Water and Electricity Do Mix

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The old saying that water and electricity don't mix is not at all true when water is pumped by PV power in a safely installed system that meets the requirements established by the National Electrical Code® (NEC®). Although Article 690 of the NEC does not deal specifically with water pumping systems, other articles in the code do.

Grounding

As with other equipment in the PV system (including 12-and 24-volt systems), Article 250-43(k) requires that all exposed, noncurrent-carrying metal parts of motor-operated pumps, including submersible pumps, be grounded. These metal parts must be connected to the other metal parts of the system such as the module frames and grounded at a common point. This indicates that three-conductor cables should be used for the pump circuits–positive, negative, and equipment grounding. In three-conductor cables, the bare conductor may be used only for equipment grounding (Article 339-1(a)), and may not be used to carry current.

If the PV-powered water-pumping system operates at open-circuit voltages higher than 50 volts, Article 690-41 requires that one of the current-carrying conductors be grounded. This is in addition to the equipment grounding conductor. On certain maximum-power trackers, current boosters or pump controllers, this may pose a problem when control devices such as relays and transistors are placed in the negative conductor which is normally the grounded conductor. Grounding the positive conductor is permissible under these circumstances and will pose no problems if it is directly connected through the controller. Current shunts placed in a grounded conductor act like wires themselves, but care must be taken that they are not bypassed by unintentional multiple grounding of this conductor. In any event, the grounded conductor must have white insulation or, in sizes greater than 6 AWG, be marked at each termination with a white marker (Article 200-6(b)).

Conductor Ampacity and Overcurrent Devices

Each conductor must have an ampacity or current-carrying capacity equal to or greater than 125% of the maximum current flowing through it. For the PV array conductors, this would be 125% of the parallel module short-circuit current (Article 690-8). If a max-power tracker, current booster, or pump controller is used, the manufacturer should be consulted to determine the maximum worst-case condition of steady-state output current. This may be many times greater than the PV array short-circuit current and the conductors to the pump must be sized appropriately. Article 310 in the NEC gives conductor ampacities for various conductor insulation types, installation locations, and temperatures.

Overcurrent protection in the form of fuses or circuit breakers must protect each circuit in the water pumping system. The current rating of these devices must be equal to or less than the ampacity of the conductors they are protecting (Articles 240 and 690-8).

For example, a typical direct-drive water pumping system might have four 60-Watt PV modules connected in parallel. These modules can deliver 12.5 amps of rated short-circuit current to a current booster/controller. Number 10 AWG cable might be used from the PV modules to the controller. A 20-amp fuse might be selected to protect these wires from overcurrent. At certain load conditions, the current booster could supply 55 amps at 4 volts to the motor. Number 6 AWG cable would be needed between the controller and the pump, and a 75 amp fuse or circuit breaker could be used to provide the overcurrent protection.

Disconnects

Since a disconnect device will be required between the PV array and the controller (Article 690-C) and possibly between the controller and the pump, it seems appropriate to use circuit breakers since they serve as both the disconnect switch and the overcurrent device. They are very robust, easier to use than switches and fuses, sometimes less expensive than appropriately rated switches, and usually provide more satisfactory performance than fuses and switches. Square D QO residential circuit breakers are listed and rated by Underwriters Laboratories (UL) for direct-current use up to 70 amps and 48 volts (12-and 24-volt PV systems). Heinemann and Airpax breakers are UL listed with higher

