LEAST POWER POINT TRACKING METHOD FOR PHOTOVOLTAIC DIFFERENTIAL POWER PROCESSING SYSTEMS

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ABSTRACT Differential power processing (DPP)systems are a promising architecture for future photovoltaic (PV) power systems that achieve high system efficiency through processing a faction of the full PV power, while achieving distributed local maximum power point tracking (MPPT). In the PV to-bus DPP architecture, the power processed through the DPP converters depends on the string current, which must be controlled to minimize the power processed through the DPP converters. A real time least power point tracking (LPPT) method is proposed to minimize power stress on PV DPP converters. Mathematical analysis shows the uniqueness of the least power point for the total power processed through the system. The per tur band observe LPPT method is presented that enables the DPP converters to maintain optimal operating conditions, while reducing the total power loss and converter stress. This work validates through simulation and experimentation that LPPT in the string-level converter successfully operates with MPPT in the DPP converters to maximize output power for the PV to- bus architecture. Hardware prototypes were developed and tested at 140 W and300 W, and the LPPT control algorithm showed effective operation under steady-state operation and an irradiance step change. Peak system efficiency achieved with a 140-W prototype DPP system employing LPPT is 95.7%.

KEYWORDS: Differential power processing systems, power converter, maximum power point tracker, least power point tracker, PWM, IC, string current.

INTRODUCTION

As is well known, switching-mode power supply is the core of modern power conversion technology, which is widely used in electric power, communication system, household appliance, industrial device, railway, aviation, and many other fields. As the basis of switching-mode power supply, converter topologies attract a great deal of attention and many converter topologies have been proposed. Buck converter and boost converter have the simple structure and high efficiency. However, due to the limited voltage gain, their applications are restricted when the low or high output voltage are needed. Luo converters can obtain high voltage gain by employing the voltage lift technique, but the topological complexity, cost, volume, and losses increase at the same time Interleaved converters can achieve high step-up or stepdown conversion ratio with low-voltage stress, while their operating mode, converter structure, and control strategy are complicated. Quadratic converters can achieve the voltage gain of cascade converters with fewer switches; however, the efficiency of these converters are low. Additionally, some switched networks are added into the basic converters to obtain the high-voltage step-up or step-down gain, at the price of complicating construction and increasing cost. Compared with the above-mentioned converter topologies which can only step-up or step-down voltage, the voltage bucking/boosting converters, which can regulate output voltage under wider range of input voltage or load variations, are popular with the applications such as portable electronic devices, car electronic devices, and so on. The traditional buck–boost converter with simple structure and high efficiency, as we all known, has the drawbacks such as limited voltage gain, negative output voltage, and floating power switch, meanwhile discontinuous input and output currents.

The other three basic nonisolated converters: 1) Cuk converter; 2) Sepic converter; and 3) Zeta converter, which also have the peculiarity of step-up and step-down voltage, have been provided. However, the limits of the voltage gain along with other disadvantages in Cuk, Sepic, and Zeta converters are also nonignorable. The quadratic buck–boost converter, proposed by Maksimovic and Cuk has one common-ground power switch; meanwhile, it can achieve the voltage gain D2/(1 - D)2. However, due to the diodes D1 and D2 clamp the output voltage to the input voltage while the duty cycle is bigger than 0.5, so that this converter can only work in step-down mode. By combining KY converter and the traditional synchronously rectified buck converter, Hwu and Peng proposed a new buck–boost converter which can realize the continuous output current, positive output voltage, continuous conduction mode (CCM) operation all the time, and no righthalf plane zero. Unfortunately, its voltage gain of two multiplies the duty cycle (2D) is not sufficiently high or low in the situation where the converter needs to operate in a wide range of output voltage. Moreover, based on the Cuk converter, a new buck–boost converter, which has the low output voltage ripple, minimal radio frequency interference, and one common-ground power switch, is proposed in [26]. However, as a seventh-order circuit, the converter has complex construction, and both its input terminal and output terminal do not share the same ground. Besides, the voltage gain is still limited. In a boost–buck cascade converter, aggregating two separated converters with current source and current sink, is applied for the thermoelectric generator. Nevertheless, the voltage gain of this cascade converter is also constrained. Especially, in order to obtain high-voltage step-up or stepdown gain, these converters must be operating under extremely high or low duty cycle, and this point is too hard to realize due to the practical constraints. Hence, exploring new topology of buck–boost converter to overcome the drawbacks of the conventional ones for satisfying the increasingly requirements in industrial applications is very important and valuable.

