DESIGN AND DEVELOPMENT OF AIR-TO-AIR RECHARGING PLATFORM FOR RC DRONES

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Certification

This is to certify that **Hamza Salman, 326669** have successfully completed the final project **Design and Development Of Air To Air Recharging Platform For RC Drones** at the **National University of Sciences & Technology (NUST)** to fulfill the partial requirement of the degree **BE Aerospace.**

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Abstract

This project represents a critical milestone in the realm of unmanned aerial vehicles (UAVs) with the development of a proof-of-concept independent recharging kit. With an exclusive focus on recharging infrastructure, this initiative stands distinct from conventional UAV design endeavors. By intentionally excluding drone design aspects, the project directs its attention towards refining and optimizing the essential components necessary for seamless UAV operation. The cornerstone of this project lies in the meticulous design and development of a compact and lightweight recharging kit. Recognizing the importance of portability in UAV applications, the kit is engineered to be easily transportable, facilitating deployment in diverse environments and operational scenarios. Moreover, stringent safety measures have been incorporated to mitigate risks, with a particular emphasis on short-circuit prevention and ensuring secure engagement mechanisms. In pursuit of these objectives, advanced engineering principles and innovative technologies have been leveraged. Extensive research and development efforts have culminated in the integration of cutting-edge solutions, optimizing the performance and reliability of the recharging kit. By harnessing the power of modern design methodologies and manufacturing techniques, such as 3D printing, the project has achieved remarkable strides in streamlining production processes and reducing costs. Throughout the development lifecycle, rigorous testing and validation procedures have been employed to ensure the efficacy and robustness of the recharging kit. Computational simulations, wind tunnel tests, and real-world trials have provided invaluable insights into the kit's performance under varying conditions. These comprehensive evaluations have underscored the kit's suitability for deployment across a spectrum of UAV missions, reaffirming its potential as a game-changing innovation in the UAV ecosystem. In summary, this project heralds a new era in UAV technology, ushering in a paradigm shift with its innovative approach to recharging infrastructure development. With its compactness, lightweight design, and robust safety features, the independent recharging kit sets a new standard for reliability and versatility in UAV operations, offering tangible benefits for both academic exploration and practical applications in dynamic real-world scenarios.

Keywords: UAV, Air to air recharging, RC drone’s 3D Printing, Aerospace Design.

Undertaking

I certify that the project **Design and Development of Air To Air Recharging Platform For RC Drones** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

Hamza Salman

326669

Acknowledgement

All praise is due to Almighty Allah, whose guidance and strength have enabled me to fulfill the entrusted task within the allocated time and resources. It is indeed His profound guidance and blessings that have sustained my resolve and commitment throughout this endeavor. I extend my sincere appreciation to my project advisor, Squadron Leader Adnan Maqsood, whose steadfast support and judicious counsel were pivotal in navigating critical decisions throughout this project. Without his gracious assistance, the fruition of this work would have remained unattainable. Furthermore, I express profound gratitude to my esteemed seniors Pilot officer Farhan and Sir Murtaza Saleem, whose unwavering dedication and collaborative efforts significantly contributed to the realization of this project. Their steadfast support and countless hours of collaboration and guidance of Ms. Farkhanda Aziz, whom played an indispensable role in translating vision into tangible outcomes. I am deeply indebted to the trust and camaraderie we share, and I eagerly anticipate future collaborations with anticipation. Her invaluable guidance and unwavering encouragement have been instrumental in shaping my fervor for innovation and guiding my academic and professional trajectory. Their wealth of knowledge, expertise, and unwavering support have been pivotal in facilitating optimal decisions for my academic and professional advancement. I am profoundly grateful for the privilege of benefiting from their extensive experience, and I eagerly anticipate further opportunities to glean from their wisdom as I continue along my scholarly and professional journey.

Contents

Chapter 1

Introduction

Remote control (RC) drones have become very famous in recent years due to their affordability and adaptability; they have a wide range of applications such as transportation, delivery, air ambulance, photography, inspection, agriculture, livestock management, rescue operations, and much more. To increase the range and save time it has been encouraged by the society of modernization considering the advancement in energy generation retention-consumption in the form of air-to-air recharging using various methods. automation and control, tools for design and critical analysis, burdens on resources available, and their application. This also marks the right time to develop such a method. The scope of this work is to find a method that can be used as a beacon for the development of a recharging platform by the emerging aviation markets and the national authorities.

There are several prominent features of such aerial platforms:

- It will extend the flight time of RC drones.
- It will make RC drones more sustainable.
- It will open new possibilities for the use of RC drones.

To fulfill the objective, significant technical shortcomings are important. Answering all questions is not important, the weight of each component and the performance parameter modeling can be catered to in future work. The research development of air-to-air platforms involves propulsive systems, performance, rotor-rotor interactions, efficiency, safety, and airworthiness. Three conceptual vehicles including all these parameters were studied, that might span over the research space.

- The platform will consist of two drones: a mothership drone and a recharging drone.
- The mothership drone will be equipped with a battery pack that can be used to recharge the recharging drone.
- The recharging drone will be equipped with a mechanism that allows it to connect with the mothership drone and receive a charge.

1.0.1 Project Overview

The air-to-air recharging platform for RC drones represents a groundbreaking innovation poised to revolutionize aerial operations. By facilitating inflight recharging of airborne vehicles, this design promises to significantly enhance the range and endurance of drone flights, thereby unlocking new possibilities and applications in various sectors.

This pioneering concept not only extends the operational capabilities of RC drones but also addresses critical challenges associated with limited flight durations and range constraints. By seamlessly integrating recharging capabilities into the aerial environment, this platform holds the potential to redefine the scope and efficacy of drone missions across diverse domains. Moreover, the implementation of air-to-air recharging technology heralds a paradigm shift in the utilization of RC drones, transcending conventional limitations and expanding their utility beyond traditional applications. From surveillance and reconnaissance missions to emergency response operations and environmental monitoring, the

enhanced endurance afforded by this platform opens avenues for transformative advancements in aerial operations.

