SOLAR PV FOR ARCHITECTS & ENGINEERS

Lecture #1: SOLAR PV BASICS

Lecturer, Written/Checked:	Greg Sachs, PE CTO
Version:	30 Sept 2009
Company:	EmPower CES, LLC *Clean Energy Solutions*

Lecture Topics

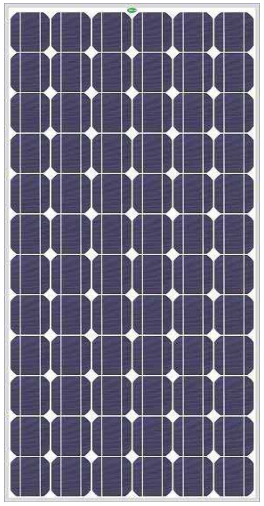
1. Solar System Types
2. PV System Components (BOS)
3. PV Racking Systems
4. PV Electrical System Design
5. Quiz

Harnessing Energy from the Sun

SOLAR ENERGY SYSTEM TYPES

TYPES, Photo-Voltaic

1. Conversion:
   Solar Radiation ->
   Moving Electrons
   (Electricity)
2. Solar PV is the Focus of this Presentation
3. Shown is the "Photovoltaic Effect"
   – Generates approx 0.5 volts



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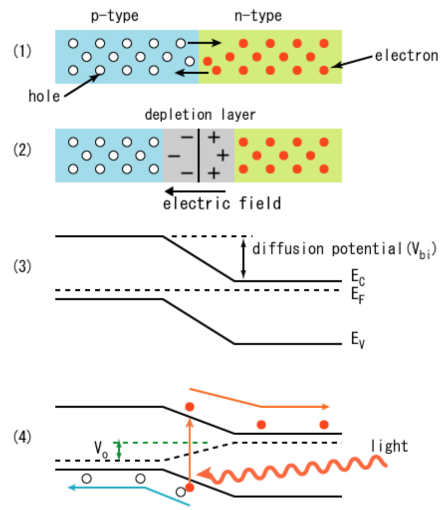
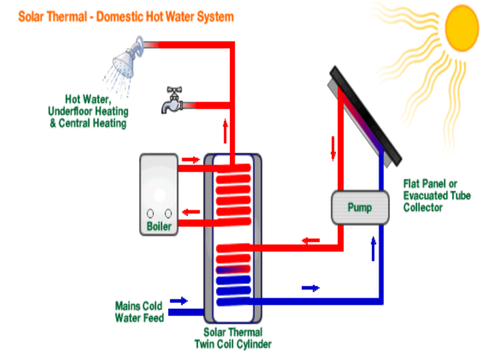


TYPES, Thermal

1. Solar Hot Water
2. Conversion:
   Solar Radiation ->
   Thermal Energy
3. Typical Collectors
   – Evacuated Tubes
   – Flat Plate Collectors



TYPES, Concentrated Solar

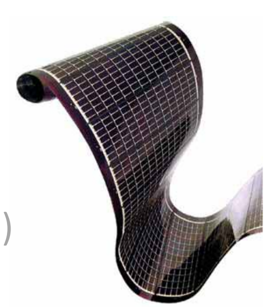
1. Thermal or PV
2. Collector Types
   – Parabolic Trough
   – Heliostats

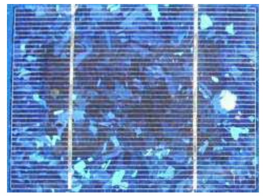
"Balance of System" - BOS

PV SYSTEM COMPONENTS

BOS, PV Products & Applications

1. Classification by Crystal Type
   - Mono-Crystalline
   - Poly-Crystalline
   - Amorphous
2. Rigid Modules
3. Thin film (glazing, rolls)
4. Building Integrated Photovoltaics (BIPV)





BOS, PV Products & Applications

1. Classification by Crystal Type
2. Rigid Modules
   - Mono or Poly Crystalline
   - Approximate 3'x5'
   - Produce approximately 12 W/SF
   - Many manufacturers
3. Thin film (glazing, rolls)
4. Building Integrated Photovoltaics (BIPV)

BOS, PV Products & Applications

1. Classification by Crystal Type
2. Rigid Modules
3. Thin film (glazing, rolls)
   - Used when there is plenty of roof space
   - Not that common in the NY market
4. Building Integrated Photovoltaics (BIPV)

BOS, PV Products & Applications

1. Classification by Crystal Type
2. Rigid Modules
3. Thin film (glazing, rolls)
4. Building Integrated Photovoltaics (BIPV)
   - Typically replaces a building material
   - Generally custom made
   - FirstSolar, GE, Sanyo, SunSlate, UniSolar

BOS, Inverters

1. Definition: Inverter
   - Converts high voltage DC into AC
2. "Grid Tied" (Most typical)
   - Typical ~450 VDC to 240/120 VAC (split ph)
   - Contains (a) "H-Bridge", (b) Filter, (c) Transformer
   - Residential Range 3kW to 7kW
3. Off-Grid (Battery)
   - Converts battery bank voltage to AC
   - Typically 12/24/48V to 240/120 VAC

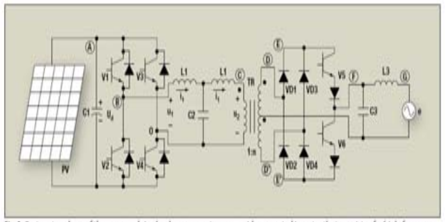


Fig. 1. System topology of the proposed single-phase current-source grid-connected inverter that consists of a high-frequency, full-bridge inverter, immittance converter, center-tapped transformer, high-frequency bridge rectifier, power-frequency inverter and low-pass filter.

BOS, Inverters

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BOS, Charge Controller

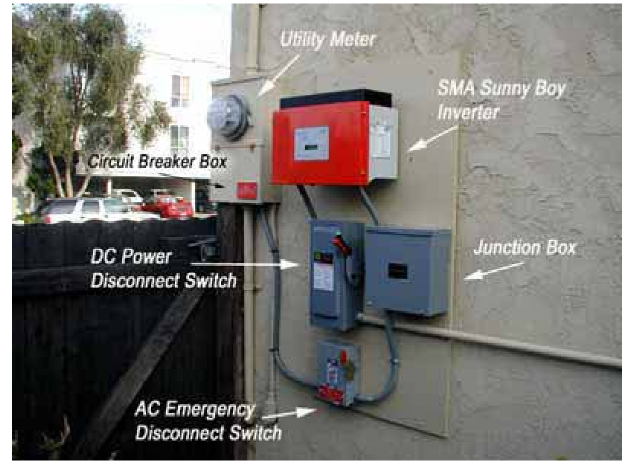
1. Definition: DC/DC Controller
   - Convert medium voltage DC to low voltage DC
   - As before, 12/24/48 VDC
2. Small Controller (Lighting)
   - Lighting controllers
   - Require small battery
   - Common types

BOS, Charge Controller

1. Definition:
   DC/DC Controller
   – Used to convert medium voltage DC to low voltage DC
   – As before, 12/24/28 VDC
2. Small Controller (Lighting)
   – Lighting controllers
   – Require small battery
   – Common types

