

Response to Reviewer 3 Comments

1. However, I only guess that the paper is review paper. Please you should find a way to tell the reader that this paper is a review paper (either in the title or in the abstract or both).

Response:

Thanks for your comment and sorry for the misunderstanding caused. Our manuscript is a review paper and we have modified the title as well as the abstract, which is shown below.

a) Title

Review on Key Technologies and Development of Magnetic Coupling Resonant-Dynamic Wireless Power Transfer for Unmanned Ground Vehicles

b) Abstract

With the fast development of magnetic coupling resonant-dynamic wireless power transfer (MCR-DWPT), it is more likely to practically realize high-efficiency wireless charging between unmanned ground vehicles (UGVs), especially in some desolate places that are far away from a city center or charging depot and always experiencing large load fluctuations, various operating conditions, and complex working targets. Based on this, the wireless charging of UGVs demands higher reliability and efficiency. This paper reviews the MCR-DWPT system of UGVs, and the basic structure and key technologies are introduced. Then, the key technologies, which include the coupling device design, compensation topology design, and system control strategy, are discussed in detail. After that, by considering the current research, the main challenges of the MCR-DWPT of UGVs are investigated and its developing prospects are explored.

2. Quality of technical presentation;

- The introduction section is scanty with some unnecessary definitions. The good Introduction section should state the purpose, the rationale for carrying out the research including background information on what is known, the current state of what is unknown and clearly highlights the gaps the present study aims to fulfil. Based on this, the introduction section should be rewrite.

- At the end of the introduction section, you should also explain why a review of the topic is necessary. The main contribution should be well stated including the main differences between your review and the previous reviews.

- There are many review papers in this domain of research. What is the difference between your work and the following.

Response:

We genuinely appreciate this wonderful suggestion, and extremely sorry for the incomplete introduction. All you mentioned have been added or modified and the revised content is as follows:

a) Modified introduction

With the development of artificial intelligence and automatic control technology, outstanding achievements regarding electric drives, electromagnetic weapons, and protection have increasingly been applied in unmanned ground vehicles (UGVs), which have an urgent demand for a reliable means of power transmission [1]. Based on the vehicles' integrated power systems, UGVs are likely to realize information interaction and power sharing [2].

Magnetic coupling resonant-dynamic wireless power transfer (MCR-DWPT) is a kind of wireless power transfer (WPT) technology that is able to transmit and receive power wirelessly with higher transmission and power efficiency at the meter level. As a non-contact power transmission technology realized by the near-field coupling of an electromagnetic field, MCR-DWPT has ability to effectively improve the drawbacks existing in traditional wired power transmission, including wire aging, plug damage, electric arcs when plugging and unplugging, potential electric accidents, high maintenance costs, and weak environmental adaptability. Compared to static wireless charging at a specified position, MCR-DWPT technology can realize "charging while moving", which meets the requirements of the UGV charging system [3].

Currently, MCR-DWPT technology has made outstanding progress in electric vehicles [4], consumer electronics [5], medical devices [6], wireless sensor networks [7,8], and other civilian fields [9]. For MCR-DWPT of UGVs, most studies focus on operating environment of city roads and factory transportation with the purpose of realizing MCR-DWPT of UGVs with transmitter buried in the ground. In the desolate places of operation such as hillside, forest and desert, the MCR-DWPT system of UGVs has made insignificant research progress in MCR-DWPT between UGVs due to the transmission power level, operating conditions, and working environment.

In order to promote MCR-DWPT of UGVs in the desolate operating environment, literatures about MCR-DWPT in the last five years have been referred to and papers of great reference and application value for key technologies of MCR-DWPT have been quoted. Based on this, the paper first introduces the research background of MCR-DWPT and focuses on the specific requirements of UGVs operating in desolate places. Then, the key technologies of the MCR-DWPT system, such as the coupling device design, compensation topology design, and system control strategy, are reviewed in detail. Finally, the main challenges of the MCR-DWPT of UGVs are summarized, which provides a reference for the

future research of the MCR-DWPT of UGVs in desolate environment.

b) Difference between our work and other review papers in this domain of research.

