc converter in the front of the inverter improves power-conversion efficiency and provides a stable dc link to the inverter. The inverters must also be able to detect an islanding situation, and take appropriate measures in order to protect persons and equipment. Islanding is the continued operation of the inverter when the grid has been removed on purpose, by accident, or by damage. In other words, the grid has been removed from the inverter, which then only supplies local loads.

The maximum efficiency of 95.3% occurred at 40% of full load; and the full-load efficiency is maintained at 92.3%. The efficiency variation is about 3%, and the flat efficiency curve is able to yield higher energy from the PV module during periods when sunlight is fading. The residential voltage discharge time of the proposed converter is 480 milliseconds, which prevents any potential electrical injuries to humans.

![Fig. 5. Measured efficiency of proposed converter.](image)

**IV. CONCLUSION**

Since the energy of the coupled inductor’s leakage inductor has been recycled, the voltage stress across the active switch S1 is constrained, which means low ON-state resistance RDS(ON) can be selected. Thus, improvements to the efficiency of the proposed converter have been achieved. The switching signal action is performed well by the floating switch during system operation; on the other hand, the residential energy is effectively eliminated during the nonoperating condition, which improves safety to system technicians. A novel PV inverter circuit suitable for an ac module system is presented. Utilization of the high-frequency flyback action of the transformer realizes ac current injection with low harmonic distortion into the utility line. Furthermore, a dc power smoothing circuit that enables a decrease in the low-frequency ripple voltage and a reduction in the total capacitance on the dc input side is presented.

**V. FUTURE WORK**

This paper proposes a converter that employs a floating active switch to isolate energy from the PV panel when the ac module is OFF; this particular design protects installers and users from electrical hazards. By using close loop PI controller we can maintain the DC-link voltage across the DC-DC converter.

**VI. REFERENCES**


