Wireless Charging Station for Drones

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An Automatic Wireless Drone Charging Station Creates An Essential Environment For Continuous Drone Operation

Introduction

This paper provides a solution to the manual drone charging problem by providing an automatic wireless charging station that charges the drone by electromagnetic induction. The process uses two induction coils positioned over each other that serve as a charging platform for the drone. The system has automatic detection of the drone and starts charging immediately when a drone positions itself over it. The wireless feature of charging removes the need for manually connecting the drone with a charging station (Choi et al., 2016).

Research Findings

The charging station is automatic and does not need a drone to position itself over it completely. The structure of the charging station is efficient, and it can charge the drone even if it is positioned slightly incorrectly. The ultrasonic sensors, after detecting the landing of the drone, give signals to stepper motors by Arduino Uno, which further controls the position of coils to adjust them below the drone to start efficient charging (Choi et al., 2016).

The charging platform has limited distance efficiency as it is working on the principle of electromagnetic induction. From the current value graph, it is observed that the station has maximum charging efficiency when the drone is positioned at a 4mm distance above the platform. The efficiency declines when the distance between coils increases from 4 mm (Choi et al., 2016).

The charging efficiency is also observed by observing the eddy currents graph made against distance, which has the lowest value at 4 mm because of maximum voltage induction.

The ultrasonic sensor’s detection of the drone is efficient at up to 1 meter. The, i.e., drone has to be in a 1-meter vicinity above the charging station to be detected by the sensor and the process of charging to be started.

The drone detection system of the station is dependent on the orientation of the drone facing the sensor. The drone, design has four landing legs placed on each corner of the drone with the charging coil in the center. The sensor has to first find the center point for maximum charging efficiency. This process is done by spanning the objects that are seen by the ultrasonic sensor. When the drone faces the sensor directly, the angle between the drone and the sensor is zero, and it can identify the three objects, two of them side legs and one is the other two legs, and the charging coil as they are positioned in a row so the sensor interprets it as one object. Similarly, when the drone positions itself at a 22.5-degree angle to the sensor face, the sensor detects four or sometimes five objects. I.e., four legs and one induction coil, or sometimes one leg is in front or behind the coil, and four objects are detected. At the 45-degree position, due to the symmetric shape of the drone, the drone again has three objects like the first position. In all cases, the determining of the center point is done by the max and min span of objects detected by dividing their sum by two (Choi et al., 2016).

The following table describes all three cases (Choi et al., 2016):

Angle with sensor (degrees)	Objects detected	Max and Min points (mm)	Determined center	X- coordinate (mm)
0 degree	Three objects	261, 423	(261+423)/2	342±2
22.5 degree	Four or five objects	245,455	(245+455)/2	350±2
45 degree	Three objects	255, 490	(255+490)/2	372.5±2

Limitations

The charging efficiency of coils is at 65% with a 300mA current and 5V voltage and it takes 75 minutes for a full charge. Less efficient stepper motors restrict quick detection of drone and coil positioning below it (Choi et al., 2016).

Design Of Power Receiving Side In Wireless Charging System For UAV Application

Introduction

This paper aims to provide an improved Capacitive Power Transfer (CPT) receiving side circuit that will be used for charging a UAV drone. This circuit is made with a focus on the compact circuit and maximum working efficiency. The design will take advantage of capacitor coupling for power transfer, which will charge the Li-ion battery by 77% output efficiency (Muharam et al., 2017). The design is

composed of five blocks: the DC power supply, the high-frequency DC/AC transmitter, the coupling capacitors, a rectifier circuit, and the battery load.

Research Findings

To overcome the lower coupling capacity, a step-up transformer is used to increase the power transferred to the load. However, increasing power creates another issue as the load side works on low power. To fix this problem buck converter is used in the design to decrease the load voltage (Muharam et al., 2017). The waveform of input and output voltage, as well as the power dissipated in the load, is regulated at 15-volt DC.

The input voltage in the waveform is seen to have a constant value of 20 volts, of which 7 volts are dissipated in the system, and 14 volts are provided to the 1-kilo ohm load. The load voltage is regulated at 15 volts.

