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Design a Solar Power system for Earth orbiting satellite

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***Abstract*—** A satellite is an object in space that orbits or circles around a bigger object in space. The satellite has four parts – a power system (which could be solar or nuclear), a way to control its attitude, an antenna to transmit and receive information and a payload to collect information such as a camera or a particle detector. The Satellites has used for some applications, such as communicate and interchanges weather forecast, navigation, earth/space perception, and logical examinations. To calculates the efficiency of solar cell using MATLAB Environment.

***Keywords*—**LEO, Photovoltaic Cell, Ultraviolet Degradation, DC to AC Convertion

I. INTRODUCTION

A satellite is an object in space that orbits or circles around a bigger object in space. Every satellite has four parts – a power system (which could be solar or nuclear), a way to control its attitude, an antenna to transmit and receive information and a payload to collect information such as a camera or a particle detector. Satellites is used some applications, for example, communicate and interchanges weather forecast, navigation, earth/space perception, and logical examinations. Because of their noteworthy effect on human lives, business furthermore, logical investigation, satellites have been broadly examined, chiefly concentrating on their physical and correspondence angles, separately from the aviation and systems administration networks [1].

A. Orbits classification

The Earth is a sphere with a slight flatness at the top. Its diameter is 12,713.54km at the poles and 12,756.32km at the equator, the difference being 42.78km. Air surrounds the Earth and extends up to 160km above the surface, beyond which the atmosphere gradually fades into space.
GEO: geosynchronous Earth orbit, circular at 35,786-km altitude - MEO: mid Earth orbit, circular at 2000 to 20,000-km altitude - LEO: low Earth orbit, generally circular at 200 to 2000-km altitude - HEO: highly elliptical orbit.There are essentially three types of Earth orbits: high Earth orbit, medium Earth orbit, and low Earth orbit. Many weather and some communications satellites tend to have a high Earth orbit, farthest away from the surface. Satellites that orbit in a medium (mid) Earth orbit include navigation and specialty satellites, designed to monitor a particular region [2]. Most scientific satellites, including NASA's Earth Observing System fleet, have a low Earth orbit. A GEO satellite moving west to east at an altitude of 35,786km (22,237 miles) results in a nominal orbit period of 24h, and remains stationary with respect to the Earth. The geosynchronous orbit is similar to the geostationary orbit, except that its inclination can be any value between 0 and 90. Inclinations other than zero requires ground station tracking antennas.

B. Components of satellite:

A satellite consists of various systems designed to meet the mission specific requirements. All but the simplest satellites require a common set of systems shown by the solid lines in Figure 1. Complex satellites require additional systems shown by the dotted lines. The systems are classified into two groups, the payload and the bus [3]. The payload consists of the communications equipment in commercial satellites or science instruments in research satellites. The bus consists of all remaining equipment grouped into several functional systems that support the payload.

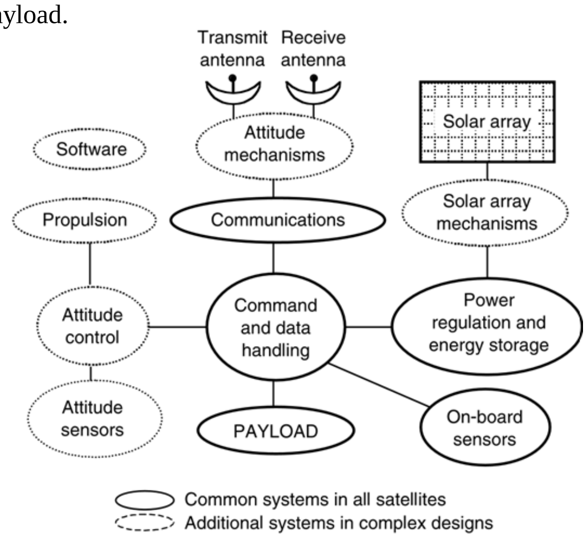

Figure 1. Satellite Power System

The power system is one of the bus systems that consist of the solar array, battery, power electronics, distribution harness, and controls. Other essential bus systems are the communications and data handling system to receive commands and return information, telemetry sensors to gage the satellite state, and a central computer to coordinate and control activities of all the systems. Satellites with complex missions also require systems to determine the spacecraft attitude and orbit orientation.

II. RELATED WORK

On many studies on the topic of interest, "Designing of the Power system for Earth Orbiting satellite" several parameters are achieved from many sources and research papers. As the power system design for different satellites orbiting in different orbits around the Earth is not same, a lot of research is necessary to obtain the various important parameters on which the power system design depends.

Article [1] titled "Spacecraft Power Systems" published by Mukund R. Patel. In this article, the basic design for the satellite system is defined. The various components associated with the satellite design are illustrated. The values for the solar flux and eccentricity for the calculation of efficiency of the solar arrays is interpreted in this article.

Article [2] titled "Solar Energy", In this article the author G. N. Tiwari, different classification of Solar Energy is explained. The advantages and usages of these individual orbits are explained.

