جامعة فهد بن سلطان
FAHAD BIN SULTAN UNIVERSITY

MECH 453 Introduction to Renewable Energy

CHAPTER FOUR

Describe photovoltaic system components and connection techniques for stand alone and grid connected

Course lectures Slides prepared by

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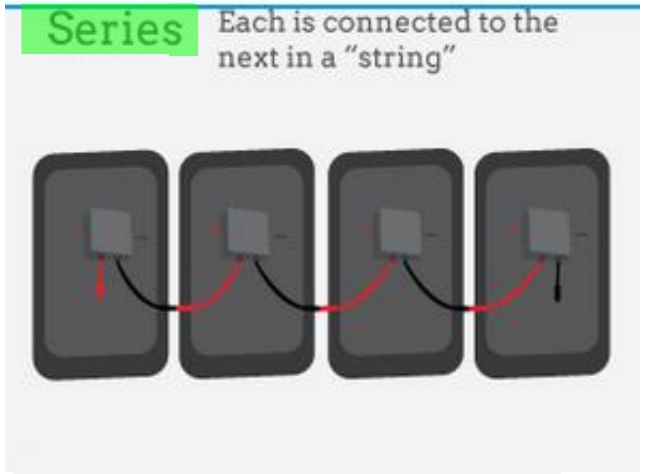
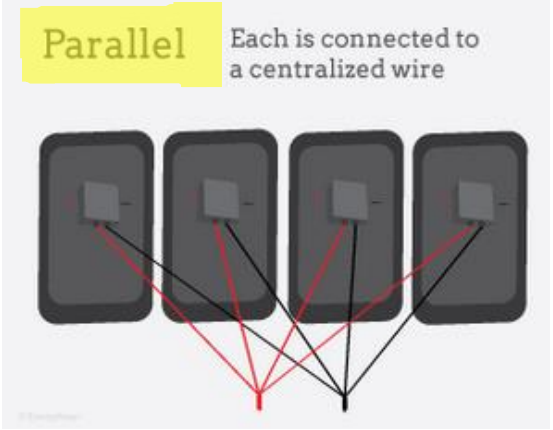
Sub-outcome 5: Describe photovoltaic panel, series, parallel and connection techniques

Describe photovoltaic Panels, Series, Parallel connection Techniques.

1) When circuits are wired in series:
   a) the voltage of each panel is added together, but
   b) the amperage remains the same.
2) When circuits are wired in parallel,
   a) the voltage of each panel remains the same and
   b) the amperage of each panel is added.



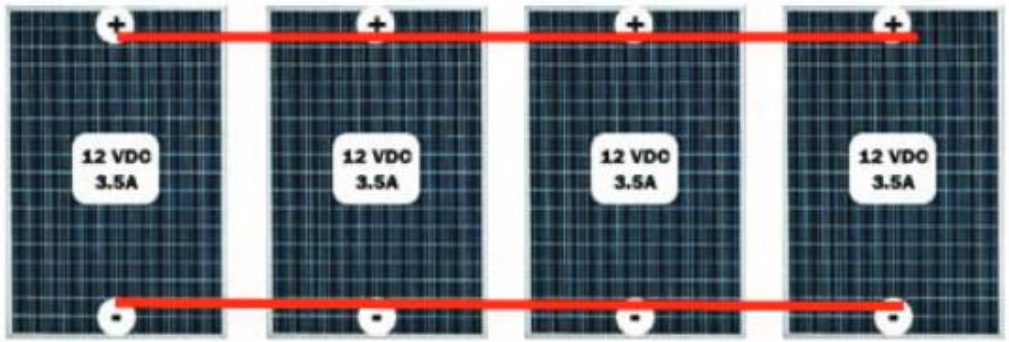


This wiring principle is used to build photo-voltaic (PV) modules. The PV cells in a module can be wired to any desired voltage and current.

- Photovoltaic modules can then be wired together to create PV arrays.

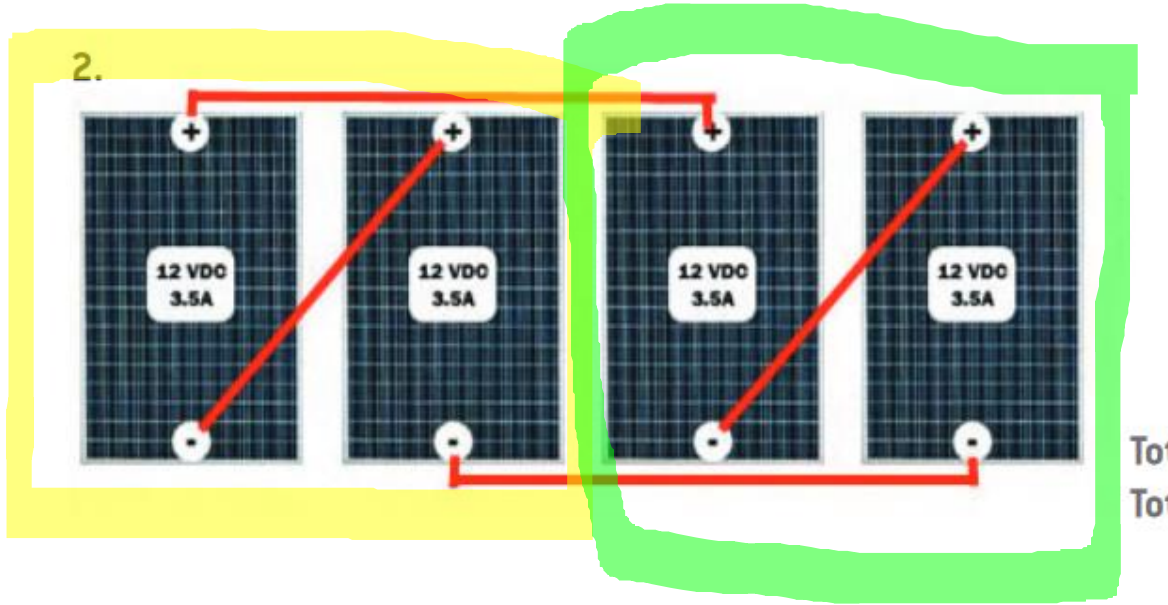
Series, Parallel connection Techniques.

