2013 Design & Trade Conference

Battery-Based PV systems and The Utility grid link under NEC 2011 and Beyond

By *Gail Burrington*

with help from Mike Holt; **ETM** solar works; Surrette; HellermannTyton; **MK** Battery; Bill Brooks; BenQ; AEE Solar; Jim Dunlop; Darryl Thayer

OutBack Power Systems; SMA; Schneider Electric

May 30th, 2013

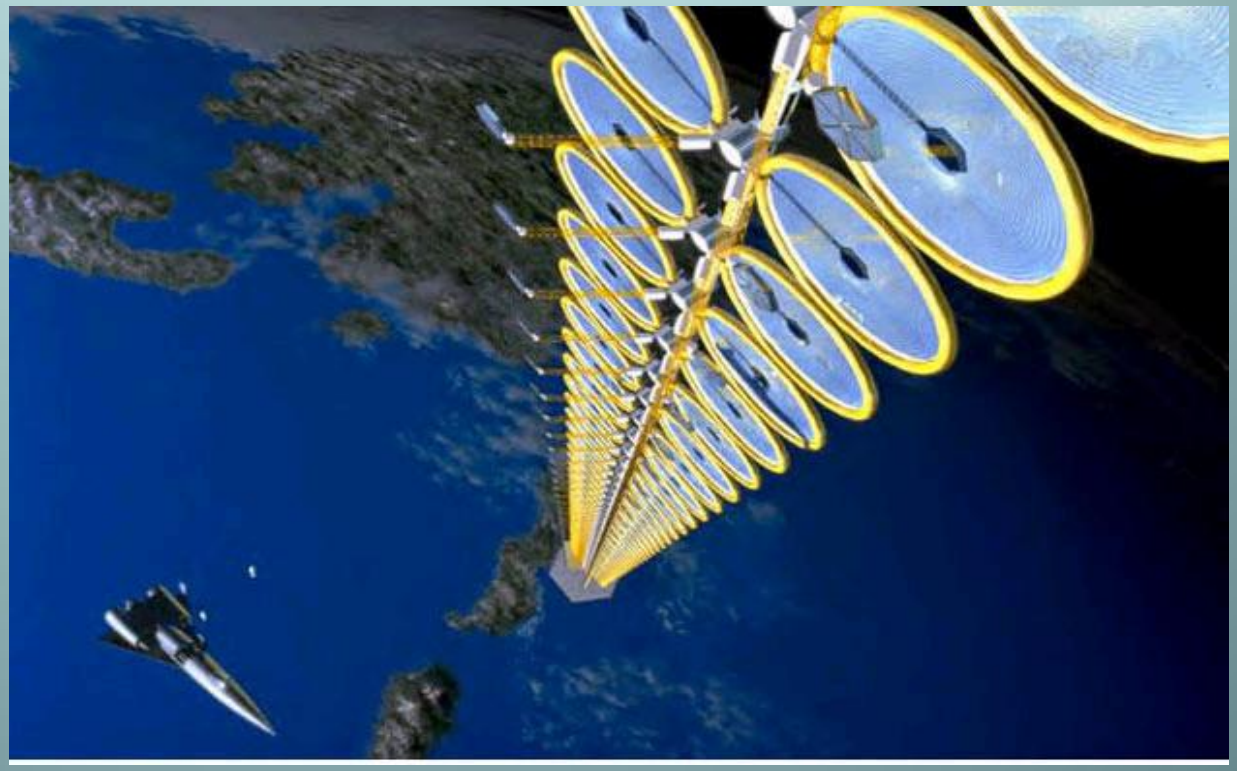
Gateway Community College

REV

An overview

- In the early days...

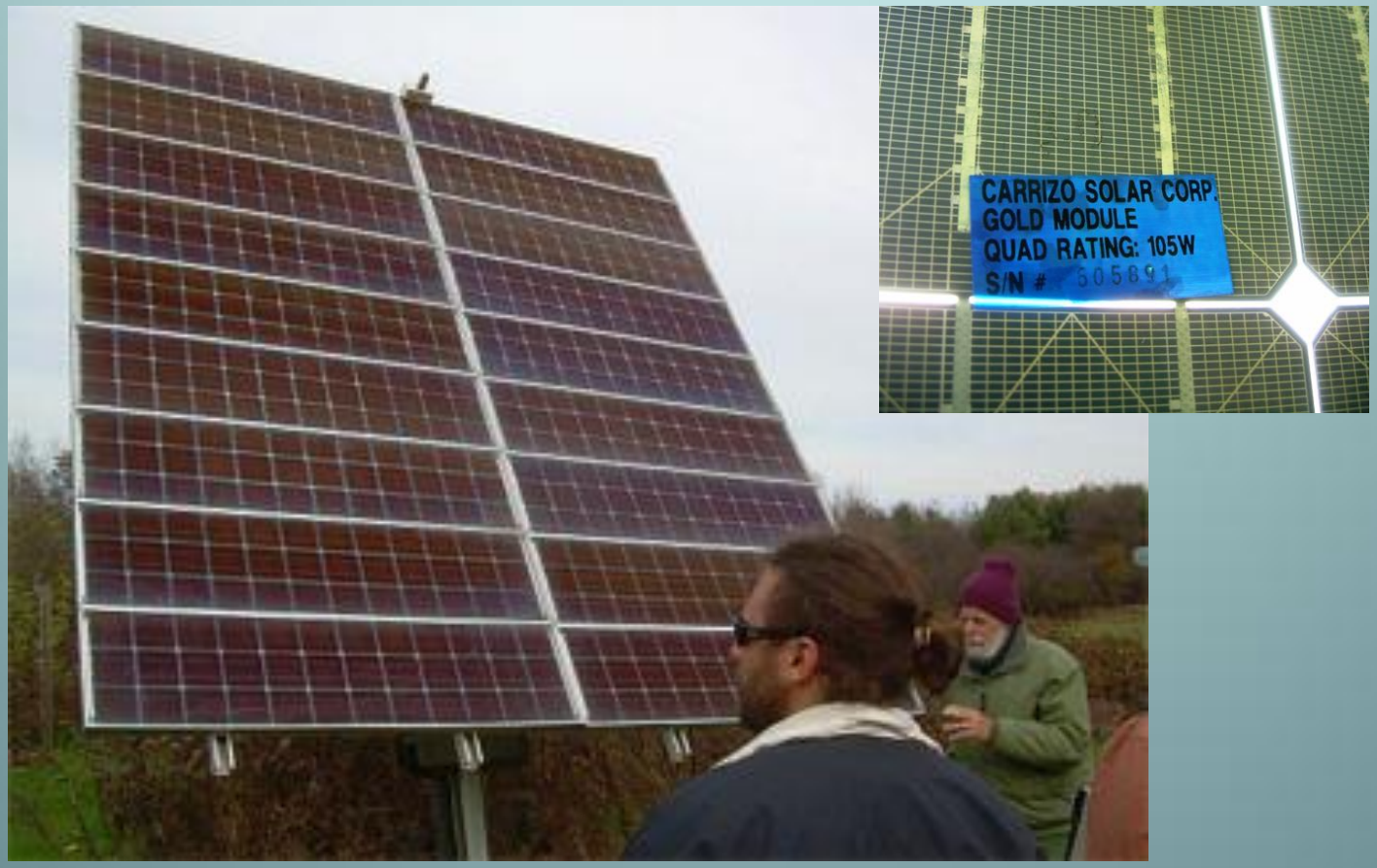
Photovoltaics seemed mostly “way out there”

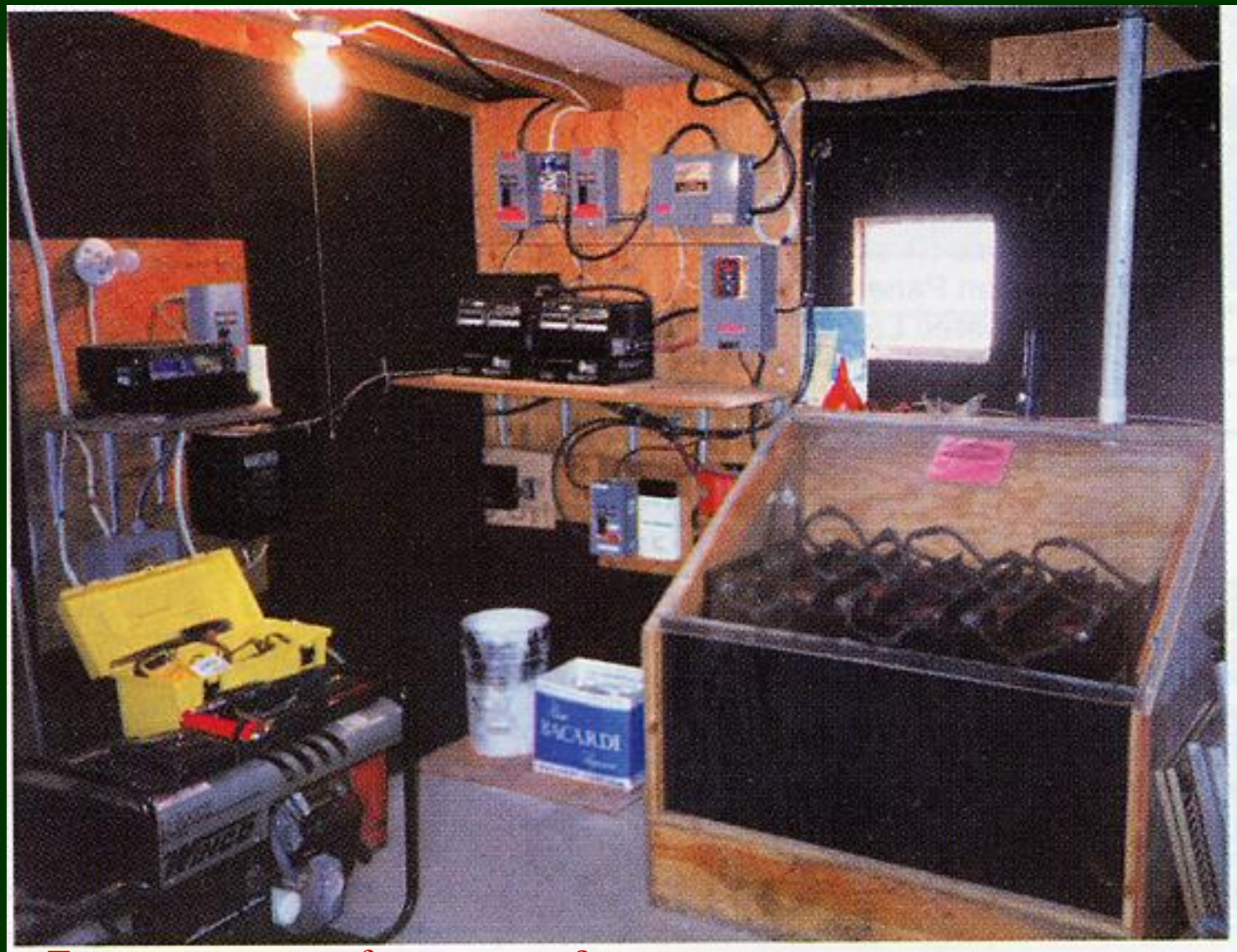


or only associated with small consumer “toys”

Until the first “used “ PV modules became available

to “creative hippies” and DIY pioneers…





-Temporary storage for generator ?

-baking soda in the “Bacardi” box ?

Direct-coupled PV

is a perfect example of
"appropriate technology":

the PV does its' work as
the sun is shining-

No batteries needed

crop irrigation, water pumped
to storage, and attic ventilation fans
directly match the solar energy
resource to a job to be done

But some jobs require batteries

Stand-alone PV

-Provides access to energy for work in **remote** areas

- Avoids the cost of extending utility lines,

- Is an alternate to the excessive use of generators that are fossil fueled

Enjoy remote

But Plan Ahead

Use Best Practices

Even partial shading of solar arrays is VERY detrimental

387 Watts

25% Shading can cause more than 50% reduction in output !!!

523 Watts

< 10% Shading can cause as much as a 50% reduction in output

1231 Watts

What really counts today

Get a little power

- And we often want more..

- The basic battery-based PV system is still a series

--Solar **PV array**

– **Charge controller** to make sure the batteries
Are not overcharged by the array

- **Battery bank** of **DC** low voltage to **Match Loads** either directly, or, as the basis for an inverter to satisfy common **AC** appliances.

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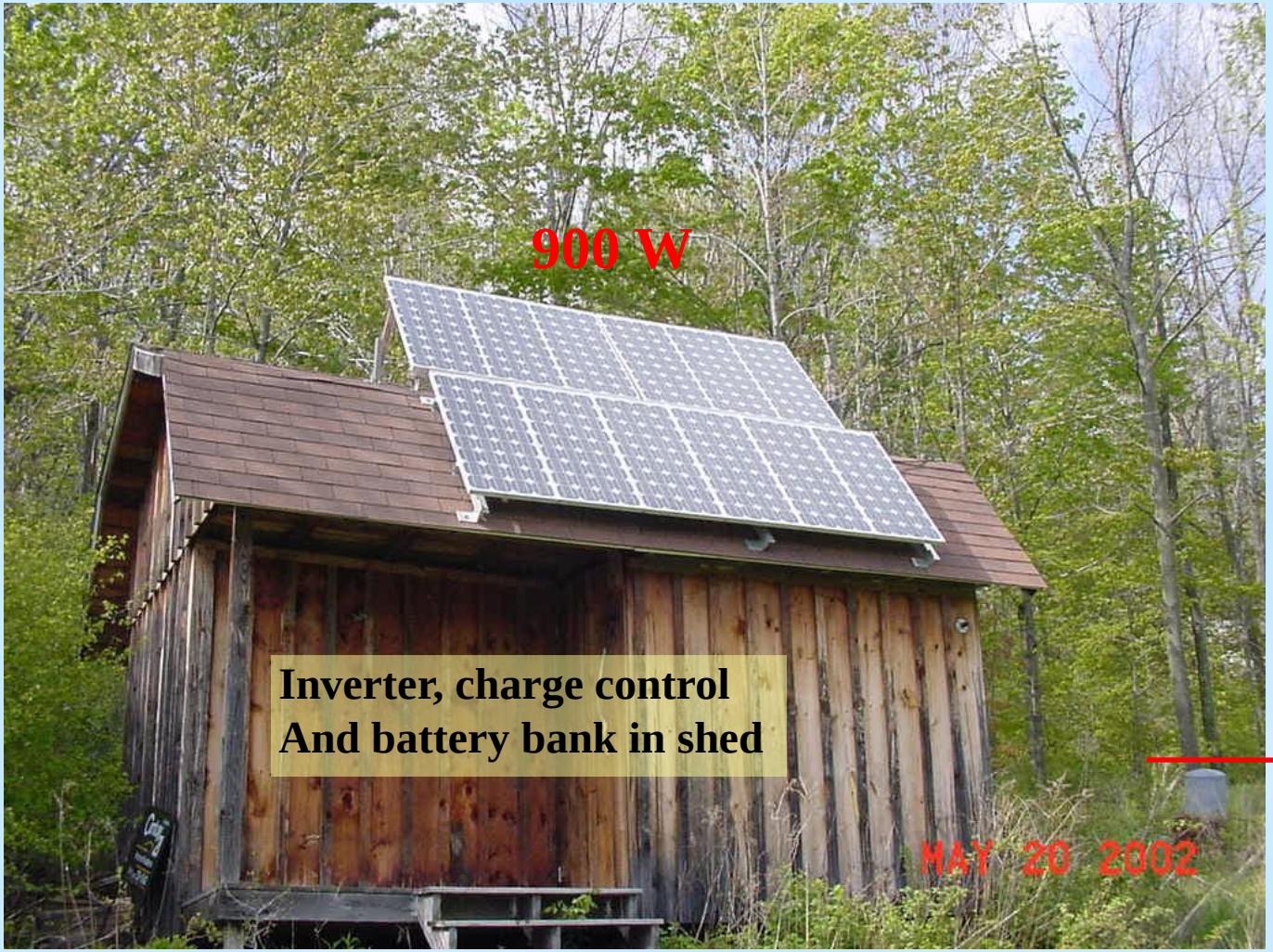
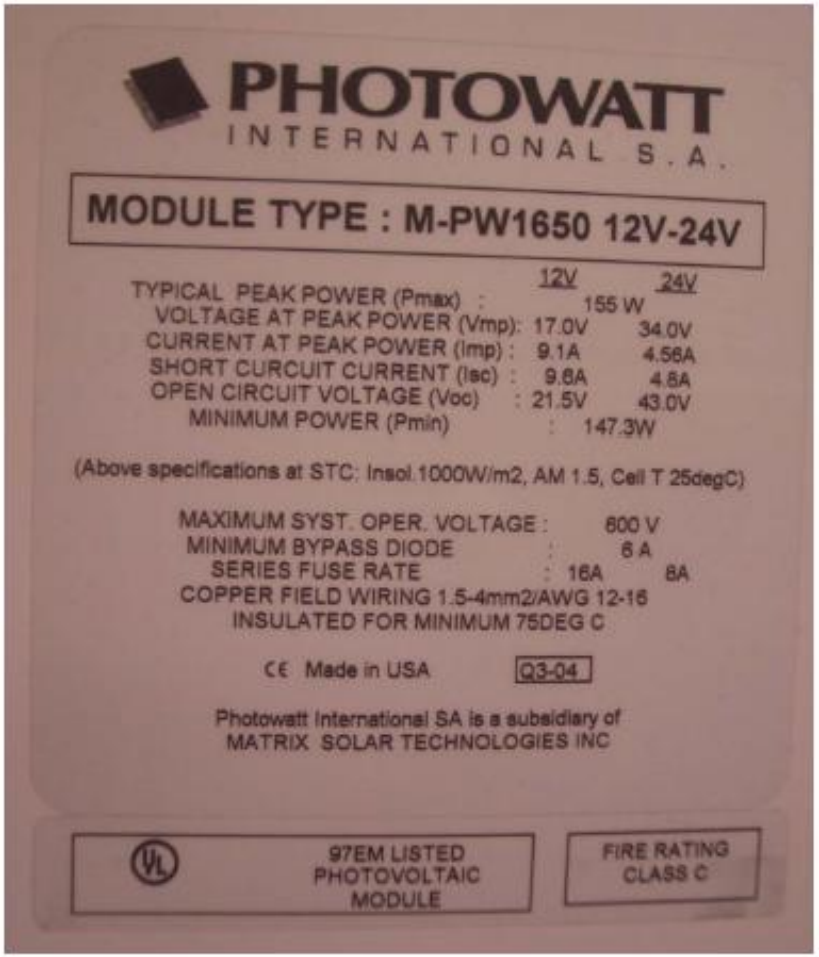
The Power Shed

