Charge Controller

Charge controllers are used in PV systems that use batteries, which are stand-alone systems in most cases. As we have seen before, it is very important to charge and discharge batteries at the right voltage and current levels in order to ensure a long battery lifetime. A battery is an electrochemical device that requires a small over-potential to be charged. However, batteries have strict voltage limits, which are necessary for their optimal functioning. Further, the amount of current sent to the battery by the PV array and the current flowing through the battery while being discharged have to be within well defined limits for proper functioning of the battery. We have seen before that lead acid batteries suffer from overcharge and overdischarge. On the other hand, the PV array responds dynamically to ambient conditions like irradiance, temperature and other factors like shading. Thus, directly coupling the battery to the PV array and the loads is detrimental to the battery lifetime.

Therefore a device is needed that controls the currents flowing between the battery, the PV array and the load and that ensures that the electrical parameters present at the battery are kept within the specifications given by the battery manufacturer. These tasks are done by a charge controller that now a days has several different functionalities, which also depend on the manufacturer. We will discuss the most important functionalities.

Charge Controllers Functioning:

When the sun is shining at peak hours during summer, the generated PV power excesses the load. The excess energy is sent to the battery. When the battery is fully charged, and the PV array is still connected to the battery, the battery might overcharge, which can cause several problems like gas formation, capacity loss or over- heating. Here, the charge controller plays a vital role by decoupling the PV array from the battery. Similarly, during severe winter days at low irradiance, the load exceeds the power generated by the PV array, such that the battery is heavily discharged. Over-discharging the battery has a detrimental effect on the cycle lifetime, as discussed above. The charge controller prevents the battery from being over-discharged by disconnecting the battery from the load.

For optimal performance, the battery voltage has to be within specified limits. The charge controller can help in maintaining an allowed voltage range in order to ensure a healthy operation. Further, the PV array will have its Vmpp at different levels, based on the temperature and irradiance conditions. Hence, the charge controller needs to perform appropriate voltage regulation to ensure the battery operates in the specified voltage range, while the PV array is operating at the MPP. Modern charge controllers often have an MPP tracker integrated.

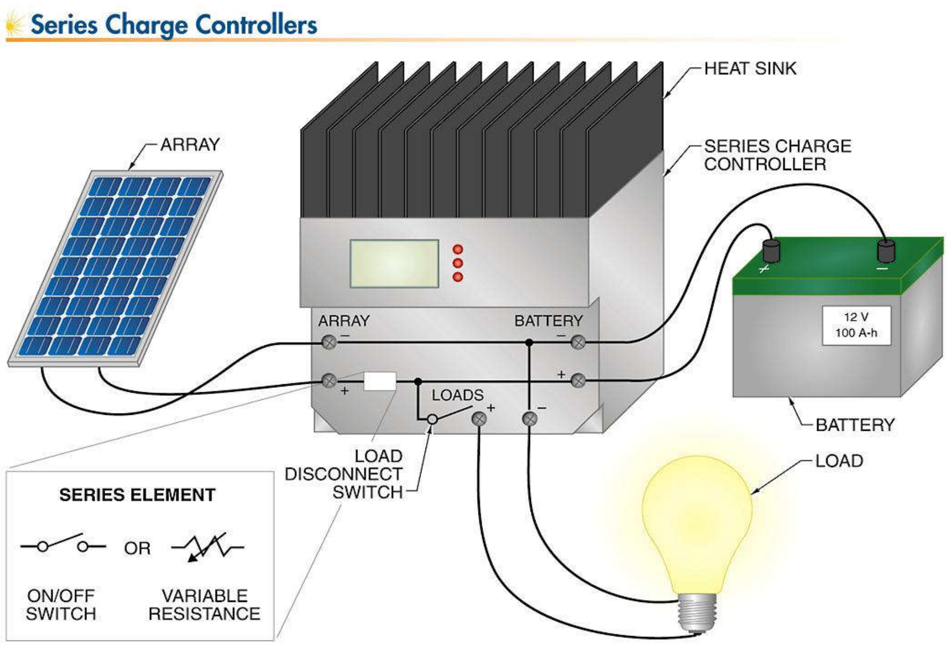
Effect of temperature on charge controllers:

Modern charge controllers have a temperature sensor included, which allows the charge controller to adjust the electrical parameters of the battery, like the operating voltage, to the temperature. The charge controller thus keeps the operating range of the battery within the optimal range of voltages. The charge controller is usually kept in close proximity to the battery, such that the operating temperature of the battery is close to that of the charge controller. However, when the battery is heavily loaded, the battery might heat up, leading to differences between the temperature expected by the charge controller and the actual temperature of the battery. Therefore, high end charge controllers also take temperature effects due to high currents into account.