1.



Total Volts = 12
Total Amps = 14

2.



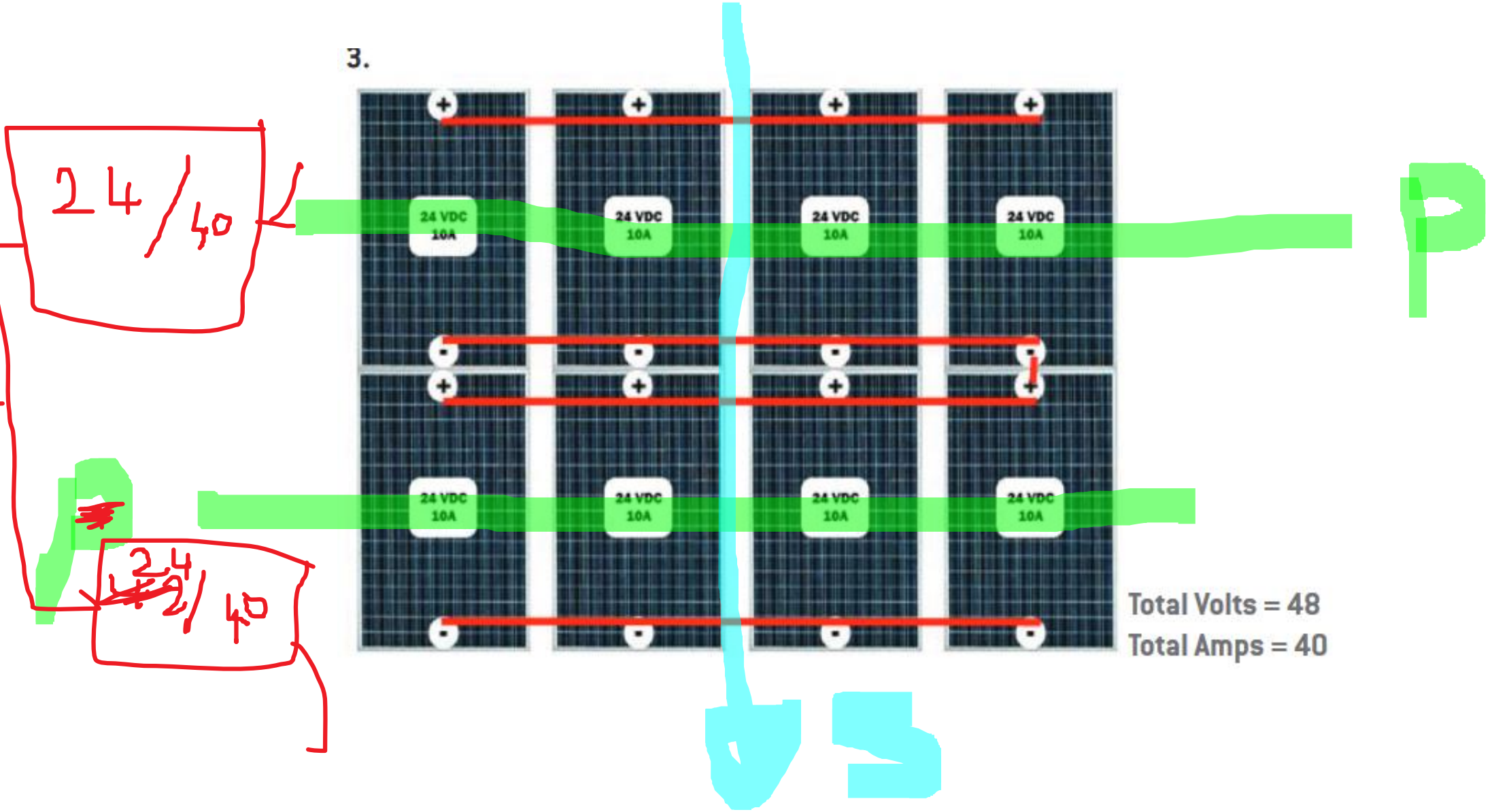
A

B

Total Volts = 27 24
Total Amps = 7

48 / 40

Series, Parallel connection Techniques.

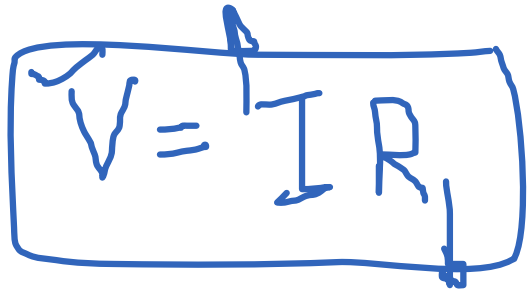


Choosing the Right Wire Size

https://www.windynation.com/jzv/inf/choosing-right-wire-size

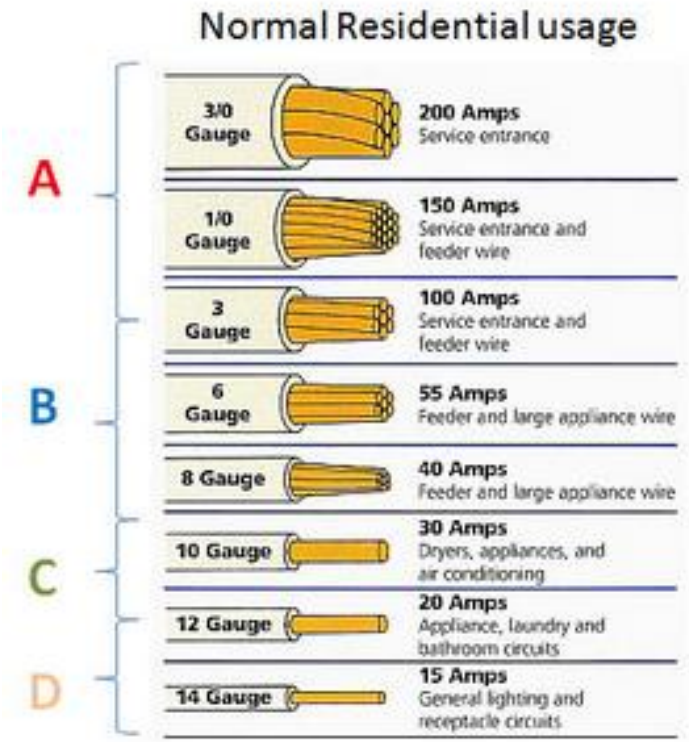
- Choosing the right wire sizes in your PV system is important for both performance and safety reasons. If the wires are undersized, there will be a significant voltage drop in the wires resulting in excess power loss. In addition, if the wires are undersized, there is a risk that the wires may heat up to the point in which a fire may result.

