

Maximum Power Point Tracking for Solar Arrays on Small Spacecraft

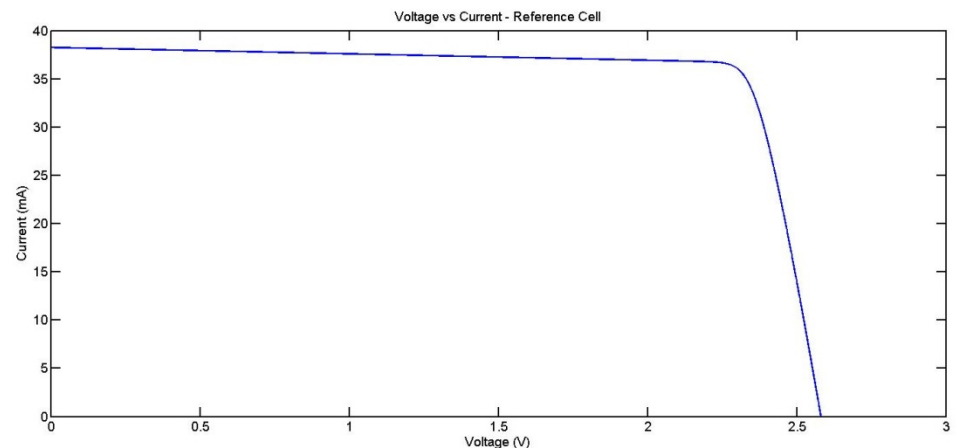
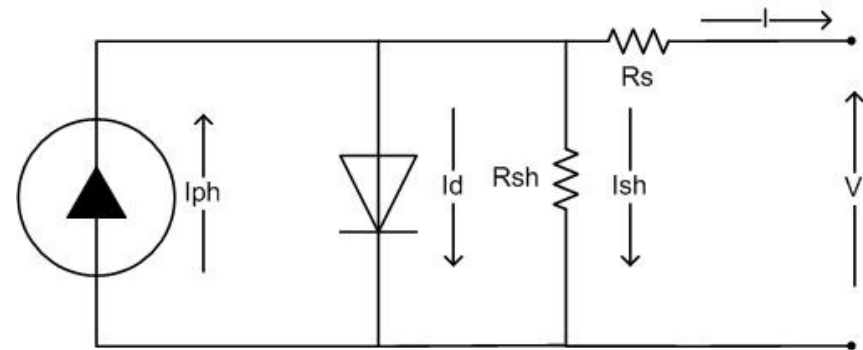
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Overview

- Solar Cell Background
- LEO Environment and its Effects on Solar Cells
- Solar Array Interfaces
- Model Implementation
- Results Summary
- Conclusions

