Asia-Pacific Economic Cooperation

Rooftop Solar PV System Designers and Installers

Training Curriculum

APEC Secretariat

March 2015


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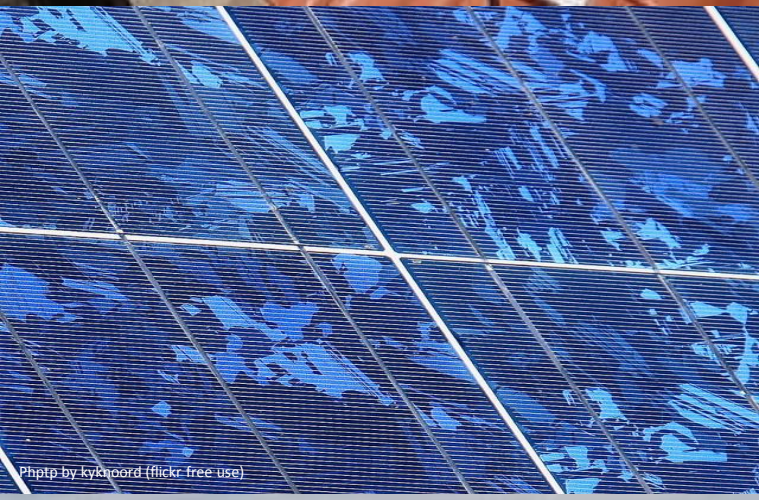
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BATTERIES and CHARGING

Training of PV Designer and Installer

APEC
Asia-Pacific Economic Cooperation

Cu International Copper Association
Copper Alliance

castlerock consulting

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B. What not to do with batteries

C. Life time cost analysis

A. Battery types

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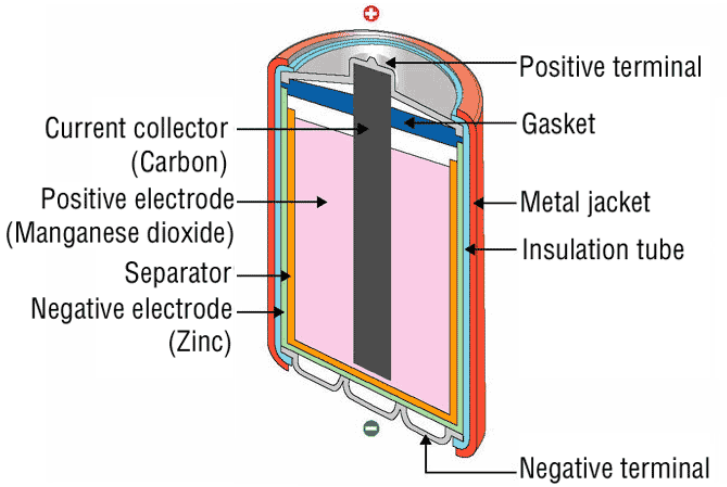
Class of batteries

