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Power Control in Dynamic Wireless Power Transfer

-Low-Speed Vehicle Testing with Active Rectification-

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In dynamic wireless power transfer (DWPT), maximum transferrable power is getting higher and higher to improve its commercial value. However, too much power transfer may cause damage in battery, especially when it is accompanied with regenerative braking in passenger vehicle with relatively small battery. This work proposes on-board power control of DWPT in order to protect battery from too much power transfer. Active rectifier, which makes short-mode to regulate transferred power, can be used for such power control. The authors have been developing it mainly in test bench to simulate DWPT at 40km/h in previous works. In this work, controllability of active rectifier is evaluated in power transfer testing to plug-in hybrid electric vehicle running at low speed, and sharp overshoot is found in the test. A countermeasure to the overshoot is also proposed and validated in simulation.

Vehicle test result is shown in Fig. 1. Dark grey line stands for DC current input to battery with power control, and light grey one does not have the control. Test vehicle passed above two primary coils, and feed-back controller in active rectifier tried to keep DC current input to battery at constant reference 2.0A. Generally DC current is controlled well, but it has a sharp overshoot as soon as it crosses the reference line and feed-back control is activated. Also, increase rate in the overshoot is higher than that in DC current wave without control, which inplies unintended power increase effect by active rectifier.

The power increase effect can be explained by power factor improvement due to unmanaged switch timing in active rectifier, and simulation result supports the theory. In testing, phase of AC current is delayed from that of AC voltage in rectifier because of inductance deviation caused by mutual interaction between primary and secondary coils, which are accompanied with felite core to draw more magnetic flux. Power factor is spoiled, but active rectifier may recover it and increase transferred power when short-mode made by active rectifier affects fundamental harmonic of AC voltage to reduce phase shift with AC current. Simulation result shows such a combination of short-mode duty and switch timing to increase transferred power actually exists (Fig .2).

A new method, frequency deviation in active rectifier, is proposed as a countermeasure to avoid the power increase. Fig. 3 shows how the method works. Frequency in switching in active rectifier is given small deviation from inverter frequency. The deviation makes short-mode phase related to rectangular wave of AC voltage sweep from 0 to 2π. In this way, active rectifier alternately experiences power increase and decrease depending on relative phase of short-mode. Actually DC current input to battery is smoothed by capacitor in rectifier, so the power increase effect is cancelled and transferred power is only to decrease. Finally, simulation result shows frequency deviation in active rectifier ensures power decrease for battery protection.

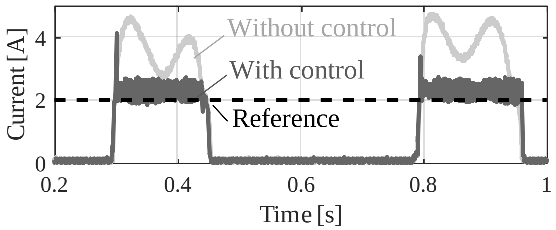

Fig. 1 DC current at battery in dynamic test with/without control

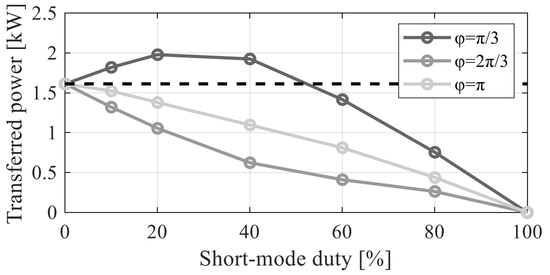

Fig. 2 Power deviation due to short-mode phase in simulation

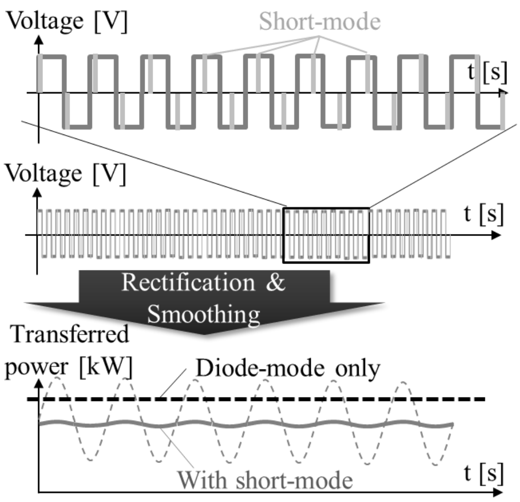

Fig. 3 Sweeping short-mode by frequency deviation

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