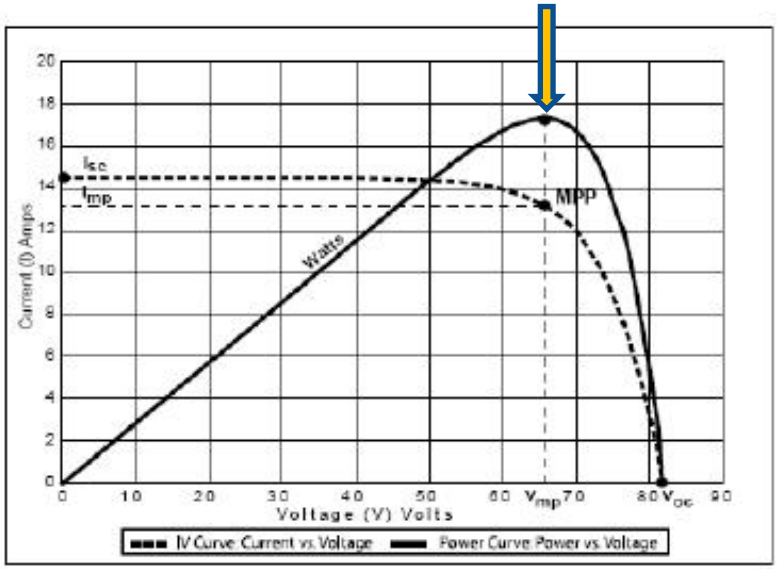


To house

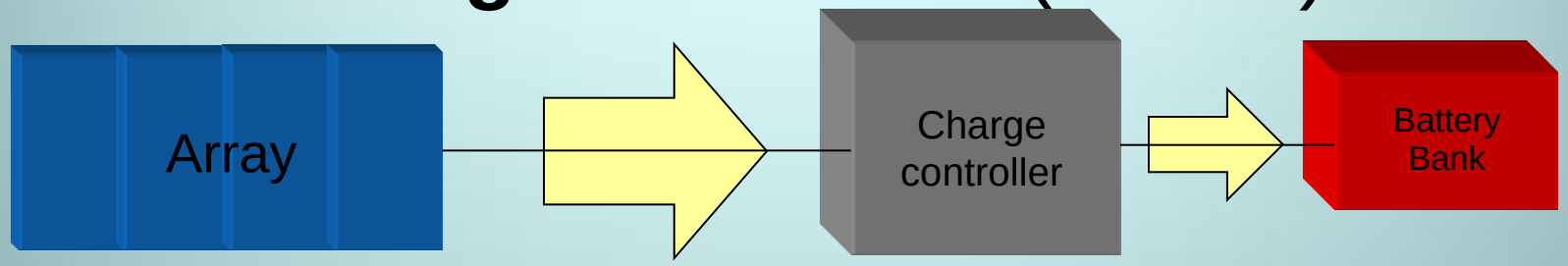


- SOLAR PANEL Parameters
  - Open-circuit voltage (V_{oc})
  - Short-circuit current (I_{sc})
  - Maximum power voltage (V_{mp})
  - Maximum power current (I_{mp})
  - Maximum power point (MPP)

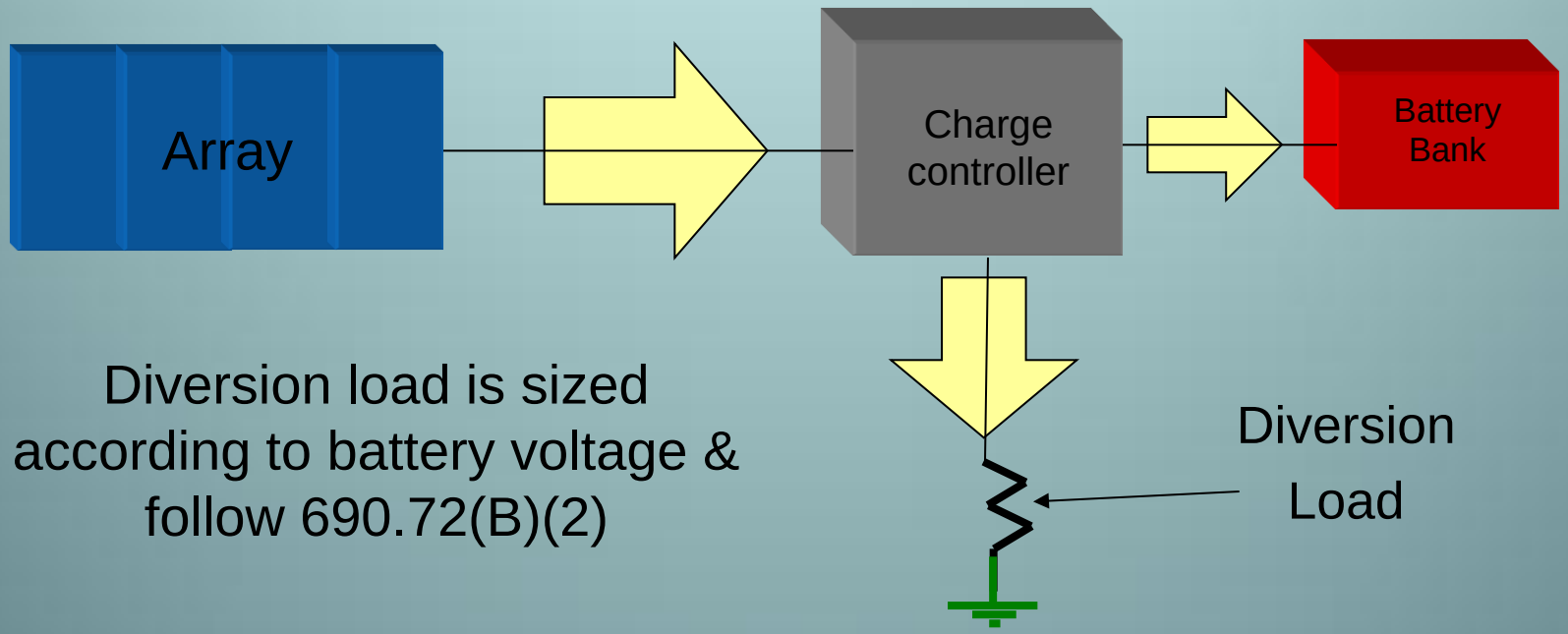
Peak Power (Pmax) is at MPP



Charge Controller (Series)



Diversion Charge Controller. (Parallel)



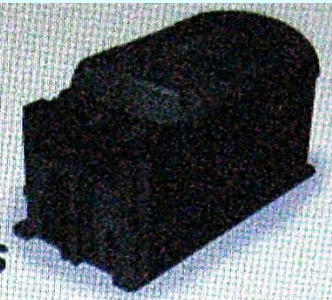
Diversion load is sized according to battery voltage & follow 690.72(B)(2)

Batteries

Most economical storage method today

- 2 – 12VDC building blocks
- Lead-Acid
  - Flooded
  - Absorbent Glass Matt (AGM)
  - Gel
- NiCd
- NiMH
- Lithium-ion

AEE Solar



Battery-Based Inverters

- Voltage sourced
  - Inverter builds its own waveform
- Fixed low-voltage input
  - Inverter fed from steady 12/24/48 VDC from batteries
- PV array MPPT provided by charge controller
  - Charge controller dictates string size
- Modest efficiency: 75-90%
- Low-voltage single-phase output
  - 120 or 240 VAC

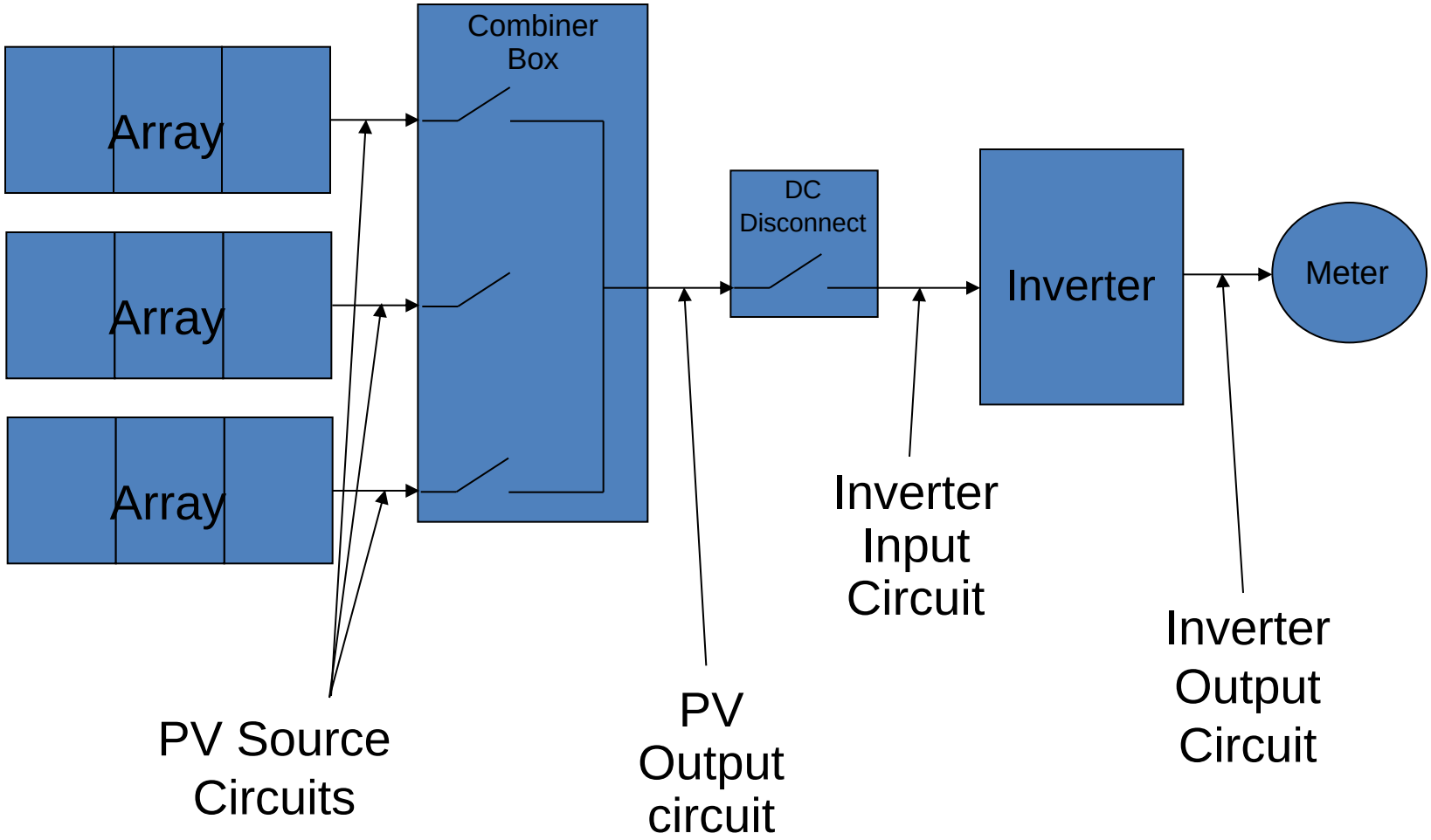
Grid-Tie Inverters

- Current sourced
  - Inverter uses grid waveform
- Actively controlled voltage input
  - Inverter uses MPPT and accepts wide range of voltages
- Inverter provides PV array MPPT
  - String sizing dictated by inverter
- High efficiency: 95-98%
- Range of outputs
  - 240 VAC or 208/277/480 3-phase

Grid –tied only PV

- PV Array feeds an inverter that **needs an active utility grid** in order to operate
- GT Inverter sends **synchronized AC** electricity into the Main Service Panel
- Household appliances use the PV power
- *excess* power produced can **backfeed** into the utility grid as a ***net meter*** credit

Direct Grid Interactive (DGI)



Highlights of Article 690

Gay E. Canough

Highlights of Article 690

Gay E. Canough

DC disconnect
Rated for up to 600 V DC

"Readily accessible" and
There is plenty of "working space"

Macro Bin
12 5:55PM

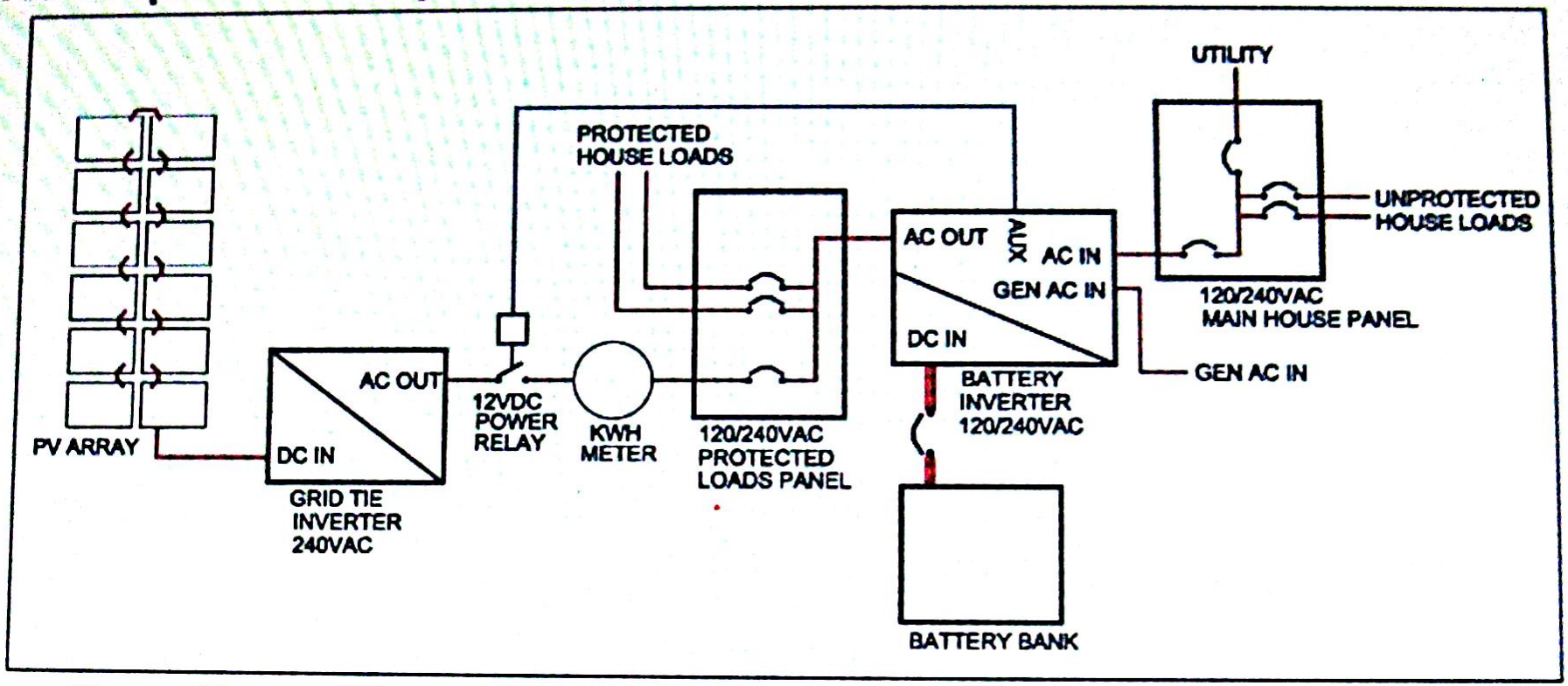
GTBB

- But if **essential loads** need power when the utility is not available…
- Battery-back up can be added ….