1. Primary cells

- Cannot be recharged
- Chemical process not reversible

i.e: zinc carbon, alkaline



A. Battery types

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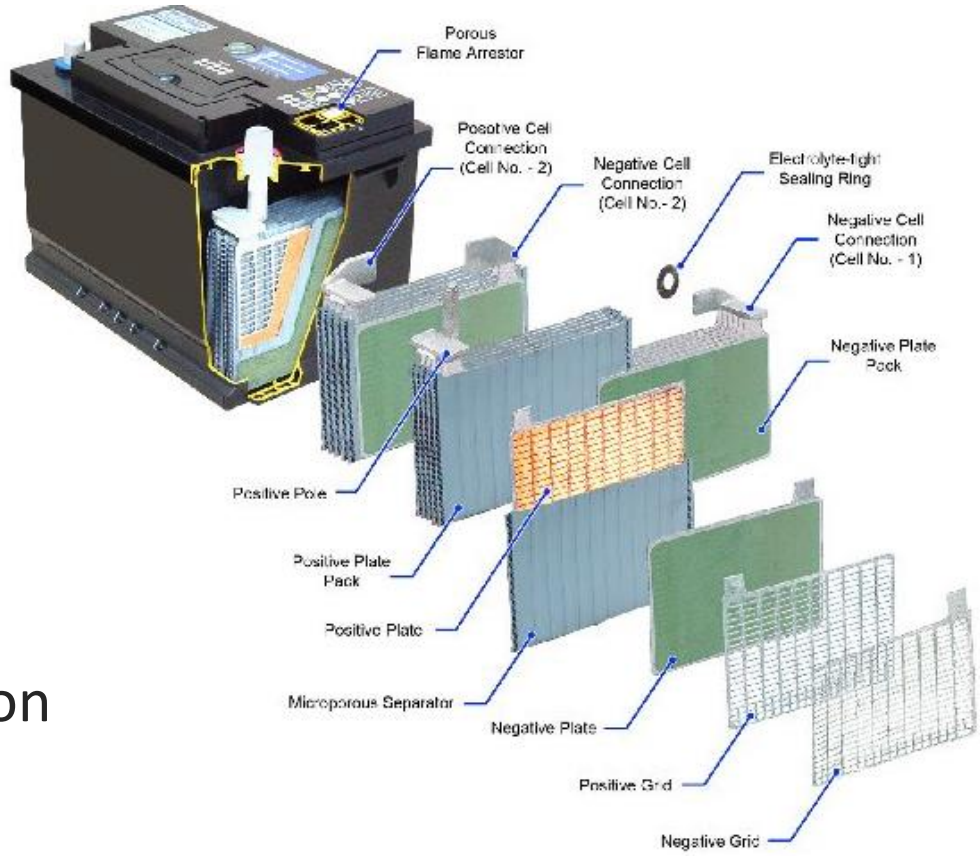
Class of batteries

2. Secondary cells

- Can be recharged
- Chemical reaction reversible

i.e: lead acid, nickel cadmium, nickel metal hydride, lithium ion



A. Battery types

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Batteries are designed for specific uses

- Deep-cycle: original battery design that was used in cars
- Maintenance-free: have cell plates made of a slightly different material
- Low-maintenance: revision of the maintenance-free battery

Battery technologies

- Flooded
- Gelled electrolyte (gel)
- Absorbed glass mat (AGM)

A. Battery types

OPzS

OPzV

AGM

How Do Batteries Work

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Essentially all batteries commonly used in Solar PV applications are lead acid construction. There are two types of lead acid batteries, flooded lead acid and sealed lead acid (VRLA). And sealed lead acid batteries, or VRLA batteries typically are constructed as gel batteries or Absorbed Glass Mat batteries.

But they're all lead acid batteries and except with specific differences are built like this:

