An Investigation of Maximum Power Point Tracking for Space Applications

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Abstract

- Maximum power-point tracking (MPPT) is a fundamental aspect of photovoltaic (PV) arrays
- When graphing the output of a PV array, the MPP is the “knee” of the curve

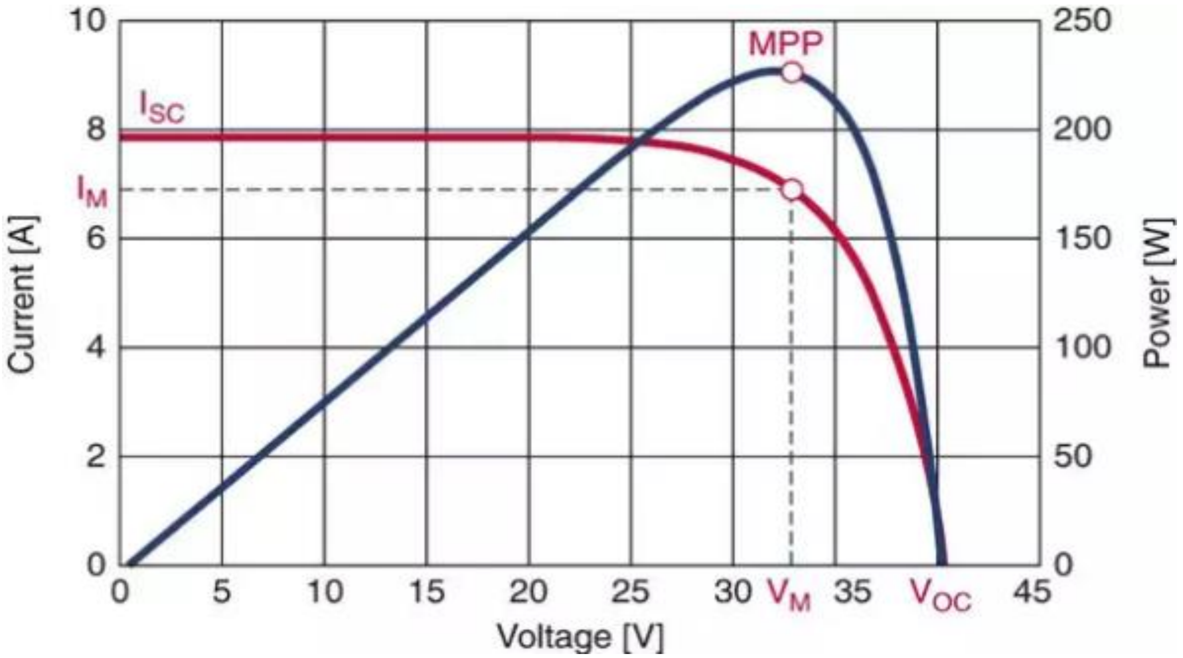

Figure 1: Graph of Current/Power versus Voltage

Project Objectives

- The space environment presents unique conditions not seen on earth
- The objective is to choose an MPPT approach most suitable for this environment

