15/09/2022

Subject: Response to Major Revision of 22-TIE-2285

Dear Prof. Radu Bojoi

Thank you for your letter and the opportunity to revise our paper titled "Carrier Phase Shift Method of SPWM for Concurrent Wired and Wireless Power Transfer Systems". The revisions offered by the reviewers have been helpful, and we also appreciate your insightful comments. The paper has been improved by the reviewers' comments. We have included our response to the reviewer's comments immediately after this letter. The modifications and additions are highlighted in the main text. We deeply appreciate your consideration of our manuscript.

Kind Regards

Dr. Ozan Keysan

Reviewer 1:
The authors propose an interesting concurrent wired and wireless power modulation method. The effectiveness of the proposed method has been proved by experimental results. Here are some suggestions.

- **Response**: Thank you for your constructive comments. We addressed your comments and made the required additions to the paper, as given below.

1. Similar multifrequency generation methods have been proposed in the following papers. Please clarify the differences and novelty of the proposed method. [R1] C. Xia, N. Wei, H. Zhang, S. Zhao, Z. Li and Z. Liao, "Multifrequency and Multiload MCR-WPT System Using Hybrid Modulation Waves SPWM Control Method," IEEE Transactions on Power Electronics, vol. 36, no. 11, pp. 12400-12412, Nov. 2021. [R2] Y. Liu, C. Liu, X. Gao and S. Liu, "Design and Control of a Decoupled Multichannel Wireless Power Transfer System Based on Multilevel Inverters," IEEE Transactions on Power Electronics, vol. 37, no. 8, pp. 10045-10060, Aug. 2022.
   - **Response:** [R1] (Reference 10) and [R2] (Reference 12) are now included in the Introduction. Section VI is expanded to discuss the differences and novelty of the proposed method.
2. According to Fig. 5, the WPT power can not be fully controlled, especially when the modulation index (ma) is near 1. Does it mean the operation region of the motor drive is narrow? Please illustrate its influence.
   - **Response:** Sorry for the confusion. The operation region of the motor can be expanded to the full range if the WPT gain is kept between 0.28 and 0.45. To discuss this issue, Section II Part C is expanded, and the gain/power restriction of the WPT system is now shown in Fig. 5.
3. In Fig. 12 (a), the primary WPT current (ITX) contains many harmonics. However, the models in Section III only consider the fundamental harmonics. The additional harmonics may lead to inaccurate models. Are these harmonics caused by the proposed control method? Please give a more detailed analysis.
   - **Response:** Thank you for your comment. Additional third and fifth harmonics exist, which deviates the output voltage from the desired values of the mathematical model. This deviation is compensated by the frequency detuning method. They are discussed in Section IV, Section V Part C, and Section V Part F.
4. In the experimental part, the waveforms of the output voltage and secondary current of the WPT parts should be given. Also, the dynamic waveforms under the DC reference voltage change should be given.
   - **Response:** Thank you for your comment. The output voltage and secondary current are now included in the experimental results (Fig. 10). Moreover, DC output reference change is given in Section V Part D (Fig. 12).

Reviewer 2:

This is an interesting and well-developed work. In this paper, a novel method for driving the motor and wirelessly suppling power for the auxiliary system is proposed. To validate the propositions and discuss the operation characteristic of the circuit, theoretical analyses, simulations and practical results are presented. However, there are still some issues for the authors to polish the paper as follows. Moreover, before this work is published, some details should be provided.

- **Response**: Thank you for your constructive comments. We addressed your comments and made the required additions to the paper, as given below.

1. I recommend explaining some actual use cases of this contactless slip rings (CSR) systems in the introduction to engage non-expert readers, including how the CSR works in the application? How much power required by the auxiliary system?

   - **Response:** Thank you for your comments. Several CSR studies are now discussed, and the operation range of such systems is defined in the Introduction Section.

2. In the experimental results, seems there is nearly no difference between the inverter drives the motor independently and drives both the motor and the WPT system concurrently. But how about the efficiency? Will the efficiency be affected by add the WPT system apparently? Moreover, will the phase shift of the carrier wave will affect the efficiency for driving the motor?

   - **Response:** Thank you for your comment. Efficiency and drive losses are measured experimentally and given in Section V Part E. Furthermore, the impact of the carrier phase shift method is discussed in Section VII Part B.

3. As the authors mentioned, the switching frequency of a conventional motor converter is always about 20kHz or even lower. But in this paper, the operation frequency is set at 65.85kHz. Indeed, with the SiC or GaN switches, the selected frequency may be achieved without apparent efficiency decreasing. However, is there any advantage or disadvantage caused by increasing the operation frequency to 65.85kHz? Or actually you can selected a lower frequency. Please give some analysis or introduction from the aspect of efficiency, harmonic component, control complexity and so on.

   - **Response:** Sorry for the confusion. The issues that should be considered in the selection of switching frequency are now discussed as a new part in Section VII Part D.

4. The WPT powered auxiliary system is an AC load? If not, the authors should provide some waveforms about the DC voltage and current after the high-frequency rectifier. With the SPWM converter, there may be an obvious fluctuation or ripple on the DC voltage of the load equipment, which is undesired.

   - **Response:** Thank you for your comment. Auxiliary systems are DC loads, and DC output voltage is now measured in the experimental results (Figures 10 and 12). The effect of low-frequency fluctuation is now discussed in Section VII part C.

