Lecture 5:
Maximum power point tracking/control

the sustainability society

a technical interest group of

engineering new zealand

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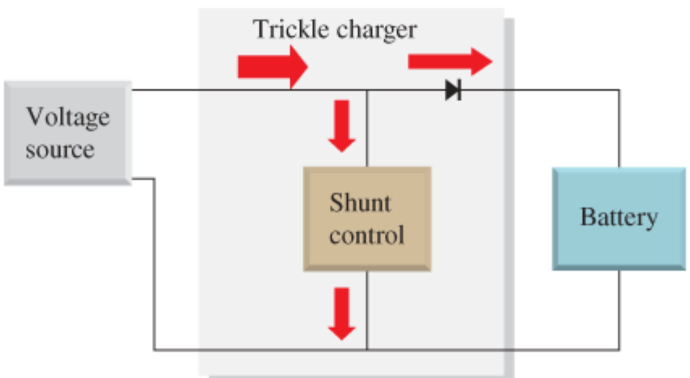
Capital thinking. Globally minded.

Why charge control? Example of batteries

- Prevents overcharging
- Monitors battery voltage and turns the charging current off or reduces it when the battery voltage exceeds a specified level

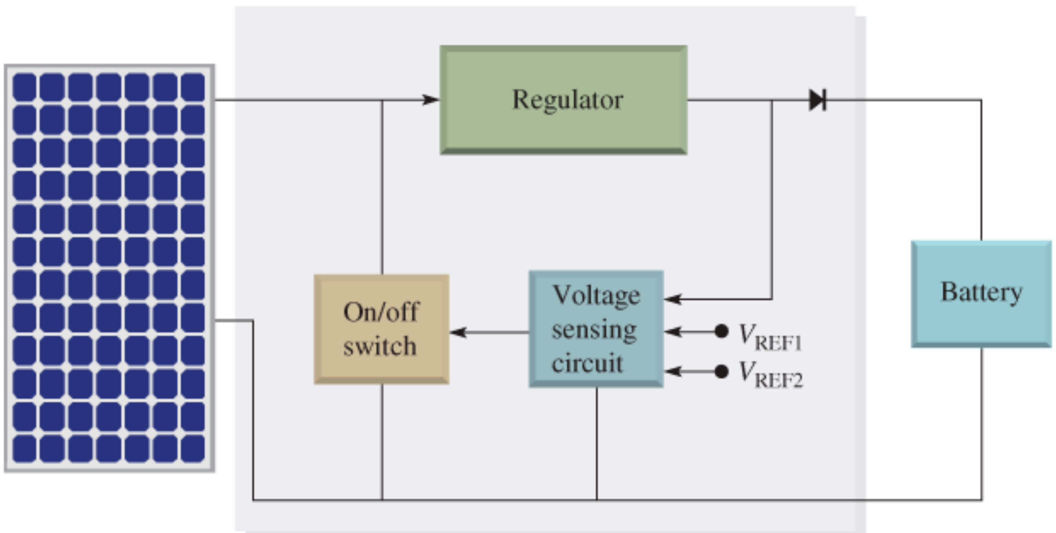
Trickle charger

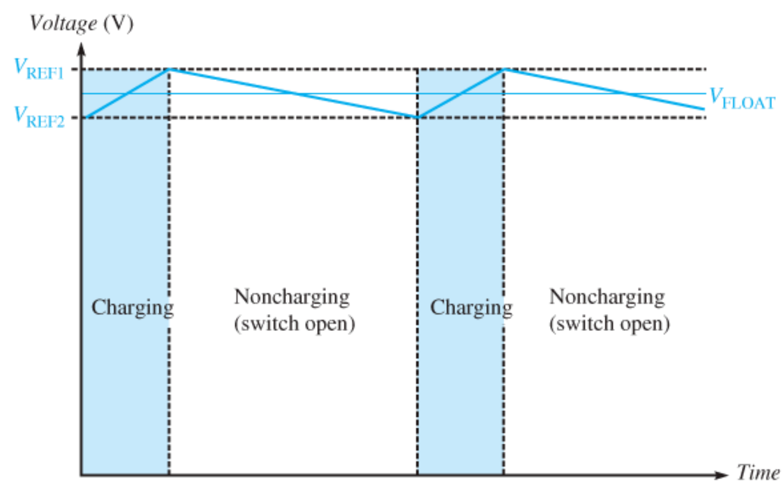
- Chargers the battery at its self-discharge rate by applying a constant voltage and current, regardless of whether the battery if fully charged
  – Could be used in small home system



Float charger

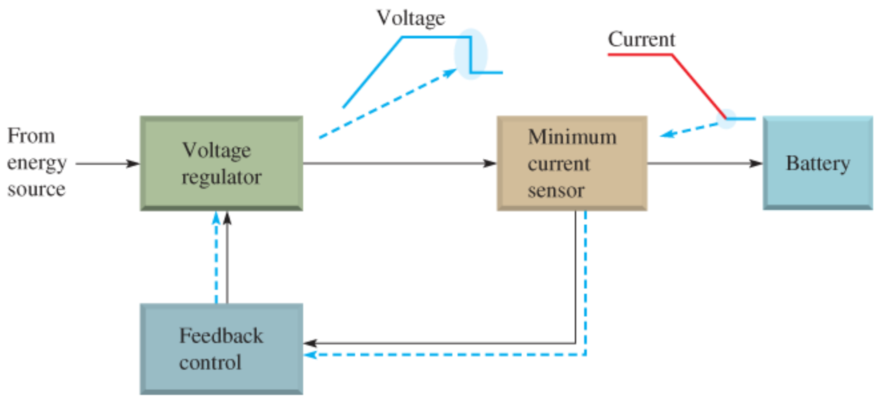
- Is a trickle charger with an automatic on/off switch