The practical application of the circuit gave results that describe the duty cycle as a factor that affects the output power of the circuit. The simulation graphs show less value of load current. Therefore, less output power is produced by the input with an efficiency of up to 77% to 73%.

The extent to which the batteries can be charged also depends on some factors:

- The battery life: old batteries take longer to charge, and their maximum charging ability decreases with time.
- It also depends on the stability of the source; varying voltage from the source needs a lot of work done by the regulator circuit to keep the battery input voltage constant.
- The type of battery, which in this case is a lithium-ion battery, has smart battery life.

The efficiency of the circuit also depends on the losses in the circuit components, the rectifier circuit, buck converter, as well as the load losses which are collectively very efficient between 73% and 77% depending upon the losses in the circuit.

The maximum power is lost in the rectifier circuit that converts AC power from the capacitor to DC to charge the batteries. The second most losses happen in buck-buck converters, while the charging circuit has the least losses.

Excessive heat is generated from the circuit, which raises the need for a heat sink, like a fan, to dissipate heat and save the circuit from burning.

Limitations

The line losses, like in every circuit, limit the efficiency to 77% maximum, which can be improved by using more efficient circuit components or by decreasing the line losses. However, the use of more

efficient components increases the cost and complexity of the circuit as well as the input power, which may not be feasible in certain conditions.

Wireless Power Transfer Technology Applied To An Autonomous Electric UAV With A Small Secondary Coil

Introduction

This research is aimed to design an optimized wireless power transfer circuit based on the principle of magnetic resonant coupling which will power up a UAV. The circuit uses a combination of coils to overcome the effects of imperfect landing on the charging platform and resultant losses of power. The circuit is unique in the design of a small secondary coil that is lightweight, lessens the load in the drone, and increases its efficiency. The study presents an automatic charging station that removes the need for manual battery replacement or charging. The contact-based charging method may be more efficient than this induction coil-based circuit, but it makes electrical contact exposed to the environment, decreasing its safety (Campy et al., 2018).

Research Findings

The system is based on the principle of magnetic induction where a change in current will induce the current in the secondary coil attached to the drone, which will further charge the batteries. The weight of the UAV, due to the added weight of the circuit, decreased the weight that is allowed for the payload, and a very compact WPT system is needed to overcome this problem. The drone, as equipped with additional components, reduces the payload capacity of the drone, and this problem is attempted to rectify in this research (Campy et al., 2018).

The distance between the charging station and the receiving coil is increased by the placement of the payload beneath the drone, so in order for effective charging, the coils used in the charging station and drone are kept significantly large. However, there is a technical issue that strong magnetic induction can interfere with the internal circuitry of the drone and can cause unnecessary currents in the pieces of equipment of the drone (Campy et al., 2018).

The charging station is made effective as electrical power will be transferred into magnetic power and transferred to the receiver coil. The system will have many kinds of losses like eddy’s current losses. Magnetic coupling losses and medium losses. To cover these losses system is improved, and more power is generated by a loss to cover the adequate amount of energy transferred to the drone in less time.

The design uses an array of primary coils. The reason behind the usage of multiple coils is the precision error while the drone is landing at the charging station. The drone can land at any orientation on the station, so the coil directly below it can be energized and used for charging. The use of one big signal coil is not efficient, as it will have more losses (Campy et al., 2018).

The circuit is composed of a DC power source that is converted to AC resonating voltage by a frequency resonating circuit by inductor and resistor combination. The electromagnetic induction then results in a change of current in the receiver coil circuit which has a resonating circuit followed by a bridge rectifier circuit to convert the received AC voltage to DC for charging the battery (Campy et al., 2018).

The resonant frequency selected for the circuit is 150 kHz due to its common application in common circuits (Campy et al., 2018).

The maximum charging efficiency achieved by the WPT system, as seen by both series-parallel combination and series-series combination of coils in the array, shows approximately equal charging efficiency. However, the series-parallel combination gives the advantage, as less number of turns are required to achieve the same level of coupling (Campy et al., 2018).