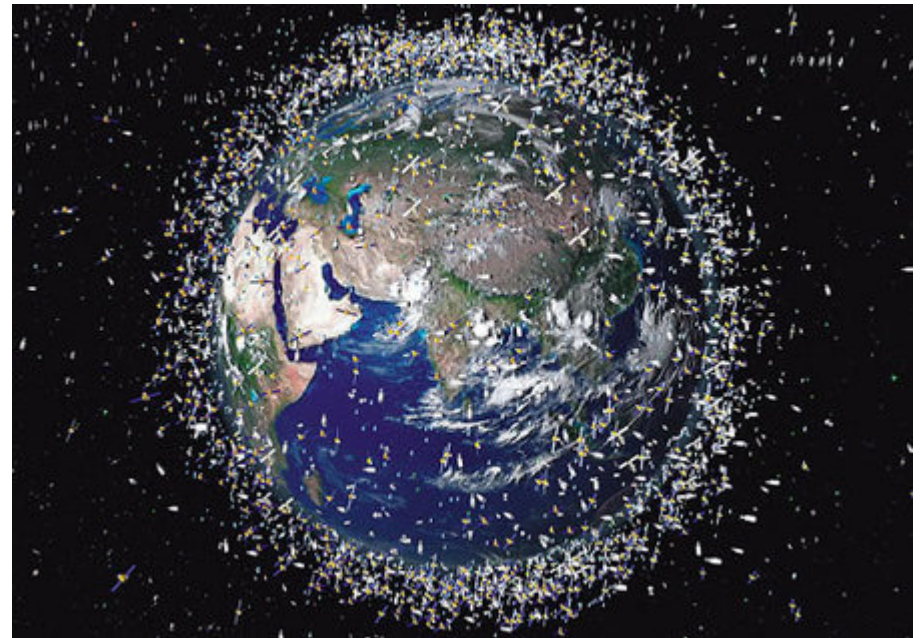
Solar Cell Background

- Semiconductor device that converts light energy into electrical energy
- Equivalent Circuit Model
- Non-Linear IV-Curve
- Optimal Power Extraction at One Unique Point