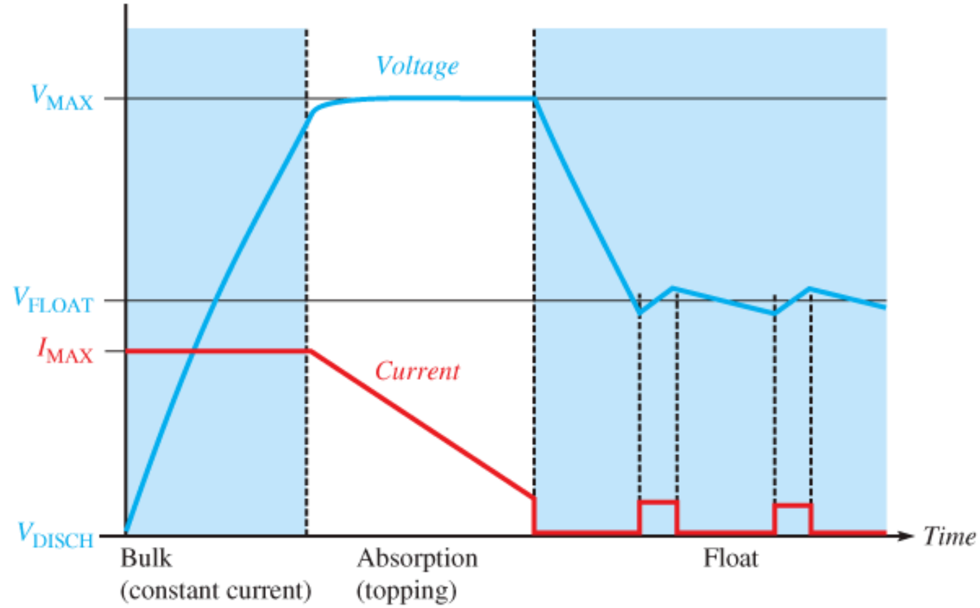




Three-stage float charger

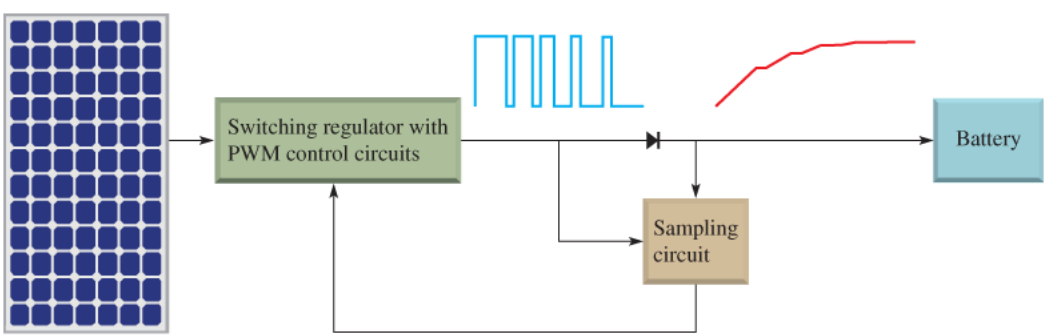
- Apply a constant voltage and let the battery draw whatever amount of current is required

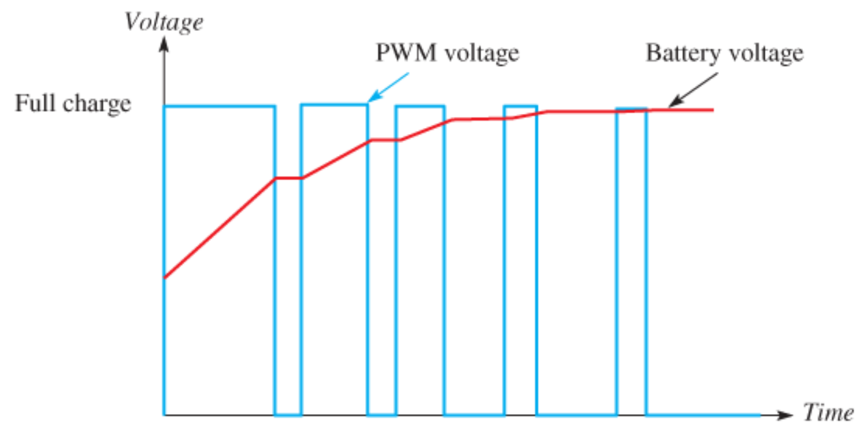




Pulse Width Modulation charge control

- PWM switches the energy from the source on and off several times per second
  - Keeps voltage more constant and is more efficient



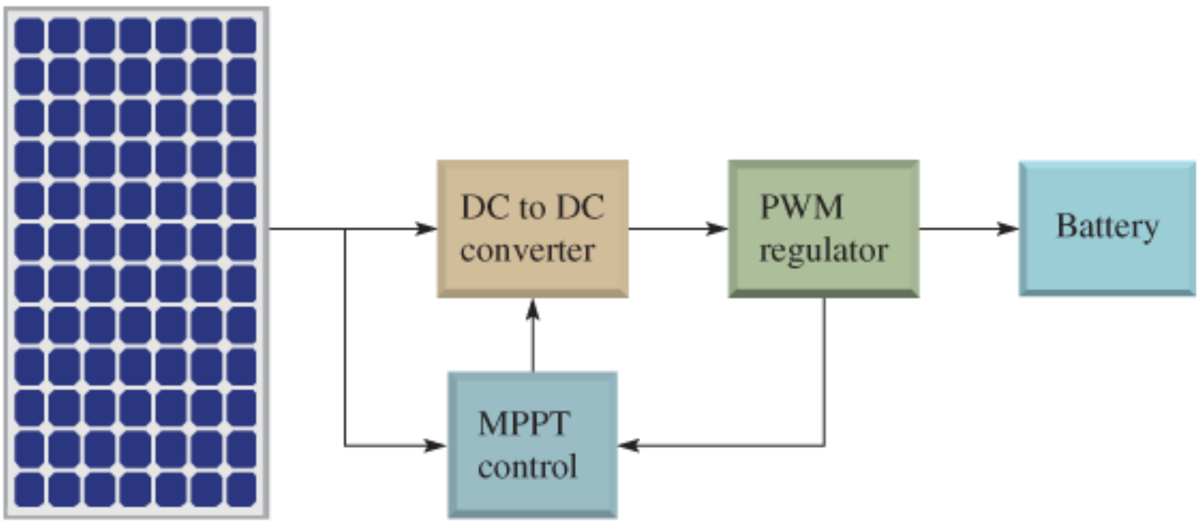


Disadvantage of PWM

- PWM controllers rarely operate at the maximum power voltage (Vmp) of the solar array
  - Energy is being wasted that could otherwise be used to better charge the battery bank and maintain power for system loads
  - The greater the difference between battery voltage and the Vmp of the array, the more energy is wasted by a PWM controller during bulk charging
    - Imagine a 36V PV panel connected to a 12V nominal battery bank using a PWM controller
    - You would clip / waste 20-24 volts of the panel voltage that makes up the usable energy!