The battery energy is "standing-by" ready to power

- Well pumps
- Heating controls for Oil and gas equipment
- Circulators for furnace, boilers, radiant floors,
- Sump pumps
- Key lighting and security alarms
- Communications

AC coupled GTBB system



- Normally uses a protected loads panel
- Uses both a direct grid-tie inverter and a battery-based inverter
- Is useful when retrofitting an existing system
- Is useful when a kWh production meter is needed
- More expensive and complex, not all equipment is compatible

DC coupled: (with charge controllers)

Outback Power Systems

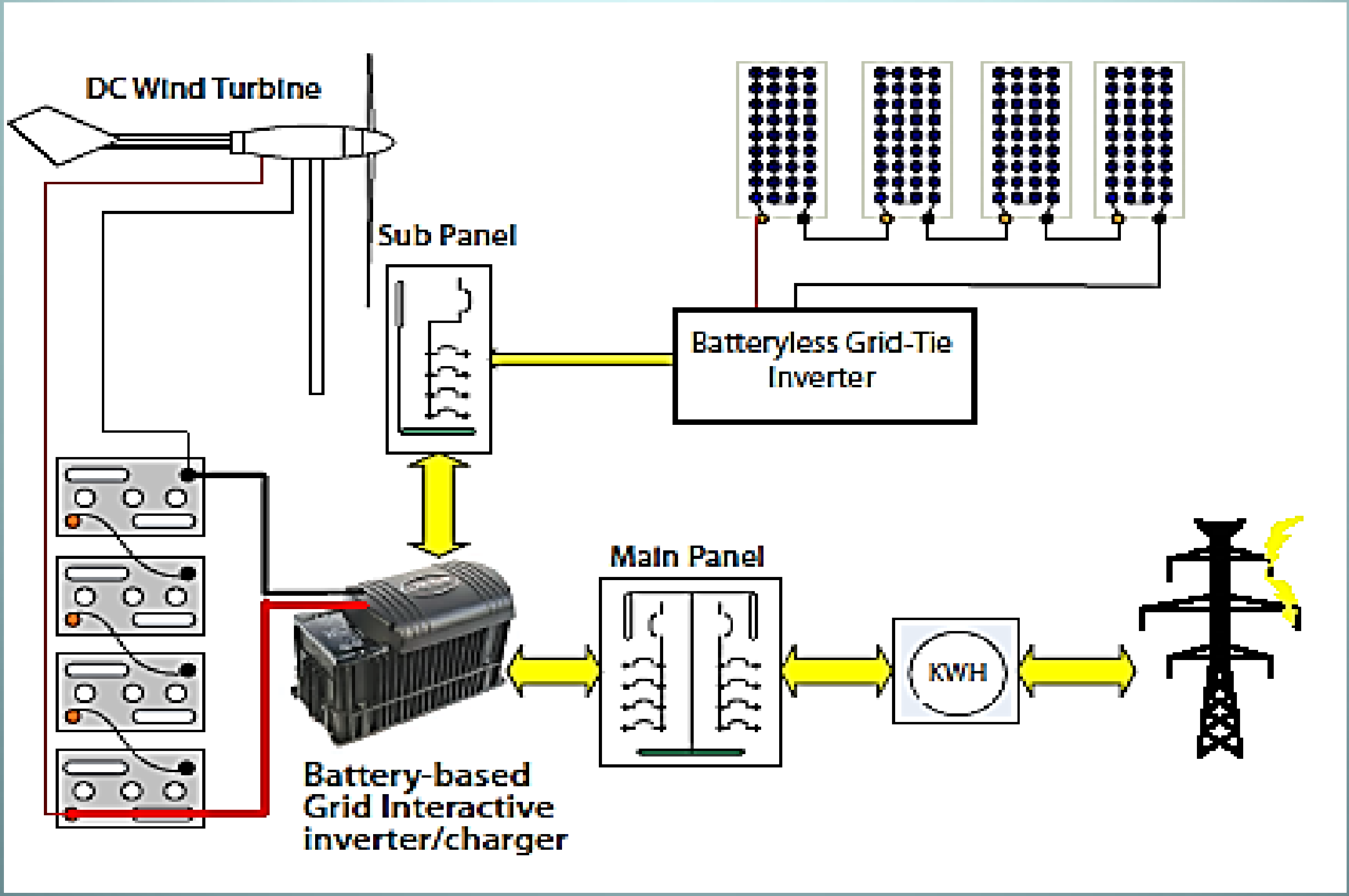
--***Flexpower*** with grid-interactive inverter

starting at 2 kW @ 120 Vac

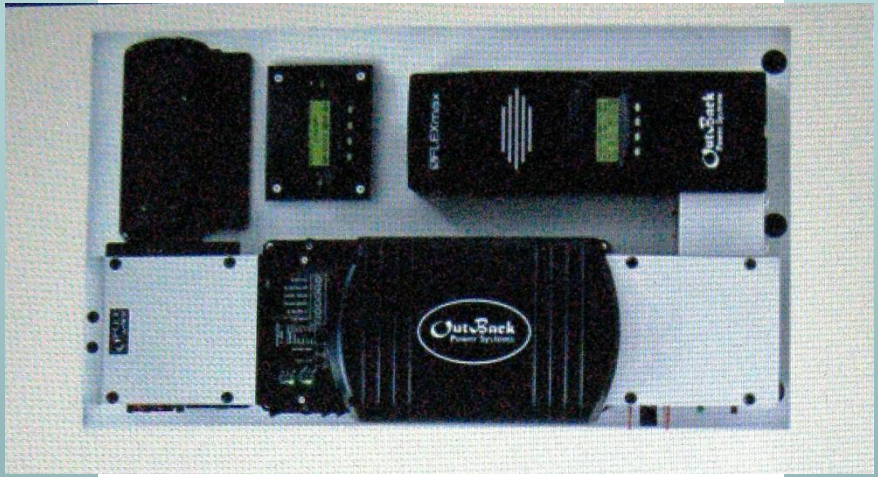
Schneider Electric (formerly Xantrex)

-***XW*** 4 kW @ 120/240 Vac

Traditional *Bimodal* inverter/charger for grid-tie

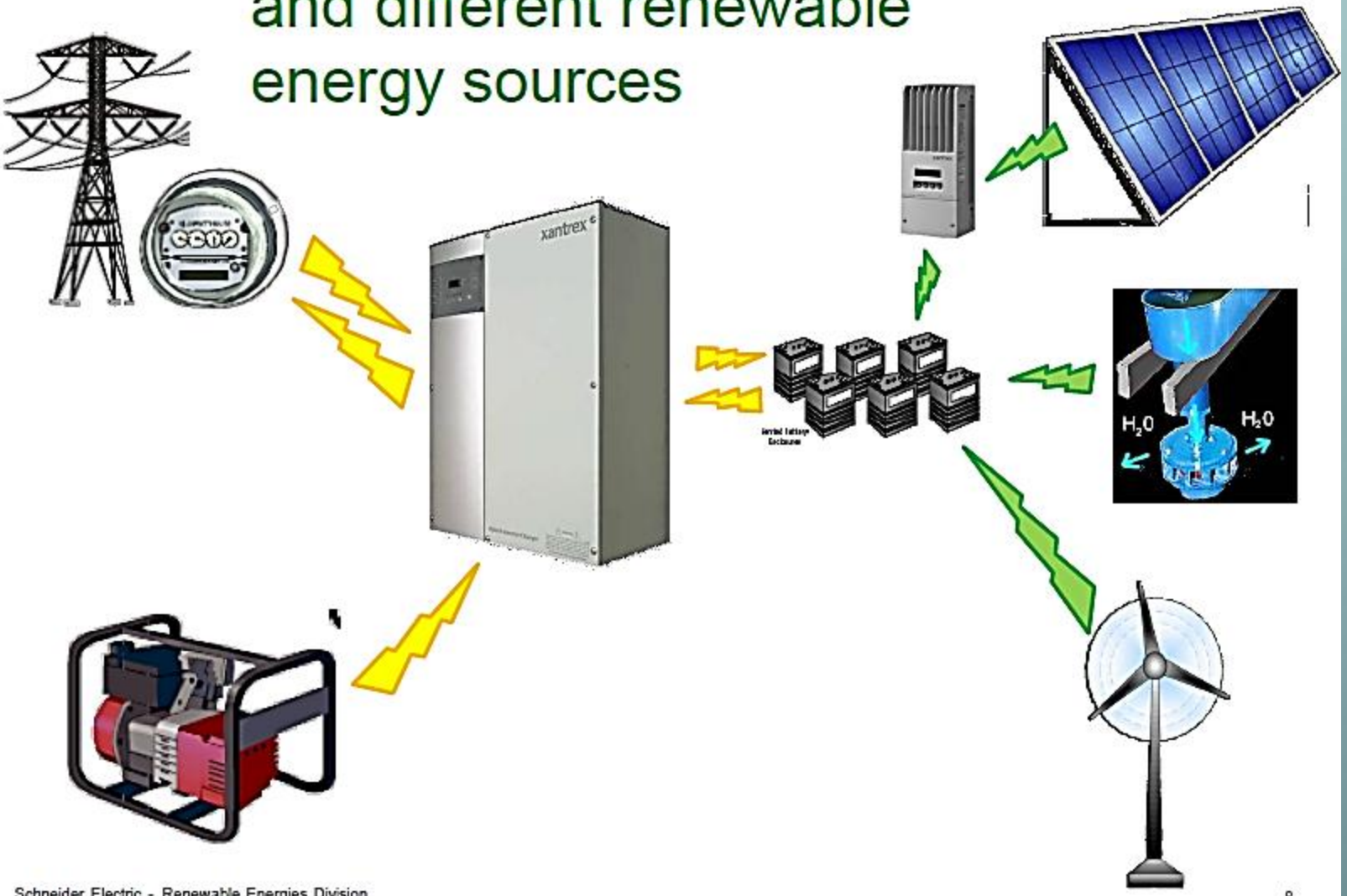


Battery Based



XW Series

The XW can utilize multiple and different renewable energy sources



X W Inverter/Charger

1. Outstanding Inverter Performance
   - Low load and peak efficiency improvements over competition
   - Continuous output power and surge improvements
2. 120/240 Vac split phase and three phase capability
3. Utility interactive, same unit

X W Solar Charge Controller

1. Dynamic maximum power point tracking with no mini or full sweeps
2. Integrated PV Ground Fault Protection
3. Convection cooled; Full output up to 45C/113F; No fan to fail

X W System

1. Easy to install, integrated system execution
   - Supports high power configurations
   - Fewer pieces, less complexity, lower installed dealer cost
2. Communications
   - All components truly networked, no “hub” required
   - Common settings shared between devices to facilitate system setup
3. 5 year standard warranty on all XW components, (10 year optional)

AC Coupled

- Uses batteries to create a replacement AC "grid" signal that is capable of keeping "grid-interactive" inverters running while the normal utility is not available.. AC to AC connection

SMA

- Sunny Island 5 kW @ 120 Vac

6.5 kW@ 120 Vac

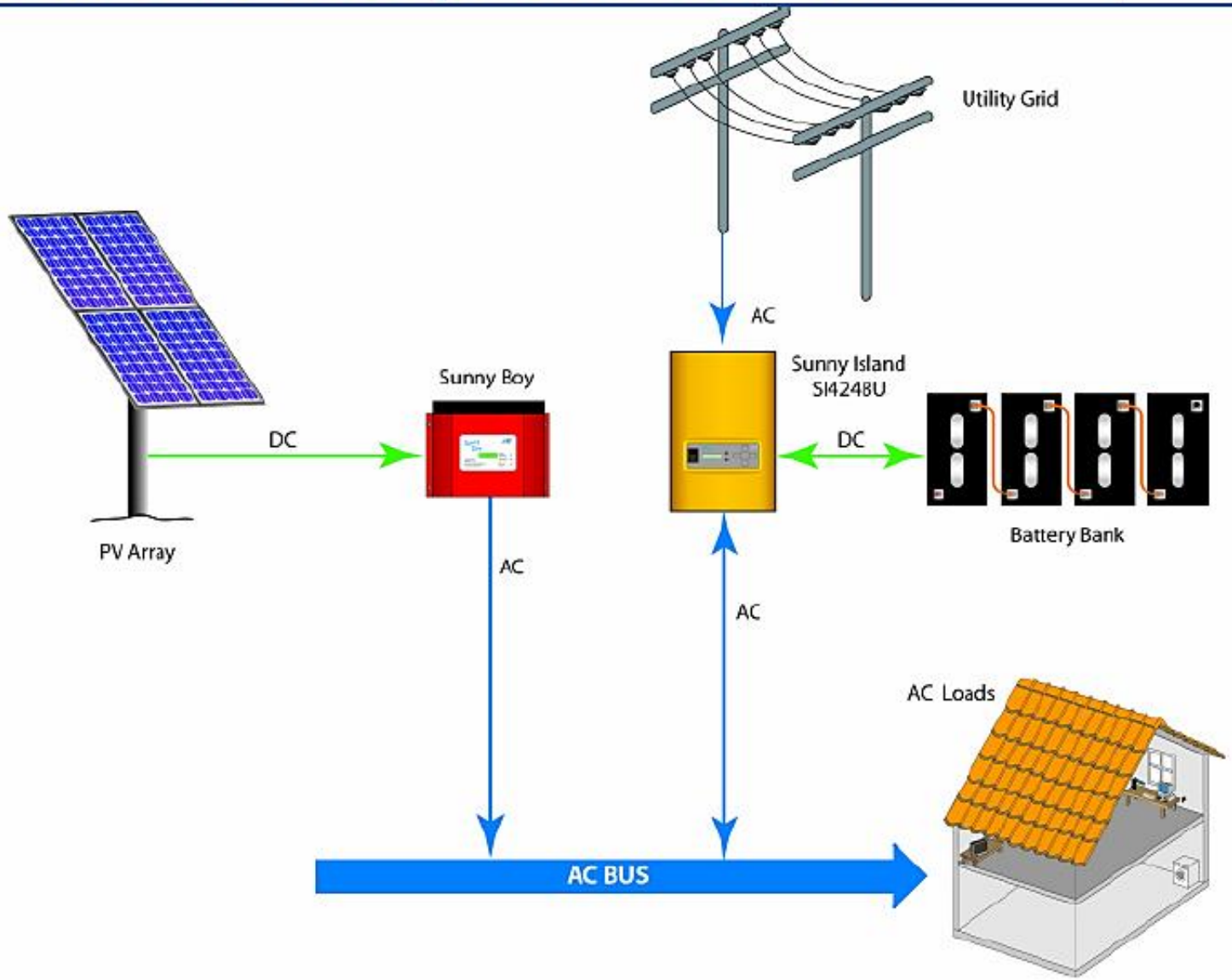
Out Back Power

-Flexpower 2kW+ @ 120 Vac

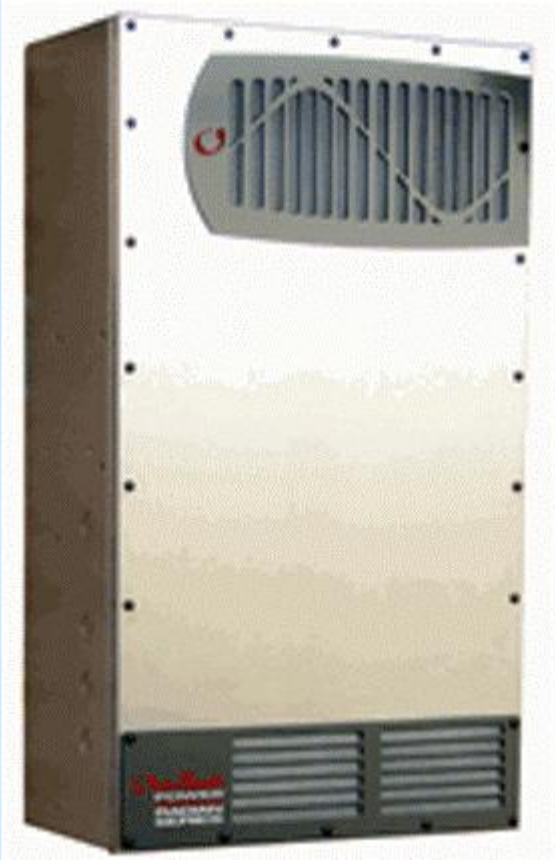
- Radian 8 kW @ 120/240 Vac

The ***Sunny Island*** was first introduced as an ***"add-on"*** to the many "Sunny Boy" grid-interactive only" string inverters already in place before the 2003 "Blackout…"