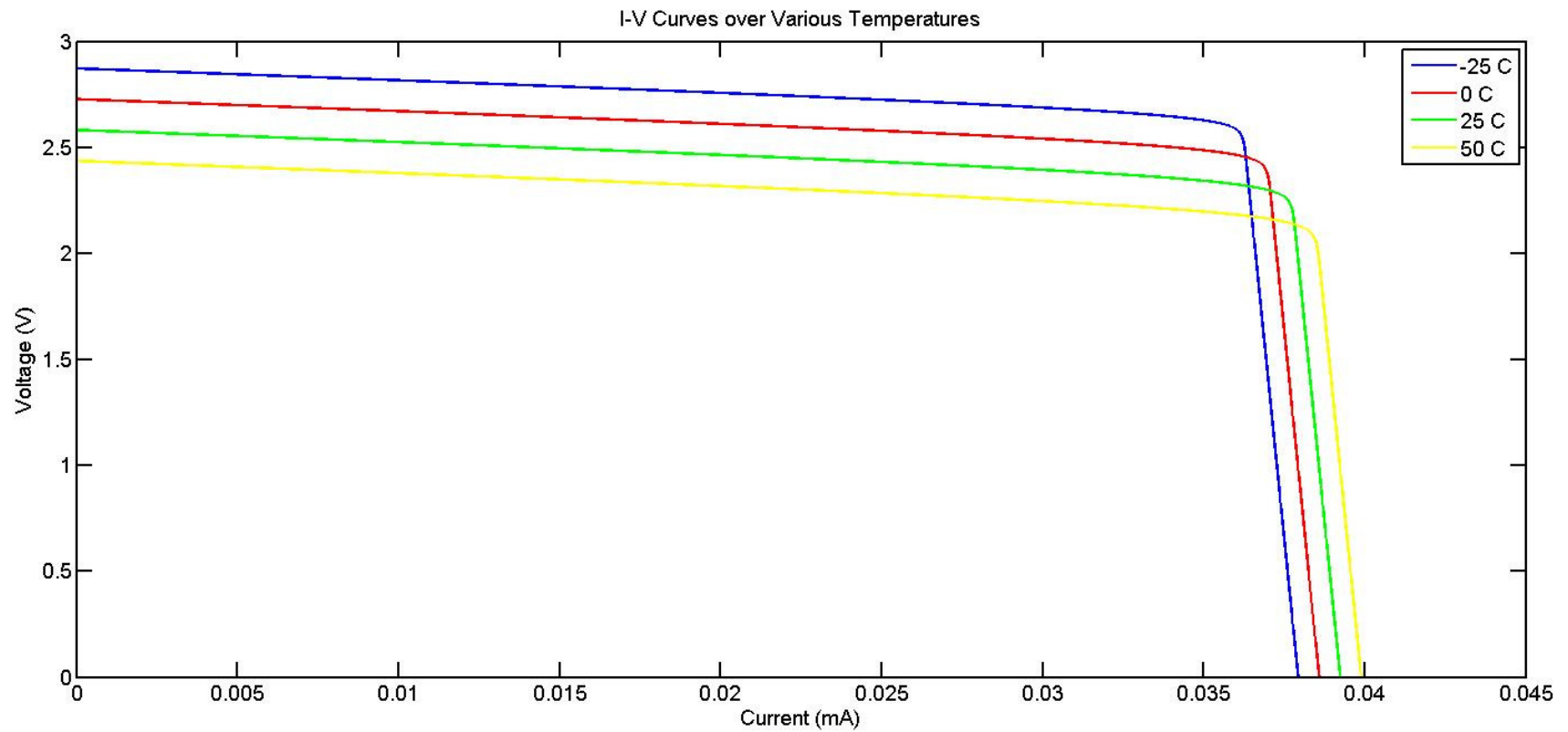


LEO Environment

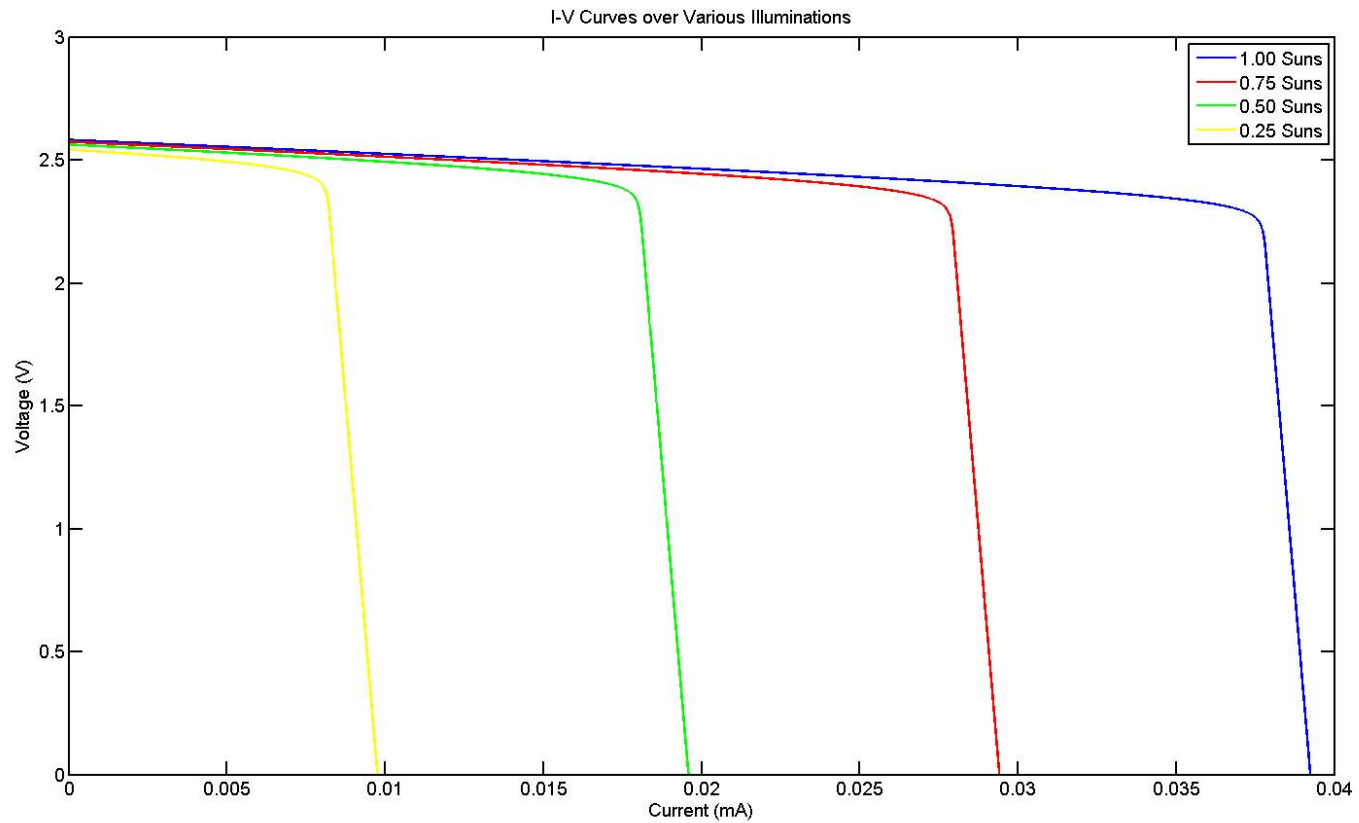
- Temperature
 - -30 to +50 C
 - Cycle Every Orbit
- Incidence Angle
 - Will vary greatly unless sun-pointing
 - Can cycle multiple times per orbit if satellite is uncontrolled
- Radiation
 - Higher Radiation Environment
 - Permanent, constant degradation of performance



