Wireless Power Transmission for EbikeCharging System

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Abstract: In this paper a Serie Series Resonant Inductive Power Transfer (SSRIPT) circuit for wireless ebike battery charger is proposed. The system architecture is accurately described, while highlighting the main features of a suitable design procedure. A simulation model is developed in PSIM software to verify the circuit is fully functional. A full scale proptotype of a 80 W battery charger has been realized, with particular attention to the layout optimization in order to minimize weight and volume of the final product. Moreover, it is equipped with two XBee-Pro S2 radios to also obtain a wifi communication between the primary and secondary side. Experimental tests carried out on the prototype confirm the effectiveness of the proposed design and control approach.

1. INTRODUCTION

Wireless Power Transfer (WPT) is a well-known technology which enables, by means of electromagnetic field, a power source to transmit energy to an electrical load across an air gap, without interconnecting cables. The two main methods for WPT are: radiative (i.e., radio frequency (RF) based) and non-radiative (i.e., coupling-based) [1]. The first one is used in very low power application due to the safety issue arising from the exposure to RF waves, while the second method is based on the coupling of magnetic field between two coils, so overcoming the previous issue. It is possible to have a capacitive or inductive coupling WPT. This latter represents the favorite choice for its reduced effect on the human body thanks to the lower intensity of the electric field. The WPT technology based on inductive coupling is called Inductive Power Transfer (IPT), which has assumed, in the last years, a relevant role in several fields such as biomedics, consumer electronics (e.g. smartphone), clean factory automation and green mobility [2],[3]. It is clear that IPT applications can spread from low-power to medium-high power systems [4]. As a consequence, the research interest is now focused on the improvements in terms of power efficiency and possible transmitting distance [5]. In particular, the use of resonance circuit topology, for both the primary and secondary side of an IPT system, can lead to better performance for larger separation distance and for power transfer capability, if the operating frequency exploits the resonant frequency. This circuit topology is referred as RIPT (Resonant Inductive Power Transfer), which is considered an excellent solution for midrange wireless powering [5]. It consists of two independent mutually coupled electrical circuits (i.e., primary and secondary side), basically representing a two-coil system, which is a loosely coupled transformer [6]. This latter provides a large leakage flux, so resulting in poor coupling coefficient or rather reduced efficiency. In order to overcome this negative effect, a compensation network is required, thus capacitors can be connected in series or parallel with the coils. Four main circuit topologies based on series and/or parallel LC resonant circuit configuration can be identified: series-series (SS), series- parallel (SP), parallel-series (PS), and parallel- parallel (PP). In all cases, the fundamental requirement for the compensation capacitor is to resonate with the primary and/or the secondary inductance [2], thus properly tuning the system performance. The primary compensation network is useful to minimize the VA rating of the power supply, so improving the power factor, while the secondary compensation network acts to enhance the power transfer capability. Among the four aforementioned circuit topologies, the most used is the series-series because of better performance in terms of efficiency [7]. The SS-RIPT topology represents a double-tuned circuit (i.e., a resonant tank is present on each side of the circuit) operated at the resonant frequency ω 0, which is the zero-phase angle (ZPA) frequency. Nevertheless, in such a circuit, it is possible to have more than one zero-phase angle (ZPA) frequency or rather multiple resonant frequencies exist. This phenomenon is known as bifurcation [8], and can be observed when the coupling coefficient k is greater than a critical value, kc. In order to guarantee stable circuit operation the bifurcation should be avoided, so particular care should be taken to properly design the magnetic components. Nowadays, the most promising use of RIPT circuit is the contactless battery charging, which falls into the so-called near-field applications. In this paper, a RIPT circuit for e-bike charging station is proposed to favor the use of a bike sharing service in order to enhance the green inter-mobility in urban context. The main advantages are related to the absence of a plug-in, so resulting more user-friendly than traditional system, while also assuring a higher safety due to the galvanic insulation between the primary (e.g., the charging station) and the secondary circuit (e.g., e-bike). This latter feature also ensure a greater reliability, ease of maintenance and longer product life-time. Moreover, the galvanic insulation and thecorresponding absence of electrical cables and mechanical contacts allows the system to be operated in ultraclean as well as ultradirty environment [9], so accomplishing with the requirements of an out-door service. This paper is particularly devoted to the e-bike charger design in terms of architecture and hardware implementation in order to provide a final product of reduced weight and dimensions, which could be easily adapted to traditional e-bike and e-bike station as retrofit system. In addition to the WPT, the proposed designalso provides a wireless communication system consisting of two XBee-Pro S2 radios based on the ZigBee protocol, useful to transmit measured data from the secondary to the primary side for control purpose.