Furthermore, the development and deployment of such a system necessitate comprehensive considerations encompassing technological feasibility, safety protocols, regulatory compliance, and integration with existing airspace infrastructure. Collaborative efforts between stakeholders including aviation authorities, industry partners, and research institutions are indispensable in realizing the full potential of this innovative solution.

In essence, the air-to-air recharging platform for RC drones embodies a convergence of technological ingenuity and practical utility, poised to usher in a new era of aerial capabilities and applications. Its implementation holds the promise of enhancing efficiency, effectiveness, and sustainability in aerial operations, thereby reshaping the landscape of unmanned aerial systems.

1.0.2 Problem Statement

This project endeavors to design and develop a sophisticated air-to-air recharging platform tailored specifically for RC drones. The envisioned platform will take the form of a compact, lightweight aircraft equipped with a battery pack, strategically engineered to fly in tandem with an RC drone. Through innovative recharging mechanisms, the platform will seamlessly transfer charges to the drone mid-flight, effectively extending its operational duration without the need for frequent landings for recharging. This transformative solution not only promises enhanced endurance for drone missions but also opens avenues for uninterrupted and sustained aerial operations across diverse applications. Furthermore, the project aims to address key technical challenges, ensuring optimal performance, safety, and compatibility with existing drone systems and regulatory frameworks.

1.0.3 Project Scope

This project aims to design and develop an advanced air-to-air recharging platform tailored specifically for RC drones. The envisioned platform, characterized by its compactness and lightweight design, will be equipped.

with a battery pack, strategically engineered to operate alongside RC drones. By implementing innovative recharging mechanisms, the platform will facilitate seamless transfer of charges to the drone mid-flight, thereby significantly extending its operational duration without the need for frequent landings. This groundbreaking solution not only ensures enhanced endurance for drone missions but also fosters uninterrupted and sustained aerial operations across various applications. Moreover, the project is committed to addressing critical technical challenges, ensuring optimal performance, safety, and compliance with existing regulatory frameworks governing drone operations.

Chapter 2

Literature Review

Air-to-air charging represents a novel concept wherein both the charger and the target device are airborne, encompassing a wide array of aerial platforms such as RC drones, planes, drone cameras, and agricultural drones. This innovative approach to recharging introduces a paradigm shift in the realm of aerial operations, offering unprecedented flexibility and efficiency. Various configurations have been explored in the literature to facilitate air-to-air recharging, each tailored to specific applications and operational requirements. These configurations include proximity-based charging, in which the charger and the device maintain close spatial proximity during the recharging process, as well as docking-based charging, wherein the device docks with the charger to initiate the recharging sequence. Additionally, advancements in wireless power transfer technologies have paved the way for inductive and resonant charging methods, further enhancing the feasibility and versatility of air-to-air recharging systems. As the demand for extended flight durations and uninterrupted aerial missions continues to grow, air-to-air recharging emerges as a promising solution with significant implications for diverse sectors including surveillance, agriculture, and emergency response. In this literature review, we delve into the current state of research and development in air-to-air recharging, highlighting key findings, technological advancements, and outstanding contemporary challenges.

2.1 Fixed wing RC drones

Fixed-wing RC drones, classified as remote-controlled or unmanned aerial vehicles (UAVs), emulate the flight dynamics of conventional aircraft. Utilizing a combination of propellers and wings to generate lift, they exhibit versatility across a range of applications. These drones vary in size, from commercial models deployed for mapping and package delivery to scaled down versions catering to hobbyist enthusiasts. Renowned for their capability to cover longer distances, fixed-wing drones are favored for extended missions requiring endurance. Notably, their superior payload capacity compared to multirotor counterparts renders them suitable for missions demanding heavy payloads. Their forward-flight reliance contributes to enhanced energy efficiency. However, their operational requirements, such as the need for a clear takeoff and landing area or runway, impose limitations in constrained environments. Additionally, their susceptibility to wind interference presents challenges, particularly in windy conditions. While fixed-wing drones offer advanced capabilities, their complexity renders them less conducive to novice pilots, necessitating proficiency for optimal operation. This overview underscores the significance of fixed-wing RC drones in modern aerial endeavors while acknowledging associated complexities and operational considerations.

2.2 Multi-rotor RC drones

Multi-rotor RC drones, commonly referred to as multi-copters, have emerged as remarkable aerial vehicles capturing the world’s attention. These machines utilize multiple rotors, typically four or six, to generate lift and navigate the skies with exceptional agility. Their unparalleled maneuverability allows for precise movements including hovering, darting, spinning, and swift navigation, rendering them invaluable for tasks such as inspecting inaccessible areas, aerial photography, and urban goods delivery. Spanning a range of sizes from nano drones, no larger than a palm,

to military-grade helicopters, multi-copters offer versatility across diverse applications. In comparison to traditional helicopters, they boast relative ease of learning and operation, making them accessible to a wider audience of pilots. Furthermore, multi-copters are categorized based on their payload capacity, catering to various mission requirements. This overview highlights the significance of multi-copters in contemporary aerial operations and underscores their potential for revolutionizing industries ranging from transportation to surveillance.

2.3 Analysis

Fixed-wing drones excel in providing long-range capabilities and extended flight times, making them ideal for missions requiring extensive coverage and endurance. On the other hand, multirotor drones offer unique maneuverability, contributing to their versatility and ease of learning, which has led to their substantial market dominance. Multirotor drones captured over 81% of the Commercial drone market in 2023, underscoring their widespread adoption and preference. Despite this dominance, fixed wing and hybrid drones also hold significant roles in specific applications, leveraging their distinct advantages for specialized missions. This evaluation highlights the complementary strengths of fixed-wing and multirotor drones, each catering to distinct operational requirements within the broader landscape of aerial technologies.

