Renewable Energy Systems

6

Buchla, Kissell, Floyd

Chapter Outline

The Charge Controller and Inverter

6

Renewable Energy Systems

Buchla, Kissell, Floyd

6-1 Battery Chargers

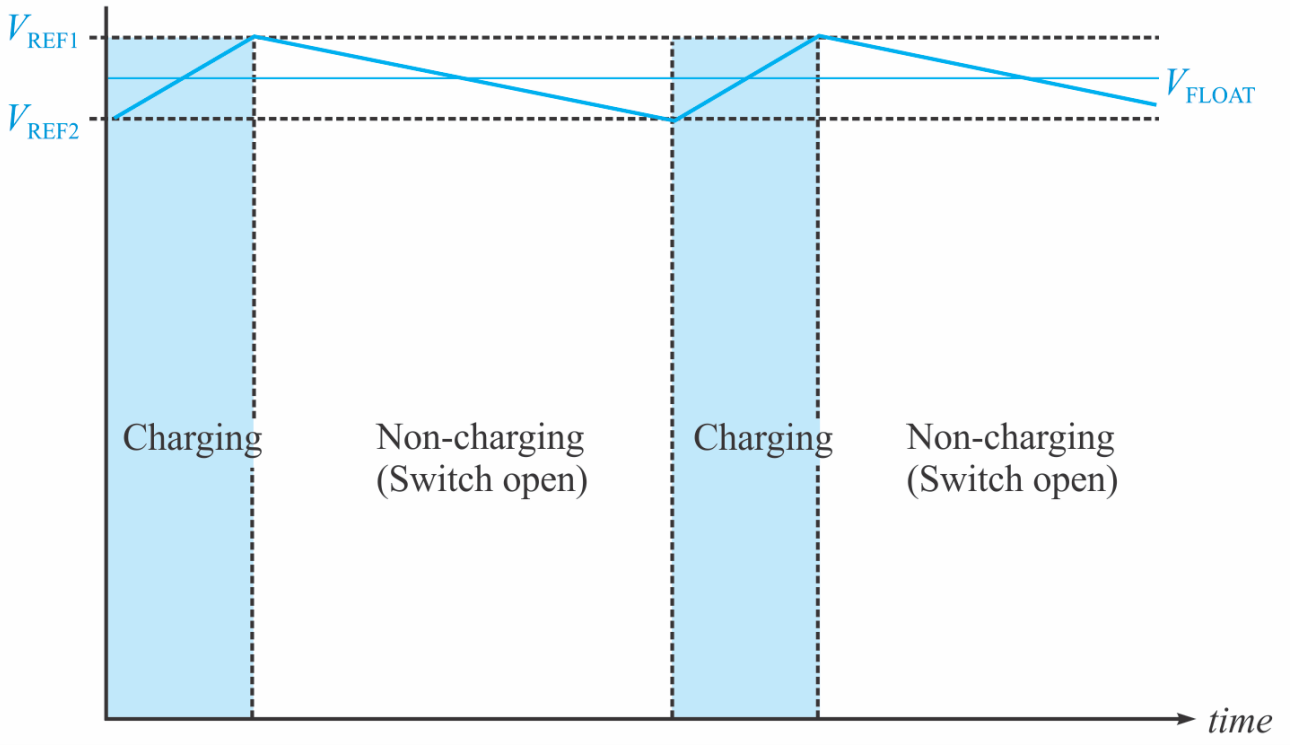
The purpose of a battery charger is to charge a battery without overcharging it. A trickle charger is a basic charger that must be manually disconnected to prevent overcharging a battery, so is not used too much in renewable energy systems.

Small solar trickle chargers are useful in applications like this LED camp light that can be charged in the daytime to provide light at night.

