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Energy Harvesting on Aircrafts Statics Charge – Energy Generation

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Abstract- **A novel energy harvesting concept is proposed for treating local electrostatic energy developed on flying composite aircrafts. This work focuses on the feasibility research on collecting static charges with capacitive collectors. The existing energy harvesting system and the electrification of the typical carbon fiber composites (CFCs) aircraft hasbeen reviewed. The detailed model experiments were then designed to characterize different configurations for electrostatic energy harvesting on aeroplane. In the lab, the static charge was produced by a corona discharging device, and a capacitor or a metal sheet was put in the electric field to collect the charges under four different configurations. After that, the rest results for these configurations were analyzed, which is followed by the discussion about the results application on the aircraft. This work has proved that it is feasible to collect the local static electricity on flying aircraft, and it could provide a new direction of energy harvesting system in aviation field.**

Keywords: **Aerospace, aeronautical, renewable energy, static charge, charge storage, frictional charge, turboelectric effect, capacitive storage, super capacitor, super battery, adder circuit, op-amp switching, charge harvesting, free energy, multi capacitive switching, weighed summer, dc to dc down convertor.**

I. INTRODUCTION

A novel energy harvesting concept is proposed for treating local electrostatic energy developed on flying composite aircrafts. This work focuses on the feasibility research on collecting static charges with capacitive collectors. The existing energy harvesting system and the electrification of the typical carbon fiber composites (CFCs) aircraft hasbeen reviewed. The detailed model experiments were then designed to characterize different configurations for electrostatic energy harvesting on aeroplane. In the lab, the static charge was produced by a corona discharging device, and a capacitor or a metal sheet was put in the electric field to collect the charges under four different configurations. After that, the rest results for these configurations were analyzed, which is followed by the discussion about the results application on the aircraft. This work has proved that it is feasible to collect the local static electricity on flying aircraft, and it could provide a new direction of energy harvesting system in aviation field.

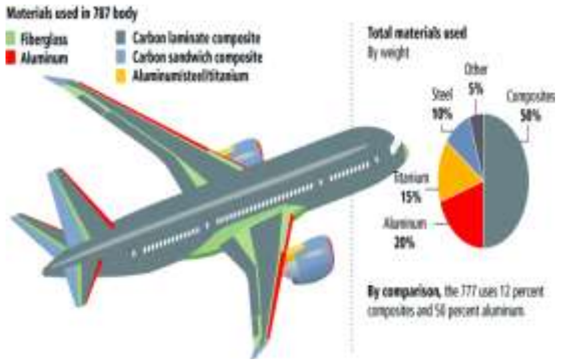
II. CURRENT METHODS:

Static dischargers, commonly known as static wicks or static discharge wicks, are installed on the trailing edges of aircraft. They control the corona discharge into the atmosphere, isolating noise and preventing it from interfering with aircraft communication equipment. The discharge creates a broad-band radio frequency noise from DC to 1000 MHz. This RF noise can affect aircraft communication. During adverse charging conditions (air friction), static dischargers limit the potential static build up on the aircraft and control interference generated by static charge.

Our Proposal:

The accumulation of electrostatic charge, generating during flight on the outer surfaces of aircraft and inside aircraft piping systems, cannot be considered as an immediate danger for flight safety, rather we can store the static charge induced in the planes body.

We can store these charges by modifying certain portions of the Aircrafts body which can act as ***Capacitor.*** Generally commercial flights use ***Carbon Laminate Composite , Carbon Sandwich Composite and Aluminum/Steel/Titanium*** materials for body framework. Capacitors made of these materials will generate static D.C. charge due to air friction during onboard navigation.



Advantages of using capacitor concept

- ❖ Charging and discharging of capacitor occurs within fraction of second.
- ❖ ***Minimal*** Energy Loss (Resistance drop).
- ❖ It will not hamper communication and will charge neutrality.
- ❖ There will be no adverse effect on body contact.
- ❖ The charge stored in the capacitor can be used for purposes like RADAR, Radio communication or internal luxuries.
- ❖ Storage in capacitors avoid recharging energy drops.
- ❖ Switching and diverting over voltage during lightening and other natural/man made issues is quite easier using a capacitor than using an over voltage circuit.