Grid-Tied AC Coupled w/ Grid & PV



Outback power's RADIAN offers true "Plug and Play" installation



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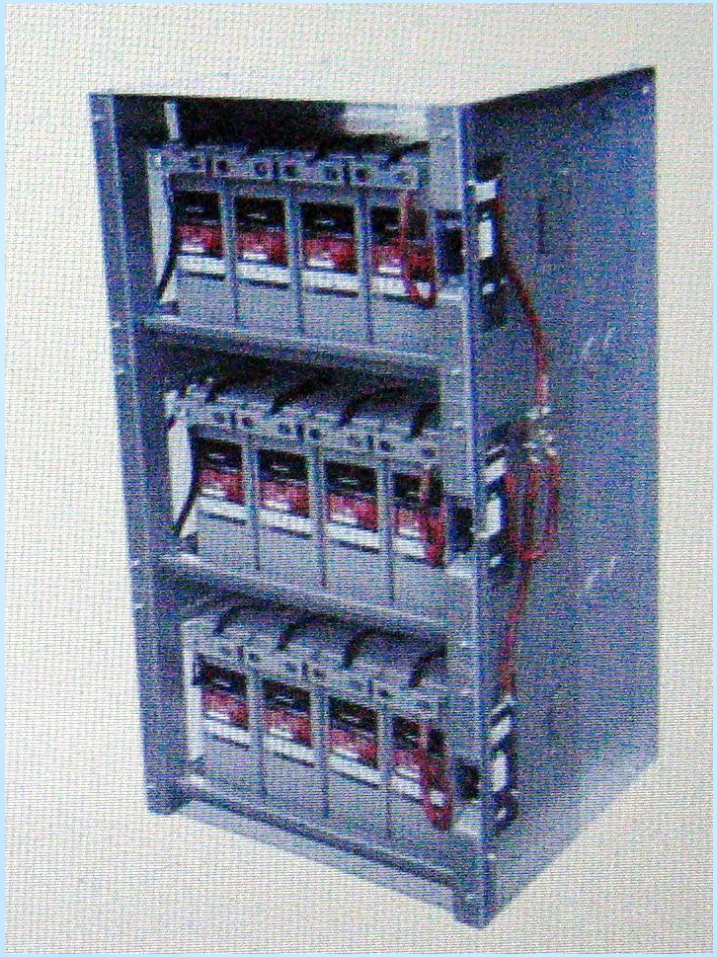
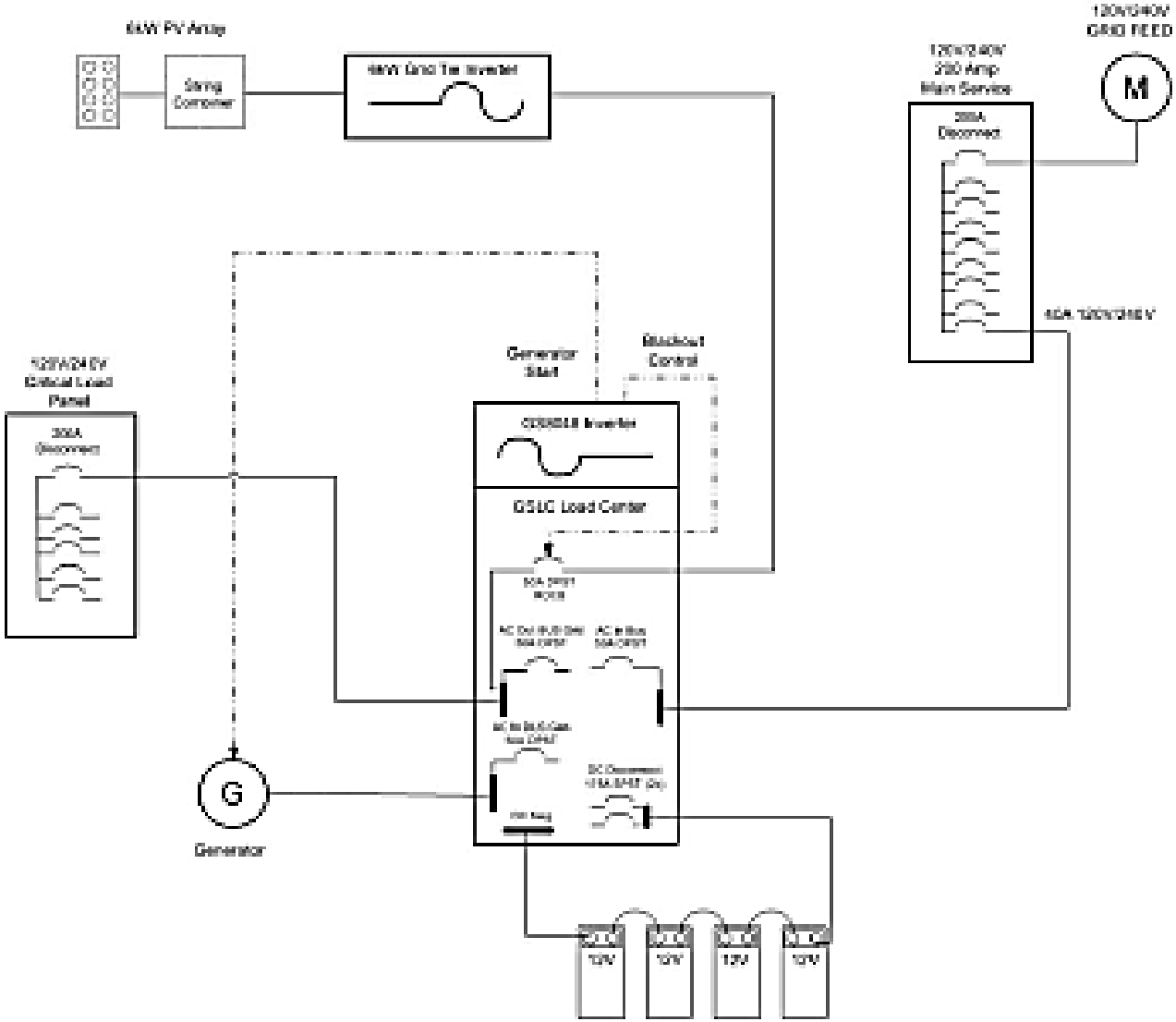
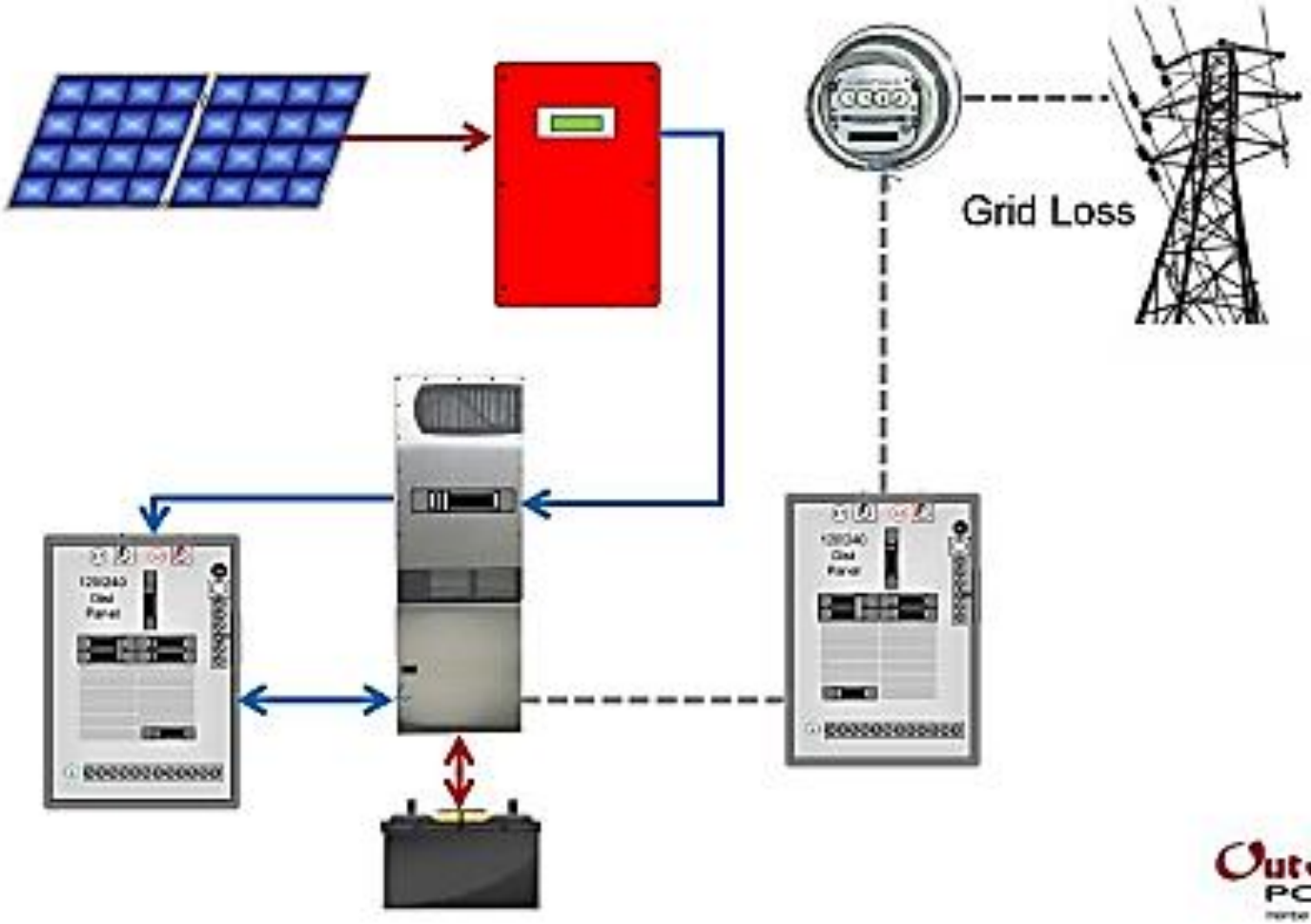


AC Coupled Radian Single Line Diagram



AC Coupled Current Flow with Grid Loss



OutBack POWER

What Kind of Battery Do I Select?

- Wet, Flooded, Vented

  Lead Acid (FLA)

  Alkaline

  -NiCad's

  - Nickel Iron (NiFe)

- Sealed VRLA

  -AGM

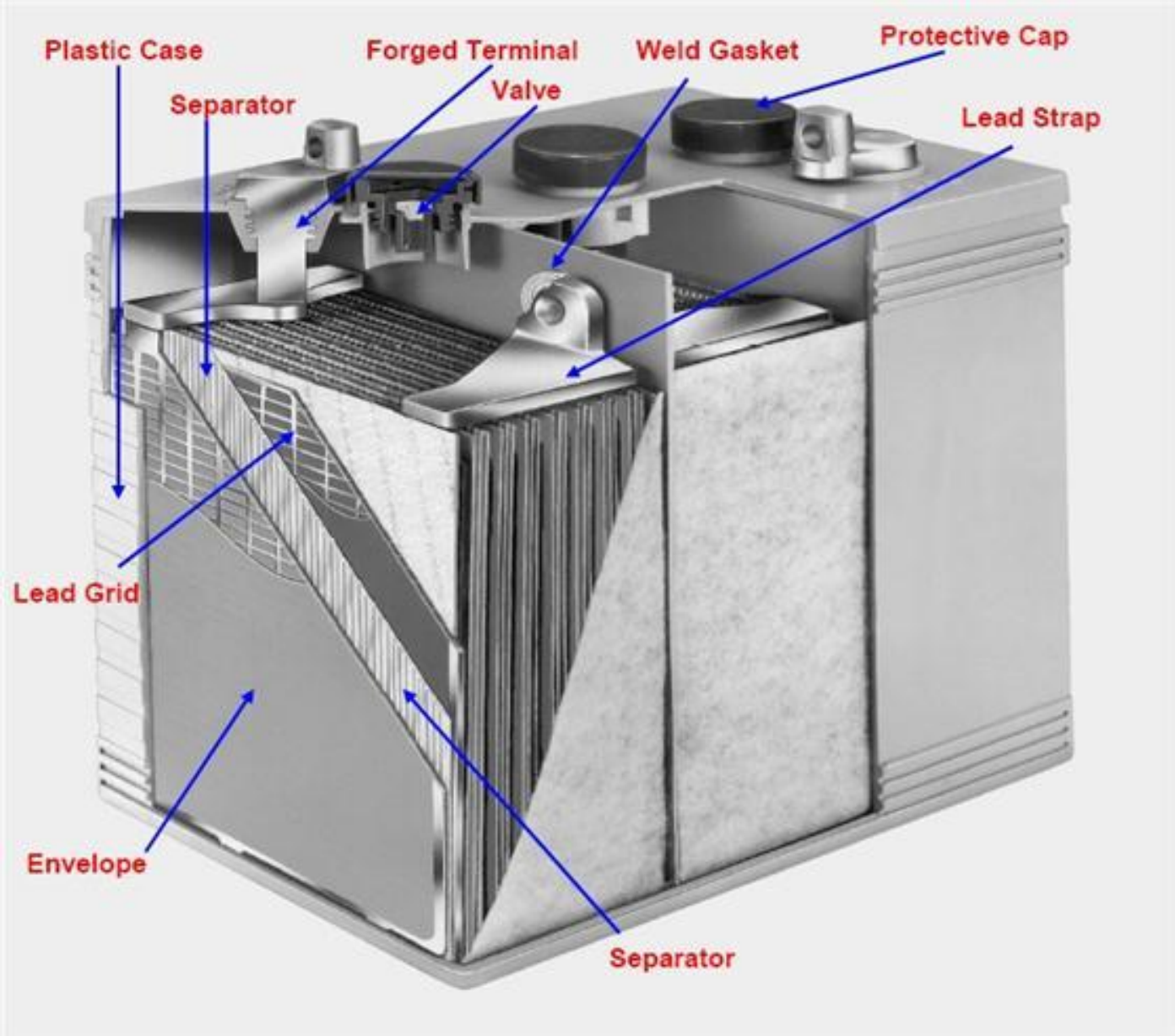
  -GEL

TABLE 2. BATTERY MATRIX

Battery Type	Grid Alloy	Original Design Application Charging / Discharging	Amp Hour Capacity	Design Life	# Of 80% Cycles	Watering / Equalizing Intervals	Expected Life*
Vented							
SLI	Pb, Ca	Random RC / Short HR DC	25 to 220	3 yr	<180	NA	1 yr
Golf Cart	Pb, Sb	8-12 hr RC / 8 hr DC	100 to 250	2 yr.	600	1M / 1W	2 to 4 yr
Scrubbers	Pb, Sb	8-12 hr RC / 8 hr DC	300 to 360	5 yr.	600	1M / 1W	3 to 6 yr
Forklift	Pb, Sb	8-12 hr RC / 8 hr DC	400 to 2500	5	1.5k -2k	1M / 1W	4 to 10 yr
General Stationary	Pb, Ca	FC / Random <4hr DC	25 to 3000	20	300	1M / 1W	5 to 10 yr
Telecom Stationary	Pb, Ca	FC / Random 4 to 8 hr. DC	400 to 4000	20	300	1M / 1W	5 to 12 yr
UPS Stationary	Pb, Ca	FC / Random Short HR DC	200 to 2000	20	300	1M / 1W	2 to 5 yr
Solar	Pb, Ca PbSbSe	Random RC / 12-240 hr DC	40 to 3000	6-20yr	600 -2k	1M / 1W	6 to 20 yr
VRLA							
Multi-cell backup	Pb, Ca	FC / Random Short HR DC	1.5 to 100	1-3	200 - 300	NA / MAN	1 to 3yr
Multi-cell UPS	Pb, Ca	FC / Random Short HR DC		10	200 - 300	NA / MAN	1 to 3yr
Multi-cell Motive	Pb, Ca	4 - 8 hr RC / 4 hr DC	33 to 220		300 - 600	NA / MAN	1 to 3yr
Forklift VRLA	Pb, Ca	8 -12 hr RC / 8 hr DC	400 to 2000			NA / MAN	1 to 8yr
Stationary 2 volt	Pb, Ca		400 to 2500	20 F / 10 C	1 to 2k	NA / MAN	1 to 8yr

RC = Recharge, FC=Float Charge, HR = High Rate, DC = Discharge, M = Monthly, W = Week, NA = Not Applicable, MAN = Manufactures Recommendation

***Expected Life** in this matrix is there to spur discussion only!!!!


Plastic Case
Separator
Forged Terminal
Valve
Weld Gasket
Protective Cap
Lead Strap
Lead Grid
Envelope
Separator

Battery Safety

Wet cell batteries should be in an enclosure with restricted access (such as screw-on top). The enclosure must be vented to the outside, since batteries evolve hydrogen when charging.

