Self-charging Unmanned Aerial Vehicle (UAV) System Using Inductive Approach

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ABSTRACT: The design and analysis of self-charging unmanned aerial vehicle (UAV) system using inductive approach is introduced in this paper. Wireless Power Transfer (WPT) is energy transmission without any physical interconnection between the device and power source. Inductive Power Transfer (IPT) is proposed in this project as electromagnetic field is used in IPT and inductive coupling not affected by dust and water. WPT system with the Class E dc-dc converter is proposed in this project. The Class E inverter with π2a impedance matching circuit has used to cascade with class E rectifier and form Class E dc-dc Converter. The simulation of Class E dc-dc converter in Simulink with optimum load and with duty cycle of 50% has obtained 16.82W dc output power for operating frequency of 1MHz, the zero-voltage switching (ZVS) condition able to achieve in both Class E Inverter and Class E rectifier and obtained with the efficiency up to 95.73%. The prototype for self-charging UAV system designed by using AutoCAD software, the system designed for UAV land and charge wirelessly.

Index Terms—Wireless Power Transfer (WPT), Inductive Power transfer (IPT).

1. INTRODUCTION

Wireless power transmission (WPT) is become major topic nowadays. Wireless power transmission technology is continuing to research and develop due to the many advantages it has provided to enhance the quality of life for humans and to make our lives better nowadays [1]. Figure 1 shows an example arrangement of IPT system which includes power supply, transmitter, receiver and battery. The working principle of IPT is built by two parts which include a transmitter coil and a receiver coil to transmit power with certain range without interconnection with cable. Transmitter and receiver coils are electrically separated from one another, and the induced current will transmitter to receiver by electromagnetic coupling [2]. As shown in Figure 2, the coupling coefficient "k" between transmitter and receiver coil is important to define the efficiency of the IPT charging system, the results of coupling coefficient between two coils high enough to ensure a consistent link and make the proper power transmission [3].

This paper is presented in the following order. Section 2 provides an overview of the proposed IPT system. Section 3 presents the simulation result and finally the conclusions that summarize the findings are presented in the last section.

2. METHODOLOGY

Figure 2 shows the proposed IPT system design for the self-charging unmanned aerial vehicle (UAV) charging system. The UAV attached with the yellow box, the box is equipped

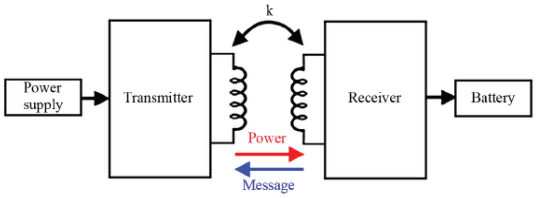

Figure 1: IPT Block Diagram

the receiver coil (Rx) and Class E rectifier circuit board, in addition, the iMax-B6 Balance charger is considered to use to connect with the output of Class E rectifier for provide stable and safe output power supply for battery of UAV. The landing area with red color is equipped the transmitter coil and Class E Inverter circuit board. The gap between transmitter and receiver coils is designed according the result of ANSYS Maxwell, according to Table 3, the distance of coil separation shows 50mm able to achieve over 0.5 of coupling coefficient, thus the range can set between 30mm to 50mm according to the hardware limitation. The prototype of self-charging of UAV system designed to let UAV land and charge wirelessly, the charging process assumed to start immediately after the UAV land on the charging station.

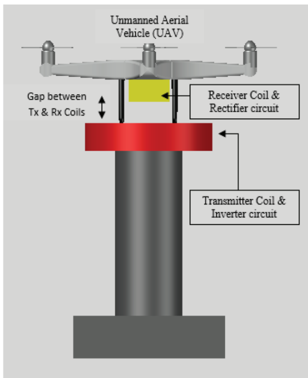

Figure 2: Self-charging UAV system

(i) Design of Class E dc-dc converter

Design of class E dc-dc converter consists of the class E inverter, π2a impedance matching circuit, inductive coupled coils, and class E rectifier. Class E dc-dc converter is one of the resonant dc-dc converters that able to reach high power conversion efficiency at high frequencies. Class E inverter and Class E rectifier in the circuit satisfy the ZVS conditions to achieve high efficiency. Simulation of Class E dc-dc converter as shown in Figure 3 had been developed by using MATLAB Simulink. The value of components in circuit designed by using the theoretical value obtained in Table 1.