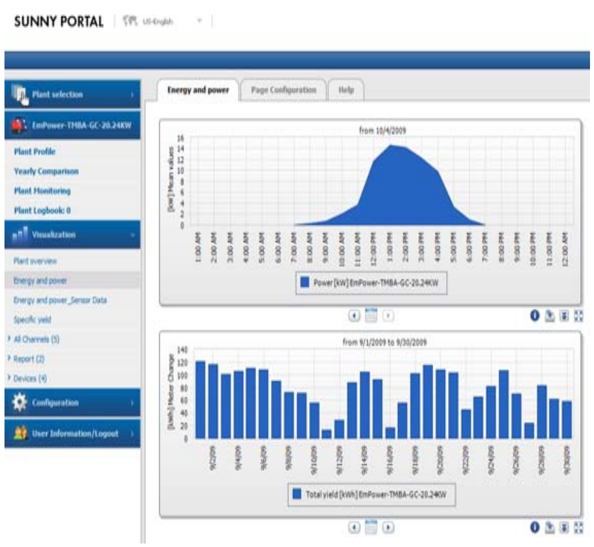
BOS, OCPD Devices

1. DC Disconnect
2. Inverter Output Breakers
3. AC Disconnect (Utility Required)



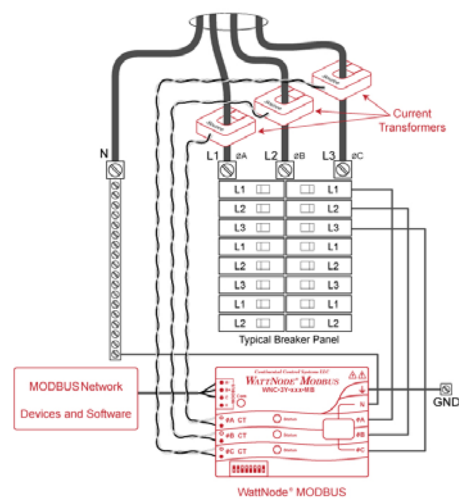
BOS, Meters & Monitoring

1. Importance of monitoring production
   – Is the system running?
   – Is the production as designed?
2. "Revenue Grade"
3. Typical Meter Socket
4. Pre-packaged "Solutions"



BOS, Meters & Monitoring

1. Importance of monitoring production
2. "Revenue Grade"
   – +/- 0.2% Accuracy
   – Used to accurately measure energy produced
   – "Performance Based" incentives, Feed In Tariff (FIT), SREC, Green Tags
   – Power Purchase Agreement (PPA)
3. Typical Meter Socket
4. Pre-packaged "Solutions"



BOS, Meters & Perf. Monitoring

1. Importance of monitoring production
2. "Revenue Grade"
3. Typical Meter Socket
   - Typical Analog Meter
   - Digital Metering Systems
4. Pre-packaged "Solutions"

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BOS, Meters & Perf. Monitoring

1. Importance of monitoring production
2. "Revenue Grade"
3. Typical Meter Socket
4. Pre-packaged "Solutions"
   - "Fat Spaniel"
   - Draker Laboratories
   - Comes with inverter

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BOS, Racking

1. Many types
2. Worthy of separate section....

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Means of Securing PV to Structure or Ground

RACKING / MOUNTING SYSTEMS

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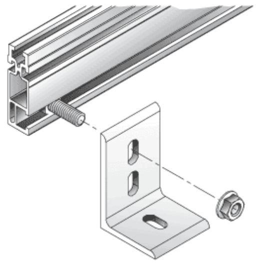
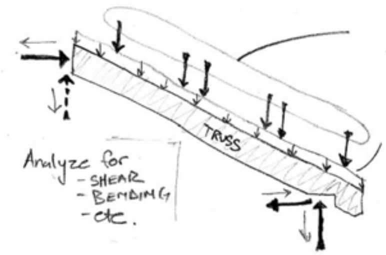
RACKING, Residential

1. Rail & L Bracket
   - UniRac , DPW, Schott
   - Top clips
   - Bottom clips
   - Cap strip
2. Considerations
3. New types
4. Custom Systems



RACKING, Residential

1. Typical Rail & L-Foot
2. Considerations
   - Height off roof
   - Attachment method
   - "Pullout" integrity
   - Watertight integrity
3. New types
4. Custom Systems



RACKING, Residential

1. Typical Rail & L-Foot
2. Considerations
3. New types
   - Sharp System
   - UniRac "Click-Sys"
4. Custom Systems
   - Used as last resort
   - Requires engineering
   - Not tested as a complete system

RACKING, Commercial

1. Key Classification
   - Ballasted (Non-Penetrating)
   - Anchored (Penetrating)
2. Examples
3. Pro's & Con's

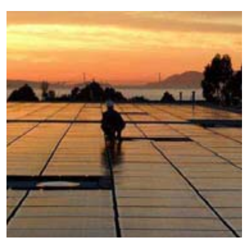
RACKING, Commercial

1. Key Classification
   - Ballasted (Non-Penetrating)
   - Anchored (Penetrating)
2. Examples
3. Pro's & Con's

RACKING, Commercial

1. Key Classification
2. Examples
   - Ballasted
   - Anchored
   - Hybrid
3. Pro's & Con's

RACKING, Commercial, Ballasted



RACKING, Commercial, Anchored

RACKING, Commercial, Hybrid

RACKING, Commercial

1. Key Classification
2. Examples
3. Pro's (+) & Con's (-)
   - Ballasted
     - (+) Doesn't penetrate roofing membrane
     - (+) Least Expensive
     - (-) Heavy
     - (-) Collection of leaves, etc.
   - Anchored
   - Hybrid
     - Can lessen amount of ballast per point of interconnection

RACKING, Commercial

1. Key Classification
2. Examples
3. Pro's & Con's
   - Ballasted
   - Anchored
     - (+) Can be esthetically pleasing
     - (+) Elevated array has a small footprint
     - (-) More complicated
     - (-) More expensive
   - Hybrid

RACKING, Commercial

1. Key Classification
2. Examples
3. Pro's & Con's
   - Ballasted
   - Anchored
   - Hybrid
     - (+) Used to reduce ballast
     - (-) Complicated installation

Managing Renewable Electricity

BASIC PV ELECTRICAL SYSTEM DESIGN

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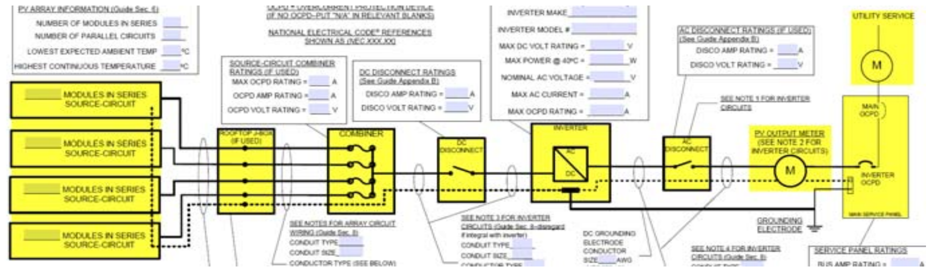
ELECT, Basic Residential Schematic



System Components:

1. PV Strings (DC)
2. Rooftop Junction Box
3. "Combiner Box"
4. "DC Disconnect"
5. Inverter
6. "AC Disconnect“
7. PV Production Meter
8. Grid Interconnection

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ELECT, Module Energy Production

1. Module Performance Standards
   - "Standard Test Conditions" (STC), Cell temp 25°C
   - "Production Test Conditions" (PTC), Cell temp approx 50°C
2. Assembling the array
3. Power = Volts * Current
4. Energy = Power * Time
5. Solar conditions affect production throughout the day

Typical Performance Characteristics

Peak Power (Wp)	Watts	205
Max. Power Voltage (Vmp)	Volts	27.2
Max. Power Current (Imp)	Amps	7.6
Open Circuit Voltage (Voc)	Volts	33.0
Short Circuit Current (Isc)	Amps	8.2
Short Circuit Temp. Coefficient	mA/°C	5.6
Open Circuit Voltage Coefficient	V/°C	-0.12
Max. Power Temp. Coefficient	%/°C	-0.5
Max. Series Fuse	Amps	15
Max. System Voltage	Volts	600
Normal Operating Cell Temperature [NOCT]	deg. C	50

IV parameters are rated at Standard Test Conditions (Irradiance of 1000 W/m², AM 1.5G, cell temperature 25°C). As with all poly-crystalline PV Modules, during the stabilization process that occurs during the first few days in service, module power may decrease approximately 3% from typical maximum power due to a phenomenon known as Light Induced Degradation (LID). All measurements are guaranteed at the laminate leads. NOCT is measured at 800 W/m², 20 deg. C ambient, and 1 m/s windspeed.

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ELECT, Module Energy Production

1. Module Production Standards
2. Assembling the array
   - Voltages add in series
   - Current adds in parallel
   - Maximize modules in series first than series circuits in parallel
3. Power = Volts * Current
4. Energy = Power * Time
5. Solar conditions affect production throughout the day

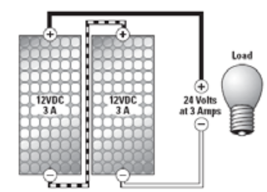

Figure 2-2
PV MODULES IN *SERIES*

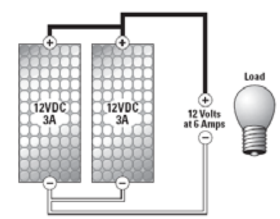

Figure 2-3
PV MODULES IN *PARALLEL*

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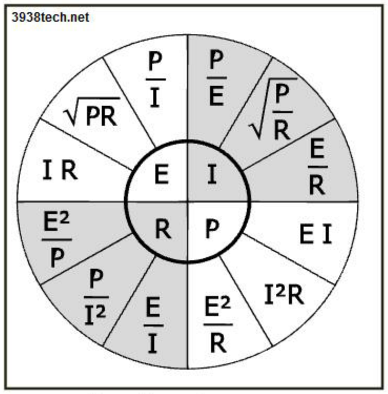
ELECT, Module Energy Production

1. Module Production Standards
2. Assembling the array
3. Power = Volts * Current
4. Energy = Power * Time
   - 100 Watt bulb = 0.1 kW
   - On for 10 hours
   - Or 1 hr, 1 kW, etc.
   - Measure of ENERGY
5. Solar conditions affect production throughout the day



E = voltage I = current
R = resistance P = power

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ELECT, Module Energy Production

1. Module Production Standards
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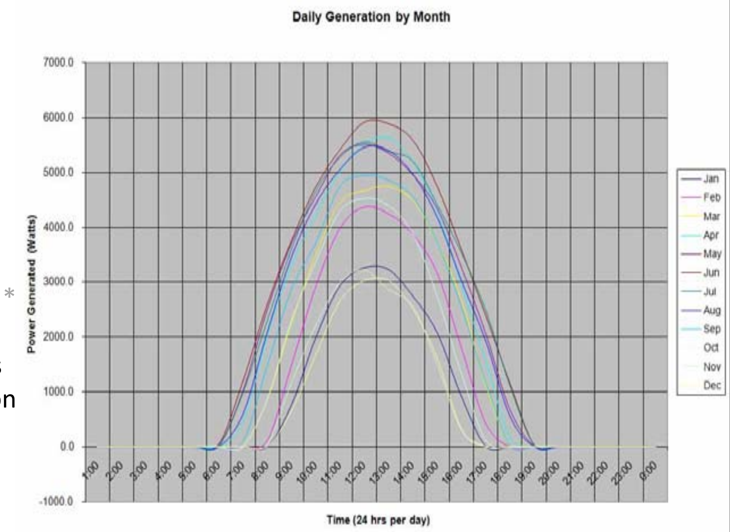
3. Power = Volts * Current
4. Energy = Power * Time
5. Solar conditions affect production throughout the day



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ELECT, Array Sizing

1. Main considerations
   - Energy usage
   - Available roof area
   - Incentives
2. Solar Insolence
3. Matching System Size to Energy Usage
4. Thumb-rules

$$P = I * V$$

$$Watts = Amps * Volts$$

$$WH = W * T$$

$$WH = Watts * Hours$$

Example: 100W light bulb

$$1000\ WH = 100W * 10Hrs$$

$$1000\ WH = 1KWH$$

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ELECT, Array Sizing

1. Main considerations
2. Solar Insolence
   - Earth Surface Expected
   - Altered based on pitch & orientation
   - Concept: Sun-Hours
3. Matching System Size to Energy Usage
4. Thumb-rules

PVWatts AC Energy & Cost Savings

Cautions for Interpreting the Results

Station Identification	
City:	New_York_Ciy
State:	New_York
Latitude:	40.78° N
Longitude:	73.97° W
Elevation:	57 m
PV System Specifications	
DC Rating:	1.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	0.8 kW
Array Type:	Fixed Tilt
Array Tilt:	33.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	14.5 ¢/kWh

Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.00	74	10.73
2	4.02	89	12.91
3	4.55	108	15.66
4	5.35	119	17.25
5	5.51	123	17.84
6	6.06	128	18.56
7	5.89	126	18.27
8	5.66	122	17.69
9	5.08	108	15.66
10	4.37	100	14.50
11	2.79	63	9.13
12	2.69	65	9.43
Year	4.58	1226	177.77

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ELECT, Array Sizing

1. Main considerations
2. Solar Insolence
3. Matching System Size to Energy Usage
   - Equating Sun Hours to Annual Production
   - Divide total consumption to get required system size
4. Thumb-rules

