iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** III **Month of publication:** March 2015

DOI:

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Wireless Induction Charging Of an Electric Propulsion System

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Abstract—The ultimate aim of this project is to develop an induction charging system for a quad copter which enables it to charge the batteries wirelessly. It does not involve any man power thus making the UAV fully autonomous. The little man power involved to recharge the electrical units of the UAVs has been removed and thus making these flying machines fully independent. This concept allows the UAVs working on routine missions to avoid manual interventions. This concept makes the UAV to locate and return to the base whenever the charge of the batteries gets low. The present project relates to a UAV that comprises an inductive charging device that utilizes the electromagnetic field emanated by overhead/utility power station, to charge the energy supplies. The UAV also includes a releasable latch for holding power station to allow for the perching of the UAV on power station during the charging process. The latch and the inductive charging device may be provided on a single device, a battery augmentation trap (BAT). The UAV may be perched in an upright orientation to allow for takeoff after the charging of energy supplies on the power station. The quad copter platform since it is capable of autonomously hovering in place and is capable of carrying a payload, such as the camera used to determine the location of the dock. A system was devised such that the quadcopter can correctly determine the location of a target ground station while hovering and then land when above the docking station. Only commercially available components and software were used so that the entire docking system is easily accessible to future researchers and UAV enthusiasts.
Index Terms—BAT, latches, overhead power line

I. INTRODUCTION

An unmanned aerial vehicle, commonly referred to a UAV, is an aircraft With no onboard pilot. UAVs may be expendable or recoverable and may fly autonomously or remotely. In autonomous applications, the vehicle is either pre-programmed with flight plans or may have the ability to deter mine its own flight plan based on a prescribed mission.
UAVs are commonly employed by the Navy, Army, and Air Force for military purposes. UAVs are also employed in the private sector to perform services such as, crop dusting, forest fire monitoring, aerial photography, and meteorological, environ mental, or other forms of surveillance. Currently, electrically powered UAVs are limited in range and duration by the size and Weight of the batteries Which they can carry. Batteries can make up a significant percentage of the available payload Weight. Consequently, there is an inherent tradeoff between duration and useful payload. Because of these constraints, the flight times of electrically powered UAVs are typically limited to less than one hour. Additionally, the distance traveled from a base location is also limited. Also of concern is that UAV batteries slowly lose their energy even When they are completely powered down. This limits the ability of UAVs to shut down for extended periods of time and then be useful again if the vehicle cannot be recharged. Because of these problems, it is desired to have a means to recharge UAV batteries that does not require a return to the base location. It is also desired to have a means to recharge the batteries that enables the UAV to perform job functions in a more efficient manner.

II. RELATED WORK

In [1] the paper is an unmanned aerial vehicle having a vehicle body. The unmanned aerial vehicle includes a vertical reference line and a horizontal reference line and a vehicle body. The vehicle body includes a propulsion system, an inductive charging device for charging energy supplies, and a releasable latch for releasably holding a utility power line. In this aspect, the releasable latch is attached to the vehicle body above the center of gravity of the vehicle body along a substantially vertical line through the center of gravity. In this aspect, when the releasable latch holds the utility power line, the unmanned aerial vehicle is supported by the latch such that horizontal reference line of the vehicle body and vertical reference line of the vehicle body are maintained in substantially horizontal and substantial vertical orientations respectively. In [2] a battery of an electric vehicle is inductively charged while the

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electrical vehicle is moving, using means for producing a magnetic field along different portions of an extended linear distance and an inductive coil mounted on an electric vehicle, by having the electric vehicle, as it traverses the different portions of the extended linear distance, move within the influence of the magnetic field. Further in accordance with the present project, an apparatus for inductively charging a battery of an electric vehicle equipped with an inductive charging coil while the electrical vehicle is moving includes means for producing an electric field along different portions of an extended linear distance, and means for sensing progress of the electric vehicle along the extended linear distance. The means for producing a magnetic field may be a power switch bank connected to an array of inductive coils, and a means for sensing may be a car sensor array.

In [3] one embodiment of the power-line detecting method and apparatus of the present project locates a power line and determines if the power line detecting apparatus is moving in a direction generally toward the located power lines so that an alarm or other warning signal is only generated if the power lines are generally in the path of movement of the power line detecting apparatus. Thus, false alarms due to the detection of power lines in the vicinity of the power line detecting apparatus, but which the power line detecting apparatus is not approaching, are significantly reduced or eliminated.

