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2012 Engineering Insurance Conference

ROCHON ENGINEERING

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Solar Photovoltaic (PV) Design and Installation

Fire, Explosion and Other Personal Safety Issues

Presented by: Jason D'Ornellas, P.Eng
Ryan Cockle, P. Eng

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Overview

1. **Solar Electricity – brief overview**
2. **Types of PV Installations (grid direct, stand-alone)**
3. **Photovoltaic System Components and Associated Hazards**
4. **Additional Information, Recommendations and Q&A**

Part 1: Solar Electricity

- Solar Electricity is produced by sunlight shining on photovoltaic (PV) solar panels

- An array of PV panels exposed to sunlight generate electricity, which can be used by the owner of the system or fed back to the power utility

- Limited past use with homes and businesses due to high costs and complexity of the systems

- In recent past companies have invested huge amounts of money and time, resulting in substantial decreases in costs and increases in efficiency and reliability

- Improvements with cost and efficiency, combined with trends toward “going green” or “Eco-friendly”, have led to significant growth in popularity

Part 1: Solar Electricity

Pros:

- The sun is an abundant renewable resource available each and every day, although less effective when cloudy
- Systems are highly adaptable – small arrays for individual homes and businesses or large scale products for commercial/industrial installations
- Cost advantages

Cons:

- Sun does not provide continuous source. Need to store energy, which results in increased costs and complexity of systems
- Size of area required to produce power is very large in comparison to other sources of power

Part 1: Solar Electricity

How is sunlight converted into usable electricity within a home or business?

When exposed to sunlight, PV modules create a flow of electrical current described as DC (direct current).

The majority of electrical equipment operate utilizing AC (alternating current)

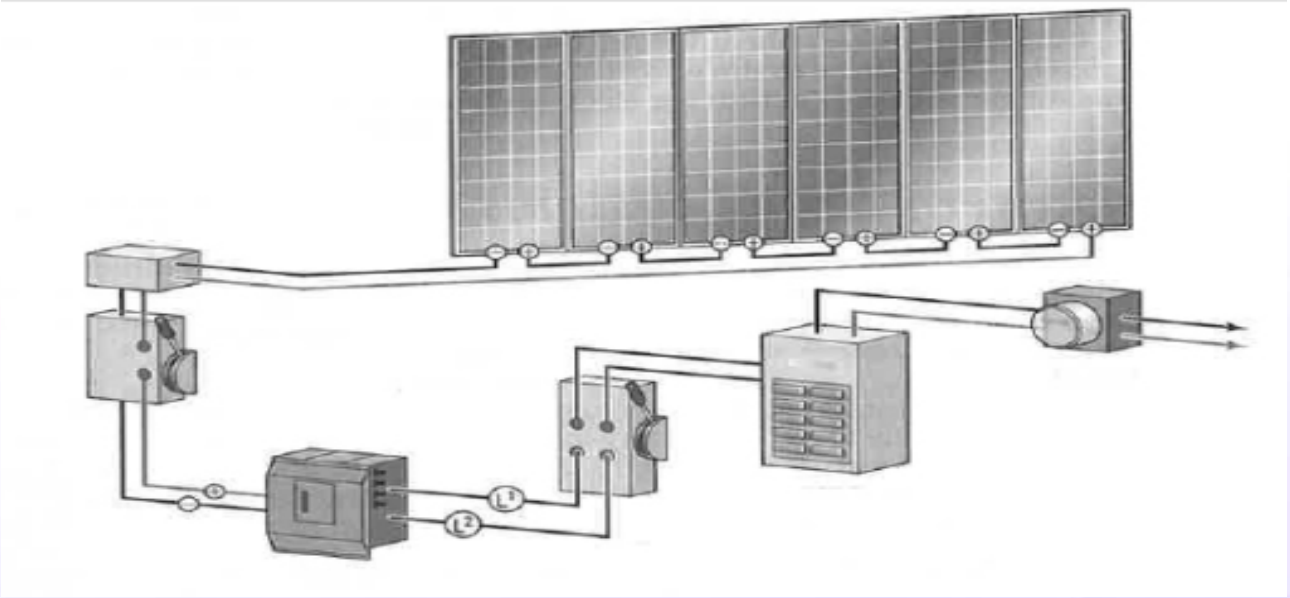
Utilities provide power in AC.