Bill Date	Days in Bill	Meter Reading	Reading Type	KWH Used
7/1/2009	21	5403	FINAL	175
6/10/2009	29	5228	ESTIMATE	196
5/12/2009	33	5032	ACTUAL	212
4/9/2009	29	4820	ESTIMATE	219
3/11/2009	29	4601	ACTUAL	403
2/10/2009	29	4198	ESTIMATE	259
1/12/2009	34	3939	ACTUAL	345
12/9/2008	32	3594	ESTIMATE	241
11/7/2008	28	3353	ACTUAL	194
10/10/2008	28	3159	ESTIMATE	170
9/12/2008	32	2989	ACTUAL	314
8/11/2008	32	2675	ESTIMATE	189
TOTAL DAYS	356		TOTAL ANNUAL KWH	2917

$$Average\ Daily\ Sun\ Hours\ (NYC) = 4.58$$

$$1\ Sun\ Hour = 1kWh/(m\hat{}2/Day)$$

$$Annual\ Consumption = 2917\ kWh$$

$$Required\ Photovoltaic\ System\ Size\ (kW)?$$

$$P = \frac{2917kWh}{1226\ kWh}$$

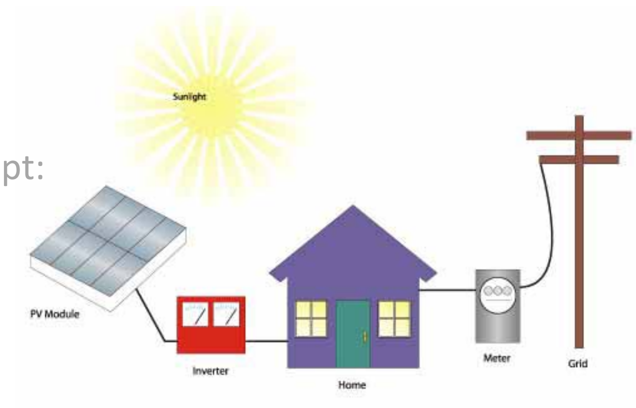
$$P = 2.37\ kW$$

ELECT, Array Sizing

1. Main considerations
2. Solar Insolence
3. Matching System Size to Energy Usage
4. Thumb-rules
   - Typical home in America uses 12,000 kWh/Year
   - A 10 kW system at ideal pitch and orientation will produce 12,000 kWh/Year
   - 80 SF = 1kW (contiguous array)

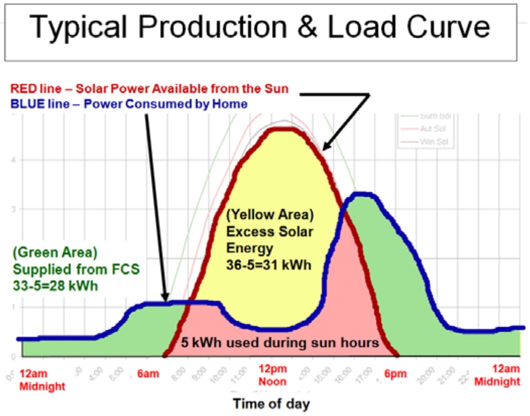
ELECT, Net Metering

1. Energy is <u>not stored</u> in a typical grid-tied installation
2. Two-way power
3. Important Concept: "Anti-Islanding" (UL1741)



ELECT, Net Metering

1. Energy is <u>not stored</u> in a typical grid tied installation
2. Two-way power
   - Supplemental energy required from the grid *(meter spin forward)*
   - Excess solar energy supplied to the grid *(meter spin backward)*
3. Important Concept: "Anti-Islanding" (UL1741)



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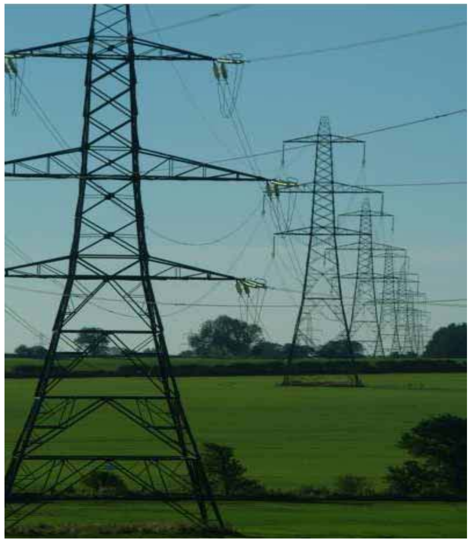
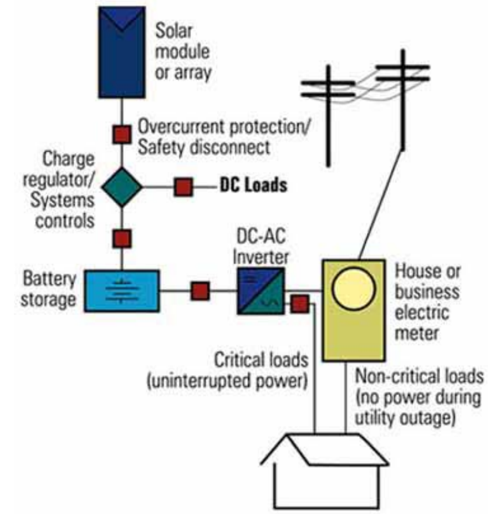


ELECT, Off-Grid Systems

1. Designed to operate without electrical grid
2. PV Energy sent to large battery bank by charge controller
3. DC Battery energy converted to AC on demand



Testing Your Knowledge

POP QUIZ

QUIZ

1. **Q1**: What are the three crystal types used in solar photovoltaics? What are the pros & cons of each?
2. **Q2**: What are the two general commercial racking methods? List the pros and cons for each.
3. **Q3**: Define "Net-Metering" & how it differs with an off-grid system.
4. **Q4**: Describe the effects of adding modules in series and/or parallel to an array.

QUIZ

5. **Q5**: Does a typical PV system supply power the home when there is a black-out? Why or why not? What governs these rules?
6. **Q6**: What is revenue grade metering and when might it be more important to use revenue grade metering?
7. **Q7**: What to STC and PTC stand for? Describe how each are determined.

Q&A

SOLAR PV FOR ARCHITECTS & ENGINEERS

Lecture #2: ENGINEERING & ARCHITECTURE

Lecturer, Written/Checked:	Greg Sachs, PE CTO
Version:	30 Sept 2009
Company:	EmPower CES, LLC *Clean Energy Solutions*

Lecture Topics

1. Guidelines for Architects
   – General "best practice" design rules (residential & commercial)
   – MEP provisions and design
2. Guidelines for Engineers
   – Typical responsibilities
   – Residential and commercial
   – Structural guidelines
   – Electrical guidelines
   – Roofing issues
   – Contractor selection

SURVEY!

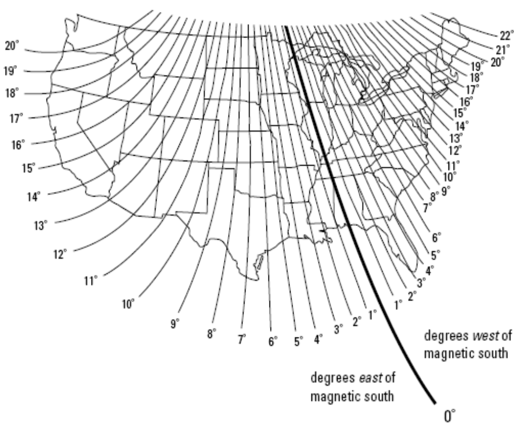
1. How many Architects in Audience?
   - Residential Focus?
   - Commercial Focus?
2. How many Engineers in Audience?
   - Electrical?
   - Plumbing?
   - Other?
3. Other Disciplines Represented?
   - General Contractors?
   - Solar Contractors?