2.LITERATURESURVEY

Wireless charging is a technology of transmitting power through an air gap to electrical devices for the purposeof energy replenishment. The recent progress in wireless charging techniques and development of commercial products have provided a promising alternative way to address the energy bottleneck of conventionally portable battery-powered devices. However, the incorporation of wireless charging into the existing wireless communication systems also brings along a series of challenging issues with regard to implementation, scheduling, and power management. In this paper, we present a comprehensive overview of wireless charging techniques, the developments in technical standards, and their recent advances in network applications. In particular, with regard to network applications, we review the static charger scheduling strategies, mobile charger dispatch strategies and wireless charger deployment strategies. Additionally, we discuss open issues and challenges in implementing wireless charging technologies. Finally, we envision some practical future network applications of wireless charging.

Wireless power transfer (WPT) is an emerging technology that can realize electric power transmission over certain distances without physical contact, offering significant benefits to modern automation systems, medical applications, consumer electronics, etc. This paper provides a comprehensive review of existing compensation topologies for the loosely coupled transformer. Compensation topologies are reviewed and evaluated based on their basic and advanced functions. Individual passive resonant networks used to achieve constant (load- independent) voltage or current output are analyzed and summarized. Popular WPT compensation topologies are given as application examples, which can be regarded as the combination of multiple blocks of resonant networks. Analyses of the input zero phase angle and soft switching are conducted as well. This paper also discusses the compensation requirements for achieving the maximum efficiency according to different WPT application areas.

3.PROPOSED METHOD

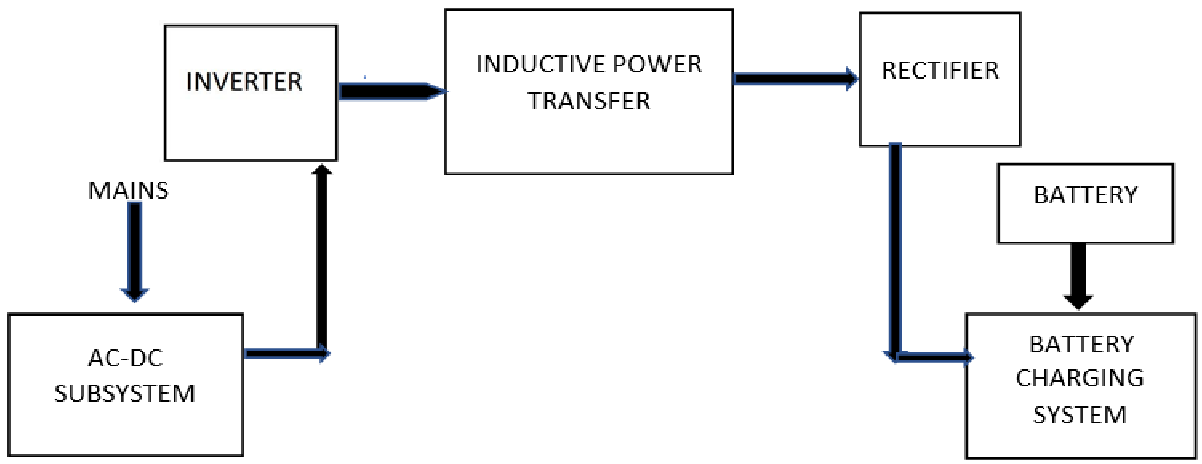


Fig 1.Block Diagram of wireless transmission for ebike charging system

The main power source is the utility grid (i.e., 230 Vrms, 50 Hz), then a AC-DC converter provides the input DC voltage Vin. The half-bridge stage converts the obtained DC voltage into the high-frequency AC voltage vp. As aconsequence, the high-frequency AC power resonates in the primary compensation tank and primary coil with a resonant frequency f0 tuned to the switching frequency at which the power semiconductor devices are operated [6]. The high-frequency AC power flows in the primary loop coil, so generating a magnetic field around it, which is induced at the secondary loop coil. The induced high-frequency AC voltage, vs, is, then, converted to DC voltage by means of a diode-bridge rectifier with a capacitive filter, Cout. The output DC voltage Vo is applied to the battery pack. In such a circuit, the coupling between primary and secondary side is weak, thus resulting in reduced power transfer. In order to overcome this issue a proper compensation of the leakage inductance should be adopted by using capacitive tank. The primary compensation network is useful to reduce the needed source VA rating with the aim of obtaining unity power factor.

