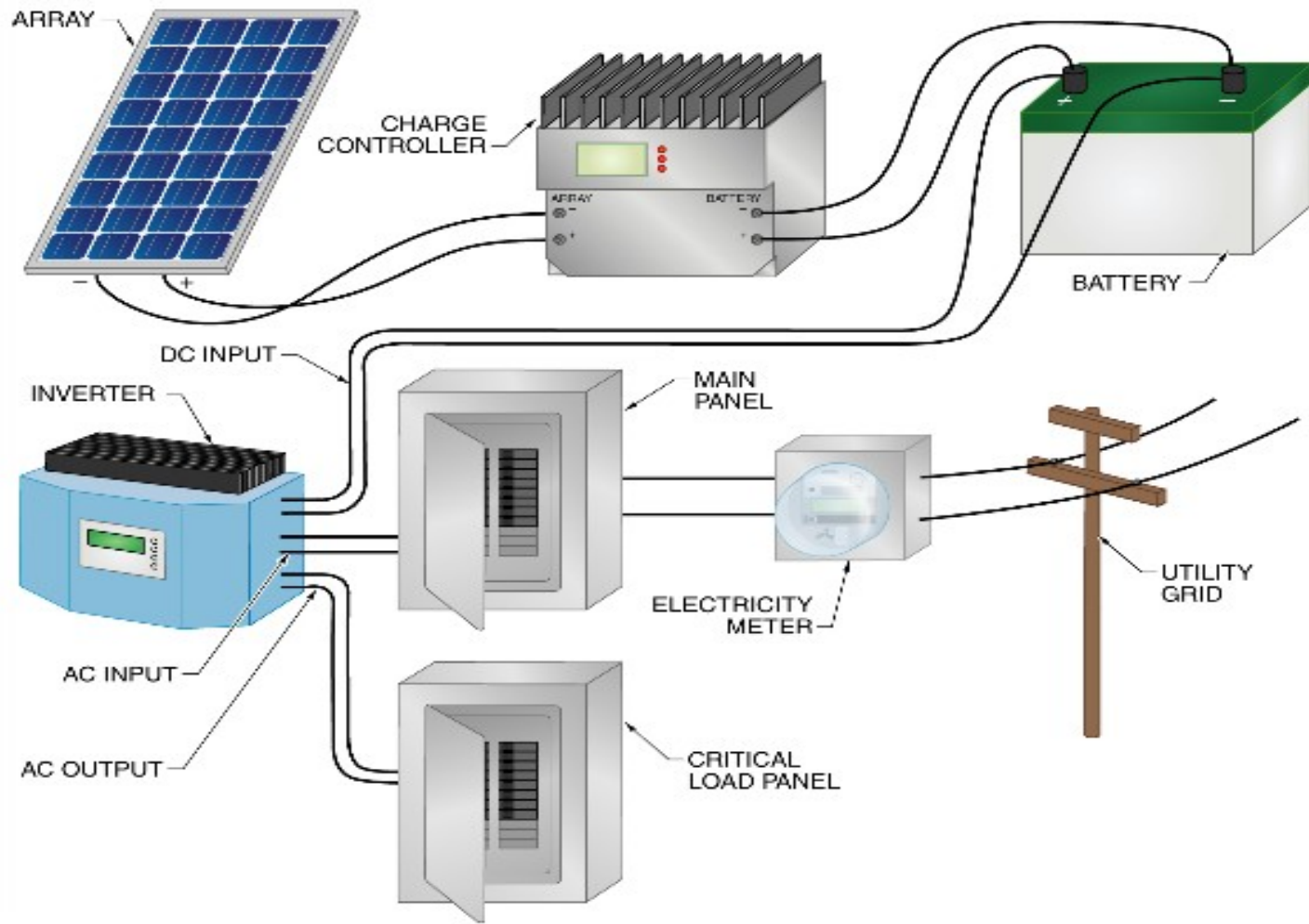




Batteries, Charge Controllers & Inverters



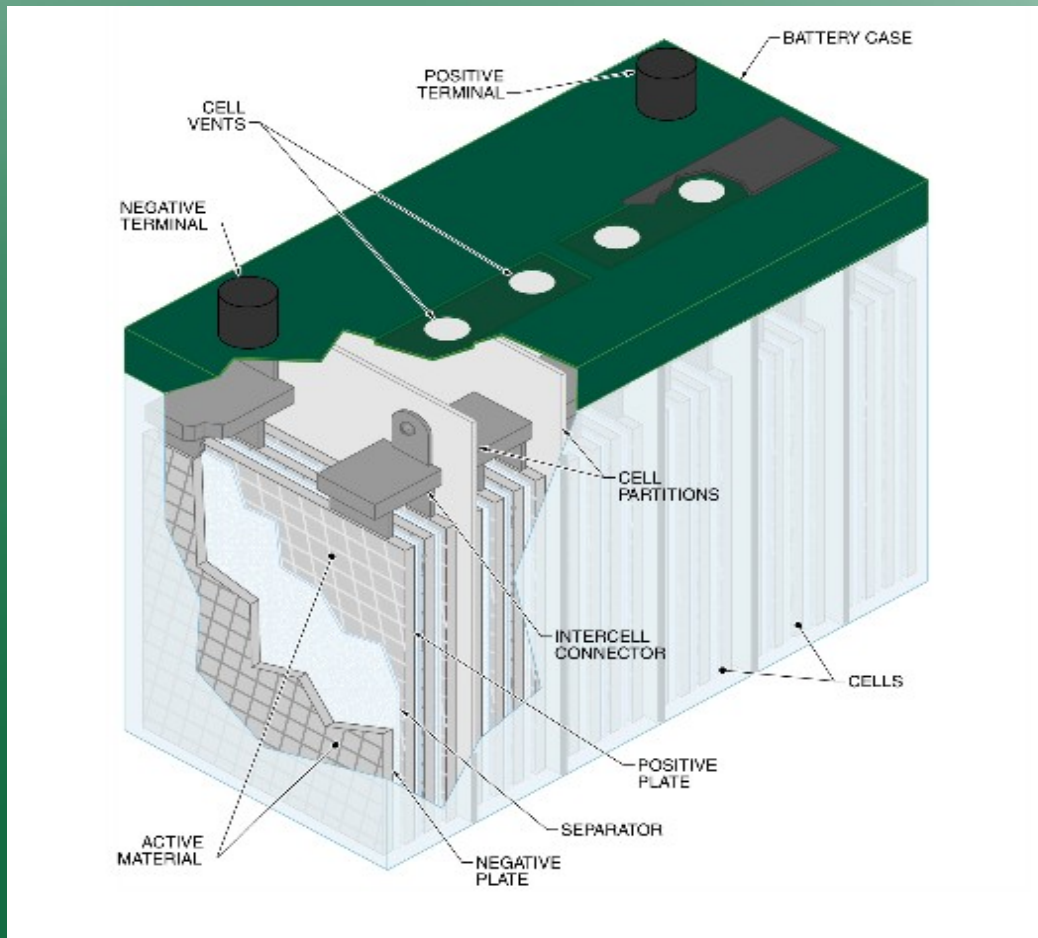


Batteries, Charge Controllers & Inverters





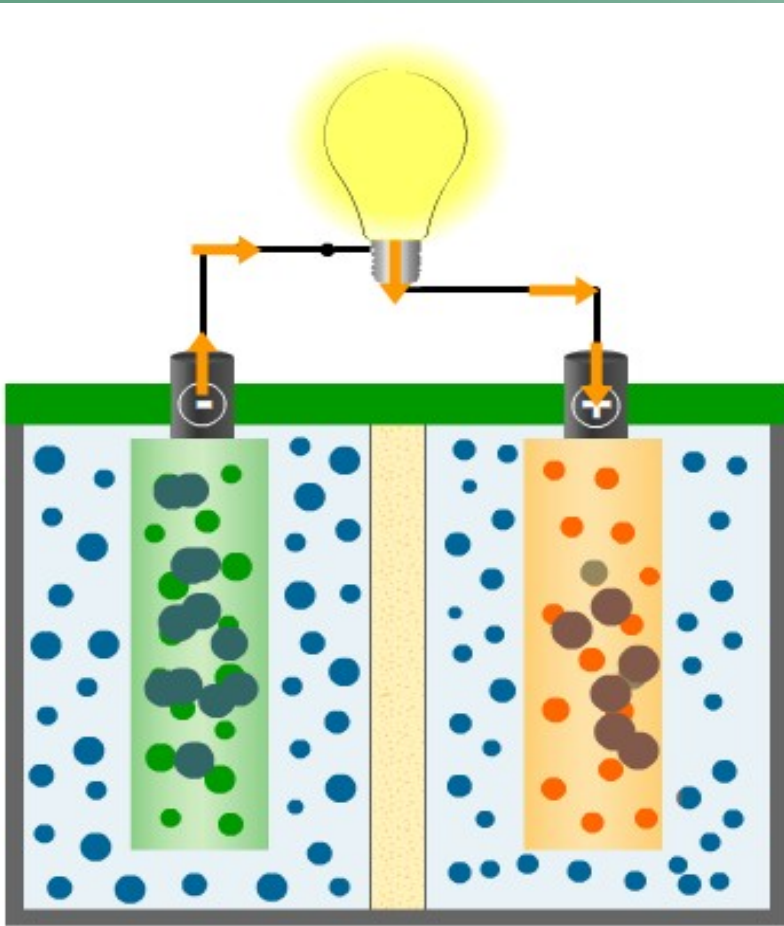
Anatomy of a Lead Acid Battery



A **battery** is a collection of electrochemical cells that are contained in the same case and are connected together electrically. Each cell consists of a positive and negative plate immersed in an electrolyte solution.



