Design and Development of Solar Powered UAV for Long Endurance

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ABSTRACT:

Unmanned Aerial vehicle (UAVs) has become huge in the field reconnaissance areas of Many Nations. Endurance is the one of the principal issue in the Unmanned Aerial Vehicle, Generally the greater part of the airplanes use ordinary fuel which cause pollution, which it additionally have a short time frame life and Expensive. So there is an Enormous need for involving a non modest exhaustible source of energy as a fuel. A sunlight based energy is one of the reachable sustainable energy. The streamlining and planning of the optimal design of Flying vehicle have gotten part of significance to expanding the use to fostering the UAV with compelling endurance and dependability at a subsonic speed. In this paper a conceptual and preliminary design approach is introduced for a solar powered unmanned aerial vehicle to achieve higher endurance. Some data has been acquired statistically from the existing aircraft and unmanned systems due do the theoretical calculations for the solar powered UAV. A better understanding of design and most optimal configuration selection can be determined by performing a historical analysis on previous UAV's. The main aim of the paper is to design a fixed wing solar UAV with high endurance. In preliminary design the wing geometry and unmanned aerial system is designed using Autodesk Fusion 360 software. Further an appropriate wing span is calculated to be 4m to complete the designing of the 3-D solar powered UAV. The performance analysis has been calculated theoretically by using various parameters. Thorough research has been done to find the desired photo voltaic solar cells and types of batteries to be installed in the system to incorporate the solar power system for long endurance. The final objective was to design and analyze a solar powered unmanned aerial vehicle for long endurance applications with implementation of batteries and solar cells.

Keywords :- *Solar powered UAV, Long endurance, Conceptual Design, Theoretical calculations, batteries, solar cells*

I . INTRODUCTION

UAV's these days becoming a part in many areas such as Military, Payload Delivery, Surveillance etc. They also been used in Disaster Areas to take pictures and allow crew members to analyze the situation. In order to meet the requirements to perform the given task UAVs are designed. Based on their Operational Characteristics, Aerodynamic Characteristics, and several attributes like Endurance, Weight, Range, Altitude, Payload etc., UAVs are classified into different types.

On basis of their Aerodynamic Characteristics UAVs are classified as Fixed Wing UAVs, Multi Rotor UAVs, Chopper, VTOL, Motor Parachute and Glider. By accounting their Operational Characteristics, they were termed as Battery powered and Solar powered UAVs. The classification based on attributes decides whether the Drone is Miniature, Medium or Large.

In this paper, we’ve considered to design and analyze Fixed Wing Solar UAV with High Endurance. Multi-purpose UAVs with rotating systems usually carry three or four propellers which can take off and land vertically (VTOL) and roam the surface with sufficient charge. And also, Rotor System UAVs are much more maneuverable than the Fixed Wing UAVs because of their ability to quickly switch from hovering, ascending and descending. But these rotor systems produce more drag due to less aerodynamic arrangement. So, using Fixed- Wing UAVs helps to attain high endurance, flight time, and high speed. But in order to maintain long flight time the battery used in UAV must store large amount of energy which reduces flight range. Ofcourse installing more batteries would increase the flight time but it also increases the weight of the drone which in turn consumes more power. This is where Solar UAV plays a major role. Solar UAVs generates the power needed to propel the aircraft and recharge the battery by using the olar Rrays that falls on the surface of UAV, so that the UAV still works during Night.

II . LITERATURE REVIEW

Philipp Oettershagen et al. (2017) represents the study on development process behind the AtlantikSolar, a small 6.9 kg hand-launchable low altitude solar-powered UAV which have finished an 81-hours of continuous flight and thus successfully achieved a new flight endurance world record for all aircraft below 50 kg mass. The AtlantikSolar project is a fixed wing nose-propeller design with a wingspan (b) of 5.6m and is made up of carbon fiber and Kevlar. The solar panels are of 1.4sq m and the electric motor is powered by a 2.9 kg of lithium ion battery. Here the payload is a digital HD camera which will transmit the live images. During the flight, the AtlantikSolar UAVs speed was 28.42 kph. At an altitude of 400m from its base station, the furthest distance during the flight was 800m [1].