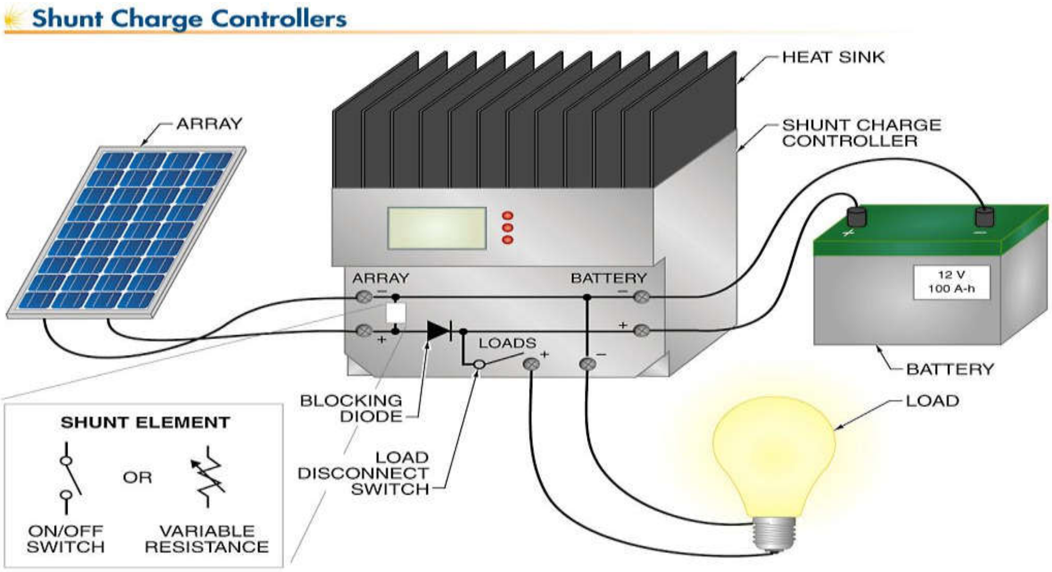
Types of Charge controller

1. **Series charge controllers**
2. **Shunt charge controllers**

In a **series controller**, overcharging is prevented by disconnecting the PV array until a particular voltage drop is detected, at which point the array is connected to the battery again.



On the other hand, in a **parallel or shunt controller**, overcharging is prevented by short-circuiting the PV array. This means that the PV modules work under short circuit mode, and that no current flows into the battery.

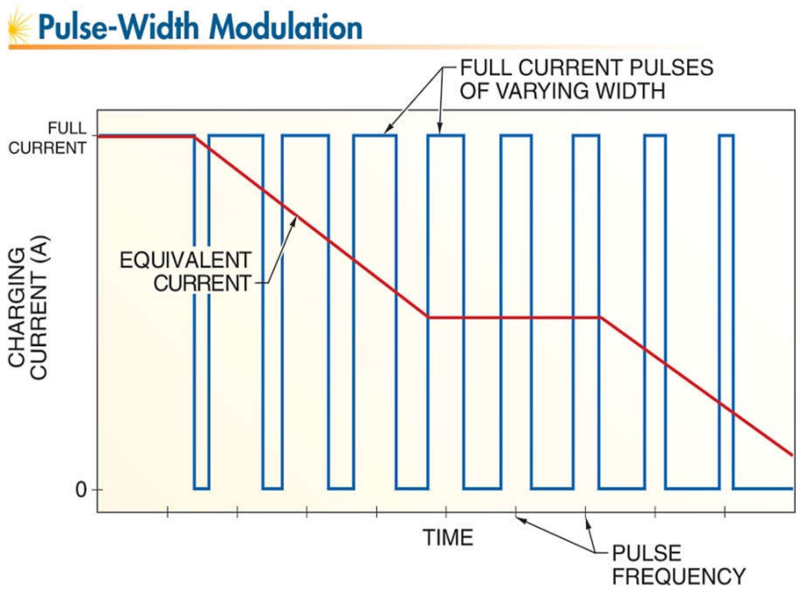


These topologies also ensure over-discharge protection using power switches for the load connection, which are appropri- ately controlled by the algorithms implemented into the charge controller algorithm. As charge controllers area necessary component of of stand-alone PV systems, they should have a very high efficiency.