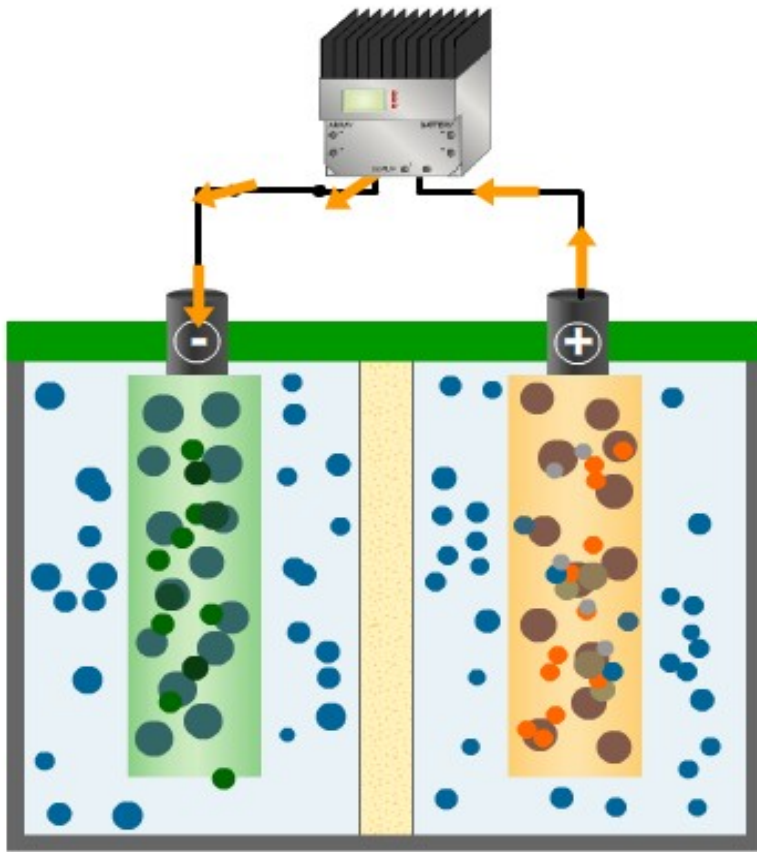
A Battery Discharging



- Cell discharge = conversion of energy in chemical bonds into electron flow (current)
- Active material at the negative terminal reacts with the electrolyte to form a new material that releases electrons



A Battery Charging



- Cell charging = charging current is applied in the opposite direction
- restores original charged state of battery by inducing the opposite chemical reaction as discharge



Battery Chemistries

| Electrolyte | Type | Cost | Availability | Deep-Cycle | Temp | Maint |
|-------------|-------------|------|--------------|------------|-----------|-------|
| Flooded | Pb-At | low | very good | good | good | high |
| Flooded | Pb-Ca OV | low | very good | poor | poor | med |
| Flooded | Pb-Ca SV | low | very good | poor | poor | low |
| Flooded | Ni-Cd PP | high | limited | good | excellent | med |
| Flooded | Pb-At/Pb-Ca | low | limited | good | good | med |
| Captive | Pb-Ca SV | med | limited | fair | poor | low |
| Captive | Pb-At/Pb-Ca | med | limited | fair | poor | low |
| Captive | Ni-Cd SP | high | very good | good | good | none |

Pb = Lead, At = Antimony, Ca = Calcium, Ni = Nickel, Cd = Cadmium
 OV = Open Vent, SV=Sealed Vent, SP = Sintered Plate, PP = Pocket Plate



Battery Units

Voltage Cell chemistry (PbA 2V Li 3-4V)
How many cells in series

Capacity measure of the amount of electrical energy that a battery can store

Example: A LA battery that has 6 cells gives nominal 12V. If it delivers 5 Amps of current for 20 hours it has 100 Amp-Hours (Ah) of capacity. $12 \times 100 = 1200$ WattHours (1.2kWh)



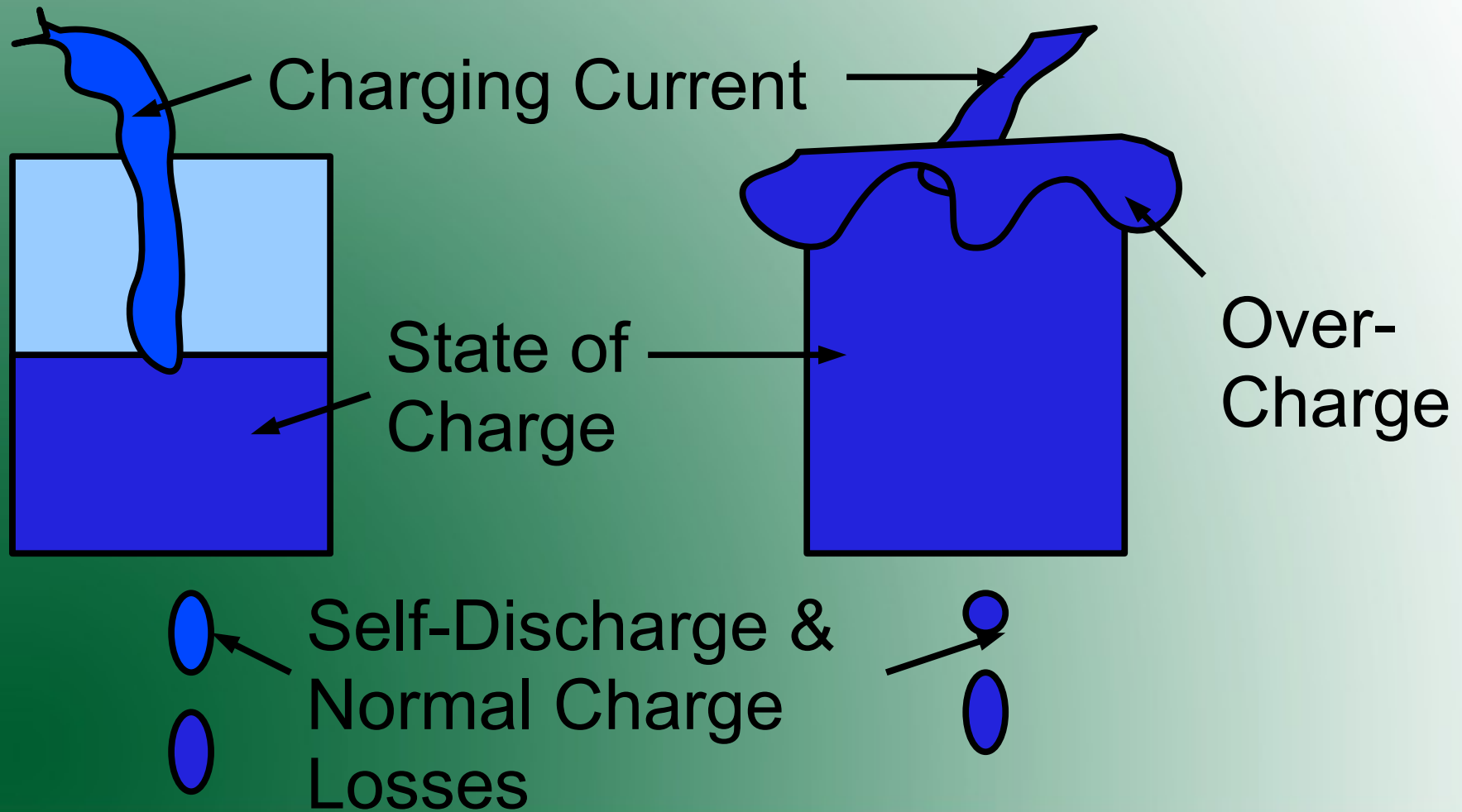
Battery: C rate

Discharge Rate = the ratio of nominal battery capacity to discharge time in hours

Example: A 100 Ah battery discharging current at 5 represents a C/20 discharge rate that could be maintained for up to 20 hours; C/5 discharge rate for the same battery would represent 20 amps for up to 5 hours