Designing "Solar Ready" Homes

ARCHITECTS: RESIDENTIAL

A: RESI, General Guidelines

1. Orientation
   - 180 deg 'True' south
   - Not to be confused with Magnetic South
2. Pitch
3. Roof Design
4. Shading
5. Roof Framing



A: RESI, General Guidelines

1. Orientation
2. Pitch
   - Latitude angle= Theoretical max irradiation eg. 40°39‘ for NYC.
   - 33° (8:12) = Ideal
   - Lat+15° = max winter
   - Lat-15° = max summer
3. Roof Design
4. Shading
5. Roof Framing

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Fixed array													
Lat - 15	2.9	3.7	4.6	5.3	5.8	6	6	5.7	5	4.1	2.9	2.4	4.5
Latitude	3.2	4	4.8	5.2	5.4	5.5	5.6	5.5	5	4.4	3.2	2.8	4.6
Lat + 15	3.4	4.1	4.6	4.8	4.8	4.8	4.9	5	4.8	4.4	3.3	3	4.3
Single axis													
Lat - 15	3.4	4.5	5.7	6.7	7.2	7.5	7.5	7.1	6.2	5.1	3.4	2.8	5.6
Latitude	3.7	4.7	5.8	6.6	6.9	7.2	7.2	6.9	6.2	5.3	3.7	3.1	5.6
Lat + 15	3.4	4.5	5.7	6.7	7.2	7.5	7.5	7.1	6.2	5.1	3.4	2.8	5.6
Dual axis	3.9	4.8	5.8	6.7	7.3	7.7	7.6	7.1	6.2	5.3	3.8	3.3	5.8

A: RESI, General Guidelines

1. Orientation
2. Pitch
3. Roof Design
   - Affects system aesthetics
   - Avoid multi-angled surfaces
   - Avoid obstructions (chimneys, vents, antennas)
4. Shading
5. Roof Framing

A: RESI, General Guidelines

1. Orientation
2. Pitch
3. Roof Design
4. Shading Issues
   - Avoid hard shading from solid structures (chimneys, vents & other roof surfaces)
   - Minimize soft shading (trees--hardwoods)
5. Roof Framing

A: RESI, General Guidelines

1. Orientation
2. Pitch
3. Roof Design
4. Shading
5. Roof Framing
   - Assessment of existing conditions (requires visual inspection)
   - Load analysis
   - Asses code requirements
   - May need extra bracing/reinforcements

A: RESI, MEP Guidelines

1. Location of electrical & plumbing equipment
   - Inverter location?
   - Conduit & pipe runs?
   - Consult with solar integrator
2. Inverter placement guidelines
3. Preparing for run from roof or array location
4. Preparing for electrical interconnection
5. Solar hot water storage

A: RESI, MEP Guidelines

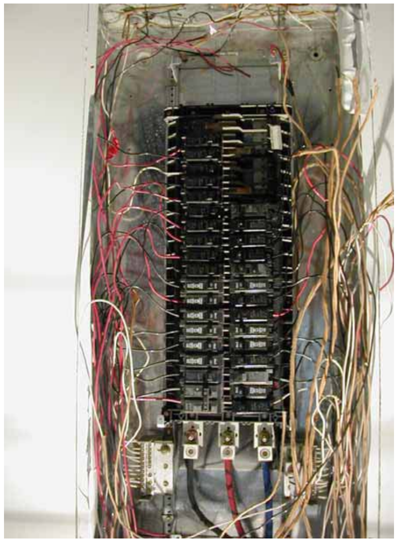
1. Preparing for electrical & plumbing equipment
2. Inverter placement guidelines
   - Typically outside—not in direct sunlight (north side)
   - Meet code requirements (accessibility)
   - Used common sense (Not near a HVAC condenser)
3. Preparing for run from roof or array location
4. Preparing for electrical interconnection
5. Solar hot water storage

A: RESI, MEP Guidelines

1. Preparing for electrical & plumbing equipment
2. Inverter placement guidelines
3. Preparing for run from roof or array location
   - Provide a pipe chase
   - Issues with running internally–need to access wall interior (rip out drywall)
   - Routing on roof (aesthetics)
   - Minimize run (energy loss)
4. Preparing for electrical interconnection
5. Solar hot water storage

A: RESI, MEP Guidelines

1. Preparing for electrical & plumbing equipment
2. Inverter placement guidelines
3. Preparing for run from roof or array location
4. Preparing for electrical interconnection
   - Leave room in electric panel for back-fed breakers
   - Leave space adjacent to panel for additional panel
5. Solar hot water storage



A: RESI, MEP Guidelines

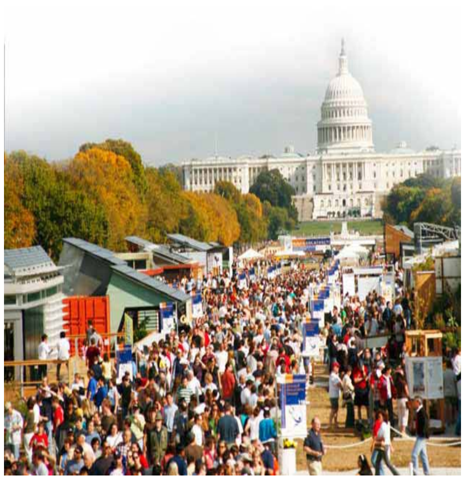
1. Preparing for electrical & plumbing equipment
2. Inverter placement guidelines
3. Preparing for run from roof or array location
4. Preparing for electrical interconnection
5. Solar hot water storage
   - Typical residential heater is 40-60 gal
   - SHW storage is 80 gal
   - Running piping is more challenging than electrical

A: RESI, Photo-Examples

1. Describe your key observations with each of the following installation photographs...

A: RESI, Relation w/Green Building

1. Zero-Energy Homes
   - Solar is part of a much bigger picture
   - “Whole Systems” approach is key
   - Solar Decathlon—good example of integrated approach
2. Energy-Star
   - DOE Program fading out
3. LEED
   - More stringent than energy star
   - Recently increased exam difficulty level
4. Energy Codes
   - State, NYC, Town
   - ASHRAE 189.1 (green bldg std)



ARCHITECTS: COMMERCIAL

A: COMM, Market Perspective

1. It starts with YOU
2. Building a market in NY/LI since Jan 1, 2009
3. Developed markets in CA, NJ (SREC)
4. Total installed 7MW
5. Typical Power Plant 200MW
6. Warehouses / Large roofs best opportunity (Not Manhattan)

A: COMM, Misc Issues

1. BIPV Vs. Standard Modules
   - Complicates wiring
   - Requires multiple disciplines
   - Produces much less power (1/4)
2. Estimating Production
   - Key question for many projects
   - Not straight forward thumb-rule
3. Enlist a good MEP early!
   - Vital to success of commercial project
   - Not many MEP firms have specific PV experience
   - Solar contractor should take part in conceptual design

Typical Engineer "Scope of Work" (SOW)

ENGINEER: TYPICAL RESPONSIBILITIES

E: SOW, Early Design & Bidding

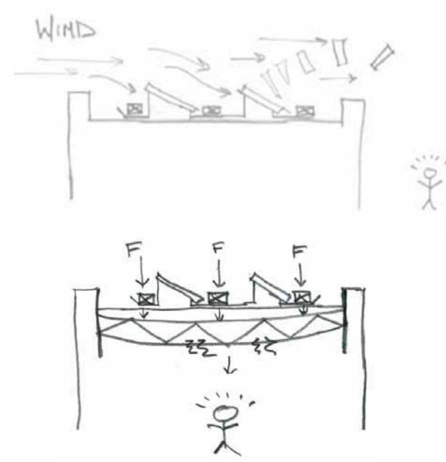
1. Working closely with architects & owners
2. Basic roof layout & making buildings "Solar Ready"
3. Writing bid specs
4. Reviewing proposals

E: SOW, Structural Design

1. **MODULE LIFT-OFF**
   Ensure the racking and/or tie-down is sufficient to prevent modules from flying off the roof
2. ROOF-COLLAPSE/FAILURE

E: SOW, Structural Design

1. MODULE LIFT-OFF
2. **ROOF-COLLAPSE/FAILURE**
   Ensuring the structure is sufficient to withstand the forces exerted by the solar equipment



E: SOW, Structural Design

NOTE:
Structural endorsement is typically required by AHJ for Issuing a bldg permit.

