.6 Power and Thermal Calculation *(Kaushik Naik)*

.6.1 Solar Panel Power and Array size Calculation [14]

Solar Panel Requirements. Parameters to be considered:

- Orbital Period $t_{orbitalperiod}$ = 1.68 hours (100.63 minutes)
- Sunlight Period $t_{sunlight}$ = 1.11 hours (66.43 minutes)
- Eclipse period $t_{eclipse}$ = 0.57 hours (34.2 minutes)
- Solar Panel Packing Factor (P.F) = 0.9
- Solar Panel efficiency, $\eta_{solarpanel}$ = 30% = 0.3
- With annual degradation factor: 2% per year = 0.02
- Operational Period (n): 3 years
- Power consumed during the sunlight period, $P_{sunlight}$ = 840W
- Energy consumed during the sunlight period in Watt-hours:

$$E_{sunlight} = P_{sunlight} \times t_{sunlight} = 840 \times 1.11 = 932.4Wh$$

- Power consumed during the eclipse period, $P_{eclipse}$ = 111W
- Energy consumed during the eclipse period in Watt-hours:

$$E_{eclipse} = P_{eclipse} \times t_{eclipse} = 111 \times 0.57 = 63.27Wh$$

- Power consumed during one orbital period:

$$P_{orbit} = P_{sunlight} + P_{eclipse} = 840 + 111 = 951W$$

- Total Energy consumption over one Orbital Period in Wh,

$$E_{orbit} = E_{sunlight} + E_{eclipse} = 932.4 + 63.27 = 995.67W$$

- Average Power consumption over one Orbital Period in Wh:

$$P_{average} = \frac{E_{orbit}}{T_{orbit}} = \frac{995.67}{1.68} = 593.66W$$

- Total degradation for three years

$$T.D = (1 - \text{Degradation factor})^n = (1 - 0.02)^3 = 0.941$$

- Power required with degradation,

$$P_{required} = \frac{P_{average}}{T.D} = \frac{593.66}{0.941} = 630.8 \text{ W}$$

- Effective power considering packing factor,

$$P_{effective} = \frac{P_{required}}{P.F} = \frac{630.8}{0.9} = 700.89 \text{ W}$$

- Solar panel area, A_{solar}

$$A_{solar} = \frac{P_{required}}{\eta \times P_{sun}} = \frac{700.89}{0.3 \times 1370} = 1.71 \text{ m}^2$$

.6.2 Battery Requirements [14]

- Battery Voltage, $V_{battery} = 28.8V$
- Depth of Discharge (DoD): 80% = 0.8
- Total Energy consumption over one Orbital Period in Wh,

$$E_{orbit} = 995.67W$$

- Average power consumption over one Orbital Period in Wh,

$$P_{average} = 593.66W$$

- Total Energy consumption during the eclipse period,

$$E_{eclipse} = P_{average} \times t_{eclipse} = 593.66 \times 0.57 \times 3600 = 1218190.32 \text{ J}$$

$$E_{eclipse_{Wh}} = \frac{E_{eclipse}}{3600J/Wh} = \frac{1218190.32}{3600} = 338.39Wh$$

- Adjusting for Depth of Discharge (DoD):

$$E_{usable} = \frac{E_{eclipse_{Wh}}}{DoD} = \frac{338.39}{0.8} = 422.99Wh$$

- Battery Capacity required,

$$\text{Battery Capacity (Ah)} = \frac{E_{usable}}{\text{Battery Voltage}} = \frac{422.99}{28.8} = 422.99Wh$$

- Number of seconds for an operational period of 3 years: 94610000 seconds
- Orbital period in seconds $t_{orbital_{seconds}} = 6037.8seconds$
- Number of battery cycles for three years of operational period:

$$\text{Number of battery cycles for 3 years} = \frac{t_{3years}}{t_{orbital_{seconds}}} = \frac{94010000}{6038} = 15670cycles$$

.6.3 Temperature Calculation for Hot and Cold Cases [14]

Parameters to be considered:

- Flux of the sunlight, $\phi_{sun} = 1370W/m^2$
- Absorptivity, $\alpha = 0.8$
- Emissivity, $\epsilon = 0.9$
- View Factor, $F = 0.85$
- Stefan-Boltzmann Constant, $\sigma = 5.670374419 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$
- Average Energy flux from Earth, $q_I = 240W/m^2$
- Area of the satellite exposed to the Sun, $A_{sat \perp Sun} = 1.7 \times 0.58 = 0.986m^2$
- Area of the satellite exposed to the Earth, $A_{sat \perp Earth} = 0.58 \times 0.47 = 0.2726m^2$
- Total Area of the satellite,

$$A_{total} = 2((1.7 \times 0.58) + (1.7 \times 0.47) + (0.58 \times 0.47) = 4.1152m^2$$

For Hot Case Temperature:

- Sun Radiation,

$$Q_{Sun} = \alpha \times \phi_{sun} \times A_{sat\perp Sun} = 0.8 \times 1370 \times 0.986 = 1080.656W$$

- Albedo Radiation,

$$Q_{Albedo} = \alpha \times \phi_{sun} \times A_{sat\perp Sun} \times F = 0.8 \times 1370 \times 0.986 \times 0.85 = 918.5576W$$

- Earth's Radiation,

$$Q_{Earth} = \alpha \times q_I \times A_{sat\perp Sun} = 0.8 \times 240 \times 0.986 = 189.312W$$

- Internal Heat generated (assuming 50% of the total power),

$$Q_{internalH} = 0.5 \times P_{internal} = 0.5 \times 840 = 420W$$

- Total Heat to be considered,

$$Q_{TotalinputH} = Q_{Sun} + Q_{internalH} + Q_{Albedo} + Q_{Earth}$$

$$= 1080.656 + 420 + 918.5576 + 189.312 = 2608.5256W$$

- Satellite Surface Temperature, $T_{satellite_H}$

$$Q_{TotalinputH} = Q_{Emitted} = \epsilon \times \sigma \times A_{total} \times T^4_{satellite_H}$$

$$T_{satellite} = \left(\frac{Q_{totalinput}}{\epsilon \cdot \sigma \cdot A_{total}}\right)^{\frac{1}{4}}$$

$$T_{satellite} = \left(\frac{2608.5265}{0.9 \times 5.67 \times 10^{-8} \times 4.1152}\right)^{\frac{1}{4}} = 333.8044\,K = 60.7°C$$

For Cold Case Temperature:

- Sun Radiation, $Q_{Sun} = 0W$
- Albedo Radiation, $Q_{Albedo} = 0W$
- Internal Heat generated (assuming 50% of the total power),

$$Q_{internalH} = 0.5 \times P_{internal} = 0.5 \times 111 = 55.5W$$

- Infrared Radiation from Earth,

$$Q_{IR_{Earth}} = \alpha \times q_I \times A_{sat\perp Earth} = 0.8 \times 240 \times 0.2726 = 52.34W$$

- Total Heat considered,

$$Q_{Totalinput_C} = Q_{internal_H} + Q_{IR_{Earth}} = 55.5 + 52.34 = 107.84W$$

- Satellite surface Temperature, $T_{satellite_C}$

$$Q_{Totalinput_C} = Q_{Emitted} = \epsilon \times \sigma \times A_{total} \times T^4_{satellite_C}$$

$$T_{satellite_C} = \left(\frac{107.84}{0.9 \times 5.67 \times 10^{-8} \times 4.1152}\right)^{\frac{1}{4}} = 150.54\,K = -122.6°C$$