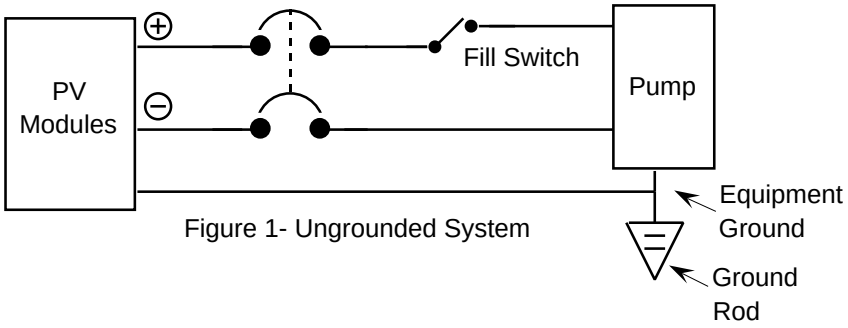

Figure 1- Ungrounded System

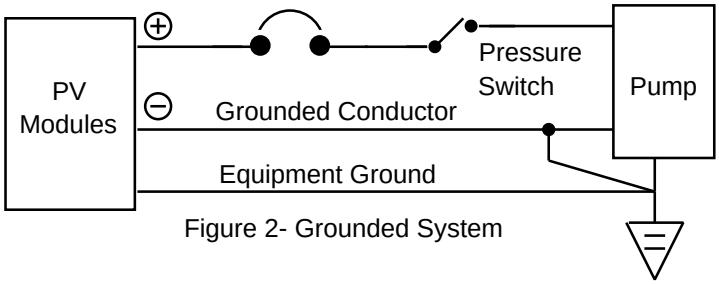

Figure 2- Grounded System

voltage and current ratings for the larger systems.

Pumps use electrical motors that are addressed by several sections of the code. Article 430 deals with motor circuits and controllers. Section H of this article requires a disconnect device for both the motor and the controller, and it is to be within sight of the controller and be readily accessible. This disconnect device can be either a switch or circuit breaker, but it must plainly indicate whether it is open (off) or closed (on). The branch-circuit overcurrent device such as a fused disconnect switch or circuit breaker may be used as the motor disconnect if it is rated and listed as a branch circuit protective device.

If a separate pump house is used, there are specific requirements for the disconnects which are based on the type of cable used between the power source and the pump house. If USE (Underground Service Entrance) cable is used, Articles 230-90 and 230-91 spell out the requirements. If UF (Underground Feeder) cable is used, then Article 339 tells how to install this cable.

Example Diagrams

There are several possible ways that a PV system might be connected to pump water. These examples are all direct-drive systems and have no batteries. The addition of batteries complicates the situation considerably and these issues have been addressed in previous Code Corner Columns.

Figure 1 shows a small system that uses only a fill or pressure switch and does not have a controller or power tracker. A disconnect switch is required between the PV array and the pump. Since one of the current carrying conductors is not grounded (OK if less than 50 volts open-circuit voltage), a two-pole disconnect switch must be used to simultaneously disconnect both the positive and negative conductors. If one of the current-carrying conductors is grounded, then only a single-pole switch is needed in the ungrounded conductor (Figure 2).

Figure 3 shows a grounded system with a current booster/controller. Disconnect/overcurrent devices are shown before and after the controller. They are shown ganged to completely disconnect the controller from the system, and they will more than likely have different current ratings.

Summary

Water and electricity can be mixed safely. Good judgment and compliance with the guidelines in the NEC can add up to a safe, PV-powered, stock-watering tank or a potable water system.

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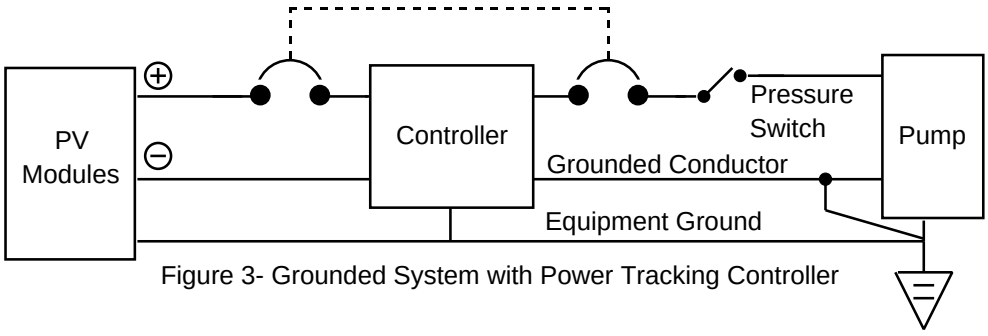

Figure 3- Grounded System with Power Tracking Controller