Background

It is Well known that an aircraft Will build up a significant static charge on its external surfaces While flying due to impact of the aircraft with rain, snow, sleet, dust, ash or fog resulting in triboelectric charging due to particle impact, this being the major contributor to aircraft charging in general. This type of charging has been labeled P-Static charging by those Working in the field of aviation and is a distinct and different process of electrical charging phenomena than, for example, the process of generating static charge by the rubbing of two materials against each other such as a glass rod against Wool or fur. To a lesser degree, static charge may also be acquired on an aircraft due to its movement through the earth's electrical and magnetic fields, when in the vicinity of electrical storms or by that generated by the aircraft' s propulsion system either jet engine or propeller type. For purposes of this application, the invention is for the local harvesting of P-Static charge, its conversion locally to useful low voltage electrical power, and the use of that electrical power by locally collocated electronic devices and a Wireless transmit ter. The other types of aircraft static charge mentioned above Will also be captured by the invention if they are found to be locally available too. It has been noted by others that a large aircraft such as a Boeing 707 aircraft Will charge in-flight to a level of several hundred thousand volts or higher if the aircraft does not have means to discharge the static electrical charge that is building up and accumulating on the aircraft. If the aircraft cannot rid itself of static charge, the voltage potential Will build up from low to higher and higher levels and a point Will be reached Where corona discharge occurs directly from the aircraft or its appendages and the resulting electrical energy that is radiated from these high voltage discharges Will interfere with aircraft communication and navigation systems. Since 1 949 and even earlier, apparatus has been developed Which is attached to the aircraft and prevents serious corona discharge from occur ring. One example of such a discharger is that described in US. Pat. Nos. 2,466,024 and 2,466,311 by W. C. Hall Which discharges the static charge to the surrounding atmosphere.

These early efforts focused on methods to discharge the unwanted and bothersome static charge at low enough voltage potentials that interference due to corona discharge is reduced or nearly eliminated. The inventions of W. C. Hall utilized a discharger employing either fibrous surfaces of non-conducting Wicks moistened with a liquid of suitable electrical conductivity or fiber Wicks made semi-conducting by incorporation therein of finely dispensed conducting materials or by impregnating them or coating them with microscopic metal particles. Such Wicks Were mounted on the aircraft, trailing in a do Windstream direction, at its Wing tips and trailing edges as Well as on the horizontal stabilizer and vertical tail. Improvements in existing discharger designs and the development of new designs for static charge dischargers Which diminish corona discharge effects have continued to this day with over fifty related patents being granted since 1949.

As a result of recent developments in technology, electronic devices capable of performing certain tasks have been reduced substantially in physical size and power usage. For example, electronic units that previously Weighed several kilograms, took up several cubic meters of space, and used amperes of electrical power to perform a given task are now replaced by electronic chips or micro-electro-mechanical (MEMS) devices Weighing mere grams with their volumes measured in cubic millimeters and power in milli-amperes. These reductions in Weight, size and electrical power requirements now allow the realization of innovations not previously believed possible.

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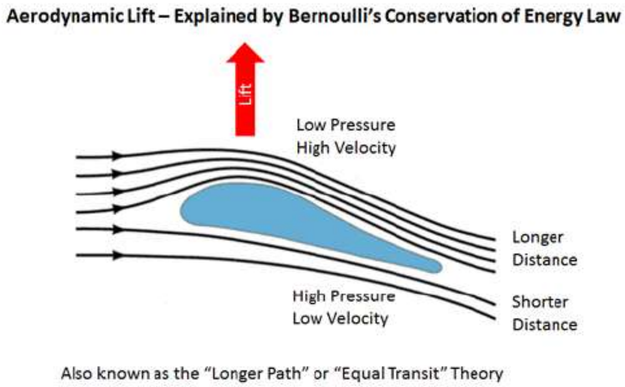