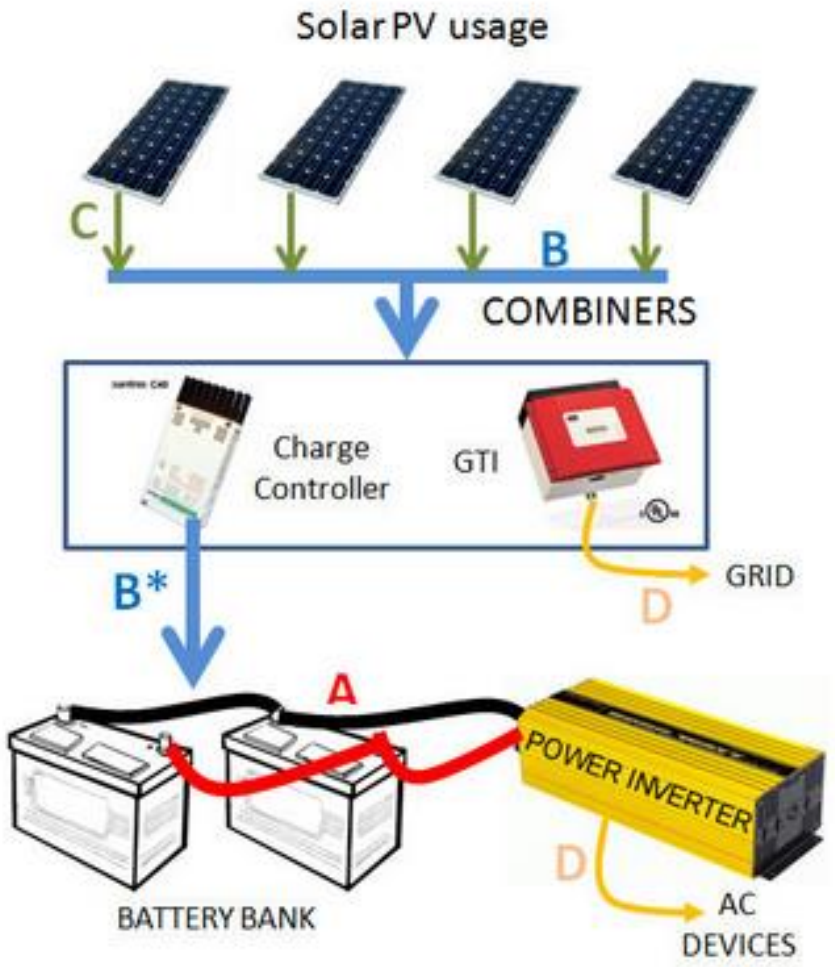
- **Copper wires** are sized using the gauge scale: **American Wire Gauge (AWG)**. The lower the gauge number, the less resistance the wire has and therefore the higher current it can handle safely.



Choosing the Right Wire Size

- The chart shows the capacity of various wire gauge sizes and their typical amp rating and application for both residential and solar applications.





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Choosing the Right Wire Size

- Commercial solar PV panels over 50 watts or so use 10 gauge (AWG) wires. This allows up to 30 amps of current to flow from a single panel. If multiple panels are combined in parallel, then a three to eight AWG "combiner" wire set is generally needed to safely transfer the power to a charge controller or GTI.
- The wires from the charge controller to the battery bank can generally be the same or larger gauge than the main set from the PV array. The exception (B*) is when the Charge Controller is of the type that can operate a 12 or 24-volt battery bank even when the PV array is operating at higher voltages, such as 48 Vdc and larger. These Charge Controllers have large transformers that lower the voltage but in the process they increase the current going to the battery bank. Refer to the installation material for the charge controller you chose when selecting the correct wire size to use.
- The wires between batteries in a battery bank tend to be the largest in the system since they are used in conjunction with a power inverter that can at times demand more current than that the PV system can supply on its own. These same wires will also have to carry current used simultaneously for charging and for power inversion. A typical battery bank wire size is 1/0 or "one-ought."
- It is very important to match the gauge and the wire lengths when combining batteries in a battery bank. If this is not done, then the battery bank's life can be shortened and certain safety issues can result.

Choosing the Right Wire Size

Usually the longest wire run is from the PV array to the location where the charge controller or GTI is located. Since all of the combined PV power flows through this wire set, we really need to choose it correctly to maximize performance and to assure safety.

The general rule-of-thumb is to stay below 2% Voltage drop on this run. Using the known resistance of the various wire gauges, it is possible to calculate the maximum length for a wire-pair for each wire gauge size.

Here is what that calculation looks like for a 12V PV system. You can double the length for a 24V system, or quadruple it for a 48V system.

Choosing the Right Wire Size

$W = V I$

- **Example:** Let's take a 450-watt 12V system. At the Vmp of 18V, the maximum current is 450/18 = 25 amps.
- Looking at the wire capacity row, **10 AWG** is the **smallest** gauge wire that can safety be used. It is rated at **30 amps**, higher than the required 25 amps.
- Next, we look at the Array amps column, select row "25" and you can see that a 10 AWG wire pair only supports a cable length of 4.5 feet! Going up to 4 AWG supports up to 18 feet to stay within the 2% loss criteria. This is not a lot of feet!