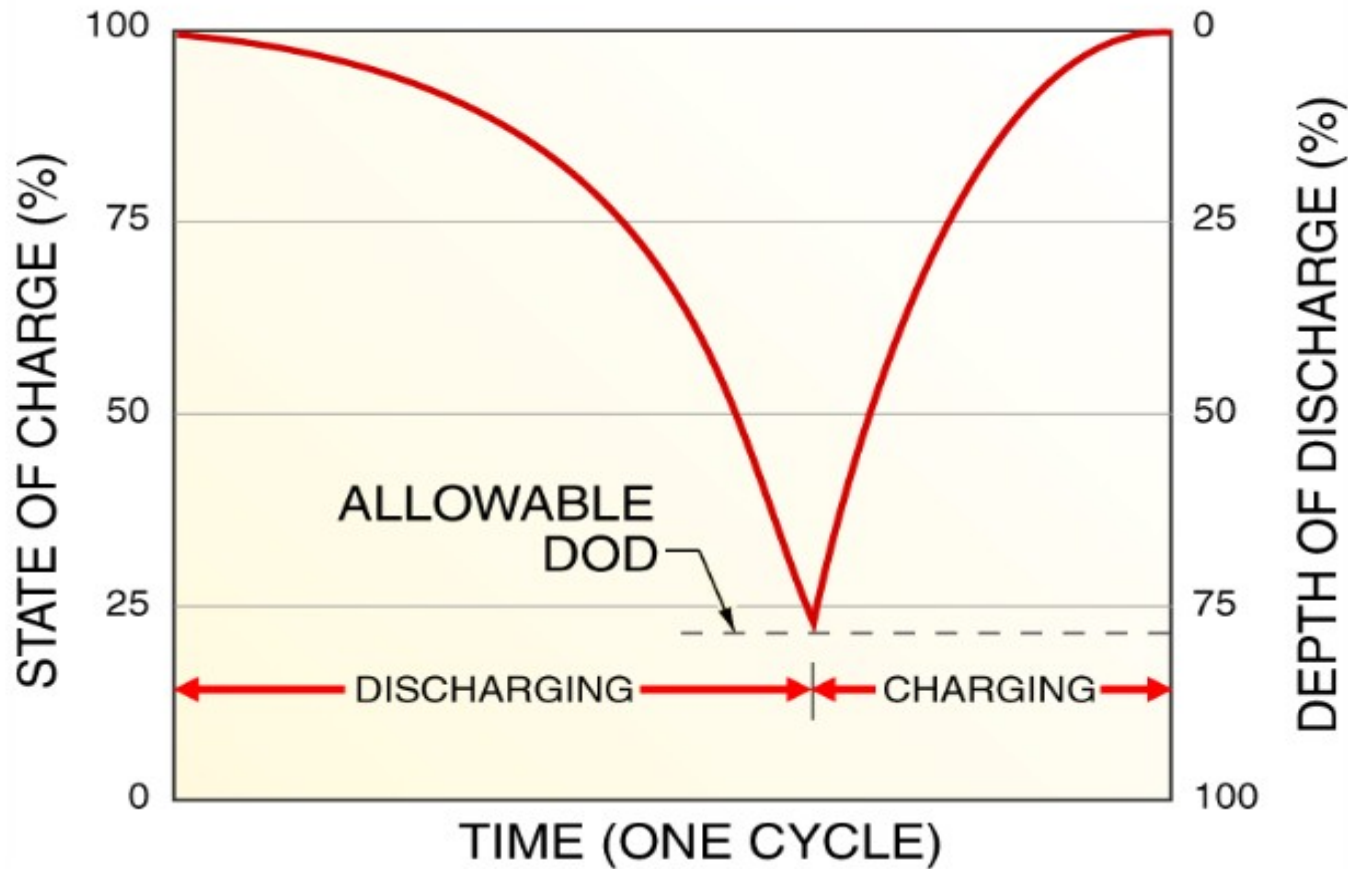


State of Charge





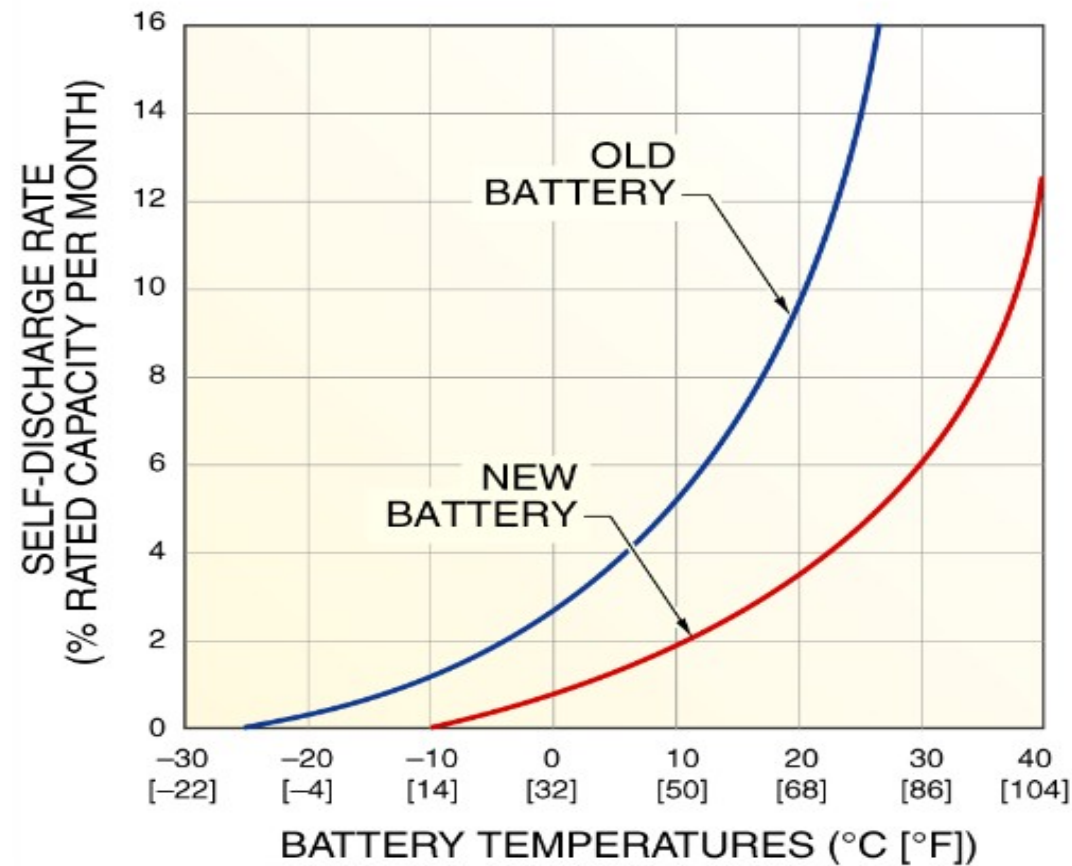
Charging/Discharging Cycles





Temperature and Age Dependency Self-Discharge Rates

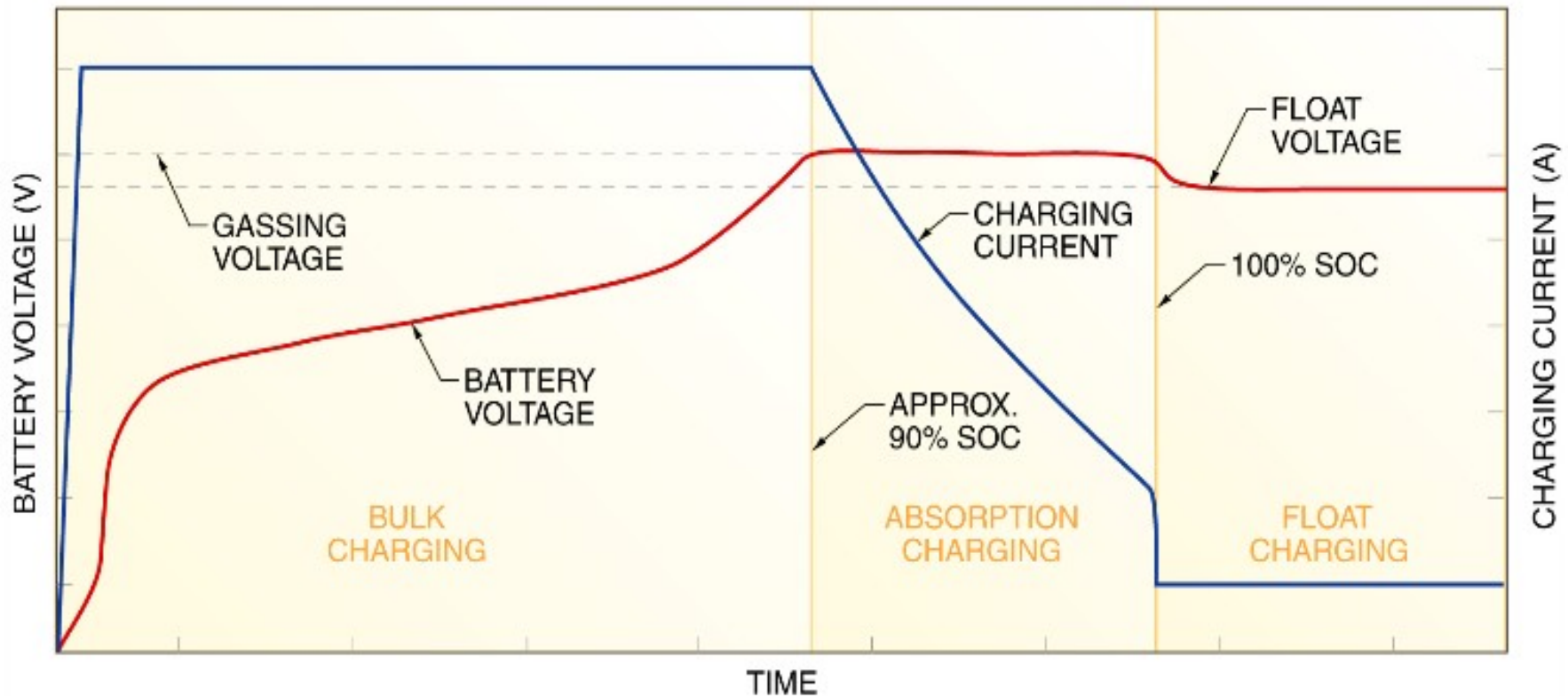
Self-Discharge Rates





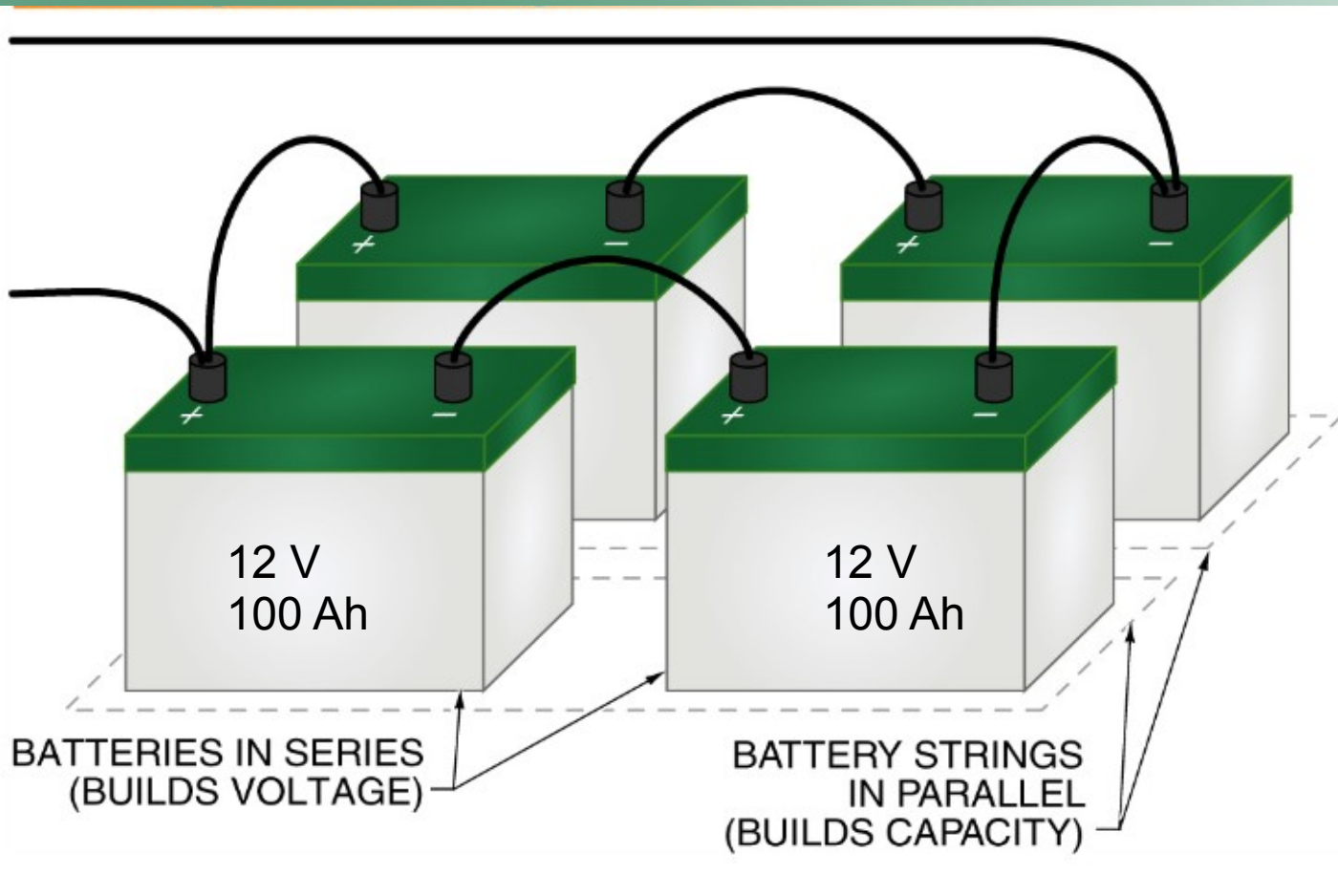
What the Charge Controller does ...