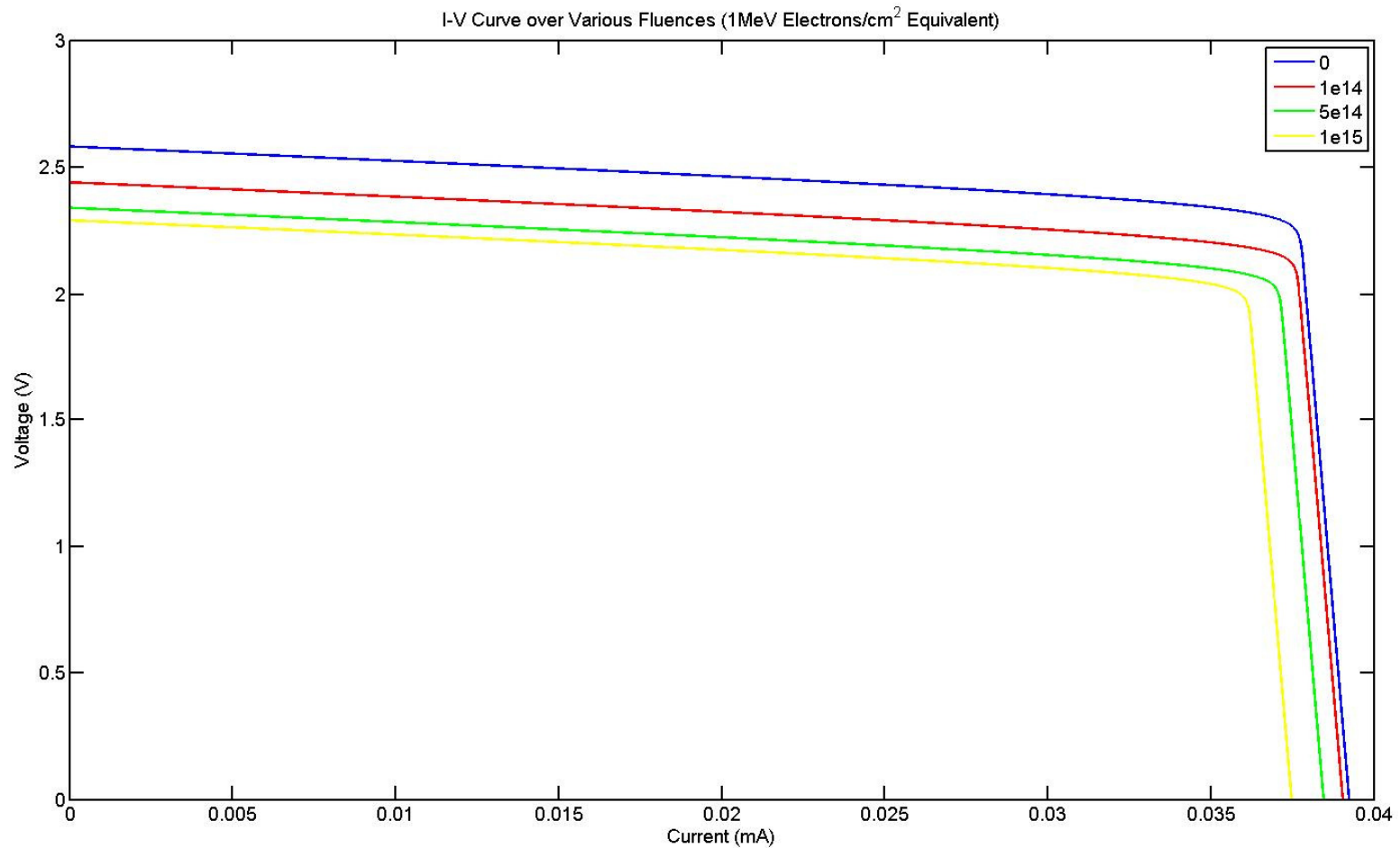
Effect on Solar Cells Temperature



Effect on Solar Cells Incidence Angle



Effect on Solar Cells Radiation



Solar Array Interfaces

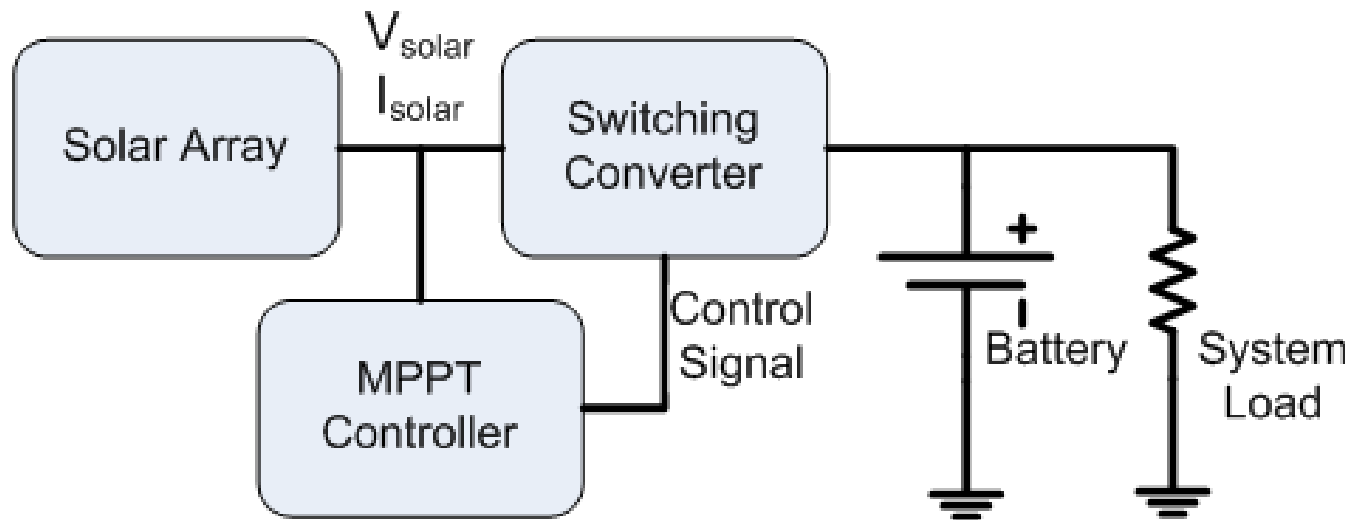
What They Do

- Interfaces the solar arrays to the rest of the system
- Controls the behavior of the solar cell, i.e. where on the applicable IV-Curve the solar cell is operating
- Active interfaces can act as an ideal load so the solar cell operates at its maximum power (MPPT)