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2% Voltage Drop Chart						
AWG =	14	12	10	8	6	4
Capacity(AMPS)	15	20	30	40	55	70
ARRARY AMPS	FEET ONE WAY FOR A PAIR OF WIRES					
1	45	70	115	180	290	456
2	22.5	35	57.5	90	145	228
4	10	17.5	27.5	45	72.5	114
6	7.5	12	17.5	30	47.5	75
8	5.5	8.5	11.5	22.5	35.5	57
10	4.5	7	9.5	18	28.5	45.5
15	3	4.5	7	12	19	30
20	2	3.5	5.5	9	14.5	22.5
25	1.8	2.8	4.5	7	11.5	18
30	1.5	2.4	3.5	6	9.5	15
40			2.8	4.5	7	11.5
50			2.3	3.6	5.5	9
100					2.9	4.6

Choosing the Right Wire Size

- What this example illustrates is that we need to greatly appreciate the issue of cable length and its effect on losses. Many people have long cable runs and don't realize the impact this has on performance. Sometimes we have to tolerate perhaps a **4% loss rather than 2%,** allowing us to double the length values shown in the table. Another option is to operate at a higher voltage, such as 24V. This reduces the amps which reduces the wire losses.
- The point is to design your system using a safe wire size but also to be conscious of the trade-off between system voltage, wire length, line losses, and costs. This is why planning should be done in detail before you rush out to buy things like cables.

How to properly fuse a solar PV system

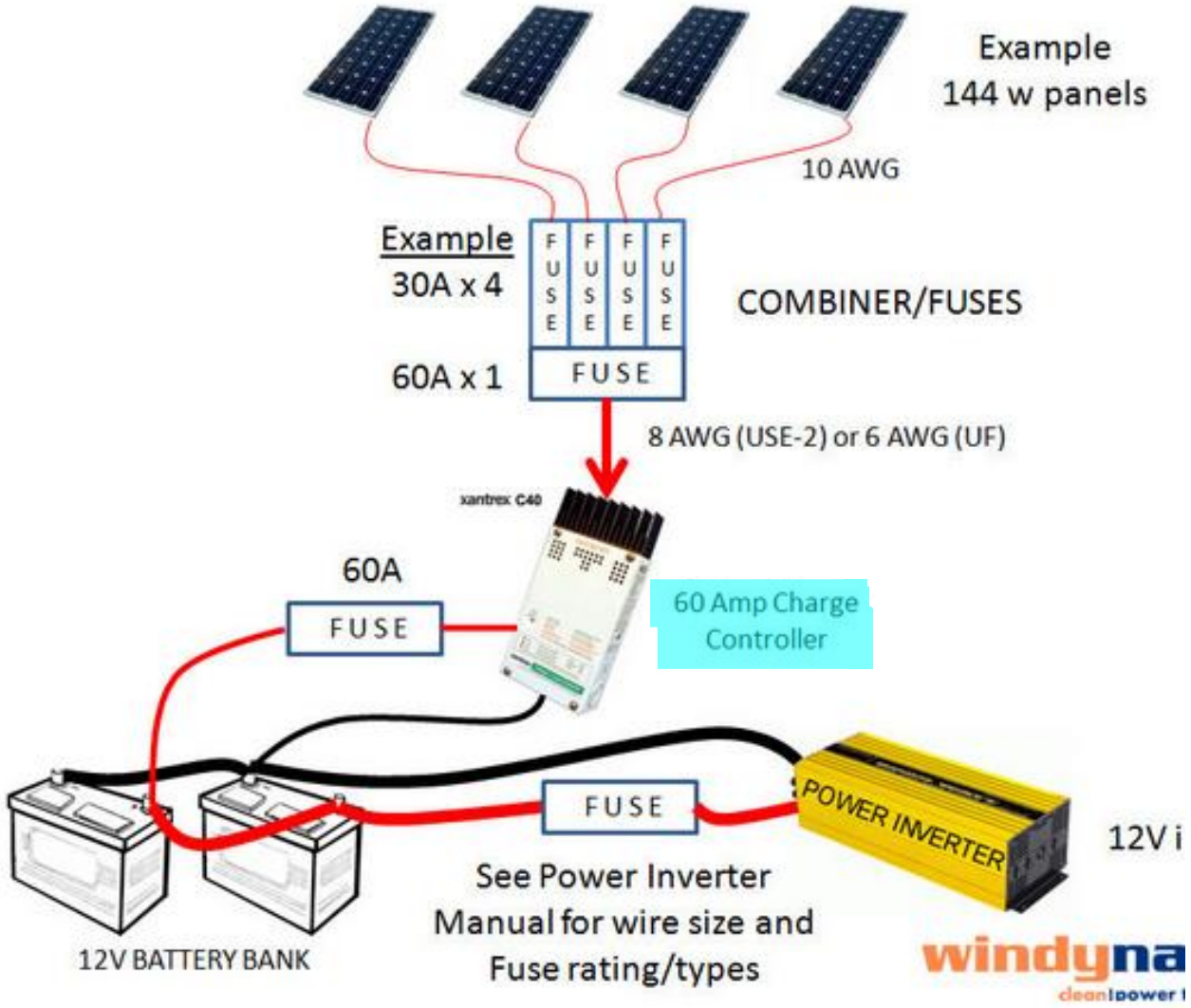
https://www.windynation.com/jzv/inf/how-properly-fuse-solar-pv-system

- The first thing to know is that fuses and **circuit breakers** are primarily used to protect the system wiring from getting too hot and catching fire.
- Secondly, they also are used to protect devices from catching fire or from becoming more seriously damaged if there is a **short circuit**.

A good example is a 12V lead acid battery. If a short develops in your AC/DC inverter for instance, a fuse between it and the battery will prevent a possible explosion of the battery and it will cut the circuit fast enough to prevent the wires from catching fire or getting dangerously hot. In this case, the battery, wires, and AC/DC inverter will be safely disabled by the fuse.

Solar Panel & Parallel/Combiner Box fusing

https://www.windynation.com/jzv/inf/how-properly-fuse-solar-pv-system



Sub-outcome 6:Describe photovoltaic system components and connection techniques for stand alone and grid connected.

Describe photovoltaic system components and connection techniques for stand alone and grid connected.