2.4 Sizes of multi-rotor drones

2.4.1 Very Small Drones

Microdrones, characterized by their diminutive size comparable to that of insects and capable of fitting on a human palm, exhibit dimensions ranging from 1 to 50 cm. Their compact stature enables operation in con-

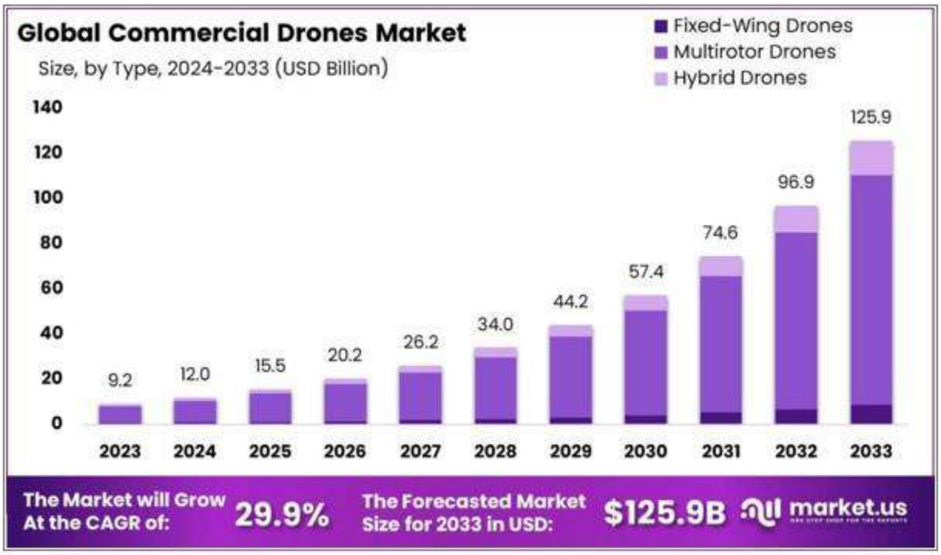

Figure 2.1

fined spaces, making them particularly suitable for navigating narrow environments with precision. Leveraging their minuscule cross-section, microdrones evade detection with relative ease, rendering them inconspicuous during surveillance operations. Primarily utilized by intelligence agencies and reconnaissance units, these drones serve as discreet tools for gathering information on individuals and objects, underscoring their significance in covert operations. This description underscores the unique capabilities and specialized applications of microdrones within the realm of unmanned aerial systems.

2.4.2 Small Drones

Small drones, slightly larger than microdrones, typically range in size from 50 cm to 200 cm and weigh approximately 0.2 to 1 kg. These drones find extensive applications in inspections and recreational activities, owing to their enhanced payload capacity and maneuverability compared to microdrones. Their compact yet robust design enables them to perform various tasks, including aerial inspections of infrastructure, monitoring of agricultural fields, and capturing high-quality imagery for recreational.

purposes. Despite their modest dimensions, small drones offer versatility and reliability, making them indispensable tools across a spectrum of industries and leisure pursuits. This description underscores the practical utility and versatility of small drones in diverse operational contexts, highlighting their significance in both professional and recreational settings.

2.4.3 Medium Drones

Medium drones, exceeding the dimensions and weight thresholds of smaller counterparts, typically measure more than 200 cm in size and weigh between 2 kg to 200 kg. Distinguished by their substantial build and robust construction, these drones serve as indispensable tools for a plethora of professional applications and amateur photography pursuits. In the professional sphere, medium drones find extensive use in aerial mapping, surveying, infrastructure inspections, and search and rescue operations. Their enhanced payload capacity and endurance make them well-suited for carrying sophisticated imaging equipment and sensors, enabling precise data collection and analysis across various industries. Furthermore, in the realm of amateur photography, these drones offer enthusiasts the opportunity to capture breathtaking aerial perspectives with ease and precision. This portrayal underscores the significant role of medium drones in advancing both professional endeavors and recreational interests, epitomizing their versatility and utility in contemporary aerial operations.

Size	Length	Propeller Diameter	Weight	Use
Very Small Drone	150mm	51 mm or less	200 grams	Military Surveillance
Small Drone	Up to 300mm	76-152 mm	200-1000 grams	Indoor equipment inspections Recreation and Photography
Medium Drone	300 - 1200mm	150-640 mm	1000 - 1200 grams	Professional applications Amateur Photography
Large Drone	1200mm	640 mm or above	2000 grams	Enemy Detection Combat capabilities6

2.4.4 Large Drone

Large drones, akin to small aircraft in their size and capabilities, are predominantly utilized by military forces for a spectrum of critical operations including combat missions, logistics support, and surveillance endeavors. Their pivotal role in modern warfare is underscored by their unmanned nature, which affords remote control capabilities from ground stations, thus poised to gradually supplant traditional fighter jets. Equipped with advanced avionics and communication systems, these drones boast unparalleled range and endurance, enabling sustained operations over vast distances. Beyond military applications, large drones have found relevance in civil industries, particularly in the domains of drone deliveries and film making. This convergence of military and civilian usage underscores the versatility and adaptability of large drones, positioning them as indispensable assets in contemporary aviation landscapes.

2.4.5 Air to Air Re charging system.

Air to air charging is a concept in which both the charger and the device to be charged both are airborne they might be any flying object for example RC drones, RC planes, drone cameras, agricultural drones, etc. Air to air recharging can be done using various configurations few are discussed below.

2.4.6 Docking method

Previously we have widely seen the in military aircrafts the concept of air to air refueling. To perform this task, they use docking configuration to transfer the fuel from the fuel tank carrying aircraft to the other aircraft using hose. This is a conventional method and widely used in the aviation industry. Figure 1 shows the docking method for refueling between aircrafts. The same ideology may be used to perform air to air recharging where fuel will be replaced by wires to transfer charge through hose.

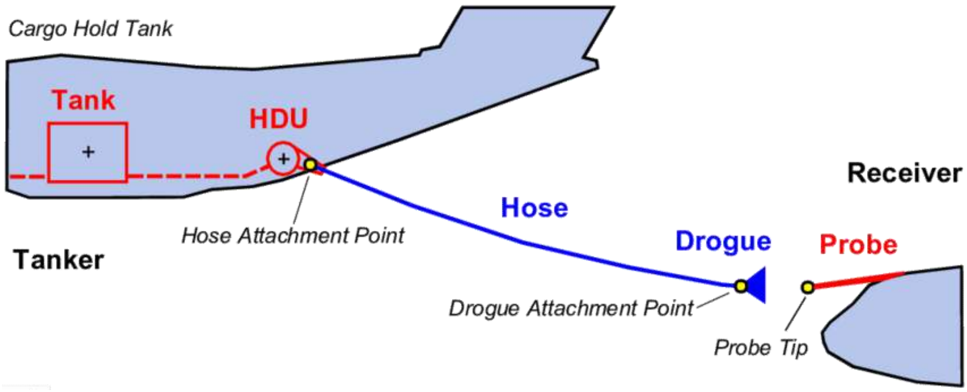

Figure 1 docking system.