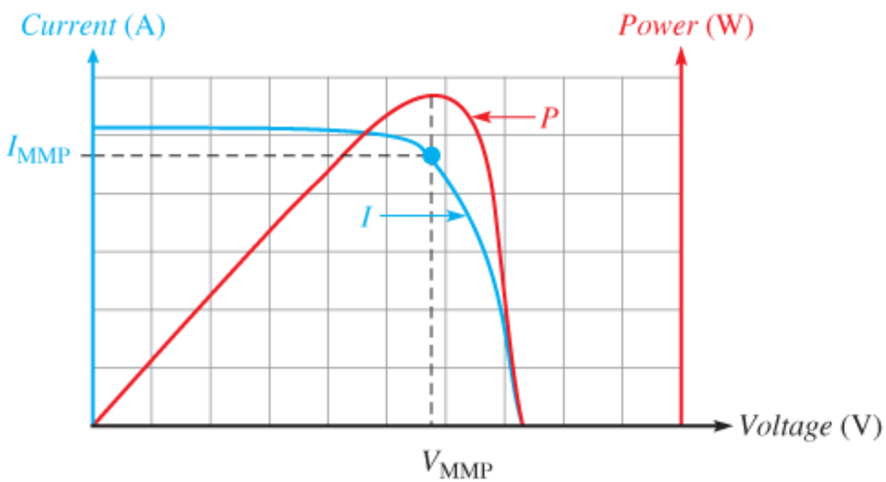
Maximum Power Point Tracking (MPPT)

- Eliminate much of the energy loses
  - Up to 30% more efficient over non-MPPT controllers



Maximum Power Point Tracking (MPPT)

- Tracks the voltage and current from the solar module to determine when the maximum power occurs in order to extract the maximum power



Fill Factor

- FF is the "squareness" of the curve
  - The quality of the PV cell
  - Typical value is between 0.7 and 0.8

$$FF = \frac{P_{\max}}{V_{oc} \times I_{sc}} = \frac{V_{mp} \times I_{mp}}{V_{oc} \times I_{sc}} \times 100\%$$

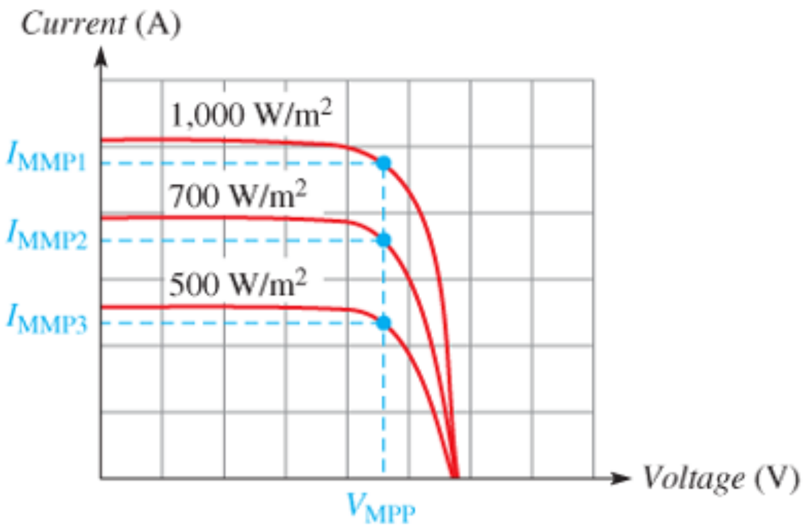
Efficiency

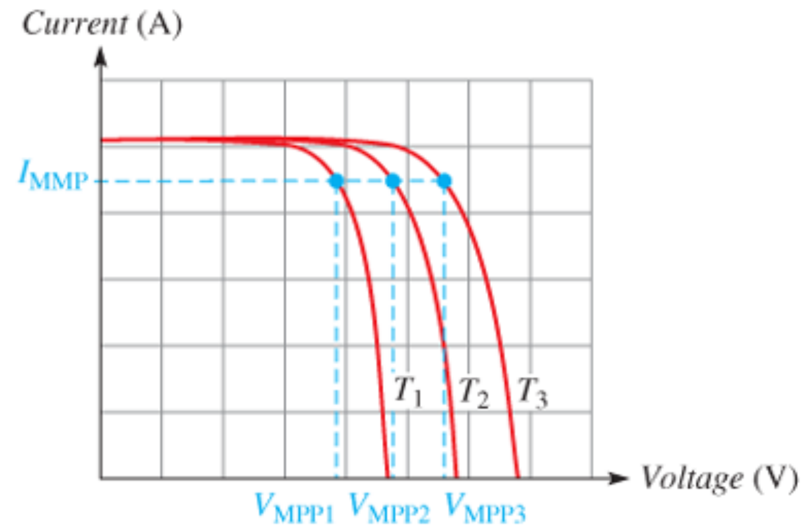
- Is the ratio between the output power compared to the received solar radiation
  - Normally in the range of 10 to 25%

$$\eta = \frac{output\ \ power}{input\ \ Sun\ \ power} = \frac{P_{\max}}{G \times A}$$

