Adaptive Frequency Tuning of Wireless Power Transfer Systems

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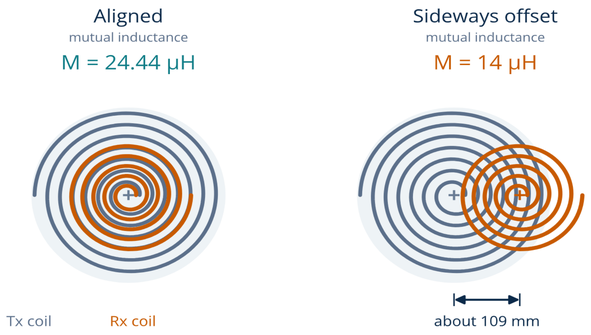
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1. Problem Statement

In a wireless power transfer system, the coupling changes when the coil drifts. This will result in:

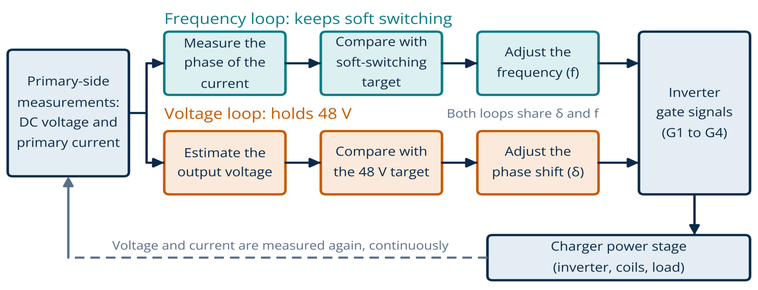
- Detuning the resonant circuit
- Loss of soft switching
- Change in output voltage



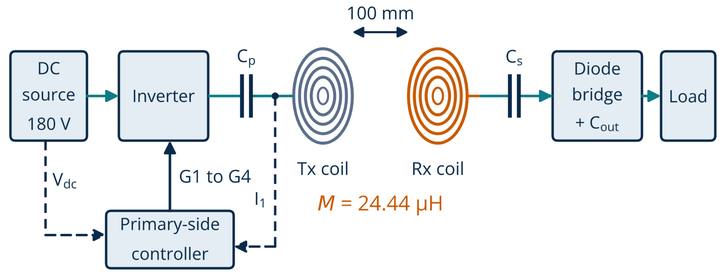
2. Methodology

This wireless power transfer system ensures fixed output voltage and zero voltage switching even during misalignment with primary side control. This system is achieved as:

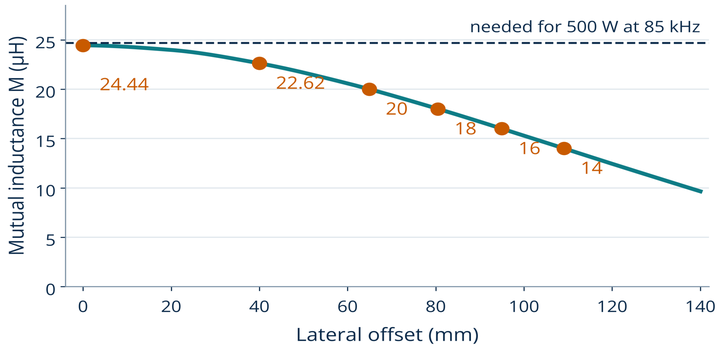
- Only primary side quantities (DC link voltage and primary side current) are measured which results in minimum hardware footprint and simplified secondary side.
- The loss of soft switching due to misalignment is fixed by closed loop frequency tuning ensuring inductive resonant tank throughout the range of operation.
- Fixed output voltage is maintained using closed loop phase shift voltage modulation using sensorless output voltage estimation.



3. System Architecture



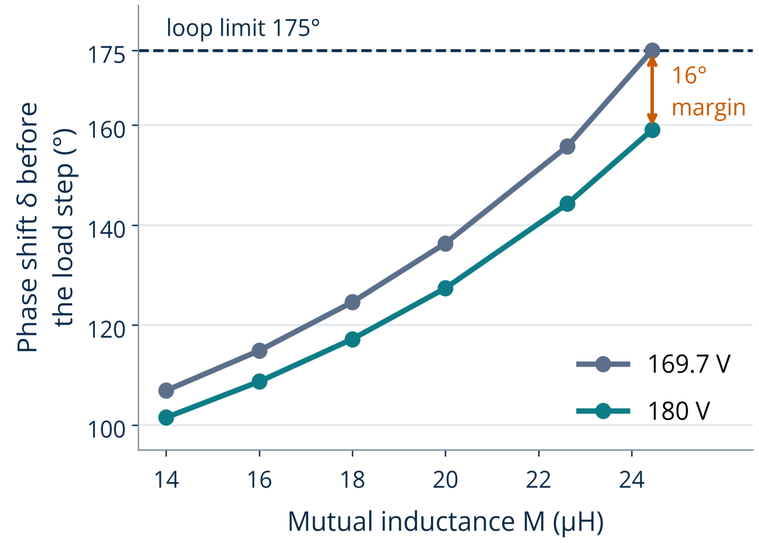
- **Power stage:** a 500 W, 85 kHz charger with series-series compensation, delivering 48 V from a 180 V DC link.
- **Coils**: flat spiral coils, a 20-turn transmitter and a 15-turn receiver, 100 mm apart. Mutual inductance is 24.44 µH when aligned.
- **Primary-side sensing only:** just the DC voltage and the primary current are measured, with no sensor on the



Mutual inductance falls from 24.4 uH to 9.7 uH over 140 mm of lateral offset

4. Results

- **Output voltage:** the steady-state output stays within ±0.8 V of 48 V in all six coupling cases.
- **Soft switching:** all six coupling cases keep ZVS, from aligned (M = 24.44 µH) to about 109 mm of sideways offset (M = 14 µH).
- **Frequency tuning:** the controller finds the right frequency by itself, between 82.7 and 84.9 kHz.
- **Load step:** after the 4.6 Ω to 6 Ω load step, the output settles in 40 ms or less.
- **Phase-shift margin:** at a 180 V DC link, the aligned coil keeps 16° of margin. At 169.7 V it runs out of range**.**



5. Conclusions and Future Work

- Primary-side frequency tuning keeps soft switching (ZVS) over a wide coupling range: M = 24.44 to 14 µH, about 0 to 109 mm of sideways offset.
- The inverter phase shift holds the output at 48 V without any sensor on the receiver.
- A 180 V DC link keeps 16° of phase-shift margin for the aligned coil, so the controller does not run out of range.
- Component accuracy limits the method: a 1% error in the primary capacitor shifts the output by −5.5% to +8%, so it needs calibration.
- Develop hardware setup and extend the power level to medium and high-power applications.
- Improve the control algorithm to reduce the dependency on component tolerance.