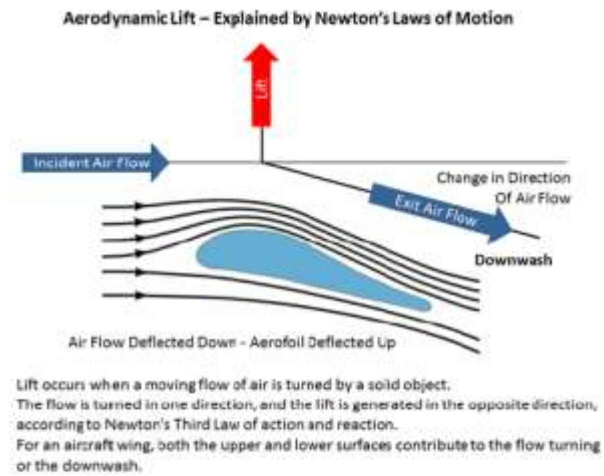

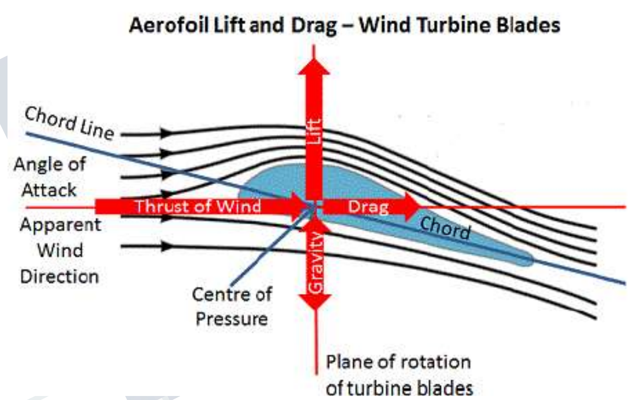

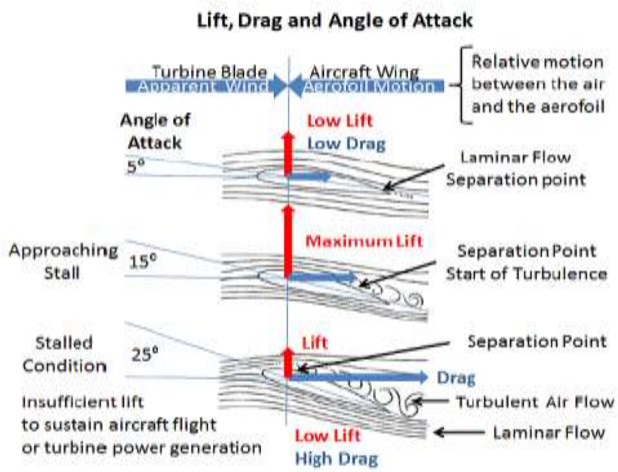

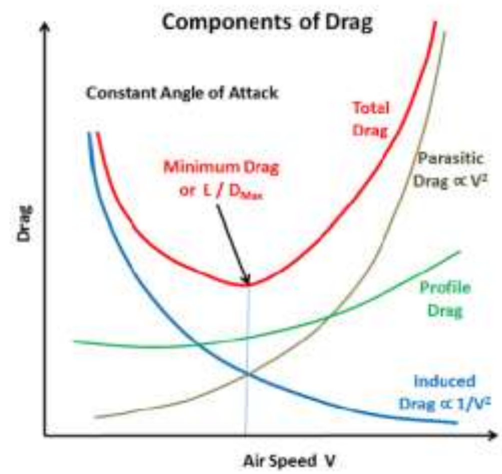

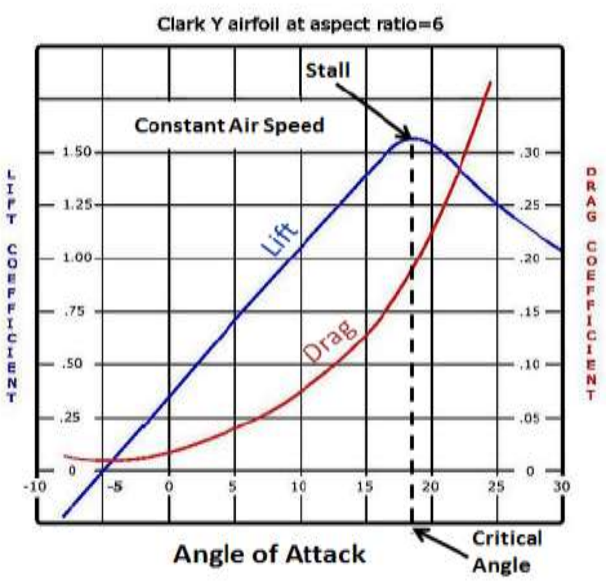

The above diagrams show the air flow around the wings and drag formation regions on wings. The much a drag region experiences more frictional surface, hence more p static charge formations over the region.

