An Improved Two-Stage Inverter with High Voltage Boosting Capability and Continuous Input Current Feasible for Low-Power Solar Applications

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Abstract

In this paper, an improved structure for two-stage inverters is proposed, which profits from high voltage boosting ability without using transformer. The proposed structure consists of two main stages, including an improved dc-dc converter and an H-bridge. Using only one switch in the input section (the proposed dc-dc converter), not only reduces the cost and dimensions of the converter, but also minimizes the number of working modes (only two modes) and, as a result, simplifies its control. The presence of a common ground point in the input section is a feature that can eliminate the leakage current caused by solar cells in photovoltaic applications. It will be possible to control the effective value of the output voltage of the proposed structure by controlling the duty cycle of the switch of the input section. In this article, the proposed structure is introduced and additional explanations about its different operational modes are provided along with calculations related to loss and efficiency analysis. Also, a comparison between the proposed structure and a number of existing structures is presented. To prove the correct operation of the proposed converter as well as the correctness of theoretical calculations, simulation results extracted from PSCAD/EMTDC software are presented.

Keywords: Step-Up DC-DC Converter, Two-Stage Inverter, Common-Ground Point, Continuous Input-Current, Maximum Power Point Tracking.

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1. Motivation of the work

In recent decades, the tendency towards the use of renewable energy sources has greatly increased. The main reasons for this trend are the clean, almost-free and permanent nature as well as the availability of such sources of energy. The Photovoltaic panels (PV) convert the solar energy - as one of popular renewable energies - into the electrical energy. The generated energy is in DC-form and has low voltage value. In most of industrial applications, usually a high step-up DC-DC converter is required to enhance the low PV output voltage up to higher desired values. Therefore, the step-up capability of applied DC-DC converter is of high importance. Also, at AC stand-alone or grid-connection applications, an inverter is needed to convert the DC form of energy into the AC form. The traditional DC-DC converters can provide the high voltage gains, only at extreme duty cycles, where the effect of parasitic elements becomes dominant. This leads to much lower gains and poor efficiencies in real applications.

2. Contributions

This paper proposes a two-stage DC-AC converter with an improved DC-DC configuration as the input stage. The proposed DC-DC configuration utilizes only single power switch and has the ability to produce high voltage gains even at low/medium duty cycles. In addition, it provides a common-ground point between input and output ports, which tackles the leakage current at PV applications. Moreover, the proposed DC-DC converter profits from important properties such as the continuous input source current, minimum number of switches (only single switch), minimum number of operating states in the continuous conduction mode (only two operating states), simple control strategy. The high step-up capability, continuous input current and availability of common ground point features make the proposed converter capable of tracking maximum power point at PV applications. The traditional H-bridge has also been applied in the output stage to converter the lifted Dc output voltage to the AC form. The working principles of the proposed converter, as well as its steady-state ideal/real gain and loss calculations have been investigated and presented. Design consideration of different components have also been provided. A comparison section has also been included which bolds the supremacy of proposed converter and its features over existed counter parts.

3. Procedures

The proposed DC-DC converter has used voltage-lifting techniques to increase the output voltage and provide high voltage boosting factors, even at medium or low duty cycles. The suggested configuration employs only single switch. Accordingly, only single gate-driver circuit is required, leading to lower size, weight and complexity of the converter. The switch has a wide duty cycle range, by which the output voltage can be regulated across a wide range. The capacitances have been designed such that their voltage ripple be limited to the desired value (less than 10%). Also, the inductors have been designed such that their current ripple be suppressed to the desired value and also guarantee the CCM operation of the converter. A common ground point has been provided in the DC-DC converter to remove the leakage current and its negative outcomes at PV applications. Since the MPPT capability is an essential property for PV-fed DC-DC converters, the P&O MPPT method has been employed and tested on proposed DC-DC configuration during different scenarios of changes in ambient temperature and solar irradiation. During loss analysis, the real model of components has been considered to achieve as real as possible results.

4. Findings

The proposed DC-DC converter provides quite high boosting factors at even mild duty cycles. The proper sizing of capacitors and inductors have fulfilled the design objectives. The proposed DC-DC converter operates at CCM mode, with limited capacitors' voltage-ripple and inductors' current-ripple. The proposed DC-DC converter can effectively track the maximum power point of PV, even at dynamic ambient-temperature and/or solar-irradiation situations. The proposed two-stage inverter successfully enhances the low output voltage of PV to desired value and inverters it to AC form by an H-bridge, which can efficiently supply the zero-unity power factor loads or be injected to the grid. The RMS of output AC voltage waveform can be tuned by adjusting the modulation index. The application of an H-bridge at the output stage has led to three voltage levels at the load side. In order to increase the quality and reduce the THD of output AC voltage, the Multi-Level Inverters (MLIs) can be applied.

5. Conclusion

In this article, an improved structure for two-stage inverters was presented, which takes advantage of the ability to increase high voltage without using a transformer. The proposed structure consists of two main parts including an improved dc-dc converter and an H-bridge. The presence of a switch in the input section has minimized the number of working modes (only two working modes) of the proposed dc-dc converter, which makes the control of the converter simpler and reduces the cost and dimensions of the converter. The presence of a common ground point in the input section will eliminate the leakage current to the ground in photovoltaic applications. The proposed structure is able to track the maximum power point of the PV panel in the dynamic conditions of the ambient temperature and/or the irradiation of the sun, due to its features such as continuous input current and high voltage boosting capability. Also, the RMS of output AC voltage of the proposed converter can be regulated by controlling the duty cycle of input stage switch. Compared to a number of existing counterparts, the proposed structure has better condition than others in terms of voltage boosting capability, removing leakage current and using reduced number of components. The simulation results prove the correct operation of the proposed converter and the correctness of theoretical calculations and the ability of the converter to follow the maximum power point in variable radiation conditions.

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