Table 1. Classification of Earth orbiting satellite

Orbit	Apogee	Perigee (km)	Ecc	Inc	Period
GEO-Stationary	35786	35786	0	0	1 Sidereal day
GEO-Sync	35786	35786	0	0-90	1 Sidereal day
LEO	various	various	0 or High	0-90	>90 min

Ecc- Ecentricity, Inc-Inclination

Article [3] titled "Solar Power Systems for satellites in Near-Earth Orbit" published by C. M. Mackenzie. In this article, basic power system configuration for the Earth orbiting satellite is illustrated. The article also describes the designing parameters for the solar array, which consists of some solar panels on which some amount of solar cells are mounted for absorption of solar energy. Power control and distribution is also an important part of the description of this article.

Article [4] titled "Power system challenges for small satellite missions" published by Craig S. Clark, Alejandro Lopez Mazarias. In this article, solar array characteristics as illustrated along with the common power system design approaches.

Article [5] titled "Contemporary measures of the solar constant". I n this article Frohlich, R. C, the energy band diagram for a p-n junction solar cell is illustrated. Band diagram for PV cells are outlined. Plot of efficiency and band gap energy for single junction solar cells are depicted.

Article [6] titled "Solar power satellite and microwave transmission from space to Earth for generating Electrical power" published by Professor V Parameswaram, Mateen Khan M Pathan. In this article the transmission of the microwave with the help of rectenna and then further conversion to electrical power is described.

Article [7] titled "Wireless electricity (Power) transmission using solar based power satellite technology" published by M Maqsood and M Nauman Nasir. In this article, the use of space solar power system and its importance is described.

III. METHODOLOGY

A. Power system of satellite

The basic configuration of the power system (Figure 1) consists of a source, a reserve or storage element, interconnections, and a load. In most space, applications the source has been a matrix connection of solar cells called a solar array. The storage element has been a secondary or rechargeable battery used to supply power during peak loads or during unilluminated portions of the orbit. The interconnections, or power conditioning circuits, contain the regulation, conversion, charge-control, and protective devices necessary to supply continuous power to the spacecraft loads. This type of system has called a solar conversion-energy storage power system. The system is two basic characteristics, one is the average power capabilities are determined by the size of the solar array and its associated constraints, another is the system must operate to achieve an energy balance. The attitude, orbit, temperature, cell efficiency, and radiation environment. An energy taken out of the battery must returned to the battery, with proper allowance for efficiency, if the system is to operate for long periods [4].

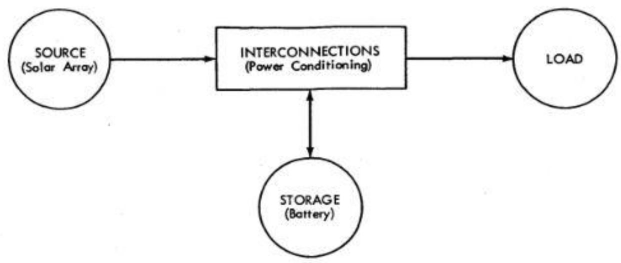

Figure 2. Interconnection for Source/Loads

As to power demand, each sub-system (payloads) (e.g., on-board computer, collector, transmitter, camera, magnetorquer, and magnetometer) expends control, and is displayed with intermittent control utilization assignments with various renditions, e.g., an undertaking that occasionally takes and transmits pictures with various goals; a higher goals devours more power [5].

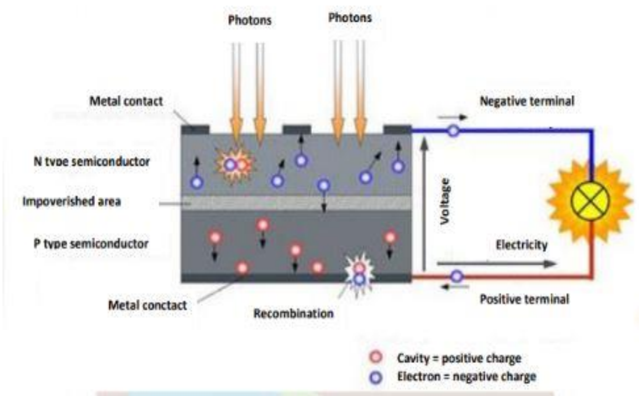

Figure 3. Photovoltaic Cell

Formula for solar efficiency of solar panels:

$$\eta = \frac{P}{E * A} \qquad (1)$$

Where,

P = maximum power radiated (in watts)

E = solar flux(in watt/m^2)

A= capture area (m^2)

The storage battery is a sealed nonmagnetic silver-cadmium battery rated at 11 ampere hours. It is composed of 13 cells connected in series providing a battery discharge voltage, when fully charged, of 15 volts. The maximum safe charging voltage is 19.6 volts [6]. Continuous charging at 19.6 volts, after the battery is fully charged, is detrimental to the cells; therefore, the regulator is designed to 'reduce the charge to 18.3 volts upon full charge of the battery (full charge is indicated when the charge current falls below 100 milli amperes at the 19.6-volt level).

B. Design Steps

1) The maximum power radiated comes from photovoltaic cell (solar cells).

2) A single photovoltaic cell produce does not produce much power so a satellite's solar panels are made up of hundreds of photovoltaic cells connected together.

