RESEARCH NEWS STORY

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Machine Learning-Based Design Enables More Efficient Wireless Power Transfer

The fully numerical technique uses machine learning and real-world circuit modeling to achieve stable, efficient wireless power transfer

Wireless power transfer (WPT) systems deliver electricity without cables but often struggle with voltage stability when loads change. In this study, researchers developed a machine learning-based design method that uses numerical optimization to achieve load-independent operation. Their approach ensures stable output voltage (fluctuations under 5%) and high efficiency (86.7%) under varying loads. This breakthrough simplifies WPT design and could help create more practical, reliable wireless power systems for a wide range of applications.

Image title: Machine learning-based design for load-independent wireless power transfer (WPT) systems
Image caption: Researchers developed a fully numerical design method using differential equations and genetic algorithms to optimize WPT systems. This approach ensures stable output voltage, high efficiency, and zero-voltage switching across varying loads, overcoming the limitations of traditional analytical-based methods.
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Wireless power transfer (WPT) systems transmit electrical energy from a power source to a load without physical connectors or wires, using electromagnetic fields. This idea goes as far back as the 1890s, when Nikola Tesla famously experimented with wireless energy transmission. Today, WPT systems are widely used to power smartphones, electric toothbrushes, and wireless sensors for the Internet of Things. A typical WPT system has a transmitter coil connected to a power source. This transmitter converts the supplied power into an electromagnetic field, which is received by a receiver coil that then powers an electrical device.

Recently, load-independent (LI) operation has been attracting attention to keep the output voltage stable and maintain zero-voltage switching (ZVS) even when the load changes. However, achieving LI operation requires very precise circuit component values, such as the inductors or capacitors, which are typically calculated using complex analytical equations. These equations are often based on idealized assumptions and do not capture real-world complexities.

To overcome these limitations and improve power-delivery efficiency, a research team led by Professor Hiroo Sekiya from the Graduate School of Informatics, Chiba University, Japan, has proposed a machine learning-based design method for designing a LI-WPT system. The study was carried out jointly with Mr. Naoki Fukuda and Dr. Yutaro Komiyama, also from Chiba University; Dr. Wenqi Zhu from the Department of Electrical Engineering, Tokyo University of Science; and Dr. Akihiro Konishi, Department of Computer and Information Sciences, Sojo University. The study was published online in the journal *IEEE Transactions on Circuits and Systems I: Regular Papers* on June 18, 2025.

In this approach, the WPT circuit is described using differential equations that capture how voltages and currents evolve over time within the system, taking into account real-world component characteristics. These equations are then solved numerically, step by step, until the system reaches steady-state conditions. An evaluation function assesses the system's performance based on key objectives such as output voltage stability, power-delivery efficiency, and total harmonic distortion. A genetic algorithm then updates the system parameters to improve the evaluation score, and the process is repeated until the desired load-independent operation is achieved.

As Prof. Sekiya explains, "*We established a novel design procedure for a LI-WPT system that achieves a constant output voltage without control against load variations. We believe that load independence is a key technology for the social implementation of WPT systems. Additionally, this is the first success of a fully numerical design based on machine learning in the field of power electronics research.*"

To test their method, the team applied it to a class-EF WPT system, which combines a class-EF inverter with a class-D rectifier. The traditional class-EF inverter without LI operation can maintain ZVS only at its rated operating point. If the load changes, ZVS is lost, and efficiency drops. In contrast, the LI version designed by the team kept ZVS and output voltage stable even when the load varied.

In the conventional system of the LI inverter, the output voltage could fluctuate by as much as 18% when the load changed. In contrast, the system designed with the fully numerical method kept this variation below 5%, demonstrating significantly greater stability. By accurately accounting for the effects of diode parasitic capacitance, the new approach also maintained better performance at light loads. A detailed power-loss analysis revealed that the transmission coil dissipated nearly the same amount of power across different load conditions, thanks to the system's ability to keep the output current steady. At its rated operating point, the LI class-EF WPT system achieved a power-delivery efficiency of 86.7% at 6.78 MHz and delivered more than 23 W of output power.

Looking ahead, the researchers believe that the implications of this work extend beyond WPT. "*We are confident that the results of this research are a significant step toward a fully wireless society. Moreover, due to LI operation, the WPT system can be constructed in a simple manner, thereby reducing the cost and size. Our goal is to make WPT commonplace within the next 5 to 10 years,*" says Prof. Sekiya. More broadly, this design method illustrates that artificial intelligence and machine learning have the potential to transform how power electronics are designed, moving toward a future of automated circuit design.

About Professor Hiroo Sekiya from Chiba University

Prof. Hiroo Sekiya received the B.E., M.E., and Ph.D. degrees in Electrical Engineering from Keio University, Yokohama, Japan, in 1996, 1998, and 2001, respectively. He is currently a Professor at the Graduate School of Informatics at Chiba University. His research interests include high-frequency power electronics, wireless power transfer systems, and wireless communication systems. He is a senior member of IEEE and a fellow of the Institute of Electronics, Information, and Communication Engineers (IEICE) of Japan. He serves as the President of the Nonlinear Theory and Its Application (NOLTA) society of IEICE, an Associate Editor for *IEEE* Journal on Emerging and Selected Topics in Power Electronics (JESTPE) and Senior Editor for *IEEE* Journal on Emerging and Selected Topics in Circuits and Systems (JESTCAS).

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