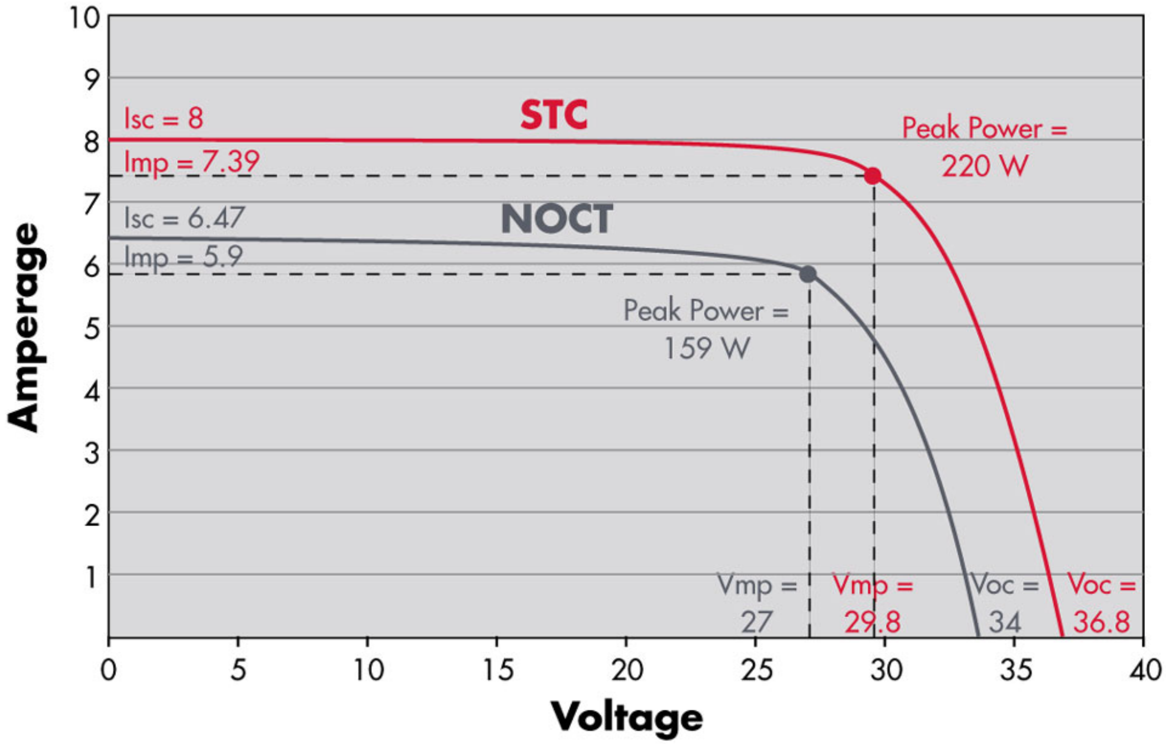
Effect of irradiance and temperature

- MPPT keeps the operating point of the solar module at the maximum power point with changes in light or temperature