An Inverter converts the DC power to usable AC power

Part 2: Types of PV Installations

1. **Grid Direct** - Connects directly to the utility grid

   - Electricity used in home or business provided by the utility grid, while solar PV generated electricity fed back to grid



Part 2: Types of PV Installations

Grid Direct

Pros:

- fewer components when compared to battery-based systems
- more simplistic and efficient design
- less maintenance
- lower cost

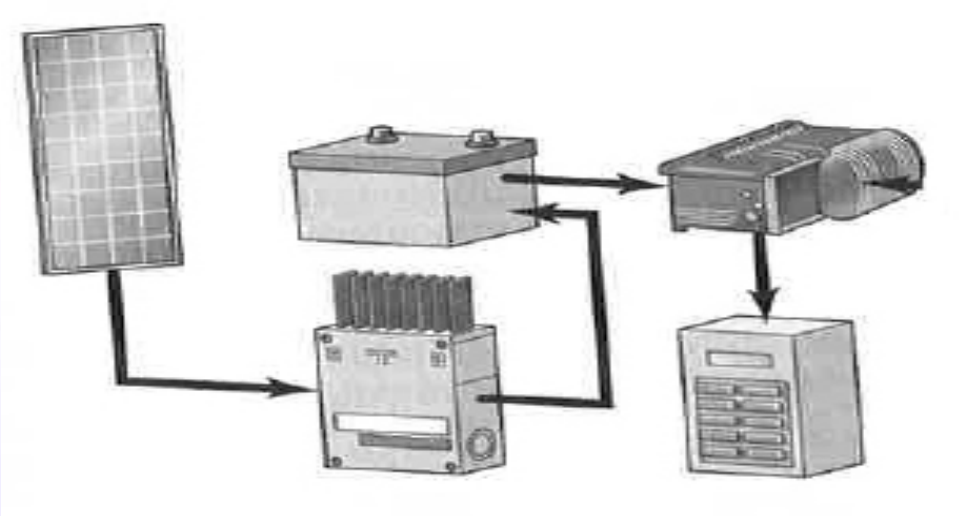
Cons:

- complete loss of power during utility outage

Part 2: Types of PV Installations

2. Battery Based, Stand-Alone

- Does not connect to the utility grid
- Solar PV generated electricity utilized by owner
- Includes battery bank for storing energy
- May also include a back-up generator



Part 2: Types of PV Installations

Stand-Alone

Pros:

- Source of power for areas not serviced by the public utility
- Not affected by utility outages

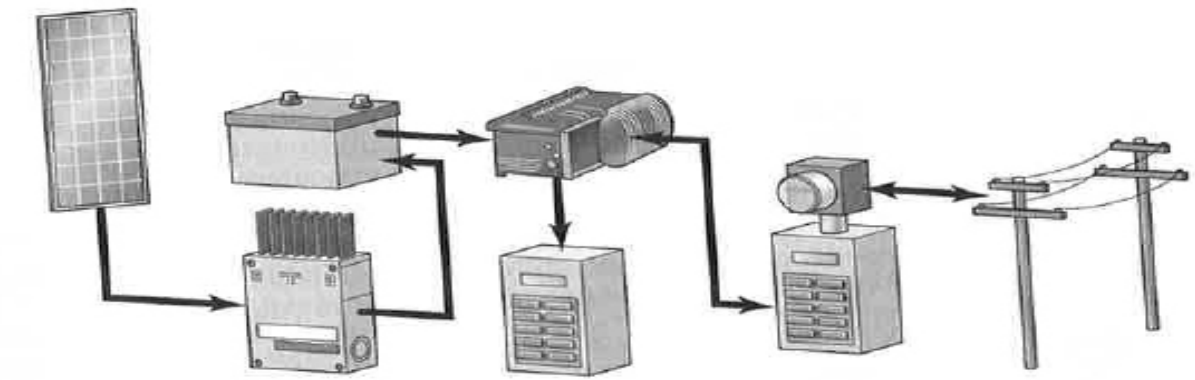
Cons:

- Unlikely to provide sufficient power for a modern home or business
- Requires more maintenance than a grid direct system

Part 2: Types of PV Installations

3. Battery based, Utility-interactive

- Hybrid of grid direct and stand-alone systems
- Similar to grid direct system in that it connects to the utility grid
- Includes a battery bank, which stores power in case of a utility outage



Part 2: Types of PV Installations

Battery Based, Grid-Interactive

Pros:

- battery bank provides power during utility outage
- benefits of grid direct and stand alone systems

Cons:

- many more components than grid direct system
- more complicated and less efficient design
- more required maintenance
- greater cost

Part 3: Photovoltaic System Components

Solar PV Array

Combiner Box

Charge Controller

Battery Bank

INSIDE

OUTSIDE

DC Disconnect

Electrical Meter

Main Distribution Panel

AC Disconnect

Inverter

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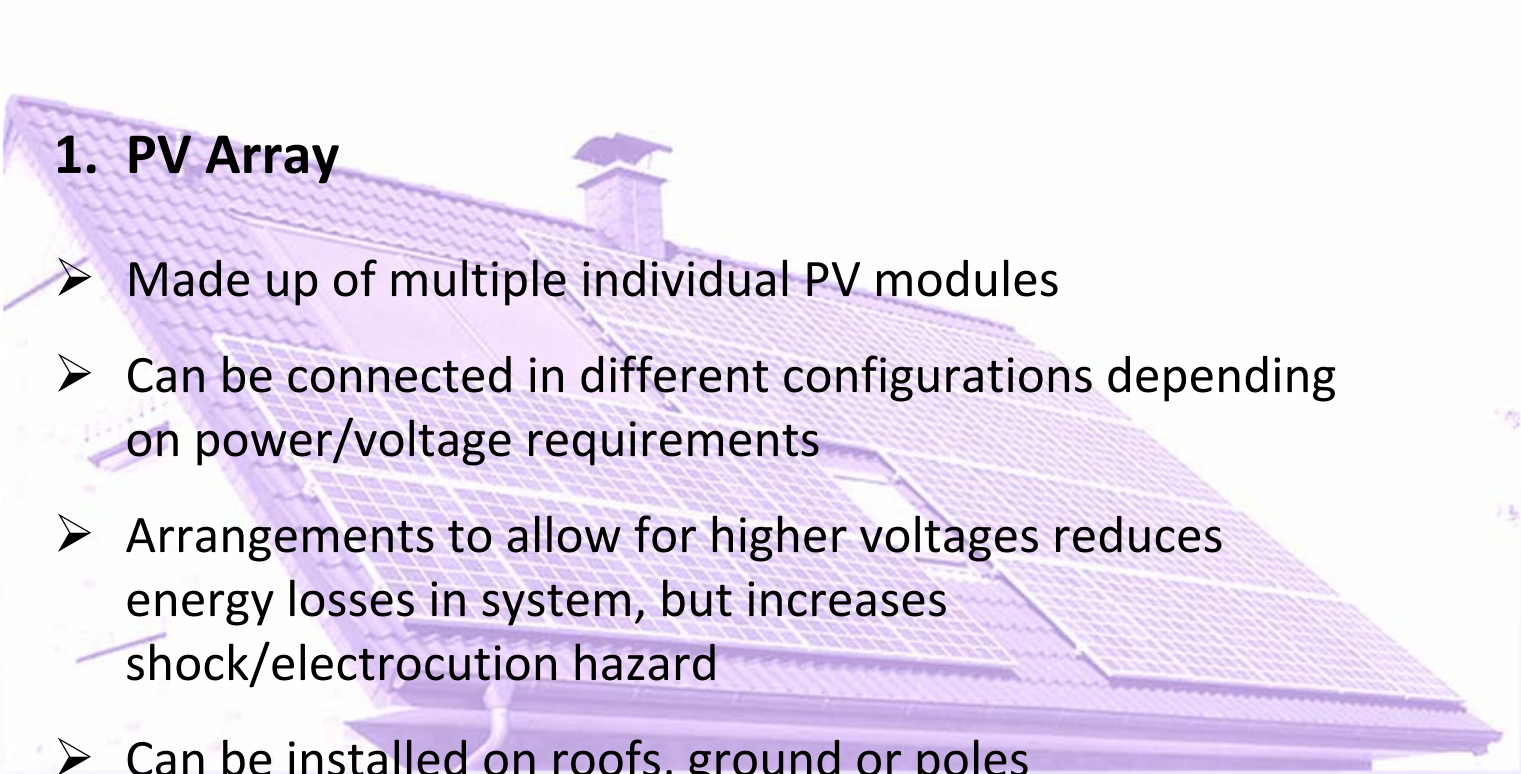
Part 3: Photovoltaic System Components and Hazards