3) Solar powered security cameras, also commonly referred to as solar panel security cameras harness the sun's energy to power the compatible security camera.

4) Solar powered security cameras use solar panels to harness the sunlight and convert that sunlight into direct current (DC) electricity. An inverter then transitions the direct current to an alternating current (AC), which can then be used to power the security cameras [7].

5) Most solar powered cameras also come with an alternative or backup power source, often-rechargeable batteries. The solar panel not only powers the security camera but also recharges the batteries [8]. When direct sunlight is not available (i.e. at night or on a rainy day), the solar powered security camera will be powered by the rechargeable batteries. The battery will start charging as soon as there is direct sunlight.

6) The main components of a satellite consist of the communications system, which includes the antennas and transponders that receive and retransmit signals, the power system, which includes the solar panels that provide power, and the propulsion system, which includes the rockets that propel the satellite.

IV. RESULTS AND DISCUSSION

- Characteristic is the efficiency degradation of solar panels, due to ultraviolet degradation, fatigue (thermal cycling) and micrometeoroid loss, the efficiency of solar panels decreases over time.

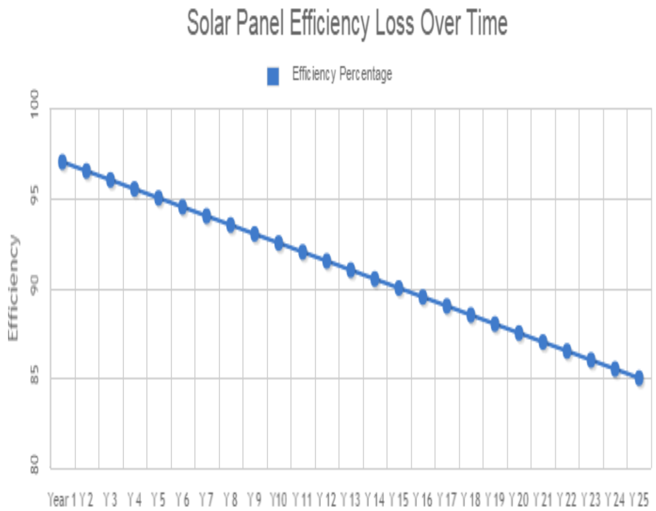

Figure 4. Efficiency Vs. Time

- A rise in temperature decreases the amount of power generated by solar Panels.

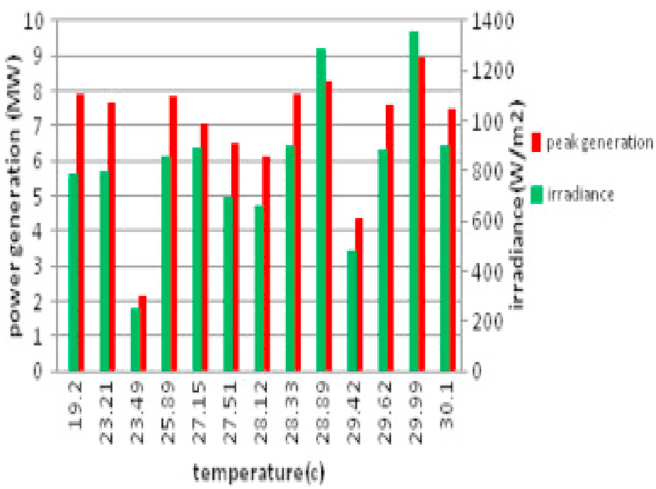

Figure 5. Power Vs Temperature

- Solar energy is converted to electrical energy by means of a total of 7680 2cm by 2cm solar cells divided equally among the 4 paddles, or 960 cells on each paddle face. So the capture area is 0.0004m^2.
- The average solar radiation in the earth orbit is taken as 1358 ± 5W/m², but the conservative number of 1358 – 5= 1353W/m² continues in wide use.

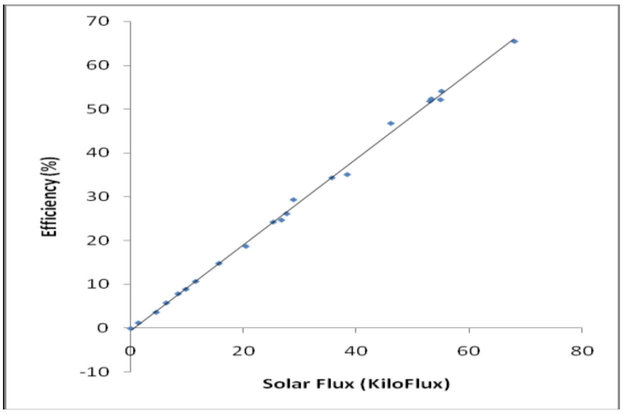

Figure 6. Efficiency Vs. Solar Flux

- The maximum power radiated from solar cell is 460watts for LEO-satellites.

V. CONCLUSION AND FUTURE SCOPE

The solar power system design for low earth orbiting satellite, the efficiency of solar panel has achieved as 22.134%. Generally, the efficiency of solar panel is about 15-25%.

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