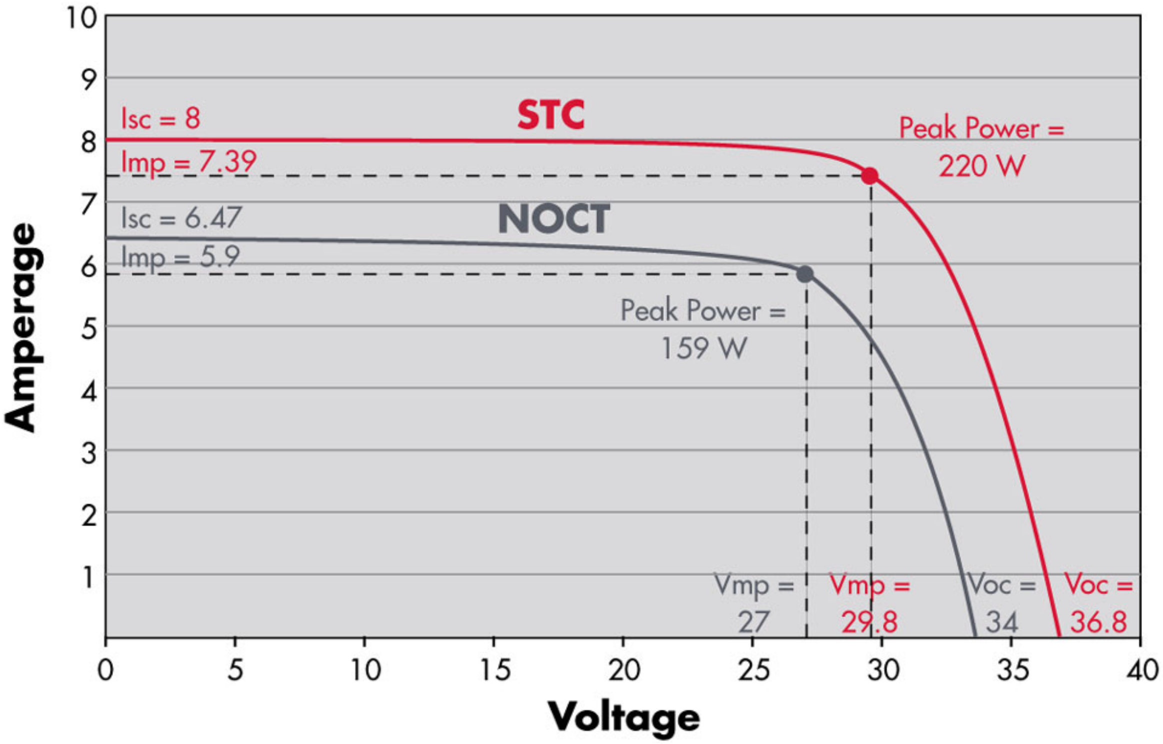


STC and NOCT



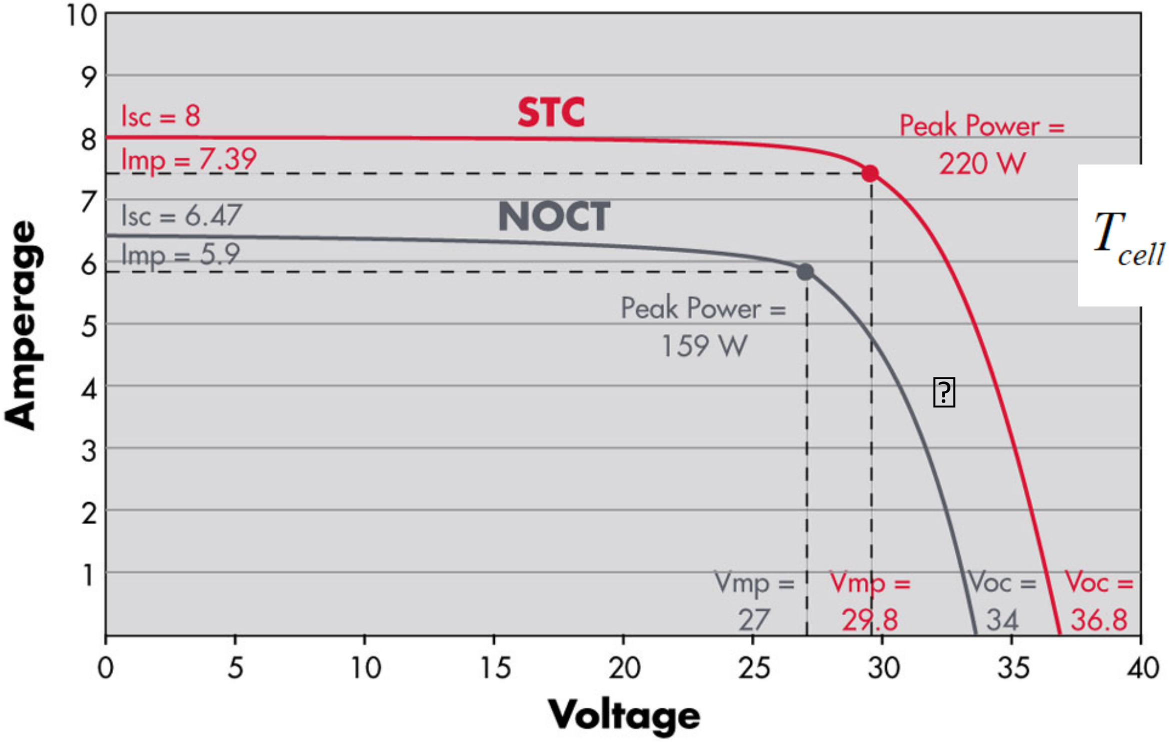
- FF?
- η?

STC and NOCT



- FF =220/36.8/8
- η = 220/1000
  - At STC

STC and NOCT



- NOCT is ~45°C