Multiple-Stage Charging





Building capacity – Series/Parallel



Volts?

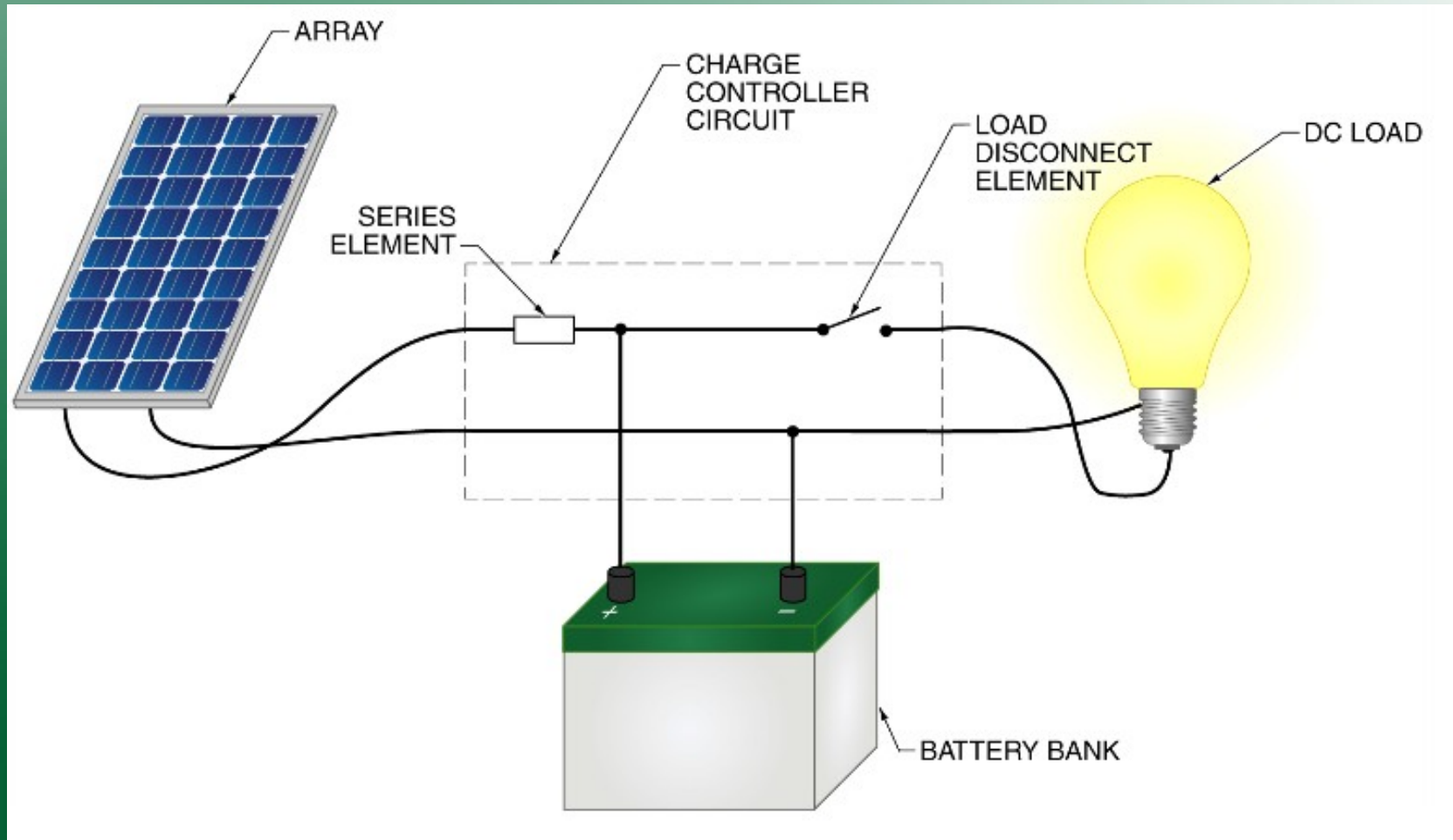
24V

Capacity?

