جامعة الانبار
كلية العلوم التطبيقية – هيت
قسم الفيزياء الحياتية

Renewable Energy Course

Photovoltaic System Design and Installation

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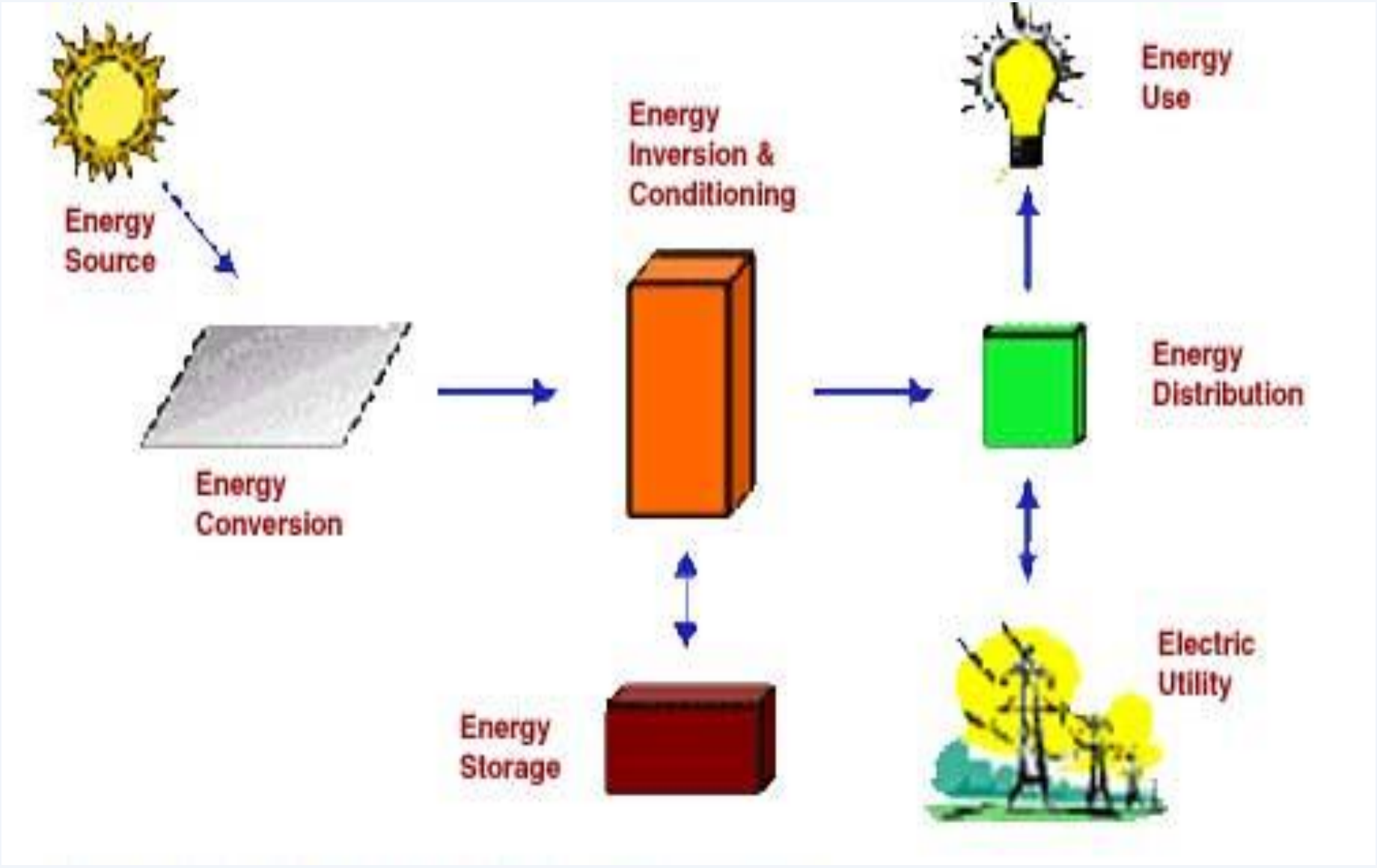
PV Systems


Energy Source
Energy Conversion
Energy Inversion & Conditioning
Energy Storage
Energy Use
Energy Distribution
Electric Utility

Electricity Terminology

- Voltage (E or V)
  - Unit of electromotive force
  - Can be thought of as electrical pressure
- Amps (I or A)
  - Rate of electron flow
  - Electrical current
  - 1 Amp = 1 coulomb/second = 6.3×10^{18} electrons/second
- Resistance (R or Ω)
  - The opposition of a material to the flow of an electrical current
  - Depends on
    - Material
    - Cross sectional area
    - Length
    - Temperature

Electricity Terminologies

1- Watt (W) are a measure of Power = Amps x Volts

- Unit rate of electrical energy

2- Watt-hour (Wh) is a measure of load energy = Watts x hours

- Unit quantity of electrical energy (consumption and production)