E: SOW, Electrical Design

1. **PV, DC Power Collection**
   - Module "Stringing"
   - Array & Combiner Box placement
   - Wire selection, etc
2. AC Interconnection

E: SOW, Electrical Design

1. PV, DC Power Collection
2. **AC Interconnection**
   - Inverter selection
   - Method of 'tie-in'
   - Panel / Switchgear Impacts

E: SOW, Electrical Design

<u>NOTE:</u>

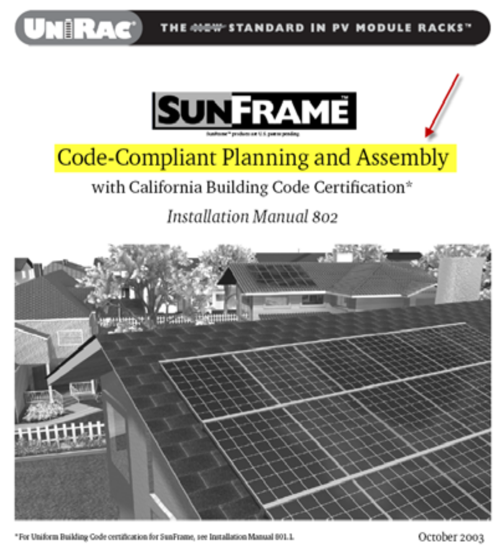
Electrical endorsement Typically <u>**not**</u> required by AHJ on Long Island.

Requirements for the typical residential "solar job".

ENGINEER: RESIDENTIAL

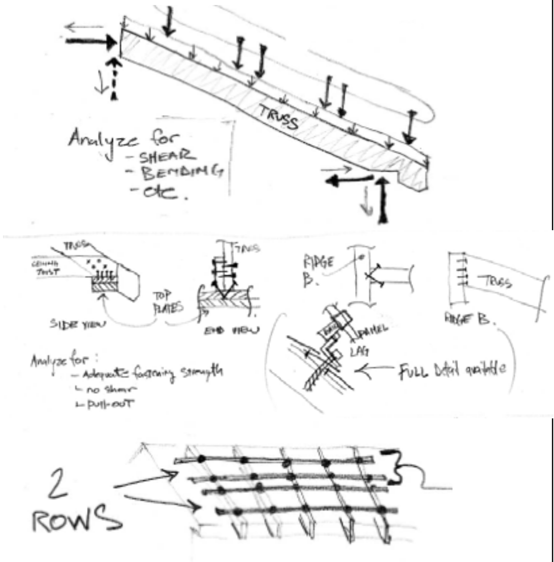
E: RESI, Key Issues

1. Recall Two Requirements...
   - "Lift-Off"
   - "Roof-Collapse/Failure"
2. Lift-Off
   - <u>Racking</u> frequently stamped by PE in that state by the manufacturer (i.e., UniRac)
   - Must be installed to "manufacturer guidelines / specifications"
   - *ONLY COVERS RACKING INTEGRITY, NOT ROOF!*
3. Roof-Collapse/Failure
4. Electrical Interconnection



E: RESI, Key Issues

1. Recall Two Requirements…
2. Lift-Off
3. Roof-Collapse/Failure
   - Your Responsibility!
   - Must understand the racking force interactions
   - Should review integrator selected location of tie-downs
   - Look specifically at rafter capacity
   - Look at integrity of roof structural system
4. Electrical Interconnection



E: RESI, Key Issues

1. Recall Two Requirements…
2. Lift-Off
3. Roof-Collapse/Failure
4. Electrical Interconnection
   - Typically done by a solar knowledgeable electrician / solar contractor
   - Detailed interconnection / PE stamp typically not required

Large Scale Solar, etc.

ENGINEER: COMMERCIAL

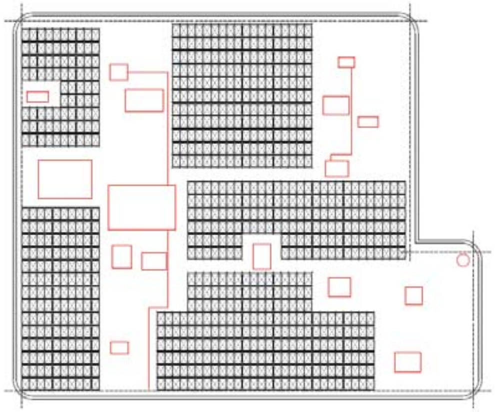
E: COMM, Orientation & Obstructions

1. Building/Solar System Orientation
   - On flat roofs PV modules are typically oriented parallel to roof sides
   - Sea saw PV array layout is more complicated to install
2. Rooftop Mechanical Equipment
3. Parapet Shading

Tilt	Azimuth	Sun Hrs	AC Prod.	% Loss
32	180	4.58	1225	0%
32	90	3.73	974	-19%
32	270	3.70	960	-19%
0	NA	4.00	1050	-13%
90	90	2.37	586	-48%
90	180	3.09	798	-33%
90	270	2.33	572	-49%

E: COMM, Orientation & Obstructions

1. Building/Solar System Orientation
2. Rooftop Mechanical Equipment
   - For pitched roofs locate RTUs on north side of roof
   - For flat roofs group RTUs on north side of roof (minimize shading)
3. Parapet Shading



E: COMM, Orientation & Obstructions

1. Building/Solar System Orientation
2. Rooftop Mechanical Equipment
3. Parapet Shading
   - Consider reduction or elimination of parapet

E: COMM, Orientation & Obstructions

NOTE:

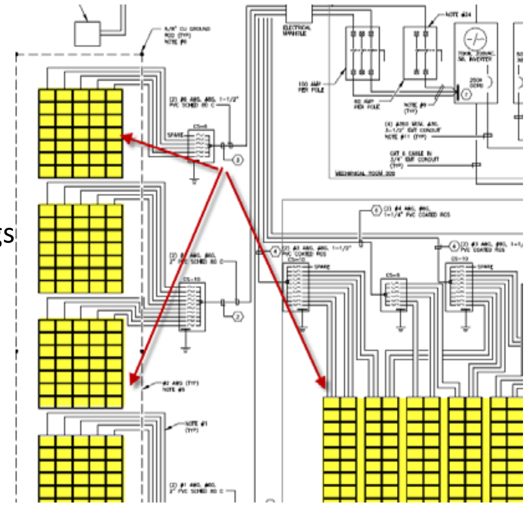
Commercial sites are often "ruined" by amount of equipment on roof