1. PV Array

- Made up of multiple individual PV modules
- Can be connected in different configurations depending on power/voltage requirements
- Arrangements to allow for higher voltages reduces energy losses in system, but increases shock/electrocution hazard
- Can be installed on roofs, ground or poles

Part 3: Photovoltaic System Components and Hazards

1. PV Array - Hazards

- Will always be generating electricity when there is a source of light
- Additional structural load of the array can increase risk of roof collapse
- Fire Service personnel may not attempt to enter building due to possible shock or electrocution hazard
- Resulting in fire extinguishment delays and much greater damage to the structure

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Part 3: Photovoltaic System Components Hazards

2. Combiner Box

- Combiner boxes are used in solar installations to combine the inputs from multiple strings of solar panels into one output circuit
- Located as close to the PV array/modules as possible
- Output circuit from combiner box feeds to the charge controller for battery based systems, or directly to the inverter (via a dc disconnect) in battery-less grid direct systems
- May contain fuses for overcurrent protection

Part 3: Photovoltaic System Components and Hazards

2. Combiner Box - Hazards

- Risk of overload/fire if not appropriately rated (voltage/current/power)
- May be appropriately rated for original installation, but additions to the PV system could result in ratings being exceeded
- Contains numerous electrical connections – connection points are a common weak link in a circuit and a likely location for overheating

