A CONTACTLESS POWER STATION FOR CELLULAR BATTERY CHARGER

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Abstract – *A Contactless Power Station (CLPS) is a new breakthrough to transmit power without wires in electronic devices such as cellular phones. Power transfer capability of a CPLS system can be increased if the system is designed to operate under resonance condition. The power transfer is then controlled by controlling the inverter frequency. In order to ensure that the power transfer is maximum, a maximum power point tracker is employed to control the CLPS. Several simulated and experimental results are included.*

Key Words: resonance, *contactless power station, maximum power point tracker*

I. INTRODUCTION

Wireless charging technology development was developed so that the electronic devices can be charged without any physical contacts. Many types of wireless or contactless power transfer strategies and applications have been reported in the literature [1]-[4]. One application of wireless power transfer is wireless battery charger, the one that is discussed in this paper, Contactless Power Station (CLPS).

At first, the general design and construction of wireless battery charger is discussed in this paper. As the energy is transferred through air core transformer, a volt-ampere power supply is needed to transfer the required energy. In order to solve the problem, a resonance concept is proposed in this paper. By operating the system under resonance condition, the voltage drops across the leakege inductances air core transformer are cancelled. Thus, a large volt-ampere power supply is not needed anymore. As the transformer leakage inductances vary with the secondary winding position in relative to the primary winding, the inverter frequency must be changed continuously to ensure that the power transfer is maximum. Thus, a maximum power tracker must be designed to control the inverter to ensure that the power transfer is maximum. Several simulated and experimental results are included in this paper. It is shown that the designed system is successfully operated to transfer the required battery charger power.

II. DESIGN OF CLPS SYSTEM

Essentially, a CLPS system can be divided into two parts; primary and secondary. The primary side of the system is made up of a high-frequency inverter, series resonance capacitor, and the primary coil. This inverter produces a high frequency sinusoidal current in the coil. The secondary side (or 'pickup') has a smaller coil, a series resonance capacitor, and a rectifier. The scheme of the system is shown in Fig. 1.

Step by step proceses of designing the CLPS system are described below:

1. Determine the spesification of charging object.
2. Determine the design of the coil, both primary and secondary, as the core of CLPS system.
3. Measure the coil's inductance and the coupling coefficient between the primary and secondary.
4. Determine capacitance value, in the primary and secondary side, so that the CLPS system works in resonance.
5. Wireless power transfer experiment and measurement.
6. Simulation of the CLPS system to validate the experiment results.
7. Determine the power transfer characteristic of the designed CLPS system.

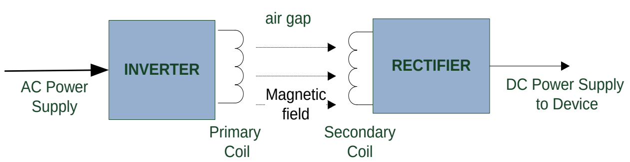


Figure 1. Basic CLPS system

The device that will be the charging object are a cell-phone with battery spesification as in Table 1. In designing the primary coil, the dimention are determined by the type of power transfer in this CLPS system. After several trials it has been found that a CLPS system with several primary coil that smller than secondary coil, has a better efficiency in case involving a moving charge object.

High number of coil turns are required to increase the power transfer. The secondary coil must fit in the device, however, can not be so thick to be fitted in the electronic device and, therefore 7 layer was selected. As for the primary, the main considerations are to get the highest inductance as possible, so 10 layer was choosed. Fig. 2 shows the realization of the coils.

The next step was to measure the inductance of coils and then, determine the required resonance capacitors. An LCR meter was used to measure the coil's inductances. Table 2 shows the results. Resonance capacitors can be determined from this data, knowing the system was designed to operate at 100 kHz. Table 3 shows the calculated results.

Table 1. Battery Spesification

Charge (Q)	600 mAh
Nominal Charge Voltage (V)	3.7 Volt
Maximum Charge Voltage (V)	4.2 Volt
Power	2.2 Watt
Load Impedance (for experiment)	5 Ω

Fig. 2. Secondary and primary coils.

