Review of solar unmanned aerial vehicles (UAV) and its sustainability

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ABSTRACT

UAV stands for Unmanned Aerial Vehicles, which is a type of aircraft having no onboard pilot. UAV can be controlled by remote or can be operated autonomously using preprogrammed flight plans. It has wide numbers of applications in different fields; it can be used in military, search and rescue operations, weather forecasting, traffic monitoring, surveillances, firefighting, photography etc. Traditionally, battery powered Unmanned aerial vehicles are used, but they all have certain limitations such as flight time, improper design and endurance limit. Therefore, to overcome these problems, we applied new practices using ultimate source of energy, that is, Solar Energy for better flight time and endurance limit.

Key words: Solar energy, UAV, solar drones, solar cells, design analysis, materials, endurance, flight time.

INTRODUCTION

UAV is also a known drone which is controlled by remote controlled computer system. It is a kind of aircraft system that can be operated without onboard operator. UAVs consist of many subcomponents like- UAV, ground-based controller, and a communication system. The UAVs flight can be operated by various degree of autonomy.

UAV can also be referred to as Drone, malp, probe, unmanned aircraft, pilotless aircraft and many more. Each term has its own significance, but meaning of all is same as 'Drone', a term mostly used by public.

The reason for UAVs requirement is that a human or a country is safe from land areas but the weak point is the sky, from where it can be attacked or destroyed. So, to protect the country or a human, the UAVs come into existence.

HISTORY OF UAVs

Unmanned Aerial Vehicles comes into existence many decades ago and were only used in the field of military. The first use of an unmanned aerial vehicle was in 1849 when an Italian city got attacked by Austrians using balloons filled with explosives. But according to definition, the first unmanned aircraft were developed after World War I in 1916. After much technological advancement, the US Navy invented a radio controlled aircraft named as Curtiss N2C-2 in the year 1937. After 1980, the US is able to start a mass production and supply to the US military for their security purposes. In 2000, a mini and micro version of UAV, that is, Predator, was used in Afghanistan for search of Osama Bin Laden. In recent years, many small sizes with fixed wigs UAV like- Raven, Wasp, and Puma have been introduced. Raven is mostly used by many countries. After 2014, UAVs also record their existence in Photography and film...
industry (https://interestingengineering.com/).

**SOLAR UAVs**

The main reason for the requirement of Solar UAV in place of simple UAV is Flight Time and its Endurance Limit. The simple or Battery powered UAV are not such efficient and cannot be used for longer time. To recharge them again, they are required to land after every hour. By coming back after every hour, to recharge again will be very dangerous and extremely costly as well.

To reduce this problem by increasing the battery size, number of cells will also not be beneficial because it will increase the weight of the UAVs and it is not acceptable as Flight time is inversely proportional to weight of the UAVs.

The best solution for this problem is using of Solar cells on UAVs for the power source. By this, UAVs will able to collect solar energy from sun and use it for UAV functioning. Then returning for recharge (R/R) will not be required. Most important, the efficiency of the solar UAV will also increases due to usage of light weight subcomponents (Gaurav et al., 2015).

**WORKING OF SOLAR UAVs**

The motive of using solar energy is to utilize unlimited energy source, that is, solar energy and convert it into electricity using solar cells. When the photons strikes on solar cells, the cells generates electrons and holes as a charge carriers and, when the complete circuit is formed, the free electrons go through a certain barrier or junction in order to recombine with holes and, by this, the current starts to flow across solar cells. Here, by making the alignment of the solar cells in series at the top side of the wing and then covering or wrapping the whole wing with transparent material for the safety purpose of solar cells during flight, and to get the required voltage, the cells are organized in series to charge the 3S battery. After that the power of batteries is given to the motors for throttling during the constant level flight (Sushil, 2017). The working of the Solar UAV is described with the help of the flow chart in Figure 1.

**COMPARATIVE STUDY OF BATTERY POWERED UAVs AND SOLAR POWERED UAVs**

This is shown in Table 1.

**LITERATURE REVIEW**

UAV is also known as drone and is controlled by remote controlled computer system. The main problems associated with normal UAVs are flight time and endurance because batteries and conventional fuel have limited energy, which is costly also. This problem can be resolved using solar energy through solar cells which will give more flight time without increasing the battery size or fuel system. The sailplane aero foil is named WE3.55/9.3 because it is excellent at less speed due to less Re (Reynolds number) selected. Finally, it can be concluded that the use of solar cells of gallium arsenide based technology will not require power grid (Sushil, 2017).