1. Introduction

When an aircraft flies through the atmosphere, electrostatic charges build up due to the interaction between the aircraft and the surrounding atmospheric environment, which has potential hazardous effects on airborne avionics systems, fuelling system and human's safety. Since 1920s, aviation researchers and engineers have tried various ways to research the adverse influence of P-static on the airborne system and reduce the electrostatic hazard. In other words, the conventional treatments about electrostatic charges are to dissipate them.

However, in the energy harvesting field, the emerging energy harvesting researches in the aviation domain have focused on the vibration-based energy harvesting system for several years in order to provide the power supply for the wireless sensors. In a sense, this type of energy harvesting can be regarded as the process of creating energy.

In view of the points mentioned above, it is proposed an idea to connect them together. That means, the static energy accumulated during flight is a local energy, and there is no need of additional device to generate this energy. Why not collect it as a usable energy rather than only bleed off it? Based on this idea, this paper is aimed at finding an available approach to collect this local electrostatic energy which may be used as a new source of an energy harvesting system.

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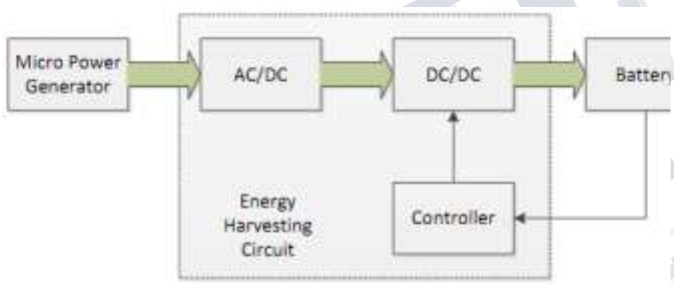
2. Energy harvesting system and electrification on an aircraft

2.1. Existing energy harvesting system

In the last decade, the field of energy harvesting has attracted increasingly research interest. The applications for energy harvesters cover a wide range of civilian and military components. Out of these applications, powering wireless sensor nodes is the substantial application.
A typical vibration-based energy harvesting system block diagram is shown in Fig. 1. Micro power generator can collect energy from mechanical vibration. A diode AC-to-DC rectifier is used to convert the AC source to DC source. Then a DC-to-DC converter is applied to improve the energy harvesting efficiency. A stand-alone energy harvesting system with simplified control unit has been proposed by using the discontinuous conduction mode operation of DC/DC converter. Then the stable energy will be stored in batteries for powering the load like a wireless sensor.



In aerospace domain, the main energy sources used as energy harvesting are vibration-based and thermoelectric energy.

2.2. Principle of electrostatic on the aircraft

It is well known that the contact or friction between two objects may produce the static electricity due to the Movement of electric charges. But what are the main characteristics of static electricity?

Normally, metallic material allows static charges to move freely, especially when the metal is grounded, this will make the static charges quickly move into the ground. By contrast, the static electricity cannot move in insulators, namely, if some static charges accumulate on an insulated surface, it will stay there.

Because this paper focuses on the electrostatic produced on aircrafts, this section will start from the electrification of an aircraft. In summary, there are three main causes resulting in the electrostatic on aircraft:

- Frictional electrification: Generated by precipitation particles impact on the aircraft, which causes uncharged particles to be positive charged with an equal and negative charge being produced on the external surface of the aircraft.
- Engine charging: Due to the positive charge from engine exhaust expelled to the surrounding environment, which leads to the aircraft been charged with negative charges.
- Exogenous charging: Occurs when the aircraft flies through an electric field such as clouds in a thunder storm.

However, these causes mentioned above are mainly based on the metallic aircraft. How about the situation on composite aircrafts? As a matter of fact, in comparison with metal aircrafts, static electricity accumulation capacity on composite is much bigger. Moreover, the decay time for electrostatic discharging is longer. This phenomenon is mainly due to the relatively lower conductivity of composite aircraft.

Table 1. Typical resistivity values [12].