In this study, by inserting an additional switched network into the traditional buck–boost converter, a new transformerless buck–boost converter is proposed. The main merit of the proposed buck–boost converter is that its voltage gain is quadratic of the traditional buck–boost converter, so that it can operate in a wide range of output voltage, i.e., the proposed buck– boost converter can achieve high or low voltage gain without extreme duty cycle. Moreover, the output voltage of this new transformerless buck–boost converter is common-ground with the input voltage, and its polarity is positive.

LITERATURE SURVEY

INTRODUCTION TO POWER CONVERTERS:

In this project, a hybrid photovoltaic- fuel cell PV/FC system for grid connection is proposed. PV and Fuel cells produces low voltage dc output. Grid interconnection of PV/FC system requires power converters to meet the grid requirements like voltage amplitude, frequency, and phase angle. First convert the low voltage dc into high voltage dc by using boost dc-dc converter and then convert this dc voltage into ac by using inverters and finally connect the whole system to grid. This type of system (dc-dc and dc-ac conversion) is called two stage conversion system. For two stage conversion of hybrid system requires following power converters.

1. DC-DC CONVERTERS

2. INVERTERS (DC-AC CONVERTERS)

DC-DC CONVERTERS:

DC-DC converters are electronic devices used whenever we want to change DC electrical power efficiently from one voltage level to another. They are needed because unlike AC, DC cannot simply be stepped up or down using a transformer. In many ways, a DC-DC converter is the equivalent of a transformer.

The dc-dc converters can be viewed as dc transformer that delivers a dc voltage or current at a different level than the input source. Electronic switching performs this dc transformation as in conventional transformers and not by electromagnetic means. The dc-dc converters find wide applications in regulated switch-mode dc power supplies and in dc motor drive applications.

DC-DC converters are non-linear in nature. The design of high performance control for them is a challenge for both the control engineering engineers and power electronics engineers. In general, a good control for dc-dc converter always ensures stability in arbitrary operating condition. Moreover, good response in terms of rejection of load variations, input voltage changes and even parameter uncertainties is also required for a typical control scheme.

After pioneer study of dc-dc converters, a great deal of efforts has been directed in developing the modeling and control techniques of various dc-dc converters. Classic linear approach relies on the state averaging techniques to obtain the state-space averaged equations. From the state-space averaged model, possible perturbations are introduced into the state variables around the operating point. On the basis of the equations, transfer functions of the open-loop plant can be obtained. A linear controller is easy to be designed with these necessary transfer functions based on the transfer function.

DC to DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different than that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage, and possibly even negative voltage). Additionally, the battery voltage declines as its stored power is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing.

DC-DC converters are electronic devices that are used whenever we want to change DC electrical power efficiently from one voltage level to another. In the previous chapter we mentioned the drawbacks of doing this with a linear regulator and presented the case for SMPS. Generically speaking the use of a switch or switches for the purpose of power conversion can be regarded as a SMPS. From now onwards whenever we mention DC-DC Converters we shall address them with respect to SMPS.

A few applications of interest of DC-DC converters are where 5V DC on a personal computer motherboard must be stepped down to 3V, 2V or less for one of the latest CPU chips; where 1.5V from a single cell must be stepped up to 5V or more, to operate electronic circuitry. In all of these applications, we want to change the DC energy from one voltage level to another, while wasting as little as possible in the process. In other words, we want to perform the conversion with the highest possible efficiency.