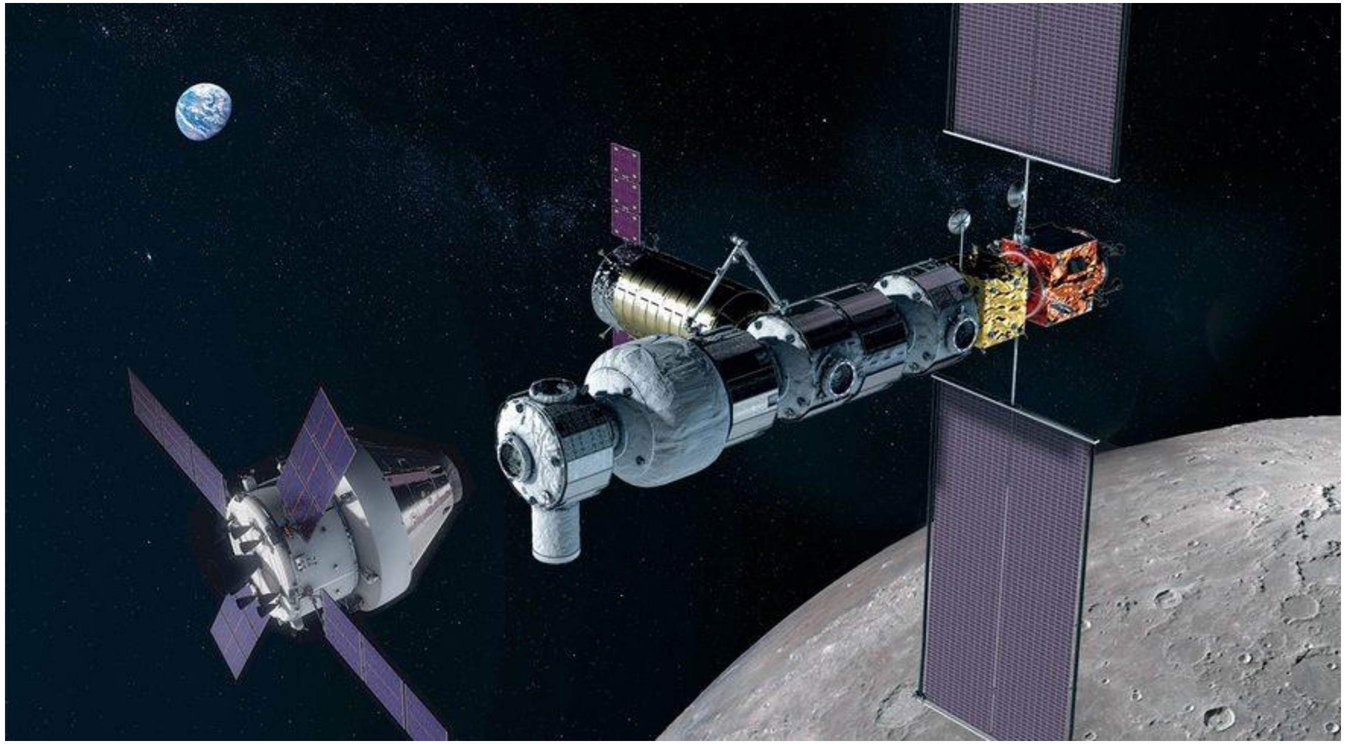

Figure 2: Lunar Gateway

Methodology Used

- PV arrays are usually connected to a DC-DC converter similar to the boost converter shown in Figure 2
- The main investigation compares the attributes of several MPPT methods
- Each MPPT method is evaluated for its suitability for a space-based system

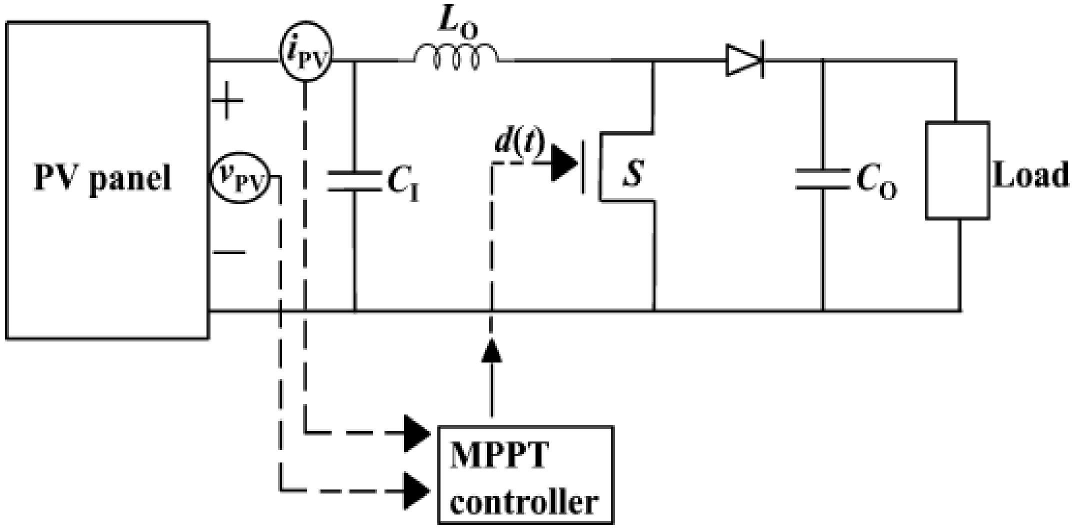

Figure 3: Example of MPPT controller in a photovoltaic boost converter system

Results Obtained: Perturb and Observe

- Perturbation is introduced to the system
- External perturbation is inherently inefficient
- Load voltage oscillates around MPPT
- Susceptible to confusion by variations in atmospheric conditions resulting in undesirable operation

Observation	Effect
$dP/dV > 0$	Perturbation moved the system's operating point closer to the MPP
$dP/dV < 0$	Perturbation moved the system's operating point further from the MPP