Table 2. Inductance Measurement Results

Coil	**L (μH)**	**X_L (Ω)**
Primary	138	86.7
Secondary	48	30.16

Table 3. Resonance Capacitors

Coil	**Capacitance (nF)**
Primary	18.3
Secondary	52.7

III. MAXIMUM POWER TRANSFER

As the coil inductances varies with the object (secondary coil) positions, the resonance frequency also varies with the position. Thus, the inverter frequency must be controlled to ensure that the power transfer is maximum. In order to investigate the inductance variations, three extreme positions are investigated as shown in Fig. 3. Under these positions, the inverter frequency is varied to determine the maximum power transfer. The results are shown in Table 4. The results are also plotted in Fig. 4.

In order to ensure that the power transfer is maximum, an MPPT strategy is developed. The proposed method is based on the perturb and observe method as described as follows:

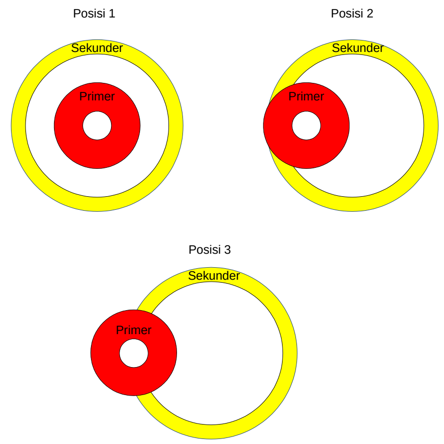


Fig. 3. Relative positions primary to secondary coils.

Table 4. Voltage, current, and power for several frequency for each configuration

Position		Primary		
1	f (kHz)	V (V)	I (A)	P (Watt)
	89	38	0.56	6.95
	94	48	0.7	10.13
	100	68	1	17.8
	107	68.8	0.92	15.5
	114	48.7	0.6	7
2	85	43	0.6	7
	91	54	0.7	11
	95	67	0.95	16.2
	98	80.2	1.1	21.2
	106	63.5	0.8	11
	113	48	0.56	6.2
3	83	43	0.6	5.5
	89	67	0.9	13.4
	94	101	1.3	26
	100	89	1.1	20
	106	62	0.7	10

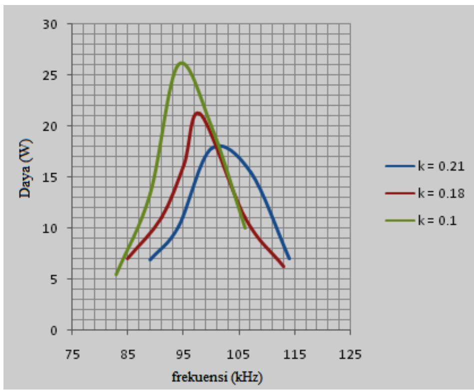


Fig. 4. Power vs frequency for each positions

1. Determining the initial value for the frequency and measure the value of power at the f value.
2. Raise and lower reference frequency and measure its value
3. Calculate sign(ΔP) and sign(Δf)
4. $f_{ref} = f_{ref} + sign(\Delta f) * sign(\Delta P) * f_{step}$
5. Back to step (3) until maximum point found.

The curve in Fig. 5 below illustrates the movement of tracking point to get the optimum point.

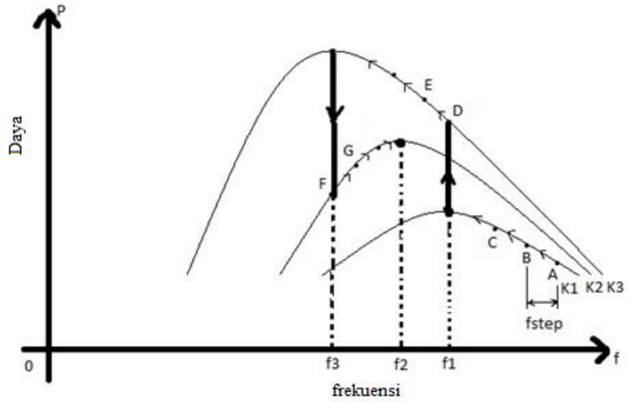


Fig. 5. Algorithm illustration.

IV. SIMULATED AND EXPERIMENTAL RESULTS

In order to verify the proposed concept, the whole system is first simulated. The scheme of the simulated system is shown in Fig. 6. The secondary coil is loaded by a fixed resistor.

Fig. 7 shows the simulated and experimental results under the same conditions. The results show that the simulation gave a good result and can be used for further investigation.

