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Comparison of LCL and LCLC Compensation Circuit for Capacitive Power Transfer System

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Abstract: *Capacitive power transfer is one of the techniques to transfer power wirelessly. In this paper, LCL compensation topology and LCLC compensation topology were studied and simulated. The aims of this study are to determine the parameter value of the LCL and LCLC compensation topologies, simulate and compare both circuits. The operating frequency of 1Mhz was used in all topologies and had been simulated in LTspice XVIII simulation software. The value of parameters were obtained and simulated successfully. The comparison result is presented.*

Keywords: Wireless power transfer; Capacitive Power Transfer.

1. INTRODUCTION

Wireless power transfer (WPT) becomes one of the interesting topics in engineering and technology industry due the WPT promises an energy sustainability in delivering energy. WPT transfers power between the supply source and electronic devices without using cables and it is more reliable and convenient.

Capacitive power transfer (CPT) in wireless power transmission is using electric field coupling between electrodes for transferring energy between transmitter and receiver. Meanwhile Inductive power transfer (IPT) is using magnetic field coupling between cores. Both methods become an interesting subject for delivering power without cable and can be applied in many electrical and electronics appliances such as wireless vehicle charging [1], unmanned aerial vehicle [2], machine[3] and others.

There are many advantages and disadvantages between IPT and CPT in wireless power transfer. CPT has advantages in relatively low cost and weight, negligible eddy-current lost and excellent misalignment performance [4].

The main factor in WPT is its efficiency. The factor that effected to the efficiency of WPT systems are coupling factor between transmitting and receiving elements, load current, fire angles of rectifier switch and semiconductor devices.

2. CAPACITIVE W POWER TRANSFER (CPT) SYSTEM

Capacitive power transfer consists of capacitor plate as a main part for transferring power and others component. Size of capacitive plates and the distance between the plates give the value of coupling capacitance.

Fig. 1 shows the wireless power transfer system in which contains a supply, primary and secondary part, load and capacitive interface. The plates are arranged in parallel for transferring power and produce the capacitance effect.

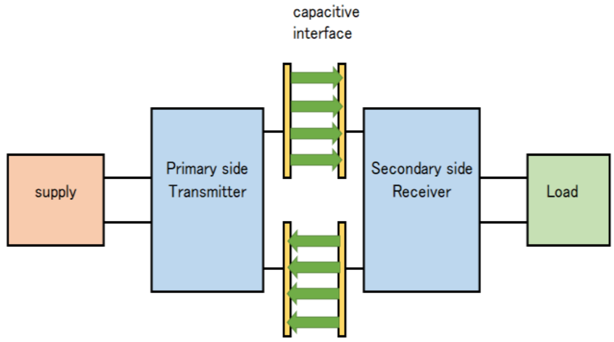


Fig. 1. Wireless power transfer system.

There are a lot of compensation topologies proposed by researcher, including series L, LC, LCL and LCLC compensation and these compensation circuits determine the system power capabilities, frequency properties with output and input condition and power capabilities [4]. A compensation circuit able to increase the voltages and maximize the output efficiency. At the secondary side, additional DC-DC converter can be used to achieve better performance [5].

2.1 LCL double compensated CPT system

By combining LC and series inductor, it can result in a double sided LCL compensation topology as shown in Fig. 2.

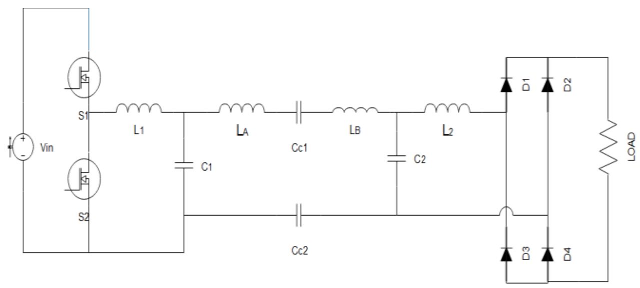


Fig. 2. LCL compensated CPT system.

The LCL compensation circuit can able to tune the system power in flexibility, but needs the larger value of series inductor [4].

2.2 LCLC double compensated CPT system

LCLC double compensated circuit gives an advantages of power regulation through the circuit without affecting coupling coefficient [4] and LCLC network can helps both output and input to achieve unity power factor [6].