3- Amp-hour (Ah)

a) Quantity of electron flow
b) Used for battery sizing
c) Amps x hours = Amp-hours
d) Amp-hours x Volts = Watt-hours

- A 200 Ah Battery delivering 1A will last _____ hours
- 200 Ah Battery delivering10 A will last _____ hours
- 100 Ah Battery x 12 V = _____ Wh

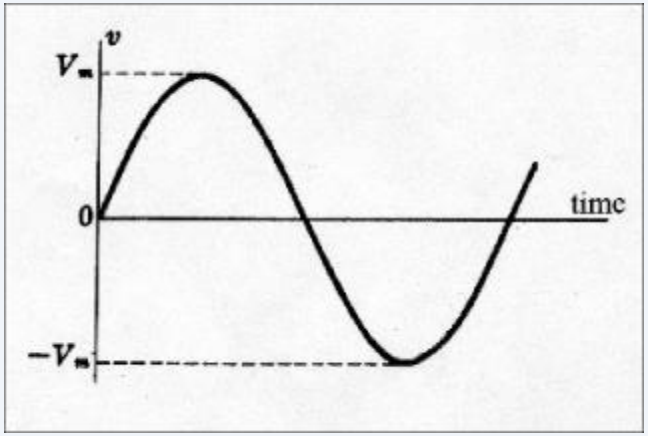
Panels and power calculation

- Draw a PV array composed of four 75 watt modules.
- What size is the system in watts ?

Types of Electrical Current

- DC = Direct Current
  - PV panels produce DC
  - Batteries store DC

- AC = Alternating Current
  - Utility power
  - Most consumer appliances use AC



Meters and Testing

Clamp on meter

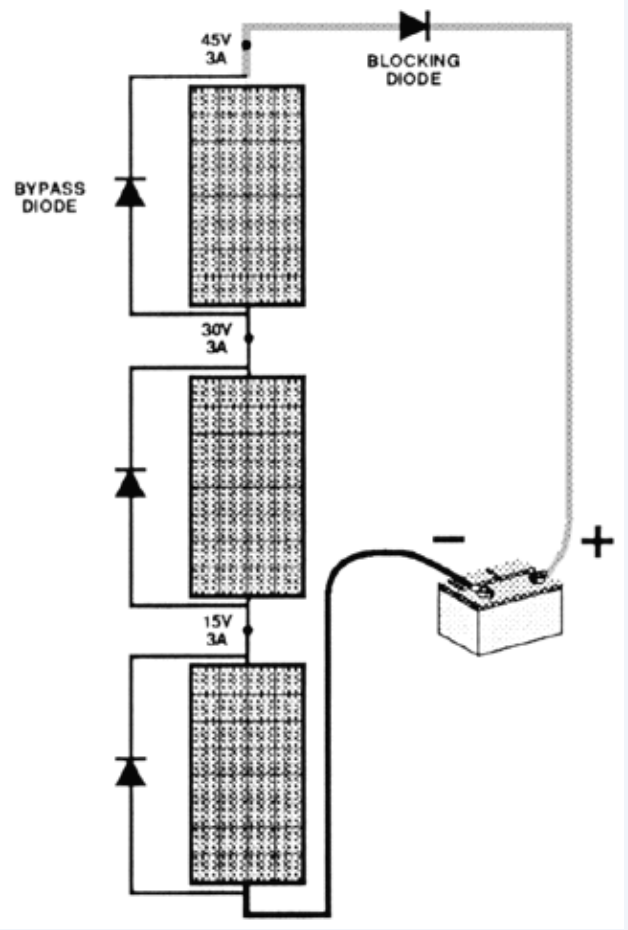
Digital voltmeter

- Never test battery current using a multimeter!

Series Connections

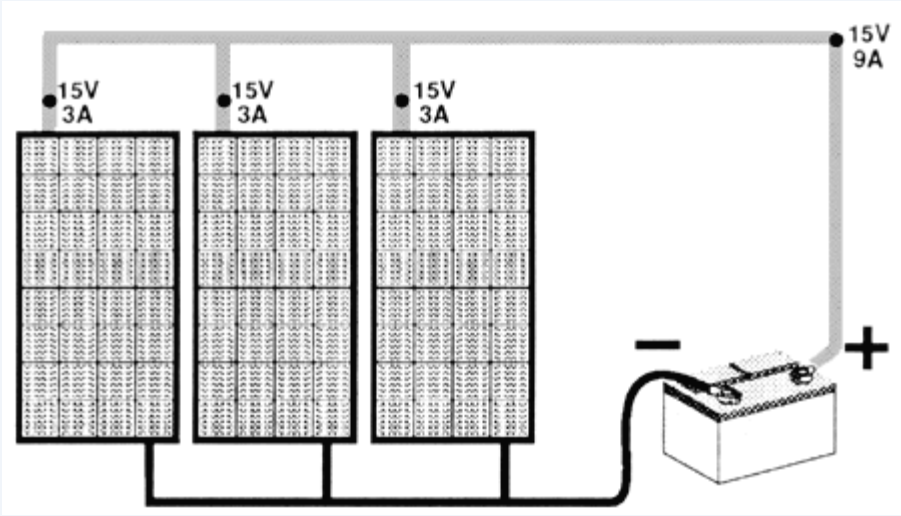
- Loads/sources wired in **series**

1. VOLTAGES ARE ADDITIVE
2. CURRENT IS EQUAL
3. One interconnection wire is used between two components (negative connects with positive)