2.5 Wireless Charging

In this phenomenon the charging mothership drone conveys power through an air opening to electrical devices. wireless charging is in the development phase. The same configuration might be used to charge RC drones during flight in which charging frame is deployed on mothership drone and recharging drone to hover over it to receive charge. Wireless charging can be done using the following methods.

2.5.1 Inductive coupling

It is a common technique used for wireless power transfer. It done using electromagnetic fields to transmit energy between two coils one on the mothership drone and the other on the recharging drone [2]. When the coils are brought into vicinity, the energy is transferred wirelessly, which enables recharging of the drone's batteries.

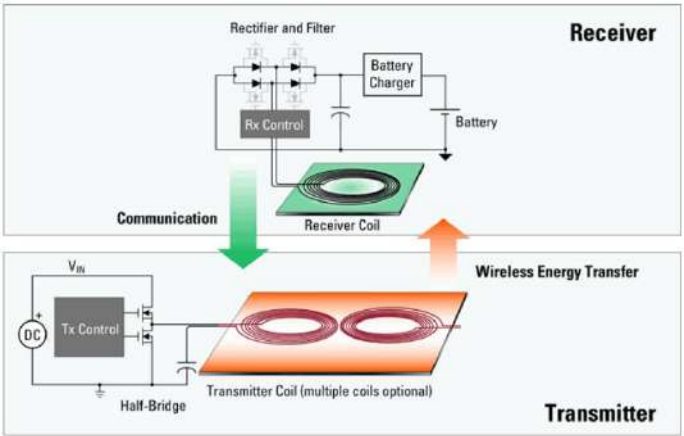

Figure 2 inductive coupling.

2.5.2 Laser Power Beaming

Laser power beaming is the latest method that utilizes focused laser beams to transfer power [3]. A laser transmitter on the charging station or aircraft sends a laser beam to a photovoltaic cell or a receiver on the drone. The receiver converts the laser energy into electrical power, which can be used to recharge the drone's batteries.

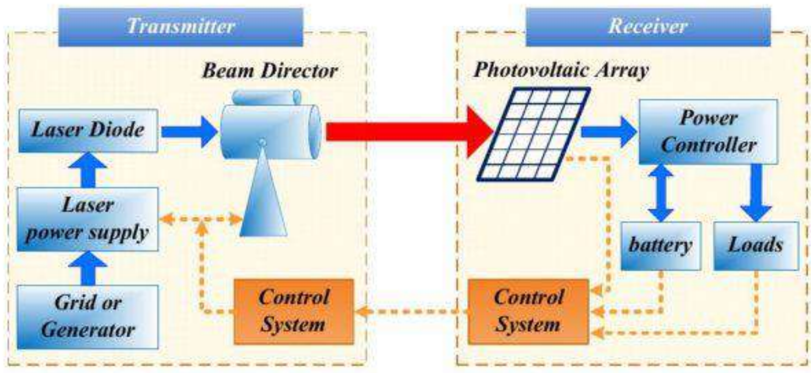

Figure 3 laser power beaming.

2.5.3 Resonance coupling

Resonance coupling is a phenomenon in which the coupling between two coils becomes stronger when the coils are tuned to the same resonant frequency. This is because the coils can efficiently transfer energy when they are oscillating at the same frequency.

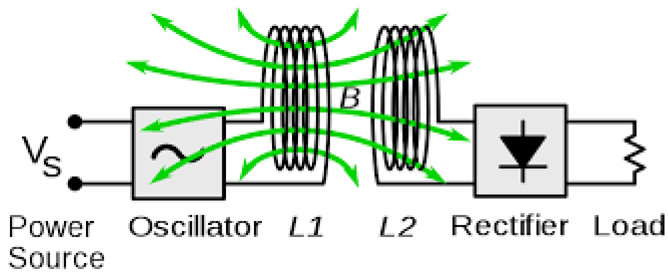

Figure 4 resonance coupling.

2.5.4 Infrared Power Transmission

IRPT works by using infrared light to transmit power from a transmitter to a receiver. The transmitter generates infrared light, which is then focused into a beam. The beam of infrared light is then directed towards the receiver, which converts the infrared.

light back into electrical power. Infrared power transmission (IRPT) is a wireless power transfer technology that uses infrared light to transmit power from a transmitter to a receiver [3]. IRPT is a promising technology for a variety of applications, including charging electronic devices, powering sensors, and even medical applications.

Figure 5 infra-red power transmission.

2.6 Batteries

RC drones mainly use three types of batteries which are as follows.

2.6.1 Lithium Polymer (LiPo) batteries

These batteries are most used in RC drones. It has a polymer electrode than the liquid one. It is rechargeable battery easily available in market.it is available with the minimum capacity of 35 Mah to maximum of 2800 Mah batteries.

Figure 6 Lithium Polymer (LiPo) batteries.

2.6.2 Nickel Metal Hydride (NiMH) batteries

In NiMH batteries hydrogen storage alloys are used as negative electrodes whereas nickel hydroxide is used as active metal in positive electrode with alkaline electrolyte. Fine fibers are used to separate the electrodes. Embedded in metal casing with sealing plate and a self-sealing safety vent. They have low cost and are an alternative to Lithium Polymer (LiPo) batteries. They have more weight and less energy density then LiPo battery, but They are more durable.

Figure 7 Nickel Metal Hydride (NiMH) batteries.

2.6.3 Lithium Ion (Li-Ion) batteries

A lithium-ion battery belongs to the family of rechargeable battery types in which lithium ions travel from the negative electrode to the positive electrode during discharge and vice versa when charging. The main components of cells of lithium-ion batteries are cathode, anode, and electrolyte [4]. Although lithium-ion batteries are actively used tool for today's miniaturized and rechargeable electronics devices, they exhibit some serious drawbacks including their limited life cycle ,high costs, and low energy density.