Material	Thickness (*cm*)	Volume resistivity (*Ohm/m*)	Surface resistivity (*Ohm/square*)	Conductivity (*Mho/m*)
Copper	0.100	1.72E-08	1.72E-05	5.81E+07
Aluminum	0.100	2.87E-08	2.87E-05	3.48E+07
GFRP (typ.)	0.100	1.80E-05	1.80E-02	5.56E+04
40% Carbon fiber	0.178	1.00E+00	5.62E+02	1.00E+00

According to [12], the material with surface resistivity less than 1×10^7 ohm/square has no capability to keep static charge when electrically bonded to the conductive structure. In comparison, the material that has resistivity values above 1×10^{12} ohm/square can retain static charge that will not dissipate even when bonded.

The increasing widespread application of advanced composite materials in airframe causes many different problems due to their low electrical conductivity. As a matter of fact, the carbon fibre composites (CFCs) have Sufficient electrical conductivity to flow off the static electricity. So the static accumulation is not the problem for CFCs, while it is an issue for nonconductive composites.

2.3. Electrical characteristics of local electrostatic

Usually, the capacitance (*C*) of an aircraft with respect to the earth can be regarded as a constant , and the potential difference (*V*) is the value with respect to the surrounding atmosphere. In addition, for the purpose of controlling electrostatic charging, it is required that "all structural surfaces are at least mildly conductive, that all parts are electrically bonded, and that an electrical path to earth is provided" . Usually the airborne systems will be grounded or bonded to main structures. And the main structures bond together in inner parts or in external parts. Because the inner surface and external surface is usually electrically conductive, the external conductive surface can be regarded as the reference ground for the airborne systems and structures. From other point of view, the aircraft is an instantaneous equipotential body with the potential everywhere on the external surface of *V* in a very short interval .

According to the static charge accumulation process on the surface of the aircraft during flight can be represented through following equations :

$$\frac{\partial Q}{\partial t} + \frac{Q}{RC} = i(t) \qquad (1)$$

Integrating the above equation, the static charge Q can be derived.

$$Q = I_0 RC\left(1 - e^{-t/RC}\right) \qquad (2)$$

Where
R = the leakage resistance of the aircraft (Ohms)
C = the capacitor for energy storage (Farads)
I_0 = the current (Amps)
The aircraft during flight can be considered as an insulated conductor with a capacitor C, so its potential voltag between the aircraft and surrounding environment can be calculated through the following equation:

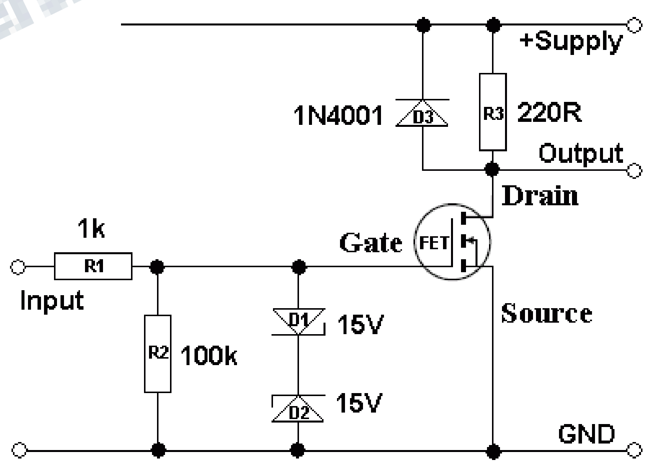
$$V = \frac{Q}{C} = \frac{\int i(t)dt}{C} \qquad (3)$$