Pulse-Width Modulation

Pulse-width modulation (PWM) simulates a lower current level by pulsing a higher current level ON and OFF for short intervals.

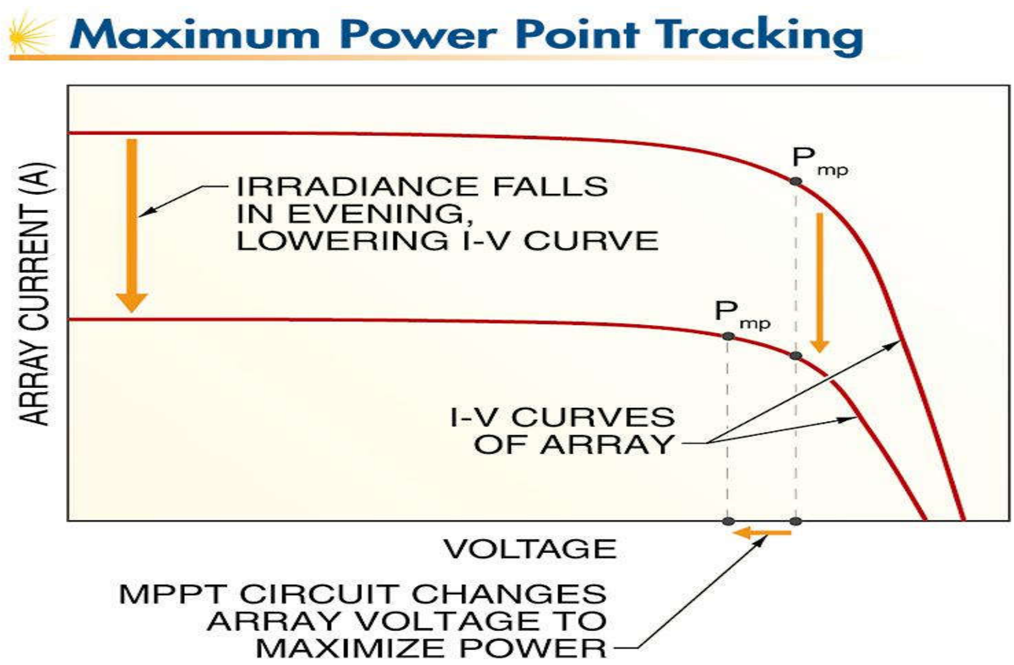
Pulse-width modulation is the process of modifying the width of the pulses in a pulse train in direct proportion to a small control signal; the greater the control voltage, the wider the resulting pulses become. By using a sinusoid of the desired frequency as the control voltage for a PWM circuit, it is possible to produce a high-power waveform whose average voltage varies sinusoidally in a manner suitable for driving ac motors.



Maximum Power Point Tracking

Maximum power point tracking manipulates the load or output voltage of an array in order to maintain operation at or near the maximum power point under changing temperature and irradiance conditions.

This concept is very unique to the field of PV Systems, and hence brings a very special application of power electronics to the field of photovoltaics. The concepts discussed in this section are equally valid for cells, modules, and arrays, although MPPT usually is employed at PV module/array level as discussed earlier, the behaviour of an illuminated solar cell can be characterised by an *I*-*V* curve. Interconnecting several solar cells in series or in parallel merely increases the overall voltage and/or current, but does not change the shape of the *I*-*V* curve. Therefore, for understanding the concept of MPPT, it is sufficient to consider the *I*-*V* curve of a solar cell. The *I*-*V* curve is dependent on the module temperature and the irradiance.



If a PV module (or array) is directly connected to an electrical load, the operating point is dictated by that load. For getting the maximal power out of the module,it thus is imperative to force the module to operate at the maximum power point. The simplest way of forcing the module to operate at the MPP, is either to force the voltage of the PV module to be that at the MPP (called *V*mpp) or to regulate the current to be that of the MPP (called *I*mpp).

However, the MPP is dependent on the ambient conditions. If the irradiance or temperature change, the IV and the P-V characteristics will change as well and hence the position of the MPP will shift. Therefore, changes in the I-V curve have to be tracked continuously such that the operating point can be adjusted tobe at the MPP after changes of the ambient conditions. This process is called *Maximum Power Point Tracking* or MPPT. The devices that perform this process are called *MPP trackers.*