I'm writing this article as a customer, for the customer and so the prospective PV installer can win the bid by explaining the correct installation procedure per the manufacturer's instructions in order to maintain the warranty and harvest the maximum power from the system and the customer will not be among the over 50% that are having their PV system installed *incorrectly* voiding the warranty without the customer's knowledge of it.

The problem today is too much material is being written that little or no maintenance is required after installing a PV system. After reading this article containing the Manufacturer Installation Instruction Manual it should put an end to those fantasies.

As I write I have over 53 years in the electrical industry of which several years involved inspection and electrical expert testimony in personal injury and death cases.

I learned at an early age in the electrical trade that anything mechanical can fail. It requires maintenance and inspection to maintain quality and operation.

So you'll hear me say the words maintenance and inspection several times throughout this workbook. The word *maintenance* is mentioned 223 times in the National Electrical Code and the word *inspection* 61 times.

It's time for the PV industry to return to craftsmanship skills when installing a PV system that may operate 40-50 years exposed to the inclement outdoor weather.

The customer is investing a substantial amount of money in the PV system expecting a continued savings on their electric bill.

The system must be installed correctly to produce the maximum possible energy.

The system must be designed to the manufacturer's specifications which requires maintenance, cleaning and inspection periodically, which requires access space to the modules. These are requirements in the product warranty.

One must first understand that heat is resistance and will reduce the power output of the PV system. Untorqued connections, and modules mounted too close to the roof surface are examples of contributors of heat that will lower the wattage output.

It's not a matter of just spinning the net meter backwards as desired by the customer to save money on the electric bill. It's a matter to ensure the customer the meter is spinning backwards at a maximum possible rate and it will continue in the future to harvest the maximum power as the system was installed correctly to the manufacturer's product specifications which include torquing the connections mechanically and electrically to the required inch-pounds or foot-pounds, cleaning of the modules, maintenance, and required inspection of the entire system periodically for corrosion, loose connections, wiring damaged by rodents, etc.

When I ask an installer if they torqued the connections as required, the reply is "no one does it that way." I've always maintained, "wrong is wrong, even if everyone does it that way. And right is right even if no one does it that way."

I'm not your average customer, so you'll do it the right way when installing my system.

A PV Installation must be above inspection and beyond the Code

Recently I e-mailed a person to inform him the photo that appeared in an electrical magazine had the PV modules installed *incorrectly*. His reply, via his personal solar contractor was the inspectors signed it off and stated there wasn't any violations.

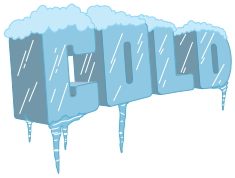
I have been employed as an electrical inspector in the years past and have written a book on *Electrical Inspection*. What one must understand is a correctly installed PV installation goes way beyond the inspector and the Code.

Let's start at the beginning, why did the prospective customer call the PV installer? To reduce their electric bill, simple as that!

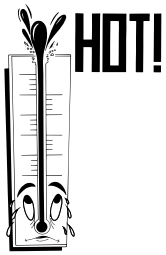
Guess what, the inspector enforces the Code, which is for safety and has nothing to do with reducing your electric bill!

If you read the National Electrical Code it states their intent in the very beginning of the book:
Section 90.1(A) Practical ***Safeguarding*** of persons and property.
Section 90.1(B) Adequacy. Compliance therewith and proper maintenance in an installation that is essentially free from hazard ***but not necessarily efficient***.
Section 90.1(C) Intention, This Code is ***not intended as a design specification*** or an instruction manual for untrained persons.

In reality, PV modules will operate in a wide range of temperatures that are specific to the project location. ***To properly design a system***, it is important to know the performance of the modules at the specific temperature extremes. The temperature coefficients, which are determined by Nationally Recognized Test Labs, are used to calculate the performance of the modules at these temperatures.



In Table 690.7 the Code recognizes the cold temperatures by requiring a correction factor. The reason is cold temperatures actually raise the voltage of the module. The Code has a 600 volt maximum as does the insulation of most wires and with several modules in series you can reach extremely high DC voltages. So the Code steps in for ***safety*** purposes, not designing. With colder temperatures you have higher voltages and also more power (watts).