Solar Electric – Basic Components

- **1. Modules** – solar electric collectors. 3 basic types in the marketplace: Mono crystalline, poly crystalline, thin film

  2. Array – modules connected together into a system

  3. Inverter – converts the DC power produced by the modules to A/C

- **4. Grid Tie Inverter** – converts DC to AC and feeds the utility grid with the A/C power
- **5. Charge Controller** – regulates the power going to the batteries
- **6. Batteries** – stores DC power

Types Of Systems

1. Stand Alone – Off grid

- Modules, charge controller, batteries, and may or may not have an inverter which converts DC power to A/c power

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2. Grid Tie – Grid connected

- Modules, and inverter connected to the power grid

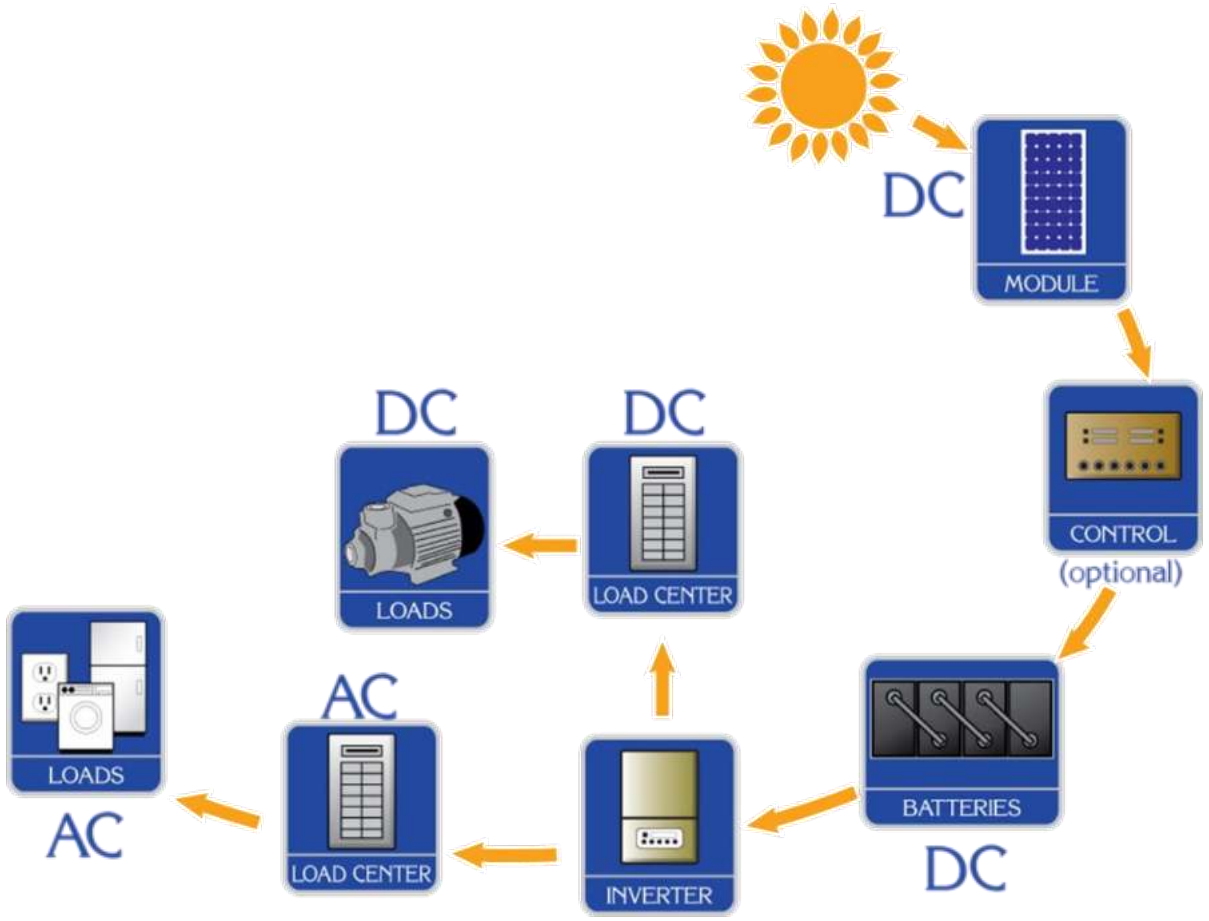
3. Hybrid – Grid connected with batteries

- Modules, grid-tie inverter, and batteries for storage when the grid is unavailable