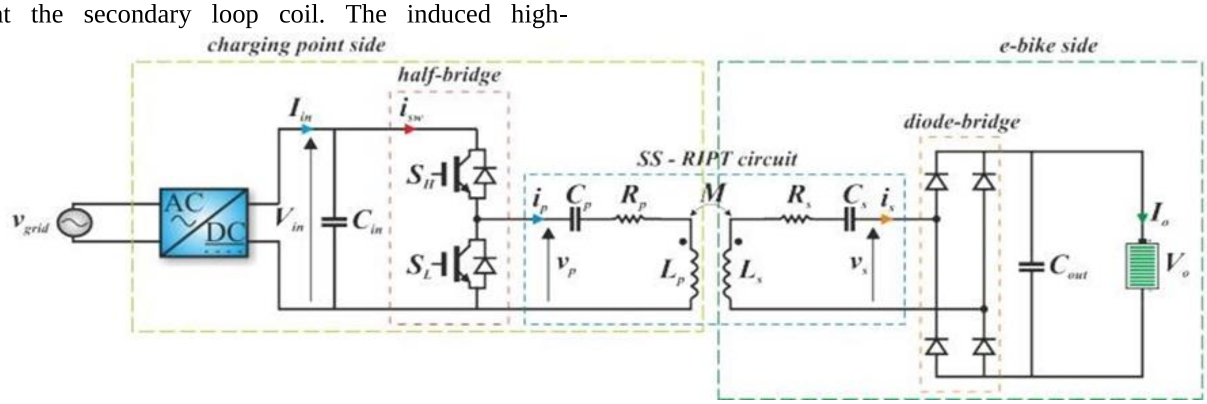


Fig 4.Circuit Diagram

4.SIMULATION RESULTS

Fig. 5 shows the steady-state behavior of the main circuit voltages and currents, obtained by means of PSim simulator. The Fig. 7.a) reports the primary and secondary current waveforms, which both result almost sinusoidal. The primary and secondary voltages are shown in Fig. 7.b) and, as expected, they result in high- frequency (i.e., resonance frequency) square-waves. In particular, the primary voltage is a positive quantity spanning from zero to Vin as per the connection of the half-bridge. Fig. 7.c) highlights the stable behavior of the output voltage, which reaches the desired voltage level of 42 V