The use of fewer coils by intelligent use of space resulted in more changing efficiency in less space and by adding less weight to the system. The difference in series and the series-parallel combination is observed in the graph made between a number of turns in both topologies, and their efficiency proves that the series-parallel combination is more efficient than the series-series topology (Campy et al., 2018).

The number of coils added to the circuit has a trade-off with the coil weight, and weight increases as more coils are added to the circuit. That is why a number of coils cannot be added to the circuit, as it will decrease payload weight carrying capacity.

The strategy used in this WPT system is the usage of more coils with less diameter. This configuration provides fewer losses and more flux linkage ultimately increasing the achieved efficiency. The overall efficiency is measured by incorporating the frequency, area of the coil, and magnetic coupling; together, they result in increased efficiency.

The load side impedance is calculated by the voltage currently used by the battery side and the status of the battery, which deteriorates with time.

The efficiency maps of three different orientations of drone placement above the station represent that maximum charging efficiency is achieved by the complete overlapping of primary and secondary coils.

The charging efficiency affected by drone placement on the coil can be observed in the given table.

Alignment (TX, Ty)	Input voltage	Efficiency (%)	Power
0,0	12.5	88	75
100,0	10.8	7.3	78.8
200,0	9.9	76	84.1
0,35	12.6	87	73.5
0,70	12.8	89	71.2

Limitations

The battery condition in the system plays a huge role in governing the maximum efficiency of the system. In addition, the number of coils that can be used in the system cannot be exceeded to achieve better efficiency, as it will increase both the cost and weight of the UAV. The magnetic coupling cannot be increased in the drone as it will generate unnecessary currents in the equipment and may cause other technical problems.

Design Of An Effective Wireless Air Charging System For Electric Unmanned Aerial Vehicles

Introduction

This research was made to provide a solution for a traditional method of UAV charging and proposes a system, which wirelessly charges the UAV with higher efficiency. This system is also a wireless power transfer system like the previous study but with a difference in structure from the primary transmitter coil. The system works on the same principle of electromagnetic induction in which magnetic flux is generated by a large AC resonating circuit (Ke et al., 2017).

Research Findings

The circuit design of the system is relatively simpler and smaller than the previous research design, but the transmitter unit, instead of the use of an array of coils, uses a single large coil for more flux production.

The efficiency of the system is dependent on the mutual inductance factor, which is dependent on the

shape and turns of coils. The equations derived from the current and power calculation of the circuit show the factors of mutual induction, resonating frequency, and internal resistance of the system to be responsible for power transfer and maximum efficiency (Ke et al., 2017).

The transmitting coils of the charging station are three in number, square-shaped, and have dimensions in decreasing order, with the largest coil on the outside and smaller on the inside. These three coils are connected in series with each other, and the secondary coil is meant to be positioned in the direct middle of these three coils for maximum flux coupling. This design provides maximum flux strength in the middle of the station as seen in the graph between the dimensions of the station and electromagnetic flux density (Ke et al., 2017).

The distance between the transmitting and receiving coils also affects the power of the system. The maximum power and efficiency are observed at the distance of 120mm between the charging coil and the receiving coil. It can be observed that efficiency does not very much as compared to the power and stays above 90 when the distance is between ranges of 120 to 150. The power, however, reduces from 190 Watts to 100 Watts when the drone is within this range distance (Ke et al., 2017).

The graph between output power and operating frequency shows an increase in power value when the frequency is increased from 350 to 370 kHz, but it decreases in value at the same rate when it is increased further. The maximum power value is 370 kHz, which is 6.6 Watts (Ke et al., 2017).

The coil charging capacity, due to its symmetrical shape, is maximum when the drone is placed in the exact middle of the station, but it decreases when it is placed far from the center of the charging coils in any direction (Ke et al., 2017).

Limitations

The charging station has no facility to adjust itself for maximum charging capacity in case the drone lands further from the center of the station. The system has high losses of flux when the drone is far from the station. The system has increased power losses when drone placement is further, but it maintains efficiency until 30mm.

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