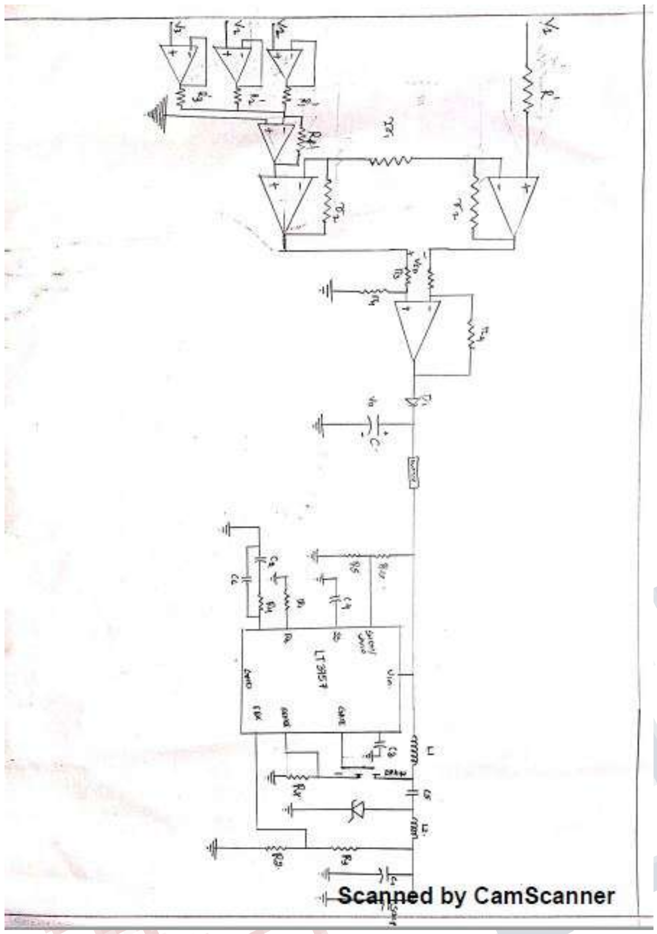
For a medium size transport aircraft, the equivalent capacitor is about 300 pF. So the aircraft potential will reach 30 KV in 1 second providing the charging current is 10μA. According to the precipitation project executed in 1945, the maximum current on the surface of an aircraft in the condition of heavy snow is around 155 μA [1], then the aircraft will reach a high voltage about 520 KV in 1 second. However, each aircraft has its own different capacitance due to different geometric shape and size, it is impossible accurately to calculate its capacitance. Usually, the estimated capacitance for an aircraft can be 1000 picofarads (1nF) [15].

(Ref: "APISAT2014", 2014 Asia-Pacific International Symposium on Aerospace Technology,
APISAT2014, Feasibility of an Electrostatic Energy Harvesting Device for CFCs
Aircraft, Huiling Xiea,*, Zhaorong Huangb, Shijun Guob, Ekiyor Torrub)

WORKING:

Voltages from different regions of the plate is connected to buffer amplifiers which provide the required high impedance to the system. All these voltages are given to a summing amplifier which is again given to instrumentation amplifier for better CMMR and gain stability. This is then stored in a high voltage capacitor. Then through a switching circuit (MOSFET)(This separates the other part of the circuit and also keeps from voltage overloading), the above capacitor is connected to dc to dc down converter which brings the voltage down to the voltage rating of our storage unit ,i.e. an ultra-capacitor. The supercapacitor has a working voltage of 3.3v to 4v which is achieved through the dc to dc down converter. The diode D1 prevents the back flow of charge from capacitor to the opamps.





ELECTRICAL USAGE:

GENERATION:-

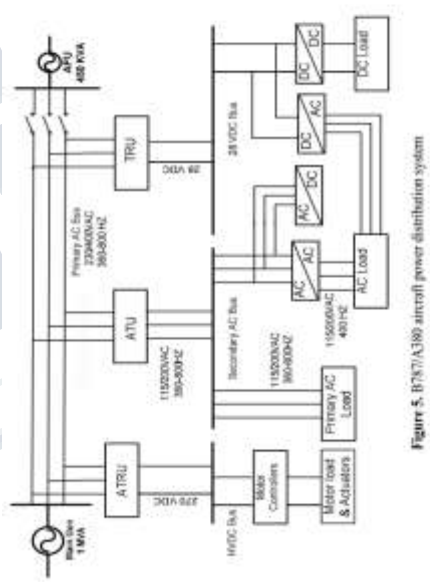
In aeroplane there are many sources of power .These are-

1.auxiliary power units (APUs),
2.external engine driven AC generators,
3.power and ram air turbines.
4.rechargable batteries