Source: NREL

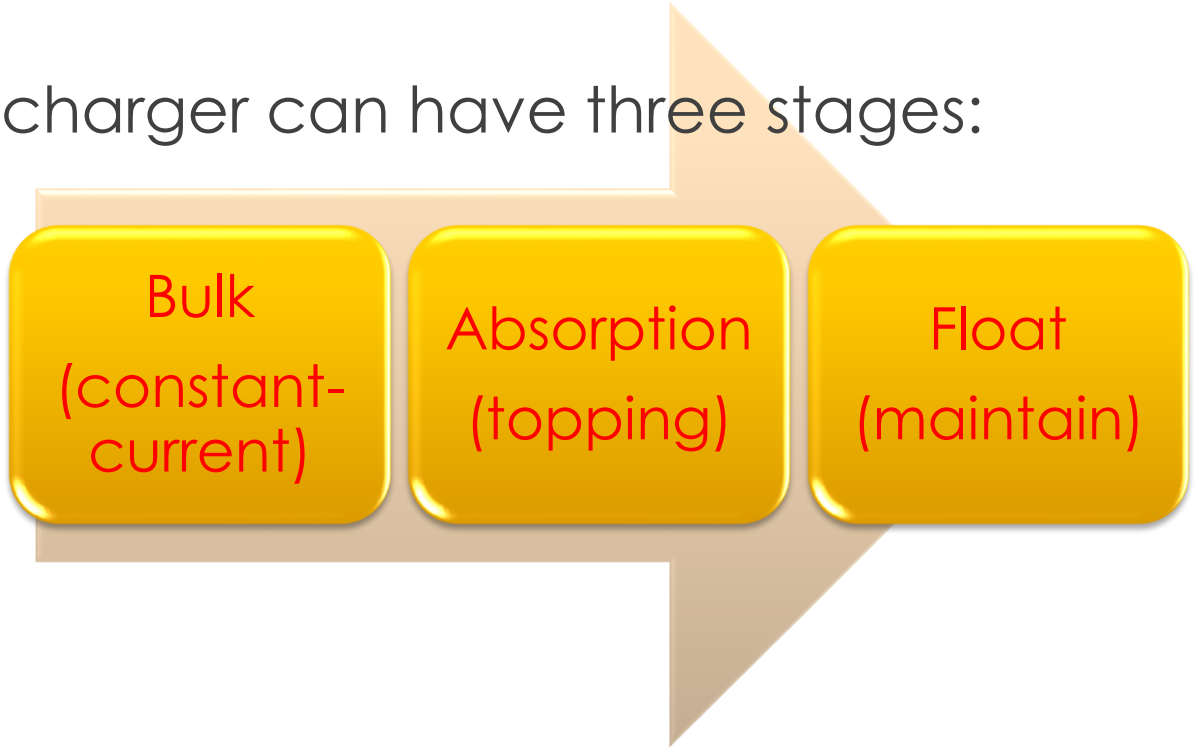
6-1 Battery Chargers

A series switched float charger is a trickle charger with an automatic on/off switch. This charger senses when the battery voltage reaches either of two reference levels to turn *on* or *off* the current to the battery.



6-1 Battery Chargers

A float charger can have three stages:



A trickle stage is sometimes included as a fourth stage (as well as bulk, absorption and float stages). The purpose of including a trickle stage is to safely charge overly discharged batteries at a slow rate.

6-2 The PWM Charge Controller

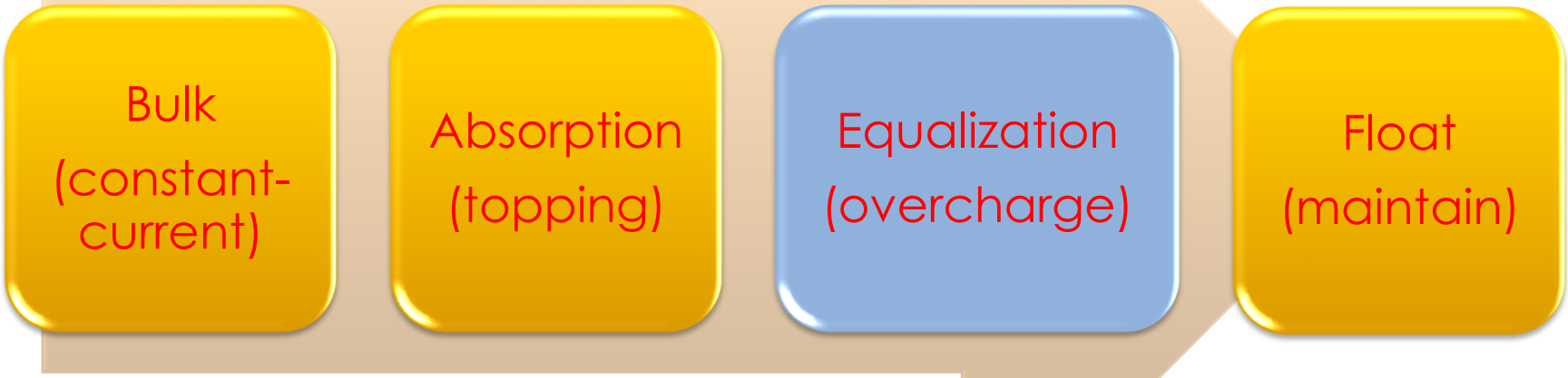
The PWM charge controller keeps the back-up batteries charged by switching *on* and *off* several times per second. This keeps the battery voltage more constant than continuous charging methods.