$$T_{cell} = T_{ambient} + G \times \frac{(NOCT - 20°C)}{800\,\mathrm{W/m^2}}$$

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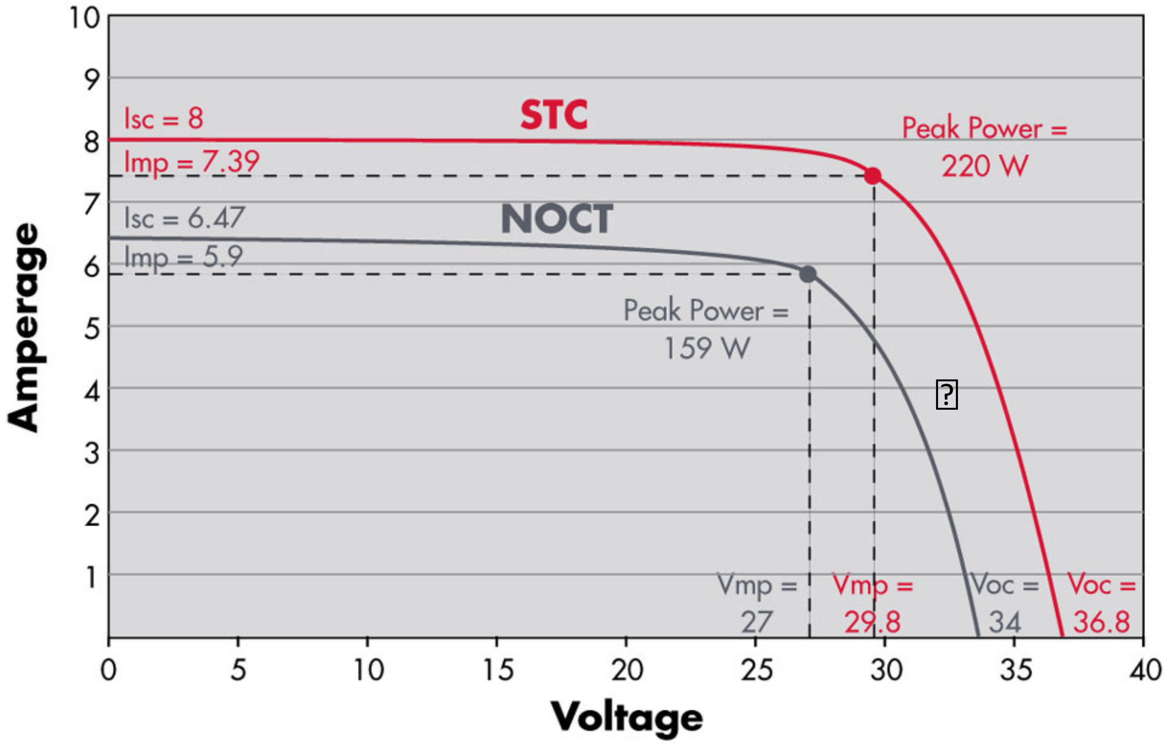
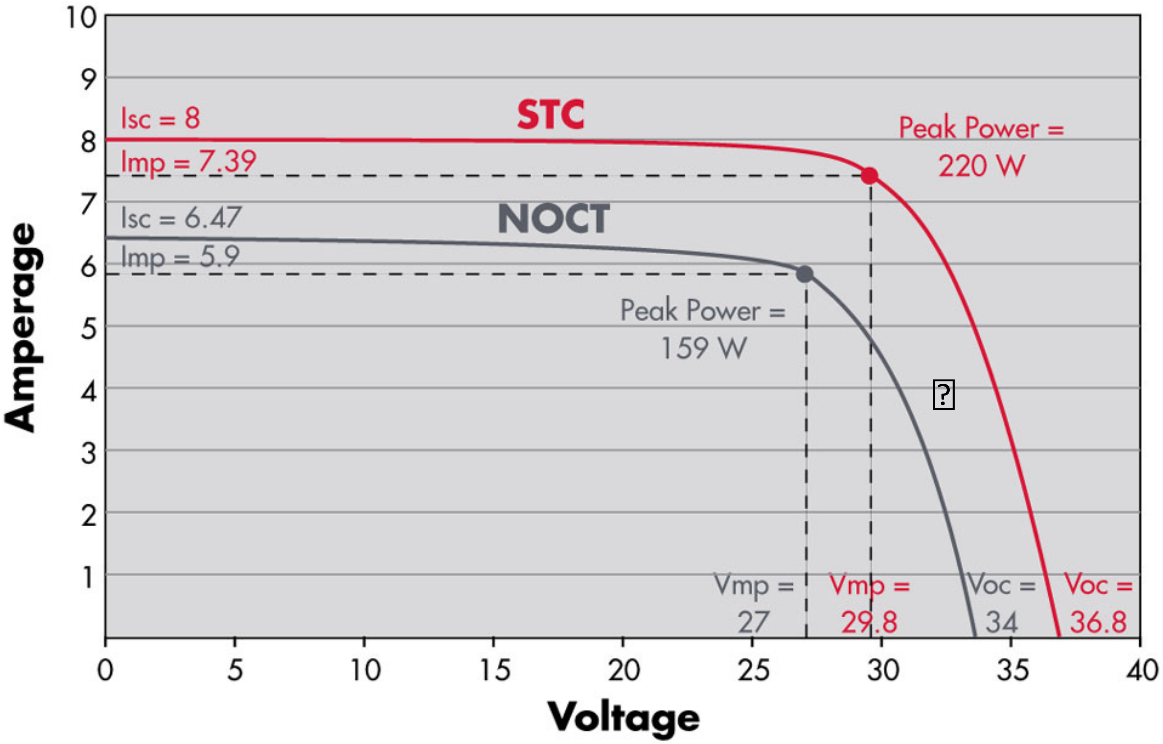
STC and NOCT