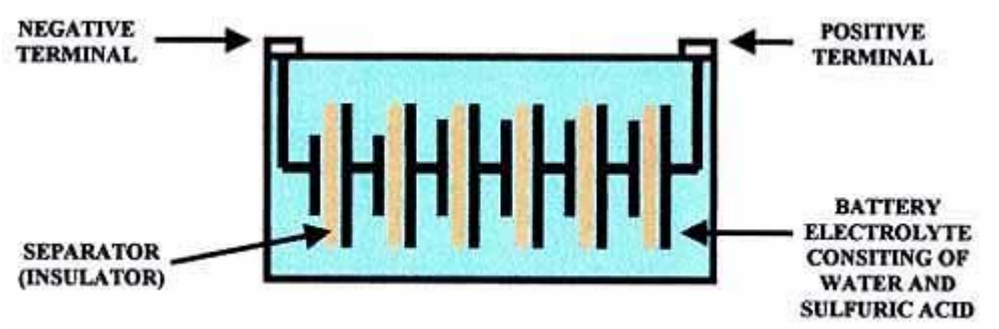

Image credits: http://www.progressivedyn.com/battery_basics.html

How Do Batteries Work

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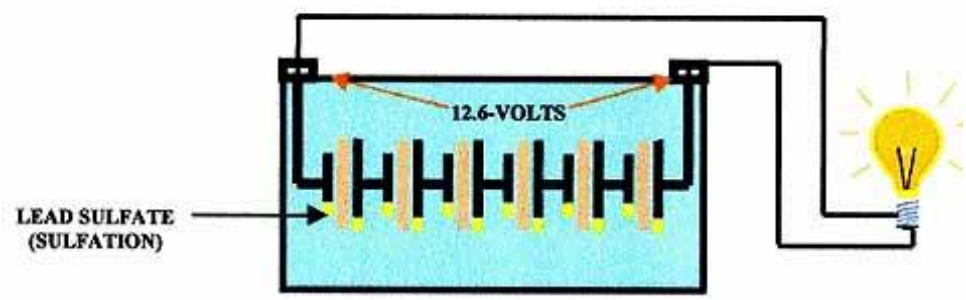
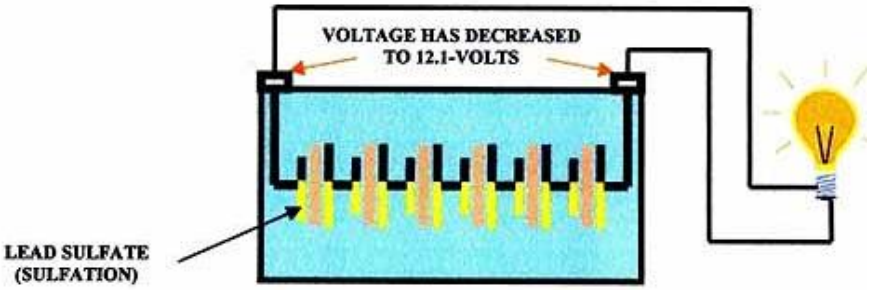
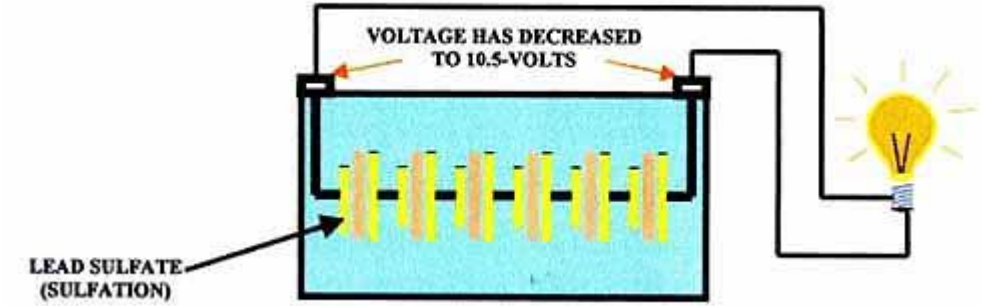
Discharging of batteries





Lead sulfate is an insulator, and when there is enough build up of lead sulfate on the plates, it prevents the electrons to move and reduces the voltage produced by the battery