200 Ah

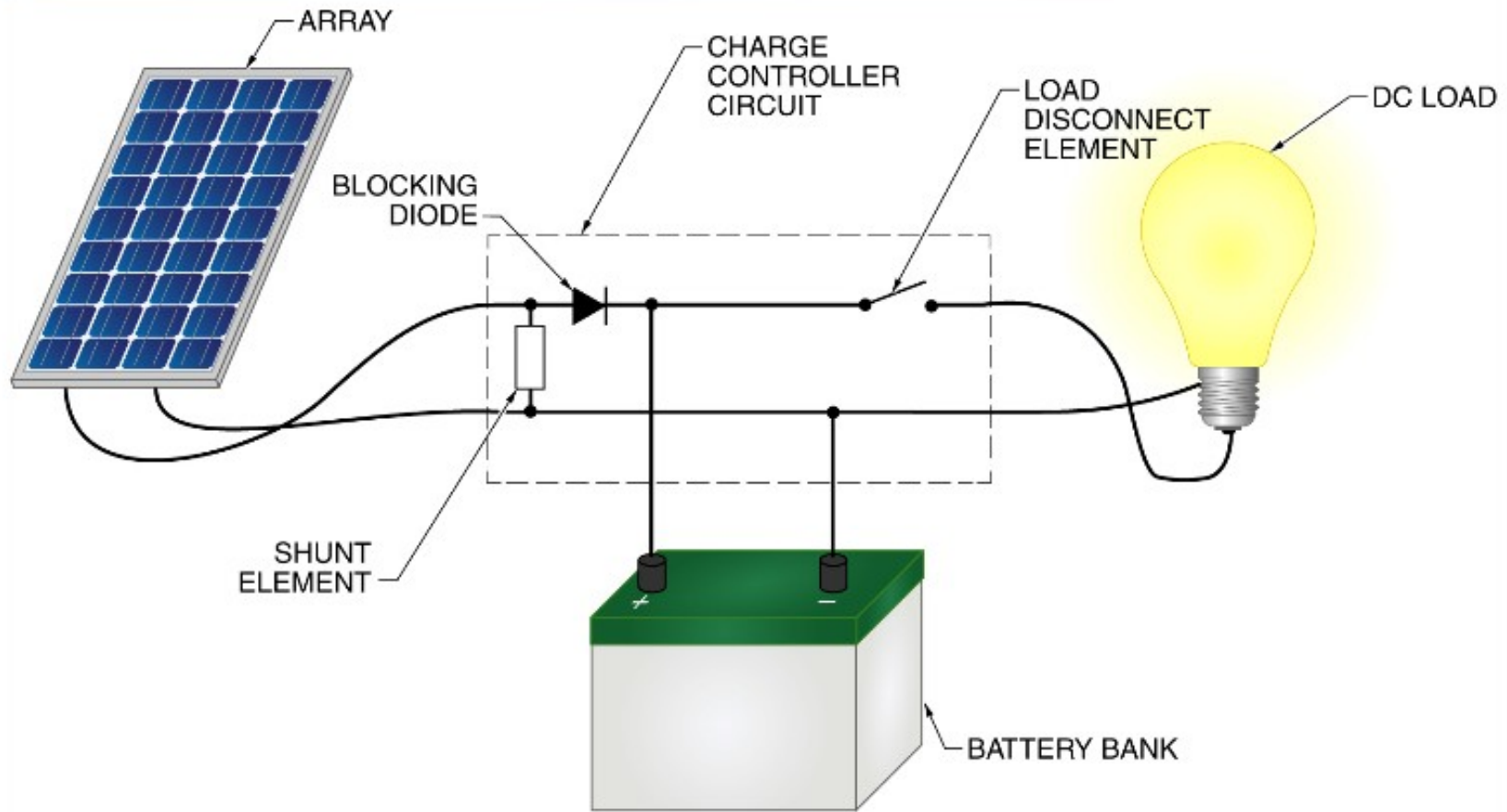


Series Charge Controllers



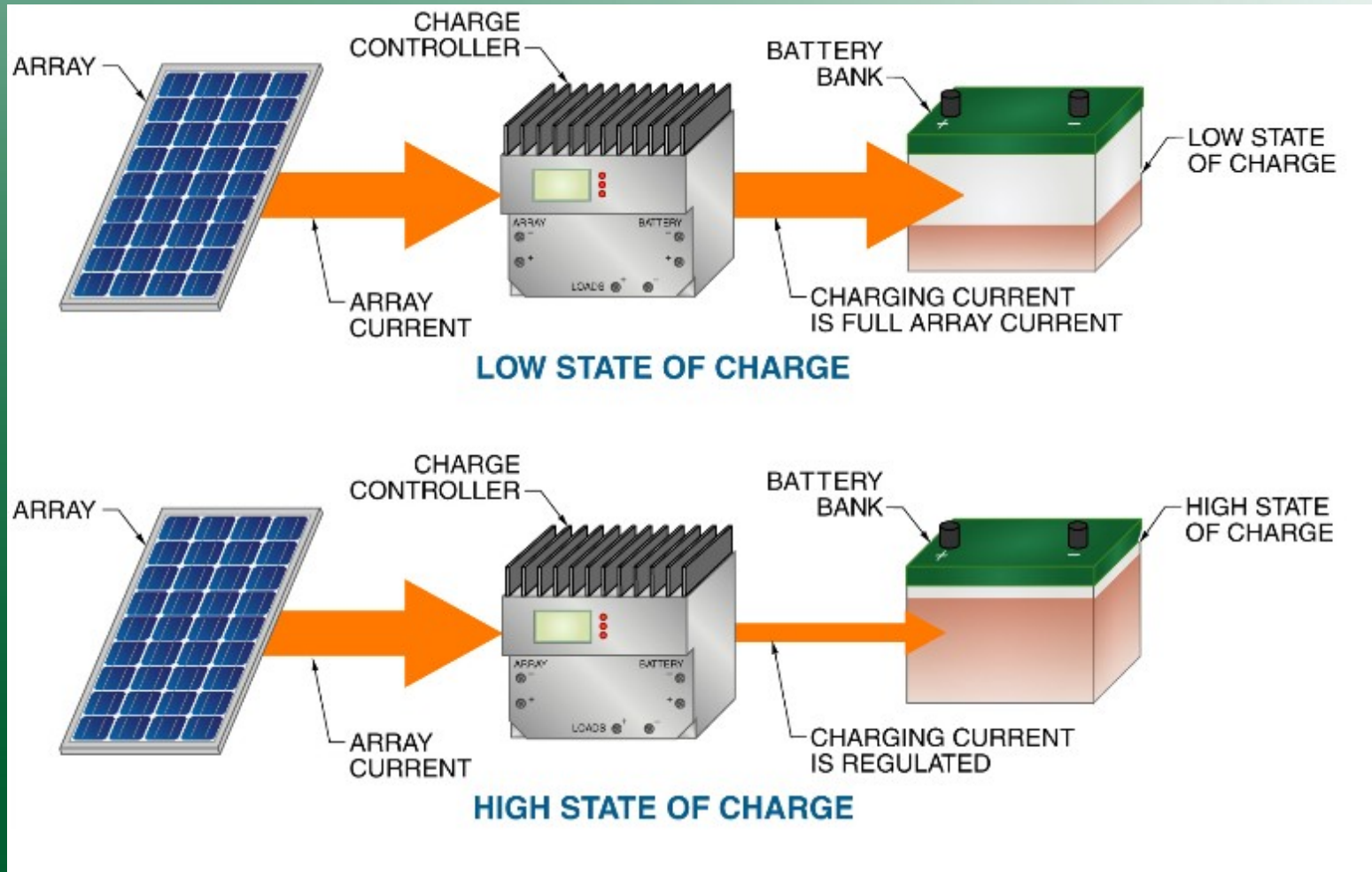


Shunt Charge Controllers



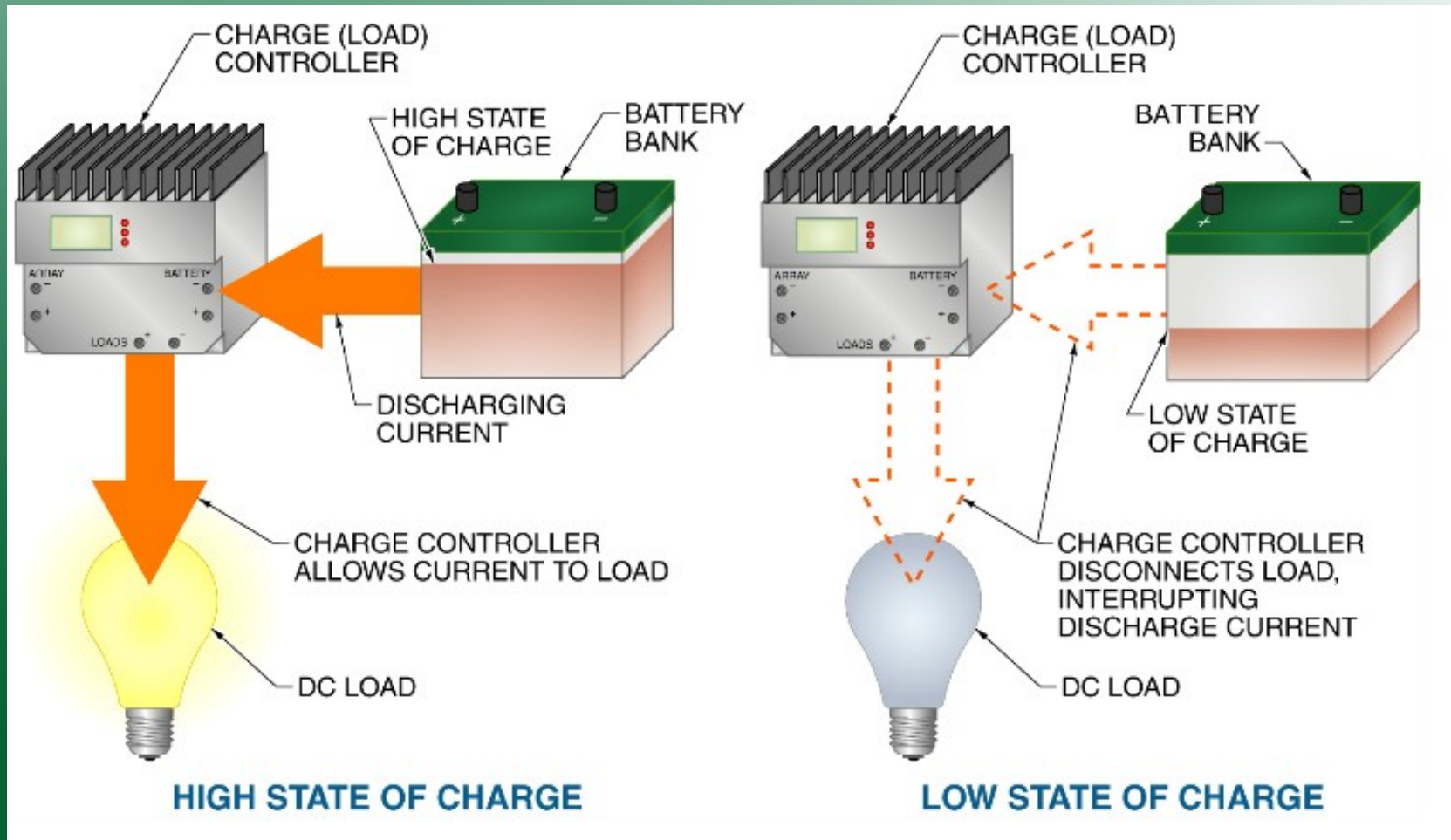


Overcharge Protection