TYPES OF DC-DC CONVERTERS

There are many different types of DC-DC converters, each of which tends to be more suitable for some type of applications than for others. For convenience they can be classified into various groups, however. For example some converters are only suitable for stepping down the voltage, while others are only suitable for stepping it up a third group can be used for either. In this we are going to main types of DC-DC converters.

Currently DC-DC converters can be divided into two types

- Non-isolated dc-dc converters
- Isolated dc-dc converters

NON- ISOLATED DC-DC CONVERTERS

The non-isolated converter usually employs an inductor, and there is no dc voltage isolation between the input and the output. The vast majority of applications do not require dc isolation between its input and output voltages. The non-isolated dc-dc converter has a dc path between its input and output. Battery-based systems that don't use the ac power line represent a major application for non-isolated dc-dc converters. Point-of-load dc-dc converters that draw input power from an isolated dc-dc converter, such as a bus converter, represent another widely used non-isolated application.

Most of these dc-dc converter ICs use either an internal or external synchronous rectifier. Their only magnetic component is usually an output inductor and thus less susceptible to generating electromagnetic interference. For the same power and voltage levels, it usually has lower cost and fewer components while requiring less pc-board area than an isolated dc-dc converter. For lower voltages non-isolated buck converters can be used.

There are five main types of converter in this non-isolating group they are

- Buck Converter
- Boost Converter
- Buck-Boost Converter
- Cuk Converter

The Buck converter is used for voltage step-down reduction, while the Boost converter is used for voltage step-up. The Buck-Boost and Cuk converters can be used for either step-down or step-up, but are essentially voltage polarity reversers or 'inverters'. The Charge-pump converter is used for either voltage step-up or voltage inversion, but only in relatively low power applications.

ISOLATED DC-DC ONVERTERS

For safety considerations, there must be isolation between an electronic system's ac input and dc output. Isolation requirements cover all systems operating from the ac power line, which can include followed by an isolated "brick" dc-dc converter, followed by a non-isolated point -of-load converter. Typical isolation voltages for ac-dc and dc-dc converter employs a transformer to provide dc isolation between the input and output voltage which eliminates the dc path between the two.

Isolated dc-dc converters use a switching transformer whose secondary is either diode-or synchronous-rectified to produce a dc output voltage using an inductor capacitor output filter. This configuration has the advantage of producing multiple output voltages by adding secondary transformer windings. For higher input voltages transformer isolated converters are more variable.

There are two main types of isolating inverter in common use they are

- Fly back converter
- Forward type converter

BOOST CONVERTER

A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

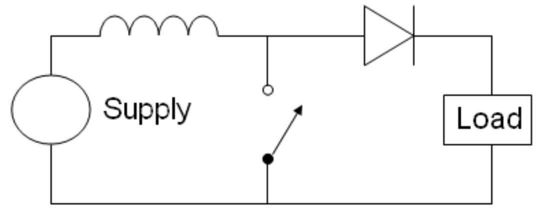


Fig: 2.1 The basic schematic of a boost converter

Overview

Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power ($P = VI$) must be conserved, the output current is lower than the source current.

Operating principle

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure 2.1 When the switch is closed, current flows through the inductor, which stores energy from the current in a magnetic field. During this time, the switch acts like a short circuit in parallel with the diode and the load, so no current flows to the right hand side of the circuit.

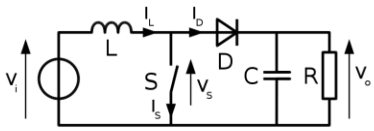
When the switch is opened, the short circuit is removed and the load is back in play in the circuit. This represents a sudden increase in the impedance of the circuit, which, by Ohm's law will demand either a decrease in current, or an increase in voltage. The inductor will tend to resist such a sudden change in the current, which it does by acting as a voltage source in series with the input source, thus increasing the total voltage seen by the right hand side of the circuit and thereby preserving (for a brief moment) the current level that was seen when the switch was closed. This is done using the energy stored by the inductor. Over time, the energy stored in the inductor will discharge into the right hand side of the circuit, bringing the net voltage back down.