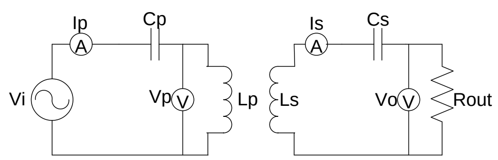
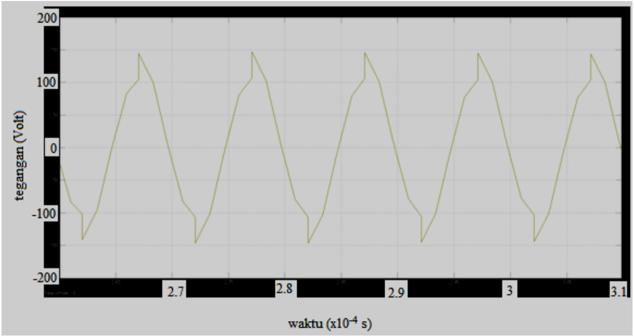
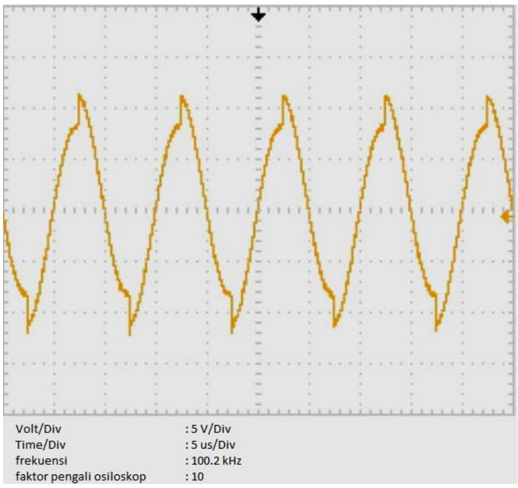


Fig. 6. The scheme of the system.

The proposed MPPT algorithm is then simulated by using Simulink. Initial reference frequency value used in the simulation is 110 kHz with a level of change in frequency of 100Hz (fstep). The simulated results are shown in Fig. 8. The results show that the proposed MPPT able to control the CLPS system successfully.

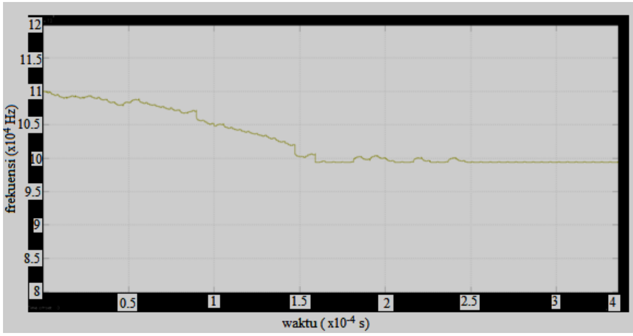


(a) Simulated.

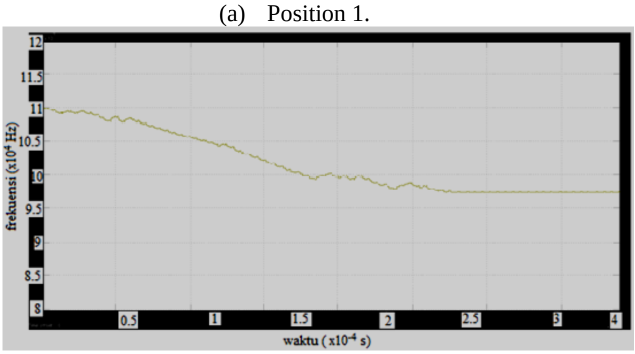


(b) Experimental.

Fig. 7. Simulated and experimental primary coil voltage.



(a) Position 1.



(b) Position 2.

Fig. 8. Frequency variation to find the maximum power.

Table 5 shows comparison between simulated and experimental results. Once again, the results show that the system has been worked as expected.

Table 5. Simulation vs experiment

k	Simulation results			Experimental results		
	Frequency (kHz)	Voltage (V)	Current (A)	Frequency (kHz)	Voltage (V)	Curretn (A)
1	99.50	64.15	0.85	100.20	69.10	1.0
2	97.50	78.75	1.10	98.23	80.50	1.1
3	93.15	98.34	1.30	94.16	101	1.3

V. CONCLUSION

A CLPS system for cellular battery charger has been proposed in this paper. An MPPT strategy has also been proposed. Under resonance condition, the power transfer can be controlled by controlling the inverter frequency. Simulated and experimental results have shown that the proposed system has been working as expected.

VI. REFERENCES

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