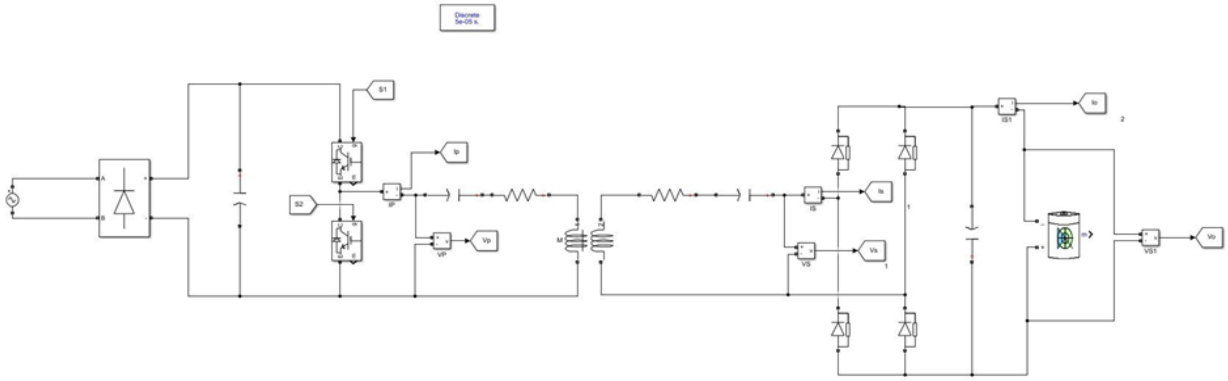


Fig 5. MATLAB/SIMULINK circuit diagram of the proposed system

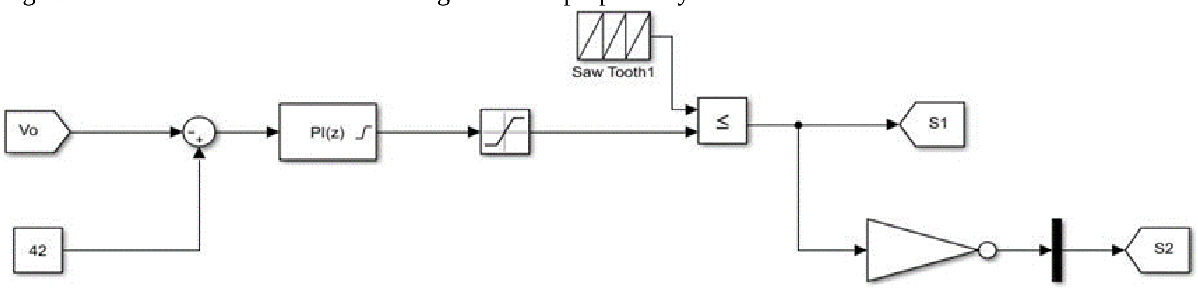
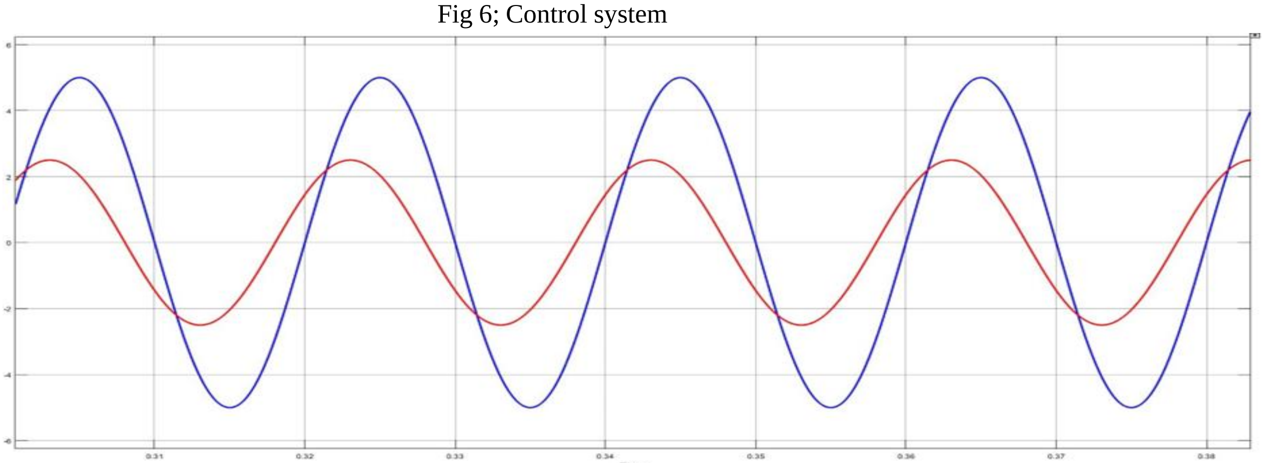
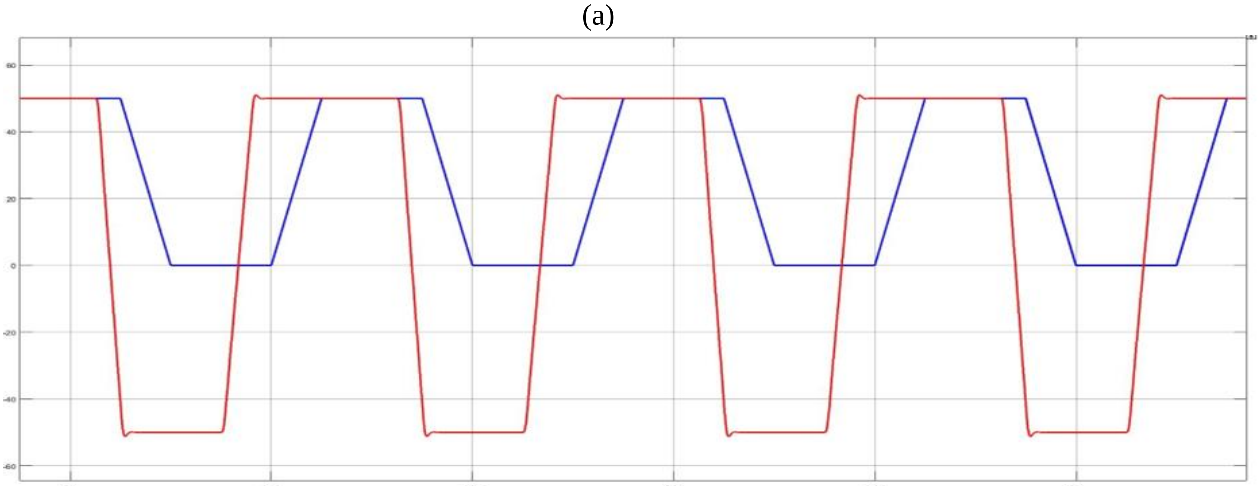


