The solar powered airplanes engineering essay

Environment, Air

I have no doubt that we will be successful in harnessing the sun’s energy…. If sunbeams were weapons of war, we would have had solar energy centuries ago. – Sir George Porter

Once upon a time the concept of travelling from one place to another through a flying object just seemed impossible, however the Wright brothers made this dream possible and now people can travel from one place to another with comfort and ease. The traditional airplanes worked on an expensive fuel namely ATF which stands for Aviation Turbine Fuel. Similarly there was time when the concept of solar powered aircraft which could fly continuously was still a dream, but this challenge has become possible today. Science has progressed considerably over time and now it is possible to have solar powered aircrafts. This has a number of benefits over the conventional aircrafts which works on aviation turbine fuel.

The idea behind solar powered airplanes is very simple; the airplane’s wings are equipped with solar cells. These solar cells help in trapping the solar energy from the sun and thus help in converting this heat energy into electric energy which can help us in propelling the system also in control of electronics and surplus can be stored in batteries. The energy stored in the batteries can be used during night and places where there is scarcity of sun’s solar energy. According to the report it aims to build a airplane which is made keeping in mind a balance between the solar energy and the energy obtained from the aviation turbine fuel. This report will explain various key points which are to be considered during the process of building such solar powered airplanes.

Chapter 2:

Requirement Gathering & Analysis

Sr. No.

Name

Date

Description

1

Sunrise I & II

4th Nov. 1974

and

12th Sept. 1975 respectively.

The first flight of a solar powered aircraft took place on the dry lake at Camp Irwin, California. Sunrise I, designed by R. J. Boucher from Astro Flight Inc. under a contract with ARPA, flew 20 minutes at an altitude of around 100 m during its inaugural flight. An improved version, Sunrise II, was built and tested. The new cells, with a higher efficiency of 14%, delivered a power of 600 W.

2

Solaris

16th August 1976

The pioneers of solar model airplane were Helmut Bruss and Fred Militky. His model Solaris completed three flights of 150 seconds reaching the altitude of 50 m

3

Solar One

and

Solar Riser

In 1978 and 1979 respectively

They used the concept to charge a battery on the ground using their solar panels and then achieve short duration flights.

4

Gossamer Penguin

In 1979

1st Solar manned flight without energy storage by Dr. MacCready (US)

5

Solar Challenger

In 1981

Crossed the English Channel

6

Solair I

In 1983

A 16 m wingspan solar airplane that incorporated a battery by Günter Rochelt. On the 21st of August 1983 he flew, mostly on solar energy and also thermals, for about 5 hours 41 minutes

7

Sunseeker.

1986 – 1990

In 1990, crossed the USA in 21 solar-powered flights with 121 hours in the air.

8

Icare 2

In 1996

Won the Berblinger Contests in Ulm.

9

Solair II

In 1998

Its first flight took place in Germany.

10

Pathfinder

In 1993

With its 30 m wingspan and 254 kg, was tested at low altitude and became in 1994 part of NASA's Environmental Research Aircraft Sensor Technology (ERAST) program.

11

PathfinderPlus

From 1994 to 2003

Environmental Research Aircraft Sensor Technology (ERAST) program2. 1 History of Airplanes:

10

Pathfinder

In 1993

With its 30 m wingspan and 254 kg, was tested at low altitude and became in 1994 part of NASA's Environmental Research Aircraft Sensor Technology (ERAST) program.

11

PathfinderPlus

From 1994 to 2003

Environmental Research Aircraft Sensor Technology (ERAST) program

12

Centurion (NASA)

From 1994 to 2003

Environmental Research Aircraft Sensor Technology (ERAST) program

13

Helios (NASA)

From 1994 to 2003

Reached 29′ 524 m altitude. With energy storage, was aimed at flying continuously but crashed in 2003.