Both AC &DC power is used in aircraft.In AC system voltage requirement is 115 V ,400Hz.In DC system voltage requirement is 28 V. The propeller fixed in wings of aeroplane drives the generators. It produces 115 V 400 Hz AC power. The DC requirement of aeroplane is fulfilled by converting AC to DC by transformer rectifier unit(115V AC to 28 V DC).For emergency there is ram air turbines which generates power during engine failure. The DC batteries are required for motor starting purpose during taxi period.The generators are synchronised to the bus bar.Electrical power generation for Boeing 777 is given below:-

• Power Sources:– Two - 120 kVA, 115Vac, 400Hz engine driven generators– One 120 kVA, 115Vac, 400Hz Auxiliary Power Unit (APU) driven generator– Four 950 W Permanent Magnet Generators (PMG) integrated into the two backup generators – One 7.5kVA Ram Air Turbine (RAT) – Main, APU, and flight controls batteries

• Conversion Equipment: – Four 120 Amp DC Transformer Rectifier Units (115Vac to 28Vdc) – Battery chargers and inverters



HVDC-High Voltage DC
ATRU-Autotransformer rectifier unit
ATU-Autotransformer Unit
TRU-Transformer Rectifier Unit

ELECTRICAL LOADS:-

For operation of aeroplane many electrical machines are required such as motor, heater, refrigerator etc. Those may be considered as electrical loads to the aeroplane electrical system. Different Electrical loads of aeroplane are listed below.

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***Actuators**

***Motors**

***pumps**

***Valve operation**

***Engine starter**

***Charger**

***Light**

***Communication**

***Heater**

***Refrigerator**

The output from generator and batteries are connected to the main bus bar. The bus bar is maintained at proper voltage. From there output is drawn. The DC power requirement for a typical flight is tabulated in next page.

Developed charge can be used in those Electrical system which are generally operated during flight period. There are many Electrical systems which are only used in taxi or take off or landing period. Those systems which are operated during flight and their maximum current requirements are listed below.

***Motor de-icing 5A**

*** Prop auto ctl. 10A**

***Fuel boost pump 20A**

***Engine Inst. 12A**

***Lights 20A**

***Vent Fans 30A**

***Auto pilot inv. 15A**

***Inst flight inv. 5A**

***Radio receiver 5A**

*Intercommunication 5A

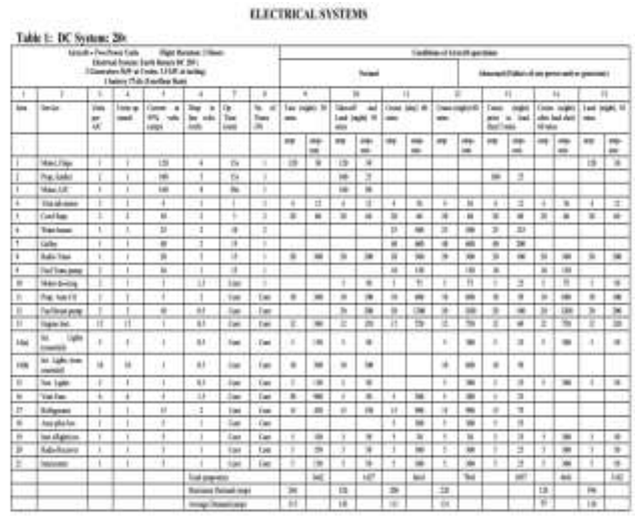
ELECTRICAL SYSTEMS

Table I: DC System: 28v

CONCLUSION

According to the investigations executed and analysis for the results, the main theoretical findings andconclusions can be drawn as follows:

1. tatic electric properties on typical carbon-fibre composite airframe follow the same way as that of a metallic aircraft

2. he configurations with grounded capacitors allow collective capacitors to harvest static charges, and have equivalent electrical properties to that of the theoretical charging process of the aircraft

3. he configurations with ungrounded capacitors show different properties as compared with the configurations for grounded capacitors, but the collective capacitors in these configurations also collect static charges with much smaller magnitude

4. he local electrostatic energy available on the aircraft can be regarded as a DC constant current source

5. he utilization of capacitor alone will constrain the electrostatic energy harvesting due to the properties of DC current source, which requires a conversion circuit for the electrostatic energy harvesting system

6. ulti switching using micro controller can be helpful in setting up timer circuits for auto switching and intelligent sensing of charge accumulation.

7. oltage difference is basically measured between outer

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charge accumulated sections and the grounding system of the aircrafts.

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