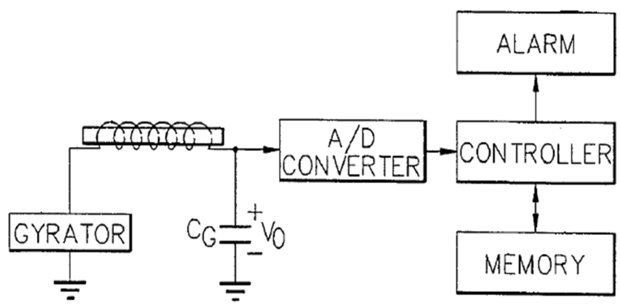

FIG. 1: Apparatus for power source detecting

In [4] an apparatus for charging batteries of an electric vehicle equipped With an armature While the vehicle is moving includes means for automatic on and off switching of short sections of said magnetic field source, means for activating long sections of said magnetic field, means for inducing current into vehicle mounted armature coils, means for identifying the vehicle as it enters and exits the charging area for billing purposes, and means for lowering said armature to optimum proximity of said magnetic field. Means for producing a magnetic field may be a series of primary inductive coils controlled by sensor activated switches, and means for identifying a vehicle for billing may be a vehicle mounted bar code read by scanners located at the entrance and exit stations of a charging lane, said scanners having a designation number or code and information relay capabilities.

III. LIMITATION IN THE EXISTING SYSTEM

A. Physical plug
B. Plug can be messy
C. Requires User to plug in routinely
D. Difficult to remember
E. Complex design & cost is high.
F. Very expensive
G. Maintenance (due to moving part)

IV. PROPOSED WORK

Wireless power transmission (WPT) technology has been widely treated in recent years. Wireless power transfer will be achieved via resonant inductive coupling between the transmitting and receiving coils in the near field. The purpose of wireless power transfer system is to successfully demonstrate the transfer of power by battery augmentation circuit. The device will be able to transmit the power over a distance of some meters. The charging of a battery will be accomplished using a rectifying circuit that will

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ISSN: 2321-9653
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attempt to cancel harmonics and transfer the maximum amount of power.

The design will develop a wireless power apparatus which will be used to power charge a battery.

A. Power supply
B. Transmitting coil
C. Receiving coil
D. Circuit (convertor and rectifier unit)
E. Battery augmentation system.