Parallel Connections

- Loads/sources wired in **parallel**:
  - VOLTAGE REMAINS CONSTANT
  - CURRENTS ARE ADDITIVE
  - Two interconnection wires are used between two components (positive to positive and negative to negative)
  - Leave off of either terminal
  - Modules exiting to next component can happen at any parallel terminal



Quiz Time

1. If you have 4 (12V / 3A) panels in an array, what would the power output be if that array were wired in series?

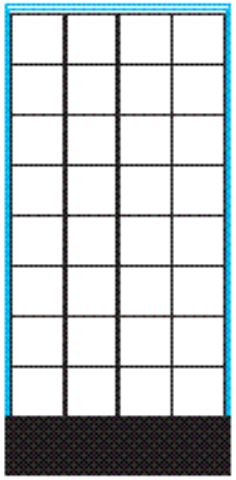
2. What if it were wired in parallel?

3. Is it possible to have a configuration that would produce 24 V / 6 A? Why?

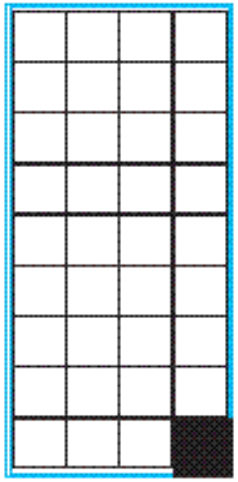
Shading on Modules

- Depends on orientation of internal module circuitry relative to the orientation of the shading.

- SHADING can half or even completely eliminate the output of a solar array!



Example of full-cell shading that can reduce PV module power to zero



Example of full-cell shading that can reduce PV module power by ½

Wire Size

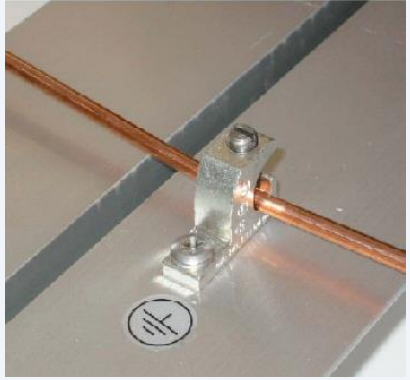
- **Wire size selection based on two criteria:**
  1. Ampacity
  2. Voltage drop

- **Ampacity: current carrying ability of a wire**
  1. The larger the wire, the greater its capacity to carry current
  2. Wire size given in terms of American Wire Gauge (AWG) or measured in millimeters in European standard

Note:

- The higher the gauge number, the smaller the wire, hence bear less ampacity
- Voltage drop: the loss of voltage due to a wire's resistance and length
- Voltage drop is function of wire size, length of wire, and current flow in the wire

Grounding



Provides a current path for surplus electricity to travel to (earth)

- Limit voltages due to:
  1. Lightning
  2. Unintentional contact with higher voltage lines

Types of grounding:

