General Properties, Scaling Laws & Inherent Limitations of Energy Electronics

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Abstract - Power electronics converters are utilized in a multitude of applications for the electronic control and conversion of electric voltage and power and are reaching an increasingly higher performance, i.e. efficiency and power density at reduced costs. For each application, varieties of different converter topologies, semiconductor technologies, modulation- and control schemes, and ways of practical realization are feasible and the related details are intensively discussed at international conferences. By contrast, this talk describes the general background valid for all types of power converters, by means of elementary physical considerations and scaling laws, in order to establish a general understanding of fundamental limitations and potentials of advanced concepts such as, e.g., cellular multi-level converters.

The introductory part of the presentation explains the advantages of AC systems over DC systems in the early days of electric energy utilization and retraces the development of AC electric energy distribution in large steps. The second part focuses on the analysis of a single-phase AC/DC converter with regard to power flow pulsation and electromagnetic emissions, discusses principle advantages of SiC over Si power semiconductors, and defines the characteristic impedance of a converter, which is important e.g. for the evaluation of low-inductance packages and interconnections. The presentation continues with considerations on impedance matching, by means of parallel or series operation of multiple units, and a discussion of the advantages of phase-shifted operation, i.e. interleaving, with regard to switching losses and filtering effort. The third part illustrates the implications of main loss components on the resulting converter efficiency characteristic, discusses passive and active methods to filter the power pulsation with twice the mains frequency, presents a converter design by means of multi-objective optimization, and introduces the 'Technology Node' as a measure for characterizing the technological level of power electronics converters. A discussion of the 'Hype-Cycle' that is typically traversed after the introduction of a new technology, an outlook to important future technology domains of power electronics, represented in the form of a technology-S-curve, and an indication of future applications of power electronic converters, e.g. in the fields of green data centers, electric mobility, and More Electric Aircraft are concluding the talk.