Advances in PV Inverters

Renewable energies have experienced a significant growth and importance in the last two decades, of which energy from photovoltaic plants are a major contributor. Since solar cells have low efficiencies themselves, however, the necessity of high efficiency power converters at low cost and preferably low complexity leads to new research demands. This is especially true in the field of low cost residential PV inverters where efficiencies are used as major selling arguments. Traditional converter topologies equipped with conventional Silicon based semiconductors to date reach their limitations and new approaches are necessary. Therefore, research areas typically focus on both new topologies and utilizing more advanced semiconductor devices. To this end, semiconductor devices made of Silicon Carbide have been gaining increasing interest in the last two decades after the successful commercialization of high voltage power diodes. By now, the performance potential of switching devices made of Silicon Carbide is commonly accepted, though they have not found commonplace usage within commercial converter systems for several reasons, among others reliability, availability/cost and gate driver complexity. Therefore, more complex Silicon based converters can be used instead to achieve lower semiconductor losses. While there is no absolute solution in which direction to go to achieve the aforementioned design goals, this dissertation will thoroughly investigate two potential approaches and discuss their trade-offs. The contributions are:

- Comprehensive loss analysis and identification of major loss contributors within T-Type converter topology operating in inverter and rectifier context.
- Evaluation of the use and loss benefits of Silicon Carbide switching devices in the T-Type structure.
- Thorough investigation of the Hybrid-Neutral-Point-Clamped (Hybrid-NPC) topology as an alternative for the Silicon Carbide based T-Type converter.
- Alternative methodology of semiconductor loss model validation by experimental means. As to the advanced three-level T-Type converter topology, its unusual operation mode is thoroughly described identifying its limitations for high efficiency operation. With these results, the first approach utilizes low loss switching devices and their influence on the semiconductor loss behavior is analyzed. The results show that, for near unity power factor operation, a replacement of only two switching devices per phase leg can greatly reduce the semiconductor losses. The Hybrid-NPC converter can be seen as an attractive and cost competitive alternative to the Silicon Carbide based converter, also allowing to overcome the major drawbacks with the conventional Silicon IGBT based T-Type structure. Both alternatives are based on a semiconductor/topological level and thus this is where the loss reduction occurs. The difficulty in experimentally evaluating only the semiconductor losses within a converter operating context is addressed in this work by presenting an alternative measurement approach. Using known heat loads, and a careful calibration procedure on the device heat sink, analytically obtained semiconductor loss models based on datasheet information and in-circuit switching transitions measurements can be experimentally verified and thus a fair performance comparison between two approaches is enabled.

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