Investigation of Wireless Power Transfer for Well-Pipe Applications

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Wireless power transmission is an old subject that dates back to the pioneering work of Tesla and others. The aim is to transfer power wirelessly from a transmitter to a receiver while operating at a sufficiently low frequency that the receiver is in the near field of the transmitter, with radiation effects being negligible. The power transmission is often accomplished by using the mutual coupling between two coils as the linking mechanism (similar to a normal transform operation). There are many potential applications of wireless power transfer, including the wireless charging of electronic products over short ranges, and short range communications.

In this study, we investigate some of the issues related to wireless power transmission between two coils. The targeted application is for power transfer over a discontinuous section of pipe in a well, though the general ideas pertain to many other applications as well.

The system that is studied consists of two coils, a transmit coil and a receive coil, with the transmit coil connected to a source at some frequency, with the source having a known Thévenin impedance. The receive coil is connected to a load. Capacitors are put in series with the transmit and receive coils to allow for tuning. A transformer is also used to transform the input impedance of the transmit coil as an additional means of impedance control.

One parameter of interest is the power transfer efficiency, defined as the power deliver to a load on the receive coil relative to the power being dissipated within the entire system, due to losses within the coils and the source. Another parameter of interest is the output voltage on the receive coil relative to the voltage of the source.

A simple circuit model is used to help understand the basic principles of the wireless power transmission. One of the conclusions is that the maximum power transfer efficiency varies as the square of the frequency of operation, and inversely as the sixth power of the coil separation distance. Another conclusion is that for weak coupling the capacitor on the receive coil should be chosen in order to give conjugate matching to the load (i.e., the capacitor cancels the inductive reactance of the receive coil) in order to maximize the power transfer efficiency. However, for stronger coupling the results show that conjugate matching is not optimal.