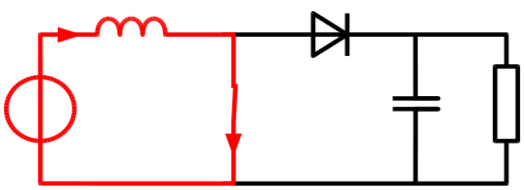
If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

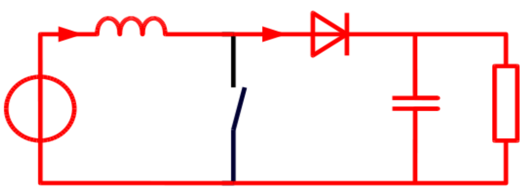
The basic principle of a Boost converter consists of 2 distinct states (see figure 2.2):

- in the On-state, the switch S (see figure 2.2) is closed, resulting in an increase in the inductor current.
- in the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.
- The input current is the same as the inductor current as can be seen in figure 2.2.So it is not discontinuous as in the buck converter and the requirements

on the input filter are relaxed compared to a buck converter

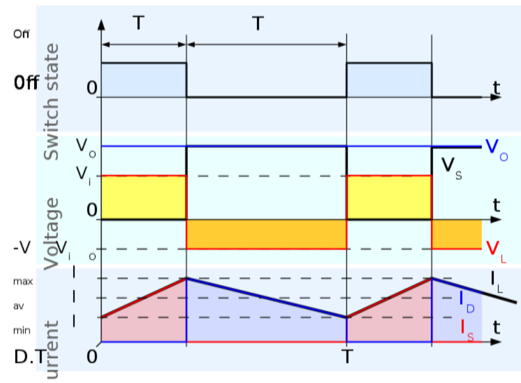






Continuous mode

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure 2.4 shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e. using components with an ideal behavior) operating in steady conditions.



During the On-state, the switch S is closed, which makes the input voltage (V_i) appear across the inductor, which causes a change in current (I_L) flowing through the inductor during a time period (t) by the formula:

$$\frac{\Delta L_L}{\Delta t} = \frac{V_i}{L}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta L_{L_{on}} = \frac{1}{L}\int_0^{DT} V_i = \frac{DT}{L} V_i$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is on. Therefore D ranges between 0 (S is never on) and 1 (S is always on).

During the Off-state, the switch S is open, so the inductor current flows through the load. If we consider zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$V_i - V_0 = L\frac{di_L}{dt}$$

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{off} = \int_{DT}^{T}\frac{(V_i - V_o)dt}{L} = \frac{(V_i - V_o)(1-D)T}{L}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2}LI_L^2$$

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{Lon} + \Delta I_{Loff} = 0$$

Substituting ΔI_{LON} and ΔI_{LOFF} by their expressions yields:

$$\Delta I_{Lon} + \Delta I_{Loff} = \frac{V_i DT}{L} + \frac{(V_i - V_o)(1-D)T}{L} = 0$$

This can be written as:

$$\frac{V_0}{V_i} = \frac{1}{1-D}$$

This in turn reveals the duty cycle to be:

$$D = 1 - \frac{V_0}{V_i}$$

CONCLUSION

Mathematical analysis was presented for the ideal case, showing that the LPP will either be a single point that is equal to one of the PV currents or a continuous unique set of points that includes atleast two PV currents. The proposed LPPT algorithm uses a P&O extremum-seeking algorithm. The control algorithms were shown to work simultaneously to achieve both individual PVMPPT and system LPPT in both simulation and experimentation. This work validates through simulation and experimentation that LPPT in the string-level converter successfully operates with MPPT in the DPP converters to maximize output power for the PV to- bus architecture. Hardware prototypes were developed and tested at 140 W and300 W, and the LPPT control algorithm showed effective operation under steady-state operation and an irradiance step change. Peak system efficiency achieved with a 140-W prototype DPP system employing LPPT is 95.7% .

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