Novel Ćuk-Buck MPPT Battery Charger for Standalone PV-Inverter Applications

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Abstract – The theme of this paper is a novel MPPT converter for battery charger. The converter combines both Ćuk and buck converters topologies to extract maximum power from photovoltaic arrays while supplying a controlled constant current/voltage to the battery simultaneously. The new topology uses two control signals instead of one control signal; one for maximum power point tracking, another for battery charger control providing constant current/voltage to the battery. The advantage of this converter is to exploit the maximum power of the PV array avoiding battery damage caused by variable MPPT voltage. As a matter of fact, the tracking voltage that tracks the maximum power is variable according to weather irradiation conditions. However, batteries need constant voltage and current for charging to avoid the damage and to extend its lifetime. Therefore, it is reliable to combine the battery charger control and the maximum power exploitation using two control signals simultaneously. The real-time implementation of the Ćuk-buck converter was carried in TMS320F28335 DSP. A 4kW prototype system was built and four 12V 100Ah batteries were used. The effectiveness of the proposed converter was tested in both simulation and experiment in various operating conditions. The experiment results verified that the PV power obtained of the two control signal converter was exploited better than that of one control signal and that battery’s full charging state was reached in a relatively short time. Copyright © 2012 Praise Worthy Prize S.r.l. - All rights reserved.

Keywords: Battery Charger, Maximum-Power-Point Tracker (MPPT), Voltage and Current Control, Photovoltaic (PV).

Nomenclature

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\[ S_1 \] MPPT switch
\[ S_2 \] Battery charger switch
\[ S_3-S_4 \] Inverter switches
\[ S_b \] Boost converter switch
\[ L_1-L_3 \] Ćuk-buck converter inductors
\[ L_i \] Boost converter inductor
\[ L_o-L_n \] Output filter inductors
\[ C_1 \] MPPT capacitor
\[ C_2 \] Battery charger capacitor
\[ C_c \] Coupling capacitor
\[ D_f \] MPPT diode
\[ D_s \] Battery charger diode
\[ V_{PV} \] PV array voltage
\[ t_{on} \] Switch on time
\[ t_{off} \] Switch off time
\[ \Delta I \] Current difference in a specific inductor
\[ V_{c1} \] Voltage applied on C_1
\[ D_t \] MPPT duty cycle
\[ T \] Time period
\[ V_c \] Voltage applied on coupling capacitor
\[ V_{b} \] Battery voltage
\[ \delta \] Battery charger duty cycle
\[ C \] Battery charge
\[ \delta_{ci} \] The current duty ratio
\[ \delta_{ci-1} \] The previous duty ratio
\[ \Delta \delta \] Duty ratio perturbation step size

\[ V_{REF} \] Reference voltage of Ćuk-buck converter
\[ SOC\% \] State of charge percentage
\[ C_L \] Output filter capacitor
\[ L_L \] Load inductance
\[ R_L \] Load resistance

I. Introduction

Solar power has increased the attention for its significant potential in solving future energy problems and the foreseen severe shortage of energy sources [1]-[6]. Photovoltaic (PV) inverter systems can be either stand-alone or grid-connected system. Grid-connected systems are used to reduce utility power [7]-[9], whereas standalone ones provide the required power without the use of utility [10]-[12]. Furthermore, standalone systems dispense with the grid, so they need batteries that store the energy to supply load when the solar-energy production is low.

Storage batteries need a deep cycle to discharge a significant amount of the stored energy. The commonest deep-cycle battery is nickel-cadmium through it costs more than does lead-acid battery. Valve-regulated lead-acid (VRLA) battery has been widely used in PV applications recently. It is low-cost, maintenance-free, and considered the most recyclable among batteries [13]. For long battery life, a charge controller preventing...