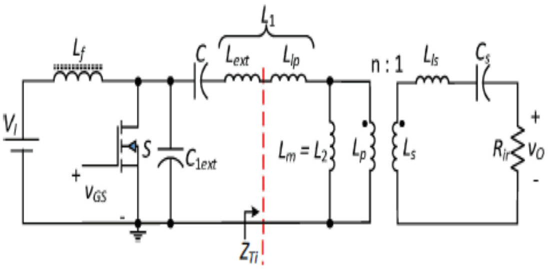

Figure 3: IPT system based on Class E π2a topology

(ii) Design of wireless charging coil in ANSYS Maxwell Software

Design and simulation of wireless charging coil in this project has been conducted by using ANSYS Maxwell software from ANSYS. Inc. Figure 4 shows the orient view of three-dimensional (3D) geometry of a pair of wireless charging coil in ANSYS Maxwell.

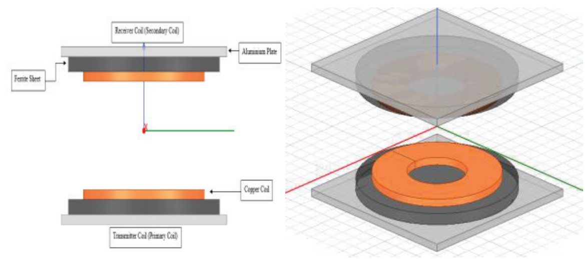

Figure 4: Design of wireless charging coils in ANSYS Maxwell

3. RESULTS

Simulation of Class E DC to DC Converter are simulated by using Simulink. The system specifications are set as input voltage (V_I) is 12V, output power (P_o) is 18W, operating frequency (f) is 1MHz, duty cycle (D) is 0.5 and loaded quality factor (Q) is 10. The values of components are slightly different with the calculated value. In order to achieve optimum operation of zero-voltage switching (ZVS), the values of components for Class E Inverter and Class E rectifier need to be tuned according to the market availability. Table 1 shows the result comparison between calculated value and simulation result.

Based on the simulation results, Class E dc-dc converter in Simulink with optimum load and with duty cycle of 50% has achieved 95.57% efficiency at 16.82W dc output power for operating frequency of 1MHz.

Table 1: Design parameter and simulation results

Parameter	unit	Cal. value	Sim. value	Difference (%)
Load Reistance, R_L	Ω	8	8	0
Shunt Capacitor, C_1	nF	3.67	3.7	0.81
Capacitor, C	nF	2.26	2.2	2.65
Choke inductor, L_f	μH	55.48	57.6	3.68
Inductor, L	μH	12.73	13.3	4.28
Magnetizing Inductor, L_m	μH	18.48	18	2.60
Secondary Leakage Inductance, L_{ls}	μH	5.52	5.6	1.43
Series Capacitor,C_s	nF	4.59	4.6	0.22
DC Input current, I_{dc}	A	1.5	1.47	2
Peak switch current, $I_{ds(peak)}$	A	4.293	3.9	9.15
Peak switch voltage, $V_{ds(peak)}$	V	42.72	41.3	3.32
Gate Threshold voltage, V_{GS}	V	5	5	0
Filter inductor, L_{fr}	μH	40	47	14.89
Filter Capacitor, C_f	nF	63.33	68	6.87
Rectifier capacitor, C_r	nF	6.33	6.8	6.91
Peak diode voltage, $V_{dm(peak)}$	V	42.744	42.1	1.51
Peak diode current, $I_{dm(peak)}$	A	4.291	4	6.76
Output voltage, $V_{o(dc)}$	V	12	11.6	3.33
Output current, $I_{o(dc)}$	A	1.5	1.45	3.33
Input Power, P_i	W	18	17.6	2.22
Output Power, P_o	W	17.7	16.82	6.78
Efficiency, η	%	98.33	95.57	2.81

4. CONCLUSION AND FUTURE WORK

In this paper, it proved the Class E inverter with π2a impedance matching circuit has cascade with class E rectifier has been able to achieve above 90% in Simulink simulation. The current wireless power transfer only applied to the immobility state of the UAV, which the UAV need to land on the charging station to start charging. For the future work, the wireless power transfer technology able to charge the UAV while it is in flight, with this work, UAV can be improving and expand its application to agriculture, city monitoring and other applications because the UAV have the advantage of work continuously with the wireless charging technology. Therefore, the wireless power transfer technology is definitely will be one of the important technologies to impact the future for every industry and every human being.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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