

11-PV Systems

ECEGR 4530

Renewable Energy Systems

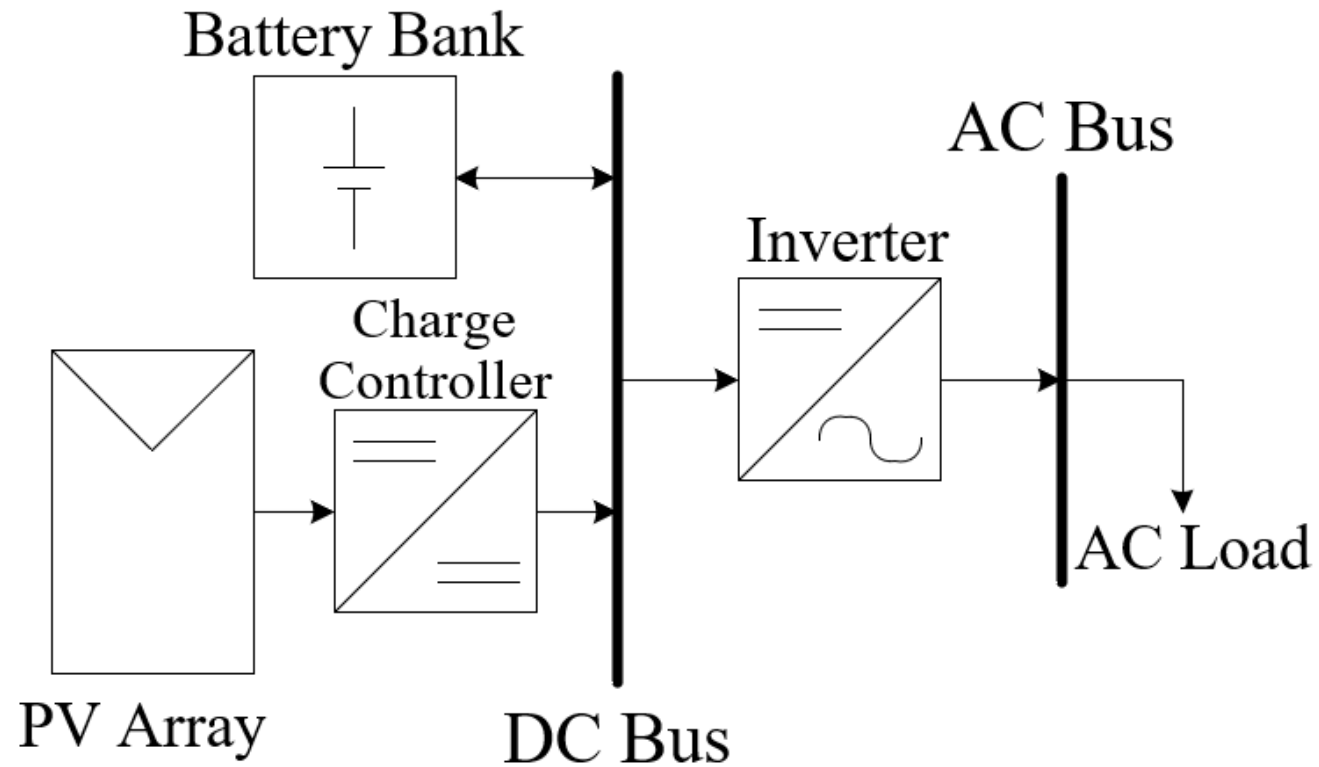
➤ Overview

- PV Applications and Architectures
- Maximum Power Point Tracking

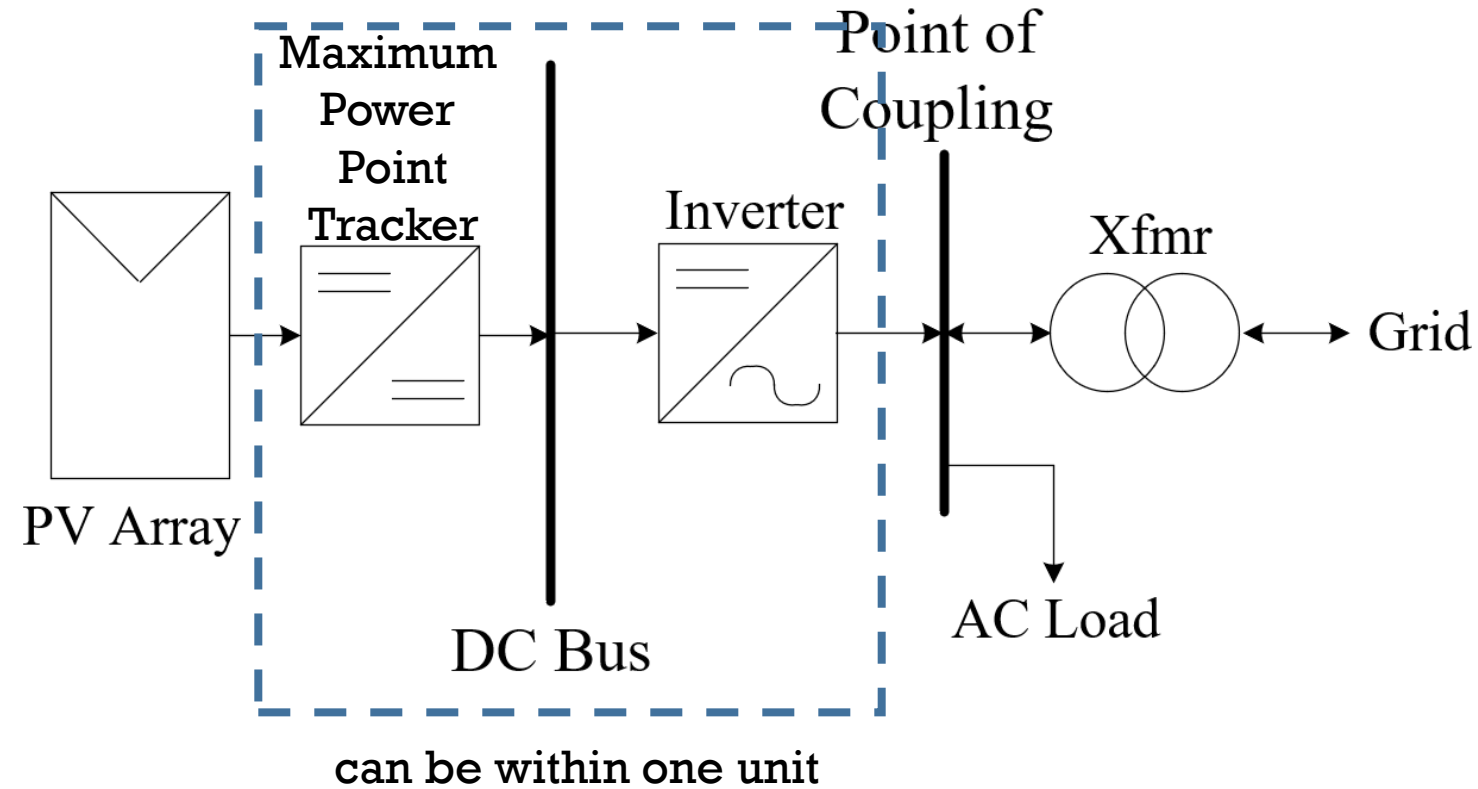
» PV Applications

- Stand-Alone: all energy supplied to load originates from PV
 - remote applications
- Grid-Tied: energy from PV may serve local load or be exported to the electric grid. Import of energy from the grid possible
 - PV power plants
 - urban applications