- γ is ~-0.5 per °C

$$\eta = \eta_0 \times \left(1 + \gamma\left(T_{cell} - 25°C\right)\right)$$

STC and NOCT

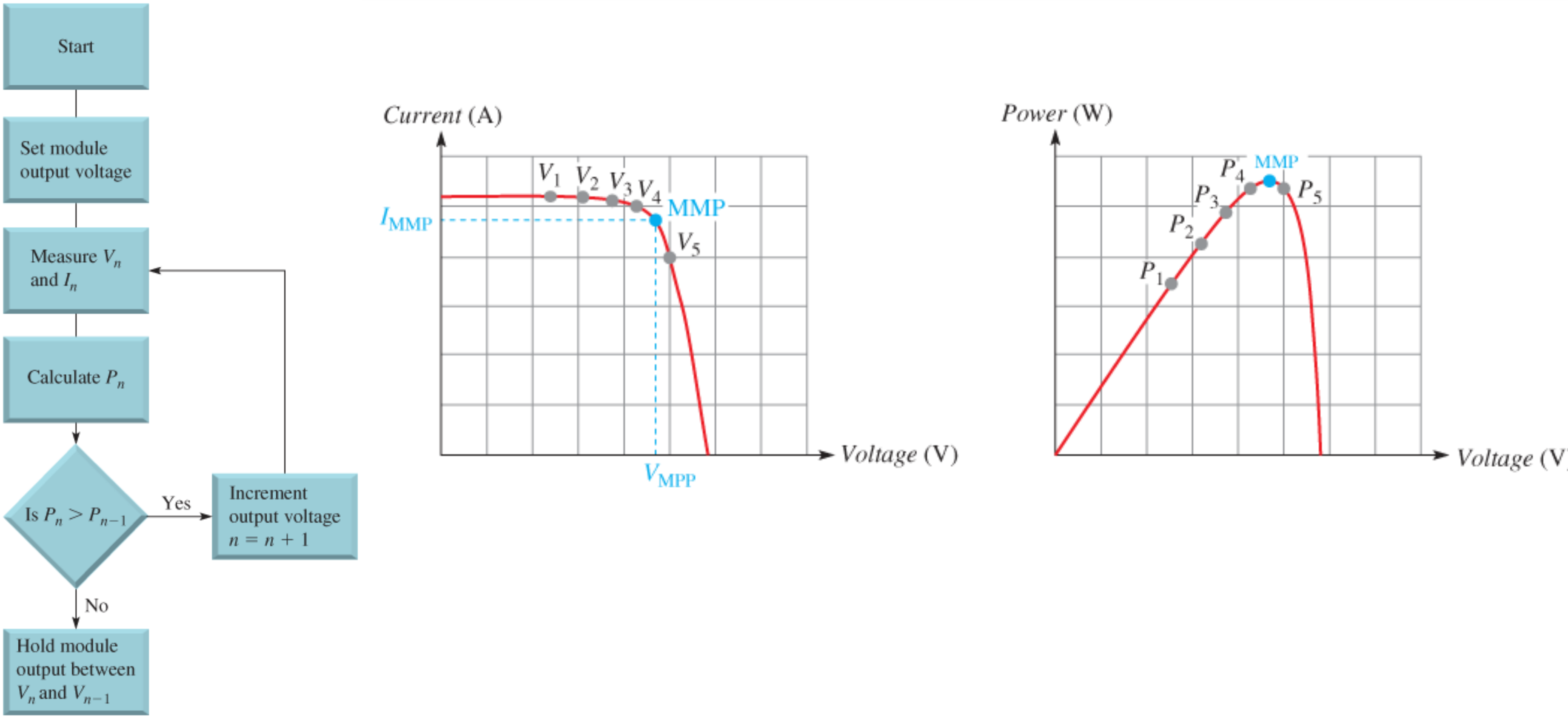


- α is ~0.025% / °C
- β is ~-0.4% / °C

$$I_{sc} = I_{sc,0}\left(1+\alpha\left(T-T_0\right)\right)$$

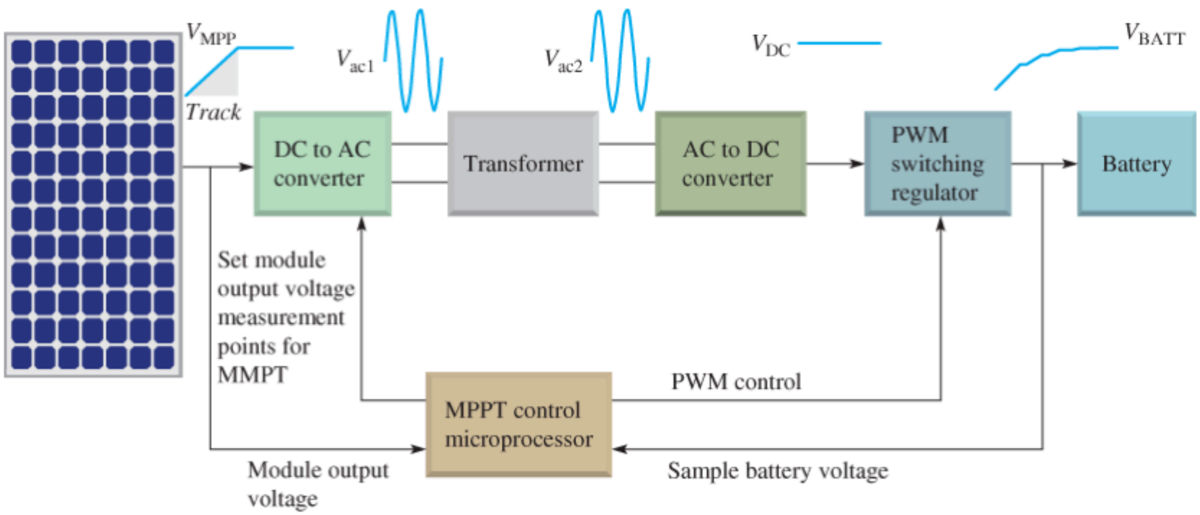
$$V_{oc} = V_{oc,0}\left(1+\beta\left(T-T_0\right)\right)$$

Perturb and Observe (P&O) algorithm



Operation of an MPPT charge controller

- A transformer is necessary for isolation
  - To allow the output CD voltage to be controlled independently of the voltage from the PV

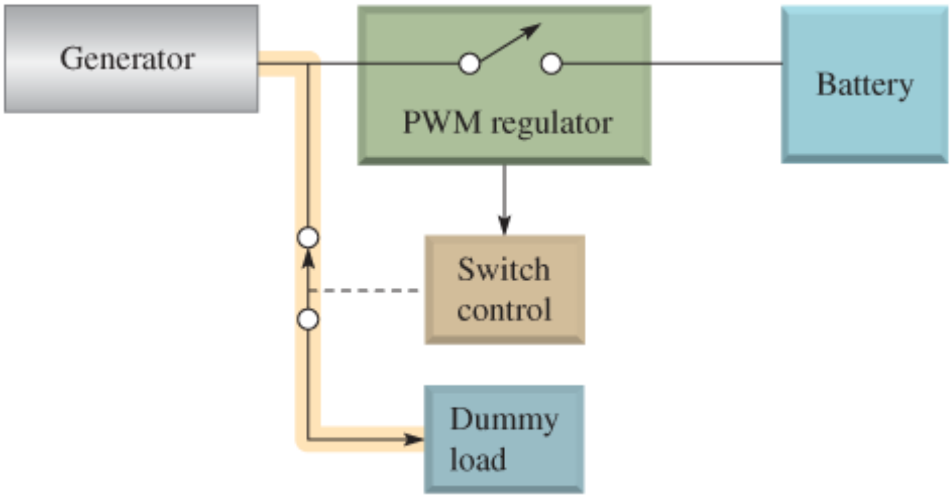


What happens to the current? Boosting

- A 100W panel (Vmp of 17V) is used to charge a battery at 12V with a MPPT controller
  - In ideal conditions, 5.88A of solar current flow into the MPPT (100W / 17V = 5.88A)
  - But the output voltage (battery voltage) is 12V, meaning current flow to the battery is 8.33A (100W / 12V = 8.33A)
    - You can see that the greater the voltage difference between the Vmp and the battery, the more “boost” current the battery will receive

Energy diversion for generators

- Certain generators, such as wind and small-hydro systems could be damaged with a sudden change in load



Inverters

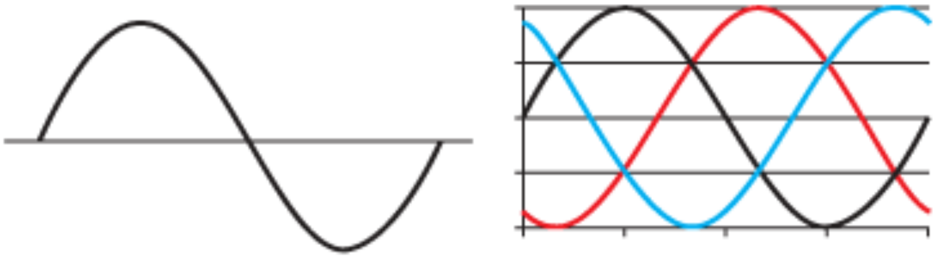
- https://www.youtube.com/watch?v=qVeERT4nyz8

(a) Small inverter units

(b) Modular grid-tie 150 kW inverters for a large solar array. The entire system is rated at 4.5 megwatts

Single- three-phase power

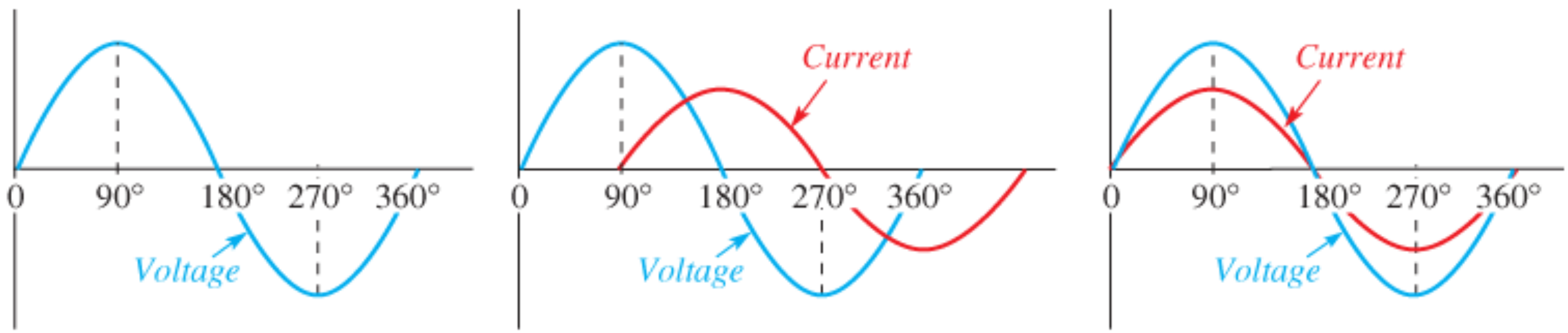
- With three-phase power, significantly more power can be delivered with three wires as can be delivered with single-phase using two wires (for the same size wires)



