Science, Engineering & Education, 1, (1), 2016, 32-35

Photovoltaic's inverter directly connected to the grid

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Received 15 March 2016, Accepted 05 September 2016

ABSTRACT

The paper describes a modification of the topology of a photovoltaic's inverter with a flying inductor connected to a single phase grid in absence of any transformer. The topology advanced provides the application of buck-, boost- and buck-boost modes of transforming at both half-waves of the grid voltage. It works as a three level inverter reducing high frequency disturbances. The symmetric work in both half-waves facilitates the control required.

Keywords: inverter, photovoltaic, topology, pulse converter.

INTRODUCTION

One of the fundamental problems of the inverters connected directly to the grid refers to the potential variation of the photovoltaics with the high frequency of the pulse modulation. This causes a significant leakage current because of the capacity between the inverter itself and the frame connected to the frame [1, 2]. Some topologies are developed where the photovoltaic potential does not vary or varies slightly with the grid's low frequency. Thus the leakage current becomes insignificant [3]. The HERIC topology [6], the H5 topology [5], the "Flying Inductor" topology (Topology "Karschny") [4, 7] are among them. The advantage of the latter is attributed to the grounding of the photovoltaic, which eliminates current leakage. The other advantage is, refers to the fact that only two switches work at a high frequency, while the rest keep the grid's frequency. But the topology discussed has disadvantages as well. They refer to its high requirements in respect to the inductor and its asymmetrical work during the positive and negative half-waves. The system works in a boost mode during the positive half-wave, while the buck-boost mode appears as the only possible one during the negative half-wave. This causes high frequency disturbances in both half-waves. They can be smaller in the course of the positive half-wave because of the optimal alternate of both modes. The control involved is another disadvantage because of the different transmission characteristics in both half-waves.

The present communication describes a modified flying inductor topology, whose work can proceed in each of the tree modes mentioned above. Besides it is symmetrical in both half-waves. It is recommended to change the mode

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from buck to buck-boost and to boost on voltage increase, when the grid voltage becomes greater than that of the photovoltaic. The changes are analogous, but in a reverse sequence on grid voltage decrease.

EXPERIMENTAL

This symmetrical topology is presented in Fig.1. The middle point between filter capacitors C1 and C2 is grounded as is the grid. The capacitors just mentioned can be only a part of all capacitors connected to the photovoltaic. The middle point between the capacitors in case of an even number of photovoltaics in a string can be grounded as well. Thus the potentials of the photovoltaic's terminals do not vary and there are no leakage currents. Each terminal voltage is equal to the half of the total voltage, what is essential for the security.

The circuit is fully symmetrical in respect to both half-waves. That is why we will consider only the positive half-wave work. At the beginning of the half-wave the photovoltaic voltage (and that of C1) is greater than that of the grid, and the buck mode is the advantageous one (in view of the disturbances). Switch S2 is permanently open, switches S6 and S3 are permanently closed, while switch S1 works at a high frequency. The circuit for this mode is presented in Fig. 2. The permanently closed switches are presented as NC contacts, while the permanently open one – as NO contacts. The arrow designates the high frequency manipulated switch.

When switch S1 is closed, the current flows to the grid via it, induction L1, diode D2, switch S6, induction L2. In case switch S1 is open, the current flows via diode D2, switch S3 and diode D1.

When the grid voltage approaches the PV voltage, the circuit goes to a bust-bock mode as shown in Fig. 3. Switches S3 and S6 are also permanently closed, while switches S1 and S2 function simultaneously. In case they are switched on the current flowing via L1 increases. When they are switched off, the current flows via S3, D1, L1, D2, S6 and L2.

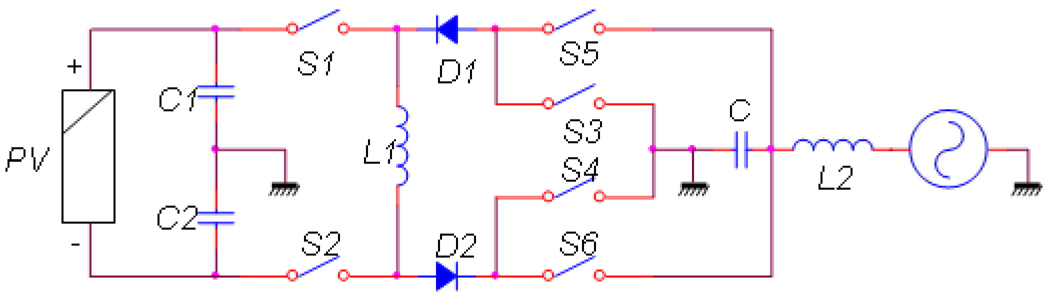

Fig. 1. The modified topology.

