Renewable Energy and Power Quality Journal (RE&PQJ), ISSN 2172-038 X, No.9, 12th May 2011, Reference Paper: 479

European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'11)
Las Palmas de Gran Canaria (Spain), 13th to 15th April, 2010

Photovoltaic Stand-Alone Power Generation System with Multilevel Inverter

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Abstract. This paper proposes a decentralized stand-alone photovoltaic (PV) system, which presents a set of advantages when compared to conventional stand-alone PV system. In the proposed system, the generated energy by the PV arrays is processed by multi-string MPPT step-up converters, which assure a maximum utilization of this energy. The storage system is designed in a decentralized configuration, enabling to achieve a reduction of maintenance cost of back-up system. Moreover, the output stage is composed by a multilevel dc-ac inverter, which enables higher efficiency, low distortion ac waveforms, low leakage currents and the use of low voltage rating semiconductor devices.

Key words

Photovoltaic (PV) systems, multi-string systems, multilevel inverters, stand-alone, battery converters.

1. Introduction

The continuous economic development of many countries and the environmental issues (gas emissions and the green house effect) observed in the last decades forced an intense research in renewable energy sources. Hydro, photovoltaic (PV) and wind energy conversion are the most explored technologies due to their considerable advantages [1]-[2], such as reliability, reasonable installation and energy production costs, low environmental impact, capability to support microgrid systems and to connect to the electric grid [3]. Among these energy sources the PV is pointed out as one of the most modular and environmentally friendly technologies. Therefore, PV systems have been frequently adopted worldwide, presenting a growth of 45% on the total PV power installed in 2009 [4] (the largest growth among the renewable energy sources).

With the continuous improvement on the energy sector, an important situation should be brought out: approximately 1.4 billion people have no access to electricity worldwide [5], which a substantial fraction refers to communities distant from the electric grid. This feature makes the stand-alone system an interesting alternative for enabling electricity access for those people, and also for remote applications. This way, it is expected that the number of installed stand-alone systems should increase in the next years. Differently from the grid-connected systems, the stand-alone systems demand a back-up system (usually a battery bank and a charger/discharger converter) to supply the load during periods with low or no energy generated. It was demonstrated in [6] that the maintenance costs related to the batteries represent 46% of the overall PV system cost due to the batteries short lifetime. Thus, it is essential to optimize the back-up system lifetime.

However, it is well know that the PV technology has some disadvantages such as high installation cost, intermittence on the energy production, low efficiency (5-16%) and requests converters for energy conversion (dc-to-ac) in order to feed the load. Additionally, due to the non-linear characteristics of the PV panel it is required a maximum power point tracking (MPPT) algorithm, usually implemented on the dc-dc or dc-ac stage. Another drawback is the unequal power produced between the PV panels caused by several reasons, such as dissimilarities of panel production, different temperatures and irradiations due to the orientation of the panels, aging and shading.

Therefore, it is imperative that the overall system must present high efficiency in order to make the employment of this energy source economically feasible and cost-effective. The former topologies were based on the centralized systems, where a single dc-ac stage manages long string arrays power production [7],[8]. However, these topologies reduce the overall efficiency due to lost of the maximum power point in some occasions. This way, to minimize these problems the decentralized PV systems were proposed, such as the multi-string systems, where the MPPT is divided into several dc-dc stages (usually step-up) and each one dedicated to a short PV string, ensuring the maximum power production.

Concerning the dc-ac stage energy processing, the multilevel inverters have been reported as a possible solution for PV systems [3], with several inherent benefits, such as high efficiency, low distortion ac waveforms and low leakage currents. Additionally, in high power applications the ac power can be synthesized from several low-level cells, i.e., low voltage semiconductors could be employed. The multilevel inverters are also suitable for multi-string topologies, where each string can be connected to the multilevel cells.