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Developing an Onboard Power Converter for Electric Vehicles: Harnessing Solar PV and Grid Functionality.

Atti Alekya[1], Matta Vinay Kumar[2], Bendi Sanjana[1], Jagu Praveen Srikar[1], Jallepalli Prasanth[1], Dharmana Prasanna Lakshmi[1]

[1] UG Student, Electrical and Electronics Engineering Department, GMR Institute of Technology, Rajam,, Vizianagaram District, Andhra Pradesh, India
[2] Assistant Professor, Electrical and Electronics Engineering Department, GMR Institute of Technology, Rajam,, Vizianagaram District, Andhra Pradesh, India

ABSTRACT:

The goal of this effort is to design a multipurpose power electronic converter that can charge plug-in electric automobiles using both grid and solar photovoltaic power sources. All vehicle modes were supported by the created configuration (charging, propulsion, and regenerative braking). When the car is at standstill, the grid either charges the battery or the grid and solar PV system charge it concurrently. Utilizing the kinetic energy of the car's wheels, the battery may also be charged via RB operation when the vehicle is in running mode. In plug-in charging mode, the suggested converter functions as an isolated SEPIC; in solar PV charging mode, it functions as a non-isolated SEPIC. Additionally, the suggested PEC operates as a conventional buck converter in RB mode and a typical boost converter in PP mode. For every mode of the suggested converter, both the simulation and the experimental validations have been provided.

1. Introduction

There are two types of electric vehicle (EV) chargers: on-board chargers, which are built into the vehicle, and off-board chargers, which are found at charging stations. Although off-board chargers provide quick charging by providing DC output directly to the battery, their substantial weight and high cost prevent them from being used widely. On-board chargers come in two varieties: conductive and inductive charging systems. They are convenient and flexible since they may be charged straight from AC mains. While certain components of inductive charging systems are located outside the car, the whole charging process of conductive charging systems is located within the vehicle. Since on-board chargers are always included with the car, they are more appealing since they need to be small and light enough to fit inside electric vehicles. Because they are simpler and need fewer parts than two-stage chargers, single-stage chargers are recommended. Although many integrated chargers employ non-isolated converters, which lack magnetic isolation, the goal of integrated chargers is to minimize the number of components by merging bidirectional DC-DC converters and front-end converters. This study's suggested approach combines solar and grid PV charging to provide two sources for charging operations and galvanic isolation for security. Reliance on traditional fuel-based energy can be decreased, vehicle-to-grid (V2G) functionality may be enabled, and grid power requirements can be decreased with solar PV charging. The suggested integrated converter offers magnetic isolation and solar PV charging capacity while functioning well in a variety of modes to overcome the shortcomings of current integrated chargers. Compared to the single-stage charging method, the integrated system has fewer components overall. In this research, a novel on-board charging solution—shown in Fig. 1—that combines grid and solar photovoltaic (PV) systems into a single stage is presented. The proposed Power Electronic Converter has several key features, including: (i) improved charger reliability through the use of two charging sources; (ii) improved safety for vehicle users and also the charging circuit through galvanic isolation; (iii) lower cost per charge from conventional fuel-based electricity; and (iv) support for all vehicle modes. The typical isolated and non-isolated SEPIC designs serve as the basis for the suggested approach. When charging solar PV, it operates as a non-isolated SEPIC and transitions to an isolated SEPIC when in plug-in charging (PIC) mode. Additionally, the integrated converter functions as a boost converter and buck converter in the PP and RB modes, respectively.

