Analysis and study of dual-frequency resonant inverters for induction heating

Abstract

The dissertation is concerned with an analysis and experimental study of novel single-inverter solutions applied to dual-frequency induction heating. These systems are characterized by their ability to output current containing one or two fundamental harmonics. Such functionality allows formation of temperature field distribution near the surface of heated elements of irregular shape, e.g. gear wheels before the hardening process.

The thesis begins with an analysis of a series RLC and series-parallel 2F circuits, described per unit, in two variants: a) related to the equivalent load resistance, b) related to the characteristic impedance. Within the same chapter an analysis of the possibility for controlling the output power in the frequency domain was conducted. The analysis has recognized a prevalent issue in solutions with a single matching transformer. Such a case does not allow for matching of impedance minima for both harmonic components. Two novel topologies 2T1C and 3T are proposed, where this issue is not present.

Furthermore, equivalent circuits showing current flow in 2T1C and 3T circuits are described, with circulating current, which does not transfer active power to the load, taken into account. An equivalent circuit model was created, allowing formulation of the circulating current. Subsequently, the series-resonant inverter was described (H-bridge) and a description of commutations in different operating conditions was provided. This model is a reference for commutations in 2T1C and 3T topologies. Power losses were also determined for a transistor half-bridge in a reference model as described above.

A customizable laboratory model was constructed for experimental verification. The inverter was built with half-bridge modules, connected differently depending on the tested topology. A series-parallel resonant 2F load circuit was modified mostly in terms of the matching transformers turns ratios and numbers of cores. The analyzed topologies were tested in mono- and polyharmonic operation. Characteristics of power as a function of the switching frequency were measured, along with corresponding efficiency characteristics. High efficiency operation (η>97 %) of the proposed 2T1C and 3T topologies was deemed possible at nominal power level. The possibility of controlling the output power of both harmonic components separately in the range of 30-100% was also proven.