E: COMM, Basic Electrical

1. First steps
   - Create a basic DC electrical design
   - Evaluate AC interconnection requirements
   - Evaluate inverter types
   - Enlist the assistance of a knowledgeable Solar Integrator
   - Step through the implications
2. Common Mistakes
3. Provisions for electrical runs & interconnection
4. Electrical Capacity Planning
5. Module types used in commercial

E: COMM, Basic Electrical

1. First steps
2. Common Mistakes
   - Not balancing strings properly!
   - Must always maintain proper combination of series and parallel strings at each “combiner” location
3. Provisions for electrical runs & interconnection
4. Electrical Capacity Planning
5. Module types used in commercial



E: COMM, Basic Electrical

1. First steps
2. Common Mistakes
3. Provisions for electrical runs & interconnection
   - Challenging to “core drill” bulkheads and floors to get to switchgear room, etc
   - Leave chase for plumbing and electrical from roof to electrical room and mechanical room
4. Electrical Capacity Planning
5. Module types used in commercial

E: COMM, Basic Electrical

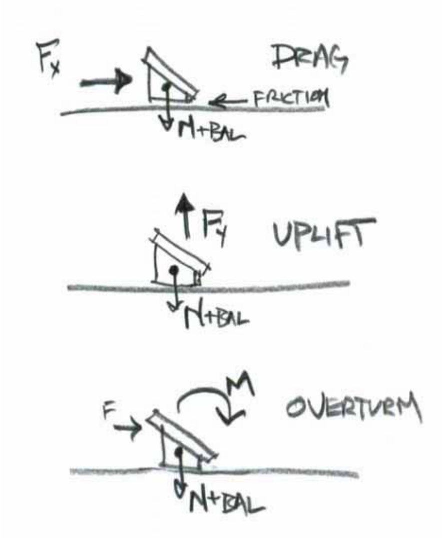
1. First steps
2. Common Mistakes
3. Provisions for electrical runs & interconnection
4. Electrical Capacity Planning
   - Leave extra physical space for inverter/s (preferably indoors)
   - Plan for extra electrical capacity
   - Inverter placement much more challenging than residential
5. Module types used in commercial

E: COMM, Basic Electrical

1. First steps
2. Common Mistakes
3. Provisions for electrical runs & interconnection
4. Electrical Capacity Planning
5. Module types used in commercial
   - Rigid panels most common
   - BIPV popular in some instances (e.g. glass wall curtain)
   - Amorphous roofing material

E: COMM, Structural – Wind

1. As before, "Module Lift-Off" or "Tear-Away"
2. Basic Calculations
   – Drag
   – Uplift
   – Overturning
3. Racking Solution
4. Wind Calculations by ASCE
5. Wind Tunnel Testing



E: COMM, Structural – Wind

1. As before, "Module Lift-Off" or "Tear-Away"
2. Basic Calculations
3. Racking Solution
   – Ballasted (pavers used)
   – Physically secured to roof structure
4. Wind Calculations by ASCE
5. Wind Tunnel Testing

E: COMM, Structural – Wind

1. As before, "Module Lift-Off" or "Tear-Away"
2. Basic Calculations
3. Racking Solution
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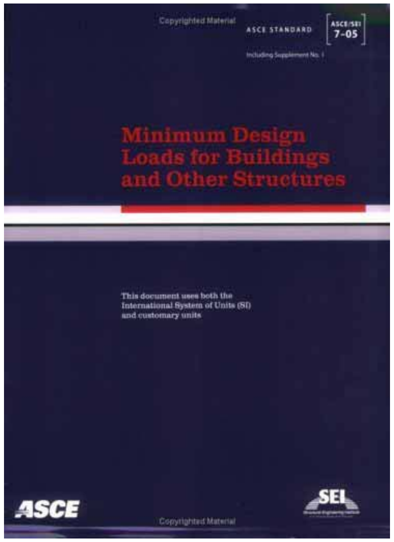
4. Wind Calculations by ASCE
5. Wind Tunnel Testing

E: COMM, Structural – Wind

1. As before, "Module Lift-Off" or "Tear-Away"
2. Basic Calculations
3. Racking Solution
4. Wind Calculations by ASCE
   – ASCE 7-05 general authority
   – See Components & Cladding section
5. Wind Tunnel Testing



E: COMM, Structural – Wind

1. As before, "Module Lift-Off" or "Tear-Away"
2. Basic Calculations
3. Racking Solution
4. Wind Calculations by ASCE
5. Wind Tunnel Testing
   – ASCE allows for tunnel testing
   – Results must be "Certified"
   – Who is liable in the event of lift-off / tear-away?

E: COMM, General Roof Issues

1. Age/Condition of roof
   – Pooling
   – Remaining useful life
2. Type of membrane
   – Built up
   – TPO (white)
   – EPDM
   – Ballasted
3. Type of attachment (prevention of billowing)

E: COMM, General Roof Issues

1. Age/Condition of roof
2. Type of membrane
3. Type of attachment (prevention of "billowing")
   – pressure difference between building interior and exterior, causing roof membrane to rise up "billow"

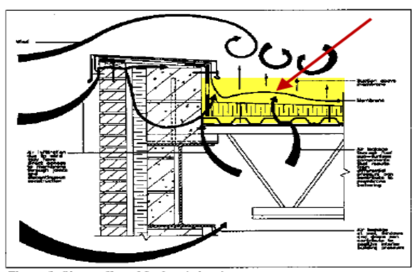


Figure 1. Shows effect of faulty air barrier.

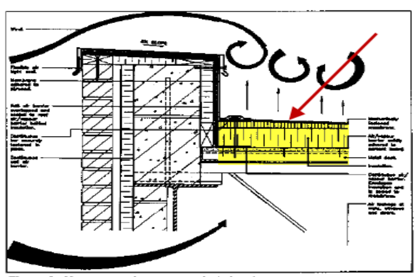


Figure 2. Shows properly constructed air barrier.