Customers should receive a manual on battery safety and care. The Northeast Solar Electric Battery Book serves this purpose well. Supply customers with large box of baking soda, eyewash and fire extinguisher if they have a battery bank.

latest update: 5-6-2010

Safety requires personal protective equipment (PPE)

Battery Safety

Acid hazard

- Lead-acid batteries have sulfuric acid in them. This can burn you and your clothes.
- Always wear safety glasses
- Wear plastic gloves and plastic apron when handling batteries
- Keep baking soda and fire extinguisher near battery bank
- Watch where ends of metal tools are when tightening bolts on battery terminals
- Do not tip batteries when handling.

latest update: 5-6-2010

Battery Safety

Electrical hazard

Never short (+ to -) battery terminals!
Never short + to ground!

Batteries can produce thousands of amps for short periods, causing large, sustained DC arcs. This will burn your hands off and cause the battery to explode (splattering you with acid).

latest update: 5-6-2010

Highlights of Article 690

VIII. Storage Batteries

Highlights:

- **High-voltage (=over 50 V) not allowed unless terminals are inaccessible**
- **Guard live parts.**
- **Make sure there is a fuse or breaker in the + wire of the battery bank.**
- **There has to be disconnect switch**
- **Wet cells must have sufficient ventilation. See Article 480.**
- **Check Article 110.26 for working space rules. Don't put the power panel directly above the battery bank.**
- **Use battery cables of the correct type.**

Highlights of Article 690

Related codes

If batteries are being installed where there is propane, check the local propane code. Usually, you cannot install a battery bank within 3' of a propane fired appliance.

If the battery box vent goes thru the wall, install a power vent.

Know the Code: PV and NEC

"More than half of all fires are caused by electricity." --NFPA

An evolving NEC code for Photovoltaics

Shows much change in temperature derating calculation

Discussion of grounding methods

And incorporates other codes and standards, especially from IFC and IBC

Gay E. Canough

Highlights of Article 690

There are 4 things we have to use NEC in PV system design on a regular basis

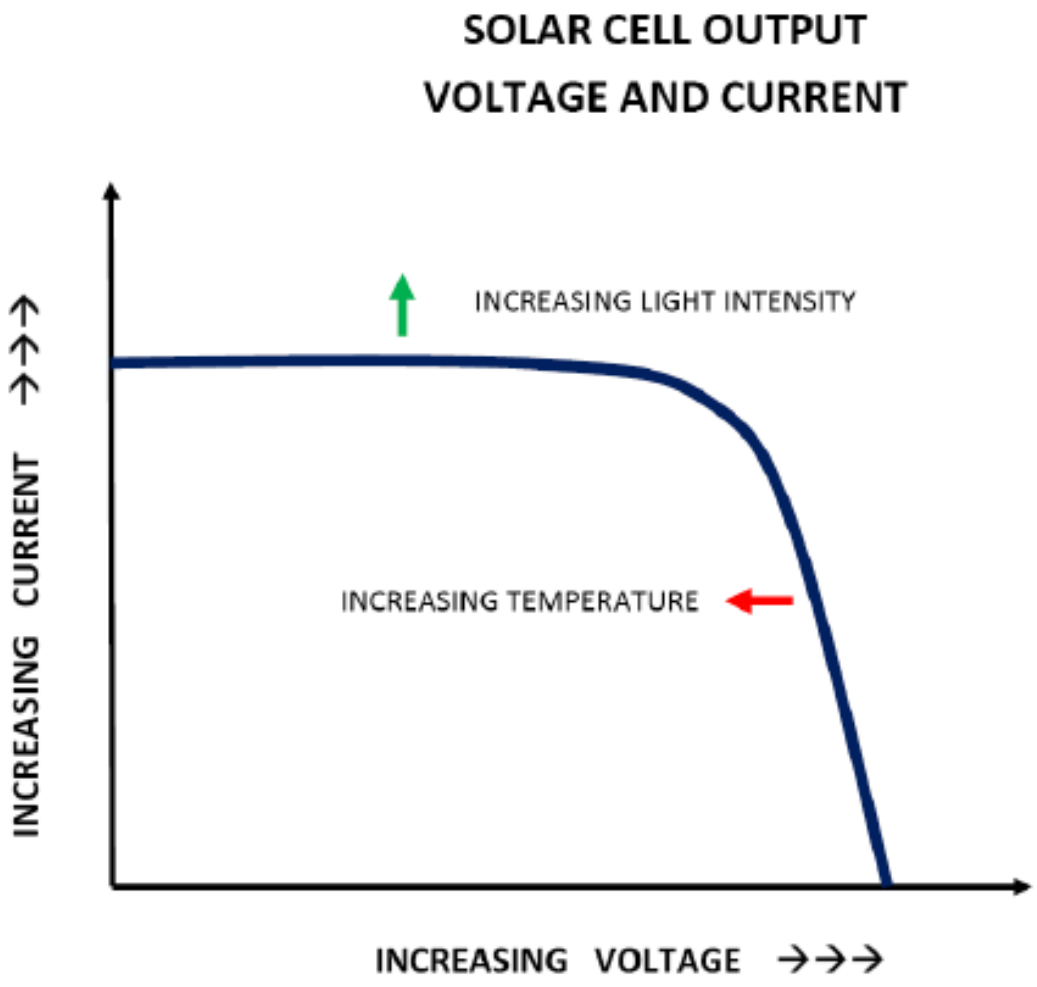
1) **DC Voltage of PV as a function of temperature**

2) **Voltage drop**

2) **Ampacity of wires, fuses and breakers**

3) **Grounding**

Solar Cell voltage and current



Highlights of Article 690

Sharp 185

Cell	Single crystal silicon
No. of Cells and Connections	72 in series
Open Circuit Voltage (Voc)	44.9V
Maximum Power Voltage (Vpm)	36.2V
Short Circuit Current (Isc)	5.75A
Maximum Power Current (Ipm)	5.11A
Maximum Power (Pm)*	185W
Minimum Power (Pm)*	166.5W
Encapsulated Solar Cell Efficiency (ηc)	17.48%
Module Efficiency (ηm)	14.23%
PTC Rating (W)**	162.43
Maximum System Voltage	600VDC
Series Fuse Rating	10A
Type of Output Terminal	Lead Wire with MC Connector

Voltages and currents are given at standard test conditions and are NOT the maximums!

A Problem

- The *Standard Test Conditions* (STC) shown on the PV module label are not "real world" *normal operating conditions* (NOC)

- Colder working temperatures increase the PV module output voltage

- heat gain from sunlight exposure decreases the PV cell's performance efficiency
  - –output voltage drops

II. Circuit Requirements

690.7 Maximum Voltage.

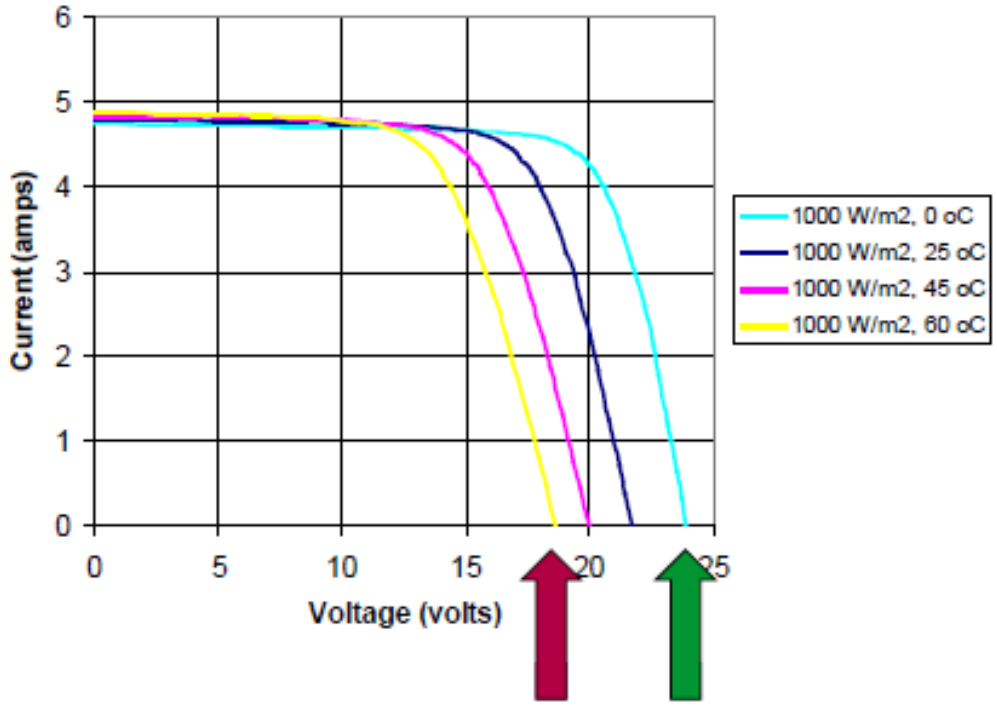
Let's look at how one section has changed in NEC 2005 & NEC 2008 – to NEC 2011

NEC 2005 requires that chrystalline wafer PV modules MUST use table 690.7 to predict the expected open circuit voltage (Voc) increase when cell temperature is colder than STC of 25 degrees C

Record cold temperatures for the location are used to find Maximum voltage predictions

Record cold temperature

- This determines the maximum number of modules per string to keep the COLD CONDITION MAXIMUM ARRAY VOLTAGE within the MPPT window



A temp. of -20 deg C ~ 1.18 factor

NEC 2008 expanded the table…

Correction Factors for Ambient Temperatures Below 25°C (77°F). (Multiply the rated open circuit voltage by the appropriate correction factor shown below.)		
Ambient Temperature (°C)	**Factor**	**Ambient Temperature (°F)**
24 to 20	1.02	76 to 68
19 to 15	1.04	67 to 59
14 to 10	1.06	58 to 50
9 to 5	1.08	49 to 41
4 to 0	1.10	40 to 32
-1 to -5	1.12	31 to 23
-6 to -10	1.14	22 to 14
-11 to -15	1.16	13 to 5
-16 to -20	1.18	4 to -4
-21 to -25	1.20	-5 to -13
-26 to -30	1.21	-14 to -22
-31 to -35	1.23	-23 to -31
-36 to -40	1.25	-32 to -40

Also , Manufacturer instructions MAY be used for cold temperature corrections , and suggests criteria other than historical record cold temperature be used in order to define " lowest expected ambient temperature". (Ashrae –"extreme annual mean minimum temperature")

Gay E. Canough

Series String Sizing

Calculating Voltage Change with Temperature

COLD

V (at Temp) = V (at STC) + [Temp coeff x (T of interest – 25 C)]

The Sharp 224 module has a temperature coefficient of -0.120 V/C (That's volts per degree C). It is negative because the **voltage** gets HIGHER as the **temperature** gets **LOWER.** The open circuit voltage is 36.6 V at STC (1000 W/sq. m. , 25 C).

At – 20 C (-4 F):

Voc (at -20) = 36.6 + [-0.120 x (-20-25)]
= 36.6 + [-0.120 x -45)
= 36.6 + [5.4]
= 42.0 V

Compare to using table factor= 43.2 V

For the longest string of modules, take inverter's max DC input voltage and divide by Maximum module Voc:

For SMA 6000 that would be 600 42 = 14.28 modules

NEC 2011 requires use of Manufacturer information

- table 690.7 is used only if Temperature Coefficients are not available
- Manufacturer TC data maybe in form of

  % / degree C or, V / degree C

  Calculation = TC x temperature difference between ambient and STC (25deg C)

  Will give correction required to find

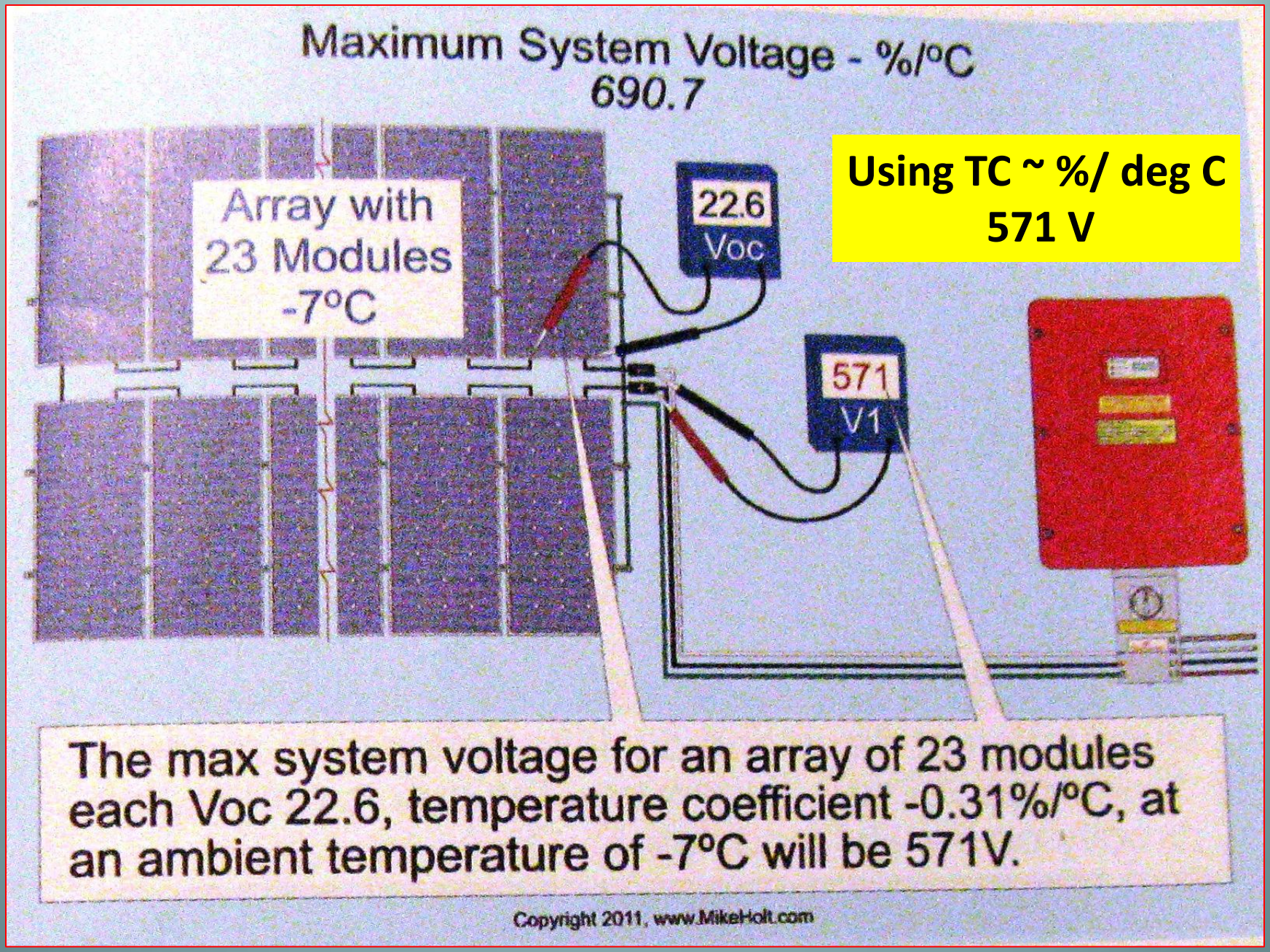
  Maximum PV system Voltage

In NEC 2011..