14

Solitair and Helinet

From 1994 to 1998

Projects studied the feasibility of HALE platforms

15

Zephyr

In 2005

By December 2005 : 6 hours at 7’925 m

-July 2006 : 18 hours flight (7 during night)

-Sept 2007 : 53 hours

-August 2008 : 83 hours

16

Solong

In 2005

Use of Solar Power and Thermals 22nd of April 2005: 24 hours 11 min 3rd of June 2005: 48 hours 16 min

17

Solar Impulse

In 2009

The next dream to prove continuous flight with a pilot on board perhaps comes true with Solar-Impulse, an 80 m wingspan lightweight solar airplane built in Switzerland.

18

AIRBUS – 380

In 2011

Research and Developments has showed that there are great chances of building solar powered Airbus, which will prove great boon for the airline industry and also be efficient in terms of fuel usage and efficiency.

2. 2 Analysis of Data

One of the important factors that are to be considered in this report is the analysis of solar energy available. The main fact of this report topic lies on the success of accumulating enough solar energy which can be converted and used to run the airplane propulsion and the electronics. However these factors should meet the minimum threshold value to make it a feasible option. If this topic works out for Airbus-380 it may help the common people by lowering the burden on them. It may also reduce the burden on the limited resources such as fuel which are used in conventional airplanes.

Certain factors that should be considered include:

Solar Energy Model

Solar Panels and its efficiency

Energy required for a flight

Mass Models

But before we learn about the above key areas let us first have a look at the basics of the Solar Energy and its collection.

We are very familiar with the term Solar panels. It is composed by solar cells connected in a particular configuration; in a solar powered aircraft it covers a certain surface of wing or other part. During the day, depending on the sun irradiance and the inclination of the sun rays, the convert light into electrical energy.

A converter, called Maximum Power Point Tracker (MPPT), is used to ensure that maximum amount of power is obtained from the solar panels. As discussed before, below is the figure that explains how solar panels are used to convert the solar energy to power the propulsion group and the onboard electronics, also without a miss the surplus is used to charge the battery which is used during the night.

Chapter 3:

Solar Power

3. 1 Solar Energy Model

Solar energy available per unit area depends on various conditions such as atmospheric conditions and concentration of atmospheric gases. The atmosphere is considered to be transparent where the efficiency of the solar panels is independent of the height. However the atmospheric gases, cloudiness, pollutants, etc affect the efficiency and their altitude is accounted. Our first model consists of the solar energy in ideal atmosphere.

Under the hypothesis of ideal atmosphere, the power per unit area, on a panel that is normal to the beam radiation, at given latitude and in the nth day of the year, I0n depends on the actual position of the Earth along its elliptical trajectory about the Sun. The law of variation in function of the day of the year is given by:

The total solar energy per unit area over a period T is given by Integrating the Equation over T:

The available energy depends on the hour in the day, the day in the year, the latitude and the position of the photovoltaic panels.

Figure on the right shows the beam radiation decrement through the atmosphere.

3. 2 Solar energy inside the atmosphere

When the panels are located inside the atmosphere, other parameters become important as, for example, sky cloudiness, dust concentration, pollutants and altitude; during the passage of the beam radiation through the atmosphere, a part of the radiation is scattered toward space (about 3% of I0), a part is scattered toward the Earth (about 7% of I0), another part is absorbed by the atmospheric gases (about 18% of I0), the rest (70%) constitutes the direct beam radiation.

Scattering: Air molecules, dust molecules and water vapour in the atmosphere, produce the phenomenon of scattering.

Absorption: The absorption transmittance is due to the presence of ozone and water vapour, both related to the flight altitude.

3. 3 Solar panels and its efficiency

Today solar cells for power generation on houses have an efficiency of up to 17 %. For special purposes mono crystalline cells may convert more than 20 % of the incoming energy into electric energy. The trivial, however, for flying extremely important conclusion is: the electric energy collected is proportional to the solar cell area.

The principle scheme of the solar powered propulsion system is shown below. Typical efficiencies are provided for individual components. Consideration of all losses along the route from the solar beam to the propelling force (including battery charging and discharging) results in losses of 87 to 89%. This figure clearly indicates that each system component must be optimized to result in a good overall system.