E: COMM, Structural – Roof Integrity

1. Use input based on Wind Calculations
2. Accounting for Snow Loading, "Drifting" effects and other factors
3. Structural anchors (column extensions)
4. Extra roof capacity (Dead Load for evenly distributed ballast systems)

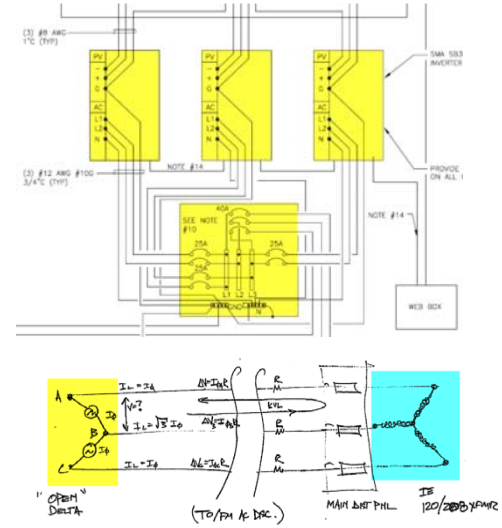
E: COMM, Structural – Roof Integrity

1. Use input based on Wind Calculations
2. Accounting for Snow Loading, “Drifting” effects and other factors
3. Structural anchors (column extensions)
4. Extra roof capacity (Dead Load for evenly distributed ballast systems)

EmPower Clean Energy Solutions

E: COMM, Advanced Electrical

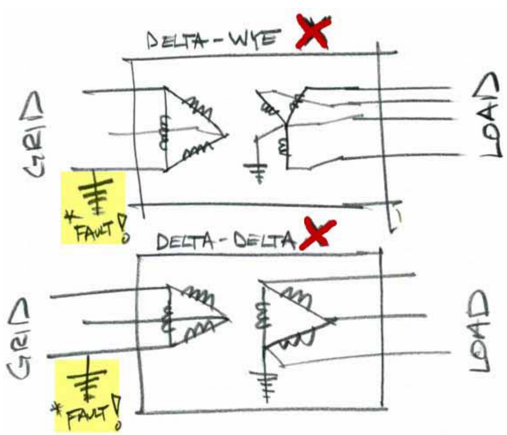
1. Types of Inverter Arrangements
   – Single three phase inverter
   – Multiple inverters connected in a delta fashion (may not be exactly balanced)
2. Service Transformer Interconnection Issues



EmPower Clean Energy Solutions

E: COMM, Advanced Electrical

1. Types of Inverter Arrangements
2. Service Transformer Interconnection Issues
   – Need to determine whether the service transformer has a delta wound or WYE wound primary
   – Pre-approval form with LIPA should be filed (See procedure on LISEIA website www.LISEIA.org)



EmPower Clean Energy Solutions

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1. Types of Inverter Arrangements
2. Service Transformer Interconnection Issues
   – Need to determine whether the service transformer has a delta wound or wye wound primary
   – Pre-approval form with LIPA should be filed (See procedure on LISEIA website www.LISEIA.org)

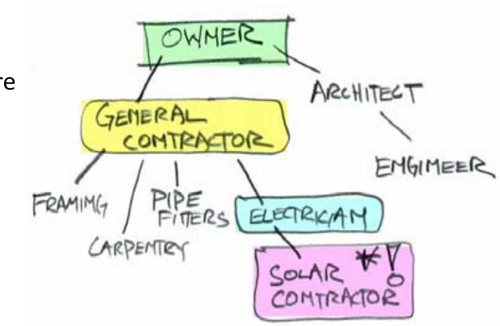
EmPower Clean Energy Solutions

E: COMM, Other Considerations

1. Importance of "Performance Monitoring"
2. “Revenue Grade” Monitoring
3. Integrating System monitoring with BMS or EMS

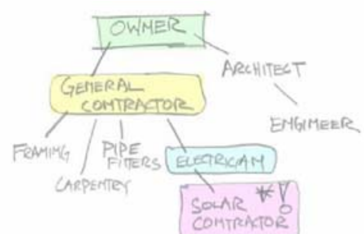
E: COMM, Specs & Bidding

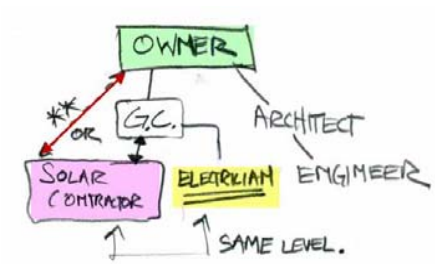
1. Subcontracting Challenges
   - Naturally GC will opt to work with Electrical Contractor
   - Many Electrical Contractors are not familiar with PV
   - Result=sub contracting to the 2nd degree
2. Our Recommendation
3. Few truly familiar with territory
4. Trade Crossover



E: COMM, Specs & Bidding

1. Subcontracting Challenges
2. Our Recommendation: Owner should seek bids from PV Integrators /Contractors directly, not via Electrical Contractor (QBS)
3. Few truly familiar with territory
4. Trade Crossover





E: COMM, Specs & Bidding

1. Subcontracting Challenges
2. Our Recommendation
3. Few truly familiar with territory
   - "Everybody" entering the solar field now days
   - IE, electrical contractor with no experience offering to do solar
4. Trade Crossover
   - Not just one trade
   - Specialized Electrical interconnection
   - Structural / Iron Work
   - Added complications in NYC

Testing Your Knowledge

POP QUIZ

QUIZ

1. **Q1**: What are to two key issues the structural professional engineer must ensure when assessing a PV system?
2. **Q2**: What are the three basic types of wind effects which should be examined by the PE?
3. **Q3**: What are the key impediments to installing solar (mass adoption) on existing ***residential*** homes?
4. **Q4**: What is the optimal angle of installing modules in New York? How might you adjust the tilt angle for optimizing production for winter or summer production?

QUIZ

5. **Q5**: Define "Billowing" and what its impacts might be on a solar array. What must be done to prevent it?
6. **Q6**: What do you think are the most common impediments to adoption of solar on ***commercial*** structures? What must you do to prevent them?
7. **Q7**: Where can you find procedures to assess AC interconnection & LIPA permitting process?
8. **Q8**: Approximately how much production capacity (in percent) is lost when modules are installed flat, as opposed to 33 degrees?

Q&A

SOLAR PV FOR ARCHITECTS & ENGINEERS

Lecture #3:
CASE STUDIES & EXAMPLES

Lecturer, Written/Checked:	Greg Sachs, PE CTO
Version:	30 Sept 2009
Company:	EmPower CES, LLC *Clean Energy Solutions*

A typical system for your home

RESIDENTIAL ELECTRICAL PV SYSTEM DESIGN

RESI-PV, Basic Sizing (1/4)

1. Determine pitch & orientation of roof
2. Measure space available for modules
3. Select a PV modules quantity & orientation
4. Estimate PV Production (using PV Watts)
5. For existing homes determine annual energy offset from LIPA bill

RESI-PV, Basic DC System Design (2/4)

1. Select inverter model
2. Determine maximum number of modules per inverter
3. Assess voltage & current options
   – WWW based calculator available for many inverters
4. Assess basic electrical issues
   – Location of junction boxes
   – Conductor & Conduit Sizing

RESI-PV, Basic AC Interconnection (3/4)

1. Determine size of inverter breakers
2. Determine if the AC panel can be back-fed (120% rule)
3. Consider "Line-side-tap" option

Ensuring the system will not 'fly-away'

TYPICAL WIND CALCULATION

RESI-PV, Typical ASCE Method (4/4)

1. Building Classifications
2. Factor Selection
3. Calculate Velocity Pressure
4. Design Wind Pressure
5. Interpretation of Results

Testing Your Knowledge

POP QUIZ

QUIZ

1. **Q1**: How much energy does the average home in America consume per year? How big does a PV system generally need to be to cover that load?
2. **Q2**: What is a typical DC voltage and current of a string of modules coming off the roof?
3. **Q3**: What is a typical uplift wind force (in PSF) on a solar array? What assumptions must be made to arrive at that value?

Q&A

Contact Information

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   - Work Phone: 917-536-3585