- In addition:

. Calculations will use Ashrae or ANSI standards for expected low temperature projections instead of *record low* temperatures..

i.e.“ Extreme Annual Mean Minimum Design Dry Bulb temperature”-ASHRAE handbook


Maximum System Voltage - %/°C
690.7
Array with
23 Modules
-7°C
22.6
Voc
571
V1
Using TC ~ %/ deg C
571 V
The max system voltage for an array of 23 modules each Voc 22.6, temperature coefficient -0.31%/°C, at an ambient temperature of -7°C will be 571V.
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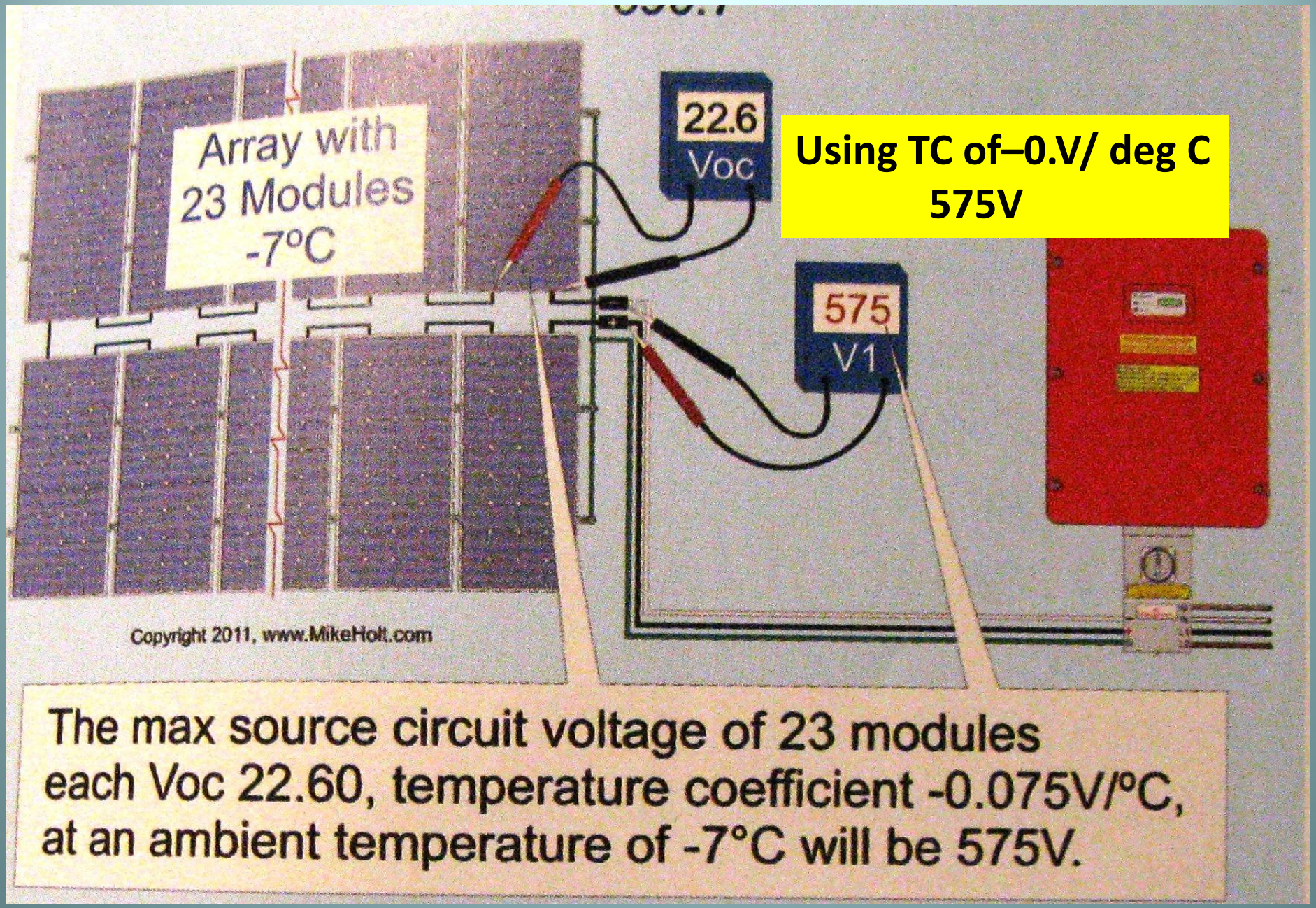
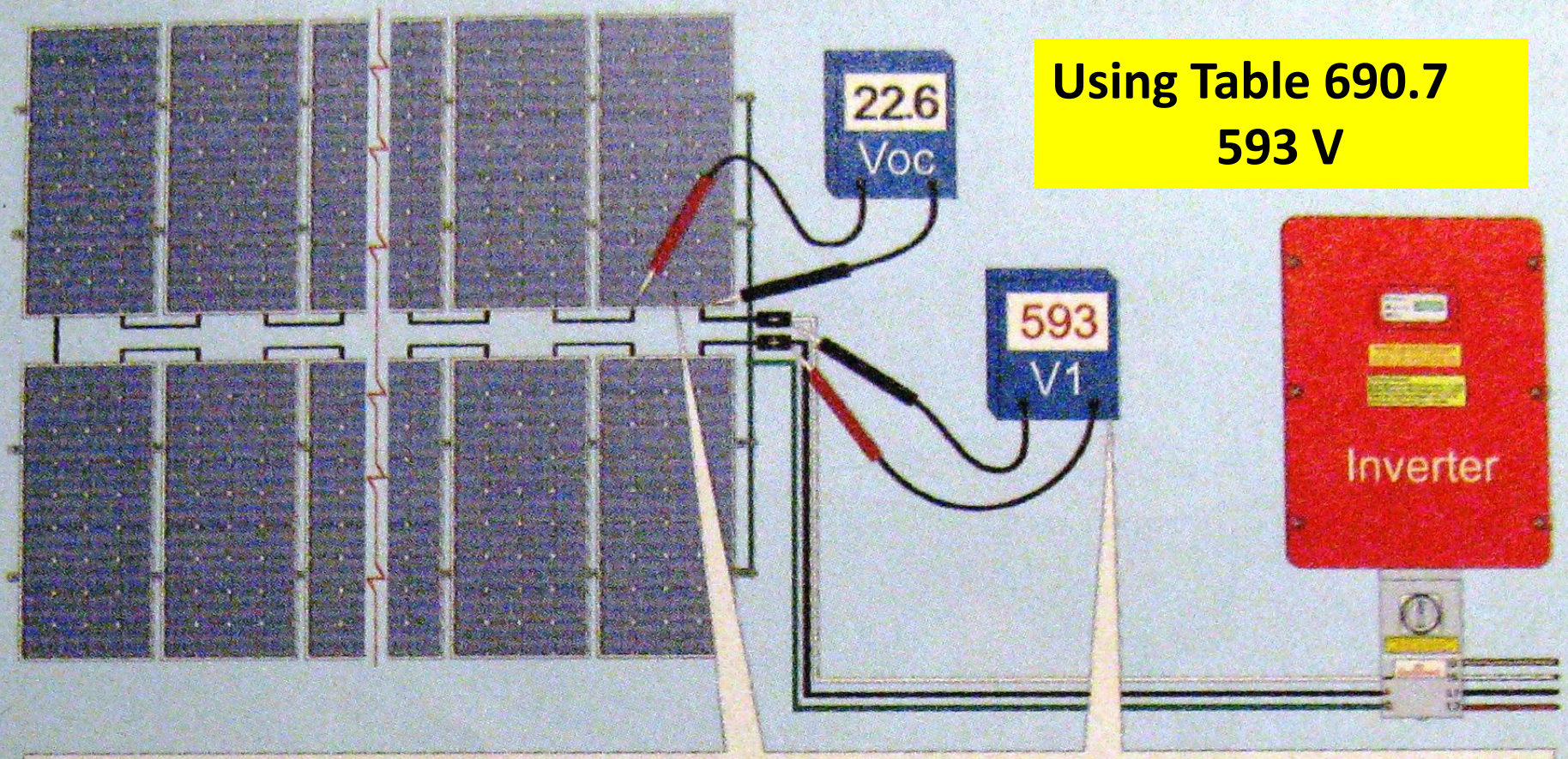


Using TC of–0.V/ deg C
575V

The max source circuit voltage of 23 modules each Voc 22.60, temperature coefficient -0.075V/°C, at an ambient temperature of -7°C will be 575V.

Maximum System Voltage
690.7(A)



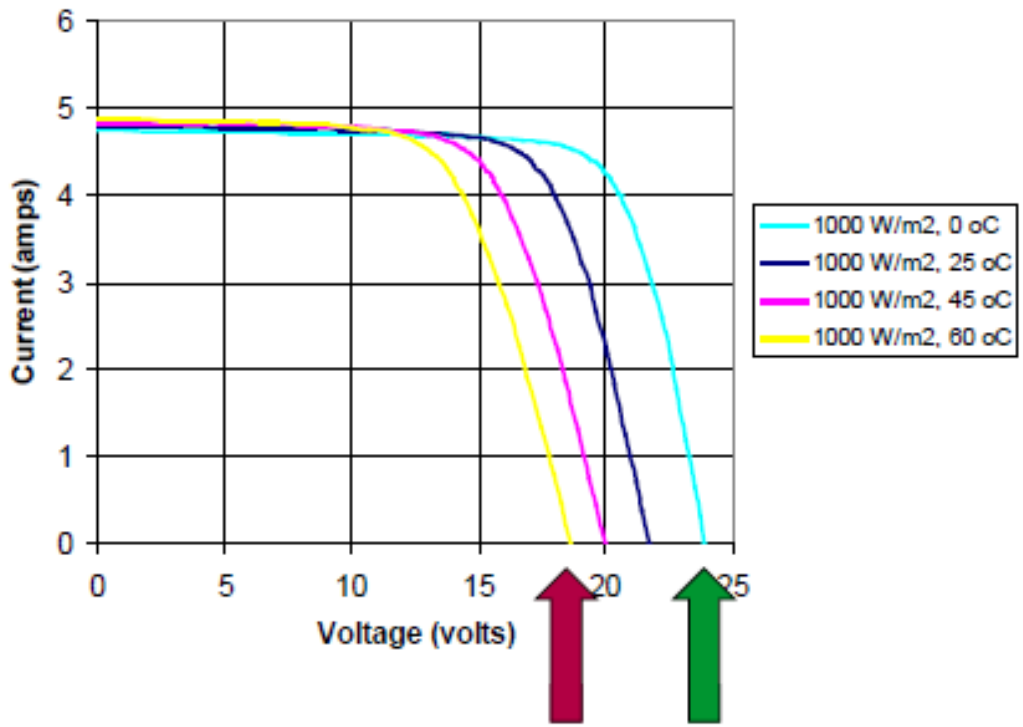
Using Table 690.7
593 V

Maximum system voltage is equal to the sum of the rated Voc of the series-connected PV modules, corrected for the lowest-expected ambient temperature.

Copyright 2011, www.MikeHolt.com

Average hot temperature

- This determines the minimum number of modules per string to keep the HOT CONDITIONS MINIMUM ARRAY VOLTAGE within the MPPT window



Highlights of Article 690

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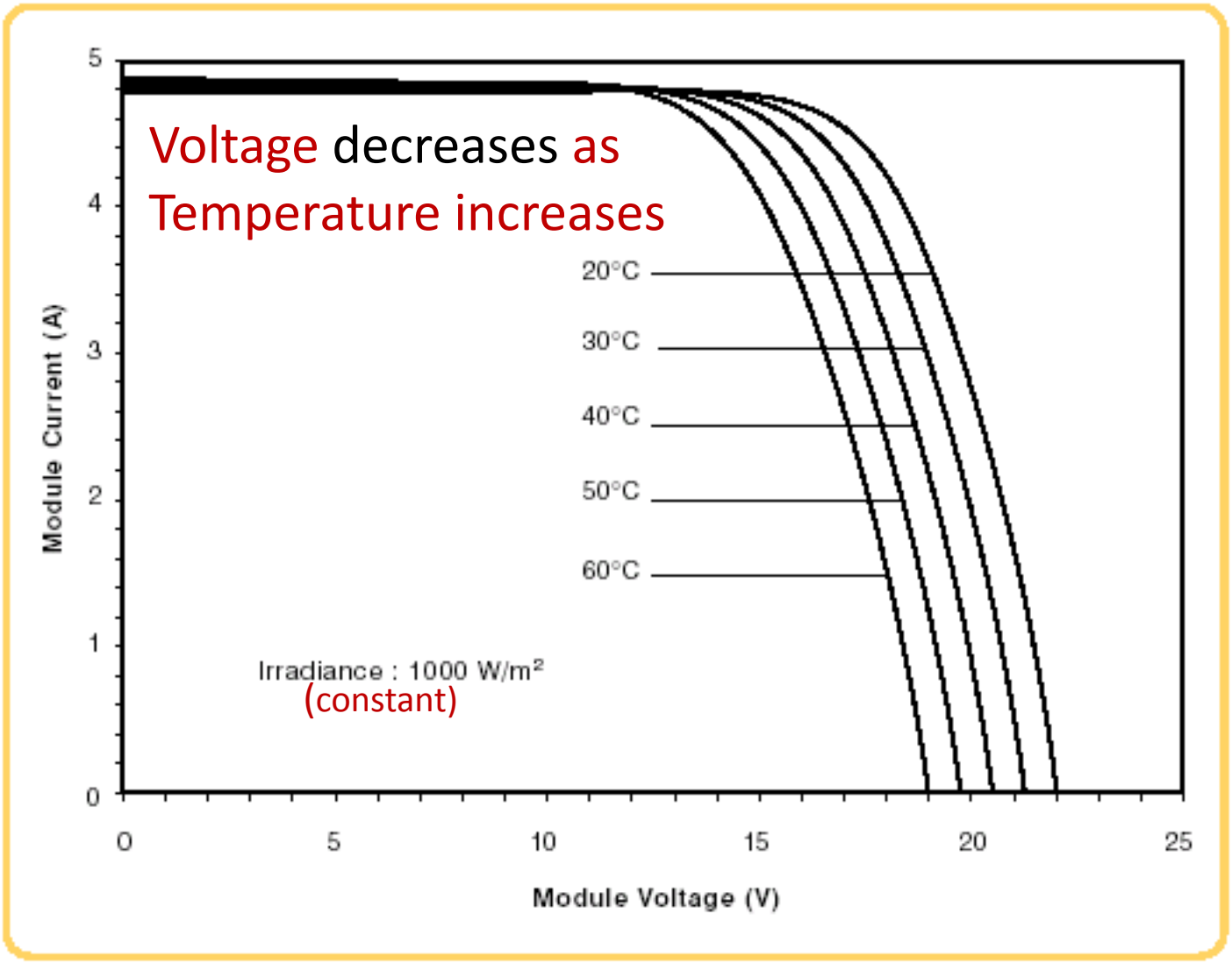


Calculating Voltage Change with Temperature

HOT

V (at Temp) = V (at STC) + [Temp coeff x (T of interest – 25 C)]

The max power point voltage, **Vmp** is 29.28 V at STC (1000 W/sq m. , 25 C). Let's see what it is at **60 C** such as on a hot sunny day, when the dark-colored module heats up to about 30 C above ambient:

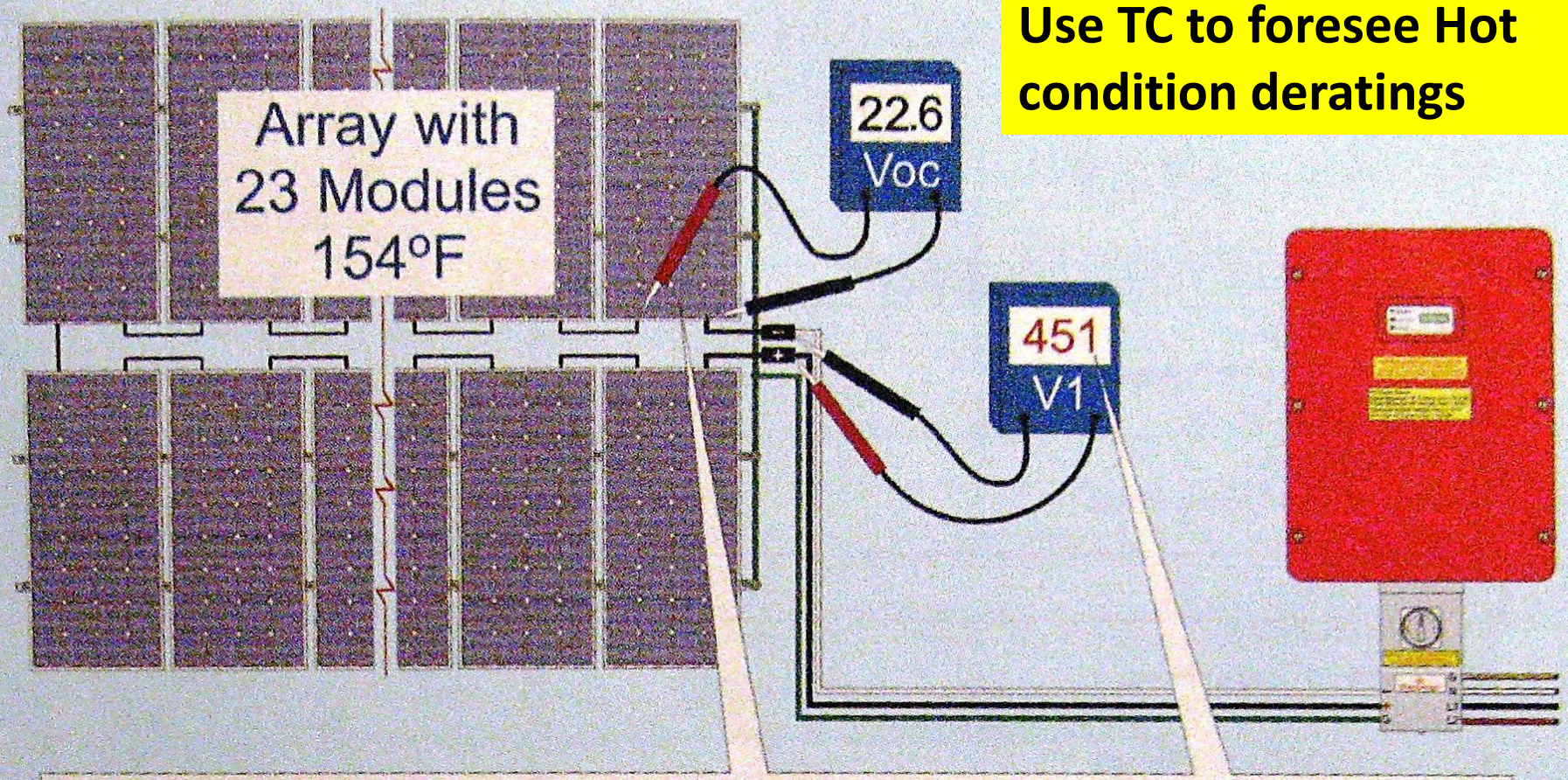
Vmp (at 60 C) = 29.28 + [-0.120 x (60-25)]
= 29.28 + [-0.120 x 35)
= 29.28 + [-4.2]
= 25.08 V

For the shortest string of modules, take inverter's minimum PPT voltage & divide by module Vmp--
For a SMA 6000 that would be 250 25.08 = 9.968 modules

PV Start Voltage - %/°C

690.7

Use TC to foresee Hot condition deratings



The PV system voltage for an array of 23 modules each Voc 22.6, temperature coefficient -0.31%/°C, at an ambient temperature of 67.8°C/154°F will be 451V.

