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High-Power Wireless Charging For EVs (Part 1): Understanding The Basics

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Charging an electric vehicle (EV) battery through wireless power transfer, also known as wireless charging: why is there interest? It is mainly because the line cord is a liability. On first thought, it might seem that plugging in a line cord is not a big deal. However doing it 365 times a year begins to be tiresome. While that's an inconvenience, the main problem is that sometimes you may forget to plug it in. Then you wake up and your car is "dry".

Of course, you certainly can plug in the line cord in your garage. However, thanks to the unions, if you work for a company with a fleet, to plug in a line cord, you need to be a qualified electrician.

Another problem is cost and reliability. High-voltage, high-current connectors made to be constantly plugged in and out are very expensive and need to be replaced periodically. But because of the fierce competition, companies are trying to cut cost. The first victim of cost cutting is usually the connector. So reliability is a casualty.

Also, people are not careful. The connector will be left on the floor collecting dust and oil. And you are going to end up driving over it and ruining it. For all these reasons, wireless charging is attractive.

This article explains the basic principles of operation for high-power wireless chargers in the range of 250 kW that are being developed for charging commercial EVs (including buses and trucks) and industrial equipment. The characteristics of power transfer in a wireless charger are compared and contrasted with those of a conductive or wired charger. In particular, the impact of the wide gap leading to poor coupling and high leakage inductance in high-power wireless chargers is discussed.

How Does Wireless Charging Work?

There are not a lot of differences between the operation of a wireless charger and a conductive charger (see the Fig. 1). The wireless charger can be seen as a conductive charger with a primary section on the floor and a secondary section on the vehicle.

The wireless converter's transformer, which is a single assembly in the conductive charger, becomes the combination of a primary pad and a secondary pad which are separated by a significant distance. As a result of the distance between pads, the cross-coupling between primary and secondary becomes horribly low. It can be as low as 20% versus close to 1 for a conductive charger.

Meanwhile, the leakage inductance in the wireless charger's transformer is four times higher than the coupled inductance. To provide enough voltage to the coupled part, we need to over drive the transformer with a voltage five times higher to overcome the leakage. That can be done with resonant circuits to step up the voltage before the transformer and step it down after the transformer.

But in order to perform well, the two (or three) resonant circuits will need to be and stay aligned during operation on a common operating frequency. This means that the tuning and stability of the resonant circuits is utterly critical and can become a manufacturing issue. This has even been a manufacturing issue outside of wireless charging, in switched-mode power supplies employing resonant switching.

Real Power And Reactive Power

Due to the huge leakage inductance, the total voltage on the pads of the wireless charger is much larger than in the conductive charger, which has little leakage. There is also a large dephasing of the voltage and current, leading to a large reactive power.

The real power transferred by the wireless charger is the same as that of the conductive charger. However the reactive power which is the product V x A is much larger. For "only" 250 kW of real power transfer, we have 1 MW of reactive power. Therefore, the two pads have to be designed for 1 MW.

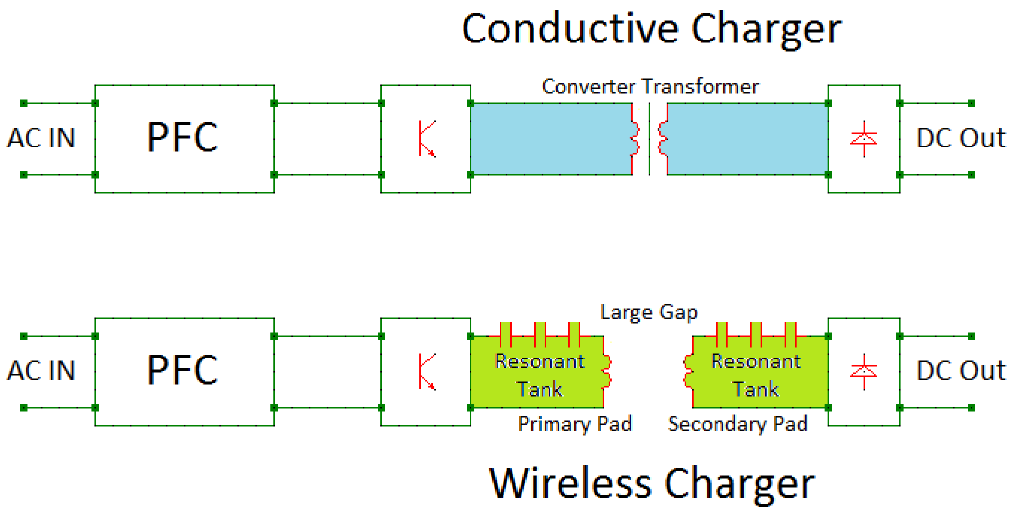

Fig. 1. Block diagram comparison of conductive versus wireless chargers.