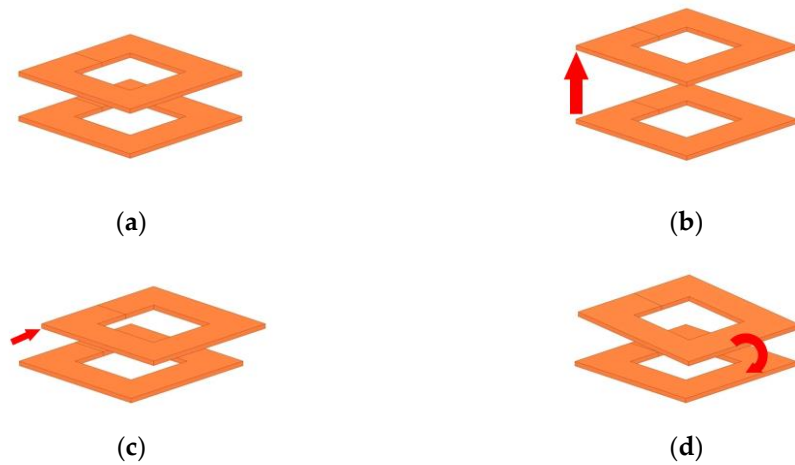
The most significant difference between our manuscript and review papers you mentioned is the application environment. The five reviews you mentioned and some other related reviews we have read focus on MCR-DWPT of electric vehicles (EVs) running on the city roads or stopping in parking lots. Under the circumstances, EVs realize MCR-DWPT with transmitter buried in the ground. The purpose of our review is to promote MCR-DWPT between UGVs in the desolate places of operation such as hillside, forest and desert and our manuscript reviews the key Technologies of MCR-DWPT for UGVs in desolate environment.

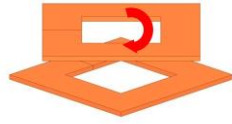
c) Questions about figures

The diagrams of the device position in space and magnetic field simulation in Table 1 were made by magnetic field finite element simulation software, and the conclusions were summarized by referring to relevant literatures and simulation results from different structures and simulation conditions of coupling devices. In order to avoid ambiguity, we have made the following modifications.

Change Table 1 to 'Figure 2. Spatial motion modes of coupling devices: (a) Reference state; (b) Axial offset; (c) Horizontal offset; (d) Horizontal turnover; (e) Horizontal rotation along the symmetry axis.'. The magnetic field simulation diagrams in the original table are deleted, and only the diagrams of device position in space are retained to intuitively show the spatial motion of two coupling devices. The description of the magnetic field simulation in the original manuscript is also modified. The revised content is as follows:

In the case of two coupling devices, there are mainly four kinds of spatial motion modes in WPT, which are axial offset, horizontal offset, horizontal turnover, and horizontal rotation along the symmetry axis, which are shown in Figure 2.





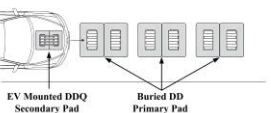
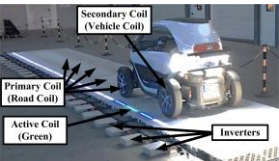
(e)

Figure 2. Spatial motion modes of coupling devices: (a) Reference state; (b) Axial offset; (c) Horizontal offset; (d) Horizontal turnover; (e) Horizontal rotation along the symmetry axis.

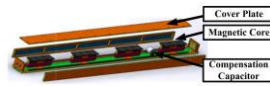
The following labels of tables and figures in the manuscript are modified in turn.

Figures in Table 2 are quoted from references [22-29] and we have added references in the table title in our modified manuscript, which is shown below.

Table 2. Coupling devices for carrier-type grouping of UGVs [22-29].

Classifications	Research Institutions	Structures	Size	Performance
Long Guide Rail Type	The Korean Academy of Science and Technology		E-Type Width: 20 cm Gap: 1 cm	Power: 3 kW Efficiency: 80%
			U-Type Width: 140 cm Gap: 17 cm	Power: 6 kW Efficiency: 72%
			W-Type Width: 80 cm Gap: 20 cm	Power: 15 kW Efficiency: 83%
			I-Type Width: 10 cm Gap: 20 cm	Power: 27 kW Efficiency: 74%
			S-Type Width: 4 cm Gap: 20 cm	Power: 22 kW Efficiency: 91%
			dq-Type Width: 80 cm Gap: 15 cm	Power: 0.2 kW Power Fluctuation: about 11%
Segmented Guide Rail Type	The University of Auckland		-	Power: about 10 kW Power Fluctuation: about 25%
	Paris-Saclay University		Single Device Side Length: 455 mm	Power: 2.5 kW Efficiency: 92%

