Disconnects:

The Home You Save May Be Your Own

John Wiles

Disconnects in a renewable energy system allow the user to turn the system off and on, safely service the system, and shut it down quickly when it malfunctions. Properly designed and installed disconnects do not cause any performance losses in the system, but poor quality disconnects may not only cause power losses, they may also present safety hazards.

NEC Requirements

The National Electrical Code (NEC) establishes requirements for disconnects. Although the NEC may not be used in some jurisdictions, it represents a minimum set of guidelines that can be used to design and install a safe renewable energy system. Some of the NEC disconnect requirements are specifically for PV systems, but these and other requirements can be applied to any electrical power system including wind and hydro systems.

Section C of Article 690 of the NEC establishes requirements for disconnects in PV systems. All ungrounded conductors from the PV array must have a switched disconnect. If the PV system is ungrounded, this indicates that a two-pole switch must be used, one pole for each ungrounded conductor. A grounded PV system, where one of the current-carrying conductors (usually the negative) is grounded, requires only a one-pole switch in the ungrounded conductors. Switches are never put in the grounded conductors of PV systems because opening such a switch during normal operations would unground the array and possibly create an unsafe condition.

All equipment in the PV system must have disconnects in the ungrounded conductors that will allow each piece of equipment to be disconnected from all sources of power. Equipment that requires these disconnects include the charge controller, the inverter, separate low-voltage disconnect devices, and external battery chargers. The power sources include the PV array, the battery bank, a backup generator, a wind turbine, a hydro generator, and any utility connection. These disconnects are required so that the equipment listed may be removed from the system for adjustment, service, or replacement while no power is being applied.

The intent behind these NEC requirements, which would apply to any renewable energy system, is that the electronic equipment in a system is very complex and will usually require adjustment or service by special technicians who might not be familiar with electrical power systems in general. The entire system is installed by a qualified person (PV dealer/installer or electrician) who is familiar with electrical power systems. The disconnect switches allow the user or the unqualified electronic service technician to work on or remove the equipment when it is unpowered and does not present a shock or fire hazard.

The NEC requires that the disconnects be manually operable switches or circuit breakers, be readily accessible, be externally operable with no exposed live parts, indicate clearly whether they are opened or closed, and be rated for the load they will carry.

Because there is usually more than one source of power in a renewable energy source, all fuses must have disconnect switches on both ends to allow all voltages to be removed from the fuse for servicing. These disconnects do not have to be connected directly to the fuse because other disconnects in the system may serve this requirement. The need for both disconnects and overcurrent protection indicates, in many cases, that circuit breakers could be used for both functions where they meet all of the necessary performance criteria.

Section 230 of the Code establishes other requirements for disconnects. No more than six motions of the hand may be used to disconnect all sources of power from a system. A complex system may require a main PV disconnect, a main battery disconnect, a main backup generator disconnect, and a main utility disconnect. This would leave two disconnects for addition of wind and hydro energy sources.

All disconnects must be grouped together and clearly marked. This requirement generally means that the PV disconnect cannot be located on the other side of the garage from the inverter disconnect, and the battery disconnect cannot be located in another room or building. When the sparks start to fly in an electrical power system, it must be shut down quickly. In an emergency situation, firefighters and others need to have the main disconnect switches grouped together and clearly marked.

Types and Ratings

In renewable energy systems, there are frequently both DC and ac circuits. Disconnects are usually required in both types of circuits. Disconnects may be either switches or circuit breakers, but they must be rated for the voltages and currents in the circuit in which they are used. Disconnects in the PV circuits should have a DC voltage rating that is 125% of the rated open-circuit voltage. This is a combination of NEC requirements and requirements established by Underwriters Laboratories (UL). The NEC required current rating of these switches should be 125% of the PV array short-circuit current. UL requires another 125% be added to this value for those days when snow or clouds increase the irradiance above the normal value. Disconnects in the DC circuits should have a voltage rating in excess of the maximum battery voltage (usually the equalizing voltage) and a current rating of 125% of any continuous currents plus 100% of any non-continuous current. Ac disconnects should have the normal 120 volt ac rating and current ratings to handle the circuit requirements. Electricians are familiar with the ac requirements and they will not be elaborated herein.

Implementation

The requirements outlined above, good engineering practices, equipment availability, and above all safety considerations sometimes present a confusing image of how to implement a system of disconnects. A few examples will be used to clarify the requirements. The following one-line diagrams do not show the details of overcurrent devices or grounding. Disconnect locations are shown by the box with the D. Starting with a simple direct-connected water pumping system shown in Figure 1, only one disconnect is required to separate

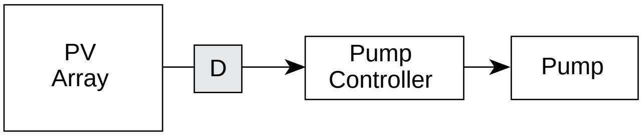


Figure 1

the PV array from the load. This disconnect is frequently a DC-rated circuit breaker mounted in a rain proof enclosure on the PV array mounting structure or PV tracker pole. Circuit breakers and enclosures are frequently more compact and less expensive than DC-rated switches.