Olivier Montagnier et al. (2010) discusses the optimization of a solar-powered high altitude long endurance UAV which was carried out aims in maximising the payload for a fixed total mass. The minimization of mass of the wing is achieved by the use of composite materials and by tolerating large flexibility. The existence of the UAV in cruise speed versus lift coefficient diagram shows the optimization and reveals an optimal solution with a payload of about 4 % of the total mass of 817 kg for a wing span of 69m. The major objective is to compute optimal parameters with straight wings for afixed wing aspect ratio and a fixed mass of UAV. Mass models, had been accurately. Wing model consists of a tubular beam with hybrid carbon/epoxy plies and constant cross section. This model can also be modified for a wide range of solar-powered HALE UAV with straight wings [2].

Saghar Hosseini et al. (2013) studied the optimal path planning and power allocation problems of a solar powered UAVs for a period of one day and night. The major aim was to enhance the remaining energy stored in the batteries at the end of duration fulfilling the feasibility constraints and the boundary conditions on the states of the aircraft and batteries. The direct and indirect optimization methods are applied to solve the optimal path planning problems. In indirect method, the Hamiltonian and Lagrangian equations are used which has low rate of convergence. In direct optimization method, collocation and nonlinear programming is done which solves the parametrized optimization problem. In the first phase, when there is availability of solar energy, the UAV climbs at an altitude of 8.5km. In the second phase, during the night it descends. In the last phase, it stays at low altitude performing the level flight [3].

S.Karthik et al. (2015) discusses the history, application and use of the solar powered aircraft. The project studies to obtain a continued flight of more than 24 hours using solar energy as their only source of energy. To predict the qualitative characteristics of the optimal paths, power ratio is used and if it exceeds a certain threshold, then the perpetual endurance is possible. They have used Li-Su rechargeable batteries which will give 400 W-hr/kg instead of normal Li-Po batteries 200 W-hr/kg. The number of battery cells they required was of 968, the area to accomplish the solar cells was of 610 ft^2 and the mass of solar cell comes to 175 lbs. The solar powered UAV which had been discussed weighed 1135lb, and has a wingspan of 224ft which could hold upto 100lb of payload [4].

Yauhei Chu et al. (2021) have modified a 2m wingspan remote-controlled (RC) UAV which is powered by a combination of solar and battery-stored power. Using appropriate system architecture and appropriate components related to solar power, the power system is designed by monocrystalline siliconcell. Considering the cost, accessibility, energy efficiency, weight, size, and flexibility; the Monocrystalline Silicon cell has been used which has a theoretical efficiency of 29%. 22 PV cells were installed that had a total weight of 0.176 kg. In order to ensure safety during flight, more sensors were added for data monitoring. The battery used in the power system is an 11.1V 3S lithium–polymer battery [5].

Scott Morton et al. (2015) for a low altitude aerial sensing applications of the solar-powered UAV design which was developed by the Centre for Distributed Robotics on a 4m wingspan. Enchancing theaircraft's efficient flight keeping the other necessary flight and sensory conditions, is the main aim for designing the airframe of small solar powered UAVs. The lift and drag characteristics of thewing has to be designed in such a way that the level flight power is minimized. Based on the discrete options available components like electric motor, gearbox, high modulus pultruded carbon fibre, solar modules, and battery cells can be optimized which may have limiting tolerances and manufacturing specifications [6].

Jianfa Wu et al. (2018) studies the 3D flight-based energy management strategies for solar-powered unmanned aerial vehicle (SUAV) long-endurance target tracking. The environment factors will be influencing the SUAV energy harvesting and consumption elements, such as the photoelectric efficiency of solar cells. The coupling of energy storage and tracking effects will increase the solar photovoltaic modules, the photoelectric efficiency of solar cells could be influenced by the flight height, temperature, and airspeed the difficulty of trajectory optimization. For the SUAV dynamic modelling ,the influence of wind on SUAV kinematics are considered [7].