Figure 8 Lithium Ion (Li-Ion) batteries.

2.6.4 Considerations

While selecting the battery special considerations are Catered. Some of them are as follows.

1. •Weight: The battery should be as lightweight as possible to maximize the flight time of the drone.
2. •Energy density: The battery should have a high energy density to provide the drone with enough power to fly for a long time.
3. •Discharge rate: The battery should be able to discharge quickly to provide the drone with the power it needs to fly quickly.

4. •Durability: The battery should be durable to withstand the rigors of flying an RC drone.
5. •Cost: The battery should be affordable to fit within the budget of the user.

2.7 Software used.

These are the following software used to simulate the mentioned problem:

2.7.1 ANSYS

Ansys is an important software in creating real-world scenarios for structural and fluid problems. This case will be solved using Ansys to study the behavior of drones while hovering over each other. A drone model will be generated, and the flow domain accurately meshed in the Fluent solver. Flow conditions including the viscous model criteria, use of energy equations, and another parameter will be defined to analyze the behavior.

2.7.2 TECHPLOT:

TECPLOT software is used to visualize the results generated from Ansys-Fluent. This software will be used in this project to see the results of the energy harvesting performance. This software will help in compiling, visualizing, and comparing the results obtained from the Ansys-fluent simulation.

2.7.3 Origin:

Origin is used for graphing and analyzing results. Its results can automatically update data or parameter change, allowing us to create templates for repetitive tasks or to perform batch operations from the user interface, without the need for programming.

Chapter 3

Methodology

Project Approach

In this project we will be involved in designing the air-to-air recharging platform and the recharging mechanism. This will involve conducting research, brainstorming, and prototyping. Then we will develop an air-to-air recharging platform. This will involve building prototypes, testing them, and making improvements. Later we will be involved in testing the air-to-air recharging platform in a variety of conditions. This will involve flying the platform with RC drones and testing the recharging mechanism. In the end we will deploy the air-to-air recharging platform.
The step-by-step methodology that will be adopted for the project is shown below.

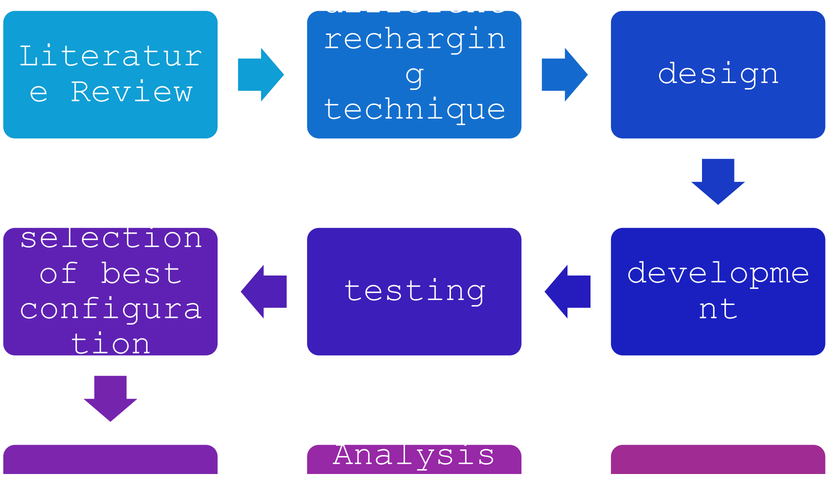

Figure 9 Methodology.

Expected deliverables:

The expected deliverables are as follows:

1. to design recharging mechanism
2. analyze [4]the recharging mechanism.
   working prototype of recharging mechanism

Chapter 4

Requirement Specification

4.1 3D Printing

3D printing technology has emerged as a pivotal tool in the fabrication of various components for unmanned aerial vehicles (UAVs), particularly in the creation of legs and charging cases. Leveraging the precision and versatility afforded by 3D printing, intricate designs and complex geometries can be realized with unparalleled accuracy and efficiency. In the context of drone legs, 3D printing enables the production of lightweight yet durable structures, tailored to the specific requirements of the UAV's design and intended application. By utilizing advanced materials such as carbon fiber infused polymers or high-strength composites, 3D-printed drone legs can withstand the rigors of flight while minimizing weight, thereby optimizing overall performance and endurance.

Similarly, the application of 3D printing extends to the fabrication of charging cases for UAVs, offering a bespoke solution for housing and protecting critical components during recharging operations. Through additive manufacturing processes, charging cases can be customized to accommodate the dimensions and specifications of the UAV, ensuring a precise fit and optimal utilization of space. Moreover, 3D printing allows for the integration of additional features such as mounting points for

accessories, ventilation channels for heat dissipation, and reinforced structural elements for enhanced durability.

Furthermore, 3D printing facilitates rapid prototyping and iteration, enabling manufacturers to quickly iterate and refine designs based on performance feedback and evolving requirements. This iterative approach not only accelerates the development process but also fosters innovation by encouraging experimentation with novel design concepts and materials.

In summary, 3D printing plays a crucial role in the production of drone legs and charging cases, offering unparalleled flexibility, precision, and efficiency in manufacturing. Through the utilization of advanced materials and additive manufacturing techniques, 3D-printed components contribute to the optimization of UAV performance, durability, and functionality, thereby advancing the capabilities of unmanned aerial systems in diverse Applications.

Figure 4.1: 3D Printer

Figure 4.2: Charger Box

Figure 4.3: Drone Legs

Chapter 5

System Design

5.1 Introduction

Our cutting-edge drone landing and recharging platform represents a significant advancement in unmanned aerial vehicle (UAV) technology, ushering in a new era of efficiency and reliability. Engineered with meticulous precision and a paramount emphasis on safety, this platform epitomizes innovation at its finest, offering a seamless solution for the critical tasks of landing and recharging small drones. One of the standout features of our platform is its robust design, meticulously engineered to withstand the rigors of repeated landings and ensure the safety of both the drone and the surrounding environment.

Moreover, our platform incorporates state-of-the-art sensing and communication technologies, enabling seamless interaction with incoming drones and facilitating precise landing maneuvers. With advanced collision avoidance systems and real-time monitoring capabilities, our platform ensures enhanced safety and operational efficiency in diverse environments. Additionally, the incorporation of intelligent power management systems optimizes recharging processes, maximizing the uptime and productivity of drone fleets.