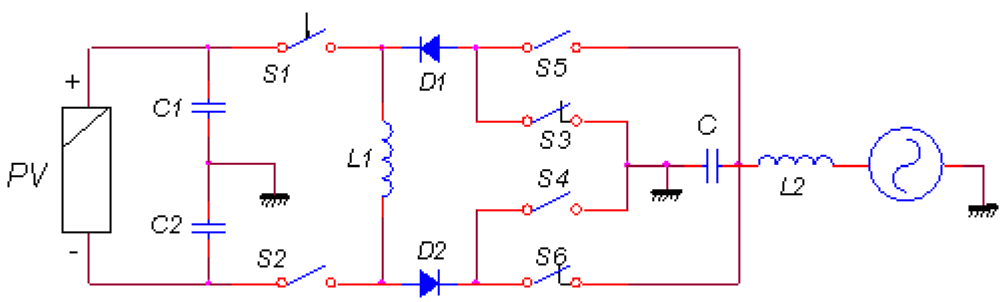

Fig. 2. Work in buck mode.

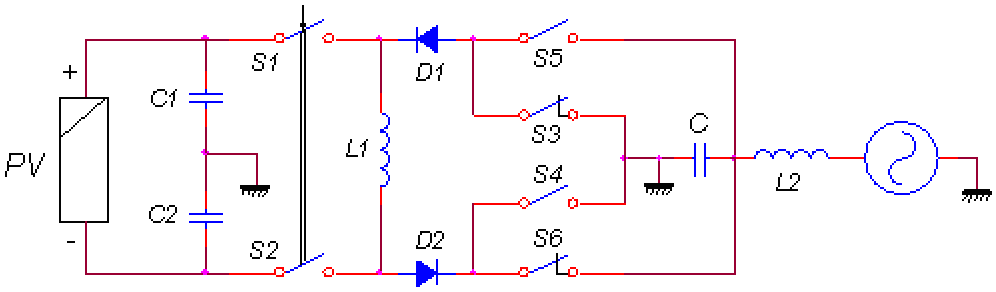

Fig. 3. Work in buck - boost mode.

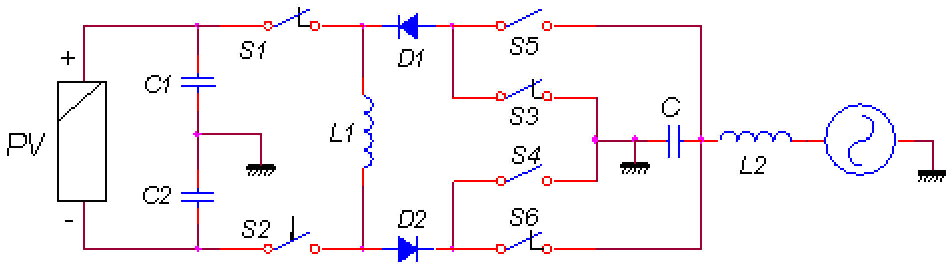

Fig. 4. Work in boost mode.

It is recommended to proceed to a buck mode on further increase of the grid voltage. In this case the energy saved only at the inductor "adds" to the difference between the voltages of the grid and capacitor C1. The circuit discussed is presented in Fig. 4. The only difference here refers to S1 which is permanently closed. Only S2 works at a high frequency. When switched on inductance L1 will be loaded with energy as in the previous case (when it is switched off), the current will flow to the grid from the positive photovoltaic terminal, i.e. C1, via S1, L1, D2, S6, L2.

During the second half of the half-wave the grid voltage decreases and the modes proceed from boost- to buck-boost- and finally to buck mode.

The work in the course of the negative half-wave proceeds similarly, but S4 and S5 are switched permanently on instead of S3 and S6. In a buck mode S1 is permanently open, while S2 is working as a high frequency switch. Both S1 and S2 are working in case of a buck-boost mode. S2 is permanently closed, while S1 is working in a boost mode.

A possible sequence of the mode changes is illustrated in Fig. 5. In area 1 the grid voltage u_G has a smaller absolute value when compared to that of PV voltage U_{PV}. The inverter is working in a buck mode in this case. The mode can change to a buck-boost one in area 2 where the voltage is close to $+U_{PV}$ and $-U_{PV}$. A boost mode is observed in area 3.

The change from a buck to a buck-boost mode can be carried out at $|u_G| \langle |U_P|$, while the change from a boost to a buck-boost mode can proceed at $|u_G| \rangle |U_P|$. The intermediate use of buck-boost mode will avoid the undesirable changes between buck and boost modes provoked by current oscillations.

The higher efficiency and the better quality of the output voltage resulting from the three level work of the inverter is another advantage.

CONCLUSIONS

The topology advanced is suitable in case of a direct connection to the grid when the PV voltage is smaller than the amplitude of the grid

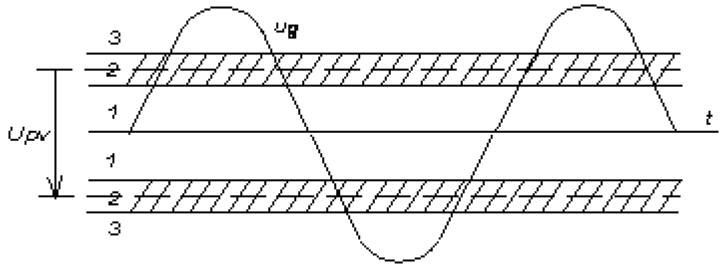

Fig. 5. Mode changes.

voltage. Its advantages refer to the smooth change of work modes and the easier control because of its symmetry in both half-waves. Furthermore, the efficiency is higher, while the disturbances are less in number because of the three level pattern of work.

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