One way to describe this situation is with a swing analogy. Consider a scenario where you have a river to cross and your mode of transportation is a swing that goes back and forth continuously at its pendulum frequency. The swing weighs as much as four passengers, yet holds only one.

To have a continuous flow, the swing needs to oscillate back and forth. The weight oscillating is five times the weight of the crossing passenger. But as our friend Gimpy demonstrates in Fig. 2, for the passenger, it is not a free ride! Because of the weight, it is hard to rock the swing.

This is like the situation encountered in the wireless charger. Think of the width of the river as the gap between primary and secondary pads and the swing is the reactive power. Our passenger Gimpy is like the charger's real power. It takes work to transfer the real power across the gap. Because we are pumping energy into the high leakage inductance we have more core losses.

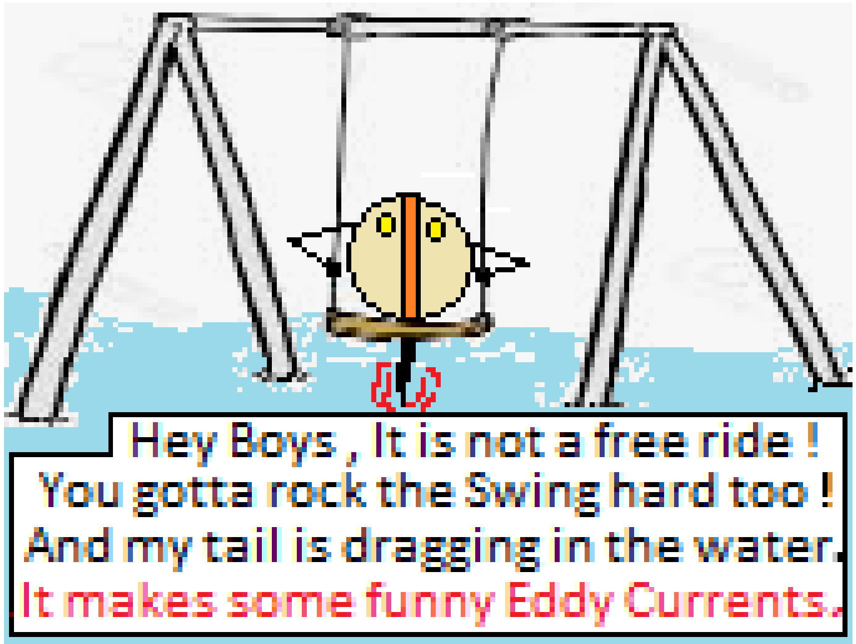

Fig. 2. Since the swing is four times his weight, Gimpy finds it hard to rock the swing across the river. This is similar to the situation with the wireless charger. Leakage inductance is four times that of the coupled inductance, so the charger is pumping four times the energy into the leakage inductance as it is into the coupled inductance.

Conclusion

High-power wireless charging is a new field. There is still a lot of work to do. The goal is to bring the wireless charging at the cost of conductive. We are getting close but it is difficult to add something at no cost.

About The Author

Patrice Lethellier has over 40 years of experience in industry as a power supply design engineer in OEM and merchant power supply companies and as an application engineer in power semiconductor companies. Since 2014 Patrice has been a senior engineer with WAVE, where he has developed wireless battery charging solutions from 50 kW to 200 kW for electric buses.

Prior to this, he served as an application engineer with notable power semiconductor companies such as Volterra, National Semiconductor and Semtech. Before that, he worked as a design engineer at various power supply and system companies including C&D Power Technology, Pioneer Magnetics, Elgar and Unisys. Patrice holds a total of 20 patents in various fields with some currently in process. He has an Engineer Diploma from ISEN in Lilles, France.

This wireless power article is based on the author's work at WAVE.

For more information on wireless charging, see How2Power's Design Guide, locate the Popular Topics category and select "Wireless Power".