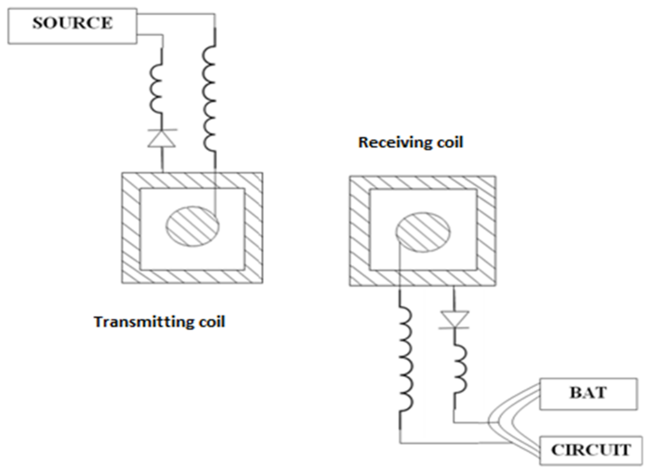

FIG.2: Circuit diagram for induction charging

V. SYSTEM ARCHITECTURE

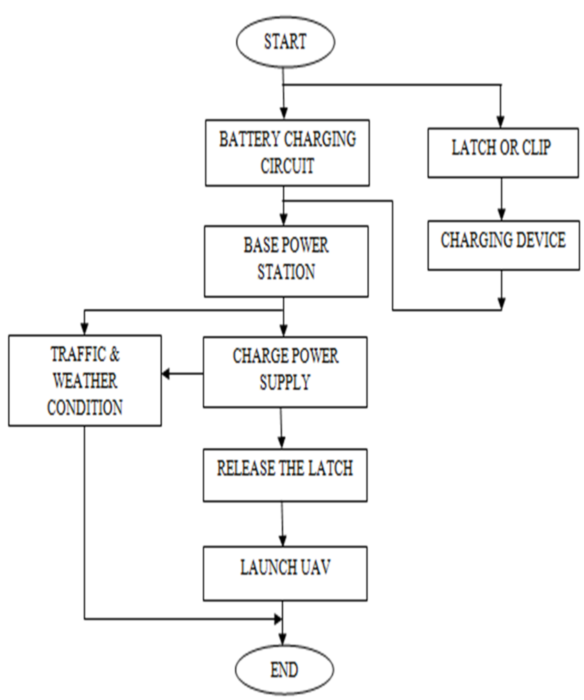

FIG.3: Flow chart

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The above flowchart outlining a method **Battery charging circuit** of charging energy supplies in an unmanned aerial vehicle (UAV). The method utilizes the electromagnetic flux associated with utility base power station that gave currents, to generate a current for charging on-board energy supplies. The UAV is preferably a vertical takeoff vehicle, such as a helicopter. Alternatively, other rotorcrafts such as a fixed pitch quad-rotor vehicle or an autogiro maybe are employed. Additionally, the UAV may be expendable or recoverable and may fly autonomously or remotely. Method **Battery charging circuit** is typically related to UAVs that takeoff from a base location, and are in mid-flight at a location remote from the base location. The method is directed towards charging the UAV' s energy supplies using utility base power station as an energy source, thereby negating the need for the UAV to return to the base location for charging purposes. **Battery charging circuit** is the providing of a battery augmentation trap (BAT). The BAT is attached to the vehicle body. In an embodiment in which the UAV is a helicopter, the BAT is located the rotors, near the center of gravity of the UAV, along a substantially vertical line through the center of gravity. In an embodiment in which the UAV is an airplane, the BAT may be located above the vehicle body, above the center of gravity of the UAV, along a substantially vertical line through the center of gravity. The BAT includes a releasable latch for releasably holding a utility base power station. The BAT also includes an inductive charging device that utilizes the electromagnetic flux associated with the power line to generate a current for charging energy supplies on the UAV. As an alternative to **Battery charging circuit**, **Latch or clip** and **charging device** may be implemented in the method of charging energy supplies in a UAV. At **Latch or clip** a releasable latch is provided on a lower surface of the UAV, as shown in flow chat. At **Base power station**, an inductive charging device is provided on the UAV at a location independent of the latch. In an embodiment in which the UAV is a helicopter, the inductive charging device may be provided on tail boom portion to maximize the utilization of the electromagnetic flux associated with utility base power station. **Base power station** is the perching of the UAV on a utility base power station. This step includes the detecting of the base power station, which may be accomplished by on-board sensors, or from a remote location such as the base location. Upon the detection of the power line, the UAV maneuvers towards the power station so that the releasable latch of the BAT secures the base power station. The securing of the power station may involve the opening and/or closing of the releasable latch. The UAV may be perched in an upright orientation. Alternatively, the UAV may be perched in another orientation, particularly in situations involving persistent surveillance; Where the UAV is indefinitely perched on the base power station. If the UAV is a rotorcraft such as a helicopter, the step of securing the power line would involve the hovering of the UAV in close proximity to the base power station in order to reduce stresses on the power station. If the UAV is a non-vertical takeoff vehicle such as an airplane, the step of securing is accomplished by flying the UAV at a reduced speed into the base power station so that the releasable latch contacts and secures the base power station. As outlined above, on-board sensors may be used to detect the presence and location of base power station. **Charge power supply** is the charging of the energy supplies with the inductive charging device. The energy supplies include all of the UAV's on-board energy supplies such as batteries associated with the propulsion system and sensors. As outlined above, the electromagnetic flux associated with utility base power station induces an electric current in a nearby Wire in the inductive charging device. This current is subsequently utilized to charge the energy supplies, such as batteries of the UAV. **Charge power supply** may be followed by **Traffic and weather condition monitoring** where one or more sensors on the UAV are used to monitor environmental conditions indefinitely, by for example, performing surveillance imagery. The environmental conditions may include Weather conditions, temperature conditions, traffic patterns, human activity etc. At **Traffic and weather condition monitoring**, the UAV may be indefinitely perched on the base power station, which the UAV monitors environmental conditions. **Traffic and weather condition monitoring** is preferably applicable in embodiments Where the UAV is a non-vertical lift vehicle such as an airplane because subsequent takeoff may be difficult. However, **Traffic and weather condition monitoring** may also be performed in embodiments Where the UAV is a vertical takeoff vehicle, such as a helicopter. In this embodiment the charging of the energy supplies with the inductive charging device is provided either continuously or repeatedly to provide energy for the one or more sensors. **Release the latch**, the opening of the releasable latch to release the UAV from the perched position, may optionally follow **Charge power supply**. **Launch UAV** is the launching of the UAV into an airborne state. **Launch UAV** maybe commences after **Release the latch**. Alternatively, **Release the latch** and **Launch UAV** may commence simultaneously.