E Mermer et.al (2013) studied that the solar powered UAV should have low slopes to use the sunlight effectively to assure maximum exposure to sunrays. For this purpose the airfoils with low absolute value of slopes were considered so to increase the effective solar cell area. This slope threshold value is used due to the fact that at high sun light inclination angles of solar cells would not generate enough power even to lift its own weight. The solar cell area calculations are given as the percentage of the projected areas to the chord line. The upper usable surface areas calculated in the tangency range in considerationin order to calculate maximum solar power obtained at solar noon condition[8].

Gustavo de arvalho Bertoli et.al (2015) presents the concept of a solar-powered UAV, key components in general construction and concept of the energy balance of a solar-powered UAV system. In addition, introduced aircraft-related forces and the energy required during a constant flight and power flow when considering both batteries and photovoltaic cells as energy sources. Introducing a flight measurement system endurance expansion after the electric UAV adapted photovoltaic cells. This approach showed up accuracy compared to the test case performed[9].

Abu Bakar(2021) used a genetic algorithm to develop a solar-powered UAV so that it has a certain length, travel speed and stationary genes. The wing airfoil is also considered a design variant and a new weight-bearing model is proposed. The purpose is to design the airfoil for thespecified flight conditions, taking into account the overall performance and weight of the measurement. To add stability to construction, additional battery is added as the system starts using the battery as soon as the required power is less than the available solar power. The upgraded configuration weighs 7.08 kg and the battery weight is 3.4 kg. The prepared airfoil is very smooth, thick with a camber of 9.7% and 4.6%, respectively [10].

Parvarthy Rajendran et.al (2017) developed a detailed model to study how the sun works movementaffects the functioning of the solar system. Parametric considerations are made in this model including time and day of year, longitude and length links to the flight area, as well as the position ofthe sun and a solar cell. These parameter values are used in determining rising sun, shrinkage and azimuth, the earth's inclination angle axis and angle of inclination of solar cells. This ismodeling and imitation enable direct sunlight and daylight prediction. In this study, the model for the movement of the sun was adopted in the work of Muneer, in which input parameters i.e., details related to date, time, green the meridian time, latitude, longitude, and altitude of the operation are defined. Modeling then determines the given date falls in the connecting year to ensure that the next parameter is determined correctly. By measuring the Power required by using necessary parameters we would be able to the predict lift and drag coefficients [11].

G.Sachs et.al (2015) describes the Occasional precision flying is a way to contribute to the acquisition of unlimited endurance in each case the formation of solar-powered UAVs. The purpose of the efficacy of the treatment presented in this paper to gain the ability to stay high with little or no energy stored on batteries flying at night. It is shown that this is possible with a proper trajectory control. The timing of the planned flight means trajectory can be performed after a full day and nightcycle in the same way as before. It's true mathematical models of UAV Dynamics and op power management system solar energy consumption is used. Using a well- functioning approach, it is available at Timely UAV aircraft delivering operational purpose aimedat launch. With less or zero power will be stored in batteries, the associated weight loss may be reduced or avoided [12].

W. W. Zhang et.al (2018) depicts the formation of high-altitude and long distance solar planes is different from that of regular flights. Its unique power system and operating conditions make it. It is necessary to carefully measure the important technical details in the construction. The building is huge influence on the endurance performance of solar aircraft. The weight of the structure can be approximate it is estimated at the rate of the air force system to the total weight of the aircraft, therefore to increase composition. With the analysis of several common solar planes, it can be so concluded that aerodynamic design and architecture have a profound effect on aircraft the timing and operation of solar aircraft [13].

Figure 1. 3-D Solar powered UAV

Enrico Cestino et al. (2006) aims to design a HALE/UAV (High Altitude Very-long Endurance/Unmanned Air Vehicle), which is capable to climb to an altitude of 17-20km with the use of direct solar radiation and continuing a level flight even during the night. In order to minimize the airframe weight, high modulus CFRP has been used in designing the structure. To carry out the parametric study for the platform design, a computer program has been established. For the analysis of wing plans and several profiles, the CFD software Xfoil and Vsaero has been used. t. A Blended Wing Body (BWB) configurationof Solar HALE Aircraft Multi Payload & Operation

(SHAMPO) with 8 brushless electric motors provides good performance, availability of surfaces for solar cells, volume for payload purposes [14].