Fig. 3 shows the arrangement of inductor and capacitor for LCLC compensated CPT system

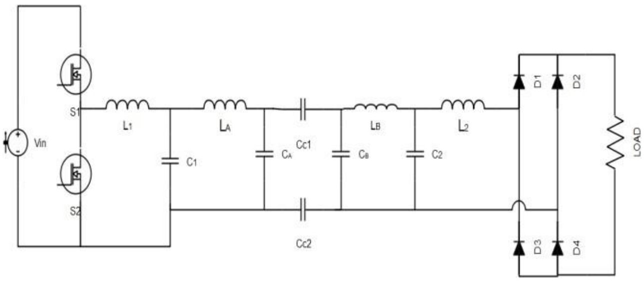


Fig. 3. LCLC compensated CPT system.

3. DESIGN OF THE CIRCUIT

In order to simulate LCL and LCLC double compensated circuit, the value of duty cycle, D and Inductor, L_1 were determined firstly. After the both value of D and L_1 were obtained, others parameter value was calculated based on resonance at the same frequency by using the formula given by [6]. Then, the LCL and LCLC topologies were proposed and simulated in LTspice XVII simulation

3.1 Determination of Duty cycle and Inductor L1 value of maximizing output

Duty cycle, D of the power MOSFET contributes to the high efficiency. Thus, the variation value of D and inductor L_1 are taken into consideration for finding better output. Thus, this study was done to find the suitable value for both inductor and inverter duty cycle for producing maximum efficiency. Fig. 4 shows a circuit which is used to determine the value of D and L_1.

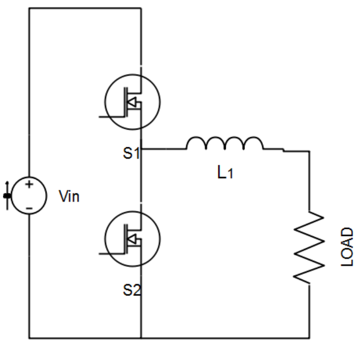
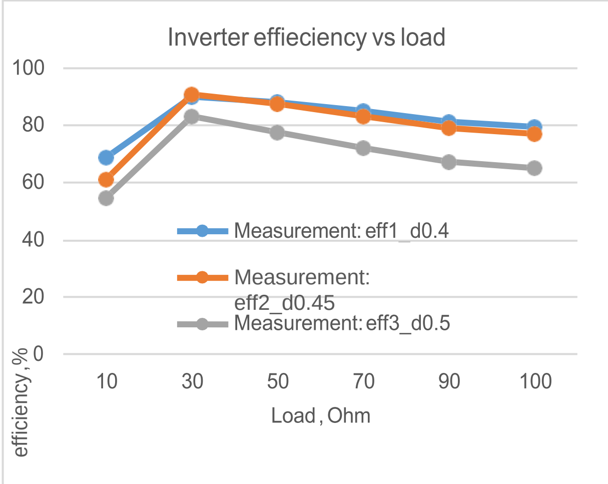


Fig. 4. A circuit to determine the value of Duty cycle and Inductor L_1

The higher value of inductor will result in the bigger size of inductor and internal series resistance as well as higher cost. Thus, these factors also need to take into consideration for choosing the value of inductor even though the efficiency is the most important factor for the circuit.

The circuit was simulated by using DC voltage supply and operating frequency of 60V and 1MHz respectively. First, the duty cycle value was changed with 0.4, 0.45 and 0.5 and inductor value was 4µH. Secondly, the inductor value was changed with 0.4µH, 4µH and 40µH. The result of the simulations is presented in Fig. 5 and Fig. 6.



. Fig. 5. Fixed Inductor (4µH) with changing of duty cycle, D

Fig. 5 shows duty cycle of 0.4 is the best in comparison with D = 0.45 and 0.5. Thus, the value of 0.4 is chosen for the duty cycle.

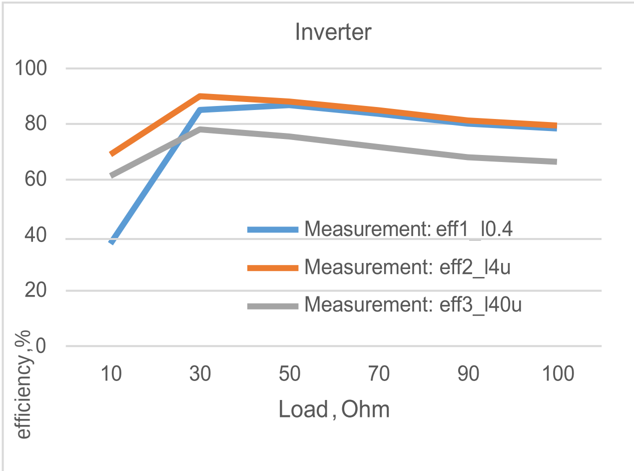


Fig. 6. Fixed duty cycle, D (0.4) with changing of inductor.

