12 June 2022

Subject: Response to Major Revision of JESTPE-2022-03-0351

Dear Jessica Uherek

Thank you for your letter and the opportunity to revise our paper titled "Fault Tolerant Multi-Tx/Multi-Rx Inductive Power Transfer System with a Resonator Coil". 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 the 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:
Thank you for your constructive comments. We address your comments and make the required additions to the paper as given below.

1. The idea is effective, but the necessity and analysis is inadequate.

   - **Response:** Thank you for your comment. The analysis parts are improved, and the contribution of the paper is emphasized in the introduction section. Section V and section IX are now included, and section VI is extended based on your comments.

2. In page-1 line 39, "a multi-Tx/multi-Rx IPT system is introduced for dynamic applications". Please explain how to use this method in dynamic applications.

   - **Response:** Sorry for the confusion. Dynamic applications include moving or rotating parts of Tx or Rx modules such as field excitation systems, radar systems, or electric vehicle charging systems. This part is now explained in the introduction section.

3. The premise of this proposed method is that Rx and MSR coils are relatively stationary, which is only satisfied in slip ring applications. But, the power in this applications is small, and why use multi-Tx/multi-Rx IPT system in slip ring applications?

   - **Response:** The main purpose of multi-Tx/multi-Rx IPT systems is to increase the reliability and fault tolerance of the system. The parts discussing the purpose of the proposed system are extended in the introduction section and section II. The proposed system is compared with existing 1Tx/1Rx studies in section IX.

4. What is the influence of coupling between multiple primary coils or multiple secondary coils? It will influence the resonant state. Please explain in this paper.

   - **Response:** Thank you for your comment. The cross-couplings between Tx or Rx modules change the resonant frequency and voltage gain, as now discussed in detail in Section VI (subsections C-1 and C-2). Moreover, the coil design structure procedure that minimizes these undesired couplings is now included in Section VII.

5. In Fig. 6 and Fig. 11, it seems that the coupling between primary and secondary coils is non-negligible, and what is the influence of this coupling? Please explain.

   - **Response:** Thank you for your comment. The direct couplings between Tx and Rx modules change the resonant frequency and voltage gain. The effect of this coupling can be compensated by varying mutual inductances between Tx-MSR and Rx-MSR. This is now addressed in section VI (subsection C-3). Moreover, the couplings in the proposed coil structure are now discussed in detail in Section VII and also in the experimental results.

6. When secondary coil are open-circuited, the resonant is changed. How to ensure ZVS operation in primary side? Variable frequency? How to realize variable frequency control?

   - **Response:** Thank you for your comment. The bifurcation-free operation under the open-circuit fault of Rx is now discussed in detail in section IV and the changes are highlighted.

Reviewer 2:

This paper proposed a multi-transmitter/multi-receiver IPT system with a middle-stage resonator, which can balance the power distribution and increase the reliability and fault tolerance. However, I still have some questions about your research. Please follow my comments below.

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

1. As far as I know, the structure of the single-Tx/single-MSR/ single-Rx system in this paper is known as relay coil in the IPT system. What's the difference between them? or what's the improvement of your research compared to well-known relay coil?

   - **Response**: This paper aims to pass from the Single-Tx/single-MSR/ single-Rx, conventional relay coil, to multi-Tx/single-MSR/multi-Rx by guaranteeing bifurcation-free operation so that fault-tolerance increases. The contribution of the proposed system is now extended in the introduction section.

2. In the Section II.C, "Introducing an MSR eliminates the direct couplings between Tx and Rx modules". Can you explain what's the reason? Besides, has this paper considered the couplings between TXs modules? and considered the couplings between RXs modules?

   - **Response:** Sorry for the confusion. A new section on the coil design procedure (Section VII) is now included. Also, the effect of these couplings are now discussed explained in section VI (subsection C).

3. The description of the multi-receiver is confusing because this system has only one load. In the Fig.11, I can get that the MSR coil is the LR (TX), but I can't understand the "Rx/MSR coils (HFCI)". Whether the LRX is similar in the shape to the Tx coil? Or the LRX is just an inductor designed by PQ 3535? Therefore, the definition of multi-receiver is confusing.

   - **Response:** Sorry for the confusion. Multi-receiver is connected to parallel, creating a modular structure that increases the fault tolerance. A new section coil design procedure (Section VII) is now included. We prefer using a coupled inductor with PQ 3535 for Rx modules, but Rx coils can also be designed like Tx coils.

4. The analysis of currents sharing is not clear. It is necessary to give the derivation process of the currents sharing. It is the main contribution of this paper.