There is a method for the selection of batteries and flight trajectory to ensure long endurance. In a solar cell, there is no emission of carbon that makes it useful for future prospect. According to Vijay Shankar Dwivedi, Sun power C60 is the best solar cell as compared with silicon cell. The minimum altitude for the flight is 1000 m from sea level. 30 Amp-hour batteries can be taken for maximum endurance and 20 h, 30 min is the endurance of the Unmanned Aerial Vehicles (Vijay et al., 2018).

There is a great influence of altitude and payload mass on the size and design of the Unmanned Aerial Vehicles. The available solar irradiance is small at sea level due to the presence of clouds. According to T.R. Nada, there is a great impact of change in payload and altitude on different parameters such as, solar panel area, weight, wing’s aspect ratio, required thrust and battery charging. These parameters can affect cost as well as weight of the aircraft (Jashnani et al., 2012).

UAVs can last for 4 h using battery technology. This duration can be increased using Hybrid powered Solar and Battery system. Lithium polymer batteries have high specific energy and power and can easily recharged in couple of hours and having 100% efficiency with low 5-10% discharge rate per month. After certain research and discussion, it can be concluded that the concentrated PV cells have higher efficiency as compared with other solar cells (Parvathy and Howard, 2015).

The function of commercial drone or Unmanned Aerial Vehicles is to send the internet to different places with a speed of 1 gigabit per second. They can be used in disaster relief, ozone hole detection, indicating pollution affected zones and many more. Increasing battery size does not give any expected results. Using solar cells, the UAV does not require returning to recharge. It is concluded that to attain maximum height, UAVs requires maximum power for longer duration of time (Gaurav et al., 2015).

For small solar powered electric UAV's, we have to focus on weight, performance and aerodynamics of UAV. By this, the consumption of power to take-off mass ratio is enhanced or improved by 25% of previously designed UAVs. The mass of battery is increased with increase in payload. The simple UAV can carry high payload at a given endurance requirement. Payload has a prominent role on maximum take-off weight, followed by battery, body, and propulsion mass (Parvathy and Howard, 2018).

The problems aroused in micro UAV's like endurance,
flight time, cost and limited life. These problems have solution, that is, use of solar energy as a fuel which result in the increase in endurance without adding any significant mass and increase in size of fuel system. After certain calculations, it is concluded that the power required for a cruise is 10.14 W and for battery is 27.11W. All the components are designed under factor of safety which is 2 (Karthik et al., 2016).

Here, we will discuss about solar power system that consists of solar cells, converter, inverter, filter, switch mode power supply, load. There is a method of conversion of Photovoltaic energy which uses a semiconductor material in the form of p-n junction. After many research and mathematical calculations, it can be said that Concentrated PV cell (CVP) has higher efficiency of 41% as compared with others. The output of the solar power system does not only depend on the cell but also on the inverter performance (Gopinath et al., 2019).

According to many research, the solar and wind turbine is used to convert energy into electricity. This is suitable for all seasons. The fabrication and installation of this solar Unmanned Aerial Vehicles are very simple and reliable as compared with others systems. In this type of Solar Unmanned Aerial Vehicles, the battery stores both wind and solar power.

It has been widely observed many years ago that the Unmanned Aerial Vehicles are preferred for dull, dirty and dangerous conditions. After performing many experiments, it can be surely said that the efficiency of UAVs depends upon performance, design, maintenance cost and many more. The shape of the Unmanned Aerial Vehicles wings is preferably Rectangular. For the fabrication, the aluminum alloys, titanium alloys, and high strength light composite materials can be chosen.

Software aided flow analysis is also implemented to understand the behavior of the flow over the wing surface including velocity distribution, temperature distribution, pressure distribution, vorticity distribution etc. (Abdus Samad et al., 2016).

As we know, the Solar cell or PV cell produces electricity from visible light. The factors which affect the solar efficiency are Cell temperature, MPPT and energy conversion efficiency. The cell temperature is inversely proportional to voltage, that is, when the temperature of cell increases, the voltage decreases and vice versa.

Currently, the electricity conversion efficiency of solar cells is 14%, which is very less. So to increase that efficiency, one of the method used is Maximum Power Point Tracking (MPPT), which operates at DC to DC maximum efficiency converter that gives suitable and optimal power

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**Table 1:** Comparative study of battery powered UAVs and solar powered UAVs.