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How Do Batteries Work

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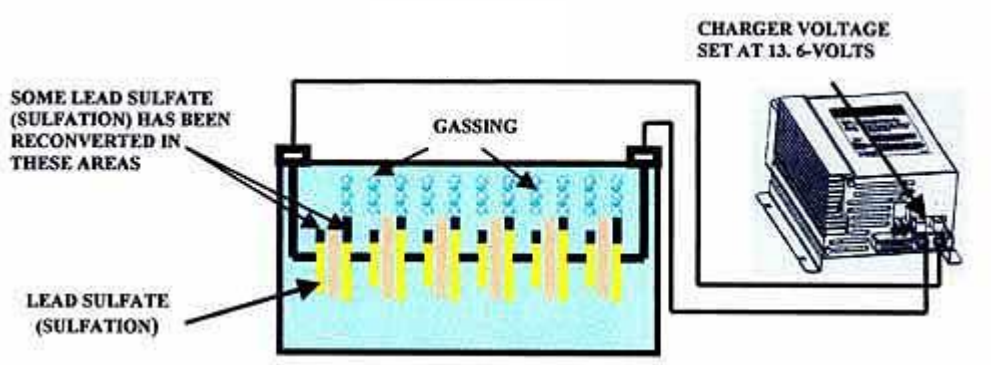
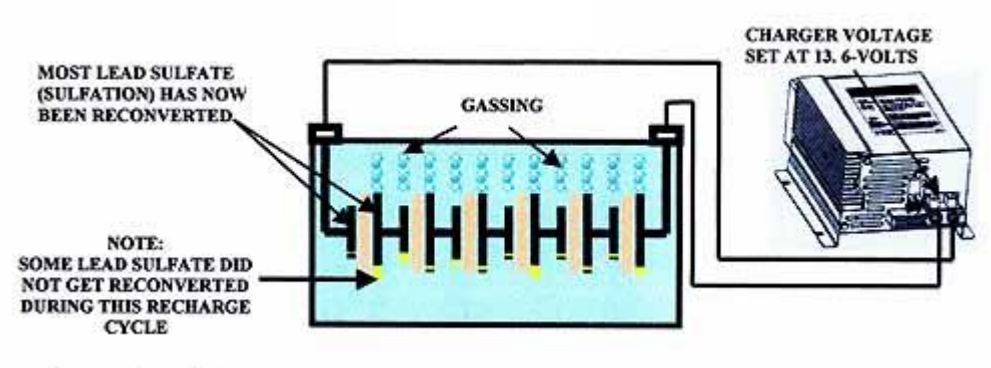
Charging of batteries





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How Do Batteries Work

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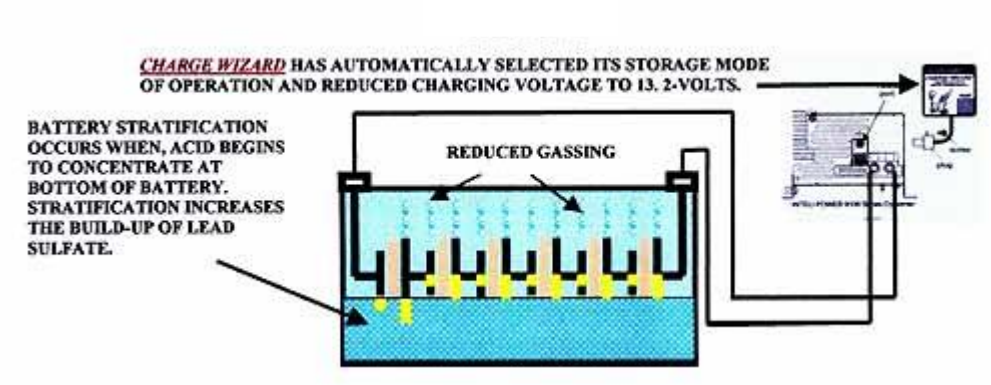
Equalization Charge



Flooded lead acid batteries typically experience stratification, where the concentration of the acid is higher on the bottom. This causes sulfation and if not treated will reduce the capacity of the batteries permanently. One simple treatment is to program an equalization charge periodically. This is when the batteries are charged at a higher voltage than normal to cause the electrolytes to mix evenly

WARNING: VRLA batteries do not require an equalization charge and can even damage the batteries

Image credits: http://www.progressivedyn.com/battery_basics.html

B. WHAT NOT TO DO WITH BATTERIES

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The following is detrimental to the life span of a battery:

- Incorrect charge voltage.
- Too low a voltage means that the battery does not charge to 100% - the sulphate then hardens on the plates and the battery loses some of it capacity. Excessive voltage causes the batteries to generate excessive gas leading to water los and drying out.
- Excessive discharging.
- Discharging a battery further than its capacity greatly (called DoD – Depth of Discharge-).
- Too many cycles, high charge voltage, excessive discharging and significant voltage ripple in the charge voltage.
- Charging without 3 step regulation and very high electrolyte temperatures.
- Loss of electrolyte
- Using tap water to add to flooded batteries

C. LIFETIME COST ANALYSIS

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A 48 VDC battery system consist of 24 pieces OPzV 2V/1000Ah which cost US$ 300 each, the cost time analysis would be like this:

a. *Total battery energy*

   24 x (2 x 1000) = 48000 Wh

b. *Total energy consumption per day*

   Design for 50% DoD; 4800 x 50% = 24000 Wh/day

c. *Battery life time*

   Commonly 2000 cycles; 2000 / 365 (days) = 5.48 years

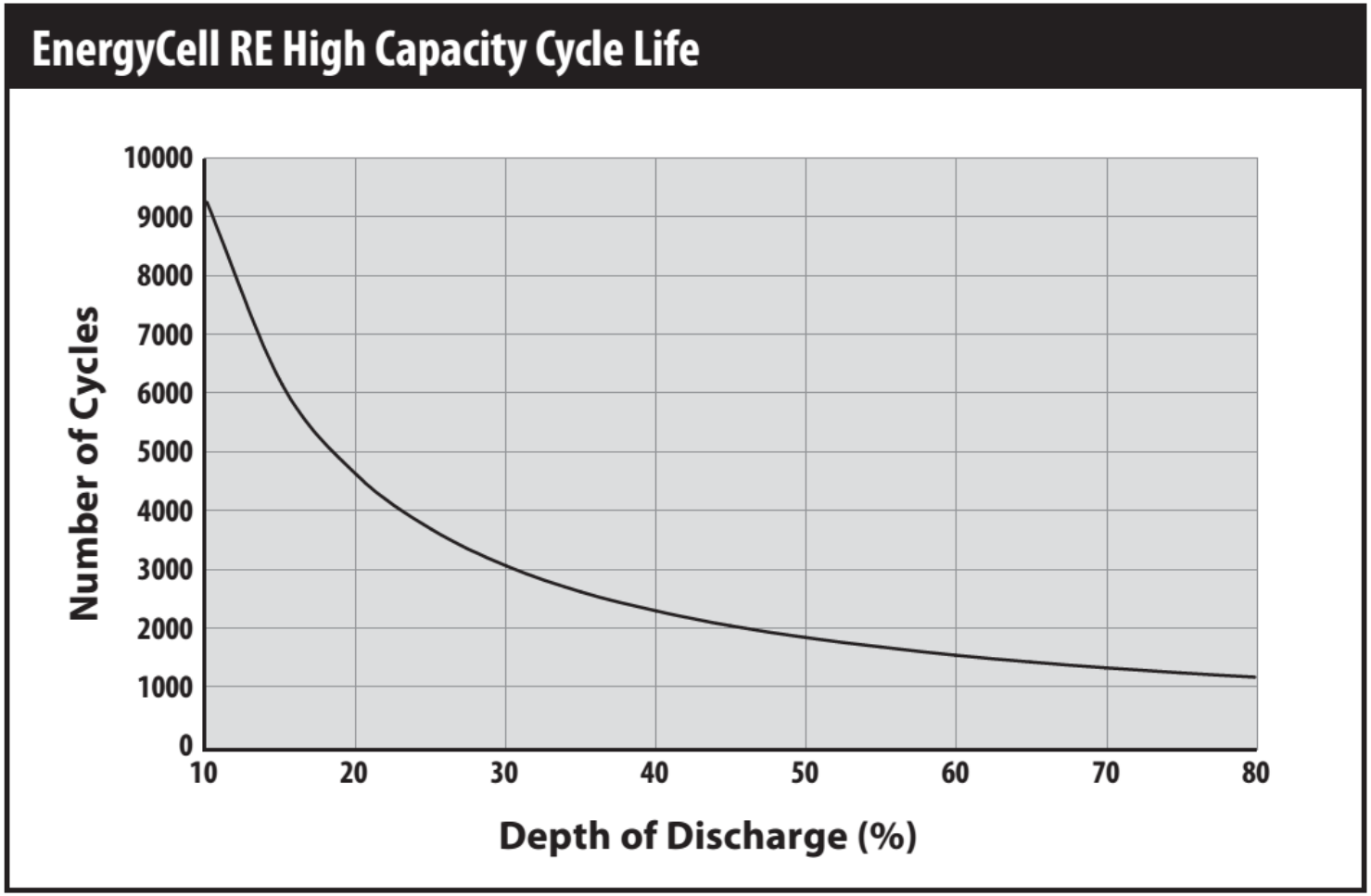
d. *Total battery energy produce for a life time*