Copyright 2011, www.MikeHolt.com

Hot "Conditions of Use" also affect the temperature of exposed wiring, when inside conduit , as exposed to sunlight, and at various distances from the roof surface- see ..Table 310.15(B)2(c)

Use Vmp for calculations to correct temperatures for "normal operating conditions"

ASHRAE "2% design temperature" may replace "average hot" temperatures previously used

Highlights of Article 690

Gay E. Canough

Use the Copper Development Association's "Outdoor design temperatures"

Design Temperatures For Various U.S. Cities

The following table indicates the 2% design temperature (averaged for June-August) for various cities; and the various temperatures inside conduit on rooftops exposed to direct sunlight.

The first column represents the ASHRAE 2% design temperature(1). The second through fifth column is the resultant ambient temperature inside the conduit - unloaded(2). It is the temperature the wire is subjected to.

The 6th column is the maximum dry-bulb temperature recorded for that city, based on 30 years of weather data.

			Temperatures inside conduit in direct sunlight				
		2% Design Temp	Distance above roof. Up to: 1/2"	3 1/2"	12"	36"	MAXIMUM Temp.
NY	**New York**						
NY	ALBANY	87	147	127	117	112	100
NY	BINGHAMTON	84	144	124	114	109	98
NY	BUFFALO	85	145	125	115	110	97
NY	DUNKIRK	80	140	120	110	105	99
NY	ELMIRA CORNING REGIONAL A	89	149	129	119	114	104
NY	FORT DRUM/WHEELER	85	145	125	115	110	97
NY	GALLOO ISLAND	77	137	117	107	102	90
NY	GLENS FALLS	87	147	127	117	112	101
NY	GRIFFISS AFB	88	148	128	118	113	100
NY	ISLIP, LI	87	147	127	117	112	104
NY	JAMESTOWN (AWOS)	82	142	122	112	107	99
NY	MASSENA AP	87	147	127	117	112	99
NY	NYC, JFK	88	148	128	118	113	104
NY	NYC, LGA	91	151	131	121	116	104
NY	NIAGARA FALLS AF	87	147	127	117	112	99
NY	PLATTSBURGH AFB	85	145	125	115	110	100
NY	POUGHKEEPSIE DUTCHESS CO	90	150	130	120	115	107
NY	ROCHESTER	87	147	127	117	112	100
NY	STEWART FIELD	88	148	128	118	113	105
NY	SYRACUSE	87	147	127	117	112	101
NY	UTICA ONEIDA COUNTY AP	86	146	126	116	111	98
NY	WATERTOWN AP	84	144	124	114	109	97
NY	WHITE PLAINS	89	149	129	119	114	103

Highlights of Article 690

New temperature calculations in NEC 2008

Table 310.15(B)2 (c)

But what ambient temp do you use?

Table 310.15(B)(2)(c) Ambient Temperature Adjustment for Conduits Exposed to Sunlight On or Above Rooftops

Distance Above Roof to Bottom of Conduit	Temperature Adder °C	Temperature Adder °F
0 – 13 mm (½ in.)	33	60
Above 13 mm (½ in.) – 90 mm (3½ in.)	22	40
Above 90 mm (3½ in.) – 300 mm (12 in.)	17	30
Above 300 mm (12 in.) – 900 mm (36 in.)	14	25

Gay E. Canough

Highlights of Article 690

Per NEC 2008 you take the design temp + temp. "adder" from NEC table 310.15(B)(2)(c)

= the temperature you will need to de-rate to in NEC table 310.16

for example: In Binghamton, NY the design temp = 84 F.

For a conduit sitting on the roof, you have to add 60 F. (33 C)
So the temperature to de-rate for is 144 F.

Highlights of Article 690

A design temp of 144 means a de-rate factor of 0.58

Table 310.16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Throug 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambie Temperature of 30°C (86°F)

Size AWG or kcmil	Temperature Rating of Conductor (See Table 310.13.)						Size AW kcmi
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient T (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–7
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–8
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–9
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–10
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–1
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–1
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–1
56–60	—	0.58	0.71	—	0.58	0.71	132–1
61–70	—	0.33	0.58	—	0.33	0.58	141–1
71–80	—	—	0.41	—	—	0.41	159–1

* See 240.4(D).

Highlights of Article 690

Gay E. Canough

The PV modules are to be connected in series with a single conductor cable.

The ambient temperature could be 170 F (77 C) between the roof and the module.

So the temperature rating of all terminals, devices, conductors and cables should be 90ºC.

Types of Conductors Used in PV Systems

Application	Conductor Type
Array Wiring	Exposed single conductor types USE-2, UF, SE permitted Multiconductor type TC (labeled sunlight resistant) Types THW-2, RHW-2, THWN-2 (only in conduit)
BOS Interconnects, Exterior Exposed, Buried	Exposed and buried conduit requires wet-rated conductors (USE-2, XHHW-2, RHW-2, THWN-2)
Interior Exposed	NM, NMC, UF (multi-conductor cables)
Battery Cables	Flexible type RHW (multi-stranded) USE, RHH, RHW, and THW (only in couduit No welding, automotive or marine cables allowed

(In NEC 2014- only "PV conductors" can be used with ungrounded DC systems)

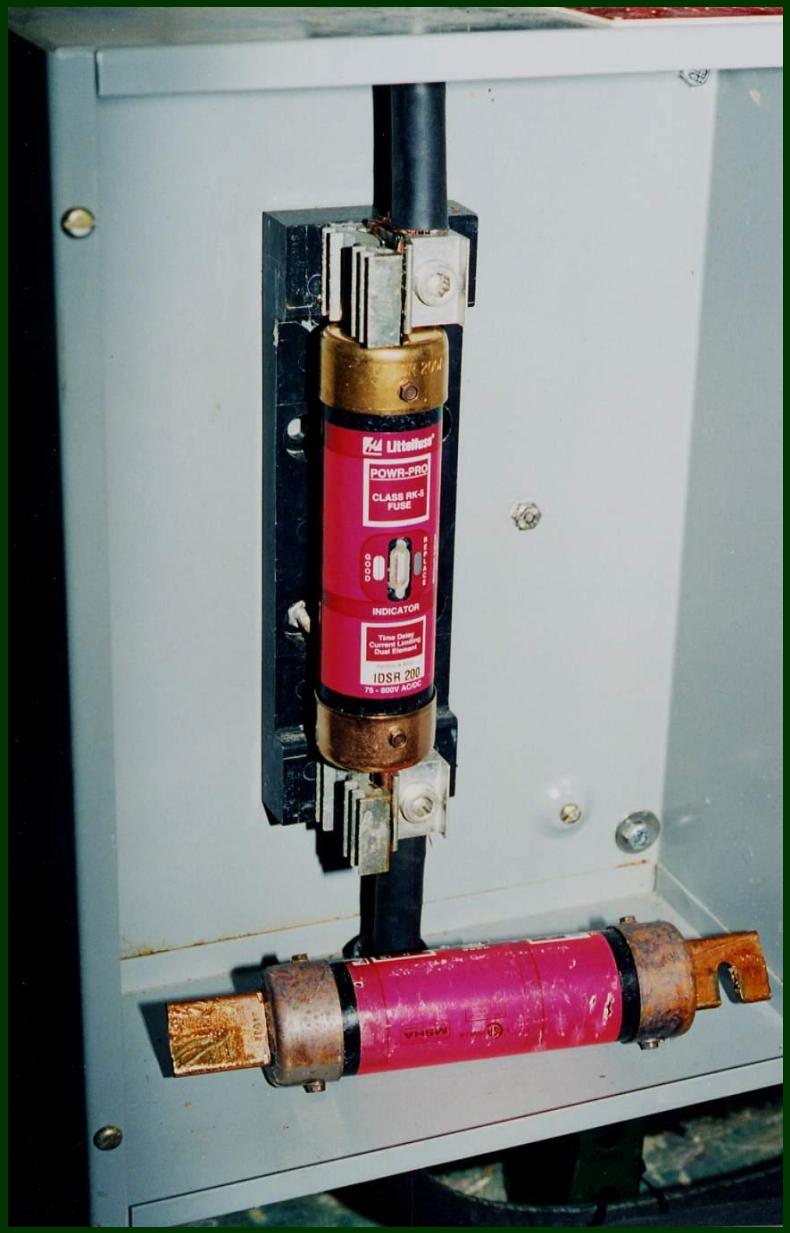
Highlights of Article 690

Gay E. Canough

690.5 Ground-Fault Protection. Roof-mounted dc photovoltaic arrays located on dwellings shall be provided with dc ground-fault protection to reduce fire hazards.

(A) Ground-Fault Detection and Interruption. The ground-fault protection device or system shall be capable of detecting a ground fault, interrupting the flow of fault current, and providing an indication of the fault.

(NEC 2011 expands GDFI to all buildings,
NEC 2014 adds ARC fault interruption to combiners)



Fuses must be rated for DC service

VI. Marking

Signs, signs, everywhere there's signs

And NEC 2014 will have more of them to IFC, ANSI and OSHA standards…

DANGER!
BATTERY
HOUSE
DANGER!

Highlights of Article 690

Gay E. Canough

Some markings are already there such as on modules. Others, you have to put on, such as:

690.53 Photovoltaic Power Source. A marking, specifying the photovoltaic power source rated as follows, shall be provided by the installer at the site at an accessible location at the disconnecting means for the photovoltaic power source:

(1) Operating current
(2) Operating voltage
(3) Maximum system voltage
(4) Short-circuit current

DO NOT OPERATE THIS SWITCH UNDER LOAD
BATTERY ROW 3 & 4
DISCONNECT SWITCH
DANGER
HIGH VOLTAGE 480 VDC
DO NOT OPERATE THIS SWITCH UNDER LOAD
BATTERY ROW 1 & 2
DISCONNECT SWITCH
DANGER
HIGH VOLTAGE 480 VDC
ON
OFF

Highlights of Article 690

Gay E. Canough

690.54 Interactive System Point of Interconnection.
Label the breaker PV is tied in to

690.55 Photovoltaic Power Systems Employing Energy Storage.
State Max voltage

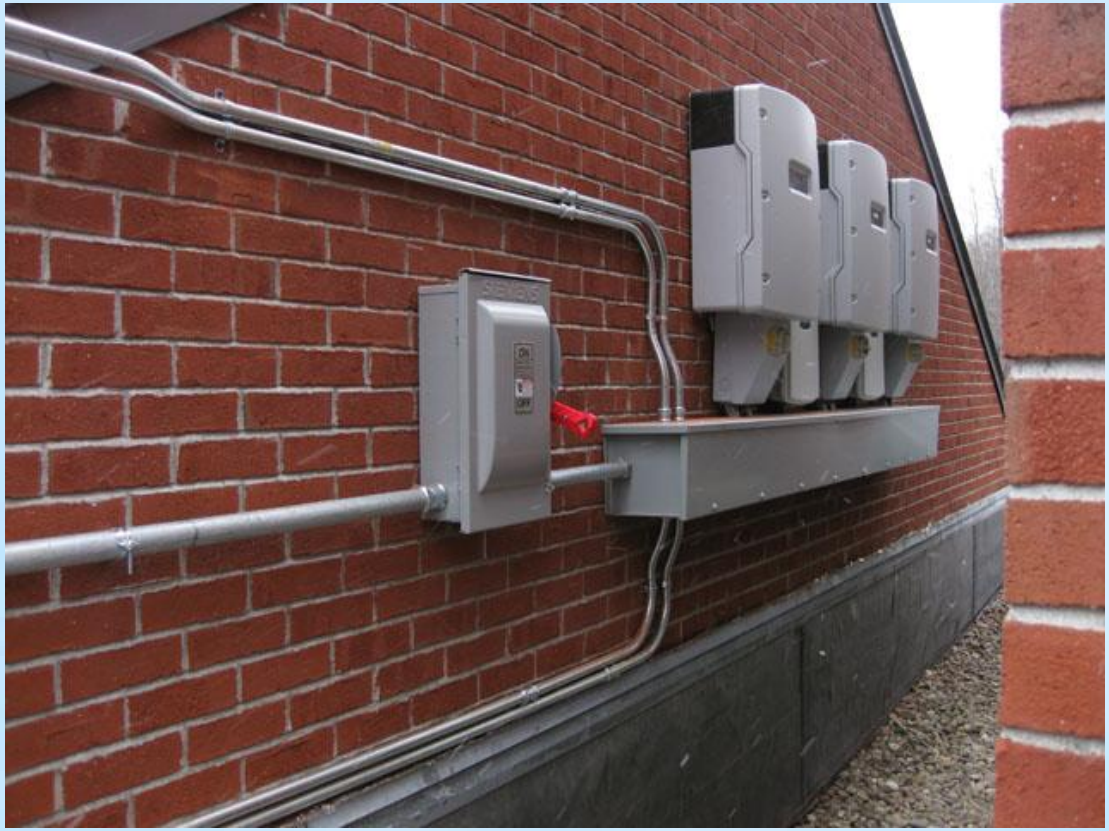
690.56 Identification of Power Sources.
Indicate where the disconnects are.

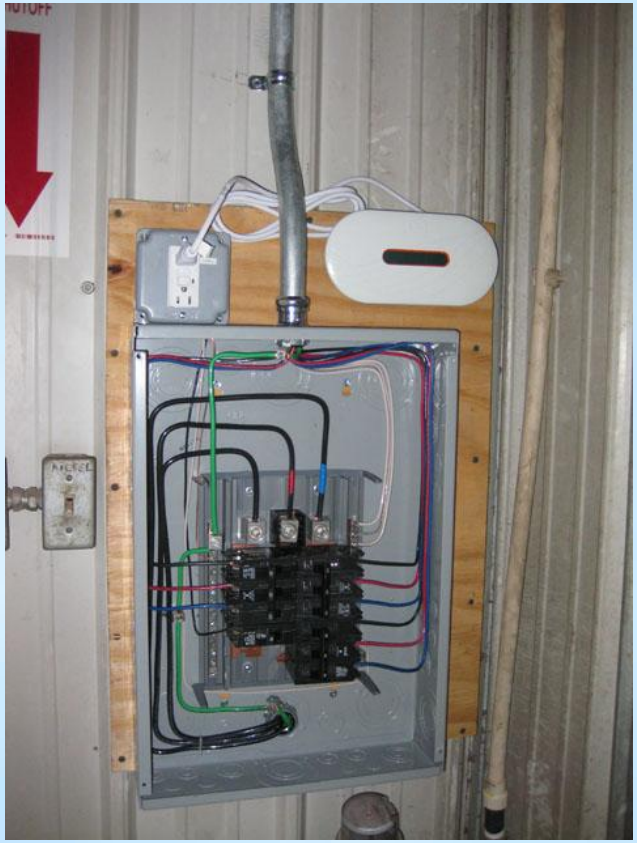
690.64 (B)(4) and (5).
Label the breaker which is back-fed by PV system and that it IS back-fed.

DANGER
NO SMOKING,
MATCHES OR
OPEN FLAMES

Highlights of Article 690

Neatness keeps inspectors happy

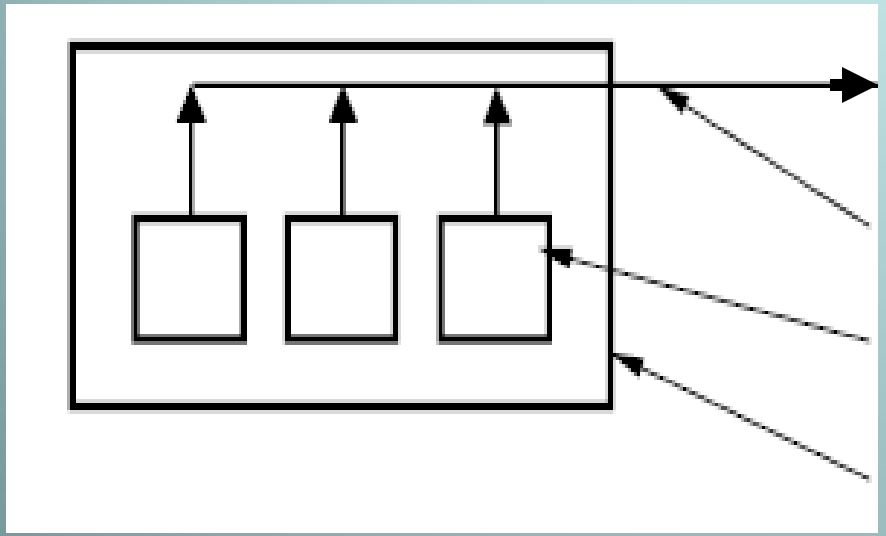




Uncertain about the future ?