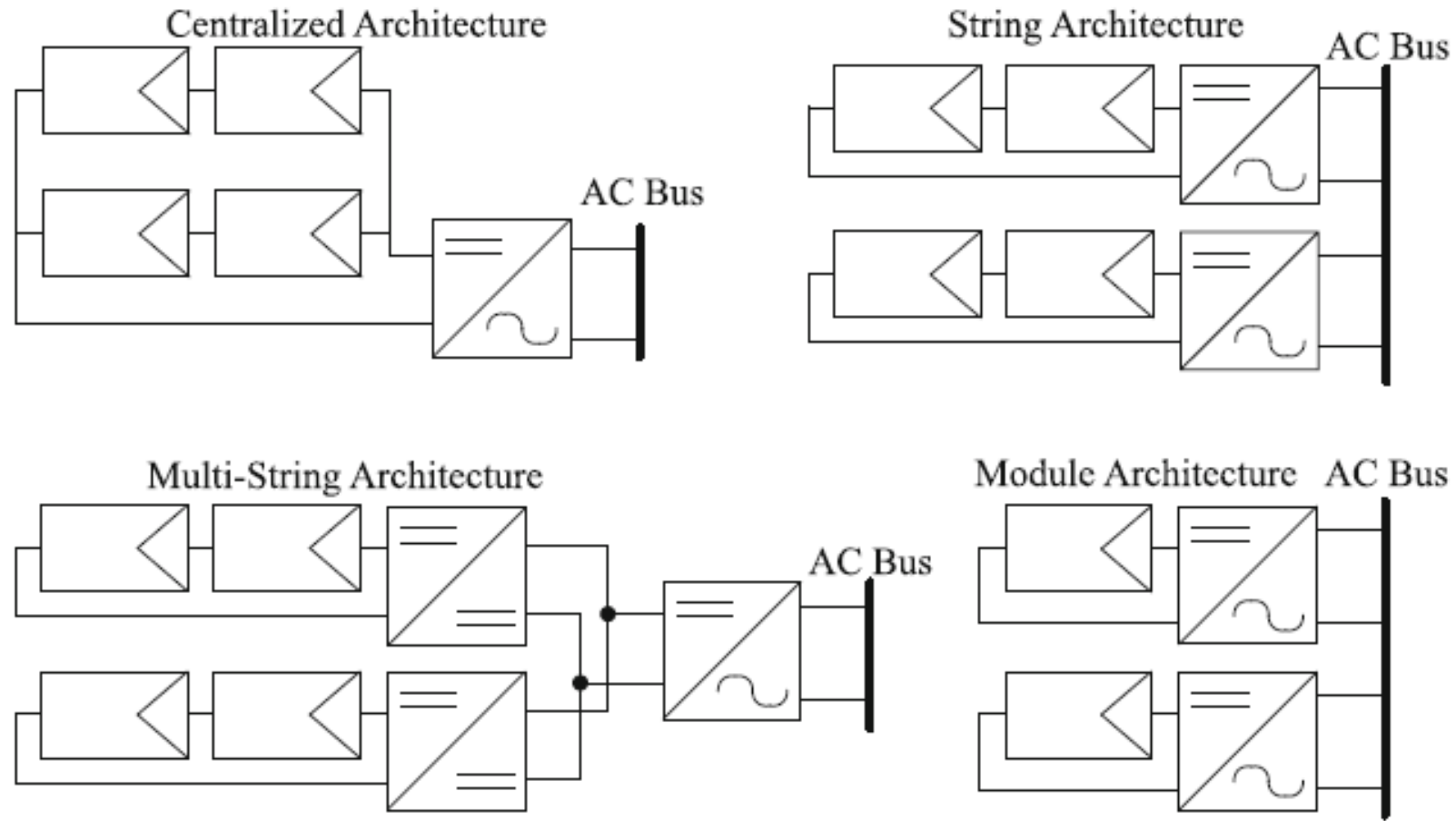
➤ Stand-Alone PV Systems



Grid-Tied PV Systems

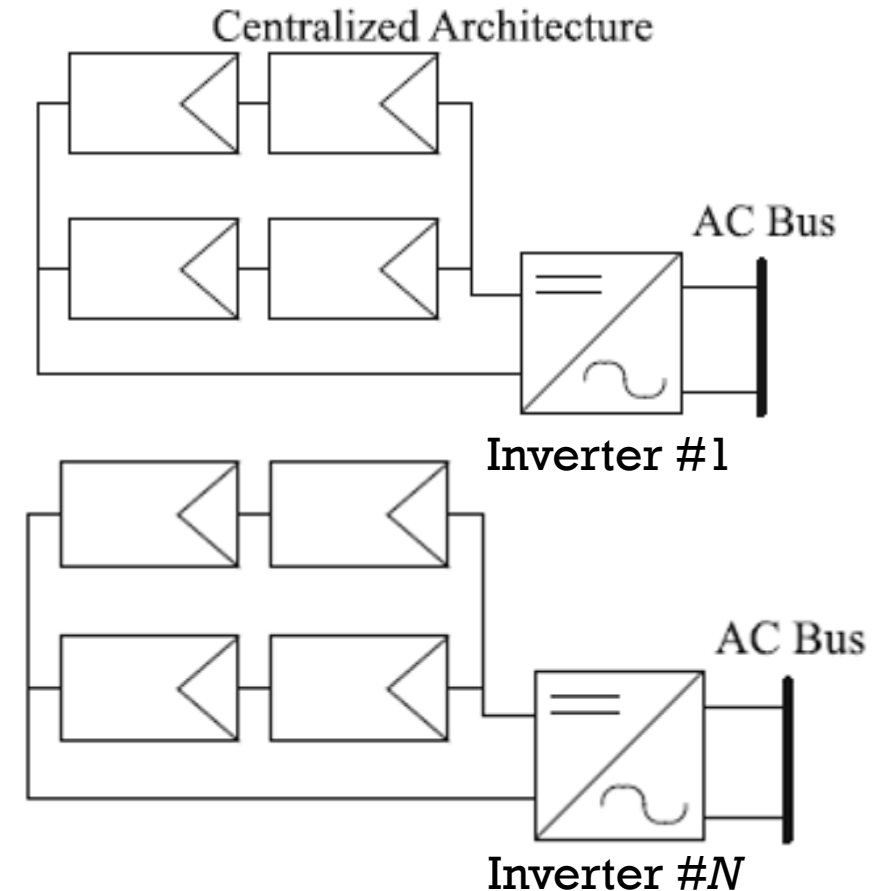


» Architectures



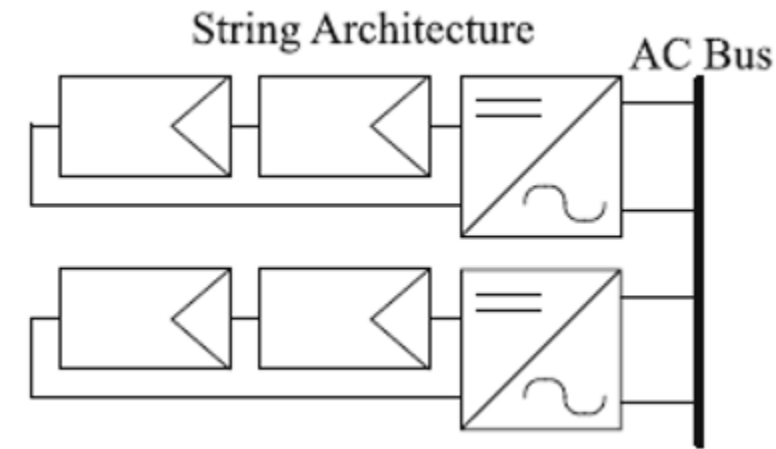
Centralized Architecture

- All strings are combined and connected to a single inverter
 - A large PV plant may have this architecture repeated several times
- Advantages:
 - Conceptually simple
 - Single control system, sensors, etc.
 - Common architecture in large plants
 - Relatively inexpensive
- Disadvantages:
 - Decreased energy production due to inefficient maximum power point tracking
 - Single point of failure
 - Increased blocking diode (between strings) losses



