NEW SINGLE-INPUT, MULTIPLE-OUTPUT CONVERTER TOPOLOGIES: COMBINING SINGLE-SWITCH NON-ISOLATED DC-DC CONVERTERS FOR SINGLE-INPUT MULTIPLE-OUTPUT APPLICATIONS

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Abstract:

This paper presents a methodology that allows the development of new converter topologies for single-input, multiple-output (SIMO) from different basic configurations of single-input, single-output dc–dc converters. These typologies have in common the use of only one power-switching device and they are all non-isolated converters. Sixteen different topologies are highlighted, and their main features are explained. The 16 typologies include nine two-output-type, five three-output-type, one four-output-type, and one six-output-type dc–dc converter configurations. In addition, an experimental prototype of a three-output-type configuration with six different output voltages based on a single-ended primary inductance (SEPIC)-Cuk-boost combination converter was developed, and the proposed design methodology for a basic converter combination was experimentally verified.

Keywords: Dc-dc converter.

1. INTRODUCCTION

Today, dc–dc power converters are becoming the main branch of power electronics. Recent reports indicate that dc–dc converters represent the largest percentage of total conversion equipment production. The worldwide dc–dc converter market has grown an average of 7.5% in recent years. In addition to its high growth rate, the dc–dc converter market is undergoing drastic changes because of two major trends in the electronics industry: low voltage and high power density. The production of dc–dc converters in the world market is now much higher than that of ac–dc converters. The divided market comprises three subsegments, including low power, medium power, and high power.

In recent years, different techniques for multiple dc outputs and different voltage levels have been studied and developed. This research has focused on isolated dc–dc converter configurations, such as those for flyback, forward, push-pull, half-bridge, and fullbridge (H-bridge; this term is derived from the typical graphical representation of such a circuit) converters, as well as non-isolated dc–dc converters. Several applications have also been studied, such as integrated dual-output converters, integrated multiple-output converters, and single-inductor multiple-output converters. In addition, emerging power architectures oriented toward renewable energy sources (such as wind turbine, solar array, and fuel cells), batteries, and distributed-generation utility grids have proliferated in important ways.

Configurations and properties of dc–dc converters are well known and described in relevant literature. DC conversion relations depend on the converter topology and the particular operating mode. The efficiency depends on how closely the converter circuit elements conform to the ideal. Considering the same elements, efficiency depends on the converter topology. The switch electrical stress (voltage and current) determines the choice of semiconductor devices used to implement the switches. Low losses on parasitic resistances involve more efficient filtering and low generated noise. Continuous input/output currents are a desirable attribute for dc–dc converters, since the discontinuous input current causes high electromagnetic interference, whereas the discontinuous output current is responsible for the higher output voltage ripple. The number of inductors, capacitors, and switches contributes to the complexity of a converter. Efficiency and density (watts/volume) have long been the metrics used to compare the performance of power converters.

Most basically, dc–dc converters are classified according to whether their typologies are isolated and non-isolated, i.e., depending on whether the converter is used with or without electrical isolation by means of a high frequency transformer. The transformer can provide multiple outputs (by adding more secondary windings), which allows the creation of one or more output voltages. The utilization of the power transformer affects the size of the power converter.

On the other hand, the concept of multiport converters applies to a static power electronic converter, which is capable of interfacing with different sources and storage systems and with loads having different voltage levels. Multiport converters are particularly interesting for sustainable energy-generation systems that must integrate various low-power sources and storage elements. A first classification of the multiport converters can be performed as a function of the input and output number; these include configurations for multiple-input, multiple-output (MIMO); multiple-input, single-output (MISO); and SIMO converters. This article proposes MIMO and MISO dc–dc converters for dc distribution in emerging applications such as the integration of renewable energy sources into the grid, energy storage systems, interface for satellite, and power charger-supply applications. SIMO dc–dc converters, in both their isolated and non-isolated versions, have been traditionally used for multiple supplies with different output levels in many applications, such as telecommunications, microelectronics and lighting, that include electronic ballast and light-emitting diodes, and hybrid/electric and electric vehicles.