VI. DETAILED DESCRIPTION

A. Working Principle of Induction

Inductive charging works on the principle of transformer. A **transformer** is a device that transfers electrical energy from one circuit to another through inductively coupled conductors the transformer's coils. A varying current in the first or *primary* winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic field through the *secondary* winding. This varying

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Volume 3 Issue III, March 2015
ISSN: 2321-9653
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magnetic field induces a varying Electromotive force (EMF) or "voltage", in the secondary winding. This effect is called *mutual induction.*

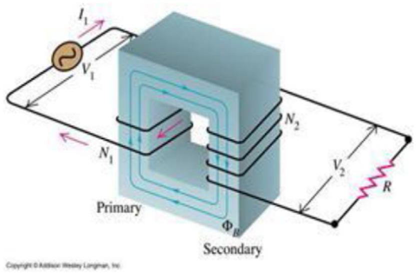

FIG.6.1: Basic Transformer [1]

B. Induction

The action of an electrical transformer is the simplest instance of wireless energy transfer. The primary and secondary circuits of a transformer are not directly connected. The transfer of energy takes place by electromagnetic coupling through a process known as mutual induction. (An added benefit is the capability to step the primary voltage either up or down.) The battery charger of a mobile phone or the transformers on the street is examples of how this principle can be used. Induction cookers and many electric toothbrushes are also powered by this technique. The main drawback to induction, however, is the short range. The receiver must be very close to the transmitter or induction unit in order to inductively couple with it.

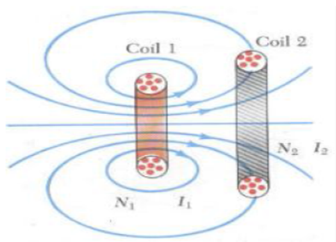

FIG.6.2: Electric Toothbrush [1]

C. Working Principle of Transformer

The working principle of transformer is very simple. It depends upon Faraday's law of electromagnetic induction. Actually, mutual induction between two or more winding is responsible for transformation action in an electrical transformer.

D. Faraday's Laws of Electromagnetic Induction

"Rate of change of flux linkage with respect to time is directly proportional to the induced EMF in a conductor or coil".

E. Basic Theory of Transformer

Say you have one winding which is supplied by an alternating electrical source. The alternating current through the winding produces a continually changing flux or alternating flux that surrounds the winding. If any other winding is brought nearer to the previous one, obviously some portion of this flux will link with the second. As this flux is continually changing in its amplitude and direction, there must be a change in flux linkage in the second winding or coil. According to Faraday's law of electromagnetic induction, there must be an EMF induced in the second. If the circuit of the later winding is closed, there must be an current flowing through it.

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ISSN: 2321-9653
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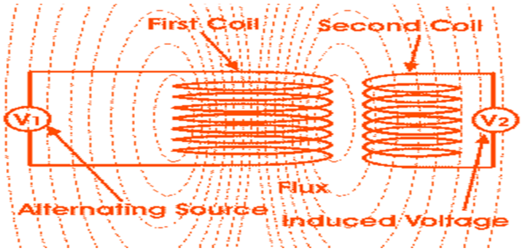

FIG.6.3 Mutual induction

This is the simplest form of electrical power transformer and this is the most basic of working principle of transformer**.**

F. Losses in Transformer

As the electrical transformer is a static device, mechanical loss in transformer normally does not come into picture. We generally consider only electrical losses in transformer**.** Loss in any machine is broadly defined as difference between input power and output power. When input power is supplied to the primary of transformer, some portion of that power is used to compensate core losses in transformer i.e. Hysteresis loss in transformer and Eddy current loss in transformer core and some portion of the input power is lost as I2R loss and dissipated as heat in the primary and secondary windings, because these windings have some internal resistance in them. The first one is called core loss or iron loss in transformer and the later is known as ohmic loss or **copper** loss in transformer. Another loss occurs in transformer, known as Stray Loss, due to Stray fluxes link with the mechanical structure and winding conductors.