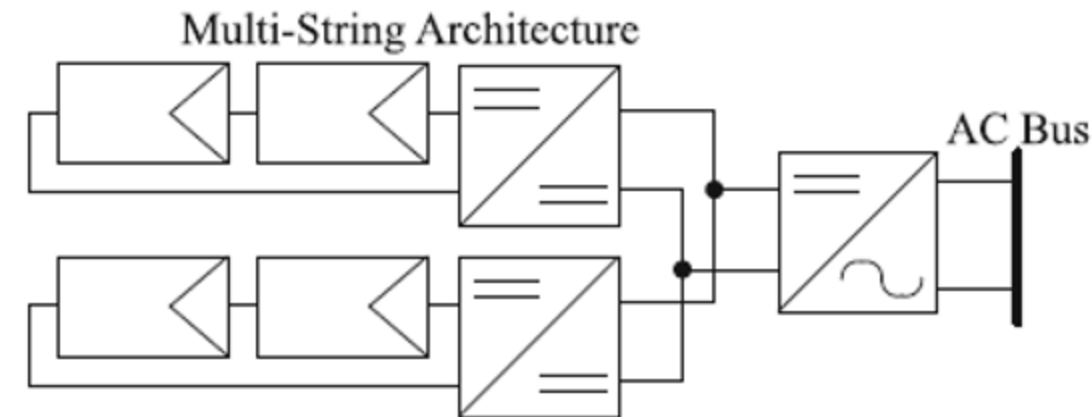
String Architecture

- One inverter per string
- Common in smaller scale or rooftop systems
- Advantages
 - No blocking diode
 - Improved maximum power point tracking
 - Partial shading losses reduced
 - Increased modularity
 - Strings can have different number of panels in series
- Disadvantages
 - More complex and expensive than centralized architecture



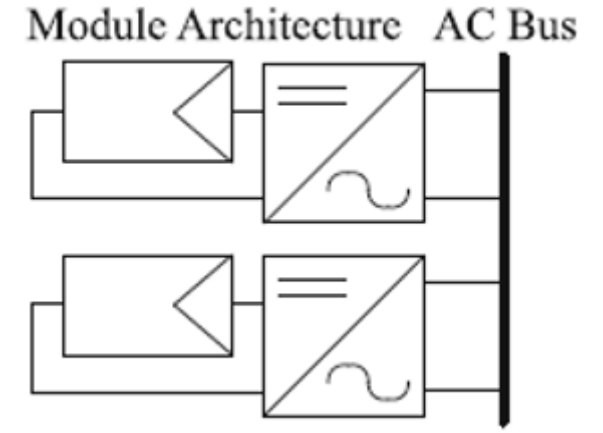
Multi-String Architecture

- Blend of Centralized and String Architectures
- Advantages
 - Improved maximum power point tracking
 - Modularity
 - Single AC-side control
- Disadvantages
 - More complex than centralized system
 - Additional DC losses



Module Architecture

- Each module has its own inverter (“micro-inverter”)
- DC side usually includes boost DC/DC converter because single module voltage is low
- Common on small scale residential solar
- Advantages:
 - High maximum power point tracking efficiency
 - Lowest impact of shading
 - Modular
- Disadvantages:
 - High cost