Examples

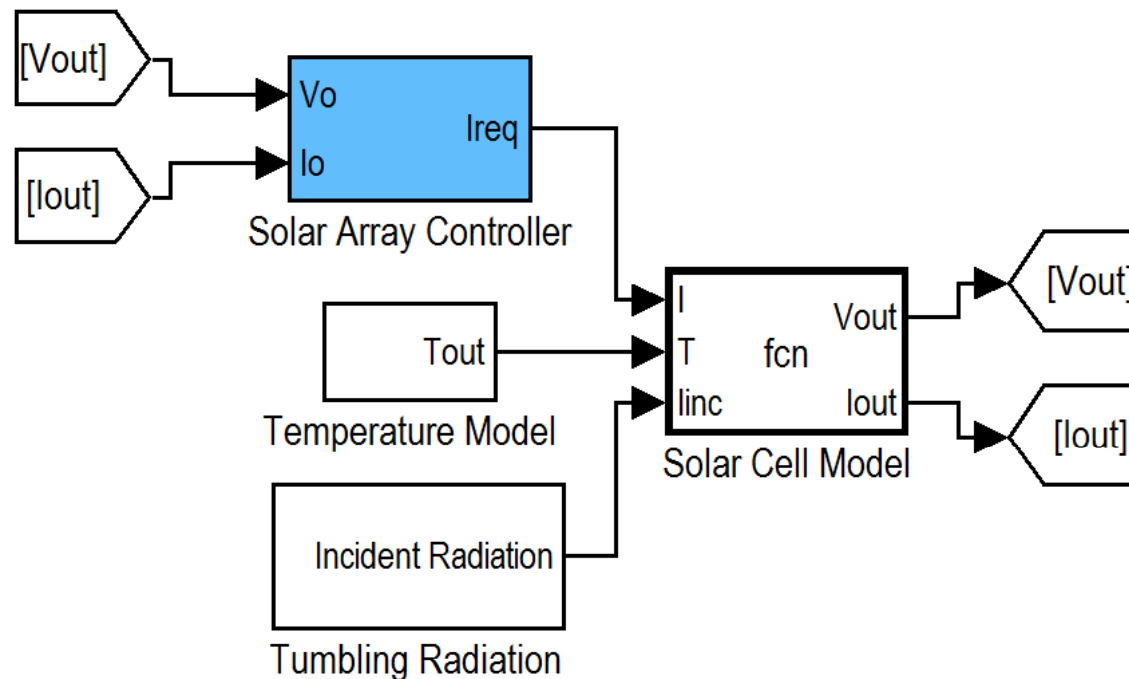
- MPPT (Active)
 - Perturb and Observe
 - dP/dV
 - Fractional Voltage
- Non-MPPT (Active)
 - Fixed Point
 - Temperature Compensated Fixed Point
- Non-Active
 - Direct Energy Transfer

Active Interfaces



Both MPPT and Non-MPPT requires the use of a switching regulator to actively adjust the load seen by the Solar Arrays

Model Implementation



- Numerical Implementation of Solar Cell Model
- Simulink Modeling of other Systems and Orbital Parameters
- Battery and System Load Modeling for Direct Energy Transfer (Not Shown)

Results Summary

Solar Interface	No BCR		With Expected BCR Efficiency (85%)	
	Spin 1°/s, No Radiation		Spin 20°/s, No Radiation	Spin 1°/s +Radiation
Fractional	99.1%	84.2%	67.9%	84.1%
P&O	98.6%	83.8%	52.6%	83.9%
dP/dV	98.9%	84.1%	46.7%	84.0%
Fixed	95.7%	81.3%	51.2%	57.2%
TC Fixed	99.2%	84.3%	29.1%	66.4%
DET (No BCR)	86.5%		86.5%	91.0%

Conclusions

- Active Interfaces Decouple Solar Array Design from the Rest of the System
- Battery Charge Regulator losses equalizes performance gained from Active Interfaces
- Non-MPPT Active Interfaces can bring detrimental results given certain environmental effects
- For short, high-risk acceptable missions, Direct Energy Transfer should be used for the Solar Array Interface due to lower complexity, lower volume, and approximately equal performance levels

Questions?

Thanks!

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