2. PROPOSED METODOLOGY

This paper presents a methodology for SIMO applications based on singles witch non-isolated dc–dc converters. It is based on the combination of the basic converters of single input single output. The methodology has been derived from nine two-output-type, five three-output type, one four-output-type, and one six output-type dc–dc converter configurations by combining traditional non-isolated single-inductor dc–dc converters—such as boost, canonical switching cell (CSC), and buck-boost single-inductor and also two-inductor topologies, Cuk, SEPIC, and Zeta converters.

Inspecting the basic converters of single input single output, it is observed that some configurations have an identical front end. So, the combination of two or more converters that share the elements common to their input will result in a new converter of one input and multiple outputs, depending on the number of converters combined. This allows the derivation of multiple output configurations by modifying and combining these basic topologies, and, therefore, obtains new topologies that are single-switch with only one input inductor.

The main advantage of the proposed configurations is that they allow implementation of SIMO converters with only one controllable switch, which simplifies the implementation of control strategies because it is not necessary to synchronize multiple switches. The use of a high-frequency transformer is not required, which reduces the size and improves the efficiency. This allows the establishment of two aspects of the proposed configurations: simple structures, since they use only one switch and few active elements, and a simple driver circuit, since there is only one switch that needs to be controlled. All of the configurations derived by combination inherit the characteristics discussed. The new topologies have been analysed from the output type, features of the input and output currents or number of passive components.

An experimental prototype was developed following the methodology described, based on a SEPIC-Cuk-boost combination converter (Fig. 1). It has allowed the development of a power supply bank of six different voltages. Some design rules have been proposed for choosing the right elements of the converter. Basically, these rules are based on: maximal ripple of the inductor current, the converter works in continuous conduction mode (CCM) and maximal ripple of the output voltage.

A control circuit has been designed to regulate the output voltage. The control parameters were the output voltage of the SEPIC side and the current through the power switch in the order of the avoiding overcurrent. This control method is based on the cross regulation feature of SIMO converters.

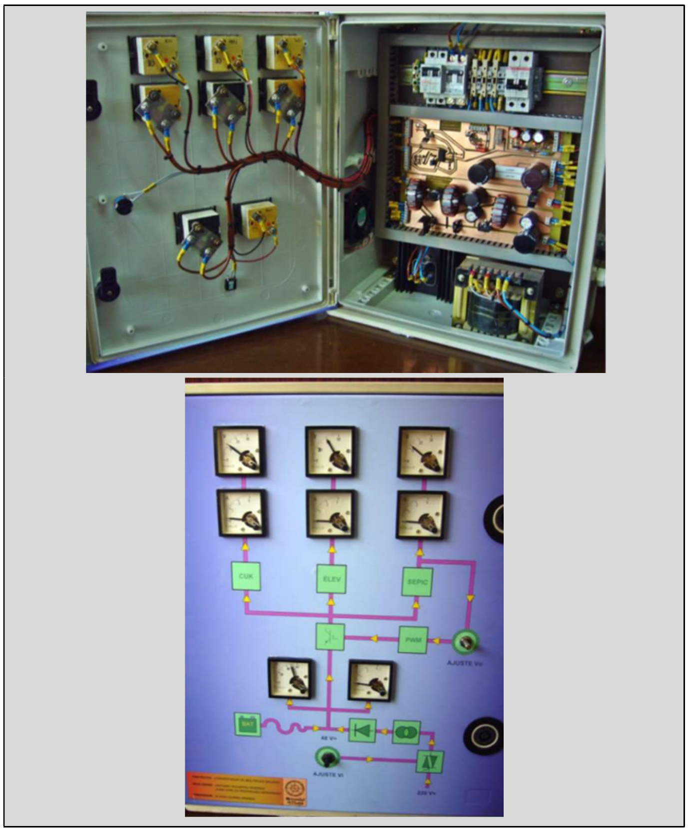

Figure 1. *Experimental prototype.*

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