G. Core Losses in Transformer

Hysteresis loss and eddy current loss, both depend upon magnetic properties of the materials used to construct the core of transformer and its design. So these losses in transformer are fixed and do not 28 depend upon the load current. So core losses in transformer which is alternatively known as iron loss in transformer can be considered as constant for all range of load.

Hysteresis loss in transformer is denoted as,

$$W_h = K_h f (B_m)^{1\cdot 6}\ watts$$

Copper loss can simply be denoted as,

IL2R2′ + Stray loss

Where, IL = I2 = load of transformer, and R2′ is the resistance of transformer referred to secondary.

Now we will discuss Hysteresis loss and Eddy current loss in little bit more details for better understanding the topic of losses in transformer. As the current flowing through the solenoid is alternating, the flux produced in the iron ring is also alternating in nature, so the emf (e′) induced will be expressed as,

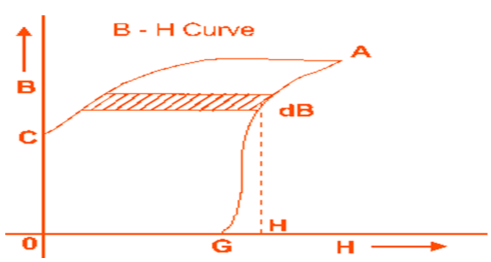

FIG.6.4 b-h curve [1]

H. Circuit Diagram

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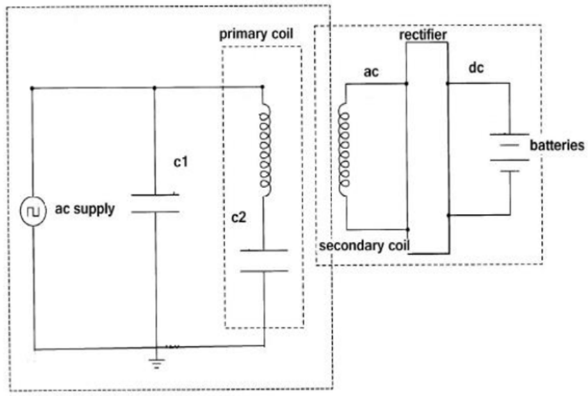

FIG.6.5: Circuit diagram for induction charging

1) *Transmitter Coils and Circuitry:* Unlike the multiple-layer secondary of a non-resonant transformer, coils for this purpose are often single layer solenoids (to minimize skin effect and give improved *Q*) in parallel with a suitable capacitor, or they may be other shapes such as wave-wound litz wire. Insulation is either absent with spacers or low permittivity, low loss materials such as silk to minimize dielectric losses. A capacitor stores energy in the electric field between its plates, depending on the voltage across it, an inductor stores energy in its magnetic field, depending on the current through it
2) *Receiver Coils and Circuitry:* The secondary receiver coils are similar designs to the primary sending coils. Running the secondary at the same resonant frequency as the primary ensures that the secondary has low impedance at the transmitter's frequency and that the energy is optimally absorbed. To remove energy from the secondary coil, different methods can be used, the AC can be used directly or rectified and a regulator circuit can be used to generate DC voltage.

I. EMI shielding design

Electromagnetic interference is a serious issue for small-scaled UAV helicopters as all of the highly integrated electronic components are required to be mounted in a very limited space.

The main problems aroused by EMI include:
1) Reducing the effective range of RC manual control;
2) Generating errors in INS/GPS measurements; and
3) Causing data losses in wireless communications.

These problems have to be eliminated or reduced to minimum before conducting actual flight tests. In SheLion, we use aluminum boxes and foil to isolate the necessary electronic components. More specifically, the key hardware components such as the servo controller board, RC receiver, MNAV100CA and wireless modem
are kept in separate aluminum boxes, and the onboard system is protected with aluminum foil. As a result, we have successfully maintained the original manual control range and the reliability of the MNAV100CA and wireless modem.

J. Battery power

Currently only micro- and mini-UAV are powered by batteries and electric motors. Although considerable improvements are continuously being made in battery design and production, the demand on the battery is made not only by the motor, but also by the payload and communication system. Therefore the flight endurance and speed of such UAV systems and the capability of their payload and communication systems are limited. The systems are small and light enough to be back-packed so they have a place in very short range operations under relatively benign conditions. Back-up batteries must be carried and regularly charged to ensure an electrical supply.