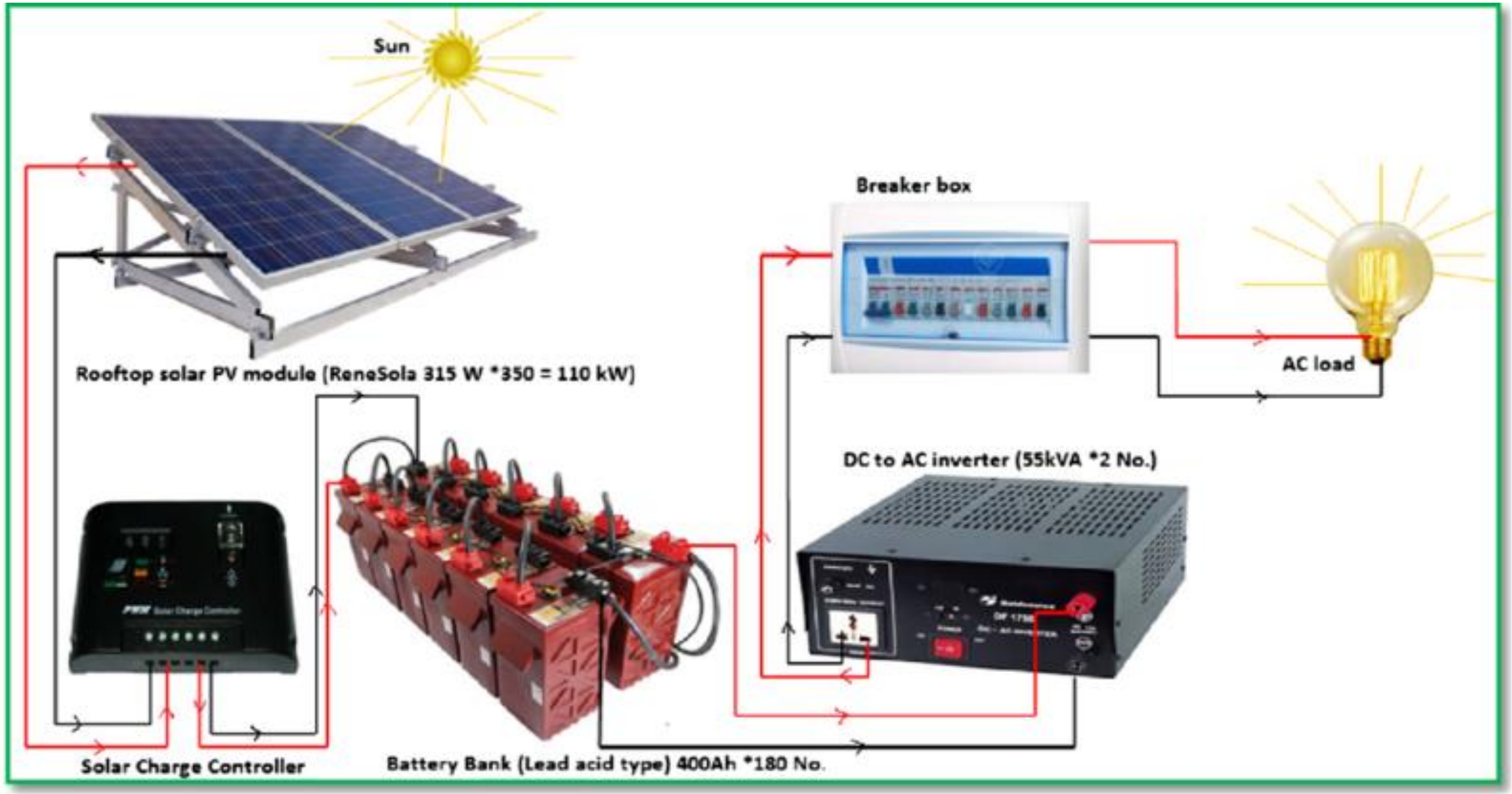
1. OFF – Grid system

Stand-alone PV systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC and/or AC electrical loads.

- Common applications are direct power to DC loads, water pumping and telecommunications.
- With an inverter it can also power AC loads
- For systems with no battery the energy is used immediately; only works when it's sunny



OFF – Grid system



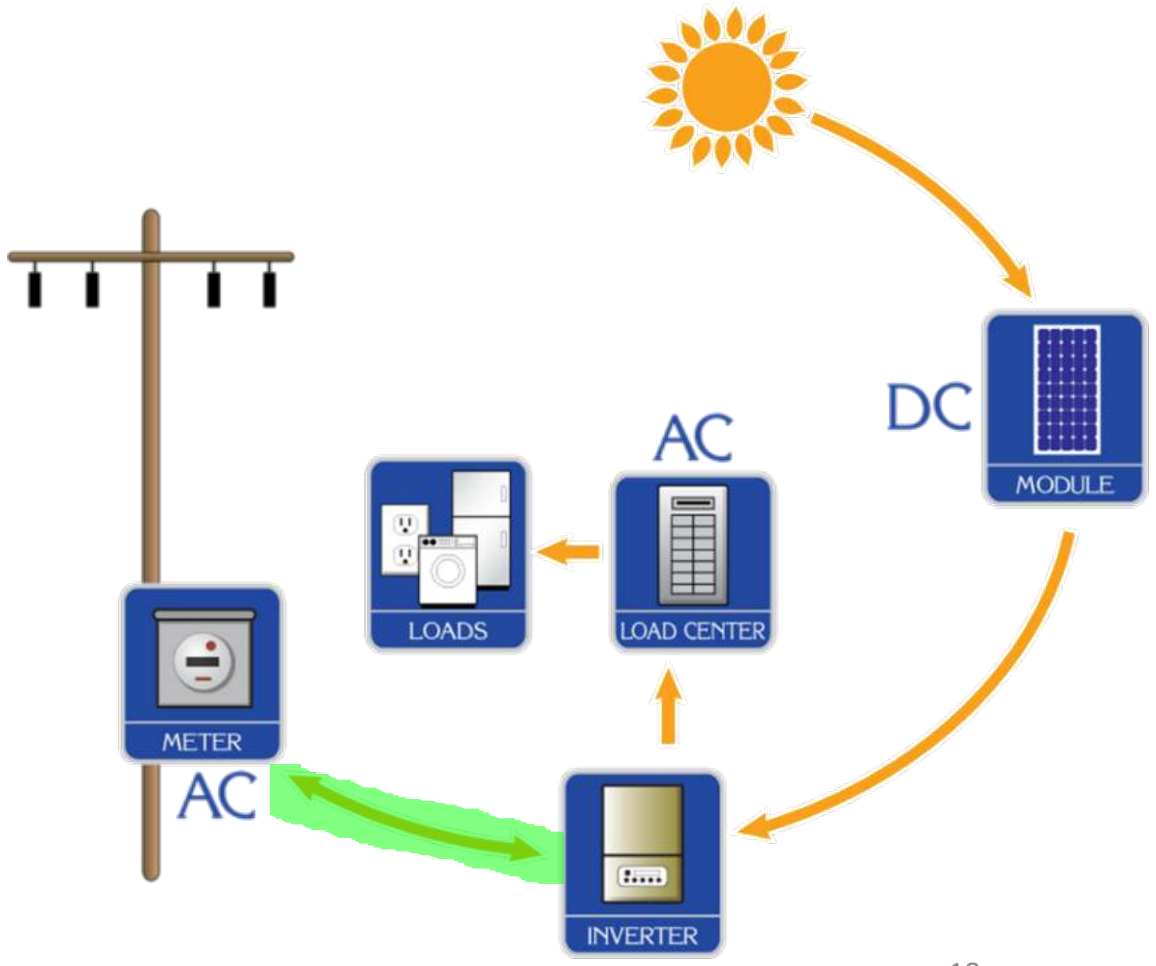
2. Grid Tie – Grid Connected System Components

