Implementation of Maximum Power Point Tracking On High Boost Ratio Hybrid Transformer Based DC-DC Converter

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Abstract: ***A non-isolated, high boost ratio hybrid transformer dc–dc converter with applications for low-voltage renewable energy sources like solar energy is proposed. The proposed converter utilizes a hybrid transformer to transfer the inductive and capacitive energy simultaneously, achieving a high boost ratio with a smaller sized magnetic component. As a result of incorporating the resonant operation mode into the traditional high boost ratio pulse width modulation converter, the turn-off loss of the switch is reduced, increasing the efficiency of the converter under all load conditions. The input current ripple and conduction losses are also reduced because of the hybrid linear-sinusoidal input current waveforms. The voltage stresses on the active switch and diodes are maintained at a low level and are independent of the changing input voltage over a wide range as a result of the resonant capacitor transferring energy to the output of the converter. The main aim of the paper is to implement a suitable MPPT algorithm considering the input and load variation.***

Keywords: mppt,pcs,pv module,dc-dc converter

1. Introduction

The energy consumption around the globe is increasing at an alarming rate, due to the rising costs and limited amount of non-renewable energy sources, there is an increasing demand for the utilization of renewable energy sources such as photovoltaic (PV) modules. Integrating the power from the PV module into the existing power distribution infrastructure can be achieved through power conditioning systems (PCS). The double-stage PCS consists of a dc– dc conversion stage that is connected to either a low power individual inverter or a high-power centralized inverter that multiple converters could connect to. The dc–dc conversion stage of the PCS requires a high efficiency, high boost ratio dc–dc converter to increase the low dc input voltage from the PV panel to a higher dc voltage. This voltage has to be higher than the peak output voltage of the dc–ac inverter, nominally in the 380–400V range. The double-stage design can also suppress ac line double frequency by utilizing the active ripple cancellation technique transformer-isolated converters tend to be less efficient and more expensive due to the increased manufacturing costs. A non-isolated dc–dc converter with a high boost ratio would be advantageous for a two-stage PCS because it can be easily integrated with current PV systems while reducing the cost and maintaining a high system efficiency [1].

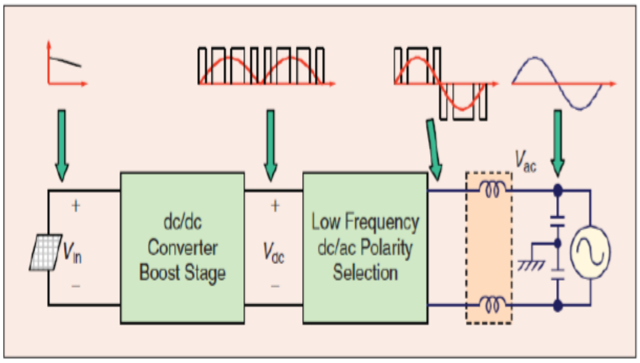

Figure 1.1: A PCS architecture with a dc–dc converter

Due to the different output voltages from the PV panel, it would be beneficial to have a system with a high efficiency over the entire PV voltage range to maximize the use of the PV during different operating conditions. Another important function of the dc–dc converter for PV applications is being able to implement maximum power point tracking (MPPT). The ability to implement MPPT for an individual PV panel would ensure that a large cluster of PV could maintain maximum power output from each panel without interfering with the other panels in the system. The major consideration for the main power stage of the converter in being able to implement an accurate MPPT is that the input current ripple of the converter has to be low.

2. Theory

A high boost ratio dc–dc converter with hybrid transformer is presented to achieve high system level efficiency over wide input voltage and output power ranges. By adding a small resonant inductor and reducing the capacitance of the switched-capacitor in the energy transfer path, a hybrid operation mode which combines pulse width modulation (PWM) and resonant power conversions, is introduced in the proposed high boost ratio dc–dc converter[2]. The inductive and capacitive energy can be transferred simultaneously to the high voltage dc bus, increasing the total power delivered and decreasing the losses in the circuit. As a result of the energy transferred through the hybrid transformer that combines the modes where the transformer operates under normal conditions and where it operates as a coupled-inductor, the magnetic core can be used more effectively and smaller magnetics can be used. The continuous input current of the converter causes a smaller current ripple than that of previous high boost ratio converter topologies that used coupled-inductors[3]. The lower input current ripple is useful in that the input capacitance can be reduced and it is easier to implement a more accurate MPPT for PV modules. The conduction losses in the transformer are greatly reduced because of the reduced input current RMS value through the primary side. The voltage stress of the active switch is always at a low voltage level and independent of the input voltages. Due to the introduction of the resonant portion of the current, the turn-off current of the active switch is reduced[4][5]. As a result of the decreased RMS current value and smaller turn-off current of the active switch, high efficiency can be maintained at light output power level and low-input voltage operation.The resonant capacitor transfers energy to the output of the converter, all the voltage stresses of the diodes are kept under the output dc bus voltage and independent of the input voltage.

