Abstract

The principle objectives of this research are to seek alternative avenues to enhance qualitative and quantitative understanding at a fundamental level of the internal electromagnetic environment in reactive components during energy flow, conversion and transfer processes. That can be seen, for example in power electronic converters. The study of these fundamental energy processes is necessary, as it has been documented in literature that the adoption of wide-bandgap (WBG) semiconductors and the increased switching frequencies they enable, are facilitating the miniaturisation of components which leads to increased power densities. Consequently, this means that multiple components or converter functions can be packaged in discrete or integrated power modules. The spatial arrangement of the components in these densely populated power modules means that greater emphasis needs to be placed on the internal electromagnetic structure and environment of the various components. The ramifications of these environmental conditions are seen as fundamental switching limits or bottlenecks to the maximum realisable switching frequency. The implications of these limits are seen as increases in switching frequency passed a certain threshold provide diminishing returns in terms of power density as well as negatively affecting converter efficiency. From these observations and the ones made in contemporary literature, it has been established that a more wholistic approach to improving power electronic converters that is not solely dependent on the switching function is necessary for improvements in contemporary as well as future converters. Consensus from various sources in literature suggest that a fundamental breakthrough is required in the power passives i.e. reactive components of the converter before appreciable performance gains are established. In this work the fundamental energy manipulation interactions between electric and magnetic energies in these power passives i.e. reactive components will be analysed as a potential means of providing this paradigm shift. Increased insight and understanding of the energy manipulations processes in reactive components may provide the foundational framework for improved power passives to be developed in future

These energy manipulation processes are examined by considering the common LC Resonant tank and *Twin Capacitor* topologies. These topologies are selected because they are fundamental examples of electric to magnetic and electric to electric energy manipulation processes respectively. It is shown in this work that analysing the *Twin Capacitor Paradox* with conventional circuit theory leads to the violation of conservation of energy, highlighting the limitations in circuit theory in modelling energy manipulations. In this research, the reactive components are modelled using lossless 1-D TLM Link-Line equivalent transmission line models. The implications of this mean that the interconnection of two components effectively forms a cascaded transmission line with three principle nodes. The *Energy Conversion Efficacy* (ECE) quantification metric is coined to establish the quality of an energy manipulation process. ECE is principally concerned with establishing the maximum amount of energy that can be transferred from a primary energy store to a secondary energy store and the maximum amount of energy that can be reconstituted back into the primary energy store in the original form. Additionally, the term *Fragmentation* is coined to better explain some of the *diffusion* and *scattering* effects that may take place at the interface or junction of the transmission lines segments with arbitrary lengths. Consequently, the implications this imposes on ECE are subsequently analysed.

The nature of this research is purely theoretical and as a direct consequence; the contributions arising as a result are purely theoretical. A major contribution arising from this work is the derivation of an alternative solution to the *Twin Capacitor Paradox* in which the perceived loss or deficit in energy is found to be present in the self-inductors of the respective capacitors. It is also shown in this work that a condition for maximum ECE can only be achieved provided both transmission line segments have identical impedances and propagation delays. If the ratio of propagation delays in the cascaded transmission line structure is increased an accompanying increase in generated noise will also be seen.