

Abstract

The work in this thesis mainly focuses on the design and development of new coil structures which provide high coefficient of coupling for large air-gaps, and low variations in output voltage, output power and efficiency under horizontal misalignment condition. Attaining high coupling coefficient for large air-gaps improves overall efficiency, output power transfer capability, low voltage stress across components, and lower leakage fields around the charging area. With conventional coils, achieving high coupling coefficient for large air-gaps (applications such as in drones and EVs) is quite challenging due to physical limits imposed due to space constraints. To increase the coupling factor, a single sided flux coupler is developed that enhances the nominal coupling factor, also yielding better flux density towards receiver (RX) coil. The proposed coupler is auxiliary coil based square coupler (AXBSC). The basis of AXBSC is conventional square coil which is evolved by adding auxiliary coil around ferrite core to enhance the flux linkages and collection by effectively magnetizing the ferrite cores. This thesis investigates the systematic design and geometric optimization using finite-element analysis (FEA) simulations. The performance comparison of AXBSC with existing coil structures (circular, square and DD coil) is presented in simulation in terms of self-inductance, mutual inductances and coupling factors against variation in vertical distances. To demonstrate the efficacy and suitability of AXBSC coupler in WPT systems, 150 W laboratory prototype is developed and simulations results are validated through experimentation.

The AXBSC coupler enhances the nominal coupling factor but rate of change of mutual inductance profile under misalignment conditions is very high, as a result the output voltage, output power and efficiency of system changes drastically even for small horizontal misalignment cases. To misalignment issues, a new modified TX coil structure is evolved from conventional square coil by adding tertiary coils. Initially, the improvement is achieved along y-axis only and later this concept is extended in other directions. Here, the concept of magnetic field shifting is adopted where magnetic field is shifted in the desired direction with the help of tertiary coils. Furthermore, coil polarity arranger (CPA) block and misalignment detection circuit (MDC) is proposed to implement this technique. The geometric design is carried out through FEA simulation and the performance comparison is carried out with existing coil structures. As compared to other structures, the proposed transmitter (TX) coil structure under misalignment scenarios outperforms

the other WPT coil structures. The modified TX-coil structure is effective in mitigating the fluctuations in output power and voltage within 5% tolerance up to 60 mm against lateral misalignment (i.e., 30% of coil size). A 120 W laboratory prototype is designed and built to illustrate the functionality of the formulated TX-coil and misalignment detection circuit, for a 36 V input and a 48 V output. The system delivers an output power of 105 Watts with a nominal efficiency of 86 % when operating under a 100 mm air-gap (half the size of the coil). The system upholds consistent efficiency, output power, and output voltage within a tolerance of 5% up to 60 mm of misalignment (a total range of 120 mm range) along y and x-axis. The experiments are conducted for misalignments in diagonal directions and the results indicated that the range has reduced to 80 mm.