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PV power system using hybrid converter for LED indictor applications ☆

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ABSTRACT

This paper presents a LED indictor driving circuit with a PV arrays as its power source. The LED indictor driving circuit includes battery charger and discharger (LED driving circuit). In this research, buck converter is used as a charger, and forward converter with active clamp circuit is adopted as a discharger to drive the LED indictor. Their circuit structures use switch integration technique to simplify them and to form the proposed hybrid converter, which has a less component counts, lighter weight, smaller size, and higher conversion efficiency. Moreover, the proposed hybrid converter uses a perturb-and-observe method to extract the maximum power from PV arrays. Finally, a prototype of an LED indictor driving circuit with output voltage of 10 V and output power of 20 W has been implemented to verify its feasibility. It is suitable for the LED inductor applications.

1. Introduction

Due to high resolution, energy saving, and long life cycle features, light emitting diodes (LEDs) are becoming more prevalent in general indictor or lighting application [1]. Its applications include display, lighting, automotive, backlight, 3C, and traffic light products [2,3]. Particularly, indictors in traffic signals and electronic signs have rapidly grown. Moreover, serious greenhouse effect and environmental pollution caused by overusing fossil fuels have disturbed the balance of global climate. In order to reduce emission of exhausted gases, zero-emission renewable energy sources have been rapidly developed. One of these sources is photovoltaic (PV) arrays, which is clean, quiet, and efficient method for generating electricity. As mentioned above, this paper proposes a hybrid converter for an LED indictor driving system, which adopts the energy of PV arrays in traffic signal or electronic sign application.

For the LED indictor driving system, energies of PV arrays are stored in battery during day, and that of battery is discharged to the LED indictor during night. Therefore, the proposed PV power system needs a charger and a discharger. In order to increase conversion efficiencies of the charger and discharger, switching power supply is adopted in the proposed one, as shown in Fig. 1. Since the LED indictor driving circuit belongs to a low power level application, basic converters can be adopted in the proposed hybrid converter, such as buck, boost, buck–boost, flyback, and forward converters. In circuit structure considerations, it depends on the relationships among PV output voltage V_{PV}, battery voltage V_B, and output voltage V_O. Since V_{PV} is greater than voltage V_B and V_B is less than V_O, the proposed hybrid converter can choose step-down converter as the charger and step-up converter as the LED driving circuit. As mentioned above, the proposed one adopts buck converter [4,5] as the charger and forward converter as the LED driving circuit [6–8]. When forward converter is used in the proposed hybrid converter, it has two problems, which are separate the energies trapped in leakage inductor and magnetizing inductor of transformer. As a result, it will increase switching losses and result in a saturation condition of transformer core. In order to solve previous problems, a snubber is required to recover energies trapped in leakage inductor and magnetizing inductor. Thus, an active clamp circuit is introduced into forward converter to solve previous two problems [9,10]. In order to simplify the proposed circuit structure and increase its conversion efficiency, a bidirectional buck converter and forward converter with active clamp circuit are adopted, as shown in Fig. 2. Note that diode D_1 is used to avoid a negative current from load side to PV arrays. It can choose a diode with a low forward drop voltage rating, such as schottky diode. Since the charger and the LED indictor driving circuit of the proposed hybrid converter are operated in complementary and with switch S_1 to control their operational states, switches of charger and LED indictor driving circuit can be integrated with the synchronous switch technique [11] to reduce their component counts, weight and size, and to increase their conversion efficiency, as shown in Fig. 3. From the performance comparison between the conventional converters, as shown in Fig. 2, and the proposed hybrid one, as shown in Fig. 3, the proposed hybrid one can yield

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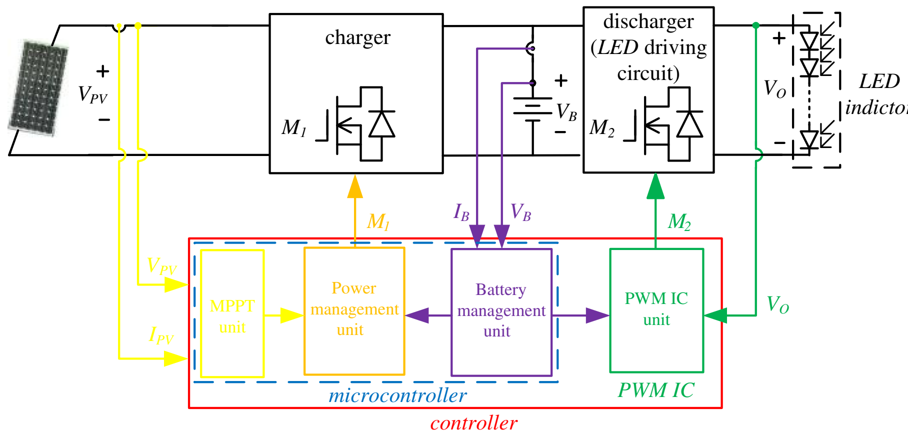

Fig. 1. Block diagram of the proposed hybrid converter for LED indictor driving circuit.