Chapter 4:

Energy and Efficiency

4. 1 Efficiencies of Solar Cells

Theoretical values for maximum efficiency for solar cells are between 25 and 30 % depending on material characteristics and are not achieved for serious production cells. Most solar cells are mechanically cut Silizium slices and the material is too thick to be light. To protect the cells from mechanical damage, humidity and temperature, they must be embedded in a foil or glasfiber. New manufacturing processes have been developed to put a thin Silicium layer onto a foil, which is very light and also flexible. The efficiency of thin solar cells has considerably improved during the last years.

Figure: Ratio between solar panel power generation for different incident angles of sun rays.

Figure: Comparison between power generations of solar panels at 90 incident angle of sun with cabin power usage.

4. 2 Energy required for a flight

Any non propelling airplane will fly in still air with the velocity V and will sink with a velocity Vs. The efficiency of the airplane is characterized by the ratio of flight velocity V divided by sink rate Vs., i. e. V/Vs. For small glide angles at 1g flight this value is equal to the Lift/drag (L/D) or weight/drag ratio (W/D).

If the Lift/Drag ratio is 20 an airplane can glide 20km from an initial altitude of 1 km. However, gliding down means losing potential energy, used as propulsive force to compensate the drag of the airplane. If the potential energy level is to be kept constant, i. e. if the altitude is to be maintained, the sink rate must be compensated. The required power is weight (W) times sink rate (Vs)

The power required to compensate the drag in horizontal flight is V * D.

A basic question then is: what is the optimum altitude to fly with a solar airplane, i. e. at which altitude is the required energy, a minimum? The efficiency of solar cells is increasing with altitude, because the atmospheric absorption and the temperature (up to 11km) are decreasing with altitude. However, flight velocity must increase with altitude to generate the same amount of lift at the lower air density at the same angle of attack. The consequence is that the required power is increasing with

altitude for the same L/D. Fig. Shows the relative change of power required and power available from the solar cells. The graph clearly indicates that (at a clear day) flying with solar power at lower altitude is more beneficial.

Hence from the above research and information it can be concluded that the required power for horizontal flight can be reduced by a better lift/drag ratio and by lower flight velocities. Smaller velocities can be achieved by a high(er) lift coefficient and a bigger wing area, which is required anyway to position a sufficient number of solar cells.

4. 3 Mass Models

For each part on the airplane, a good mass model is necessary in order to calculate the total mass m and use it for power balance for level flight. The mass of the control and navigation system is considered as fixed, just like the payload that is a requirement defined at the beginning. Concerning the battery, its mass is directly proportional to the energy it needs to store, which is the product between power consumption and night duration, and inversely proportional to its energy density.

Airplane manufacturers work tirelessly to decrease the weight of their airplanes. As a part of the aircraft designs most important aspects is weight control. Figure below shows a scenario of total weight added by the solar energy panel structure vs. the fuel saving and paint weight saved by the solar energy panel structure.

The weight per square meter of the solar cells including the substrate is 0. 316 kg= m2 which makes the entire weight of the 1277 m2 surface area 403. 5 kg. This weight is indeed slightly less when we take into account the paint which the solar cells replace. A surface area of 1277 m2 requires 230 kg of paint.

The solar cells require a number of additional supplements; extra wires and the inverter to convert the DC to AC. We were unable to find information on an inverter capable of turning out 140 kW of power and thus we had to rely on smaller domestic inverters with only 5 kW capacities used in the commercial solar industry. We combined the weight of 28 individual inverters to obtain 140 kW. This brought us to an unrealistic weight of just less than 300 kg. We believe we can safely assume that using an inverter specially designed for flight and capable of handling 140 kW will result in 8 reduced weights. In our calculations we therefore assumed a total weight of additional electrical regulatory equipment to be 200 kg. Therefore we expect that the total added weight is 390 kg.

This additional weight is countered due to the power generated by the solar cells. This extra power will allow the airline to reduce the take-off weight of the planes due to less fuel need. We can observe this relationship by viewing the results in figure below showing the weight of fuel saved by the solar cells on an A380 flight ranging from 8 to 16 hours. The results in figure where we show the total extra weight added due to the solar cells during flights ranging from 8 to 16 hours.

Fig: Weight of fuel saved per flight for varying flight times. The colors show different solar panel efficiencies.