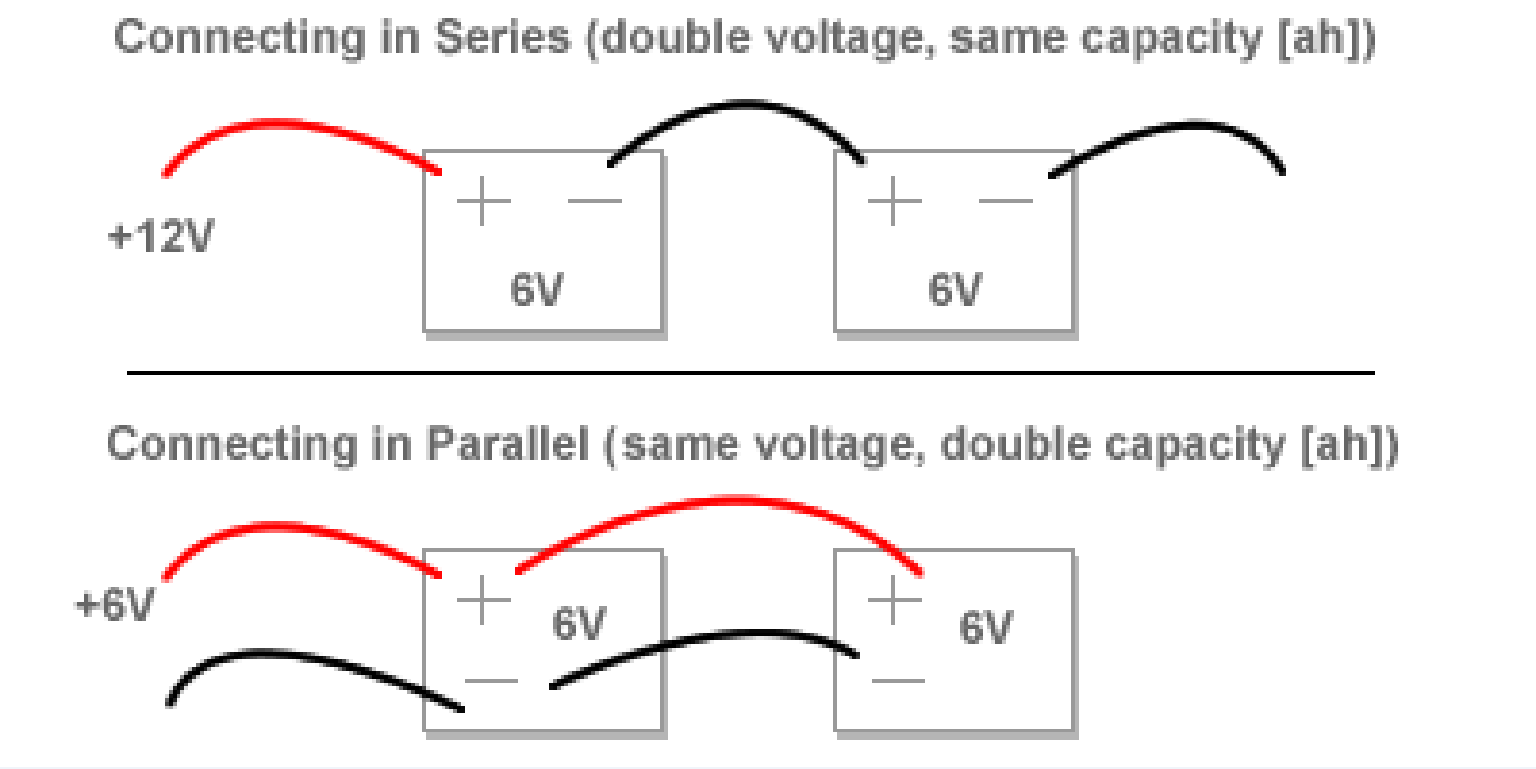
1. ***Equipment grounding*** (attach all exposed metal parts of PV system to the grounding electrode)

2. ***System grounding*** (at one point attach ground to one current carrying conductor)

   - DC side of system => Negative to ground
   - AC side of system => Neutral to ground

Batteries in Series and Parallel

- Series connections: Builds voltage
- Parallel connections: Builds amp-hour capacity



Battery Terms:

Battery is a device that stores electrical energy (chemical energy to electrical energy and vice-versa)

1- Capacity

Amount of electrical energy the battery will contain

2- State of Charge (SOC)

Available battery capacity

3- Depth of Discharge (DOD)

Energy taken out of the battery

4- Efficiency

Energy out / Energy in (typically 80-85%)

Functions of a Battery

1. Storage for the night
2. Storage during cloudy weather
3. Portable power
4. Surge for starting motors

Types

1. Primary (single use)
2. Secondary (recharged)
3. Shallow Cycle (20% DOD)
4. Deep Cycle (50-80% DOD)

Battery Capacity

Capacity = Amps x Hours = Amp-hours (Ah)

100 Amp-hours =
- 100 amps for 1 hour
- 1 amp for 100 hours
- 20 amps for 5 hours

Capacity changes with Discharge Rate and Temperature

1. The higher the discharge rate the lower the capacity and vice versa
2. The higher the temperature the higher the percent of rated capacity

Charging Controller

An interfacing device to the connect the panels to the PV systems

Functions :

1. Regulate and control the DC voltage from the panels
2. To protect batteries from being overcharged
3. Maximum Power Point Tracking
   - Tracks the peak power point of the array (can improve power production by 20%)!!

