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Z-source DC-DC Converter with Fuzzy Logic MPPT Control for Photovoltaic Applications

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Abstract

Z-source converters are recently premised DC-DC converters which can perform buck and boost operations, offer greater range of DC output voltage, high reliability and reduce in-rush and ripple currents. In photovoltaic (PV) applications, they provide better results compared to conventional DC-DC converters. These converters can be used as power conditioning units, so that the voltage boost and reception of maximum power from the PV array can be achieved. The maximum power point tracking (MPPT) is here achieved by controlling the duty cycle of the converter. A fuzzy logic control based MPPT is developed in this work to track the maximum power point of the PV array under variable solar irradiance and temperature conditions. MATLAB simulation and experimental results are given to establish the developed system.

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Keywords: Photovoltaics; Z-source DC-DC Converter; Fuzzy logic; MPPT

1. Introduction

Sustainable energy usage is steeply increased because of the environmental awareness and continuous price growth of conventional fuels. PV arrays convert the energy from an essentially unlimited source –the sun-into useable electricity. In previous years, PV arrays have been directly connected to loads. Unfortunately, direct connection of PV cells to the utility almost never allows optimum power transfer when the load, solar irradiance or

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temperature changes [1]. A PV module can produce the power at a point, called an operating point, anywhere on the current-voltage curve. But there is a particular point, called a maximum power point (MPP), at which the PV module develops the maximum output power. A maximum power point tracker (MPPT) is thus required to operate the PV array at this optimum point. To transfer energy from PV arrays into utility, power conditioning unit, which is normally a power electronic converter is required to convert the dc voltage obtained from PV array into desired voltage and to prevail the maximum power utilization of the PV array.

There are many dc-dc converter topologies intended in literature for solar photovoltaic application, some of them are derived from basic dc-dc converters, such as buck, boost, buck-boost, cuk converter, and others derived from isolated dc-dc converters, such as fly-back, forward converter. Also, there have topologies derived from half bridge and full bridge converters [2, 3, 4]. These topologies have many merits and can meet the needs of many applications. But they suffer two major limitations of short circuit effect and limited voltage gain. The high voltage gain can be achieved using isolated DC-DC converters by increasing the turns ratio of the transformer. But the input current is pulsed, which greatly affects the life of the PV array [5, 6].

New power converters like Z-source converters are developed to give better results and eliminate the above disadvantages of the conventional converters. Z-source converters have been recently studied by several researchers [7, 8, 9]. In this paper the operating principle of the Z-source DC-DC converter and its integration with PV array is explained for standalone photovoltaic applications. In this paper, a fuzzy logic based MPPT is proposed to track the maximum power point of the PV array under varying solar irradiance and temperature. Fuzzy is comparatively easy to design since it does not require any information about the exact model.

2. Z-Source DC-DC Converter

The topology of the Z-source DC-DC converter is shown in Fig.1. Unlike other buck-boost converters, Z-source converters consist of two inductors and two capacitors connected in X-shape to couple the converter to the input DC voltage. This converter can produce a desired output DC voltage irrespective of DC input voltage magnitude since the input may be the variable voltage obtained from solar panel, fuel cell or battery. Depending on switching positions of S_1 and S_2, the circuit of Z-source DC-DC converter has two operating modes: Non shoot-through mode and shoot-through mode [10].

Non shoot-through mode operation is obtained by closing the switch S_1 and opening the switch S_2. The equivalent circuit of this mode is shown in Fig.2. During this mode, the Z-network inductors L_1 and L_2 transfer the stored energies on them to the load. The capacitors C_1 and C_2 are charging using the input current I_s. The output inductor L is energized during this operation.

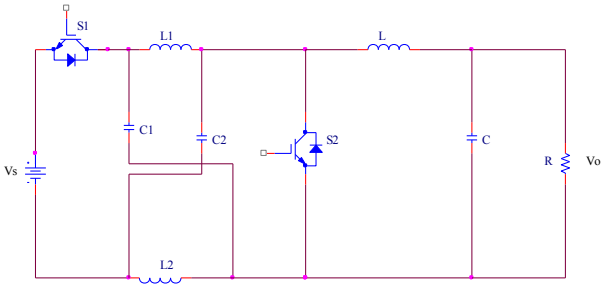

Fig. 1. Topology of Z-source DC-DC converter.

Shoot-through mode is the short circuit mode and is achieved by closing the switch S_2 and opening switch S_1. Now the charges stored in Z-network capacitors C_1 and C_2 are transferred to inductors L_1 and L_2. The inductors and capacitors are now forming a parallel connection and the equivalent circuit is shown in Fig.3. So the total voltage across the Z-network is more than the input voltage. This makes the diode in parallel with switch S_1 reverse biased. Hence the input voltage is disconnected and the input current is zero during this mode.