In this document, we delve deeper into the intricacies of our platform's design features and safety considerations, highlighting its unparalleled performance and reliability in the UAV landscape. From the seamless

integration of cutting-edge technologies to the rigorous adherence to industry safety standards, our platform sets a new benchmark for excellence in drone landing and recharging solutions.

5.2 Platform Design

5.2.1 Terminal Configuration

In our drone landing and recharging platform, precision and compatibility are paramount considerations in the design of the positive and negative terminals. The positive terminal, crafted from a non-magnetic copper plate, serves as a universal interface for recharging various UAV models. This choice of material ensures optimal conductivity while eliminating any potential interference with the magnetic components commonly found in drones.

On the other hand, the negative terminal is strategically designed with a 6cm diameter plate. This sizing allows for easy connection, even if the drone lands slightly off-center. By incorporating a larger diameter plate, we ensure that drones have ample surface area for connection, reducing the risk of misalignment and streamlining the recharging process.

Together, these terminals exemplify our commitment to precision engineering and user-centric design in our drone landing and recharging platform. They not only ensure seamless compatibility with a wide range of UAV models but also prioritize ease of use and reliability in real-world operating conditions.

Figure 5.1: Recharging Terminal

5.2.2 Safety Configuration

Non-Magnetic Materials: The use of non-magnetic copper for the positive terminal minimizes interference with the drone's magnetic components, enhancing safety during the recharging process. Magnetic Interference

Mitigation: Stringent measures are in place to mitigate the risk of magnetic interference, ensuring optimal performance and reliability.

5.2.3 Height Optimization

Ideal Platform Height: The platform is designed at an optimal height to counteract upwash effects, preventing larger drones from being inadvertently drawn towards it during landing. Enhanced Stability: By maintaining the correct height, we ensure that the platform remains stable and secure, even in challenging environmental conditions.

5.2.4 Vibration-Resistant Design

Stability and Flexibility: The grip of the platform's legs strikes the perfect balance between stability and flexibility, ensuring that vibrations do not compromise the secure placement of drones. Minimized Risk of Collisions: The design minimizes the risk of collisions or accidents caused by vibrations, guaranteeing a safe and efficient landing and recharging experience.

5.2.5 Integration of Features

Safety-First Approach: The integration of safety features, including nonmagnetic materials and vibration-resistant design, underscores our commitment to providing a robust and dependable solution for drone operations. Enhanced User Experience: By seamlessly integrating these features, our platform offers a user-friendly experience for drone operators, catering to the needs of hobbyists and professionals alike.

Chapter 6

System Implementation

Implementation is the process of moving an idea from concept to reality. The System implementation is a realization of a technical specification or algorithm as a program, software component, or other computer system through programming and deployment.