   - **Response:** The analysis of the current sharing between parallel-connected Rx modules is now included as a new section (Section V).

Reviewer 3:

In this article, the authors have presented an inductive power transfer system consisting of multiple transmitters, multiple receivers, and an intermediary resonator to improve the system's reliability and make the transmitter coils further independent from the receiver coils. The idea presented in the paper is interesting, and with proper justification, it can have a good level of contribution to be implemented in the industry. Please, find my major and minor comments below:

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

1. The idea of using brushless-field-excitation systems in synchronous generators is pretty mature and raised many years ago. How the proposed concept can compete with the conventional brushless techniques should be studied in detail, and the proposed method should be compared with optimized conventional brushless field excitation systems.

    - **Response:** Thank you for your comments. A comparison with existing work in the literature is now presented in section IX. The proposed multi-Tx/multi-Rx system increases the fault tolerance of the system compared to conventional technologies.

2. Providing the system with separated transmitters and merging their effect through a relay (resonator) coil to make the transferred power relatively uniform is an interesting idea.It seems that the system provides good reliability for the transmitter and receiver sides; however, the failure of the relay can question the whole performance of the system. The failure of the repeater coil can be similar to that of the single transmitter single receiver system.In other words, in terms of coil arrangement, if the system operation relies a lot on the relay coil, its coil-arrangement reliability can be similar to that of the single transmitter single receiver system. Therefore, the presence of multiple coils in such a system can be counted as extra complexity when compared with using radially symmetric transmitter and receiver coils.On the other hand, in a single transmitter single receiver system, the reliability of the power electronic system can also be increased by using redundant converters that are conductively or galvanically connected to the Tx/Rx coils.Therefore, the merit of the claimed increased reliability is unclear when compared with a single transmitter single receiver system. It should be investigated by comparing the system with an optimized single transmitter single receiver system and the conventional brushless field excitation techniques.

    - **Response:** Thank you for your comment. The modular structure provides lower-rated semiconductors (in this case, lower current rating due to the parallel-connected modules) hence decreasing the cost. Based on your comments, a 1Tx-1Rx system with redundant converters is now compared with the proposed system in section IX.

3. Upon the experimental setup photo and what is explained in the article, the magnetic fields are guided through some ferrites in the rotor-side and stator-side that are not relatively fixed. Therefore, it is expected to observe a reluctance variation while the rotor rotates. As a result, the nonlinear effect of change in this reluctance (couplings) should be expected. It should be reasonably clarified why these changes are neglected. If the rate of change of this reluctance (coupling) is considerable, it can result in a dominant nonlinearity in the system. It can question all the mathematical derivations discussed in the content. For this purpose, the following strategy can be used. To show that the dynamics of the inductive power transfer system (frequency associated with the poles (resonances) are high enough) is relatively high compared to the rate of change in couplings, the rate of change in the system reluctance (couplings) should be investigated. Its highest rate should be compared with the dominant dynamic response of the inductive power transfer system. If this rate of change was reasonably low, then it is possible to justify that the change of reluctance in the system can be overlooked in the design process.

- **Response:** Thank you for your comment. The effect of the mechanical rotation frequency due to the reluctance to change is now explained in section VI (subsection D).

4. Although the given explanation to avoid bifurcation is somehow reasonable, it is not enough for a journal paper. Deriving the design equations that put constraints on the analytical model is very important, as they theoretically verify the given approach. It is also strongly recommended to use zero-pole depiction and show how the placement of poles is not going to lead to any bifurcation for all the possible phase angles.

   - **Response:** Thank you for your comment. The input impedance is now calculated without ignoring reflected capacitors and inductors in section VI (subsection A). The bifurcation of zero phase angle frequncies is discussed for variations of Qrx and kTx,MSR as given in Fig. 10.

5. In reality, one cannot neglect the effect of couplings between all the coils. Therefore, between every two coils there is coupling, e.g., between a transmitter and a resonator, a resonator and a receiver, and a transmitter and a receiver (see references below). The coupling between the transmitter and receiver can be negligible compared to that of the transmitter to the resonator and resonator to the receiver. The authors are required to show these couplings and the dominant couplings between the transmitter to resonator and resonator to the receiver coils to provide a valid justification why the direct coupling between the transmitter and receiver is overlooked.

   - **Response:** Thank you for your comment. The cross and direct couplings are now investigated in detail in section VI (subsection C), where their effects on the resonant frequency and gain are analyzed. Also, the required coil geometry to minimize these effects is now discussed in Section VII.