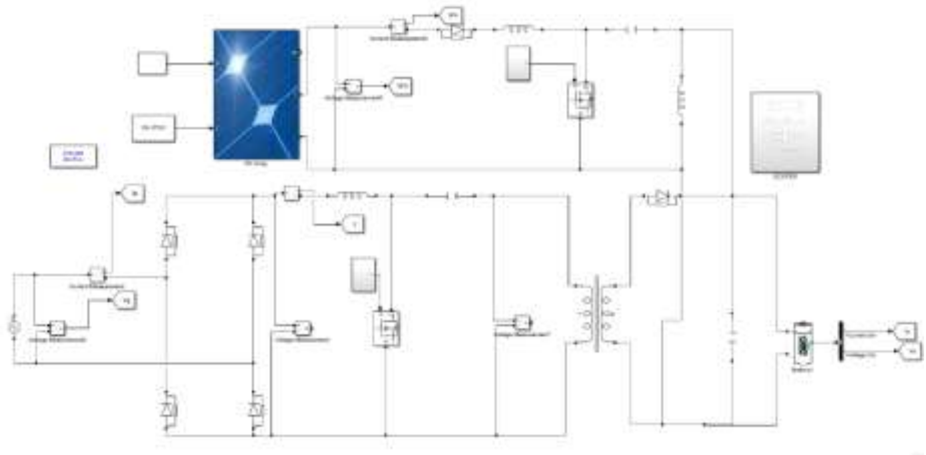

Fig. 1. Matlab simulation of Power Electronic Converter

1.1 SEPIC Converter

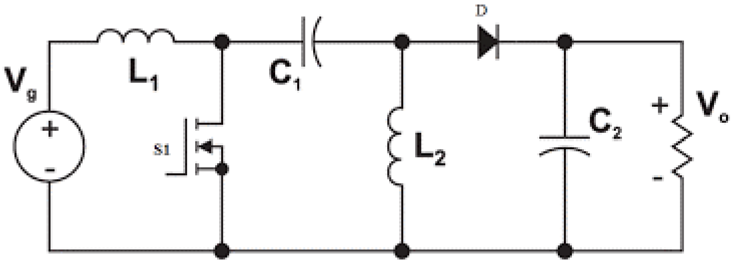

Fig. 2. Circuit diagram of SEPIC Converter

A DC-to-DC converter known by the abbreviation SEPIC, or Single-Ended Primary-Inductor Converter, may accept a variety of input voltages while producing an output voltage that is constant. Given that they can all produce output voltages that are more than, less than, or equal to the input voltage, it is comparable to buck-boost and Cuk converters. The SEPIC converter uses both the buck and boost converter functions, much as the buck-boost converter. But in contrast to the buck-boost converter, the SEPIC converter has benefits including high efficiency, employing a capacitor to separate the input and output sides, and having the same polarity for the input and output voltages. The input voltage source Vg, coupling capacitor C1, output capacitor C2, two inductors, a diode, and a load resistance are the parts of the SEPIC converter circuit. The way this converter works is that it transfers energy from the input DC voltage to the appropriate output voltage level via inductor L1, capacitor C1, and inductor L2. To control the energy exchange, a power transistor switch, such a MOSFET, is often used. Additionally, coupling inductors may be used in the design of the SEPIC converter in place of discrete inductors, which can increase efficiency and decrease the amount of PCB space needed. When two windings are coupled inside of one core, the device is referred to as a coupling inductor.

1.3 MPPT Techniques:

There are several types of techniques but we used P & O technique in this simulation.

Perturb and Observe Technique

The P&O method works by perturbing the PV system, affecting the high of the generator running voltage and then observing this change's effect on the power of the generator. The system oscillates highly because the step length is constant, especially in unstable environmental conditions. Even though some investigators utilized time to prevent large oscillations. However, it causes the MPPT harder to control to changes of weather. Finally, in the case of several local maxima as part of PSC, this method also works wrong. The P&O method is widely recognized as the most convenient way to study due to its simple appearance. Thus, the PV module terminal voltage gets disturbed in each MPPT cycle. Hence, as soon as the MPP is attained, the output power fluctuates about the MPP, and as a result, the power loss happens in the PV system. This shortcoming was addressed by introducing the modified P&O approach, which multiplies the change in the duty ratio by the dynamic constant determined by the scale of the prior change in the extracted power. One more approach utilized artificial neural network to predict this multiplying constant. These measures make the system more sophisticated while increasing the probability of oscillations in the fair weather.