K. MUAV or Rotary-wing Aerodynamics

The aerodynamics of rotary-wing aircraft are, by nature, more complex than the aerodynamics of fixed-wing aircraft.

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Volume 3 Issue III, March 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

1) *Lift-induced Drag:* The same basic mechanism applies for rotary wings as for fixed wings, the difference merely being that the 'fixed wing' moves on a sensibly linear path in order to encompass the air, whilst the rotary wing, whilst hovering, moves on a circular path. The latter therefore draws in 'new' air from above in order to add energy to it and accelerate it downwards, compared with the former which receives it horizontally to accelerate it downwards. At each element of the rotary wing, the aftward-inclined vector of the lift force produces a drag at the element which translates into a torque demand at the rotor hub. For the same reason as with the fixed wing, the rotary wing must induce a large mass of air for efficiency. Therefore the larger the diameter of the circle (or disc) traced out by the rotary wing, the more efficient it is.
2) *Parasitic Drag:* Again, the same elements, form drag, friction drag, momentum drag, etc., as discussed for the estimate of fixed-wing aircraft performance, apply to the rotary-wing aircraft. There is a small difference, however, in the accounting. Due to the more complex 'flight path' of a rotor, its drag is accounted for separately under the heading of 'profile drag' or 'profile power'. The drag of the remaining elements, i.e. fuselage, undercarriage, cooling drag, etc., then comprise the parasitic drag which is calculated in the same way as for a fixed-wing aircraft.
3) *Profile Drag or power:* In hover flight, the profile power required to turn the rotor against the profile drag is computer-calculated by the summation along the length of the rotor blade of the drag of the blade split into elemental sections and multiplied by the local element velocity and radius from the hub. This is referred to as blade element theory. However, for simpler analysis, an average value of drag coefficient δ is used and mathematical integration produces the following expression;

Where *A* is the total blade area and *VT* is the speed of the rotor tip.

$$\text{Profile power } P_o = \frac{1}{8}\rho\,\delta A V_T^3$$

In forward flight, each blade element no longer describes a circular orbit, but a longer, spiral path which becomes increasingly asymmetric as the forward speed increases. The result is an increase of the profile Power compared with that of the hover. Power is expended in translating the rotor as well as rotating it.

An exact expression of the multiplier to obtain this power is a power series equation in μ, the 'advance ratio' – i.e. the ratio of the forward speed to the rotor tip speed. This multiplier is usually simplified to the close approximation: (1 + 4.73 μ2), so that the profile power in forward flight is calculable as:

$$P_{o\mu} = P_o(1 + 4.73\,\mu^2).$$

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VII. SUMMARY

The present invention addresses aspects of problems out lined above. Preferred embodiments of the present paper provide a method and apparatus for charging energy supplies in an unmanned aerial vehicle. In one aspect, the project is a method of charging energy supplies in an airborne unmanned aerial vehicle. The method includes the providing of a battery augmentation trap, which is attached the unmanned aerial vehicle. In this aspect, the battery augmentation trap comprises a releasable latch, and an inductive charging device for charging the energy supplies. The method also includes the perching of the unmanned aerial vehicle on a utility power station. This is accomplished by maneuvering the airborne unmanned aerial vehicle so that the releasable latch of the unmanned aerial vehicle secures the utility base power station within the releasable latch, after which the utility power line supports the unmanned vehicle. The method further includes the charging of the energy supplies with the inductive charging device. The inductive charging device utilizes the electromagnetic field associated with the utility base power station to generate power for the energy supplies. In another aspect, the invention is an unmanned aerial vehicle. The unmanned aerial vehicle has a vehicle body that includes a vertical reference line and a horizontal reference line. In this aspect, the vehicle body has a base portion, a propulsion system, and a battery augmentation trap. According to the invention, the battery augmentation trap comprises an inductive charging device for charging energy supplies, and a releasable latch for releasably holding a utility power line. The battery augmentation trap is attached to the vehicle body above the center of gravity of the vehicle body along a substantially vertical line through the center of gravity. According to the invention, when the releasable latch holds the utility base power station, the unmanned aerial vehicle is supported by the latch such that horizontal reference line of the vehicle body and vertical reference line of the vehicle body are maintained in substantially horizontal and substantial vertical orientations respectively.