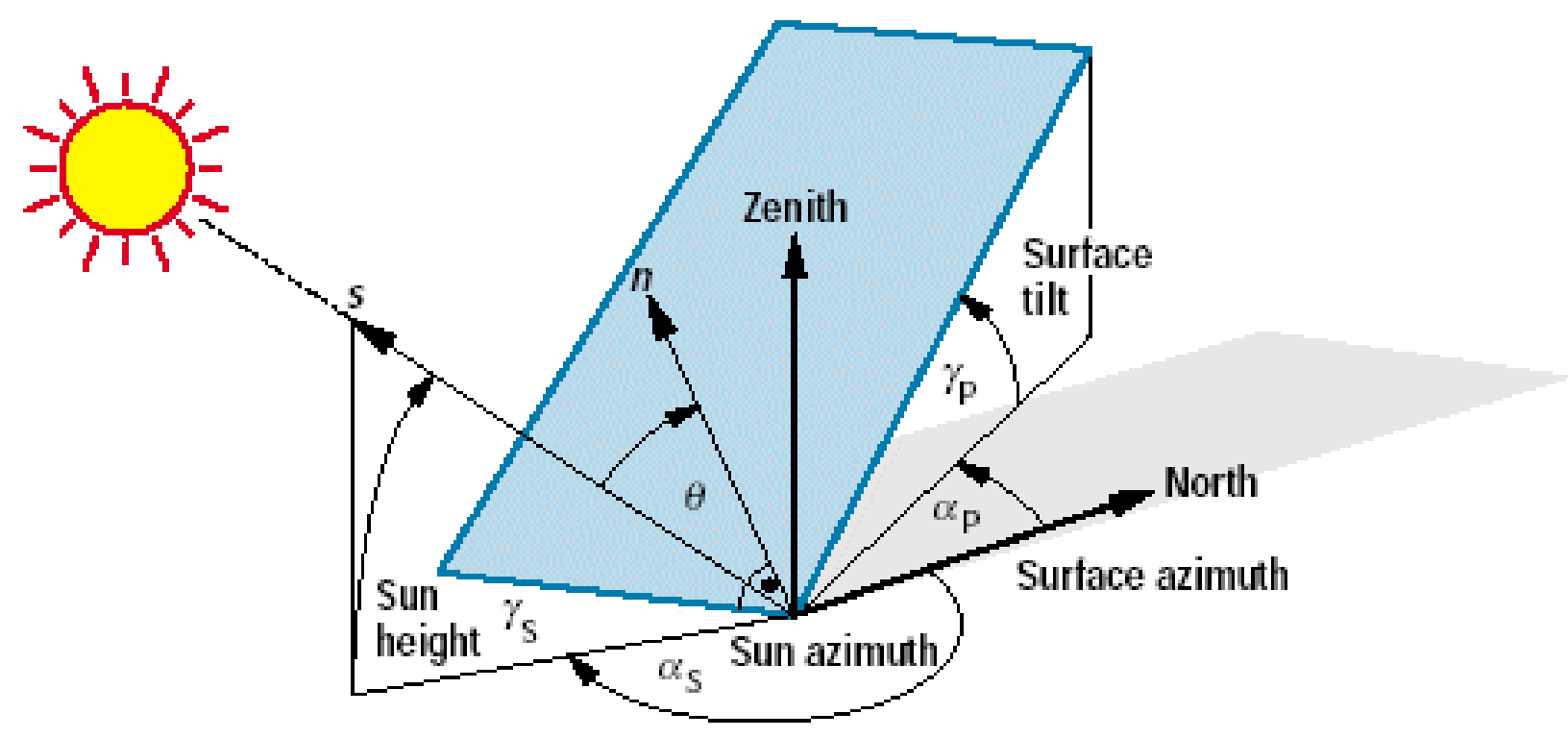
Power Inverter

An electronic device used to convert direct current (DC) electricity into alternating current (AC) electricity