2. Vehicles modes of power Electronics Converter.

2.1 Solar PV Mode:

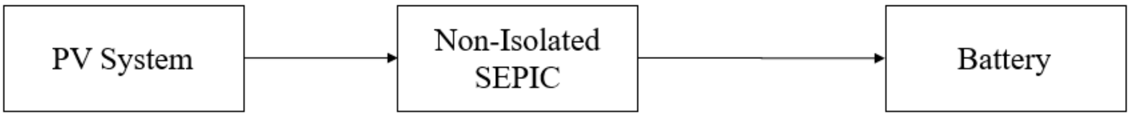

Fig. 3. Block diagram of PEC in Solar PV mode

When grid power is unavailable, a solar PV system is the sole method used to charge the battery. A SEPIC converter is used to link the system to the battery. This SEPIC converter is used to construct the maximum power point tracking (MPPT) controller that is based on perturbations and observations in order to maximize PV array performance. Fig. 3 displays the comparable circuit representation of this mode. Current flows through the two inductors when switch is switched ON. One Inductor transfers its stored energy to the battery via the diode when switch is switched off. Capacitor is being charged by inductor.

2.2 Grid Mode:

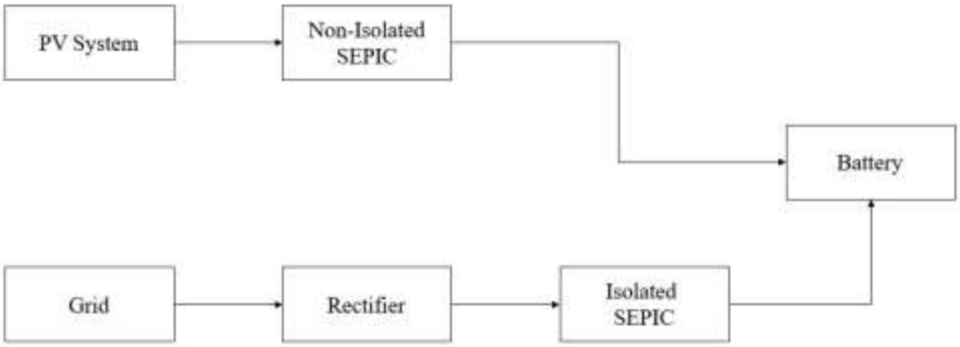

Fig. 4 Block diagram of PEC in Grid mode

Grid electricity is used to charge the battery in situations when solar power is not available. Inductor receives the rectified grid voltage when switch is turned ON, building up current across it and allowing inductor to store magnetic energy. Figure 4 depicts the current's passage via inductor. Additionally, the high frequency transformer's (HFT) magnetizing inductor L receives the stored energy from the capacitor C. Because the battery is not linked to the grid during this time, electricity is supplied to the battery via capacitor. As seen in Fig. 4, stored energy of L is transferred to the battery by diode when switch goes OFF.

2.3 Solar PV and Grid

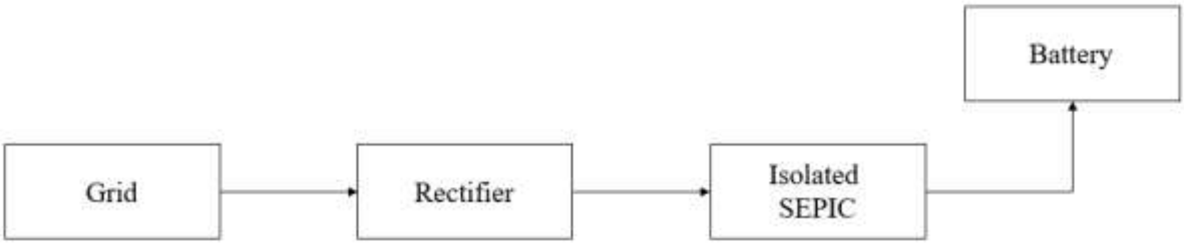

Fig. 5. Block diagram of PEC in Solar and Grid mode

When a solar PV system is unable to provide the reference charging power necessary to charge the battery, this mode takes place. In this scenario, the grid is providing the leftover electricity (solar PV power − reference power). The battery is concurrently charged by the grid and the solar PV system.