Chapter 5:

Design Methodology

5. 1 Design Consideration

The most important point to be considered in the making of an aircraft is its design consideration. Now for a Solar powered aircraft it is even more crucial. The steps involved in the design of the aircraft are shown in the figure below:

The design process of an airplane is composed of three main phases:

1. CONCEPTUAL DESIGN:

In this phase emphasis is done on configuration arrangement, size, weight and performance. It is used to guide and evaluate the development of the overall aircraft configuration. The level of detail is not deep but a good understanding of the interactions among all the different components is crucial.

2. PRELIMINARY DESIGN:

In this phase, the specialists in areas such as structures, control systems, propulsion, etc. will design and analyze their portion of the aircraft. The design evolves with ever-increasing level of understanding and confidence that it will work.

3. DETAIL DESIGN:

Assuming a favourable decision for entering full-scale development, the detail design phase begins in which the actual pieces to be fabricated are designed. The many little pieces not considered during the two first phases must be designed and it has also to be decided how everything will be produced and assembled.

This report focuses on the design of solar powered tenability for Airbus-380. We propose a new design methodology and want to address the problems. The contributions concerning this methodology lie on four pillars:

1. SIMPLICITY:

The first objective is to develop a method that is clear, complete and still very simple, which is not contradictory. Simplicity should be such that the reader can very easily output a valid conceptual design in only minutes with the help of the short Mat lab program.

2. LARGE DESIGN SPACE:

Methodology is applicable to a large scale of solar airplanes, from the tiny MAV to the manned aircraft. Aim of all the designs is to reach this goal, the mathematical models of the subparts, for example the weight or the efficiency of electric motors according to their power, was not only studied in a limited domain, but over a very large scale, for some models with up to 7 orders of magnitude, showing on the same graphics a tendency that encompasses motors from 1mW to 10 kW. Combining this very large final design space with the analytical character of the methodology allows achieving sensitivity analysis on certain parameters.

3. CONCRETE AND EXPERIENCED BASED:

The mathematical models and the various technological parameters used in the methodology are based on real and practical cases. Large amount of data that is interpreted to understand the hypothesis has to be concrete and can be gathered from experiences also but it may not be assumed and theoretical.

4. FLEXIBILITY AND VERSATILITY:

This method can be used to design not only an airplane that achieves 24 hours continuous flight, but also for many other scenarios; one that stores its electrical energy into potential energy gaining altitude or another one that would have an endurance of a few hours, flying only during the day time.

The above are the key areas which are to be considered during the design process, however the application of these key areas for the design of various parts of the body of an airplane is explained below.

The main parts of an aircraft which is to be considered keeping in mind the solar power domain is the Wing, which comprises of the major part of the solar panels.

By careful considerations and calculations the total area available on AIRBUS 380 for mounting solar panels is 1277 m2 , this includes the wing top area and the fuselage top area. The following paragraphs will now highlight the key points necessary for the mounting of solar panels and its installations

5. 2 Wing Structure

Wing is an integral part of the structure of the aircraft. Till date in most of the planes which are solar powered the wings have played an important role and they cover the majority of the portion. They consist of solar panels covering them which are the most important ingredient in generating energy from the incident rays and help to run the aircraft.

5. 2. 1 Aerodynamics of a Wing

Figure below shows the cross section of a wing in a laminar airflow with a constant speed v. The circulation of this airflow creates a different pressure distribution on the upper and lower side of this section that once integrated can be represented as two forces, the lift and the drag.

The above figure helps us get a deeper view about the aerodynamics involved in the formation of a wing structure. The important point to be considered is the allocation of the wing.

5. 2. 2 Integration in the Wing

The solar panels are directly glued on the ribs and the spar, where a special notch with the same thickness was made to ensure a good continuity of the profile. The wing was designed to be very stiff so that the solar panels don't encounter flexion or torsion moments that could potentially break the solar cells. The glue, containing silicon, is especially important as it has to hold very well but at the same time allow small elastic displacements due to torsion. More generally, for all assemblies on the airplane, a correct selection of the glue to use is very important and according to the various locations and materials, different types of glue have to be used, some are even charged with carbon fibres to make it stiffer or others contain special tiny plastic bubbles to save weight.