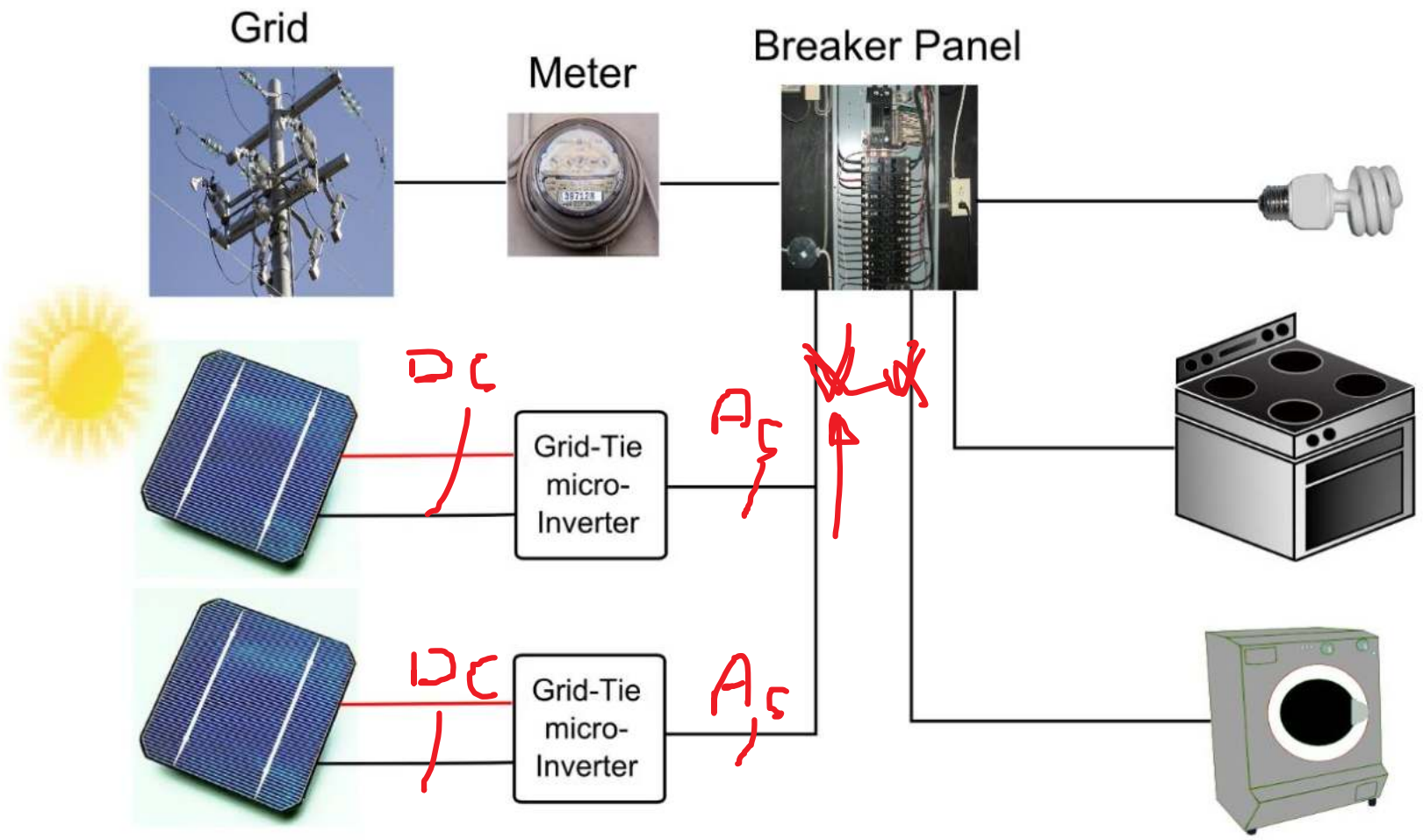
Grid Tie System is the simplest and most cost effective way to connect PV modules to regular utility power.

Grid-Connected systems can supply solar power to your home and use utility power as a backup.

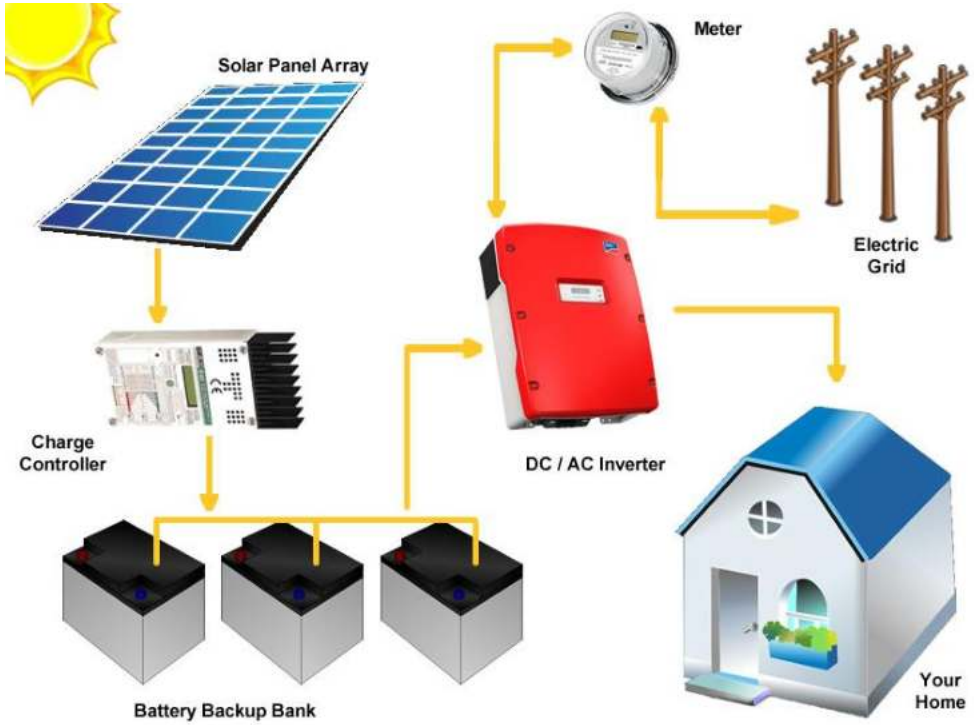
As long as there is enough electricity flowing in from your PV system, no electricity will flow in from the utility company.