The pulse width is adjusted constantly to control current to the batteries for optimum charging.

Courtesy of Morningstar Corporation

6-2 The PWM Charge Controller

In some chargers, the fourth stage is an equalization stage, which is a controlled overcharging.

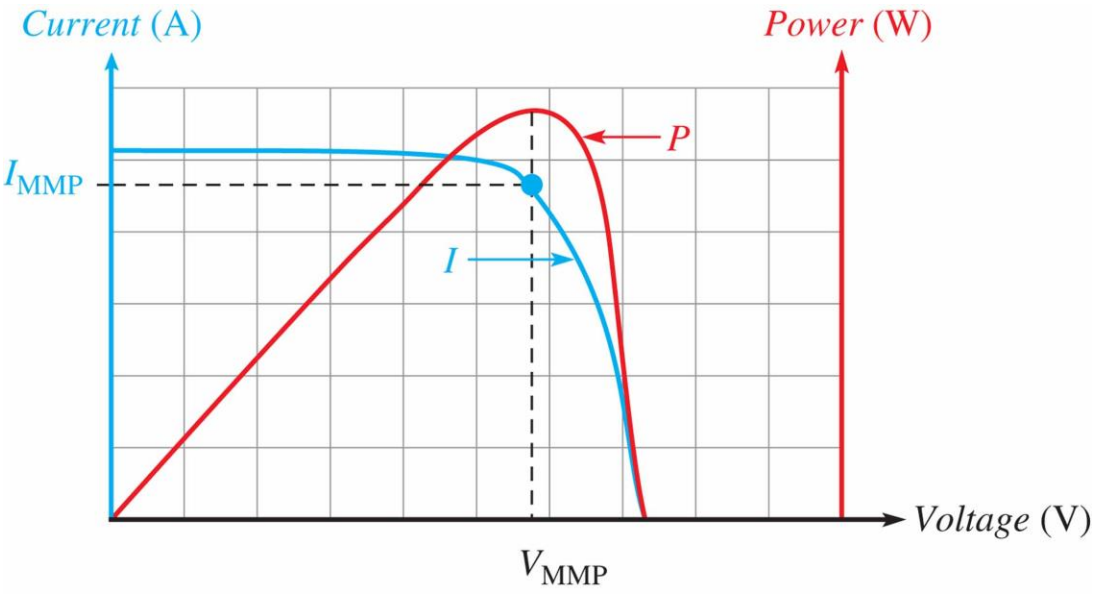


A controlled overcharge applied periodically prevents stratification, which is a layering of acid, which can reduce battery storage capacity and life.