The electrical connection between the wing and the ailerons is especially important and has to withstand the thousands of deflections during the flights. In the case of Sky-Sailor, it is done using very flexible wires, but for an airplane staying in the air for many weeks or months, the use of metallic hinges should certainly be preferred. For the connections between the three wing parts, special connectors were realized in order to save weight

Mechanical and electrical connections between the middle and the right part of the wing. On the left image, the panel is covered by a protection film removed just before the flight

Upper and lower side of the middle part of the solar wing

5. 3 FUSELAGE

A new fuselage structure has been designed for a better positioning of the masses inside the fuselage and for a better centre of gravity excursion.

Alternative Means of Installation of Solar Planes:

Example of adjunctive panelled no-lifting surfaces.

The prime design characteristics for an aircraft are:

A very low wing loading, which will result in low air speeds and low power requirements and also allow the installation of sufficient solar cells.

A large wing span (i. e. high aspect ratio) to achieve an acceptable aerodynamic performance (L/D)

Very low structural weight

5. 4 Comparing Solar Impulse and Airbus 380

If we consider there are large number of differences and very few similarities between the above mentioned aircrafts, but according the goals of this report we do not want to transform airbus 380 to solar impulse or vice versa, instead our aim is to make the airbus more efficient, more economical for common man and leverage the burden on the conventional fuels used.

As we know the width covered by these two aircrafts are more or less the same but there is a vast difference in their weight and the electronics which makes the work more complicated. However with the right expertise and approach it would not be much difficult to achieve the advantages of solar impulse into airbus 380.

5. 5 TOTAL COST INCURRED:

Chapter 6:

Airbus 380 & Solar Cells

6. 1 Solar Panels for The Airbus A380 Aircraft

Our project will focus on designing and evaluating solar energy panels to be fitted on the Airbus A380. A typical A380 cabin needs about 211 kW in-flight which is 0. 5% of the planes total fuel consumption per hour. This power is obtained by generators connected to each engine. We will show in this report that a substantial percentage of the fuel needed for cabin use can be saved by solar energy panels. The practical available area for mounting solar energy panels onto the A380 is 1277 m2. This total was arrived at after careful consideration and calculations; it includes the top of the wing and the top of the fuselage. The following graphs show the power output obtained from this surface area with respect to 10%, 20% and 30% solar cell efficiencies (see table 1).

6. 2 Solar Cells

The majority of commercial solar cells have been produced using very energy and labour intensive methods which require glass substrates and silicon wafers; high purity silicon is an element in high demand in the technology sector, but is in relatively low supply. These solar cells are fragile and very heavy. The solar cell industry appears to be heading in a direction where their products are smaller, lighter, more efficient, cheaper and more versatile. The corporate executive officers of nano-technology companies talk of a day when there will be no need to install solar cells onto the roof of a building. They envision a time when the sunlight absorbing material in solar cells will simply be a part of every buildings structure creating plentiful green energy for all.

6. 3 Overview Of Solar Cell Technology

Currently there are three main types of thin-film solar cells in production:

Sr No.

NAME

DESCRIPTION

1.

Amorphous-Silicon (a-Si):

The a-Si technology is very similar to conventional solar panels, only thinner. As such this technology is tested and proven, but is unfortunately not very effective for large scale use due to their dependence on a glass substrate and silicon wafers as we mentioned before.

2.

Cadmium Telluride (CdTe):

The CdTe cell technology relies on the availability of the rare element Tellurium. It seems too uncertain if enough new Tellurium mines will be discovered to guarantee enough CdTe cell supply. Moreover, CdTe cells also need Cadmium which is a highly toxic substance and a possible environmental hazard. The most common production process of CdTe cells is within a vacuum chamber, which is both energy and labor Intensive.

3.

Copper (Indium, Gallium) (di)Selenide (CIGS):

CIGS rely mainly on very cheap and available elements and compounds, which have a wide variety of uses in the industrial sector. CIGS-on-foil can be manufactured by simply printing the semiconductor on to a foil substrate in an open-air environment. This creates a potential for inexpensive mass production After researching these different solar cells we came to the conclusion that the most promising technology in relation to this project is the CIGS solar cells. From here on after we will focus entirely on them.