III. METHODOLOGY

The entire solar is made up of carbon fiber which high strength to weight ratio. The estimated weight of drone along with equipment is 4kg. The Sunpower C60 PV cells were induced on the wings, horizontal and vertical stabilizers. Li-Po battery of 16000mAh capacity with 12V is used in the UAV. Based on the formula, estimated power generated by solar cells and the average current drawn from the battery is calculated. Thereby using these parameters, the flight endurance is determined.

Carbon fiber :

Material used for making the solar UAV is carbon fiber, due to its high strength to weightratio. As the main task in making a UAV is to reduce its initial weight as low as possible. Therefore, using carbon fiber as building material will be the best choice. Because of their light weight, incredible strength, and smooth finish, carbon fiber alloys are an ideal way to build many flight components. The use of carbon fiber in airplanes allows them to save more fuel, use hot air, and be made with fewer and simpler components. The material is stronger than steel, lighter than aluminum, and can be formed in any form by computational fluid dynamics that claim to create a lightweight plane. An important choice for a particular application meant analyzing the entire area of the air frame to determine what was best, considering the work area and loads a particular component felt throughout the life of the air frame.

Fuselage:

The fuselage part of the solar UAV is used to carry the drone driving equipment like battery, flight controller, connecting wires etc. The fuselage is made up of carbon fiber material. It is the main part of the UAV that carries load in it. The air flows around the parabolic nose cone and the trailing edge is designed in such a way that it gives a smooth flow where highly pressured air doesn’t spill upward, this prevents the formation of wake region.

Figure 2. Fuselage (side view)

Wings:

Figure 3. Wings (Top view)

The wing span (b) of the solar UAV is of 4m. Solar cells are induced on both sides. A total of 50 solar cells are attached to the wings. Both the wings are connected to fuselage horizontal and vertical stabilizer by connecting rods. To improve the cruising range and fuel efficiency, the vertical extensions of wingtips are made (winglets). Designed as small airfoils, winglets reduce the aerodynamic gravity associated with vortices from the wing tip as the airplane travels in the air.

Horizontal Stabilizer:

Figure 4. Horizontal stabilizer (Top view)

The horizontal stabilizers are connected to both connecting rods at the tail part of solar UAV. Solar cells are also induced on the surface of horizontal stabilizer and the connection wires are connected to battery through connecting rods. A total of 8 solar cells are attached to horizontalstabilizers. The elevators are placed in between the gaps shown in above fig 4.

Vertical Stabilizer:

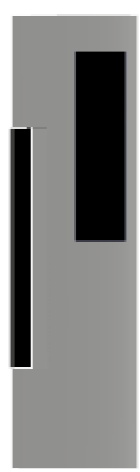

Figure 5. Vertical stabilizer (Side view)

The vertical stabilizer is connected to Horizontal Stabilizer at the Tail part of the UAV, Solar cells are induced on the surface of the Vertical Stabilizer and the Connecting wires are connectedto battery through Connecting Rods. A Total of 2 Solar Cells (1 on each side) are induced to it. The rudder is placed in between the gaps shown in fig 5.

Propeller:

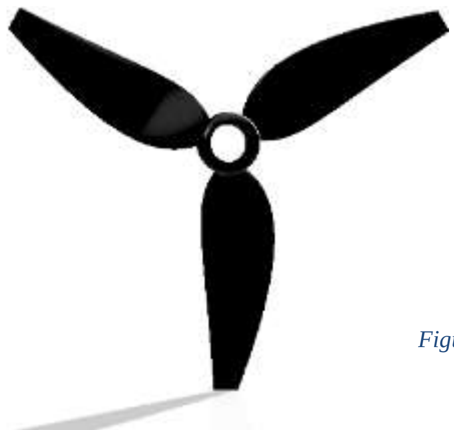

Figure 6. 3 Blade Propeller

The 3-blade carbon fiber propeller requires low manufacturing cost, exhibits high speed and better acceleration performance. The pitch angle of the propeller blade is 20 degree. The 3-blade propeller will produce three small pulses per turn with the same total push value. As a result, the 3-blade prop will be naturally smooth and quiet.