(a) Single-phase (b) Three-phase

Power Factor correction

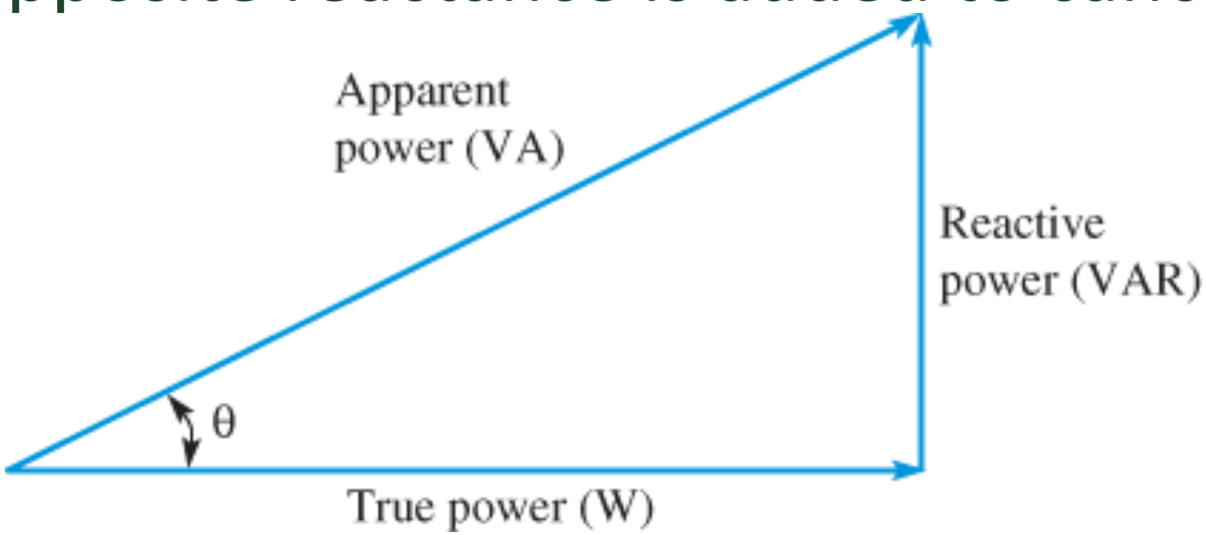
- Pure inductive/capacitive vs Pure resistive loads



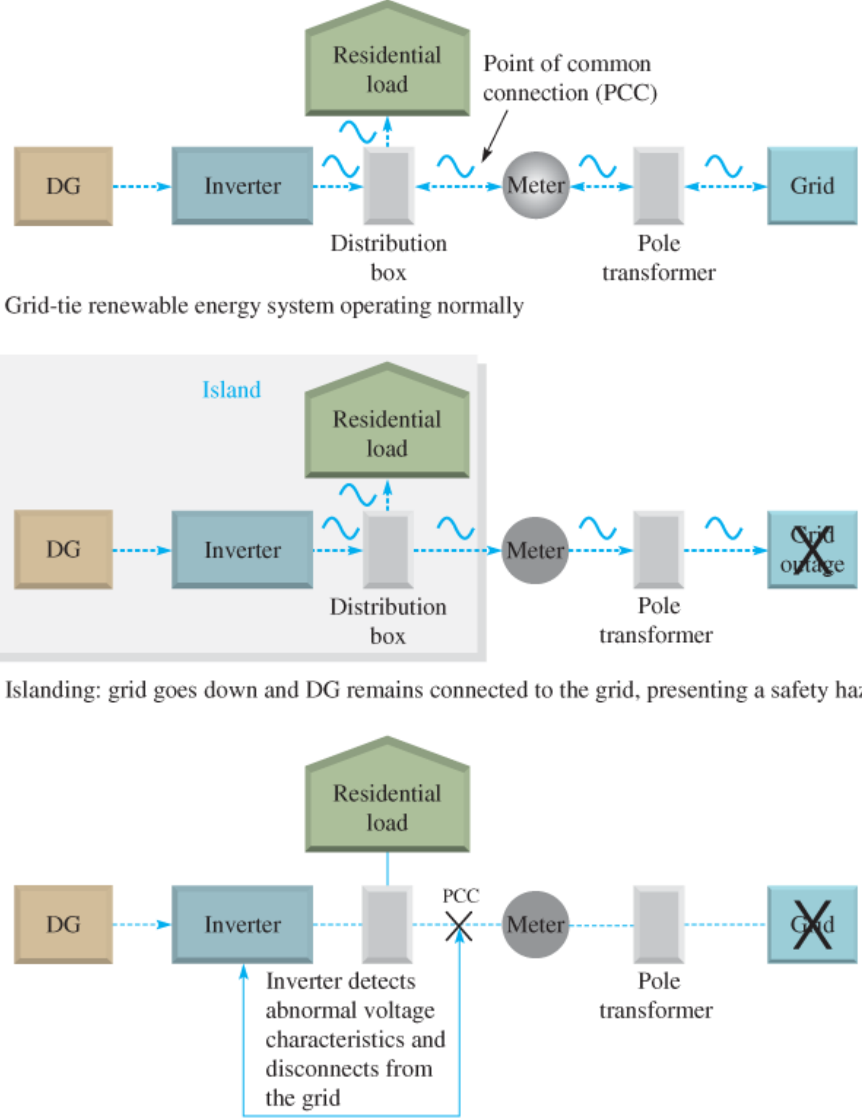
(a) Angular measurement (b) Current 90° out of phase with voltage (c) Current and voltage in phase

Power Factor correction

- Reactive power is returned to the source and not delivered to the source
- Opposite reactance is added to cancel the effects



Anti-islanding



(a) Grid-tie renewable energy system operating normally

(b) Islanding: grid goes down and DG remains connected to the grid, presenting a safety hazard

(c) Anti-islanding: inverter detects abnormal voltage at the PCC and disconnects from the grid

Discussion

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