Table 1: Perturb and Observe Operation

Results Obtained: Incremental Conductance

- Operates similarly to perturb and observe method
- Instead of dP/dV, instantaneous (I/V) and incremental (dI/dV) conductance are evaluated
- Subject to confusion from high variations in irradiance

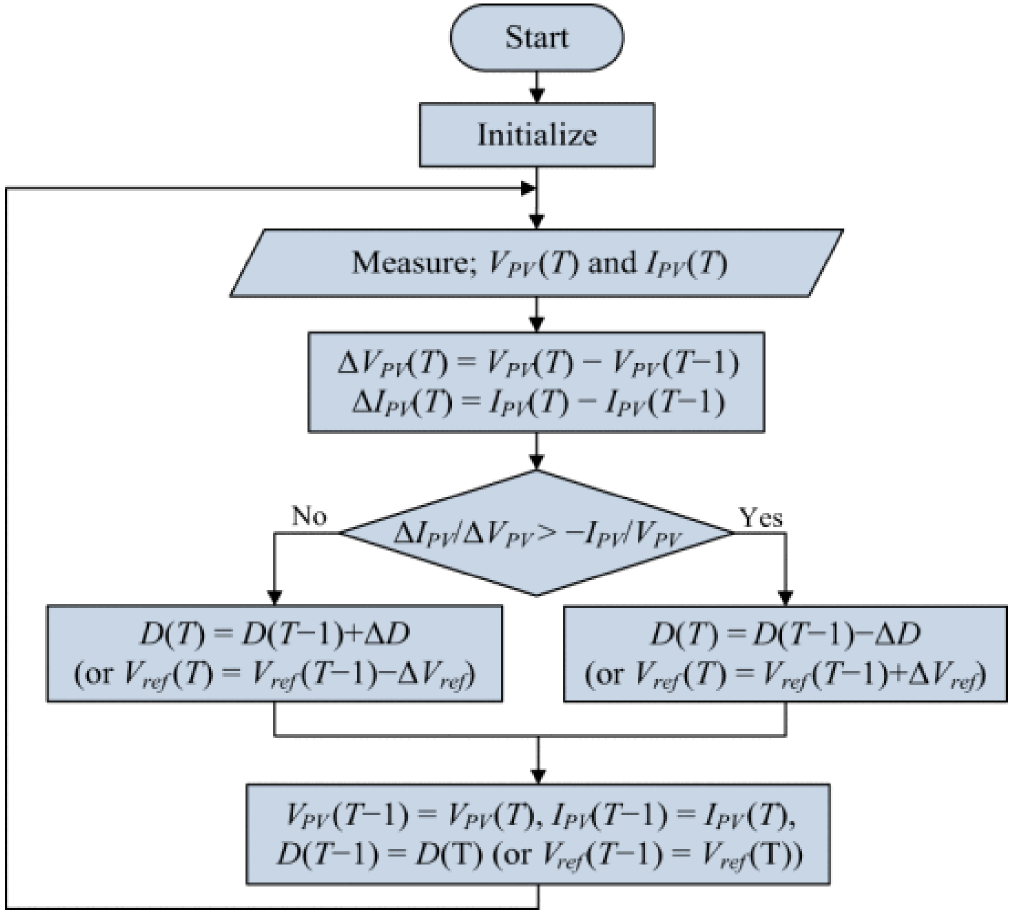

Figure 3: Example of a Flowchart for Incremental Conductance Algorithm

Results Obtained: Perturb and Observe vs. Incremental Conductance

- Both methods are referred to as hill-climbing methods and are considered nearly identical
- Both methods suffer from confusion due to variations in environmental factors
- Confusion produces undesirable effects in the PV array system

Note: Constant voltage method in Figure 4 was not explored in this paper.