Figure 2 shows a basic stand-alone PV system with battery storage and DC loads. A disconnect is needed

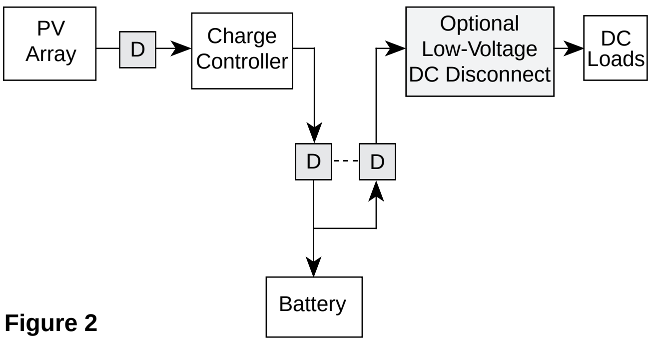


Figure 2

for the PV array, and two disconnects for the battery. The PV disconnect and the charge-circuit battery disconnect serve to isolate the charge controller should it need service.

Figure 3 shows a common stand-alone PV system with DC loads, an inverter, and ac loads. There are several ways to arrange the overcurrent devices and the

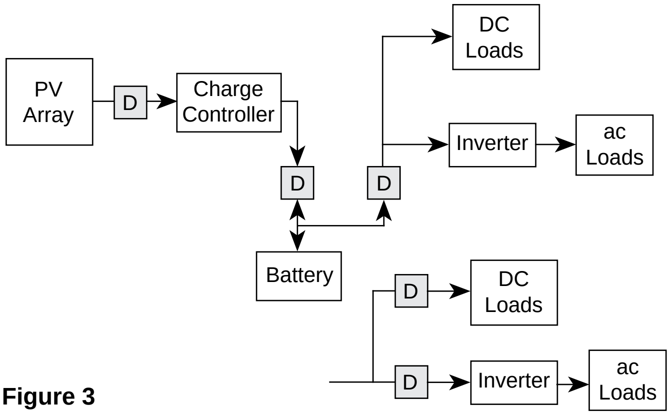
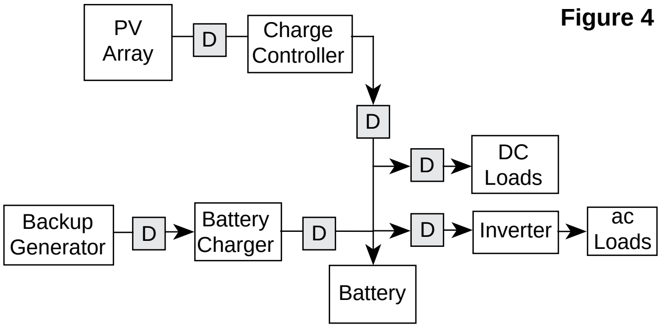


Figure 3

disconnects for the DC loads and the inverter. The lower diagram separates the disconnects for the DC loads and the inverter so that they may be operated independently. Some inspectors may require that the output of the inverter also have a disconnect.

Figure 4 adds a backup generator to the stand-alone system with a separate battery charger. An ac disconnect is needed between the generator and the battery charger and a DC disconnect is needed between the battery and the battery charger. Some of the DC disconnects could be combined, but charge

Figure 4



circuits should be kept separate from discharge circuits.

Figure 5

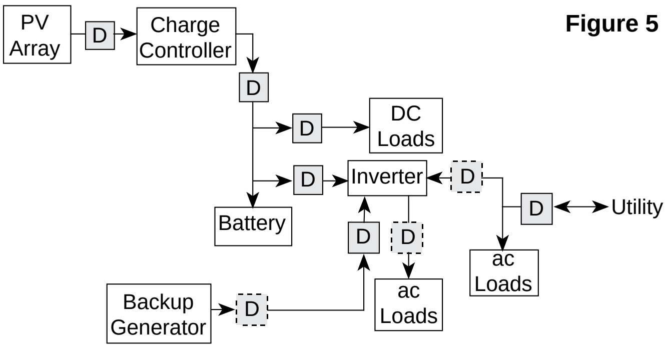


Figure 5 shows one of the more complex systems with an inverter with built-in charger and a utility-intertie capability. The inverter provides the transfer capability for the ac loads between the grid and the backup generator depending on what source of power is available. Excess power can be fed to the utility after appropriate contractual and safety arrangements have been made. The Trace Sinewave 4024 inverter provides all of these features. The disconnects shown in dotted boxes may be required to meet the grouping of disconnects requirement.

If the main ac service entrance disconnect for the utility is located some distance from the PV and battery disconnects, an additional ac disconnect will be needed near the inverter. Inspectors may also require an overcurrent device at this location to protect the cable when the inverter is feeding power to the grid. Since the generator is remotely located from the inverter, a disconnect will probably be needed at the generator location. This is particularly true if, as in the case of the Trace SW 4024, the inverter can feed power to the generator under certain circumstances.

The additional requirements for overcurrent devices will complicate these diagrams. Stay connected for a future Code Corner in which all of the requirements for grounding, overcurrent devices, and disconnects will be combined and shown in diagrams.

Access

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