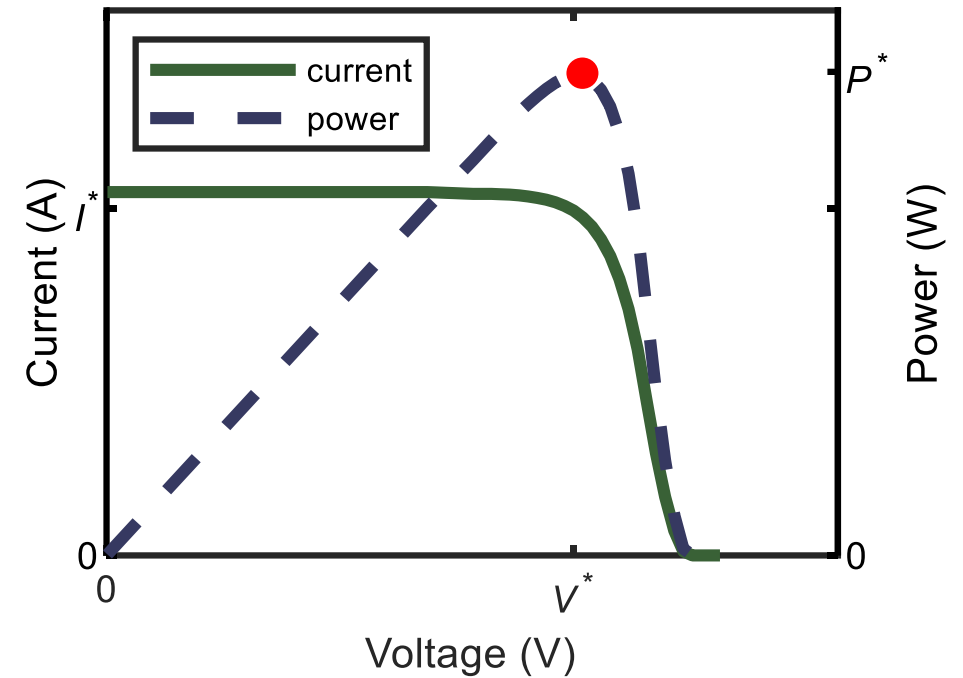


Small enough to fit on the back of a PV module

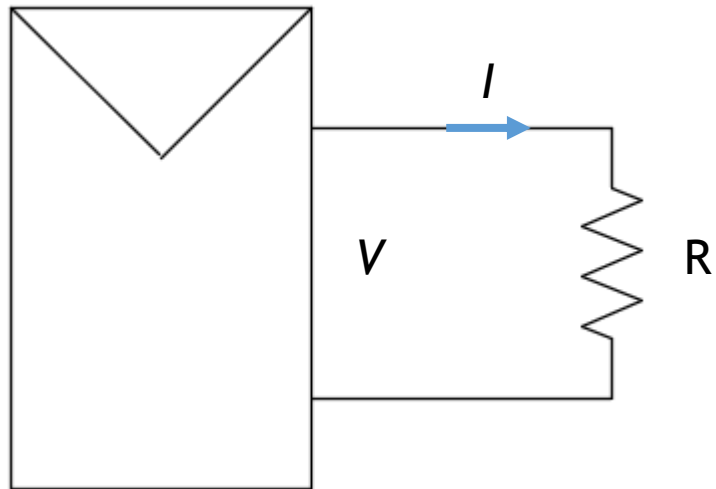
Maximum Power Point Tracking

Maximum Power Point Tracking

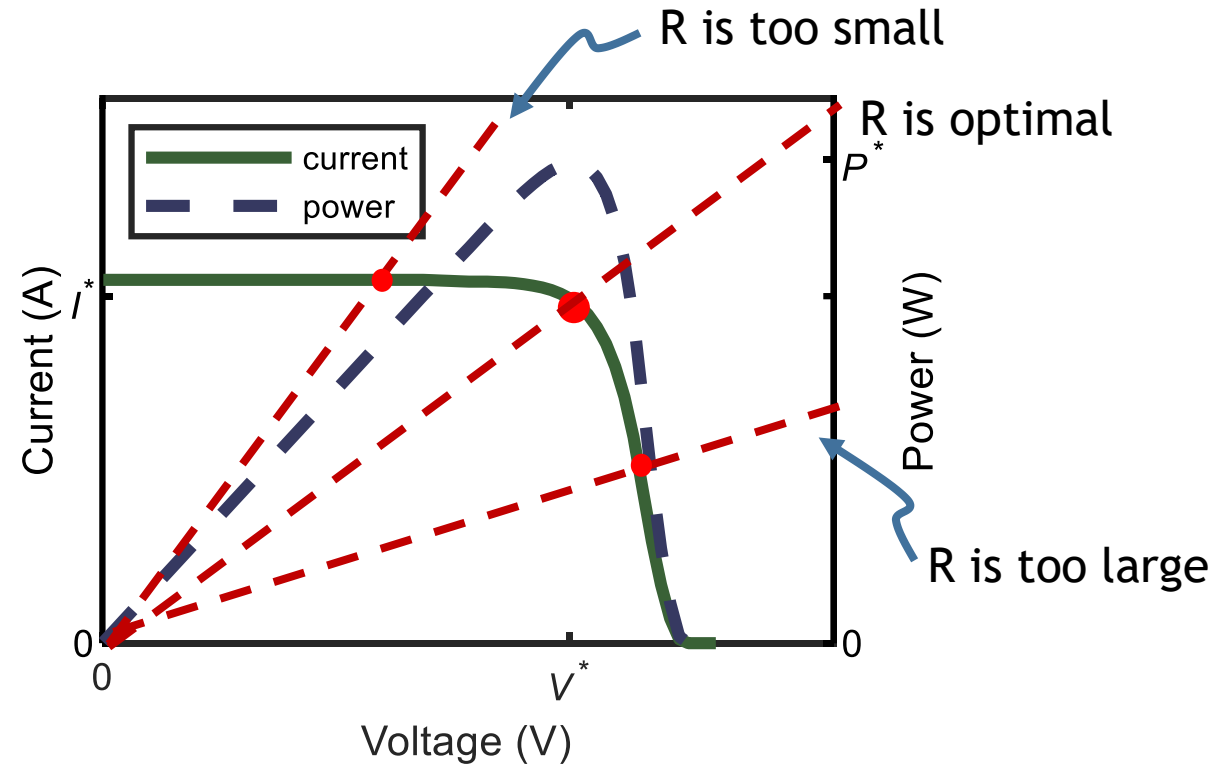
- Recall that a PV module (or array) has a unique operating point that maximizes power production for given irradiance, shading and temperature conditions
- How do we ensure the module operates at the maximum power point?



Load Matching



Operating point for a given resistance is found by the intersection of the IV curve with the line whose slope is $1/R$