	Constant Voltage	P&O	INC
Measured parameters	V_{PV}	V_{PV}, I_{PV}	V_{PV}, I_{PV}
Decision based on change in	one parameter (V_{PV})	one parameter (P_{PV})	two parameters (V_{PV} and I_{PV})
Perturbation parameter	N/A	V_{ref} or D	V_{ref} or D
PV array dependent	yes	no	no
Implementation	analog or digital	analog or digital	digital
Implementation cost	very low	low	slightly higher
Steady-state fluctuations in array voltage	no	yes	yes
Convergence speed	very fast	parameter dependent	parameter dependent
Dependence of tracking efficiency on cell temperature & irradiance level	highly dependent	less dependent	less dependent
Lower tracking efficiency at rapidly changing irradiance	no	yes	yes
Confusion due to noise	no	yes	less confusion than P&O
Confusion due to system dynamics	no	yes	less confusion than P&O
Confusion due to irradiance increase	no	yes	more confusion than P&O
Confusion due to irradiance decrease	no	yes	yes
Tracking efficiency; reference voltage control	91%	95% - 98%	95% - 98%
Tracking efficiency; duty ratio control	N/A	96% - 99%	96% - 99%

Figure 4: Comparison of Perturb and Observe and Incremental Conductance

Results Obtained: Ripple Correlation Control

- Similar to the hill-climbing methods, but uses inherent system perturbation
- Reduces complexity of system as it removes the need for external perturbation circuitry
- Proven performance advantage over hill-climbing methods in tracking effectiveness, transient performance, and dynamic range
- Can be incorporated in both digital and analog fashions

Observation	Effect
dP x dV > 0	Array voltage is less than MPP voltage
dP x dV > 0	Array voltage is greater than MPP voltage
dP x dV = 0	Array voltage is equal to MPP voltage