5. Please improve the graphs and figures. Some of the figures are not clear, and some font in the figures are incongruous.

   - **Response:** The quality of the figures and graphs (Fig. 1, Fig. 2, Fig. 6, Fig. 9, Fig. 11, and Fig. 15) are enhanced.

Reviewer 3:

An interesting design was presented in this manuscript, which implemented the concurrent operation between the motor and wireless power transfer. But some features need to be discussed further and more experimental results are required such as more current and voltage waveforms.

- **Response**: Thank you for your constructive comments. We addressed your comments and made the required additions to the paper, as given below.

1. When discussing whether the scheme has the application prospect, some questions should be solved. The frequency of the motor current is low in Fig.10, only 20Hz is presented (motor speed is not high). What can happen if the motor speed changes among the whole operation range. For example, from 0 to 3000 RPM? Whether the scheme can work normally in this situation?
   - **Response:** Thank you for your comment. The effect of carrier phase shift is investigated for varying fundamental frequencies of SPWM between 0-50Hz and discussed in Section V Part D. Fig. 13 shows that the proposed system is not affected by the fundamental frequency, and Fig. 5 shows the operating limits of the WPT system to operate under any modulation index.
2. In Fig.11, carrier phase shift is regulated to realize a stable power output. How is it implemented? Details should be presented.
   - **Response:** Thank you for your comment. The control scheme of the WPT system is now included in Section IV. Furthermore, the implementation of the proposed control method of carrier phase shift and frequency detuning is given in Section V Part F.
3. For equations (3-5), simplified derivation or reference is suggested to be presented.
   - **Response:** Sorry for your confusion. The equation (3-5) is explained in Section II Part B, and Fig. 3 is added to illustrate the phasor operation.
4. Because the power supply of WPT is from phase A and phase B of the inverter output, will this cause the three-phase imbalance of power supply?
   - **Response:** Thank you for your comment. You are right this will create an unbalance. The effect of this unbalance in efficiency and operating temperature is now discussed in Section V Part E.
5. How will the three-phase voltage harmonics of the motor be affected after applying the carrier phase shift strategy? When the motor is running at high speed, will the harmonic voltage introduced by carrier phase shift modulation affect the motor?
   - **Response:** Thank you for your comment. The effect of carrier phase shift method on the motor is now discussed in Section VII Part B. Also, the independence of the proposed method with the operating speed is shown in Fig.13.
6. The challenge mentioned in Section III is how to determine the phase shift angle to keep the output power constant. But the paper does not say how to regulate it. Besides, equation (6) is established on the premise that switching frequency harmonics are orthogonal to its sideband harmonics. Please carefully verify whether they are orthogonal
   - **Response:** Sorry for the confusion. The orthogonality issue is now discussed from the perspective of power conservation in Section II Part C. Furthermore, a hybrid carrier phase shift and frequency detuning control scheme to regulate the output voltage is introduced in Section IV and Section V Part F.

Reviewer 4:

In the article authors presents an approach for concurrent power transfer to wired and wireless systems (systems used in contactless slip rings (CSR), which transfer power to auxiliary loads such as sensors, radars, and IoT devices) using just a single inverter. The control concept proposed in the article uses the carrier phase shift (CPS) method, which independently controls the output voltages of the inverter at the fundamental frequency and the switching frequency. The proposed method is tested in the article analytically for sinusoidal PWM (SPWM) and experimentally using a 3-phase 3-wire GaN-based inverter and a 3-phase motor. The authors of the article should refer to the following questions and comments.

- **Response**: Thank you for your constructive comments. We addressed your comments and made the required additions to the paper, as given below.

1. Fig. 1a shows a schematic diagram of the proposed power supply system. It shows that the second circuit powered by the converter is a rotating circuit. The description of the system did not refer to this issue at all. Please refer to this issue, is the Rx coil a coil rotating at the speed of rotation of the rotor? Please indicate an example of such a load.

    - **Response:** Sorry for the confusion. A few examples used in the industry for such rotating loads are now included in the Introduction Section.

2. Figures are cited incorrectly. First, the text cites Fig. 3 and then Fig. 2. Authors should renumber the figures.

    - **Response:** Thank you for your comment. The cross-references were checked and updated.

3. Table I is not quoted in the text. Instead, table II-A is cited. Authors should correct the numbering of the table in the text of the article.

    - **Response:** Thank you for your comment. The cross-references were checked and updated.

4. It is not entirely clear what is shown in Fig. 4d). What is this signal "The waveform of the switching frequency and its sidebands of (VAB)". Please provide a more detailed comment. What mathematical dependence does this result from?

    - **Response:** Sorry for the confusion. Equations (3), (4), and (5) are now discussed in Section II Part B, and Fig. 4 (which is now cited as Fig. 3) is replaced with a new diagram to clarify phasor operations.

5. What is the rotational speed of the electric motor? How does the power supply voltage of the WPT depend on the speed of the electric motor?

    - **Response:** Sorry for the confusion. The rated motor speed is 1425 RPM (25 Hz fundamental frequency, and the induction machine has slip) in the experimental setup. Fig. 5 is updated to show the achievable gain under any modulation index. Fig. 13 shows the WPT power is independent of the fundamental frequency of SPWM.