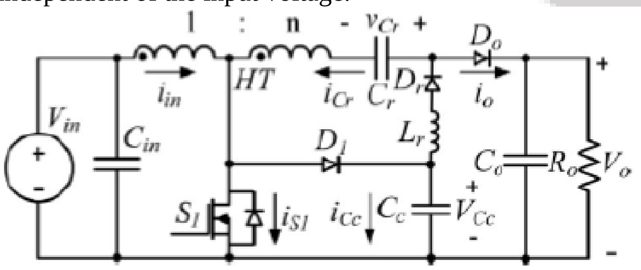

Figure 2.1: Proposed high step-up dc–dc converter with hybrid transformer.

*C*in is the input capacitor; *HT* is the hybrid transformer with the turns ratio 1:*n*; *S*1 is the active MOSFET switch; *D*1 is the clamping diode, which provides a current path for the leakage inductance of the hybrid transformer when *S*1 is OFF, *Cc* captures the leakage energy from the hybrid transformer and transfers it to the resonant capacitor *Cr* by means of a resonant circuit composed of *Cc* , *Cr* , *Lr* , and *Dr* ; *Lr* is a resonant inductor, which operates in the resonant mode; and *Dr* is a diode used to provide an unidirectional current flow path for the operation of the resonant portion of the circuit. *Cr* is a resonant capacitor, which operates in the hybrid mode by having a resonant charge and linear discharge. The turn-on of *Dr* is determined by the state of the active switch *S*1 . *Do* is the output diode similar to the traditional coupled-inductor boost converter and *Co* is the output capacitor. *Ro* is the equivalent resistive load.

MPPT:- Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power [6][7].MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different.

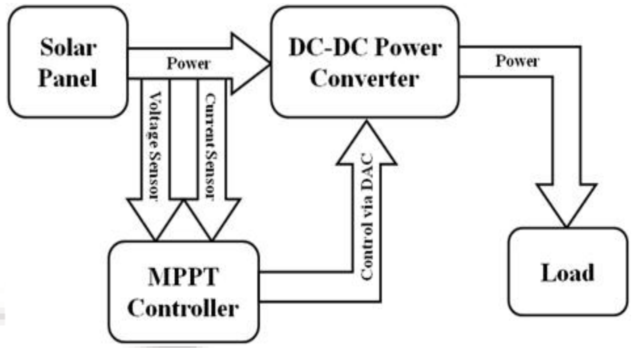

Figure 2.2: General layout of the system

2.1 Mppt Technique

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by incremental conductance method. The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V .This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than P and O.

2.2 Incremental conductance mppt algorithm

This method uses the fact that slope at the maximum point is zero. We have,

$P = V I$

Applying the chain rule for the derivative of products yields to

$\partial P/\partial V = [\partial(VI)]/ \partial V$

At MPP, as

$\partial P/\partial V = 0$,

The above equation could be written in terms of array voltage V and array current I as

$\partial I/\partial V = - I/V$

The MPPT regulates the PWM control signal of the dc – to – dc boost converter until the condition: $(\partial I/\partial V) + (I/V) = 0$

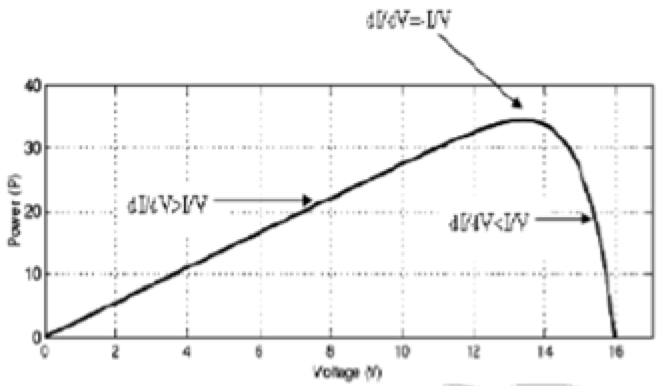

Figure 2.3: Power vs voltage curve

is satisfied. In this method the peak power of the module lies at above 98% of its incremental conductance. The Flow chart of incremental conductance MPPT is shown below

Figure 2.4: IC algorithm

The incremental conductance algorithm keeps the system at its maximum power point, thus providing a constant output under wide range of varying condition. This algorithm can be implemented with help of high speed controller like DSP, dSPIC etc[8].This system along with dc-dc converter makes it possible for low power source like a photovoltaic module to be connected to a grid.

3. Features and benefits

1. This converter transfers the capacitive and inductive energy simultaneously to increase the total power delivery reducing losses in the system.
2. The conduction loss in the transformer and MOSFET is reduced as a result of the low- input RMS current and switching loss is reduced with a lower turn-off current. With these improved performances, the converter can maintain high efficiency under low output power and low-input voltage conditions.
3. With low-input ripple current feature, the converter is suitable for PV module, where accurate MPPT is performed by the dc–dc converter.
4. The incremental conductance algorithm keeps the output constant under different irradiation condition.

4. Conclusion

A high boost ratio dc–dc converter with hybrid transformer suitable for alternative dc energy sources with low dc voltage input is proposed. The resonant conversion mode is incorporated into a traditional high step-up PWM converter with coupled-inductor and switched-capacitor obtaining very high efficiency. The voltage stress on switch is greatly reduced. Thus the proposed converter is suitable for low power energy source like solar energy. The characteristics of proposed converter are suitable for implementing an accurate MPPT. Incremental conductance is the most suitable MPPT algorithm for the proposed converter.

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