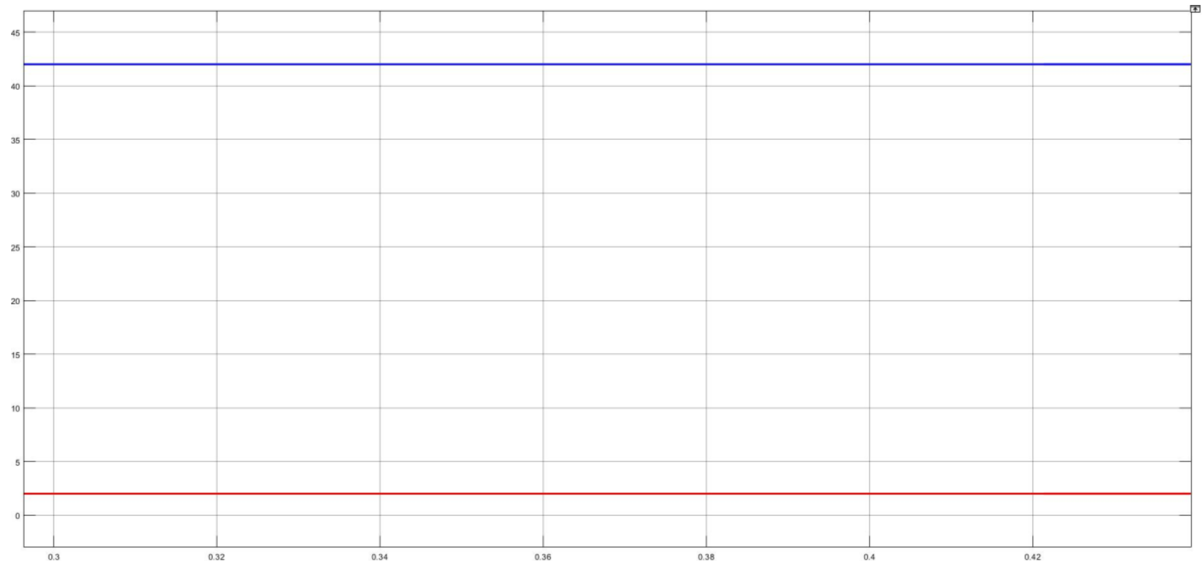
Fig 6; Control system



(a)



(b)



(C)

Fig. 7. Simulated performance: a) primary and secondary currents; b) primary and secondary voltages; c) load voltage and current.

5.CONCLUSION

This paper has been focused on the design and control of an e-bike battery charger based on a wireless power transfer circuit topology. In particular, a SS-RIPT circuit for e-bike charging station is proposed to favor the use of a bike sharing service also thank to a more user-friendly system than traditional ones. A proper system description has been provided in order to highlight the main features of the chosen circuit architecture, so determining the suitable design procedure. A numerical analysis has been conducted to show the correctness of the aforementioned design procedure, while also testing the control strategy. The 80 W e-bike battery charger has been built and the simulation results clearly show the effectiveness of the proposed design and control approach.

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