Astronautics (SESA2024)

Section 8: Electrical Power – Exercises

1. Explain the principal of operation of the following electrical power sources used on spacecraft:
    - Solar cells
    - Solar dynamic
    - Radioisotope thermoelectric generators (RTGs)

2. Suggest types of primary electrical power sources for missions
    - lasting a few hours
    - lasting several years

3. What is the solar power available per unit area at 1 AU (W/m^2)? How does this value change with distance from the Sun? For what approximate range of solar orbital distances are nuclear electrical power supplies useful?

4. What effect does temperature have on solar cell performance? What happens to solar panel output when a spacecraft exits from eclipse?

5. What environmental effect has the greatest impact on the long-term performance of solar cells?

6. How can the voltage from solar cells be increased from a fraction of a volt to tens or hundreds of volts? How can the current from solar cells be increased from milliamps to tens of amps?

7. Describe the terms maximum power point (MPP), and MPP tracking.

8. Explain the following terms related to battery performance:
    - total capacity
    - energy density
    - depth of discharge

9. Describe qualitatively, with the aid of sketches, the operation of NiCd and NiH_2 battery cells, and show how they are packaged into useable units for electrical power storage on spacecraft.

10. A communications spacecraft in geostationary Earth orbit (GEO) requires a continuous 8000 W of electrical power for payload and subsystem operation. While in sunlight this power is supplied by solar arrays, and while in eclipse by batteries. During the sunlit periods, an increment of power is required from the arrays in addition to the 8000 W, to charge the batteries.

    Assuming a worst-case eclipse duration on each orbit, calculate the eclipse period and the number of charge-discharge cycles for a satellite lifetime of 10 years.

Use the notes and the data below to calculate the battery capacity and mass, for a NiCd system.

Calculate the EOL (end of life) power required of the array to supply the payload, subsystems and battery charge, and use the notes and the data below to estimate the area of the solar array.

Data:
Radius of Earth, R_E = 6378 km.
Radius of GEO, $R_{GEO} = 6.611\ R_E$.

Depth of discharge: 40% (NiCd)
Battery energy density: 30 W-h/kg (NiCd)
Battery discharge voltage, V_B = 27.5 V dc

Array voltage, V_A = 33 V dc
Solar intensity, S = 1350 W/m^2
Max deviation of array normal from Sun direction, $\delta\theta = 7^{o}$
Solar cell efficiency, η = 0.105
Cell packing efficiency, η_p = 0.9
Degradation factor over mission lifetime, D_0 = 0.2