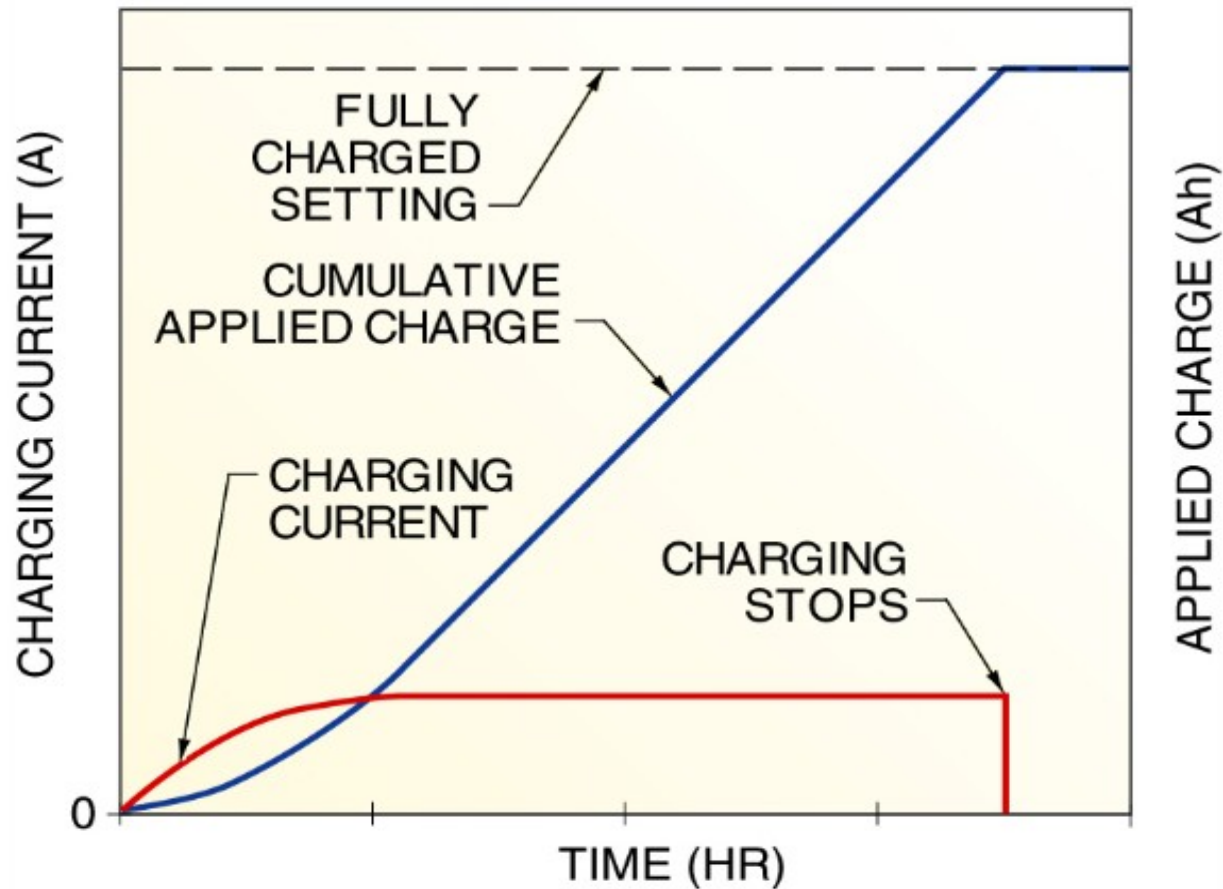


Overdischarge Protection



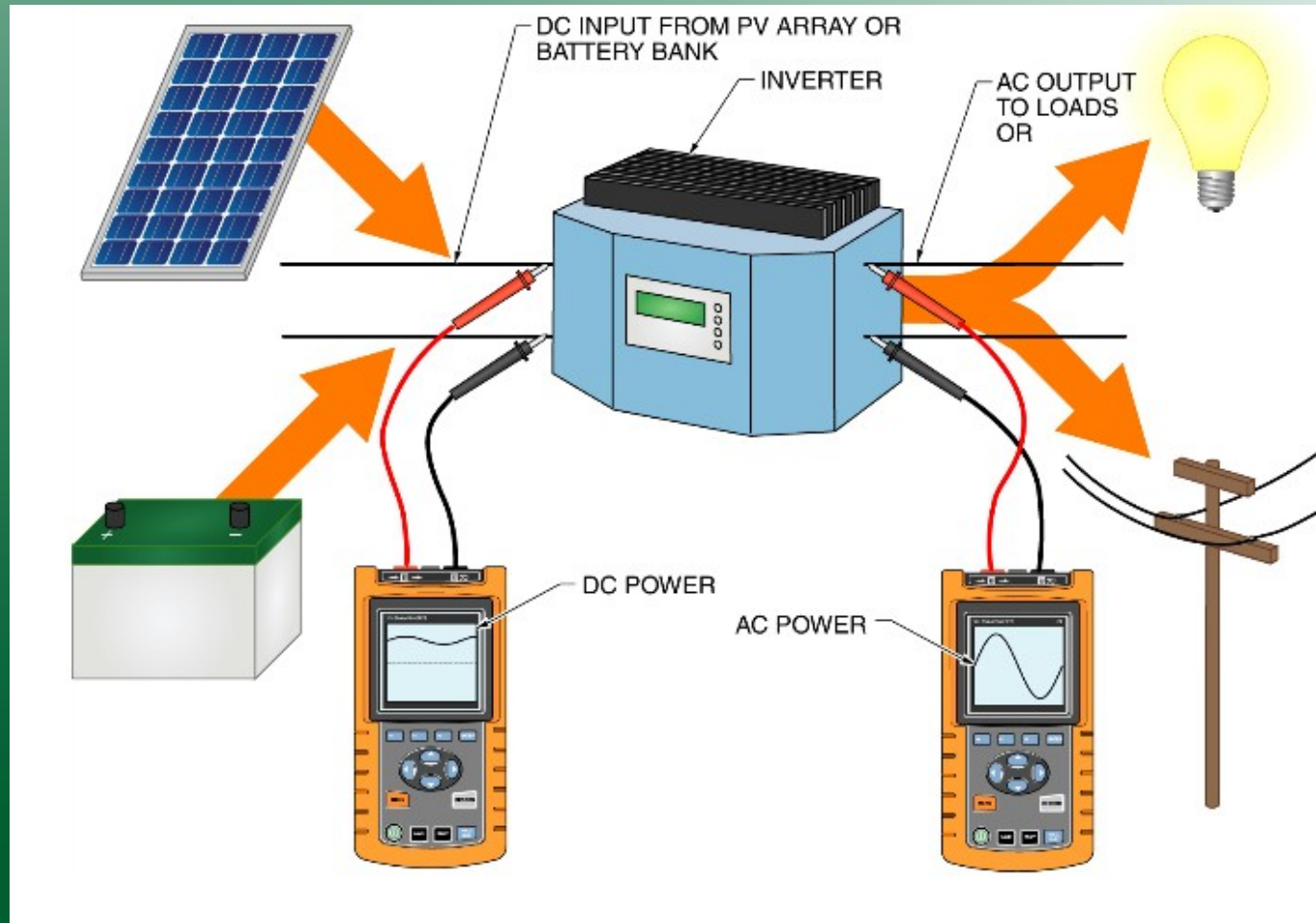


Ampere-Hour Charge Controller



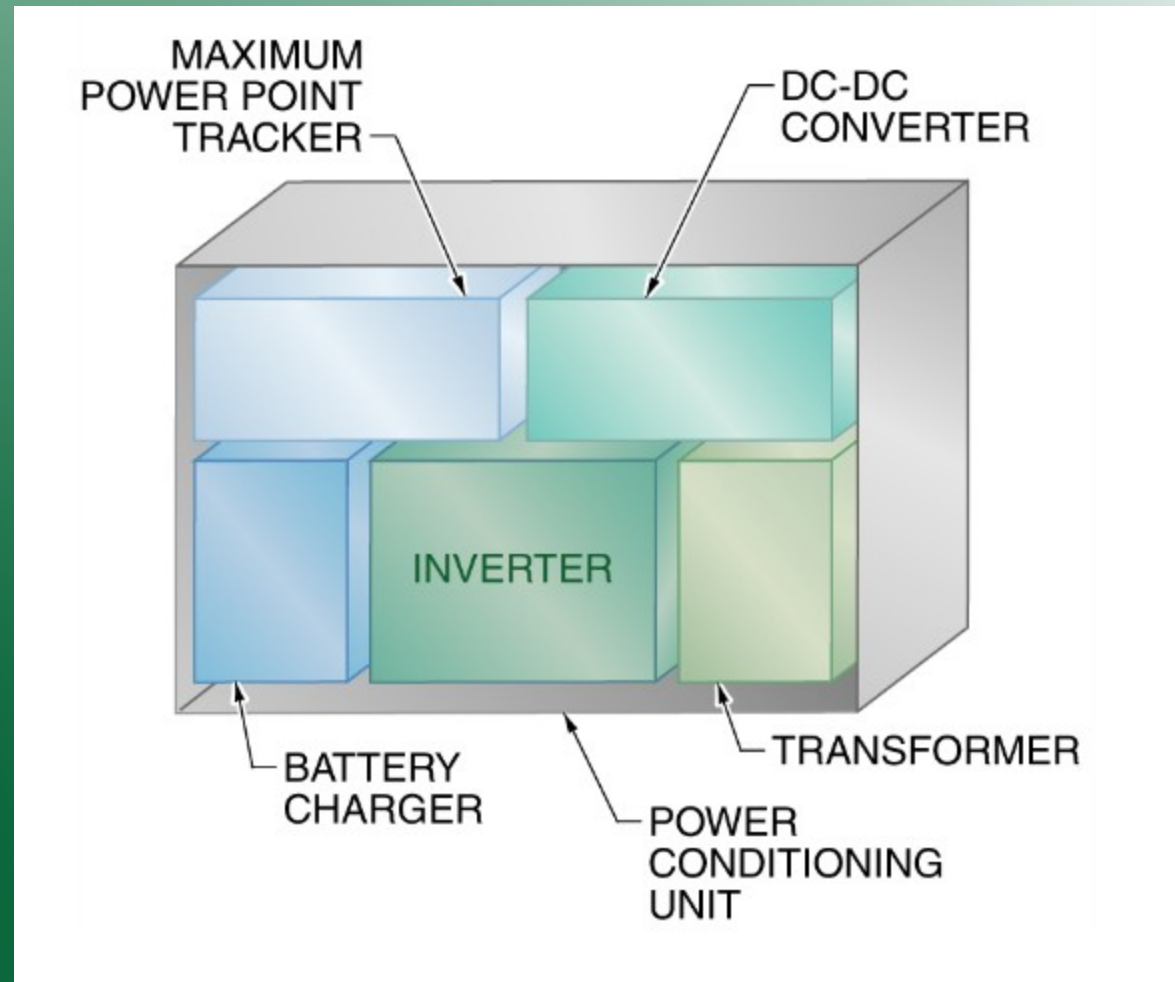


Inverters



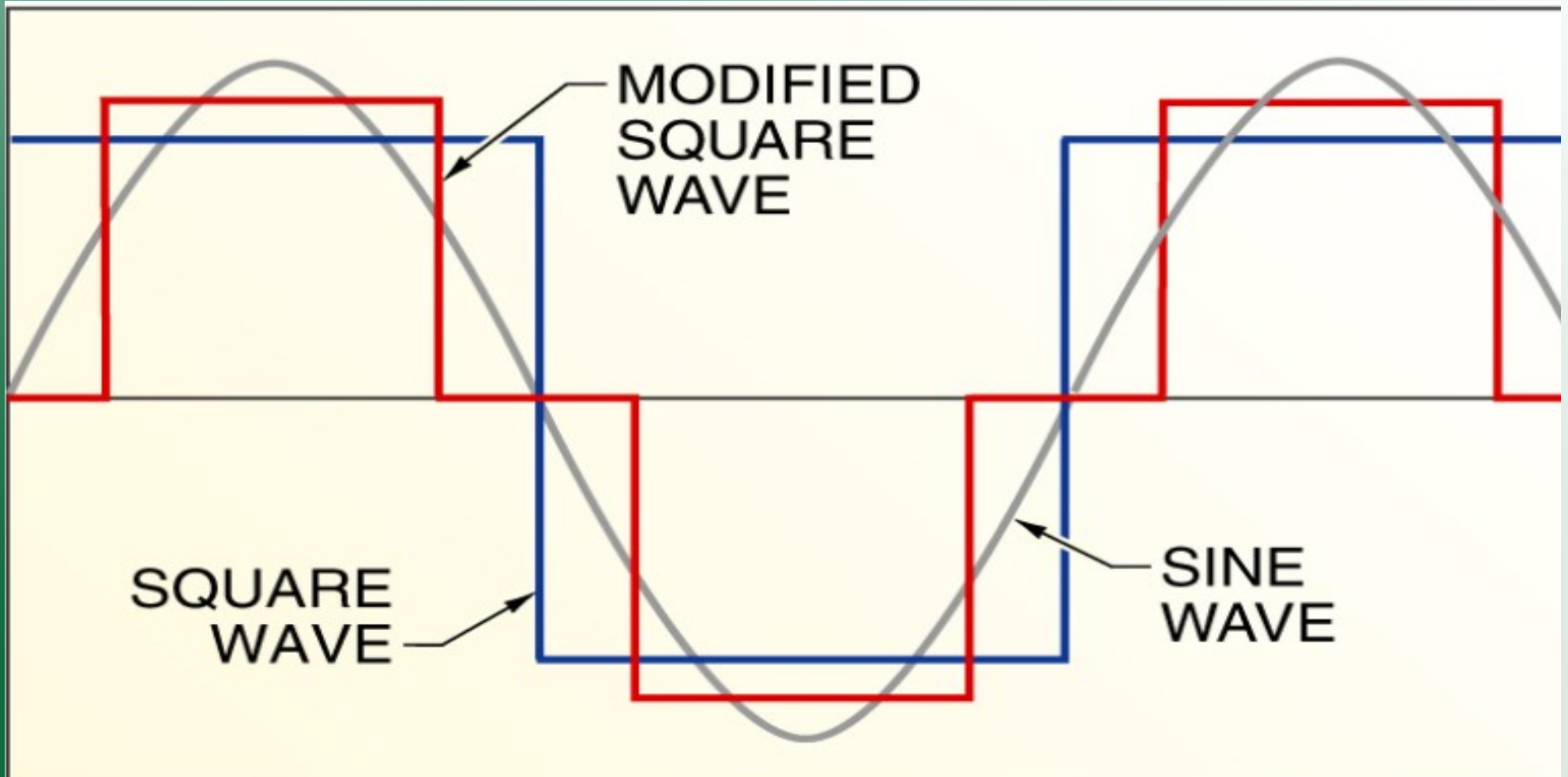