Li-po Battery:

Battery used in solar UAV is Li-Po of 16000mAh capacity with 22.2V. It has been chosen due to its properties like small volume, huge capacity, light weight, eco-friendly, high voltage of single cell, more discharging rate, more cycle times and good temperature control. The weight of the battery is 1.9kg.

Solar Cells:

Selecting high efficient solar cells is a crucial step while making solar UAV. Sun power C60 solar cellshas the high efficiency of 22.8%. A total of 60 solar cells are used. SunPower solar cells produce about 25-30% energy when compared to other cells which is an outstanding advantage. It's a renewable energy source without any maintenance. The solar cells could produce electricity anywhere. It just requires sunlight to make it into a useful energy source.

THEORETICAL CALCULATIONS:

Total wing span = 4m

Wing span of each wing = 2m

Average chord = (Root chord + Tip chord)/2

= (167.653 + 31.469)/2

Total chord length = 199.91mm

Wing area = s*chord length

= 4*199.91 = 0.8m^2

Aspect ratio, AR = s^2/A

= 10

The aspect ratio obtained is 10. The wings have high aspect ratio to reduce the downwash made by the vortex.

3S, Li-Po Battery, capacity = 16000mAh

Batteries nominal voltage = 22.2V

Required power = Capacity*Voltage

= 16Amph*22.2

=355.2Wh

Time required to fully charge the battery is 3.5 hours. (355.2Watts are required in 3.5 hours)

BLDC motor with 2400KV has been used.

SunPower C60 PV cell,

Mass = 0.008Kg

Area = (0.125*0.125) m^2

Number of solar cells required on main wings = Area of wing/ Area of 1 solar cell

= 0.8/0.016

= 50

Wing span of horizontal stabilizers = 1600mm

Chord length = 0.083m

Area = 0.1328 m^2

Number of solar cells required on horizontal stabilizers = Area of horizontal stabilizers/Area of 1 solar cell

= 0.1328/0.016

= 8 (4 solar cells on each horizontal stabilizer)

Wing span of vertical stabilizer = 300mm

Chord length = 0.083m

Area = 0.025 m ^2

Number of cells required on vertical stabilizer = Area of vertical stabilizer/ Area of 1 solar cell

= 0.025/0.016

= 2 (1 solar cell on each side)

Therefore, total number of cells required = 60

The Solar Cells produce a power of 290Watts per hour if they are exposed to sunlight continuously. As the power required to charge the battery is 355.2Wh, approximately 659.8-Watt power can be used directly to supply power for the UAV. During the absence of sunlight the battery's energy is used to supply power for the UAV. In this way the UAV will constantly use its reserved power supply without draining.

The estimated weight of the drone is 4Kg and the power required is 80 W/Kg. For efficient systems, the power required will be less.

Average Ampere Drawn = Weight of Drone*(P/V) (P = Power required to lift 1Kg of payload)

= 4*(80/22.2) = 14.141 A (V is the Voltage of Battery)

As Li-Po batteries will be damaged, if they were discharged totally. In order to avoid this, the batteries should never be discharged by 90%. Hence, the discharge is considered to be 0.9 .

Flight Time = Capacity*(Discharge/AAD)

= 16000*(0.9/14.141)

= **17 hours (Approximately**)

RESULT AND DISCUSSION

The Solar UAV has achieved flight time of 17 hours with high end power reserves. Thesolar UAV can fly upto 17 hours on single charge and also has almost 659-Watt power that can be directly used to fly the UAV. During the absence of sunlight or during the night time UAV will be able to use the battery power. This enables the solar UAV to fly continuously without getting drained.

CONCLUSION

In this study, we found that using high powered solar cells with optimized design and efficient power equipment, the endurance of the UAV can be increased and used without getting the battery drained. The solar UAV designed above is the modified and optimized design of Albatross UAV. The UAV is designed in such a way that it exhibits less weight. The material used in building the solar UAV is carbon fiber which has high strength to weight ratio.

The long-ranged wings helps to increase the surface area of the UAV which enables us to induce more number of solar panels which resulted in producing more amount of power. Thishelps the UAV to fly without getting the Battery Drained.

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