特集に寄せて （5 ページに "和文翻訳" 掲載）

Preface to the Special Issue on "Power Electronics"

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Raising the efficiency of energy use and increasing the integration of renewable energy in energy production are today mandatory goals of the energy policy of leading industrial nations. In the case of electrical energy, power electronics, i.e. the electronic control of power flows and the conditioning of electrical voltages and currents by means of high switching frequency power semiconductors represents a key technology in this context. Examples are the feeding of photovoltaically generated DC energy into AC grids with simultaneous assurance of solar cell operation at the maximum power point, and the minimization of transmission losses on the connection of windparks to geographically distant load centres by means of high-voltage DC transmission. On the other hand one should mention here the possibility of avoiding inefficient industrial processes by means of a controllable voltage that is flexible with regard to amplitude and frequency which, e.g., enables high efficiency, variable speed drives to be realized with controlled torque.

Because of the abovementioned advantages, power electronics converters exhibit a considerable variety of application possibilities and over the past few decades have been significantly improved by the continuous development of power semiconductor technology, the employment of digital signal processing, new converter topologies and modulation and control schemes in respect of functionality, cost/performance ratio, physical size and efficiency. In spite of the high state of the technology thus attained, there still exists a demand for a massive further increase in performance, whereby typically not only one performance index but simultaneously several objectives need to be improved, e.g. efficiency and size or costs and efficiency.

New component technologies such as wide bandgap, i.e. SiC and GaN power semiconductors offer a technological basis for the above but because of the high switching speed, this must be complemented by new packaging technologies. Integration of the gate driver and the power switch is obvious here and in future will also enable programming of the switching behaviour as well as local monitoring. Further enablers are new joining technologies in power semiconductor modules, such as the replacement of soldering by low temperature silver sinter processes, whereby higher operating temperatures and/or lower cooling effort become possible. With regard to passive components one should mention new ceramic capacitor technologies with high energy density and current rating, and new heat management processes such as double-sided cooling and local two-phase cooling. Finally, the technology and design space will be extended by an even broader implementation of digital technology: on the one hand in converter control, and on the other hand for identification procedures as basis for optimal on-line controller parametrization. Furthermore, in the field of power supplies a transition from hard-switching converters operated in continuous current mode is to be expected to converters with discontinuous or triangular-shaped current curves and soft switching; the higher conduction losses compared with continuous current flow are here compensated by the low on-state resistances of new power semiconductors. In order to limit the EMC filtering effort, it is then sensible to employ phase-shifted operation of several systems working in parallel, i.e. interleaving, by means of which a continuous current curve again results. The overall more complicated modulation in this case can be managed through the continuous further development of digital technology (Moore's Law) by means of signal processors or FPGAs.

Furthermore, as always with the further development of established technologies, increased integration of partial functions will take place on all levels. For example, on the converter level integration of motor and inverter is advantageous as it allows an optimal design of an overall system and an easier application for the user. Finally, the further development of simulation tools should be mentioned, which will facilitate a multidomain analysis of power electronics converters, e.g. the simultaneous examination of electrical and thermal or magnetic and thermal issues. The challenges here lie mainly in model generation and parametrization.

The present Special Issue of Fuji Electric Review offers for the abovementioned points many direct examples in the form of finished products, e.g. an all-SiC PV inverter of high power, optimized with respect to efficiency and costs, a hybrid Si-SiC inverter traction converter of high efficiency and power density, a variable speed drive for air conditioners with inverter integrated in the motor to reduce size and costs, a new motor series optimized for efficiency, and uninterruptible power supplies with new T-type three-level topology. The significant improvement in performance obtained with these industrial systems over the state-of-the-art impressively confirms the highly dynamic technological progress in power electronics and a comprehensive practical mastery of an extremely broad technology spectrum.

Despite of the very high technological level now attained, the improvement of the performance of power electronics will continue in future. The next development step will presumably focus on cost reduction and the assurance of high reliability and robustness. New production technologies such as the encapsulation of power semiconductors, optical signal paths and heat removal devices in printed circuit boards and 3D additive manufacturing technologies will enable new geometries or increased multifunctional uses of construction elements. The highly integrated and highly compact systems, however, will then require convergence of simulation and measurement procedures in order to simulate no longer measurable quantities on the basis of adapted models directly accompanying measurement.

With regard to the fields of application of power electronics, we can expect an expansion of the present areas to direct coupling to medium voltage with isolated medium frequency converters, e.g. for the supply of DC distribution systems. At the same time, in the low power area, with utilizing microelectronics manufacturing technologies, a new branch of power electronics will be established that may be termed micro-power electronics. Finally, with the increasing spread of power electronics, one will need to consider during the design process not only minimal manufacturing costs but also the support of recyclability in order to enable a resource-conserving circular economy to be established. Considerations regarding materials use and costs should then also be addressed in academic research, as has been the case for several years at the Power Electronic Systems Laboratory at ETH Zurich.

In conclusion it should be highlighted that in central fields of application, a paradigm change is to be expected from the consideration of a single converter to the design of entire power supply chains. The demand for efficient power conversion at any given instant will be replaced by the demand for the assurance of an efficient and reliable energy supply with minimal overall costs over the lifetime of a power supply system. At the same time, apart from the analysis of the detailed functioning of converters, the investigation of interactions of converters, e.g. in micro and pico-grids will also gain significantly in importance. The power electronics converter will then become a standardized functional block, similar to integrated circuits in analogue and digital technology, which several decades ago arose from discrete circuits. The realization of smart grids and ultimately smart multi-energy carrier grids, which apart from electrical energy also integrate other energy carriers, will hence be supported to a significant extent. The necessary expansion of technological competence from the components to the system and in addition to other disciplines apart from power electronics, however, presents a massive challenge, but on the other hand offers fascinating possibilities for creativity, technological innovation and ultimately economic success!