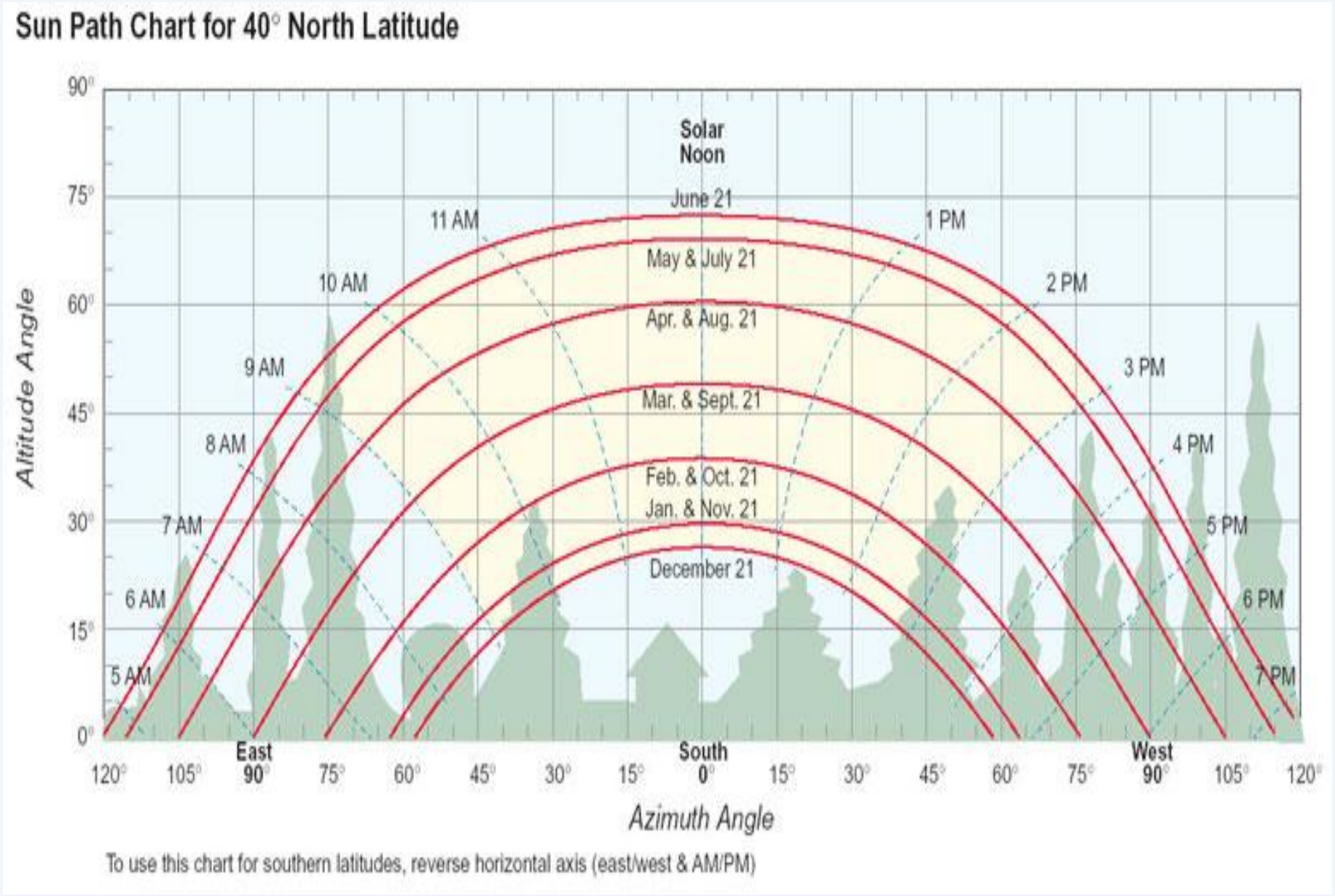
Evaluation factors:

- Efficiency penalty
- Complexity
- Cost!!

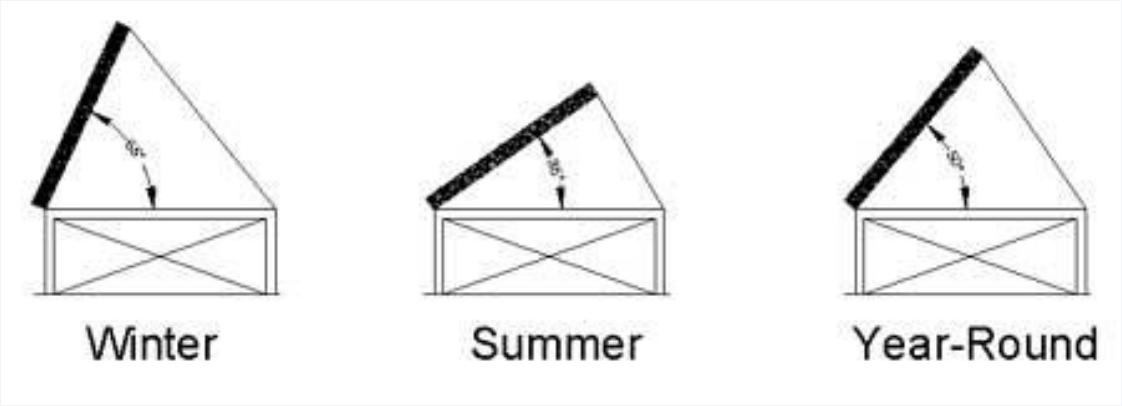
Panels Angulation



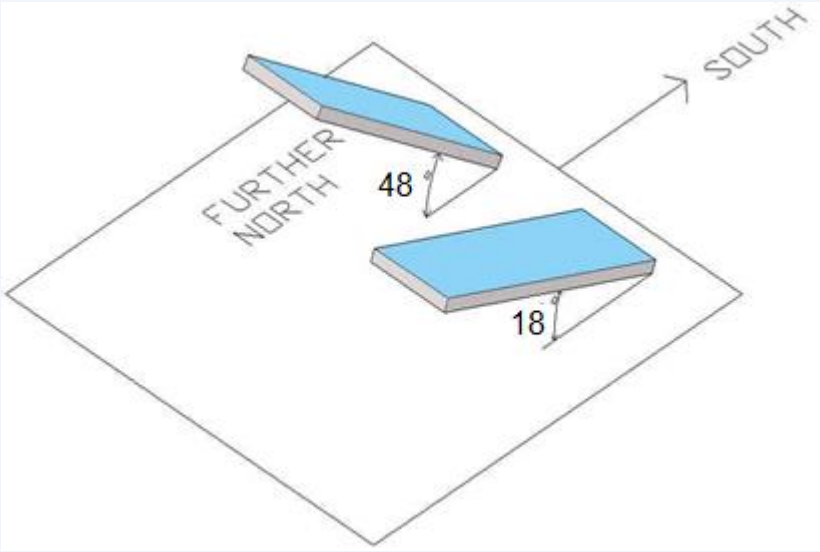
Sun Chart for 40 degrees N Latitude



Site Selection – Tilt Angle



Max performance is achieved when panels a re perpendicular to the sun's rays



Year round tilt = latitude (33 Anbar)