Chapter 7:

Evaluation

7. 1 Evaluation

After researching these above many solar cells we come to the conclusion that the most promising technology in relation to this project is the CIGS solar cells. The CIGS cells themselves are only 3 to 4 mm thick. However, with the metallic substrate which they are deposited on, the thickness becomes about 0. 5 mm.

Figure below shows the structure of the CIGS module, layer construction:

Fig: Cross-section of CIGS solar cell on foil substrate

Layer 1: Aluminium reinforced Zinc Oxide (ZnO : Al) has a wide range of industrial uses with key characteristics as good transparency, high electron mobility and a wide band gap. The main purpose in the cells is to withstand greater force and pressure and provide protection. Its wide band gap of 3. 2 eV allows about 90% of the energy to pass through without being absorbed.

Layer 2: Zinc Oxide (ZnO) is the same chemical as in Layer 1 except it is not reinforced with aluminum.

Layer 3: Cadmium Sulfide (CaS) has a large band gap of 2. 4 eV , combined with it being very thin allows the energy to pass through without being absorbed.

Layer 4: Copper (Indium or Gallium) (di) Sellenide (Cu(In; Ga)Se2) is the thickest layer and serves to absorb the energy from the sun's rays. The absorption depends on whether Indium or Gallium is used. CIGS containing Indium currently hold the laboratory efficiency record of 19. 9%.

Layer 5: Molybdenum (Mo) is a metal and is used to conduct the electrons captured by the solar cells. It has a wide range of industrial uses, including many aircraft parts. Although supply currently meets demand, this is the only element which could potentially see a fall in supply in the coming years.

7. 2 Production and Cost Analysis

Production:

CIGS solar cells are manufactured in a variety of ways. Earlier Manufacturing had disadvantages that it was both time consuming and energy intensive with a slow throughput. However, new vacuum free methods have been developed. Today the most efficient process is " roll-to-roll" printing process which occurs in an open-air environment. The " roll-to-roll" process has some major advantages in reducing the time and cost of manufacturing, something that is vital if solar technology is to become a major contributor in the world energy supply. The difficulty today is to produce such CIGS panels in large quantities. Companies such as Global Solar and Nanosolar predict that they will reach 15% efficiencies in mass production in the near future.

Cost:

Currently the price of CIGS solar cells is at about $3/Watt. With improved manufacturing processes and increased efficiencies this price is expected to drop below $1/Watt in the foreseeable future.

Like every coin have two sides there also some merits and demerits of solar powered airplanes.

Merits:

Cost reduction:

Co2 reduction

Awareness to the people about the global energy crisis

Cleaner and pollution free environment

Proper utilisation of the available energy and less use of the non renewable energy

Demerits:

Low power production as compared to other sources.

Higher initial installation cost

Needs proper insulation from lightening strikes.

Thorough maintenance

Loss of some amount of energy

Chapter 8:

Report

Report

With deep research and investigation of the pros and cons of solar powered airplanes it can be concluded that the energy generated by solar panels is far less than the energy generated by generators and batteries and there is also a lot of loss of energy.

Therefore, it is not a wise decision to replace the generators completely by solar panels as it will not be able to cover the requirements of the systems atleast till the proper solar systems have been discovered and tested. Rather it can still be of great help if it is utilised in a proper manner.

After deeply analyzing the data and the report we are of the opinion that the solar panels have the tendency to generate a handsome amount of energy which can be used for various purposes for the use of electronics in an airplane. Also to replace the paints and covering the wings with the solar panels will provide an add-on to the existing supply of energy to the airplane. It will also help to reduce the burden over the conventional resources which are on the verge of extinct.

The energy received can be stored and can be used in case of emergency or can also be used for the lightening of the aircraft. The energy can also be used for the in flight entertainment system.

As the technology is growing limitless it can be seen that in the near future there will be solar cells of great efficiency which would give almost the amount of energy received from the other battery sources. This seems to come in just few years as the well kn