6.1 System Architecture: Charger Design

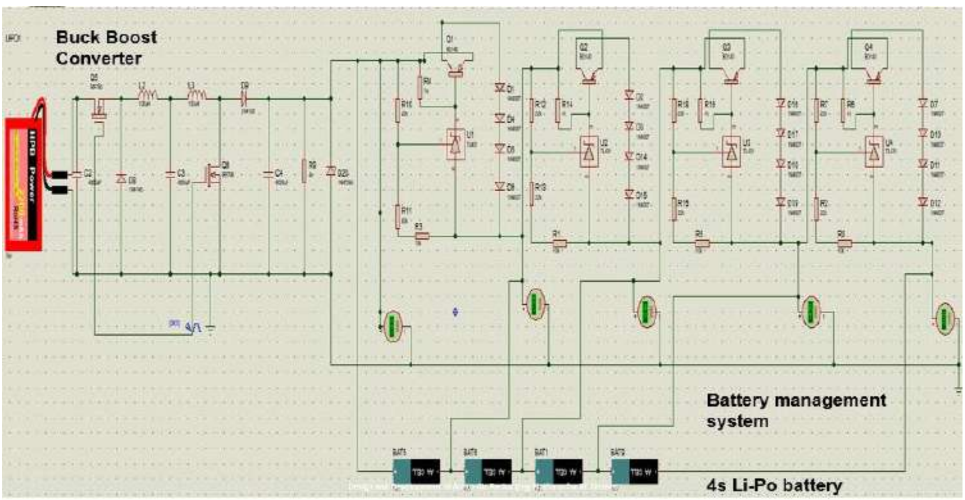

Figure 6.1

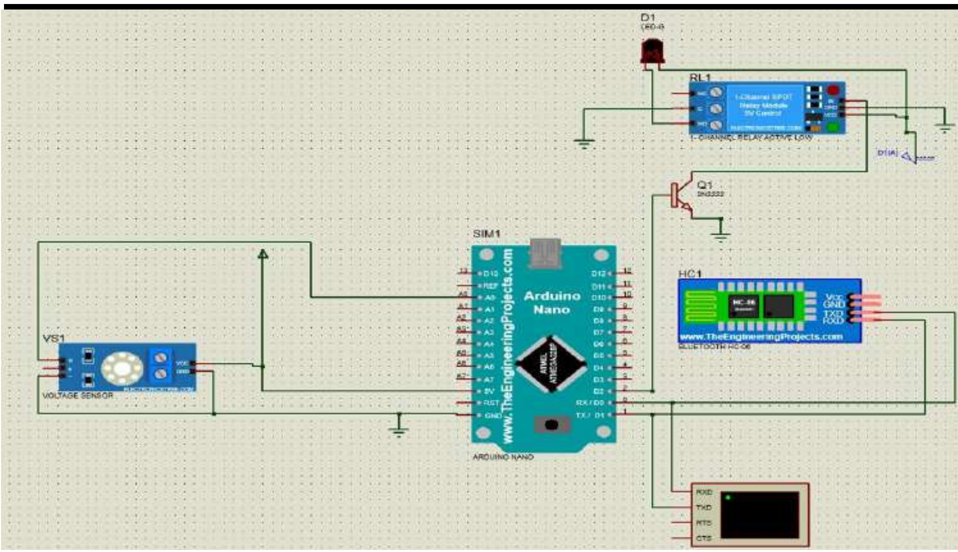

Figure 6.2

6.2 Fabrication Model

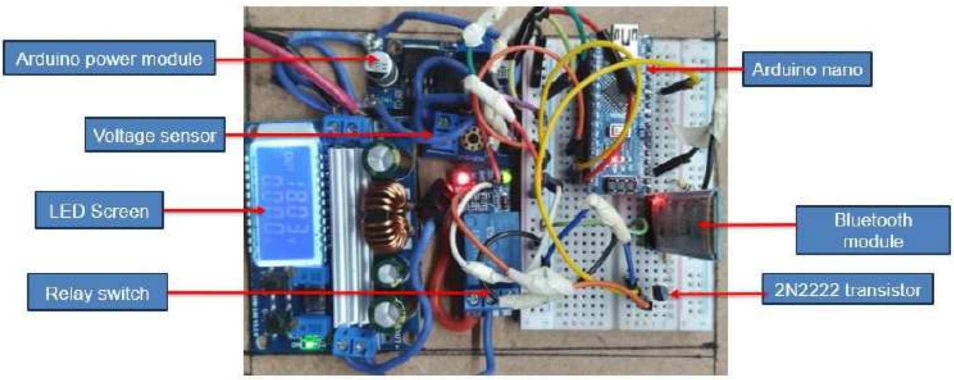

Figure 6.3

6.3 System Model

Figure 6.4: Charge Drone

Figure 6.5: Chargee Drone

Figure 6.6: Complete Setup

Chapter 7

Conclusion & Future Work

7.1 Conclusion

In conclusion, our drone landing and recharging platform offers an independent recharging kit that stands at the forefront of innovation in unmanned aerial vehicle (UAV) technology. Through the implementation of airborne vehicles transferring power via physical engagement, our platform ensures seamless and efficient recharging processes. The easy-to-connect interface simplifies the interaction between the platform and the UAV, facilitating quick and reliable recharging operations. Additionally, our platform incorporates short-circuit-safe mechanisms to mitigate the risk of electrical hazards, prioritizing safety in all aspects of operation. With these advancements, our drone landing and recharging platform not only enhances the efficiency and effectiveness of UAV missions but also sets a new standard for reliability, safety, and ease of use in the UAV landscape.

7.2 Future Work

In our pursuit of innovation within the realm of UAVs technology, our drone landing and recharging platform incorporates several key features aimed at enhancing versatility and functionality. One such aspect is the ability to accommodate various types of batteries through thoughtful.

modifications. By implementing adaptable charging interfaces and flexible power management systems, our platform can seamlessly recharge a diverse array of battery types, catering to the specific needs of different UAV models. Additionally, our formulation includes a meticulous selection process for chargers, ensuring optimal compatibility and efficiency in charging drones. Furthermore, we have developed an innovative air-to-air battery changing mechanism, allowing for swift and seamless battery swaps during prolonged missions, thereby minimizing downtime and maximizing operational efficiency. Moreover, our platform boasts a sophisticated folding mechanism design, facilitating compact storage and easy deployment in diverse environments. Through these integrated features, our drone landing and recharging platform sets a new standard for versatility, reliability, and adaptability in unmanned aerial vehicle operations.

Chapter 8

Bibliography

[1] L. Bláha, O. Severa, M. Goubej, T. Myslivec, and J. Reitinger, “Automated Drone Battery Management System—Droneport: Technical Overview,” *Drones*, vol. 7, no. 4, p. 234, Mar. 2023, doi: 10.3390/drones7040234.

[2] M. K. A. Bhavana S, “Air Charging,” International Journal of Science and Research (IJSR), 2022.

[3] F. Z. C. L. D. K. Chaoqiang Jiang, "Design of an Effective Wireless Air Charging System," Hong Kong, 2017.

[4] B. C. A. L. M.-P. PRITHVI KRISHNA CHITTOOR, "A Review on UAV Wireless Charging: Fundamentals, Applications, Charging techniques and standards," Chennai, 2021.

[5] S. (. Z. Shu Ting Go, "All Electric Aircraft Mid-Air Recharging via Wireless Power Transfer: Battery Requirement study," 2018.

[6] A. S. Gohardani and G. D. R. Singh, “Challenges of future aircraft propulsion: A review of distributed propulsion technology and its potential application for all electric commercial aircraft,” Progress in Aerospace Sciences, vol. 47, pp. 369–391, 2011.

[7] M. Henke, G. Narjes, J. Hoffmann, C. Wohlers, S. Urbanek, C. Heister, J. Steinbrink, W.-R. Canders, and B. Ponick, “Challenges and opportunities of very light high-performance electric drives for aviation,” Energies, vol. 11, p. 25, 2018.

[8] M. Simic, C. Bil, and V. Vojisavljevic, "Investigation in wireless power transmission for uav charging," Procedia Computer Science, vol. 60, pp. 1846–1855, 2015.

[9] Z. Bi, T. Kan, C. C. Mi, Y. Zhang, Z. Zhao, and G. A. Keoleian, "A review of wireless power transfer for electric vehicles: Prospects to enhance sustainable mobility," Applied Energy, vol. 179, pp. 413–425, 2016.

[10] W. Brown, "The history of power transmission by radio waves," IEEE Transactions on Microwave Theory and Technique, vol. 32, no. 9, pp. 1230–1242, 1984.

[11] N. Shinohara, "Beam control technologies with a high-efficiency phased array for microwave power transmission in japan," Proceedings of the IEEE, vol. 101, no. 6, pp. 1448–1463, 2013.

[12] S. Chatterjee, A. Iyer, C. Bharatiraja, I. Vaghasia, and V. Rajesh, "Design optimisation for an efficient wireless power transfer system for electric vehicles," Energy Procedia, vol. 117, pp. 1015–1023, 2017.