Winter + 15 lat. (48)

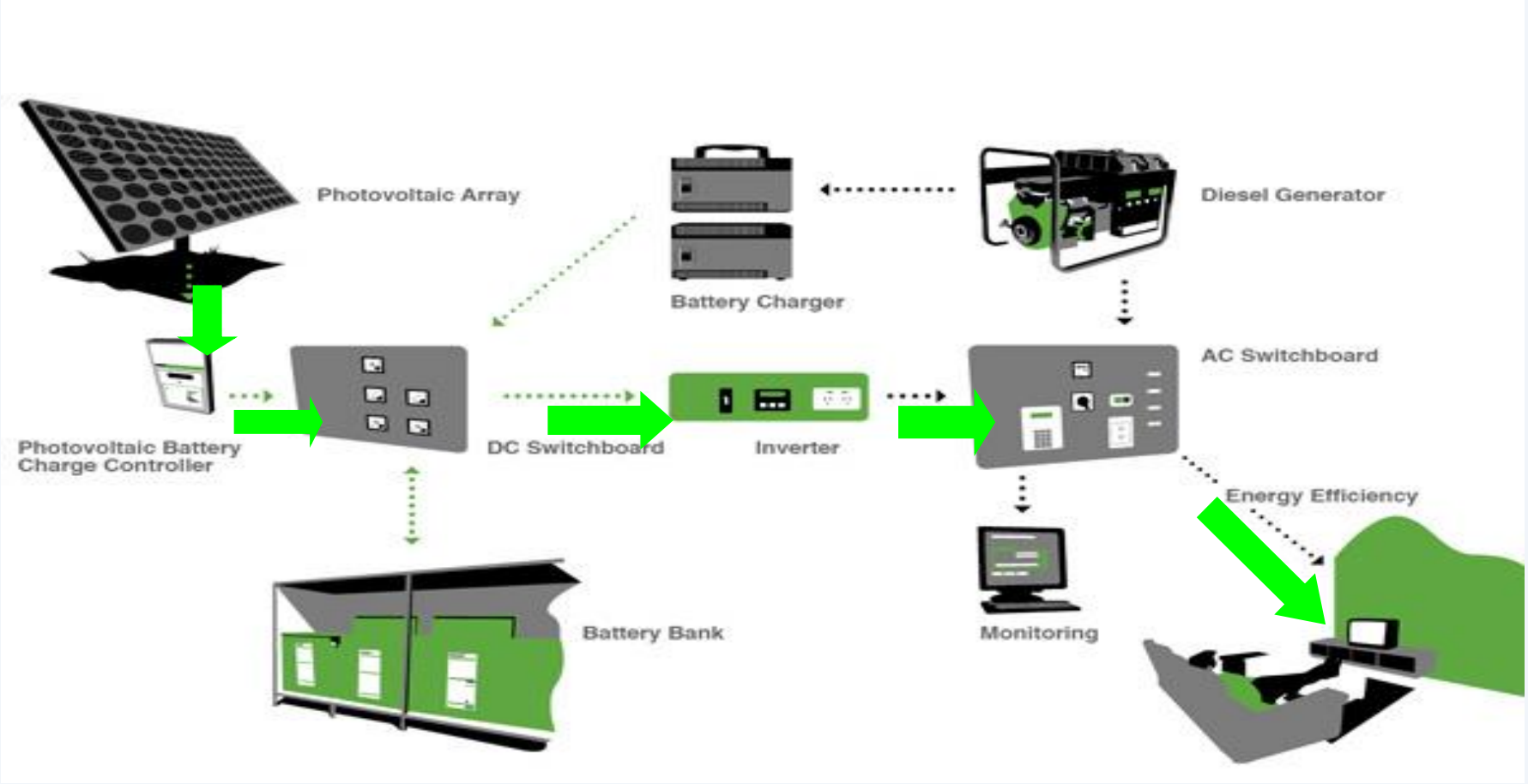
Summer – 15 lat. (18)

PV Systems

1. Stand-alone
2. Stand-alone with back-up source (generator)
3. Grid-Tied (without batteries)
4. Grid-Tied (with battery back-up)