6-3 The MPPT Charge Controller

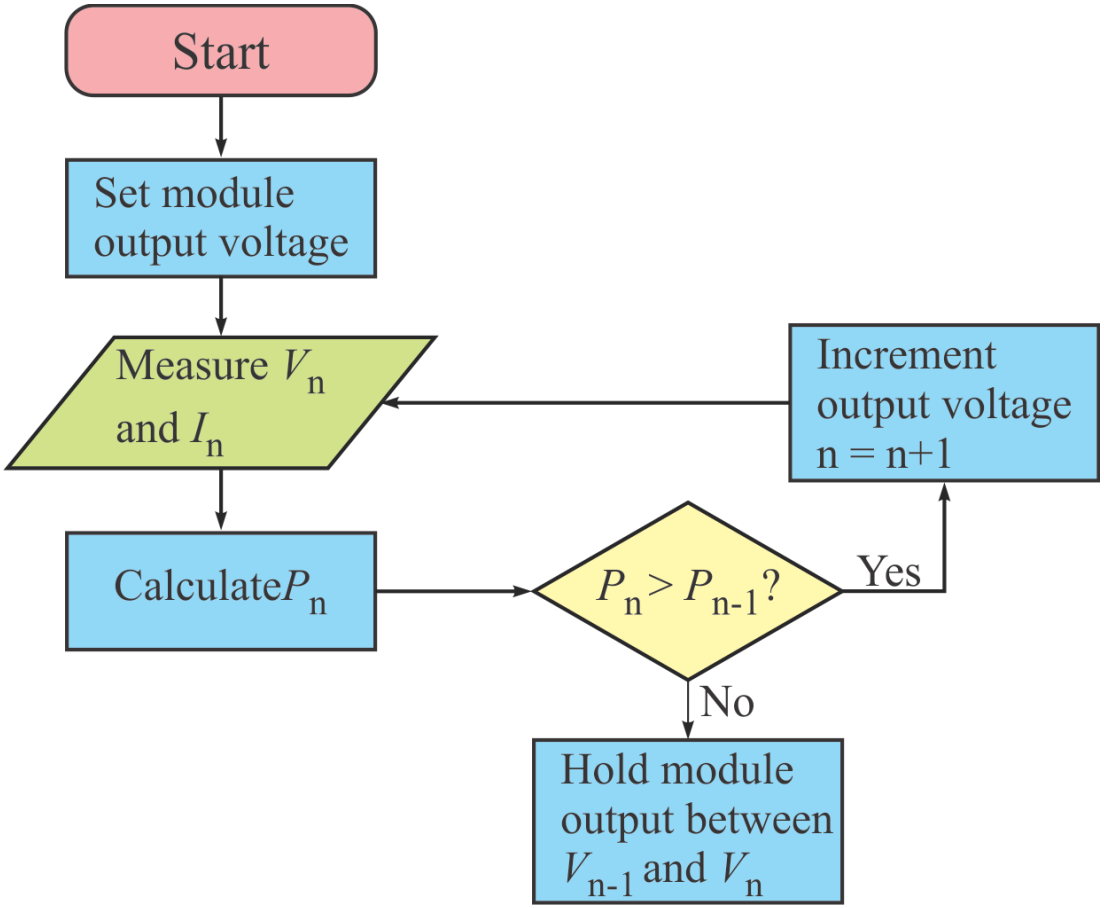
MPPT controllers track the voltage and current from the solar module to determine when the maximum power occurs in order to extract the maximum power.

The maximum power available varies as voltage and current changes from the solar input. The MPPT controller uses an algorithm to adjust the output for maximum power.



6-3 The MPPT Charge Controller

The P and O algorithm is a method for finding the MPP.



6-4 Charge Controller Specifications and Data Sheet

Common specifications for charge controllers are:

- Output current
- Maximum solar array size
- Nominal battery voltage
- PV open circuit voltage (VOC)
- Standby power consumption
- Charging regulation
- Voltage regulation set points
- Equalization voltage
- Battery temperature compensation
- Power conversion efficiency

Source: courtesy of Outback Power Technologies

6-5 Inverters

An inverter changes dc voltage to an ac voltage. For smaller renewable energy systems, the output voltage is usually the same as provided by the power company.

Typical inverters for small systems are illustrated. These can range from simple low power inverters that power isolated loads to grid tie units capable of sending excess power to the grid.

Source: NRREL

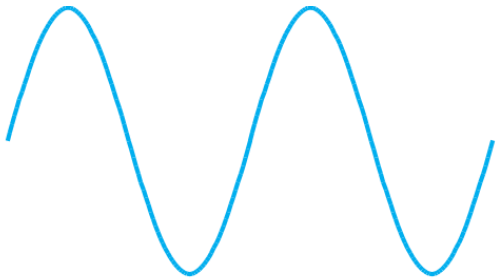
6-5 Inverters

Large grid tied inverters are used in commercial and utility systems. Large inverters reduce the installation time and do not require a special transformer. A modular approach is another method to connect an array and gives flexibility to add or or subtract capability as conditions change.