Alternating-Current Modules

ac module system



Dedicated branch circuit of the electric distribution system

Inverter output circuit

ac module (includes inverter)

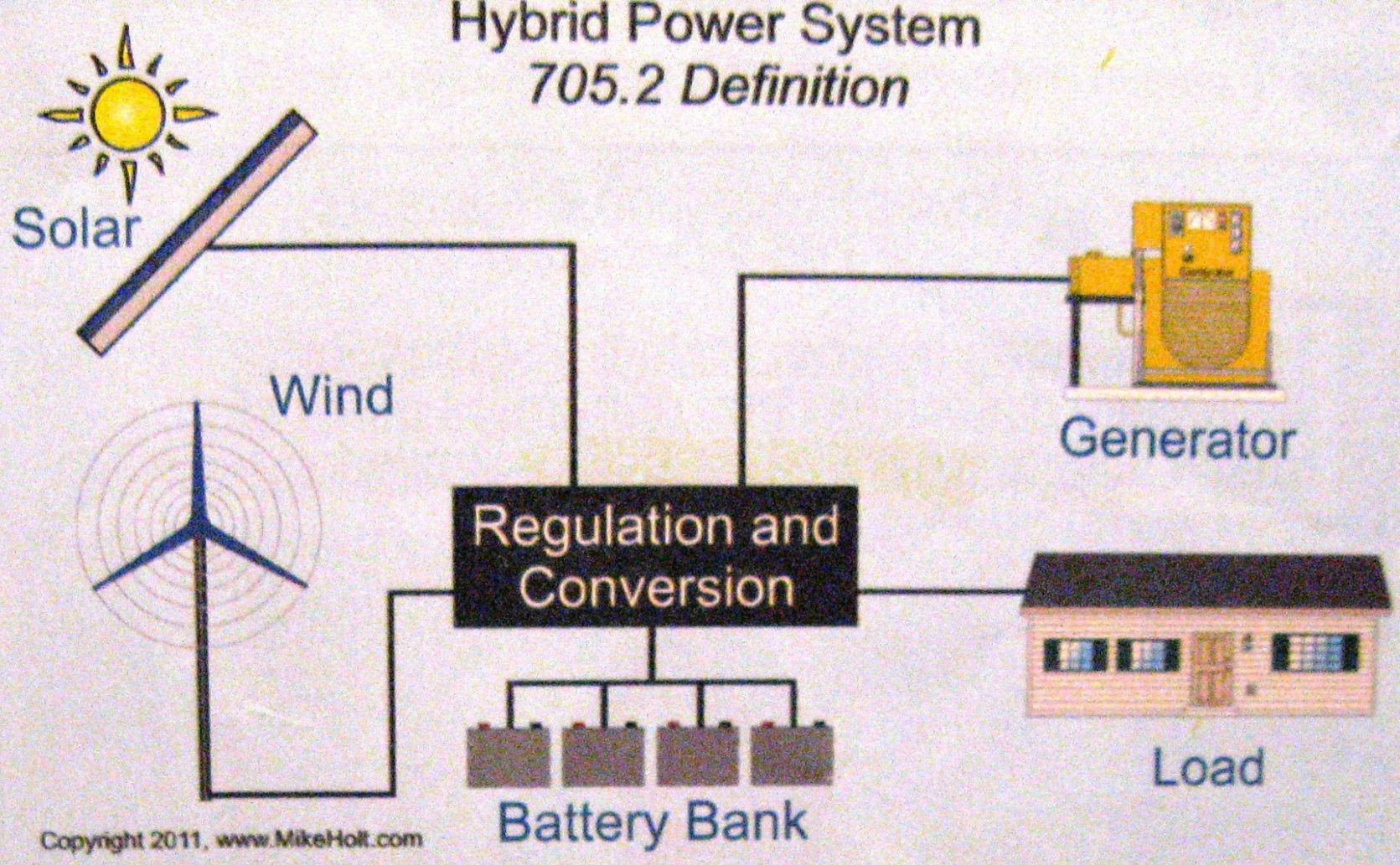
Array (of ac modules)

New homes being required
to include solar appliances

Examples of BIPV

Bank drive-thru canopy as BIPV

Rapidly deployed PV systems and "plug and play" appliances are common



A system comprised of multiple power sources, (photovoltaic, wind, micro-hydro generators, engine-driven generators, etc.) but not the utility power system.

Figure 705–2

NEC 2014 replaces “markings” with LABELS

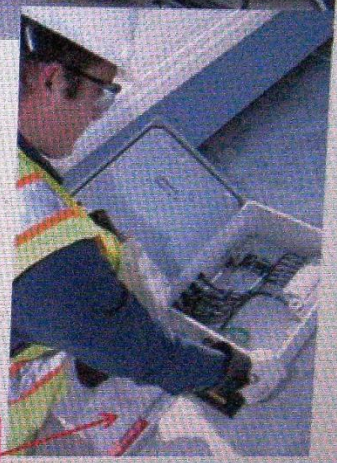
- International Fire Code (IFC) will become part of NEC 2014 to provide consistent label guidelines (NEC 2011 and IFC 2008 differed) UL 929 standard added

- Some signage must be reflective
- Yellow=Caution; Orange= warning;
- Red background with white letters

IFC rules

NEC 690.31(E)(3)(1-4)
IFC 605.11.1.4 & CAL FIRE 1.0

- IFC 605.11.1.1: Marking shall be reflective.
- IFC 605.11.1.4: Marking shall be placed on exposed raceways, cable trays or other wiring methods. Covers or enclosures of pull boxes and junction boxes. all interior and exterior DC conduit, raceways, enclosures, and cable assemblies every 10 feet (3048mm) within 1 foot (305mm) of all turns or bends and within 1 foot (305mm) above and below all penetrations for roof/ceiling assemblies and all walls and/or barriers.
- Marker must also be on the main service disconnect.



WARNING: PHOTOVOLTAIC POWER SOURCE

596-00206

NEC 2014

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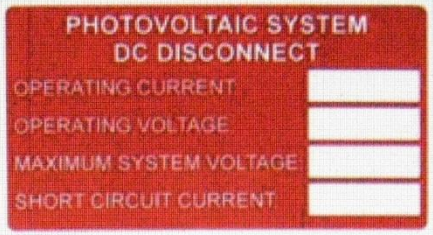
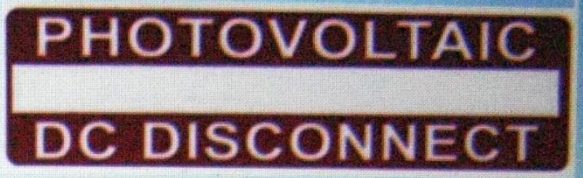
Label Formats

- Label Size
- Label Color
- Printed Text
- Label Type
- Functional purposes

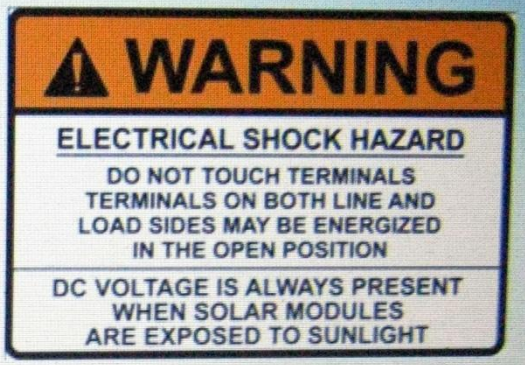


596-00241

Not to exceed 4.0" wide labels



596-00238



596-00496

596-00255

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Label Durability

- NEC110.21 = "The markings LABELS shall be suitable for the environment where it is installed. NFPA 11.1.9.3.2 = "The marking shall be of sufficient durability to withstand the environment involved."
- IFC 605.11.1.1 = "The materials used for marking shall be reflective, weather resistant and suitable for the environment.
- Cal Fire 1.0 = "The materials used for marking must be weather resistant. It is recommended that UL969 be used as standard to determine weather rating.
- Local codes will vary from city to city.

- **All** HellermannTyton materials used in the Solar labels meet the requirements of UL969 and are UL recognized.
- Many labels have been Xenon Arc tested.

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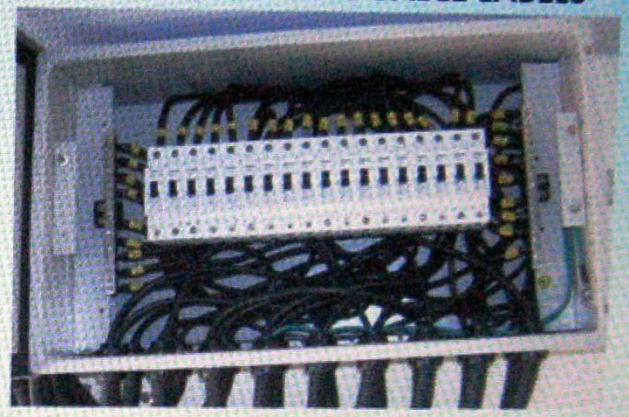
NEC Article 690.4 Installation

NEC 690.31(B)(1) through (4) Conductors shall be identified and grouped as required using color code, tags, marking tape, tagging or other means. Where AC and DC are running together, they must be grouped using cable ties and identified clearly.

COMBINER BOX CABLE LABELS



NEC 2014

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CAL FIRE 1.2.1

The NEC 2014 and IFC 2012 wording was made consistent: "**WARNING: PHOTOVOLTAIC POWER SOURCE**" but the CAL FIRE and IFC 2008 allow **CAUTION: SOLAR CIRCUIT**.

CAUTION: SOLAR CIRCUIT

596-00247

CAUTION: SOLAR CIRCUIT

596-00615

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NEC Article 690.4 (E)

Circuit Routing:
Where circuits are embedded in build-up, laminate, or membrane roofing materials not covered by PV modules and associated equipment, the location of circuits shall be clearly marked.

NEC 2014

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DISCONNECT MARKINGS: NEC 690.13(B)

Each PV system disconnecting means shall be permanently marked to identify it as a photovoltaic system disconnect.

PHOTOVOLTAIC
AC DISCONNECT

PHOTOVOLTAIC
DC DISCONNECT

MAIN PHOTOVOLTAIC SYSTEM AC DISCONNECT

MAIN PHOTOVOLTAIC SYSTEM DISCONNECT

SOLAR DISCONNECT

NEC 2014

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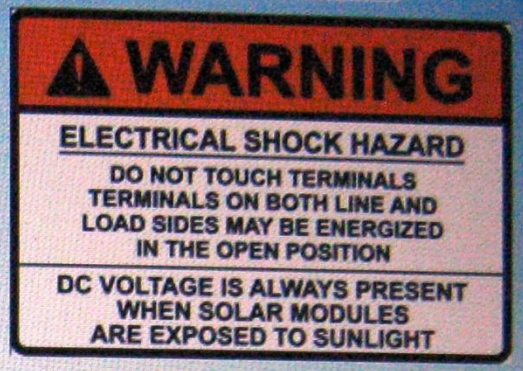
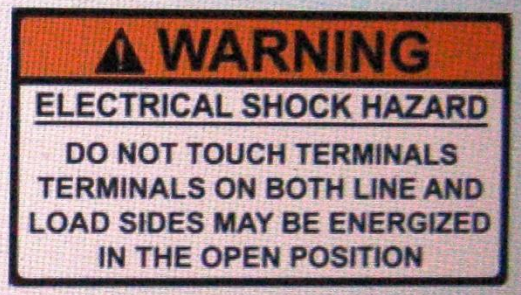
Article 690.17(E) or 690.17(4)

Building or structure disconnecting means

Where all terminals of the disconnecting means may be energized in the open position, a warning sign shall be mounted on or adjacent to the disconnecting means.



Combiner box or DC breaker box



AC breaker box, main breaker panel

Also NEC 705.22(4) for alternate power sources in general.

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Article 690.54

Interactive System Point of Interconnection

All interactive system(s) points of interconnection with other sources shall be marked at an accessible location at the disconnecting means as a power source and with the rated AC output current and the nominal operating AC voltage.

PHOTOVOLTAIC AC DISCONNECT

MAXIMUM AC OPERATING CURRENT:

NOMINAL OPERATING AC VOLTAGE:

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Article 705.12(D)(2-3)

Equipment containing overcurrent devices in circuits supplying power to a busbar or conductor supplied from multiple sources shall be marked to indicate the presence of all sources.

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NEC Article 690.53

Direct Current PV Power Source

A permanent label for the direct-current photovoltaic power source indicating items (1) through (5) shall be provided by the installer at the PV disconnecting means:

RATED MAX POWER-POINT CURRENT

RATED MAX POWER-POINT VOLTAGE

MAXIMUM SYSTEM VOLTAGE

MAXIMUM CIRCUIT CURRENT

MAX RATED OUTPUT CURRENT OF

THE CHARGE CONTROLLER IF INSTALLED

"Short Circuit Current" changed to "Maximum Circuit Current" in 2014 code.

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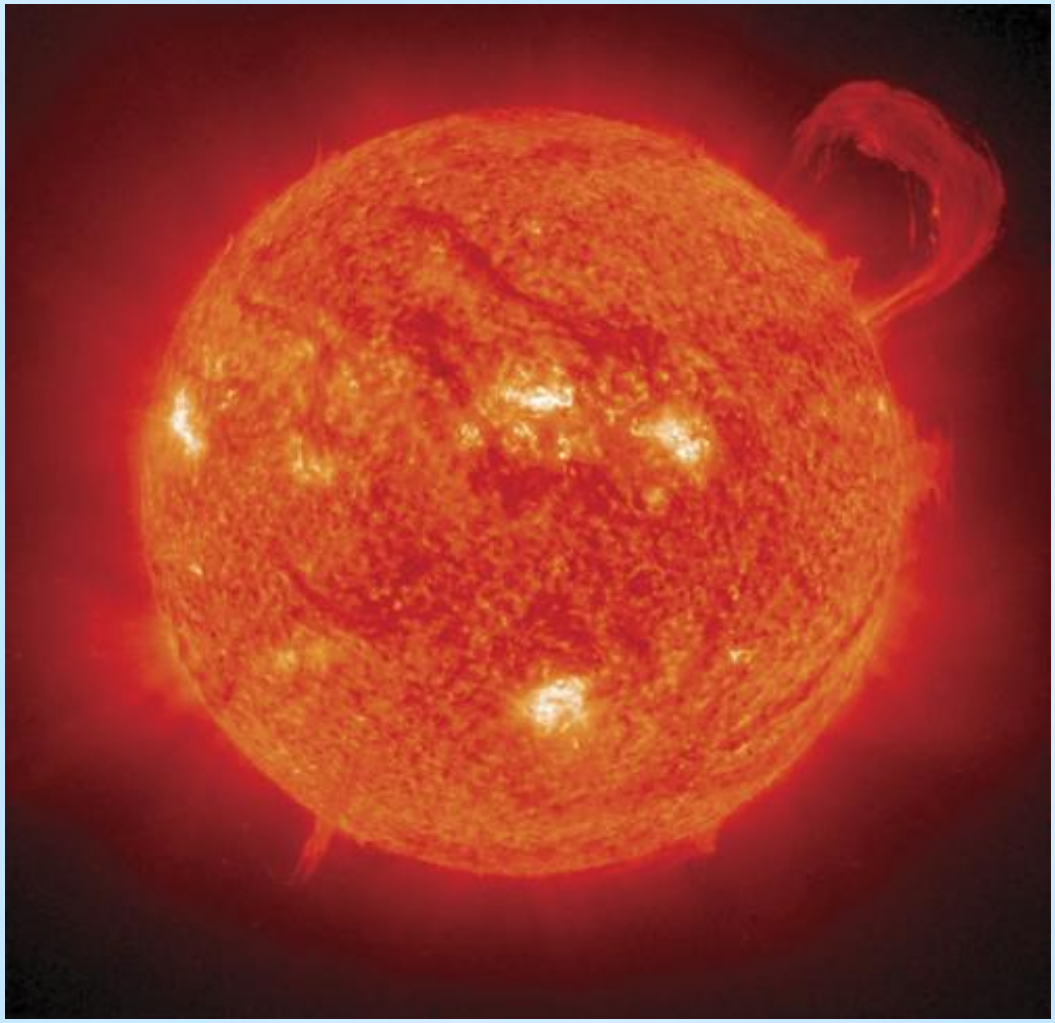
Dr. Gay E. Canough



When there's a HUGE solar energy spill, we just call it a "nice day"!