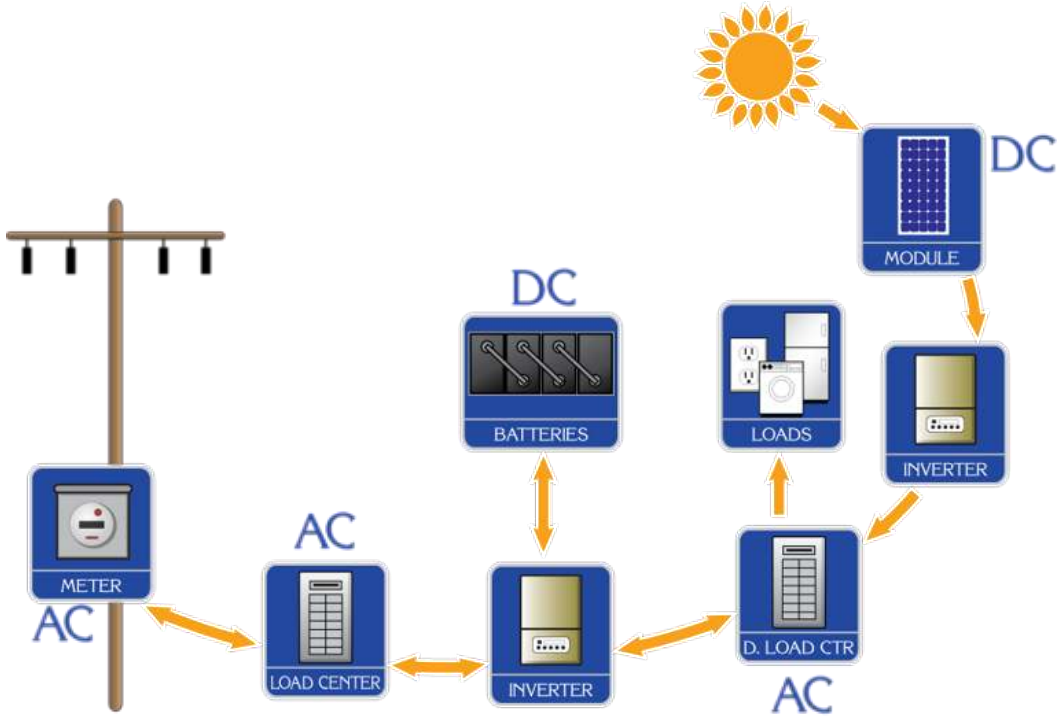
If your system is generating more power than you are using, the excess will flow back into the grid, turning your meter backwards.




Grid
Meter
Breaker Panel
Grid-Tie micro-Inverter
Grid-Tie micro-Inverter

3. Hybrid – Grid Connected with Batteries - Components





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Sub-outcome 7: Identify the needs and various types of energy storage systems.

Identify the needs and various types of energy storage systems.

- **Gel Cell, Absorbed Glass Mat (AGM), and Wet Cell are various versions of lead acid batteries**.
- The Wet comes in two styles: serviceable, and maintenance free.
- Gel Cell and the AGM batteries are specialty batteries that typically cost twice as much as a premium Wet Cell battery.
- However, Gel cell and AGM batteries do not tend to sulfate or degrade as easily as Wet Cell. As a result, there is little chance of a hydrogen gas explosion, or corrosion of electrical components and wiring in close proximity when using these batteries.
- In most cases AGM batteries will give longer life span and greater cycle life than a Wet Cell battery.

What is the difference between Gel Cell/AGM and traditional Wet Cell batteries?

- Wet Cells contain liquid electrolyte that can spill if tipped or punctured, causing corrosion to affected areas.
- Therefore, they are not air transportable without special containers. They cannot be shipped via UPS or Parcel Post, and should not be used near sensitive electronic equipment. They can only be installed "upright."

What are the advantages and disadvantages of the different types of battery designs?

- **GELLED ELECTROLYTE**
- ***Advantages***
- **Totally maintenance free** **Superior deep cycle life when compared to AGM** **Air transportable**
- **Spill proof/leak proof** **Minimal corrosion thus physically compatible with sensitive electronic equipment**
- **Installs upright or on side** **Very low to no gassing (unless overcharged)**
- **Superior shelf life when compared to Wet Cell** **No recharge current limitation @ 13.8 volts** **Rugged and vibration-resistant**
- **Very safe at sea with no chlorine gas in bilge (due to sulfuric acid and salt water mixing)**
- **Most versatile: Starting. Deep Cycle, Stationary** **Lowest cost-per-month (cost / months of life)**
- **Lowest cost-per-cycle (cost / life cycles)**
- ***Disadvantages***
- **Higher initial cost** **Water cannot be replaced if continually overcharged**
- **Voltage-regulated chargers must be used** **Charge voltage must be limited to extend life (13.5 to 13.8 volts maximum at 68°F)**

Absorbed glass mat or AGM batteries or ABSORBED ELECTROLYTE

Advantages

- Ideal for standby or back-up applications
- Higher charge and discharge currents
- Totally maintenance-free
- Air transportable
- Spill proof/ Leak proof
- Minimal corrosion thus physically compatible with sensitive electronic equipment
- Installs upright or on side
- Lower cost than gel cell batteries
- Very low to no gassing (unless overcharged)
- Excellent for starting and stationary applications
- Superior for shorter duration/higher discharges

- Disadvantages

- ½ the cycle life of Gel or flooded Wet Cell in deep cycle applications
- Charge voltage must be limited (14.1 to 14.4 volts maximum at 68°F)
- Voltage-regulated chargers must be used
- Water cannot be replaced if continually overcharged

WET CELL (FLOODED ELECTROLYTE)

Advantages

- Lowest initial cost
- Water can be added (if accessible)
- Excellent for higher current applications
- Certain designs are good for deep cycle applications
- Replacements readily available

Disadvantages

- Spillable
- Operates upright only
- Emits corrosive Gases and thus cannot be installed near sensitive electronic equipment
- Cannot be installed near sensitive electronic equipment
- Maintenance required (if accessible)

Batteries in Series and Parallel