Source: courtesy of Nextronex

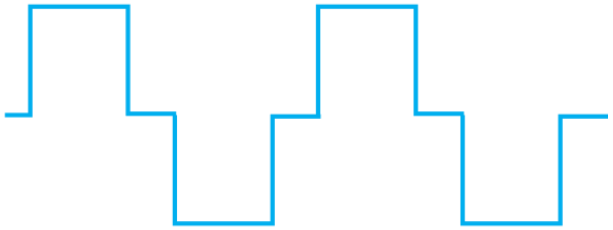
6-5 Inverters

Grid-tie inverters must produce a low-distortion sine wave for the grid; if an inverter is not connected to the grid, another waveform can be used. Low-end inverters may produce a square wave or a modified sine wave, but these are not suitable for all loads.



(a) Sine wave

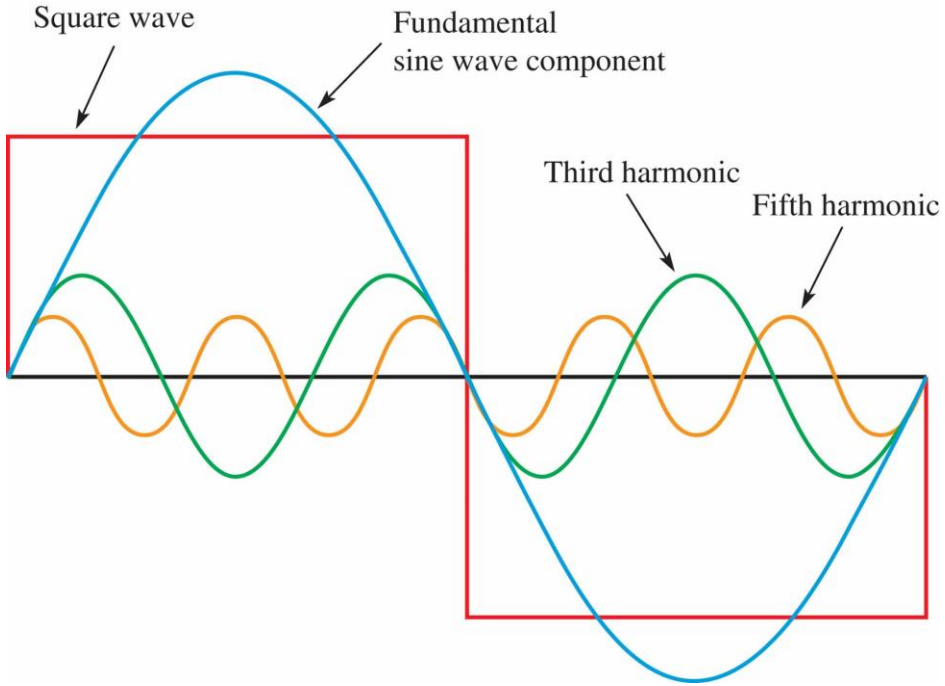
(b) square wave



(c) Modified sine wave

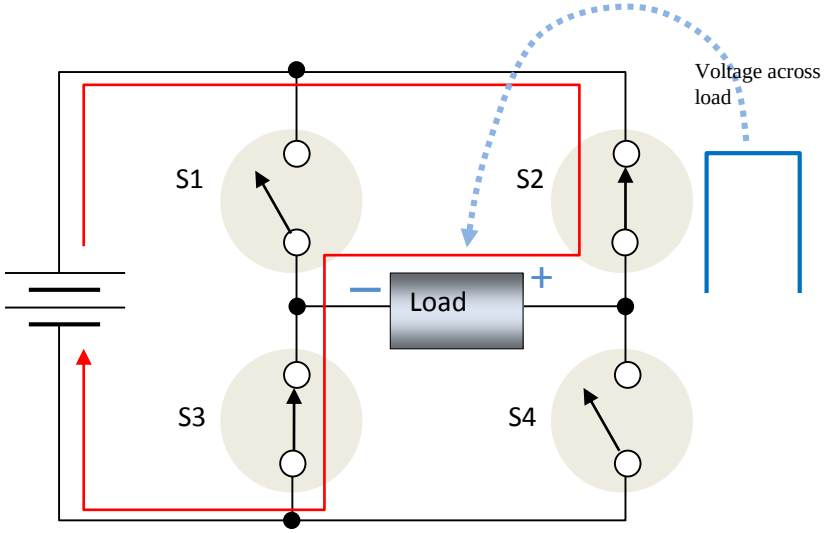
6-5 Inverters

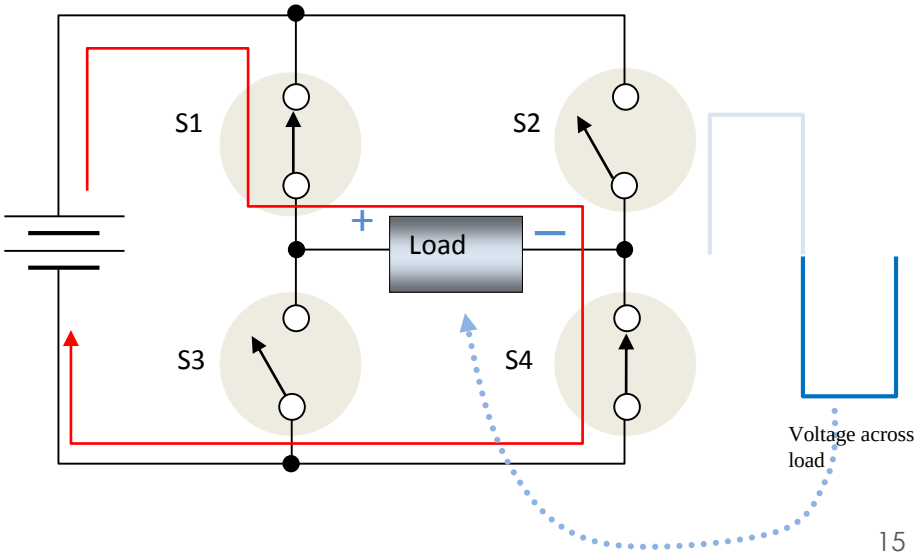
A square wave is simple to generate from dc but consists of a fundamental sine wave and multiples of the