The opposite is true with heat. Higher temperatures cause the modules to have less voltage and less power output (watts). But the Code does not recognize the higher temperatures as the modules heat is not a safety item, it's an ***efficiency*** item.

Excessive heat can cause problems as the modules now with a lower voltage may not meet the minimum DC voltage required to start the inverter.

Mounting the modules too close to the roof surface blocks the air flow to help cool the modules.

The increase in heat lowers the output power of the modules.

If the modules are installed in a location where the ambient temperature reaches 50°C (122°F) the open circuit voltage will go down do to the heat. Current increases only *slightly* with a higher temperature.

230 watts
Vmp = 29.6 volts ←
Imp = *7.76 amps*
Voc = 36.9 volts
Isc = 8.42 amps

Manufacturer's Data:		
NOTC (nominal operating cell temperature)		47°C
TC (temperature coefficient)	Isc	0.042% per°C
TC	***Voc***	***0.33% per C°***
TC	Pmax	0.45% per°C

Temperature difference from *STC* = 50°C - 25°C = +25°C (warmer)
Percentage of voltage decrease = +25°C x .33 = 8.25%
Voltage decrease per module = 29.6v x 8.25% = 2.44 volts
Therefore, the Voc at 50°C (122°F) = 29.6v - 2.44v = 27.16 or ***27 volts***

Watts = Volts x Amps 27v x 7.8a = 210 watts of power per module instead of 230 watts shown on the module nameplate. A loss of 20 watts per module. A 5 kW system would require at least 22 modules. 22 modules x 20 watts = 440 watt loss in the PV output.

But, remember the inspector is not concerned in his inspection with design or efficiency, only safety. I would expect the inspector to enforce section ***110.3(B)*** and check to see if the PV installer is using the required ***torque tools*** for the mechanical and electrical connections required in the manufacturer's product listing. After tightening the lag screw to the rafter, ***every mechanical and electrical connection*** in the entire PV system is required to be torqued to the manufacturer's specifications in order to maintain the warranty.

In my early studies of the installation of PV systems I became immediately concerned about filling the roof with modules and how could you follow the manufacturer's specifications which requires cleaning, maintenance and inspection of the mechanical and electrical components. I was told by an experienced instructor of the Code that section 110.26 does not apply as the PV modules cannot be ***serviced*** in the field. His comment was ,"The NEC does not and should not address maintenance procedures."

The reason for inspection is to check for corrosion, looseness of mechanical connections, inspection of the wiring for rodent damage and signs of loose connections, etc. His reply was, rodent damage would come under ***good workmanship*** and proper use of materials suited to the environment and protected from physical abuse. But I have yet to see the DC wiring between the modules connected in series in metal conduit in any of his published articles?

When I ask how would you remove a defective module in the center of the roof without removing several modules to get to the defective one? His reply was, "Yep, you may have to remove multiple modules to get to the defective one, ***but the code doesn't care***."

I bet the customer would care when they have to pay $$ the service bill! The first step we take in our designing a PV system is to ***allow space between the arrays*** for cleaning, inspection and maintenance which is required. I guess some people haven't taken the time to read manufacturer's installation instructions. I was told that I needed to read section 110.26 carefully so I would understand that it doesn't apply to equipment that does not require service or can be de-energized? I've been in the electrical industry 53 years now and after reading these types of replies, my last question is "*who's teaching the teacher*?"

In the *2011 Code* section 690.31(E) a change was accepted: Wiring methods shall ***not be installed within 10"*** of the roof decking or sheathing ***except directly below the roof surface covered by PV modules*** and associated equipment. To the extent practical, circuits shall be run vertically from the roof penetration point to supports a minimum of 10" below the roof decking.

FPN: The 10" requirement is to prevent accidental damage from saws used by firefighters for roof ventilation during a structure fire.

The question today with the roof being filled with panels how would a firefighter use his saw when the change states: ***except directly below the roof surface covered by PV modules***?

California fire code requires roof access for safe fire suppression and rescue operations. Solar panels must set back ***4'*** from the edges and peaks of the roofs with space between the arrays. This reduces the area for solar panel installation but provides room for emergency personnel to work around the array. It also allows for roof-peak venting in case of a fire. Now this rule makes sense. But, now the PV salesmen don't like it because now they can't fill the roof with modules.