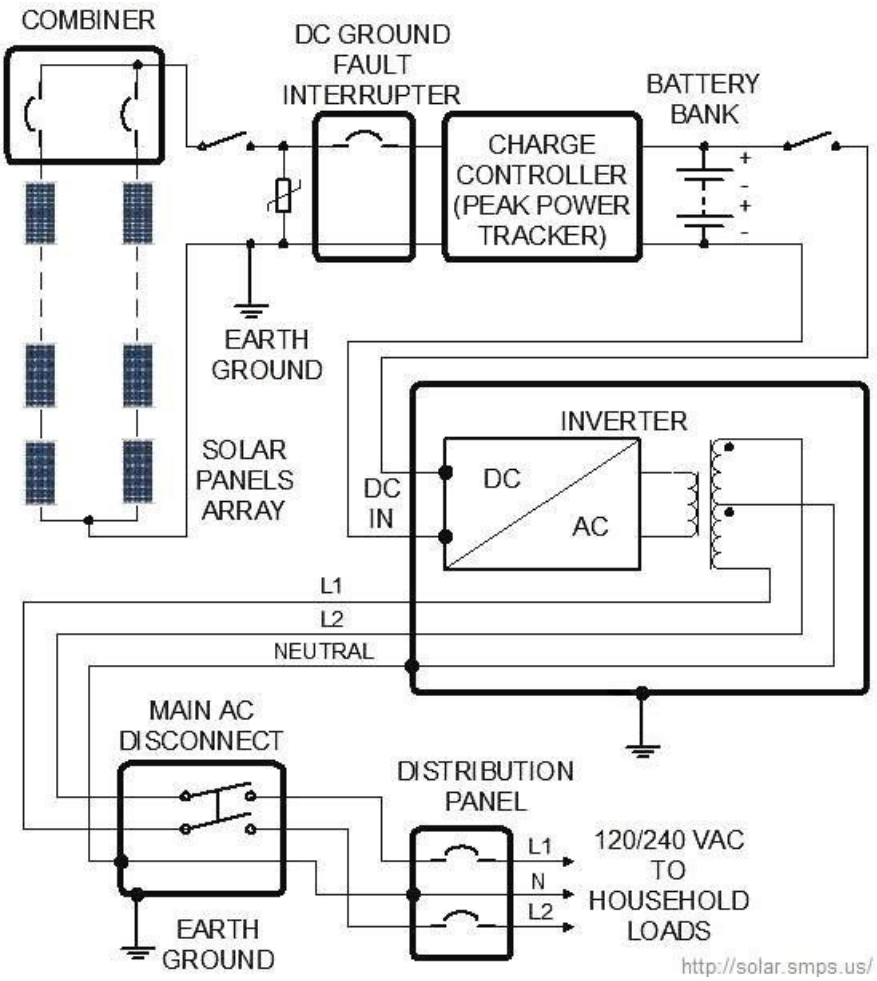
THE BASICS

Stand-alone (or off the grid) PV systems are intended to operate independent of the electric utility. Since PV panels do not store energy and can generate electricity only during daylight hours, for continuous power flow they need to generate excess of the energy which has to be stored somewhere. Normally, this extra energy is accumulated in the batteries.

If the off grid home has no other power source, both the PV array and the battery bank have to be significantly oversized by design to account for possibly 4-5 days of inclement weather. To reduce the size of the panels and the battery bank, solar systems for off-grid homes are often supplemented with wind turbines that can produce electricity at night and during cloudy periods. Electric gensets are also often used as an another auxiliary energy source that simplifies the isolated system's sizing. By the way, another reason batteries should be used off-grid is to operate the PV cells near their maximum power point.

PRINCIPLES OF THE DESIGN AND PV ELECTRICAL WIRING

Below is a simplified solar panel system wiring diagram for an off-grid home. The installations and grounding must be done in accordance with the National Electrical Code (NEC®) NFPA 70, UL 1741 and local electrical codes.



Particularly, one AC output conductor has to be grounded. In a single-phase 3-wire setup it has to be the neutral buss. PV panels can be connected in series and parallel- see various solar panel wiring methods. If you parallel several strings of solar panels, it is desirable to use a **combiner** with a fuse or a circuit

breaker for each string to prevent the panels' damage from possible reverse currents. However, I understand, with a proper conductor size, up to three strings are allowed to go to the same fuse. In all solar wiring configurations, if the DC voltage is over 50 volts, one of two DC busses should be grounded, unless the system has additional protections per NEC® 690.35. In theory, you can ground either plus or minus. However, most battery chargers and inverters come factory configured for negative ground systems. The combiner's frame or the PV arrays grounding conductor should be wired to a ground rod located as close as possible to the arrays. A DC **disconnect switch** should be installed near the place where the cables from the combiner enter the house. Since PV arrays are mounted outside, they can act like lightning rods. To reduce the possibility of a fire and to protect the system from a damage caused by lightings, it is recommended to have a voltage-clamping device across the DC buss. A metal oxide varistor (MOV) is commonly used in such applications.

The main DC disconnect switch is followed by a **DC ground fault interrupter**. It is a device that is designed to open the circuit when a certain leakage current to ground from an ungrounded bus is detected.

The current from the PV array is charging the batteries. To protect them from overcharging or from discharging by reverse currents, normally they are connected to the PV array via a **battery charger**. To extract the maximum power out of the array, the PV panels should operate near maximum power point (MPP) of their I-V curve. This requires different loading depending on the illumination and ambient temperature. That is why a special **peak power tracker** that charges the batteries while forcing the PV array to operate at an MPP is an important part of any solar system design.

A DC voltage from the battery bank is then converted to AC by a **DC-AC inverter**. The solar wiring diagram above shows a configuration with an inverter that provides 3-wire split phase 120/240 VAC which is typical for US household systems. In practice, inverter models usually provide only single 120VAC. However, many of them can be synchronized and stacked in a so-called master-slave mode for 120/240 VAC output. In this case, their inputs are paralleled, and outputs are connected in series. Note that many systems provide isolation between DC input and AC output in high-frequency boost converter stage, and do not use a bulky low-frequency output transformer. There are transformerless models as well. They work with ungrounded PV array and require overcurrent protection of both positive and negative conductors as well as a special safety warning per NEC® 2014 Article 690.35.