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Design and testing of a separate-type lighting system using solar energy and cold-cathode fluorescent lamps

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Abstract

This paper presents a solar-powered lighting system, using cold-cathode fluorescent-lamps (CCFLs), with its battery-charging circuit and lamp-ignition circuit being separated so that its solar panels can be installed at any distance deemed necessary away from the lighting site in order to receive the maximum solar energy available. This system adopts the maximum-power point tracking (MPPT) method to control the power output of the solar panels and uses the zero-voltage switching (ZVS) DC–DC converter, as the charging circuit, to increase the panels' power generation efficiency and the charging circuit's conversion efficiency. The electronic ballast circuit for the CCFL is constructed with a half-bridge inverter, a resonant inductor, and a Rosen-type piezoelectric transformer, which forms a piezoelectric resonant-type inverter: to simplify the circuitry and to improve the power conversion efficiency, the ballast circuit is designed to directly step up the battery voltage in igniting the lamp. We also establish the transmission-parameter model for the piezoelectric resonant-type inverter to provide the base for the electric-power circuit design. Our experimental results indicate that the proposed system possesses some advantages, such as greater energy efficiency, circuitry simplicity, and so on, and is suitable for night lighting in house yards, parks and advertising panels.

Keywords: Cold-cathode fluorescent lamps (CCFLs); Electronic ballast; Maximum-power point tracking (MPPT); Zero-voltage switching (ZVS) DC–DC converter; Piezoelectric transformer; Piezoelectric resonant-type inverter

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Nomenclature and abbreviations

AHS triggering signal of PMOS (V)
ALS triggering signal of NMOS (V)
a'_1, b'_1, c'_1, d'_1 piezoelectric transformer's transmission parameters
$a''_1, b''_1, c''_1, d''_1$ transmission parameters of resonant inductance
A_{PT} piezoelectric transformer's voltage step-up ratio
CCFL cold-cathode fluorescent lamp
C_{1r} resonant capacitance of ZVS DC–DC converter (nF)
C_{o1}, C_{PV} capacitances (μF)
C_1 primary capacitance of the piezoelectric transformer's equivalent-circuit (nF)
C capacitance of piezoelectric transformer's equivalent-circuit (nF) (series connection of r, L and C)
C_2 secondary capacitance of piezoelectric transformer's equivalent-circuit (nF)
C_o capacitance of CCFL's equivalent-impedance (nF) (parallel connection of R_o and C_o)
C_p primary equivalent-capacitance converted by transformer from C_2 and C_o (nF)
C_s primary equivalent-capacitance converted by transformer from C_2 and C_o (nF) (series connection of R_s and C_s)
C_{o2} filter capacitance (μF)
D_1 main power diode of ZVS DC–DC converter
D_{1r} auxiliary power diode of ZVS DC–DC converter
D duty cycle of NMOS
D_3 half-wave rectified diode
div division
E, F, G, H transmission parameters of piezoelectric resonant-type inverter
f_r piezoelectric transformer's resonant-frequency (kHz)
f_o resonant frequency of the resultant circuit comprising of the piezoelectric transformer and CCFL (kHz)
f switching frequency of inverter (kHz)
I_{PV} solar-panel's output current (A)
i_o CCFL's current (mA)
L_1 boost inductance of ZVS DC–DC converter (μH)
L_{1r} resonant inductance of ZVS DC–DC converter (μH)
L_S resonant inductance of piezoelectric resonant-type inverter (μH)
L inductance of piezoelectric transformer's equivalent-circuit (mH)
MPPT maximum-power-point tracking
NMOS(Q_2) N-channel metal-oxide-semiconductor field-effect transistor
n ideal transformer's turn ratio of piezoelectric transformer's equivalent-circuit
OVP over-voltage protection
OCP over-current protection
PMOS(Q_1) P-channel metal-oxide-semiconductor field-effect transistor
P_o CCFL's output power (W)
P_{PV} solar panel's output power (W)