The grid provides the remaining power if the solar PV system is unable to meet the reference charging power. In order to accomplish MPPT functioning and feed power to the battery, the switch is activated via PWM. In order to provide electricity from the grid to the battery, the switch is activated.

2.4 Propulsion Mode:

In this mode, the suggested system functions as a typical boost converter. PWM signals are used to activate the switch, and mechanical switches S1 and S2 are turned on permanently. When switch is switched on, inductor receives voltage V, which stores magnetic energy. Current then travels along the channel. Inductor L supplies the DC-link capacitor C with its stored energy when Sa2 is switched off. The load (motor drive system via an inverter) receives the DC-link capacitor's stored electrostatic energy.

2.5 Regenerative Braking Mode:

In this mode, the suggested system functions like a typical buck converter. PWM signals are used to drive the switch Sa3, and mechanical switches P2 and P3 are always ON, just as in the PP mode. Inductor L1 stores energy along the route shown by the pink solid line in Figure 7 when switch Sa3 is switched ON. When Sa3 is switched off, the load receives stored energy from L1 along the method shown in Fig. 7.

3. Results:

Solar PV and Grid mode:

In Solar PV and Grid mode, we get 100v of grid voltage for every 0.05 seconds and also we get approximately 10A of grid current. In Solar PV and Grid mode, we get waveforms of grid voltage and grid current in phase. In Solar PV and Grid mode, voltage is measured in volts and current is measured in amperes. And also we measure battery voltage and battery current in Solar PV and Grid mode, we get 58v of battery voltage and 19A of battery current.

Solar PV mode:

In Solar mode we get three outputs, PV voltage, PV current, PV power. In this mode we get 55v of PV voltage, 7.2A of PV current, 400W of PV power. In Solar mode, PV voltage and PV power increases with respect to time upto one point and then remains constant. In Solar mode, voltage is measured in volts, current in amperes and power is measured in watts.

Grid mode:

In Grid mode, we get 100v of grid voltage for every 0.05 seconds and also we get approximately 10A of grid current. In Grid mode, we get waveforms of grid voltage and grid current in phase. In Grid mode, voltage is measured in volts and current is measured in amperes.

Propulsion mode:

In Propulsion mode, we get four outputs, DC-link voltage, DC-link current, battery voltage and battery current. We get 150v of DC-link voltage, 3.8A of DC-link current, 50v of battery voltage and 11.6A of battery current. In Propulsion mode, voltage is measured in volts and current is measured in amperes.

Regenerative Braking mode:

In Regenerative Braking mode we get three outputs, DC-link voltage, battery voltage and battery current. Initially we get 150v of voltage and then the voltage decreases gradually with respect to time (time increases) and again maintains 100v of voltage constantly. And we get 50v of battery current initially and decreases gradually with respect to time (time increases). And we get 10A of battery current. In Regenerative Braking mode, voltage is measured in volts and current is measured in amperes.

4. Conclusion:

Using grid and solar PV sources, a novel power electronic converter (PEC) for plug-in electric vehicles (PEVs) has been created in this study. The suggested PEC is capable of working with all vehicle modes, including regenerative braking (RB), propulsion (PP), and charging. Solar PV systems and the grid (plug-in charging, or PIC) are used to accomplish the charge. When charging from the grid, the proposed PEC functions as an isolated SEPIC; when charging from solar PV, it functions as a non-isolated SEPIC. However, it functions as a typical boost converter in PP mode and a buck converter in RB mode. Compared to SEPIC operation, conventional boost and buck converter operation places less stress on switching components. Because PP and RB modes are often rated for more power than PIC and solar PV modes, they put less stress on switching devices than PIC and solar PV modes, which is advantageous for vehicle applications. Using a prototype model

and computer simulation, the suggested system's modes for 400 W of charging power and a 50 V battery have been verified. The whole system offers a dependable and effective way to charge the batteries in electric cars, and it may also hold promise for the development of more advanced electric vehicles in the future.

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