<table>
<thead>
<tr>
<th>Battery powered UAVs</th>
<th>Solar powered UAVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>In these UAVs, Batteries are used for the power source.</td>
<td>In these UAVs, Solar cells are used for the power source.</td>
</tr>
<tr>
<td>In these UAVs, Flight time is too low.</td>
<td>In these UAVs, Flight time is very High.</td>
</tr>
<tr>
<td>Endurance limit is low as compared to solar powered.</td>
<td>Endurance limit is high as compared to Battery powered.</td>
</tr>
<tr>
<td>In these UAVs, R/R rate is high.</td>
<td>In these UAVs, R/R rate is low.</td>
</tr>
<tr>
<td>Batteries are cheaper as compared to solar cells.</td>
<td>Solar cells are costlier as compared to battery.</td>
</tr>
<tr>
<td>Due to use of battery in these UAVs, they are dangerous.</td>
<td>Due to use of solar cells they provide a safer operational environment.</td>
</tr>
<tr>
<td>These UAVs have lower efficiency.</td>
<td>These UAVs have higher efficiency.</td>
</tr>
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</table>
DESIGN ANALYSIS OF SOLAR UAV

Material selection for UAV

We have to choose material by considering several factors for UAV so as to achieve maximum efficiency and durability. Factors like Properties- UAV should have resistance to buckling, low thermal gradient, less inflammable material, vibration resistance, greater endurance limit, strength to weight ratio, cost, machinability, and availability. For accuracy and precision in flight, it is necessary to have high strength to weight ratio and to achieve this, design should follow the aerodynamics laws and material should be shapeable and formable. By considering these factors, for main body, the materials that can be used are balsa wood, carbon fiber, and rohacell. Among these materials, some have slight advantage over others. The disadvantages of using BALSA WOOD are that it requires lots of maintenance and has less durability. Also, the wood has splinters that can cause harm, it is low in strength properties and readily detrotiates if exposed to water content or moisture thus it can be used as in fairings fillets and light. Low density contour blocks the disadvantage of carbon fiber that it is costly and the epoxy resins used to cure fibers are resistant to fuel, solvents and antifreezeant. Otherwise, it is stronger and has great strength and stiffness at a lower density than metals. Rohacell has high strength to weight, low cost and is easily machinable (Akshay et al., 2014).

Design of wing configuration

The wing is an important part of the UAV which decides its flight efficiency and durability. The atmospheric conditions are different in terms of temperature and pressure, and density at high altitude air temp can go as low as -30 to -60. Because of these extreme effects, the speed of light becomes 295 m/s and due to which exposed Mach number becomes 10% higher as compared to sea level, making aero foil designing a little bit challenging. We have seen that solar UAV needs high wing span and aspect ratio but we also do not want to increase the weight.

To solve this problem, we can use flying win configuration. In this configuration, empennage and fuselage are absent from the UAV due to which its weight get lowered as compared with other conventional ones.

Power consumption is restricted in solar UAV due to restricted solar panel area, that is why UAV should move at low cruise speed so as to save the power or to minimize the power consumption. As a result, flying wing configuration gives large wing area fairly low aircraft weight and low power requirement. Also that the weight of aircraft is parameterized has a function of cruise speed and area.

If we reduced the wing span, the glide ratio efficiency also dropped so that the material should be used which can withstand force distributions so that we can increase the glide ratio. It also states that 3% drag would imply 49% thrust hence reduction in consumption of fuel. To improve flexibility of wing, new material such as Active aero elastic wing (AAW) has been introduced. The future of wing design is morphing wings where the control systems such as aileron and flaps are replaced with flexible material.

We have to design wing by taking care or by considering all the above factors. By analysis, we got to know that, first we need high design lift coefficient (C) for carrying the weight of structure. Second, we need high L/d ratio for high endurance according to Breguet endurance approximation. Third solar cell area should be maximum to attain maximum solar power from the sun rays. It also states that at higher altitude factors such as c/c₈ and L/d decrease. At 14 km above sea level, power requirement increases by 250%. It can be concluded that eppler 422 is the appropriate choice for UAV at high altitude by analysis using different simulation software.

For Optimization and design in control of intelligent solar UAV at high altitude, the resolution of UAV sensors diminishes. It also states that an MPPT system can be installed to increase the operating efficiency of solar cell.

Optimization based on Gradient and Stochastic search algorithms (https://www.grc.nasa.gov.htmls).

Power unit and power supply system in UAV

The power source should be ecofriendly, have low noise emission and low infrared radiation. This study discusses about the different power sources such as thermal combustion engines, piston engine, rotary engine, Wankel engine etc. Power sources for UAV have to choose wisely according to work for which the drone is made. Brushless electric motors are used for 6 n thrust. The fuselage starts with blunt nose that extend rectangular. Aluminum struts can be used in the UAV SD 7032 aero foil and Lipo battery can be used in the UAV (Erdinc et al., 2013).