Power Conditioning Units



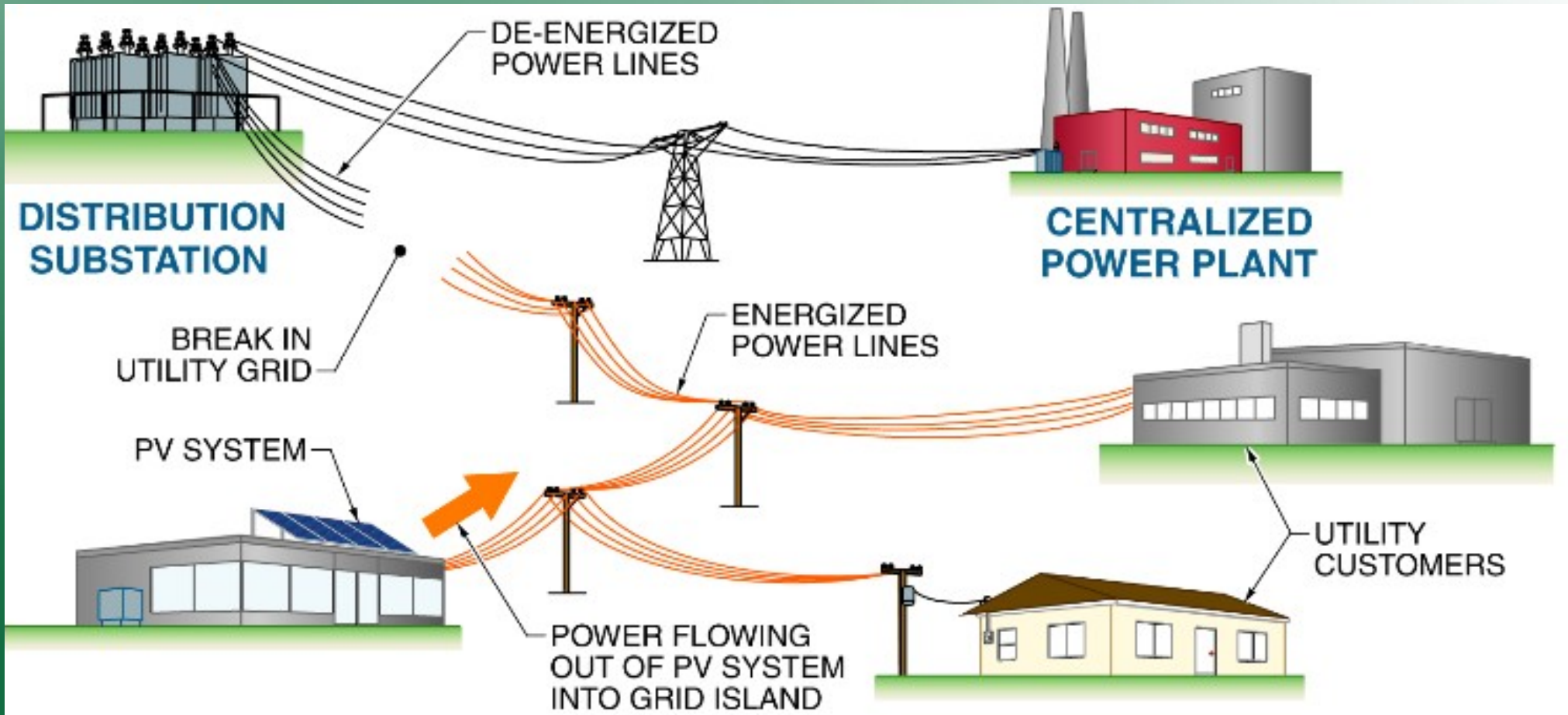


Inverter Waveforms



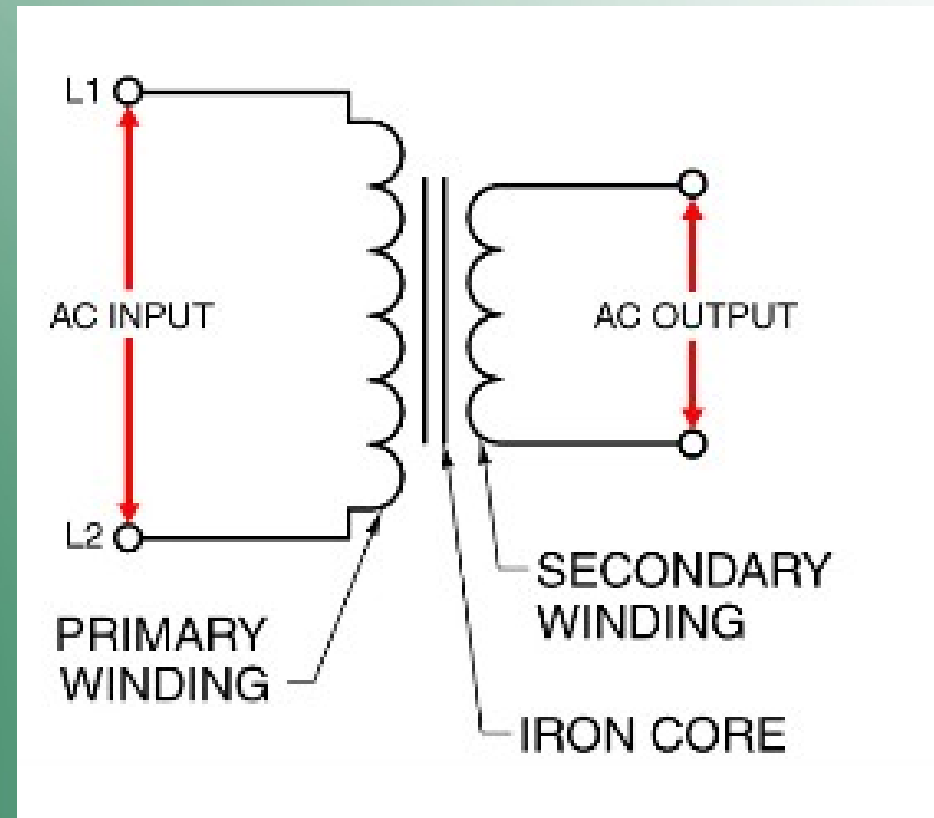
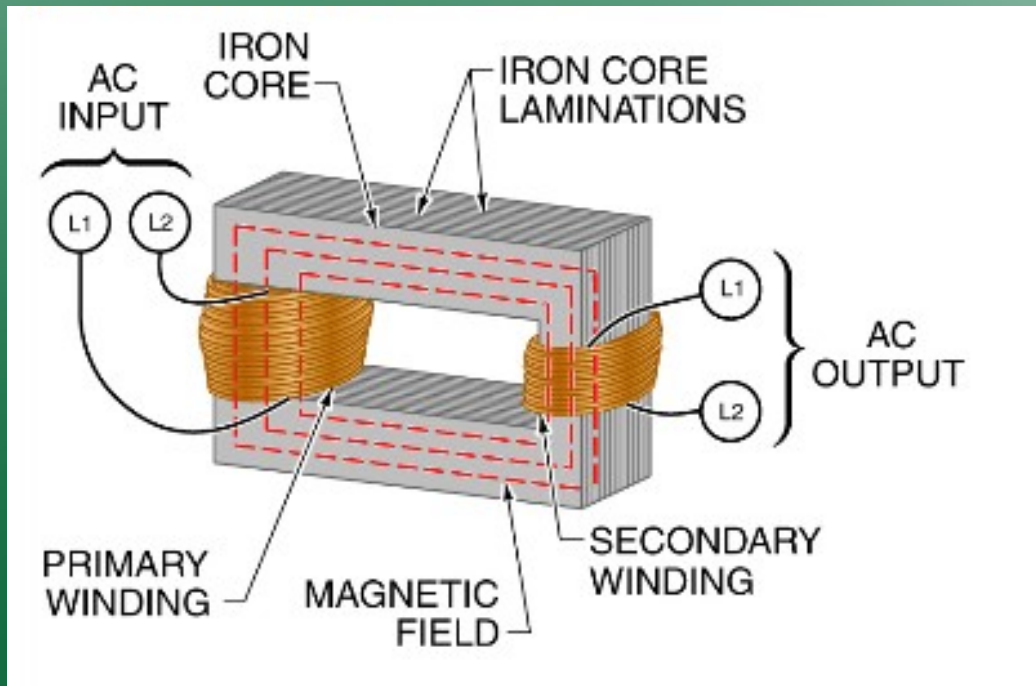


Anti-Islanding Feature (UL 1741)