Fig. 6 shows the inductor value of 4µH is the best in comparison of 0.4µH and 40µH. Thus, 4µH is selected for the value in LCL and LCLC topologies. Duty cycle of 0.4 and inductor L_1 of 4µH is chosen in this study. Others parameter was calculated based on these values and presented in simulation to analyze the output.

3.2 Simulation of LCL and LCLC topologies

Both LCL and LCLC circuit are simulated in LTspice XVII simulation with the operating frequency and duty cycle of 1MHz of 0.4 respectively. The DC supply is 60 V. The components were arranged as in Fig. 2 and Fig. 3 for LCL and LCLC circuit respectively. The inductor value of L1 and L2 were based on previous simulation result and other components value were determined by calculation. The parameters for both LCL and LCLC is presented in Table 1.

Table 1. Specifications of the system

Components	LCL	LCLC
C_1, C_2	6.33nF	6.33nF
L_1, L_2	4μH	4μH
L_A, L_B	257μH	50.4μH
C_A, C_B	-	500pF
C_{C1}, C_{C2}	100pF	100pF

4. RESULT AND DISCUSSION

The result for both circuits were obtained successfully. The efficiency of the both circuits were presented, and it was found that the efficiency of LCLC circuit are better in comparison with LCL. Fig. 7 shows the efficiency of proposed LCL and LCLC compensation circuit.

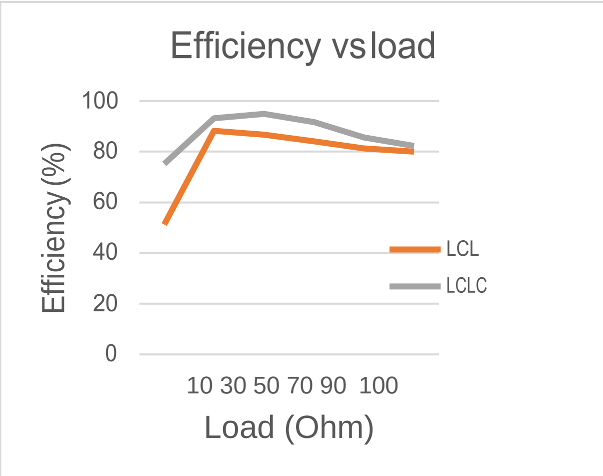


Fig. 7. LCL and LCLC compensated CPT system efficiency.

Fig. 7 shows LCLC topology has better efficiency compared to LCL topology with various value of load from 10Ω to 100Ω. The simulated and output efficiency will be used as reference for further work. The efficiency graph for both topologies show almost similar pattern.

5. CONCLUSION

The parameters of the LCL and LCLC compensation circuit were determined and simulated successfully. The efficiency of the both circuits was obtained, compared and presented. It shows that the selected inductor value of 4μH is suitable for both topologies. In comparison, LCLC compensation topology is better than LCL in term of efficiency for various load from 10Ω to 100Ω. However, further analyze need to be done to find details output data for both LCL and LCLC topologies. The simulated and output efficiency will be used as reference for further work in wireless power transfer system.

6. REFERENCES

[1] A. Ahmad, M. S. Alam, and R. Chabaan, "A Comprehensive Review of Wireless Charging Technologies for Electric Vehicles," *IEEE Trans. Transp. Electrif.*, vol. 4, no. 1, pp. 38–63, 2017.

[2] T. M. Mostafa, A. Muharam, and R. Hattori, "Wireless battery charging system for drones via capacitive power transfer," *2017 IEEE PELS Work. Emerg. Technol. Wirel. Power Transf. WoW 2017.*

[3] D. C. Ludois, J. K. Reed, and K. Hanson, "Capacitive power transfer for rotor field current in synchronous machines," *IEEE Trans. Power Electron.*, vol. 27, no. 11, pp. 4638–4645, 2012.

[4] F. Lu, H. Zhang, and C. Mi, "A review on the recent development of capacitive wireless power transfer technology," *Energies*, vol. 10, no. 11, 2017.

[5] A. H. M. Z. Alam, "Three Phase DC-DC Converter with Six Inverter for EV Application," *Proceedings of International Exchange and Innovation* Conference on Engineering & Sciences (IEICES). 3, pp. 141 - 144, 2017-10-19. pp. 141–144, 2017.

[6] F. Lu, H. Zhang, H. Hofmann, and C. Mi, "A Double-Sided LCLC-Compensated Capacitive Power Transfer System for Electric Vehicle Charging," *IEEE Trans. Power Electron.*, vol. 30, no. 11, pp. 6011–6014, 2015.