Direct three-phase single-stage flyback-type power factor corrector

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Based on the work of Hui and Chung, a three-phase converter system consisting of three single-phase flyback-type AC/DC converter modules in star-connection is proposed and investigated.

Hui and Chung described the advantages of a modular construction of converter systems for three-phase power factor correction [1]. Based on that, a three-phase converter system consisting of three single-phase flyback-type AC/DC converter modules in star-connection (Fig. 1*a*) is proposed and investigated experimentally.

For objective assessment, it is of interest to compare the circuit described in [1] with a functionally equivalent direct (i.e. not modular) three-phase solution (Fig. 1*b* and/or Fig. 2 in [2]). The equivalence is given regarding the following aspects: (i) there is only a single-stage energy conversion, (ii) a galvanic isolation between input and output is given and (iii) an automatic power factor correction is realised in both cases. The comparison is made concerning realisation effort, device utilisation, conduction loss and/or efficiency, power density and operational safety and/or reliability.

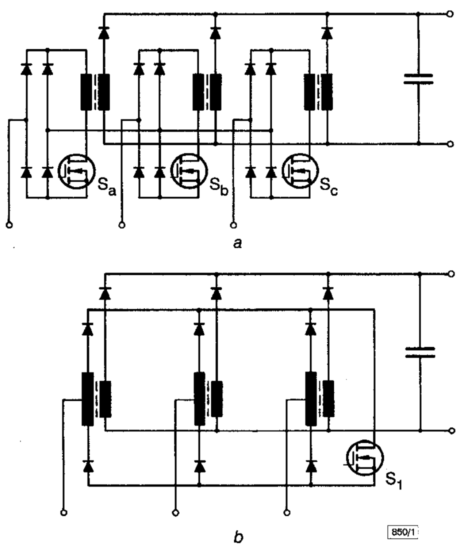

Fig. 1 *Basic structure of modular and direct three-phase flyback-type AC/DC converters according to* [*1*] *and/or* [*2*]

a Modular
b Direct

As clearly shown in Fig. 1, the modular couverter system has a larger number of power electronic devices and, therefore, a generally higher realisation effort and/or larger manufacturing costs. Note also the larger control effort for three partial systems, the higher effort for limiting the switching overvoltages across the power transistors [3] as caused by the leakage inductances of the transformers, the higher wiring effort (determining the required circuit board area) and the higher mounting effort (isolated mounting of the power electronic devices).

Furthermore, owing to the sinusoidal shape (of the envelope) of the input currents of the phase modules, only a relatively low utilisation of the power transistors S_a, S_b and S_c is given. On the contrary, for the direct three-phase realisation, a current with an approximately constant envelope is given in the power transistor S_1, optimally utilising its switching capability and current carrying capability. However, the modular system has a lower rated power and simpler transformer construction (only one primary winding).

The direct three-phase system also has an advantage regarding the conduction losses. The current flow per phase on the primary is only in one and not in two diode junctions (in series). Furthermore, for the reasons given, the transistor conduction losses are lower for the same realisation effort as compared to the overall transistor conduction losses for the modular realisation. (This is also valid under consideration of the higher blocking voltage capability required for S_1, as compared to S_a, S_b and S_c, resulting in a higher on-resistance for power MOSFET application.) The direct three-phase system has, therefore, a higher energy conversion efficiency (reduction of energy costs, especially for continuous operation [4]) and/or reduced cooling effort and, therefore, higher power density. Alternately, the thermal stress on the devices can be reduced for equal cooling effort as for modular construction. Therefore, the relatively high system reliability can be further increased, being also due to the relatively low complexity.

Summarising the points mentioned, the modular converter system is characterised by a relatively high realisation effort. This additional realisation effort, shown in Fig. 1*a*, is not compensated by an increase in operational safety (as compared to the circuit structure shown in Fig. 1*b*). (E.g. for a failure of a mains phase also with the direct three-phase system, the possibility of a two-phase operation is given.)

A utilisation of the advantages (especially in the area of operational safety and/or redundancy) of a modular power supply concept could be achieved by an extension of the partial systems of the circuit proposed in [1] to autonomous functional units. For this purpose, we would have to, for example, disconnect the star connection of the modules and operate each module across a line-to-line voltage. Furthermore, the single-phase diode bridge on the input side would have to be extended by a third bridge leg connected in each case to the third phase (c.f. Fig. 5 in [5]). The modules being affected by the break-down of one phase could than be switched over to the two remaining mains phases. Thereby, for two-phase operation (under the assumption of proper smoothing of the power which then would oscillate with twice the mains frequency) the full rated power is still available at the system output. A more detailed discussion of an adequate system control concept and of further measures required for controlling system-imminent failures (e.g. safe separation of a failing module) are not presented here for the sake of brevity.

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Input mapping algorithm for modelling of CMOS circuits

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An algorithm for mapping every possible input pattern of a complementary metal oxide semiconductor (CMOS) gate to an equivalent set of normalised inputs (inputs which have the same starting point and transition time) is presented. Such an algorithm is required in order to perform analytical modelling of CMOS gates, and the results obtained are very accurate compared to SPICE simulations.