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A 80 KW CONFINED DC-DC CONVERTER FOR RAILWAY APPLICATION

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Abstract

This paper provides an analysis of a three-phase dual active bridge (DAB) topology used as high-power-density dc–dc converter for railway applications. The three-phase DAB is analyzed concerning the current intervals, the output power, and soft-switching region, including the impact of zero-voltage switching capacitors. Furthermore, two measures are proposed to achieve soft-switching in the entire operating range, being auxiliary inductors and a straightforward switching strategy called the burst mode. Optimal component values are calculated to minimize losses in the complete operating range and to assess which measure is best suited. A prototype with the specifications acquired from the application has been built, yielding an efficiency of 95.6% at a nominal output power of 80 kW.

Index Terms—**DC–DC power conversion, power electronics, power supplies, rail transportation electronics.**

INTRODUCTION

Since the electrification of rail transportation systems, the amount of additional electrical systems in the vehicle has been increasing substantially. These, so called "auxiliary sys-tems" are all systems on a rail vehicle that have functions other than traction. Nowadays, many auxiliary systems are present on rail vehicles. Examples are lighting, compressors, pumps, air-conditioning, and passenger information systems. In order to provide energy to these auxiliary systems, an auxiliary power unit (APU) converts the voltage from the overhead line or a third rail to the required levels of supply voltages. The total auxiliary power demand is typically in the range of tens of kilowatts up to a few hundreds of kilowatts. For safety reasons, galvanic isola-tion between the input and the output of the APU is required. In conventional APUs, the galvanic isolation is often realized with low-frequency transformers, an example is shown in Fig. 1(a). These transformers are bulky and result in relatively large and heavy APUs. Especially for light rail vehicles, like trams and metros, this becomes a problem when the auxiliary power de-mand increases. Therefore, size and weight reduction of the APU is necessary to meet the auxiliary power demand within the capabilities of light rail vehicles.

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Most of the light rail transport systems are using a dc electrification system with common nominal voltages of 600 or 750 V. Adding an isolated dc–dc converter is the preferable solution for reducing size and weight of the APU. By placing the isolated dc–dc converter between the input filter and the three-phase inverter, the bulky low-frequency transformer can be omitted, as can be seen in Figure. This paper focuses on the design of an isolated dc–dc converter for railway applications.

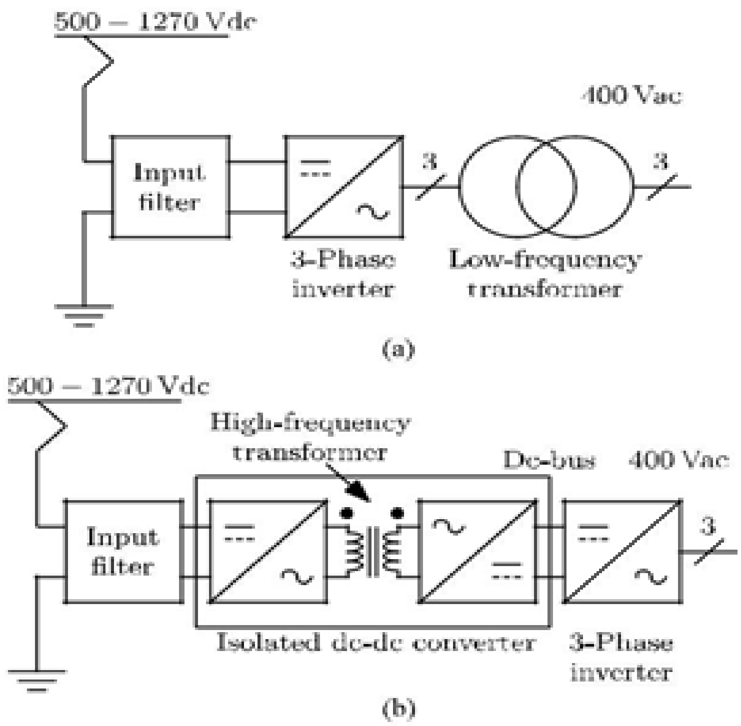

Figure. 1. Schematic of an APU. (a) Conventional APU. (b) Proposed APU.

TOPOLOGY OVERVIEW

The field of high-power-density dc–dc converters has been addressed often in the last decades. From the beginning, the conventional full-bridge converter topology has been the preferred choice to realize a high-power dc–dc converter [1]. However, due to problems with the leakage inductance of the transformer and, consequently, reverse recovery losses of the output diodes, the maximum switching frequency is limited. To solve this problem, several solutions were presented, including active clamps and/or auxiliary circuits [2]–[4]. These solutions enable higher switching frequencies at the expense of additional components and could lead to higher device stress. The additional

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components impede the increase in power density and increased complexity, while the efficiency is often not better compared to other zero-voltage switching and zero-current switching techniques.

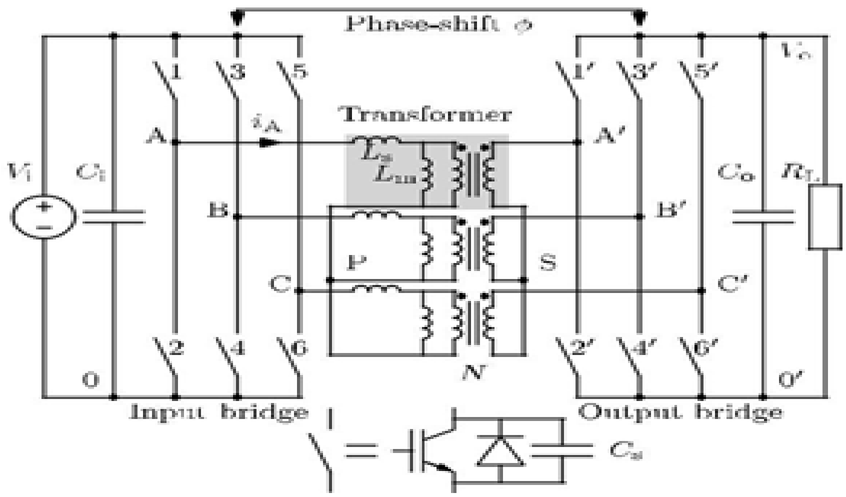

Figure 2. Three-phase DAB.

CONCLUSION

The three-phase DAB topology has been selected for applica-tion in the APU because of the preferred properties concerning buck–boost operation, low device stress, small filters, high trans-former utilization and low-switching losses. Subsequently, the soft-switching region is analyzed, including the effect of ZVS capacitors. Furthermore, two methods are presented to extend the soft-switching region: auxiliary inductors and a burst-mode switching strategy. Comprising a combination of the burst mode and auxiliary inductors, optimal component values are calcu-lated to minimize the losses. As a result of the analysis, it is found that auxiliary inductors are not necessary with the use of the burst mode. Experimental results show good agreement of measured waveforms with the idealized model. Furthermore, efficiencies of the burst and continuous mode with a measured efficiency of 95.6% at maximum output power at nominal conditions are presented. Also, the use of ZVS capacitors shows about 40% reduction of the total loss, enabling an output power above nom-inal and still preserving a good efficiency. The prototype was tested thoroughly in the entire operating range, including oper-ation in the burst mode with an input voltage of 500 and 900 V. The burst mode proves to be useful to extend the operating range in a soft-switching manner. Operation during burst mode shows slightly lower efficiencies compared to continuous operation.

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