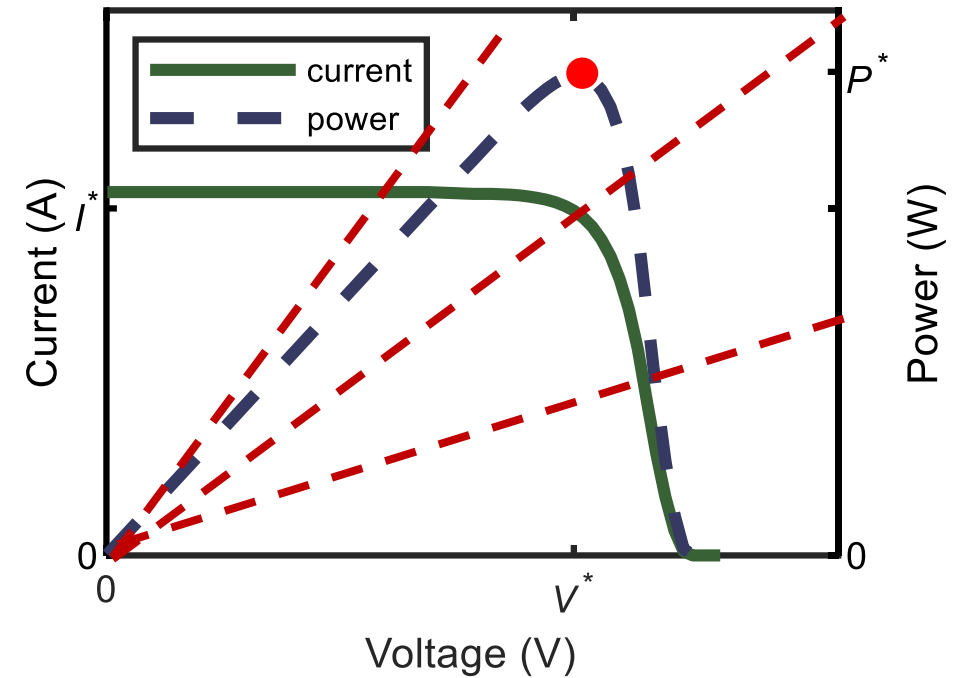


Load Matching

Solving for R^*

$$P^* = V^* I^* = I^{*2} R^*$$

$$R^* = \frac{P^*}{I^{*2}} = \frac{V^*}{I^*}$$



» Exercise

What value of load resistance must be connected to the ITEK 350SE to achieve maximum power production under STC?

ELECTRICAL DATA*	350 SE
Maximum Power - P_{MAX} (Wp)	350
Maximum Power Voltage - V_{MPP} (V)	38.55
Maximum Power Current - I_{MPP} (A)	9.08
Maximum Current - I_{MAX} (A) (O,L)	12
Maximum Voltage (TS4-L only) - V_{MAX} (V)	43.57
Open Circuit Voltage - V_{OC} (V) (D,M,S,O)	47.43
Short Circuit Current - I_{SC} (A) (D,M,S)	9.49
Module Efficiency	17.54%

» Exercise

What value of load resistance must be connected to the ITEK 350SE to achieve maximum power production under STC?

$$R^* = \frac{P^*}{I^{*2}} = \frac{350}{9.08^2} = 4.25 \, \Omega$$

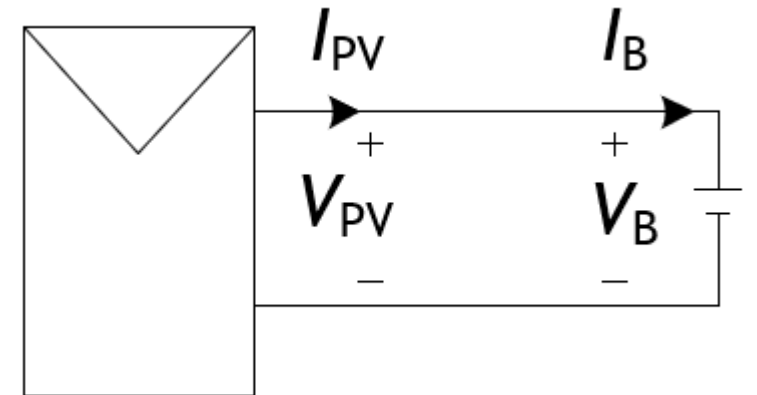
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Direct Battery Connection

- When a PV module is directly connected to a battery, the module voltage is “set” by the battery voltage