fundamental frequency called harmonics. It is the harmonics that cause difficulty with some loads.



6-5 Inverters

An H-bridge can produce a basic bipolar square wave. A variation of this circuit is used with other circuitry to produce a sine wave using pulse-width modulation (PWM).

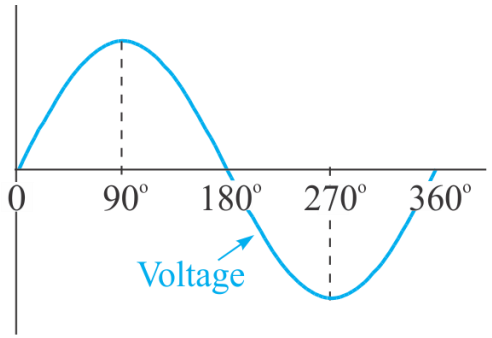


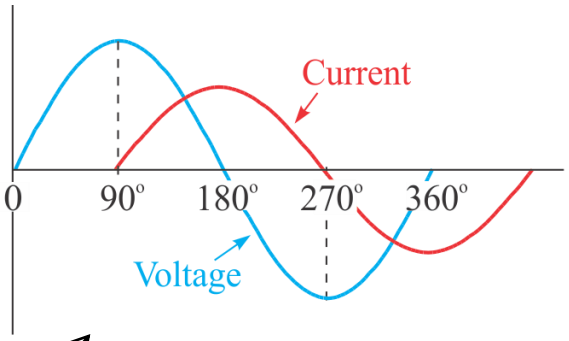


6-6 Inverter Functions

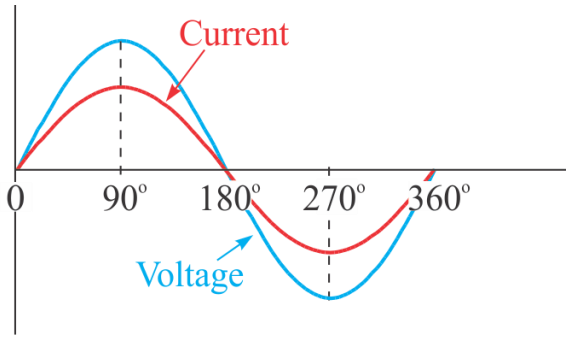
When a reactive load is connected to a source, the voltage and current shift in phase, which causes a reduction in the true power that can be delivered. To avoid this, some inverters can correct for power factor.

