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MINIMISATION OF CIRCUIT COMPLEXITY OF STEP-UP/DOWN THREE-PHASE AC TO DC CONVERTER WITH SINUSOIDAL INPUT CURRENT AND UNITY POWER FACTOR

Indexing terms: AC/DC converters, Harmonic analysis, Steady-state analysis

In Reference 1 a three-phase buck–boost pulse recitifier system is introduced where current consumption averaged over a pulse period is proportional to the mains voltage. The basic structure of the system power circuit is shown in Fig. 1*a*. The control of mains current is performed directly by mains phase voltages by analogy with

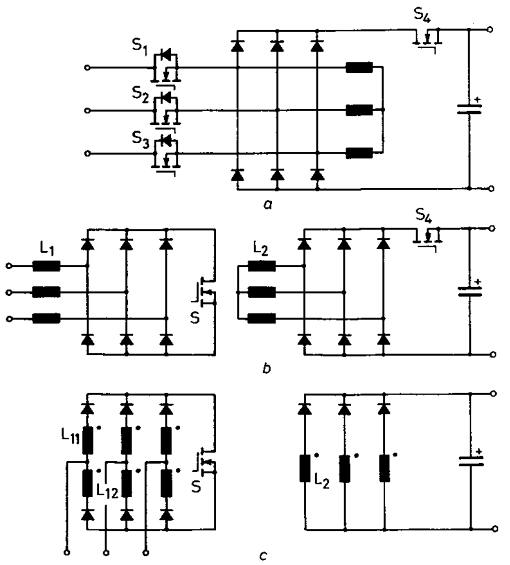

Fig. 1 *Topologies of three-phase AC to DC buck–boost converters with low effect on mains*

single-phase discontinuous-inductor current-mode AC/DC flyback converters [2] for constant duty ratio of the power transistors S_i, $i = 1, 2, 3$ being controlled synchronously (i.e. in phase). The mains current amplitude and therefore the output voltage for a given load is defined by the duty ratio. A power transistor S_4 situated on the output side and being controlled in opposite phase as compared to the input side switching group S_i allows the generation of output voltages smaller than the peak value of the line-to-line mains voltages.

This new and interesting circuit concept shows a low control complexity. However, it requires four isolated control stages for controlling the turn-off power semiconductor devices. Furthermore, the arrangement of the power semiconductor switches separated according to phases leads to a low utilisation of the switching capability of the transistors S_i. This is due to the low thermal inertia of power MOSFETs causing dimensioning of the transistors S_i according to the stress at the mains current maximum. A further limitation of the concept is the relatively narrow output voltage region defined by the minimum and maximum duty ratio (or by the high component stresses occurring there, respectively).

As shown in Reference 3, a substantial reduction of the control effort can now be obtained by the introduction of isolation between the input and output parts of the circuit (see Fig. 1*b*). Furthermore, the transformation ratio $\sqrt{(L_1/L_2)}$ results in a degree of freedom for matching the input and output voltage levels and in the possibility of forming of several isolated output voltages. The power transistor situated in the DC side of the diode bridge *D* (on the input side) replacing the switching group S_i shows an approximately constant current stress over the fundamental period here. This results in a high utilisation of the switching capability. For output voltages lower than the peak value of the transformed line-to-line voltage there remains the disadvantage of using a switch S_4 connected in series to the output voltage.

If a polarity change of secondary phase voltages is avoided by a shift of the primary windings into the bridge legs of the diode bridge *D* and by a symmetric split between the positive and negative halves (Fig. 1*c*, [4]) the output circuit can be simplified accordingly and the switch S_4 can be omitted.

A disadvantage of the realisation according to Fig. 1*b* and *c* as compared with the circuit given in Fig. 1*a* is the higher rated power of the inductors *L* owing to the addition of the secondary windings (and the split of the primary windings). In general, the concept of a discontinuous inductor current mode buck–boost converter is of only very limited applicability; this has to be seen in connection with the usually high output power associated with three-phase power converters leading to very high device peak currents and in connection with the high blocking voltage stress on the power semiconductors, especially for operating with the European low-voltage system (line-to-line voltage 400 V), [5].

An exception can be found in the field of aviation (e.g. for feeding of control modules with low effects on the onboard mains). There, the output power is typically < 1 kW, the onboard line-to-line voltage is 200 V, [4]. In such systems the simple circuit structure and, for buck–boost converters as opposed to buck and boost converters, full controllability of the power flow (independent of the ratio of the input and output voltage) are of special importance and can justify the application of the buck–boost principle.

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The authors are to be complimented on presenting a three-phase step-up/down AC to DC converter with a minimised circuit complexity while achieving both sinusoidal input curent and unity power factor. Although at the cost of higher rated power and complexity of the coupling inductors, the proposed circuit requires only one active switch and provides proper transformation ratio for matching the input and output voltage levels as well as multiple outputs. We are very glad to see the elegant result. Naturally, further analysis and design work is always necessary and reducing the current peak and voltage stress to make this circuit more practical for high power applications is certainly an important task.

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