Surge and Lightning Protection for the Stand-alone PV System

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Do you have a lightning rod on or near your house? Do you live in a high-incidence lightning area? Are you concerned with the safety of your family and your investment in a renewable energy system? Photovoltaic (PV) arrays need to receive full sunshine and not be shaded by nearby objects. They are generally mounted in the open and are frequently the highest object in the immediate area. With wiring, metal module frames, and metal mounting racks and supports, they look a lot like lightning rods. They frequently act like lightning rods by serving as dissipation points for electrostatic charge and strike points when the charge build-up exceeds the breakdown voltage of the air between the array and the clouds above.

Article 280 of the National Electrical Code (NEC) deals in general with surge arrestors. Chapter 8 of the NEC covering communications systems also mentions surge arrestors. Since PV systems are a relatively new power source, there is little available guidance in the NEC concerning surge protection of such systems. This Code Corner will address some of the techniques that have been used to suppress surges in PV and other renewable energy systems.

NEC Requirements

The NEC requires that all exposed metal surfaces be grounded regardless of the nominal system voltage. Systems with PV open-circuit voltages below 50 Volts are not required to have one of the current-carrying conductors grounded. Any system with ac voltages at 120 volts must have the neutral grounded. Some inverters do not isolate the ac and DC sides; grounding the ac neutral will also ground the DC negative. Other inverters have the case (which must be grounded) connected to the negative input which grounds the negative current-carrying conductor.

Direct Strikes

Direct and nearby lightning strikes can damage inverters, charge controllers, batteries, and other components in renewable energy systems and in homes. There are no guarantees on methods of preventing lightning damage. There are good engineering practices that can be applied that reduce the probability of damage from lightning strikes. They have been used for years by radio and TV stations, ham radio operators, remote communication systems, utility companies, and others. More protection is provided by combinations of these systems. The cost increases as the degree of protection increases. Again, there are no guarantees.

Lightning wants to travel from charged clouds to charged earth or visa versa. The strike occurs when the potential difference between the cloud and the earth exceeds the dielectric strength of the intervening air. Normally non-conductive objects, such as trees and houses, can serve as conductors to channel the charges and shorten the distance between the cloud and earth. If the charge is dissipated before the potential increases to the breakdown voltage, the lightning strike does not happen. A tall, metallic structure that is well grounded will usually protect an area around its base that has a diameter equal to 1/3 the height of the pole or structure. This indicates that a tall, grounded, metal pole directly behind the north side of a PV array may protect the array frame from direct strikes.

Induced Surges

Indirect strikes near the PV system will induce surges in conductors of the RE system and conductors coming into the house. Direct or close strikes on telephone and power lines even miles away may put large surges on the lines leading to the house. The techniques outlined below will reduce the effects of lightning induced surges on the PV system.

Ground all Metal Structures
The NEC requirement can be extended. A separate conductor (as large as possible, but not less than number 10 AWG) should be fastened to each metallic module frame with a self-threading, stainless-steel screw. The other end of these conductors should be connected to a single point on the array frame or rack — again with another self-threading, stainless-steel screw or with a stainless-steel bolt in a drilled and tapped hole. From this point, number 4-6 AWG or larger copper conductor should be run directly to the nearest earth where it is connected to the longest, deepest ground rod that can be afforded. Eight feet is the minimum length recommended. Use a UL-listed clamp to make the connection. If a steel well casing is available, drill and tap the casing and use this as the ground rod.

In dry areas, several ground rods spaced 20-50 feet apart in a radial configuration, all bonded to the central rod can be effective. Buried copper water plumbing can also improve the grounding system. Pipe or copper wire can be buried in trenches 12-18 inches deep in a radial grid. All grounding members should be connected or bonded to the central ground rod with heavy, bare conductors buried under ground. Direct-burial, UL-listed grounding clamps or welding should be used for all connections. Soldering should never be used.

The NEC requires (on systems that must be grounded) that the conductor from the grounded current-carrying conductor (usually the negative lead) to the main ground rod be unspliced and be as large as the largest conductor in the system. It is probably a good idea to tie the required equipment grounding conductors to the grounding system at the point where this large conductor connects to the negative conductor.

Limit Surge Transmission with Inductors
After a surge is impressed on an electrical conductor, the transmission of the surge may be attenuated or restricted by placing an inductor on the line. Running the conductors from the PV array to the house in grounded metal conduit will provide inductance on the lines. This will shield them from much of the initial surge pickup and slow down the surges that do get through. At a location near the entrance of the house, the conductors from the array can be coiled in a loop about 6-12 inches in diameter forming an inductor. Five to ten turns should be used in the loop, and the conductors should be tightly held together. When used with conduit, this coil can be placed in a metal box, with conduit coming into and out of the box.