VIII. CONCLUSION

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In this paper we have presented, the development of Induction charging, it has several advantages over standard power transfer. One major benefit is that it is wireless. There is no limitation on the number of devices that may be charged at once. Hence, a single inductive charging mat can charge several devices at the same time. Inductive charging carries a far lower risk of electrical shock when compared with conductive charging, because there are no exposed conductors.

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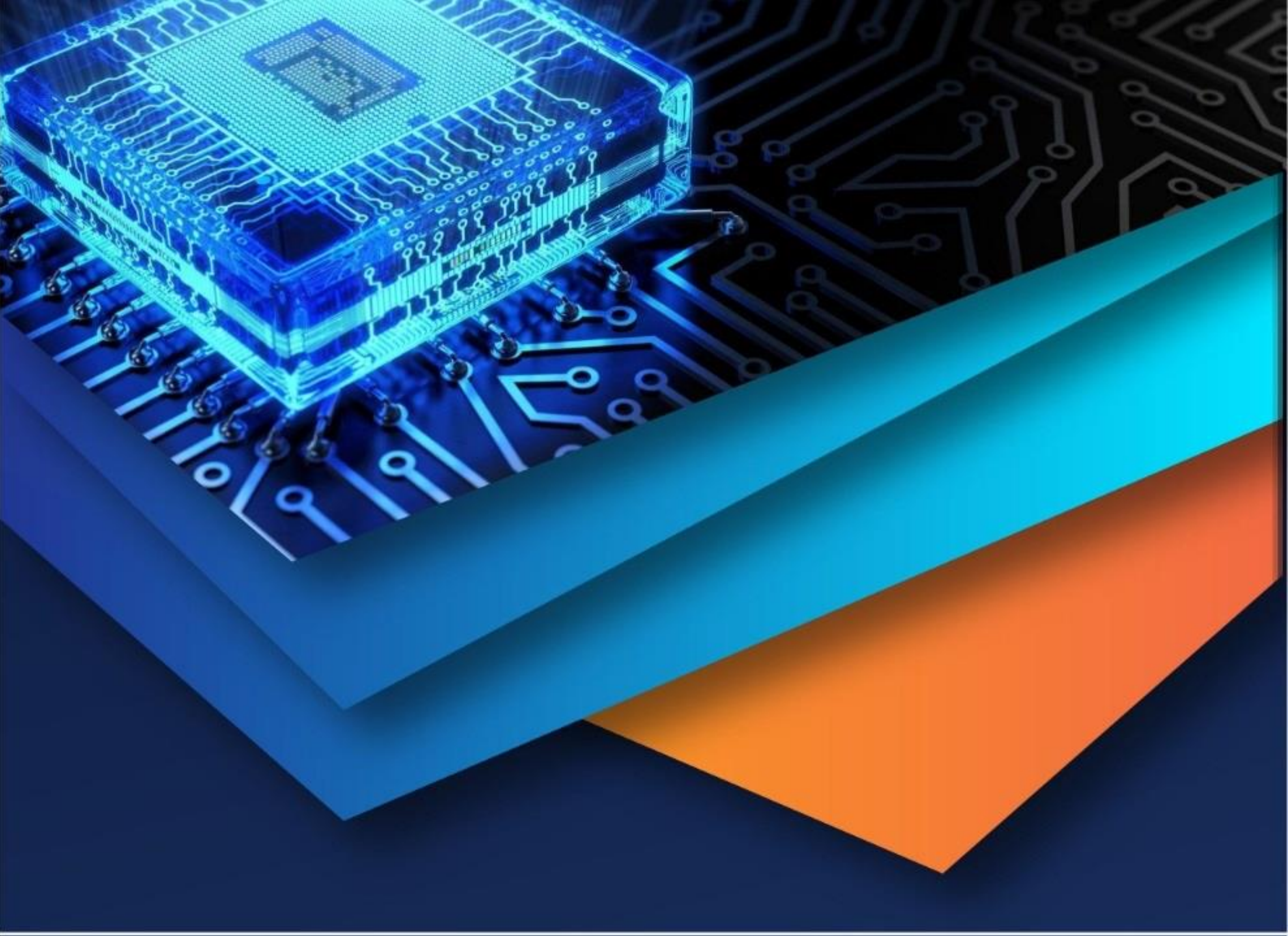

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