$$PF = \cos(\theta)$$





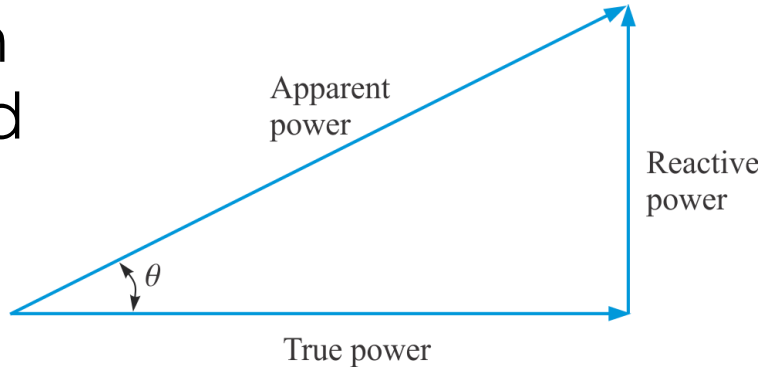
power factor = 0



power factor = 1

Inverter Functions

The power relationship between true power, reactive power, and apparent power can be illustrated with a right triangle.



Example

(a) What is the apparent power if the true power is 60 W and the reactive power is 30 VAR?

(b) What is the phase angle?