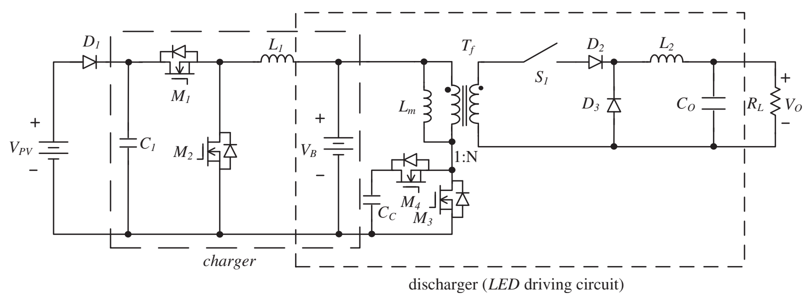

Fig. 2. Schematic diagram of the hybrid converter for LED indictor driving circuit.

higher efficiency, lighter weight, smaller size, and less volume and longer the discharging time of battery under the same discharging condition.

In order to generate a better charging performance of battery, many battery charging methods have been proposed. They are constant trickle current (CTC), constant current (CC), and CC and constant–voltage (CC–CV) hybrid charge methods [12]. Among these methods, the CTC charging method needs a longer charging time. Its applications are limited. Although the CC–CV hybrid charging method can reduce the charging time, it requires to sense battery current and voltage, resulting in a more complex operation and higher cost. Therefore, CC charging method is adopted in the proposed hybrid converter. Moreover, since the proposed one uses PV arrays as its power source, it must be operated at the maximum power point (MPP) of PV arrays to extract its maximum power. Many maximum power point tracking (MPPT) methods of PV arrays have been proposed [13–20]. They are, respectively, power matching [13,14], curve-fitting [15,16], perturb-and-observe [17,18], and incremental conductance [19,20] methods. Since power matching method requires a specific load or insolation condition, it will limit its applications. The curve-fitting technique requires prior establishment characteristic curve of PV arrays. It cannot predict the characteristics including other factors, such as aging, temperature, and a possible breakdown of individual cell. The incremental conductance technique needs an accurate mathematical operation. Its controller is more complex and higher cost. Due to a simpler control and lower cost of the perturb-and-observe method, the proposed hybrid converter adopts the perturb-and-observe method to implement MPPT. As mentioned above, the proposed PV power system can use MPPT method to promote the utility rate of PV arrays and adopt CC charging method to achieve a better charging performance.

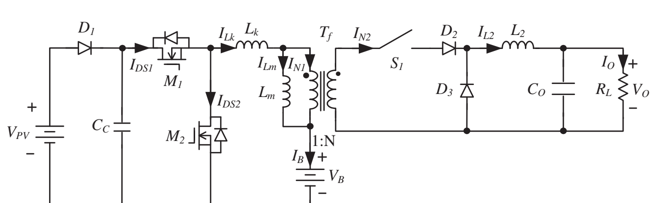

Fig. 3. Schematic diagram of the proposed hybrid converter for LED indictor driving circuit.

2. Power management of the proposed hybrid converter

In order to implement power management of battery charging and LED driving system, circuit structure of battery charger and LED driving circuit, and power management are described in the following.

2.1. Circuit structure of battery charger and LED driving circuit

The proposed PV power system includes battery charger, discharger, and controller, as shown in Fig. 1. The battery charger and discharger are illustrated in Fig. 2. Moreover, the controller consists of microcontroller, which is used to implement MPPT of PV arrays, manages battery charging, and controls battery charging current, and PWM IC, which is adopted to regulate charging current or output voltage V_O. In microcontroller, it is divided into 3 units: MPPT, power management, and battery management units. The MPPT unit adopts the perturb-and-observe method to execute the MPPT of PV arrays. Its detail operation principle of the perturb-and-observe method is described in [17,18]. The battery management unit uses the CC charging method to charge battery.