   (24000 x 365) x 5.48 = 48.004.800 Wh

e. *Lifetime cost analysis*

   (24 x 300) / 48.004.800 = ¢ 0.015/Wh

Charging Cycle



Source: Outback The EnergyCell ® RE High Capacity battery

Solar Charge Controller

- In a solar PV system, the solar module(s) regulated by a solar charge controller is the only device that charges the batteries. Some larger systems may have a bi-directional inverters that can also charge the batteries from an AC source. This inverter is also called an inverter-charger
- Solar charge controllers come in 2 basic types, PWM and MPPT
- There are also very cheap solar charge controllers that only passes through the solar PV voltage and shuts it off when it thinks the batteries are full
- Having at least 3 stages of charging (bulk, absorption and float stages) can help the batteries last longer
- Both PWM and MPPT solar charge controllers can have these 3 charging stages

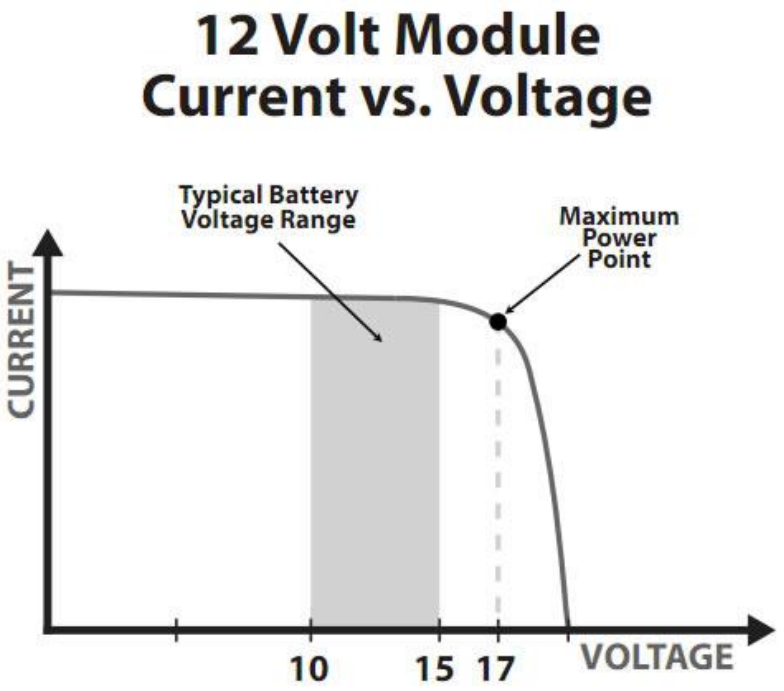
Charging Stages

- Bulk
  - Maximum voltage and current are applied
  - Typically to quickly charge the batteries up to 80% capacity
  - Needs to be programmed to the natural voltage of the batteries (AGM = 14.6-14.8 volts; Gel = 14.2-14.3 volts). Check the battery manual
- Absorption:
  - Maintain maximum voltage, current is reduced
  - Typically to finish charging the batteries up to 100% (in 2-stage chargers) or about 95% (in 3-stage chargers)
- Float:
  - Voltage will reduce to the float voltage of the battery (typically 13.2-13.4 volts; check the battery manual)
  - The current continues to decrease to a trickle. This stage may also be called the trickle charge
  - This stage (between 95-100% full) is the state at which the batteries will last the longest. When kept at this stage and never used below 95%, some batteries can last 15-20 years (depending on the construction and battery chemistry)