CFD analysis of tail wing and landing gear of UAV

Tail wing is designed in v shape which minimizes or reduces the wake effects of thrust device. Aero foil of tail wing is of symmetrical shape with camber and it is easy to manufacture. The landing gear should also be very important. Different landing gears are used according to nearby landing locations and purpose, whether they operate
only vertically or taxi movement in which tyre is used. They are designed to withstand heavy loads for short duration in tyres nitrogen, and helium gas is used to minimize expansion and contraction at extreme pressure and temperatures. Nitrogen expands at same rate but does not contain moisture, and moisture increases the expansion rate with temperature inert gas used for inflation of tyre to eliminate tyre explosion titanium alloys used to make critical structure parts, landing gears, firewall and hydraulic systems. Thus it is suitable for this purpose because of its properties such as high strength corrosion resistant etc. (Kyoung – Moo et al., 2019).

APPLICATIONS OF SOLAR UAVs

UAVs can be used to make 3D models of objects on basis of orthographic photos. It can also be used in inspection of solar parks, power lines, industrial parks, plants or in engines, Gas power plants and utilities on and offshore. It can be used for the inspection of Bridge, visual monitoring of structure and the inspection of structures. It can be used in Aerial imaging, Photography of products and landscape, Advertisement photography of up to 360° spherical panoramas, can be used for Remote sensing based UAV / Drone for mapping, monitoring of agriculture, can be responders in accident, crisis or fire, UAV based flight reproduction and automation, used as UAV based networking and swarming intelligence (http://www.asctec.de/en/).

CURRENT RESEARCH ON SOLAR UAVs

The DRDO Rustom (Warrior) is a mid-altitude high Endurance UAV made by the organization of India, that is, DRDO for Indian Army, Navy and Air Force. The Rustom is basically Light Canard Aircraft which was developed by a group under the mentorship of late Prof Rustom Damania in 1980s. The UAV may have changes in design and a new engine can be installed for more power. Rustom may work with Heron UAVs which is in usage with the Indian armed in future (https://en.www.wikipedia.org/).

Aurora Flight Sciences, which is a subsidiary of Boeing that specializes in UAV, is gearing up to develop solar-powered autonomous aircraft. This vehicle named as Odysseus is designed for persistent flight at high-altitudes and used to perform atmospheric and climate research. Its first voyage is planned in spring of 2019 and, it can carry 500 pound payload (https://www.engadget.com/).

Another current research is a Portable, Intelligent Autonomous Folding Drone, Uber planned to test the Flying Taxis in 2020 and OVNI Drones: Intelligence Rescue and search Future UAVs and many more going on (http://www.futuretechmagazine.net/).

SUSTAINABILITY OF SOLAR UAVs

For every research and development, the sustainability factors always come into existence. Therefore, the sustainable development of Solar UAVs for their proper future use needs to be considered. So, for the sustainable development of the solar UAVs, we need to develop a better design and ultimate source of Renewable natural energy. By using ultimate source of energy, that is, solar energy, we can increase endurance of the UAVs and this will be more beneficial than traditional electrical UAV (https://www.uav-drone.net). The advantages of using drone for sustainability purposes are its use in wind farms and solar power plants. So we have to use solar energy as a power source for UAVs because it is an eco-friendly energy source (https://en.www.wikipedia.org/).

COUNTER TECHNOLOGY FOR SOLAR UAVs

Counter Drone technology is also known as C-UAS technology. Counter UAV technology is used to detect or counter the UAVs systems. Currently, there are 235 C-UAS products which are in use and developed by 155 manufacturers in 33 countries. The popular anti drone technology are radar, EO, RF Detection and RF, and the popular detection system is jamming (https://dronecenter.bard.edu/).

FUTURE SCOPE

Unmanned Aerial Vehicles can be the biggest tech revolution in the near future. These automated flying machines can be used for private as well as commercial purposes in the future. The Solar UAVs have too much future scope in daily life which is increasing day by day. Amazon, a biggest online shopping site, is planning to use its Prime Air UAVs to deliver orders/packages to customers/shoppers. Facebook a social media site is planning to use the UAV’s to provide internet connections to people/users in far flung places. The Unmanned Aerial Vehicles is getting a permanent place in Armed Forces (http://www.futuretechmagazine.net/).

CONCLUSION

UAVs are an exotic sector in the Aviation world, with new inventions. In the next 15 years, UAVs will play prominent role in the armed forces. At present, each day, a new UAVs innovations is coming into existence in the world, it is hard to know what will happen next. There are many questions regarding UAVs safety, privacy and security. Unfortunately, at present, the illegal use of Unmanned Aerial Vehicles on Defence sector across the world is a major issue and to overcome this, a safer technology needs to be developed.
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