[13] W. Zhang and C. C. Mi, "Compensation topologies of high-power wireless power transfer systems," IEEE Transactions on Vehicular Technology, vol. 65, no. 6, pp. 4768–4778, 2016

[14] Wang, Y.; Sun, Q.; Berger, T.; Qi, W. A Drive-through Recharging Strategy for a Quadrotor. In Proceedings of the 2021 IEEE International Conference on Robotics and Automation (ICRA), Xi'an, China, 30 May–5 June 2021; pp. 420–425. [CrossRef]

[15]. Cokyasar, T. Optimization of battery swapping infrastructure for e-commerce drone delivery. Comput. Commun. 2021, 168, 146–154. [CrossRef]

[16]. Cokyasar, T.; Dong, W.; Jin, M.; Verbas, ˙I.Ö. Designing a drone delivery network with automated battery swapping machines. Comput. Oper. Res. 2021, 129, 105177. [CrossRef]

[17] Walendziuk, W.; Oldziej, D.; Slowik, M. Power Supply System Analysis for Tethered Drones Application. In Proceedings of the 2020 International Conference Mechatronic Systems and Materials (MSM), Białystok, Poland, 1–3 July 2020; pp. 1–6. [CrossRef]

[18] Kishk, M.; Bader, A.; Alouini, M.S. Aerial Base Station Deployment in 6G Cellular Networks Using Tethered Drones: The Mobility and Endurance Tradeoff. IEEE Veh. Technol. Mag. 2020, 15, 103–111. [CrossRef]

[19] Swieringa, K.A.; Hanson, C.B.; Richardson, J.R.; White, J.D.; Hasan, Z.; Qian, E.; Girard, A. Autonomous battery swapping system for small-scale helicopters. In Proceedings of the 2010 IEEE International Conference on Robotics and Automation, Anchorage, AK, USA, 3–7 May 2010; pp. 3335–3340.

[20] Michini, B.; Toksoz, T.; Redding, J.; Michini, M.; How, J.; Vavrina, M.; Vian, J. Automated Battery Swap and Recharge to Enable Persistent UAV Missions. In Proceedings of the Infotech@Aerospace, St. Louis, Missouri, USA, 29–31 March 2011; American Institute of Aeronautics and Astronautics: Reston, Virigina, 2011; pp. 1–10. . [CrossRef]

[21] Ure, N.K.; Chowdhary, G.; Toksoz, T.; How, J.P.; Vavrina, M.A.; Vian, J. An automated battery management system to enable persistent missions with multiple aerial vehicles. IEEE/ASME Trans. Mechatronics 2015, 20, 275–286. [CrossRef]

[22] De Silva, S.C.; Phlernjai, M.; Rianmora, S.; Ratsamee, P. Inverted Docking Station: A Conceptual Design for a Battery-Swapping Platform for Quadrotor UAVs. Drones 2022, 6, 56. [CrossRef]

[23] Liu, Z.N.; Liu, X.Q.; Yang, L.J.; Leo, D.; Zhao, H. An Autonomous Dock and Battery Swapping System for Multirotor UAV. Available online: https://www.researchgate.net/publication/325077351 (accessed on 1 March 2023).

[24] The Power of Drone Autonomy. Unlocked by FlytNow. Available online: https://flytnow.com (accessed on 26 February 2023).

[25] AIROBOTICS SOLUTION. Available online: https://www.airoboticsdrones.com (accessed on 26 February 2023).

[26] DBOX Autonomous Drone Box. Available online: https://dbox.lt (accessed on 22 March 2023).

[27] DJI Dock. Available online: https://www.dji.com/cz/dock (accessed on 23 March 2023).

[28] HEISHA Drone Charging Docks. Available online: https://www.heishatech.com/bot-mansion/ (accessed on 22 March 2023).
[29] Severa, O.; Bouˇcek, Z.; Neduchal, P.; Bláha, L.; Myslivec, T.; Flídr, M. Droneport: From Concept To Simulation. In Proceedings of the System Engineering for constrained embedded systems (DroneSE and RAPIDO '22), Budapest, Hungary, 21 June 2022; ACM: New York, NY, USA, 2022. [CrossRef]
[30] H. Lee and A. Clark, "Charging the future: Challenges and opportunities for electric vehicle adoption,' Harvard Kennedy School, Cambridge, MA, USA, Tech. Rep. HKS Work. Paper No. RWP18-026, 2018. [31] H. Greenhouse, "Design of planar rectangular microelectronic inductors," IEEE Trans. Parts, Hybrids, Packag., vol. TPHP-10, no. 2, pp. 101–109, Jun. 1974.
[32] F. Grover, Inductance Calculations: Working Formulas and Tables (Dover Books on Engineering and Engineering Physics). Research Triangle Park, NC, USA: ISA, 1982. [Online]. Available: https://books.google. co.uk/books?id=rqceAQAAIAAJ
[33] Y. Lee. Antenna Circuit Design for RFID Applications. Accessed: May 28, 2010. [Online]. Available: http://ww1.microchip.com/ downloads/en/AppNotes/00710c.pdf
[34] Y. Cheng and Y. Shu, "A new analytical calculation of the mutual inductance of the coaxial spiral rectangular coils," IEEE Trans. Magn., vol. 50, no. 4, pp. 1–6, Apr. 2014.
[35] Antenna Circuit Design for RFID Applications. Accessed: May 28, 2010. [Online]. Available: https://www.nissan.co.uk/vehicles/new-vehicles/leaf/ dimensions-specifications.html
[36] M. Mohammad, J. Pries, O. Onar, V. P. Galigekere, G.-J. Su, S. Anwar, J. Wilkins, U. D. Kavimandan, and D. Patil, "Design of an EMF suppressing magnetic shield for a 100-kW DD-coil wireless charging system for electric vehicles," in Proc. IEEE Appl. Power Electron. Conf. Expo. (APEC), Mar. 2019, pp. 1521–1527.

[37] R. Zhao, D. T. Gladwin, and D. A. Stone, "Cost efficient matrix converter employing a conventional simple controller," in Proc. PCIM Asia; Int. Exhib. Conf. Power Electron., Intell. Motion, Renew. Energy Energy Manage., Jun. 2015, pp. 1–8.
[38] R. Zhao, D. T. Gladwin, and D. A. Stone, "Wireless power system appling a microcontroller dominated matrix converter,' in Proc. IECON41st Annu. Conf. IEEE Ind. Electron. Soc., Nov. 2015, pp. 3405–3410.