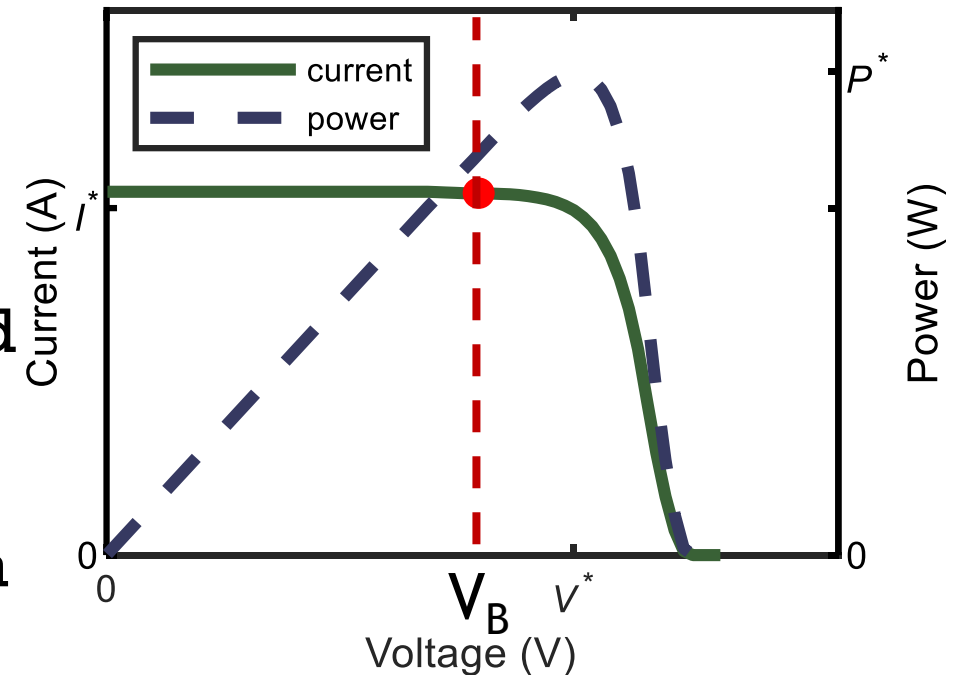
$$V_{PV} = V_B$$

$$I_{PV} = I_B$$



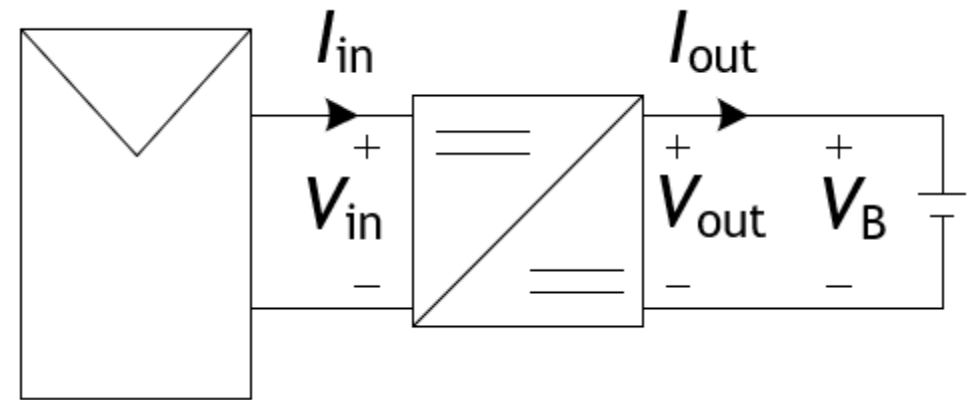
➤ Direct Battery Connection

- Operating point is found by the intersection of the battery voltage the I-V curve of the PV module
 - Note: terminal voltage V_B will change somewhat depending on the current
- The intersection generally does not correspond to the MPP (but is often reasonably close under STC)
- What happens when a battery is connected to a PV module at night (or low irradiance)?



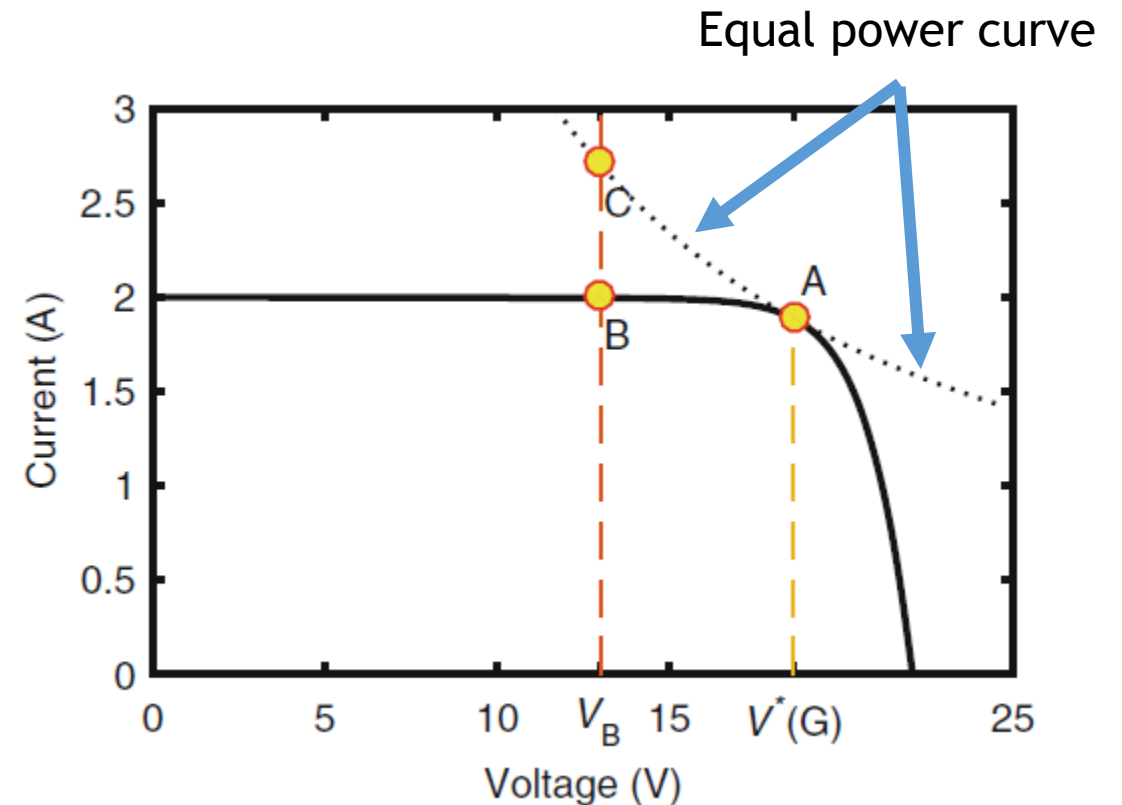
Maximum Power Point Tracking (MPPT)