PWM vs MPPT

PWM :

- Using pulses of energy, high current can be used without overheating the battery
- The ratio between the “on” pulse and the “off” pulse determines the rate of charging into the battery
- Wide pulses with little time between them provide high charging rate
- Narrow pulses with a lot of time between them provide low charging rate



Source: Morningstar Corporation

PWM vs MPPT

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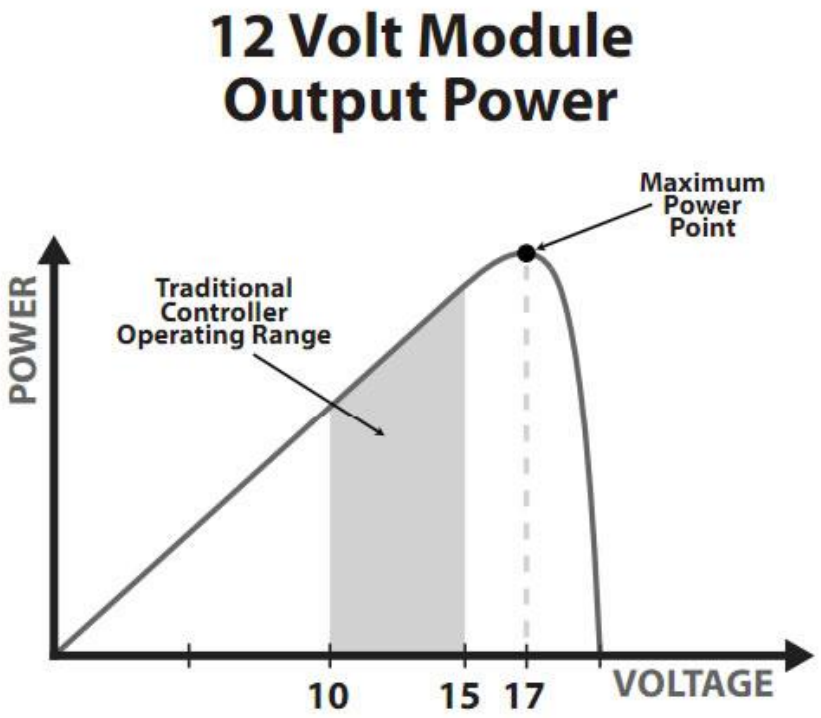
MPPT : is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more PV devices, typically solar panels, though optical power transmission systems can benefit from similar technology.



Source: Morningstar Corporation

PWM vs MPPT

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PWM Charge Control	MPPT Charge Control
PV array & battery voltages must match	PV array voltage can be much higher than battery voltage
Operates at battery voltage so it performs well in warm temperatures and when the battery is almost full	Operates above battery voltage so it is can provide “boost” in cold temperatures and when the battery is low.
Typically recommended for use in smaller systems where “boost” benefits are minimal	170W or higher to take advantage of “boost” benefits more
Must use off-grid PV modules typically with Vmp ≈ 17 to 18 Volts for every 12V nominal battery voltage	Enables the use of lower cost/grid-tie PV Modules helping bring down the overall PV system cost
PV array sized in Amps (based on current produced when PV array is operating at battery voltage)	PV array sized in Watts (based on the Controller Max. Charging Current x Battery Voltage)
Simpler series switching charge control circuit	Additional Energy Harvest by operating at PV peak power point rather than battery voltage

Asia-Pacific
Economic Cooperation

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