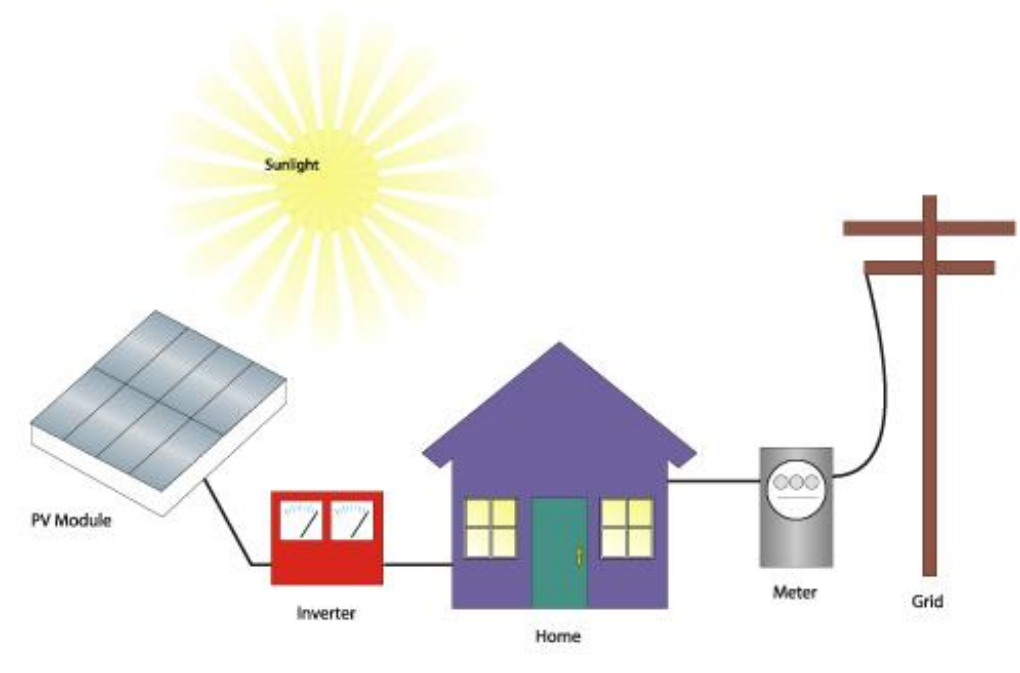
1- Stand alone Systems

2- Stand-alone with back-up source (generator)



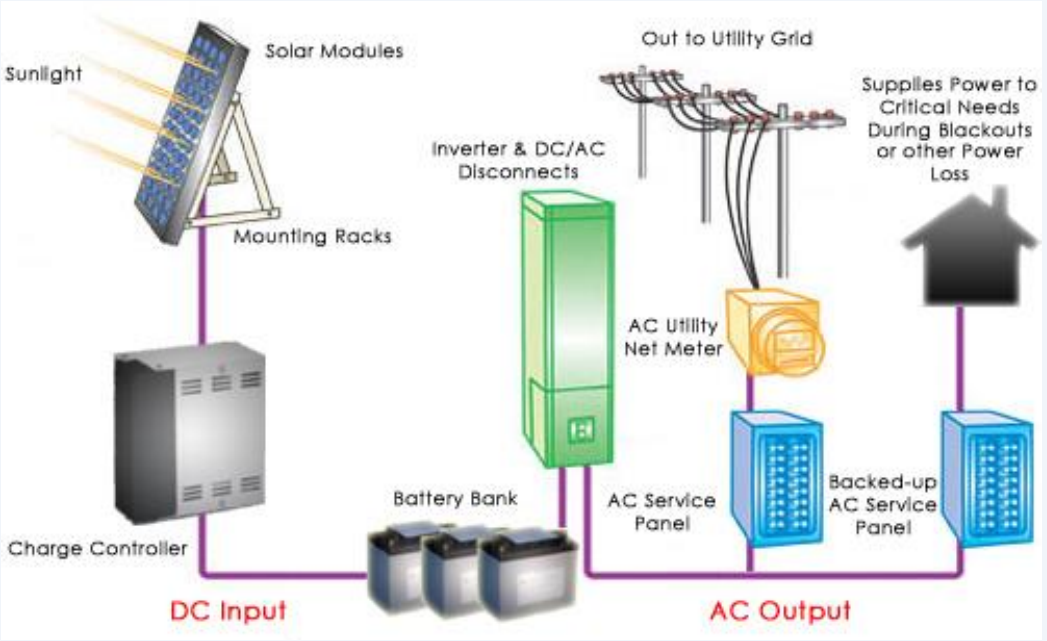
3. Grid-Tied System (Without Batteries)

- Complexity
  - Low: Easy to install (less components)
- Grid Interaction
  - Grid can supplement power
  - No power when grid goes down during night or cloudy days



4. Grid-Tied System (With Batteries)

- Complexity
  - High: Due to the addition of batteries
- Grid Interaction
  - Grid still supplements power
  - When grid goes down batteries supply power to loads (battery backup)



Next Lecture:

Solar PV System Sizing

Find it at the bookstore of CAS

Thank You for your attention