- Direct connection of PV module to battery does not optimize production
- Better approach: de-couple battery voltage from PV module voltage



MPPT

- Operating points
 - Battery: point C
 - PV array: point A
- Without MPPT both PV array and battery operate at point B



➤ MPPT: Practical Considerations

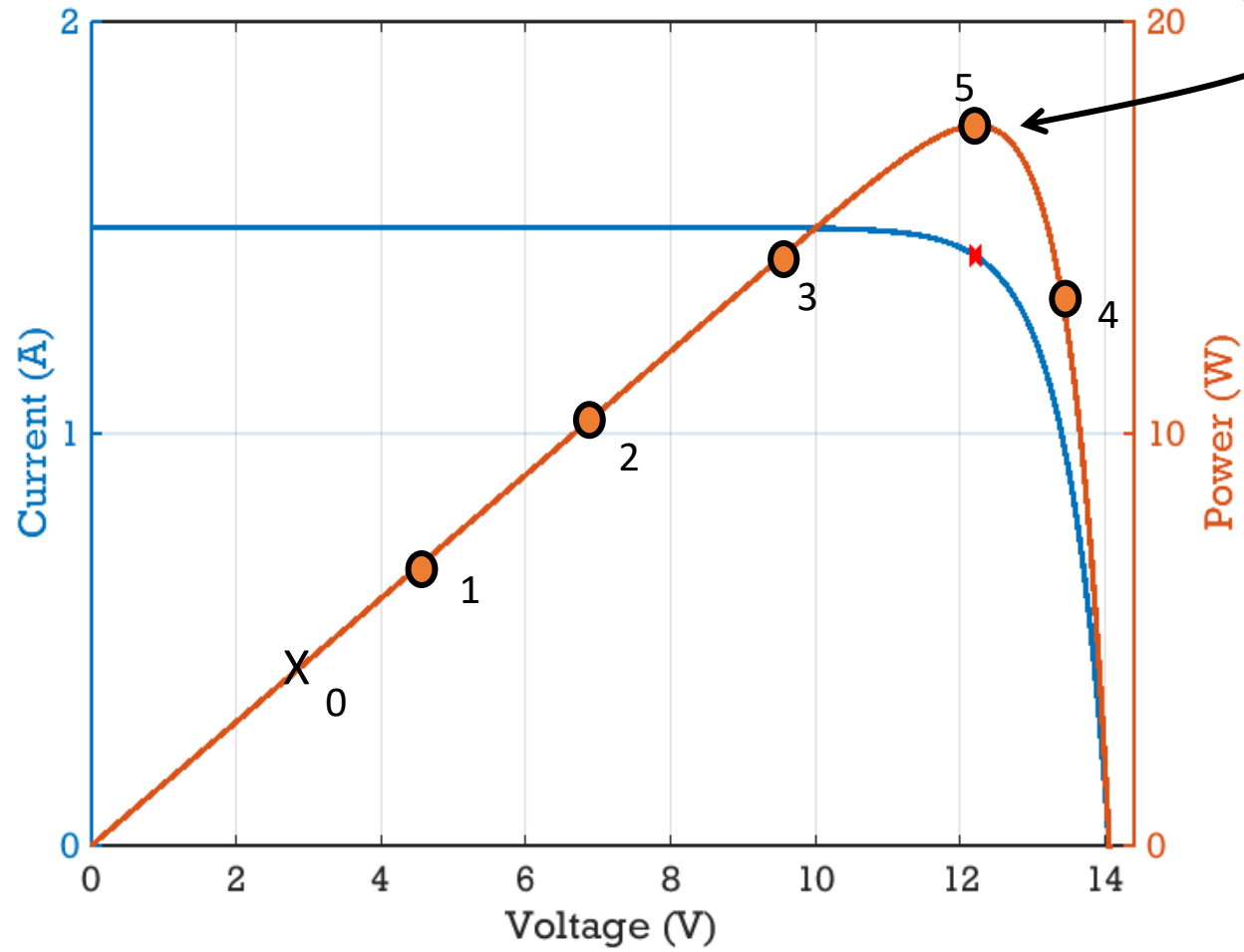
- MPPTs often increase energy production by 10-15%
- Additional cost of MPPT must be considered
- MPPT often (but not always) integrated into charge controller as a single unit
 - Charge controllers without MPPT are sometimes branded as “PWM” charge controllers (but MPPT controllers also use PWM)
- Some MPPT algorithms are better than others
 - Find MPP faster, have higher overall energy yield, less affected by shading

➤➤ Maximum Power Point Trackers

- Maximum power tracker control requires PV voltage and current sensing to control the duty ratio (irradiance and perhaps the load are constantly changing)
- Common methods:
 - Perturb and Observe (P&O)
 - Incremental Conductance (IC)
- Both methods are non-model methods (meaning you do not need to explicitly model the circuit), and both use a “hill climbing” approach

Adjust voltage by some amount until maximum is reached.

Top of the hill
(MPP)



» P&O

- Basic idea: perturb the duty cycle in a direction (e.g. increase it) and see if the power output increases. If power output increases, continue increasing the duty cycle; else decrease the duty cycle and repeat
- Disadvantages:
 - Oscillations around the MPP tend to occur
 - Does not rapidly converge on MPP when irradiance conditions rapidly change (compared to other methods)