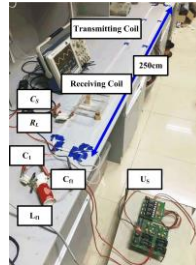
China Electric Power
Research Institute



Track Trench
Width: 200 mm
Depth: 300 mm

Power: about 20 kW

Southeast University



Transmitter
Width: 150 mm
Receiver
Side Length: 150 mm

Power: 55W
Efficiency:
more than 85%

3. Methodology

The methodology section should be included. This is to tell the reader on how you went about doing your research. Including method of searching the papers, keywords used, database used, date and limitation.

Response:

Thanks for your comments and we added a section to the introduction, which includes method of searching the papers, keywords used, database used, date and limitation. The revised content is as follows:

In order to promote MCR-DWPT of UGVs in the desolate operating environment, literatures about MCR-DWPT in the last five years have been referred to and papers of great reference and application value for key technologies of MCR-DWPT have been quoted. Based on this, the paper first introduces the research background of MCR-DWPT and focuses on the specific requirements of UGVs operating in desolate places. Then, the key technologies of the MCR-DWPT system, such as the coupling device design, compensation topology design, and system control strategy, are reviewed in detail. Finally, the main challenges of the MCR-DWPT of UGVs are summarized, which provides a reference for the future research of the MCR-DWPT of UGVs in desolate environment.

3. Results presentation

The findings of the review paper should be presented in terms of “the Future trend and general overview of the research area” or you can present like to say “Publications trend from 2019 to 2023” Then create a section that will summarise the limitations of the previous approaches and Future research.

Response:

Thanks very much for your valuable comments. Our original manuscript did not clearly clarify the future trend and general overview of MCR - DWPT technology. In view of this, we have revised the third section to emphasize the application in UGVs. The revised content of 'Key challenges in MCR-DWPT of UGV' is as follows:

Although a large number of research achievements have been made in the field of MCR-DWPT, there are still many challenges to be investigated, which are listed as follows:

1. The anti-offset performance of the coupling device has to be improved.

At present, the proposed structure of the MCR-DWPT device on UGVs generally has the shortcomings of a complex device structure, large mass and volume, and a large ferrite core, which increases the cost of the device and limits the application scenarios of the device. Coupling devices with resistance to horizontal offset are highly required for the carrier type grouping of UGVs and anti-angle-offset coupling devices are of great use to the system the formation type grouping of UGVs. In addition, in order to realize the "charging while driving" of the UGVs, it is necessary to design a coupling device to meet the requirements of high power and efficiency. Further studies are needed related to the aspects of the transmission power level, transmission efficiency, and electromagnetic shielding.

2. The topology of the compensation circuit has to be optimized.

Current research on the topology of the compensation circuit is fruitful, and various compensation topologies and parameter design methods have been proposed to reduce the reactive power of the system and improve the stability of the system's output. However, due to the relative motion of UGVs, the coupling device of the transmitter and the receiver dynamically change their relative position and the working conditions often switch according to the operating situation. Therefore, the requirements for the adaptability of compensation topology parameters to changes in coupling coefficients and load characteristics continue to increase. The future research directions of compensation circuit topology will mainly focus on the optimization algorithm design of compensation circuit parameters, dynamic system modeling, reconfigurable compensation topology design, and so on.

3. The system control strategy has to be improved.

The current research on the control strategy of the MCR-DWPT system mainly has the difficulties of poor real-time control, the low accuracy of dynamic parameter identification, the complex structures of detection and control circuits, and so on. As for both the carrier type and the formation type grouping of UGVs, the priority of power and efficiency is a question to be answered in the design of system control strategy. Moreover, simultaneous wireless power and data transfer for real-time control, intelligent algorithms to estimate the coupling coefficient and load characteristics of the MCR-DWPT system, and a simplified design of the control system need to be further researched to enhance the MCR-DWPT system.

In addition to the three challenges mentioned above, the MCR-DWPT system of UGVs also has many disadvantages related to electromagnetic compatibility (EMC), foreign object detection (FOD), and environmental adaptability that need to be studied further.

Thank you very much for your comments and consideration on this manuscript. We sincerely look forward to hearing from you soon and we will try our best to respond to any further comments you may have.

Sincerely,

The authors