Three-Phase Step-Down Reversible AC–DC Power Converter

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***Abstract*—Bidirectional dc current flow is not a natural feature of the buck (step-down) switch-mode rectifier, which leaves it at a disadvantage to boost (step-up) designs. A circuit topology is presented that allows bidirectional flow and which, by dual use of components, uses fewer devices than anti-parallel bridges. Sinusoidal current, controlled displacement factor, and variable voltage transfer ratio are demonstrated in a 1.5-kVA prototype. Dynamic performance is investigated through simulation and experiment. A PI plus velocity controller is shown to be adequate provided care is taken over changing between rectification and inversion.**

***Index Terms*—Bidirectional conversion, control, distortion factor, rectification, sinusoidal current, switch mode.**

I. Introduction

The boost switch-mode rectifier is the dominant design for both single- and three-phase rectifiers where there is a requirement to draw near-sinewave currents from the mains. This requirement is likely to follow from the need to comply with a standard such as IEC 555-2 [1]. In the three-phase case, the principle advantage of the boost topology is that it is able to operate in all four quadrants of the $P + jQ$ plane without the need for additional power components. The step-up from the three-phase voltage to a dc voltage above the line voltage peak is also a benefit in induction motor drives. The higher dc link voltage allows a larger constant torque operating region.

Not all loads, however, suit a stepped-up mains voltage. Battery chargers and dc motor drives would require a further (dc–dc) power conversion stage to operate with a boost rectifier. A further disadvantage of a boost rectifier is that it needs special protection during start-up because the converter is uncontrolled while the dc link voltage remains below the line voltage peaks.

The buck switch-mode rectifier would suit low and medium voltage dc loads, especially those that require a controlled variable voltage between 0 and the 1.5 times the phase voltage peak.

The disadvantage of the buck rectifier is that there is no path for reverse current flow [2]. Thus, regeneration is limited to loads that can reverse their voltage. There is also a small transient regeneration capability while the dc current is forward and the ac currents are phase inverted. Under these circumstance, the dc current is rapidly driven to zero.

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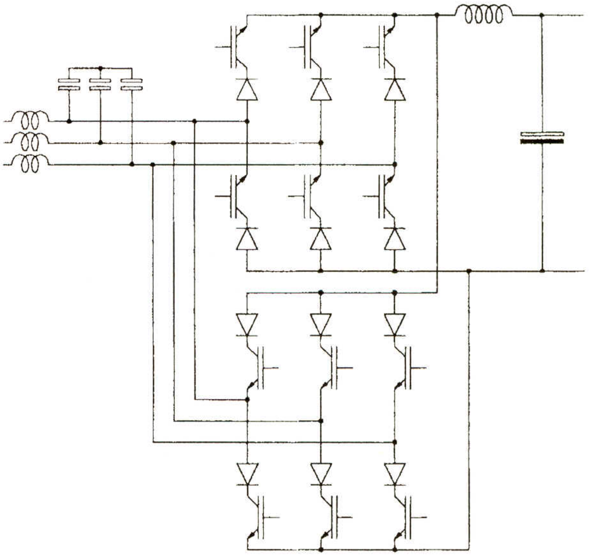

Fig. 1. Anti-parallel connected buck converters.

A buck converter with regenerative capability through reversal of the dc current flow would be a useful addition to the present family of power converters. This paper addresses that need.

II. The Bidirectional Buck Rectifier

Traditional phase-angle controlled rectifiers have the same restriction to unidirectional current flow as the buck rectifier. This is overcome by operating two thyristor bridges in anti-parallel [3]. Applying this idea to the buck converter gives the circuit shown in Fig. 1. The proposal is to take advantage of the simplification of the buck rectifier in [4] and [5], which changes the single bridge from 6 switches and 6 diodes to 3 switches and 12 diodes. The reverse connected bridge in Fig. 1 cannot be simplified in the same manner because the current paths cannot be enforced as necessary. However, the two bridges (one simplified and one not) can be consolidated so that they share diodes and save on components overall. The result is the circuit of Fig. 2. This circuit is able to deliver positive or negative dc current to a normally positive voltage link. In this sense it is two quadrant. On the ac side, it is able to operate in all four quadrants of the $P + jQ$ plane.

A. Operation in Rectifier Mode

In rectifying mode (positive dc current), switches SR1–SR3 are used and SI1–SI6 are held off. Assuming for the moment that the dc-side inductor current, I_L is constant, the switches

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