Disconnect the Array
All systems should have a PV disconnect switch (NEC requirement). If there are no conductors from the array connected to the rest of the system, then there is little likelihood that surges on the array wiring will get into the house. This disconnect switch will have two poles on ungrounded systems and one pole on grounded systems. This switch can be left open when lightning storms are nearby. The 1/4 to 1/2 inch gap in the switch will provide some protection from surges when open, but a large surge will jump the gap.

A better solution is to mount a cord-connected plug-and-socket assembly either near the base of the array frame or near the house entry point. Use some sort of unique three-conductor plug and socket that is rated to carry the current and voltage involved (possibly a 30 or 50-amp, 240-volt range or a dryer plug-and-socket set). If the system uses a blocking diode in or near the charge controller, the socket should connect to the array wiring and the plug to the house wiring . If the system has no blocking diode, a socket should also be wired to the house wiring and a jumper with two plugs should be used to connect the two sockets. The house-side socket should always be disconnected first and connected last. In this case when the plug is inserted into the array socket, the other plug has exposed contacts that are at the array voltage. The idea is to unplug the array when storms are near to create at least a 3-4 foot gap between the array wiring and the house wiring.

Absorb the Surges
Surge arrestors are available in a number of sizes—generally the larger, the better. Surge arrestors can be connected at both ends of the array-to-controller wiring to bleed surges to ground or absorb them internally. Small quarter-sized units (metal oxide varistors—MOV) can be mounted at module junction boxes and inside electronic equipment, such as inverters and charge controllers. They should have a clamping voltage slightly above the maximum PV open-circuit voltage. They are available from electronic parts distributors or mail order firms like DigiKey.

Large units (the size of a frozen orange juice can), which can absorb far more energy from surges, can be mounted on the conductors entering the house or controller box. These units are used to protect 120/240-volt service entrances on residences and deep well pumps. They contain silicon oxide and are sometimes known as silicon oxide varistors. Although rated at voltages higher than the typical 12, 24, 36, or 48-volt PV system, they can be used to absorb those really large surges. They are available from many electric supply houses or from Delta Lightning Arrestors. Delta has a good unit - the model LA 302 which is rated at 300 volts, 60,000 amps and 1500 Joules. These units should be connected positive to negative, positive to ground, and negative to ground. In the smaller MOV two-wire units, three separate devices must be used. The larger units, such as the ones from Delta, have three wires. One is connected to the positive conductor, one to the negative conductor, and one to ground.

Provide a High-Voltage Path to Ground

Close and direct hits can impose very high voltages on the array conductors. Some of this voltage will be absorbed by the surge arrestors. A spark gap can provide a path for the higher voltage surges to get to ground. Mick Sagrillo, in his excellent article on Lightning Protection in *Home Power* #24, presented an easy, low-cost method of making spark gaps using spark plugs. One of these spark gaps should be placed on both the positive and negative conductors near the bottom of the array rack or pole with a very short connection to ground. The gap can be as small as possible since it only needs to present an open circuit to PV voltages in the range of 22-44 Volts.

Utility and Phone Lines

If the RE user also has grid power (as a back-up, of course) or hard-wired telephone service, surge suppression must also be placed on these lines. The large surge arrestors described above can be used on the utility power lines and special telephone arrestors are available from Radio Shack and others.

Well Grounded Systems Last Longer and Work Better

The communications and computer industries are finding that surges and poor commercial power quality demand that all systems be grounded to a common point. Data corruption on computers, modems, and faxes and noise on telephone lines has frequently been traced to poor grounds or separate grounds for each system. Proper procedures vary from site to site and are beyond the scope of this article, but using a common grounding system can usually minimize many problems. Those trying to use telephone products that need external power have special problems which the local electronic technician can solve using isolated power supplies. Radio and TV antenna lead-ins should also be connected to appropriate lightning arrestors or ground.

Charge Controller Design

Charge controllers that use relays (either mechanical or mercury displacement) that are physically separated from the electronics control package are generally less susceptible to surges than controllers that have solid-state switching devices in a single package. The relays are pretty tough and it is relatively easy to add surge protection to the remote electronics package.

Summary

There is little that can be done to protect a renewable energy system from a direct strike. The probability of a direct strike can be reduced however and systems can be reasonably protected from surges induced by nearby lightning strikes.

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