Table 2: RCC Operation

Results Obtained: Ripple Correlation Control

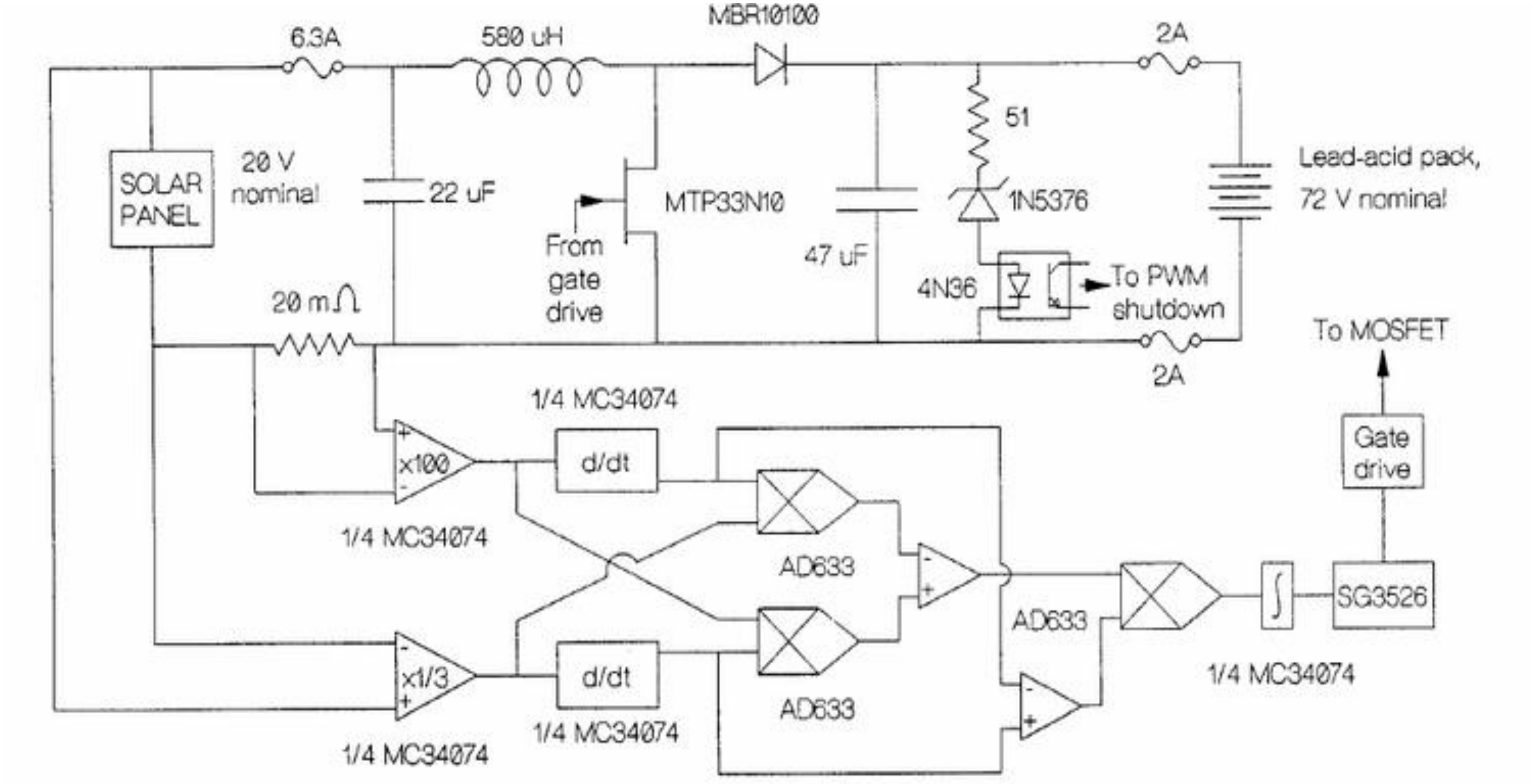

Figure 5: Example of Analog Circuit for RCC

Significance and Interpretation of Results

- Both hill-climbing conditions normally have acceptable performance, but confusion due to varying conditions is concerning
- RCC is seen as superior method for space-based application
- RCC can be implemented in digital and analog fashion
  - Digital implementation (Figure 3) offers flexibility and simplicity if rad-hardened devices are available
  - Analog implementation (Figure 5) offers intrinsic resilience to single even failures in the space environment

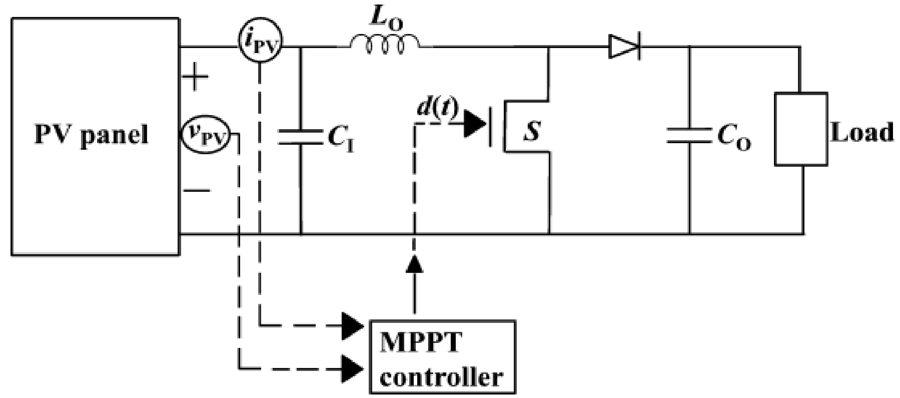

Figure 3: Example of MPPT controller in a photovoltaic boost converter system

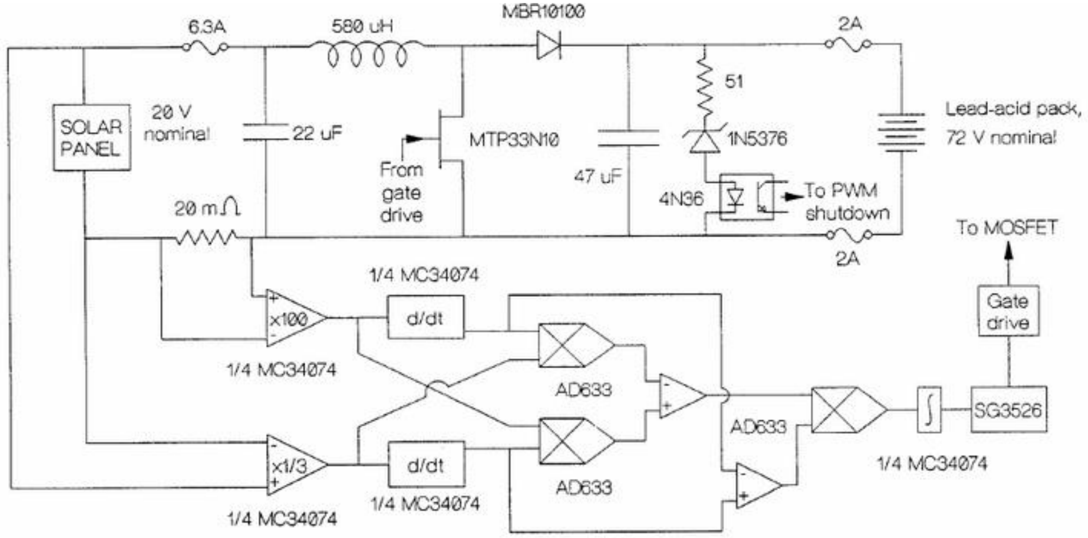

Figure 5: Example of Analog Circuit for RCC

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Questions?