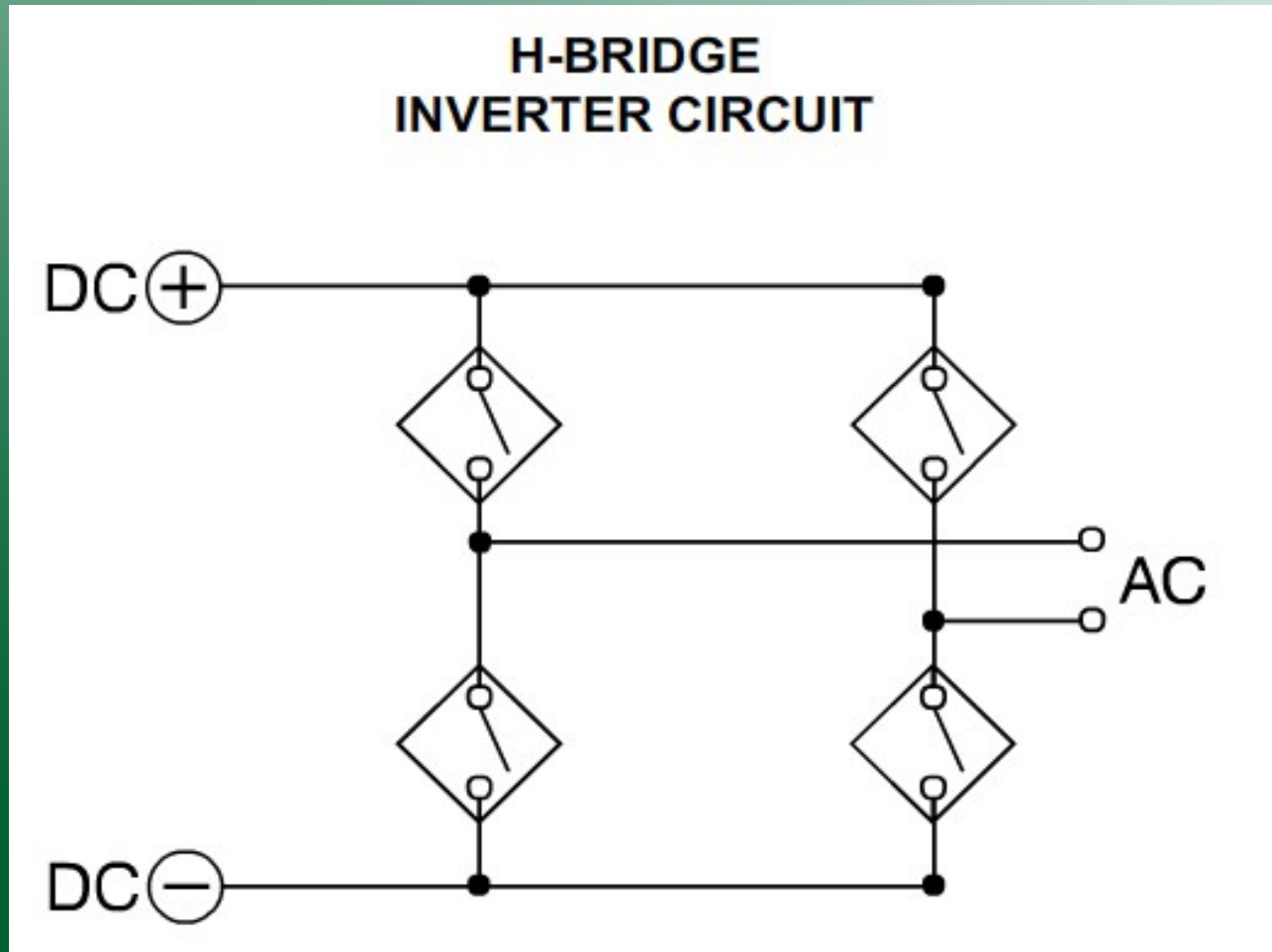


Transformer



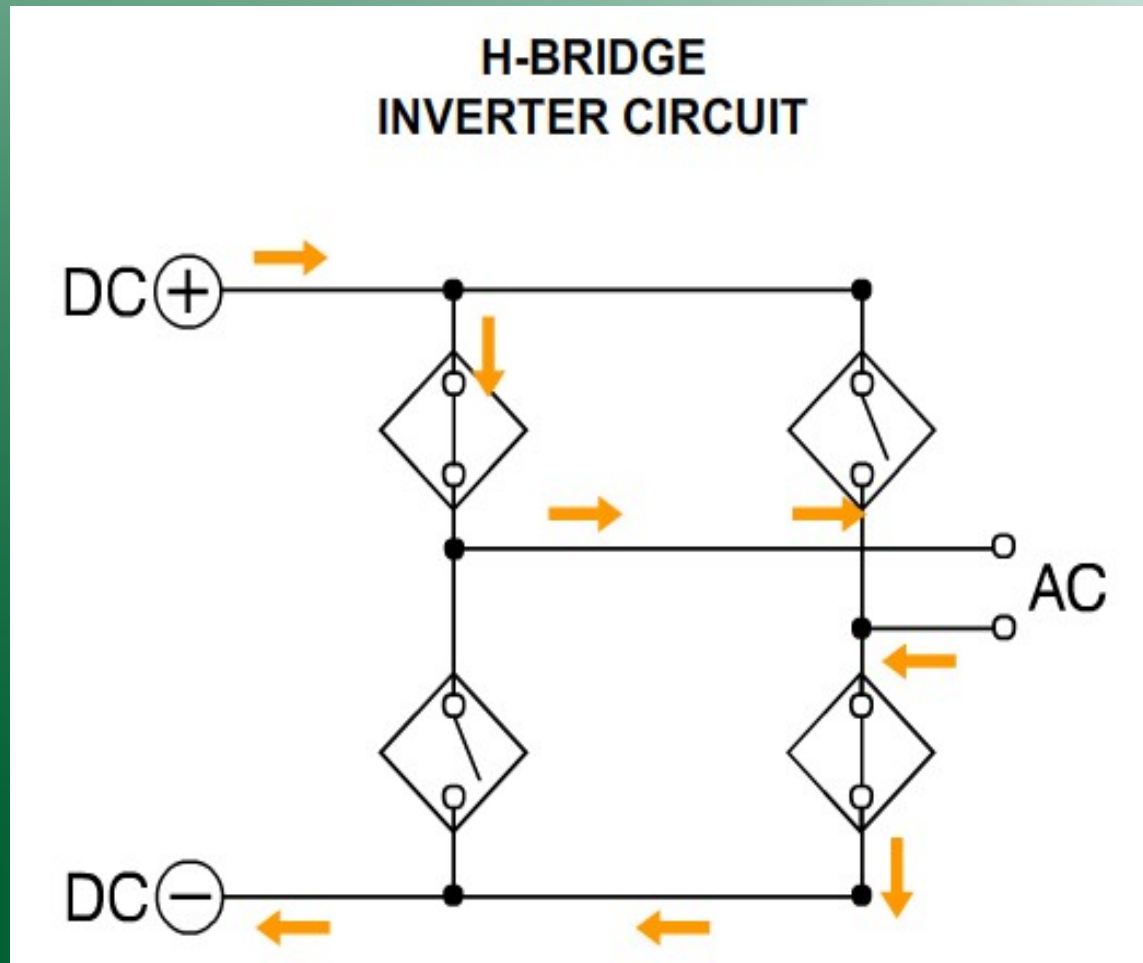


Inverter Circuits



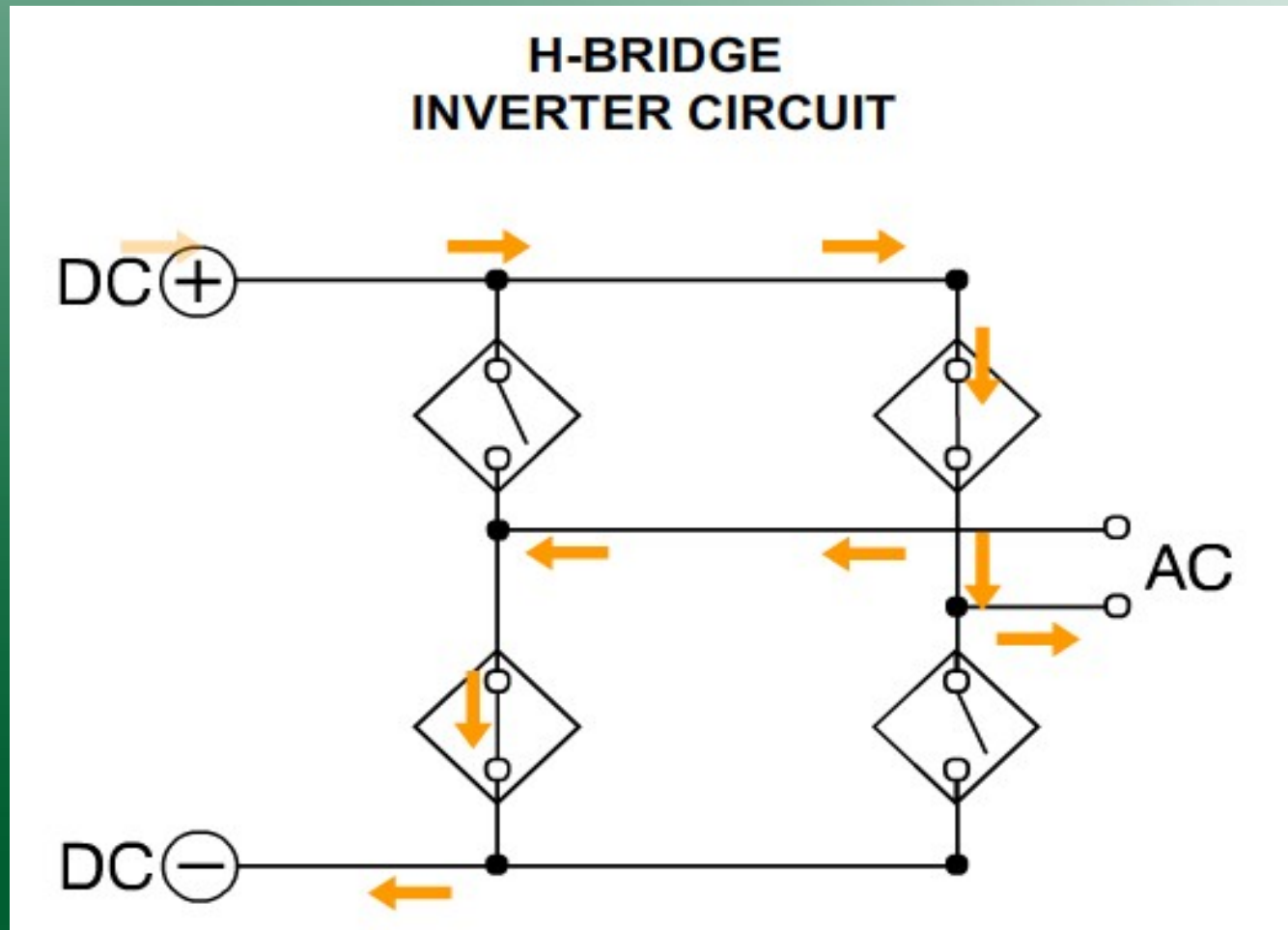


Inverter Circuit – Plus phase





Inverter Circuit – Minus phase





Next Generation Systems

- DC-DC converters in module handle MPPT and matching. Power Box, Solar Magic, Enphase
- Protecting installers with Module integrated Power Box: Low voltage until commanded by inverter
- Inverters sync to grid when available, disconnect when grid goes down (Safe Islanding)
- Smart Loads run at off peak times, allow peak shaving
- Continuing improvements in system integration