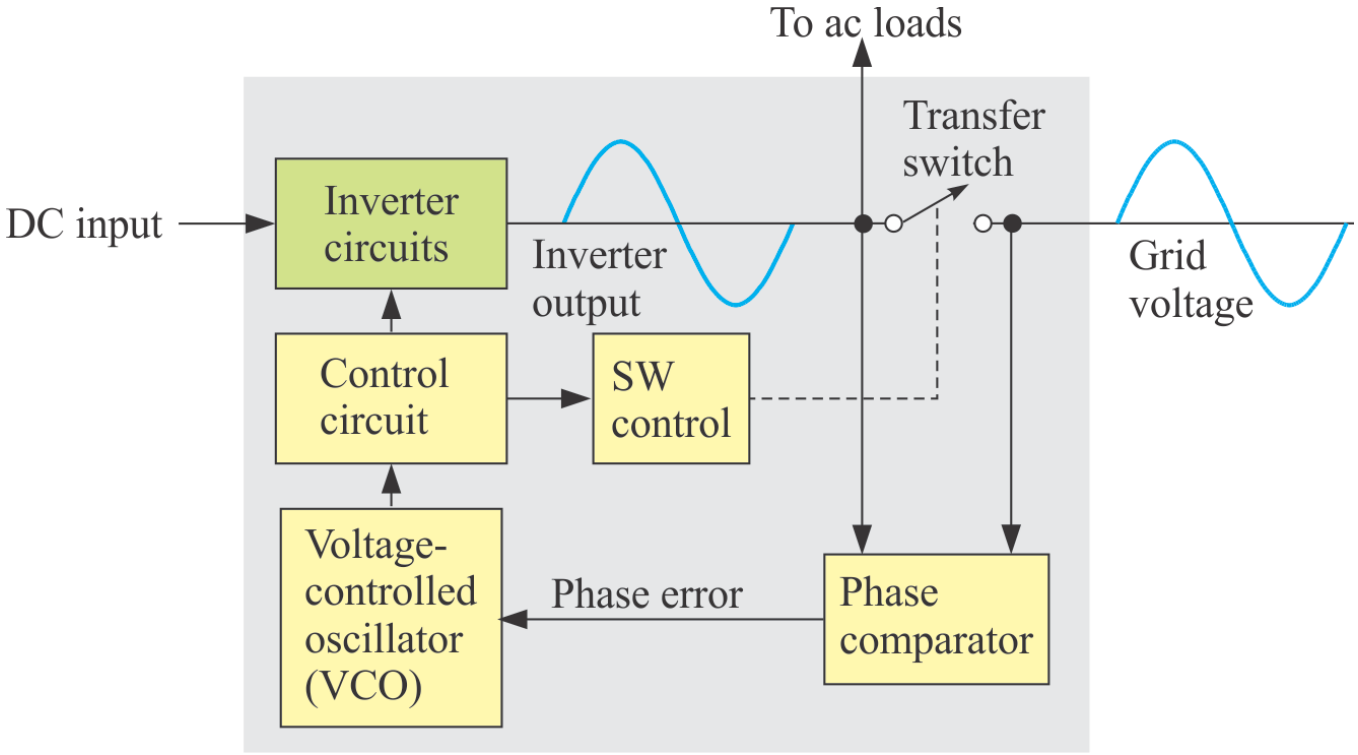
Solution

(a) $$P_a = \sqrt{P_{\text{true}}^2 + P_r^2} = \sqrt{(60\ \text{W})^2 + (30\ \text{VAR})^2} = 67.1\ \text{VA}$$

(b) $$\theta = \cos^{-1}\left(\frac{\text{True power}}{\text{Apparent power}}\right) = \cos^{-1}\left(\frac{60\ \text{W}}{67.1\ \text{VAR}}\right) = 26.5^\circ$$

6-6 Inverter Functions

A grid-tie inverter must synchronize its output voltage with the grid voltage in terms of frequency, phase and amplitude. A phase-locked loop can synchronize the inverter:



6-6 Inverter Functions

Anti-islanding is a protective feature that detects when there is a power outage and disconnects from the grid with a **transfer switch** when it happens.

Passive detection	Active detection	Utility notification
• Detects a sudden change in frequency, voltage, phase, or power	• Looks for a response to an injected signal	• Utility company issues a signal to the inverter to stop generating power

6-7 Inverter Specifications and Data Sheet

- *Maximum ac output power*
- *Peak output power*
- *AC output voltage*
- *Peak efficiency*
- *Maximum input current*

Source: NREL

6-7 Inverter Specifications and Data Sheet

- *Maximum output current*
- *Peak power tracking voltage*
- *Start voltage*
- *NEMA rating*
- *THD*

Source: NREL

Selected Key Terms

Absorption stage	The stage of battery charging after the battery voltage reaches the maximum and the current through the battery begins to decrease. The voltage is held at the maximum value while the current decreases.
Anti-islanding	A protective feature of a grid-tie inverter that detects when there is a power outage and disconnects the renewable energy source from the grid.
Equalization	The charging process in which the battery is over-charged at approximately 1 V above float in order to equalize the charge on all the cells in the battery or battery bank.

Selected Key Terms

Float voltage	A voltage supplied to a battery to maintain it at full charge and prolong its life.
Harmonics	The frequencies contained in a composite waveform, which are integer multiples of the repetition frequency (fundamental).
Islanding	The situation when a grid-tie renewable energy source continues to operate and provide power to a certain location and remains connected to the electrical grid after the grid no longer supplies power.
maximum power point tracking (MPPT)	The process for tracking the voltage and current from a solar module to determine when the maximum power occurs in order to extract the maximum power.

Selected Key Terms

Power factor	The cosine of the phase angle between current and voltage.
pulse width modulation (PWM)	A process in which a signal is converted to a series of pulses with widths that vary proportionally to the signal amplitude.
Synchronization	The process of producing a fixed phase relationship between two or more waveforms.
Three-phase	Three ac voltages that have the same magnitude and frequency but are separated by 120°.
Transfer switch	A switch used for connecting or disconnecting a source from the grid.

true/false quiz

1. With respect to battery chargers. float means to maintain the charge.

true/false quiz

2. PWM chargers use continuous charging to achieve maximum charge.

true/false quiz

3. Equalization means the battery voltage is equal to the charger voltage.

true/false quiz

4. Maximum power from a solar PV system occurs at the point where the voltage from the array is highest.

true/false quiz

5. To determine the MPP, you could use the P and O algorithm.

true/false quiz

6. Very large solar PV systems do not use inverters but rely instead on alternators to provide ac.

true/false quiz

7. A modified sine wave is commonly used to connect a PV system to the grid.

true/false quiz

8. Harmonics cause problems with some loads.

true/false quiz

9. It is best to keep the power factor as low as possible.

true/false quiz

10. Anti-islanding can detect when there is a power outage on the grid and disconnects the system.

true/false quiz

Answers:

1.T
2.F
3.F
4.F
5.T
6.F
7.F
8.T
9.F
10. T