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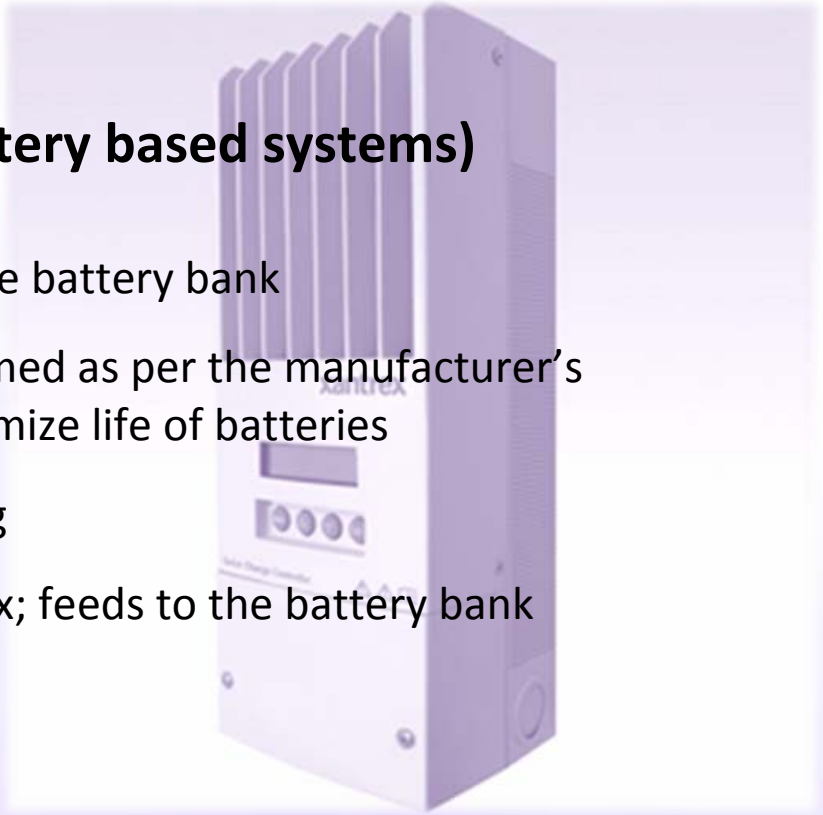
Part 3: Photovoltaic System Components and Hazards

3. Charge Controller (battery based systems)



- Controls the charging of the battery bank
- Ensures charging is performed as per the manufacturer's recommendations to maximize life of batteries
- Located within the building
- Fed from the Combiner Box; feeds to the battery bank

Part 3: Photovoltaic System Components and Hazards

3. Charge Controller - Hazards

- If settings are not appropriate for battery bank used, could result in fire/explosion at battery bank
- Internal electrical connections and electronic components susceptible to electrical failure
- Avoid non-certified “cheaper” products to limit risk

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Part 3: Photovoltaic System Components and Hazards

4. Battery Banks

- Used in Stand-Alone or Grid-Interactive battery based systems
- Feeds from charge controller; feeds to inverter (via a DC disconnect switch) – located indoors
- Charged by PV array. For Grid-Interactive systems, may also be charged via power utility (at night or when PV array not generating sufficient power)
- Stores power for situations where PV array not providing sufficient energy or during utility outage
- Typically only used to supply essential loads (Grid-Interactive)

Part 3: Photovoltaic System Components and Hazards

4. Battery Banks - Hazards

- Two or more cables connected to each battery in a bank
- High number of connections increases risk of poor or loose connection that can result in overheating/failure
- Charging of batteries results in the production of hydrogen gas, which creates an explosion/fire hazard
- If not installed in well ventilated area or near to ignition source, risk of explosion/fire increased
- Over-charging can result in significant increase in hydrogen production

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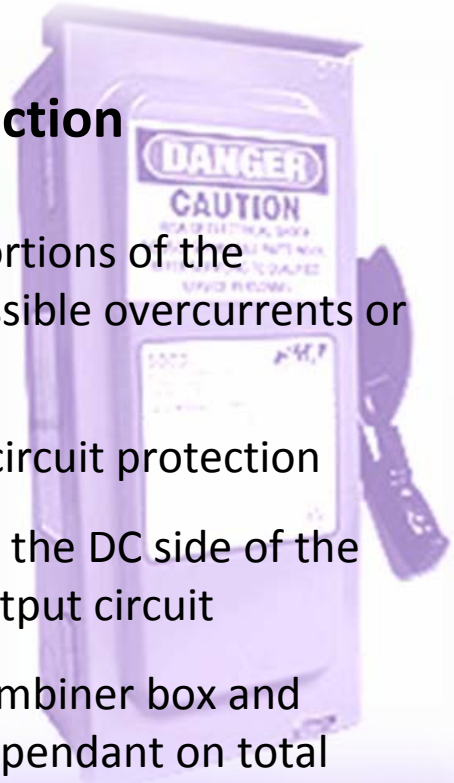
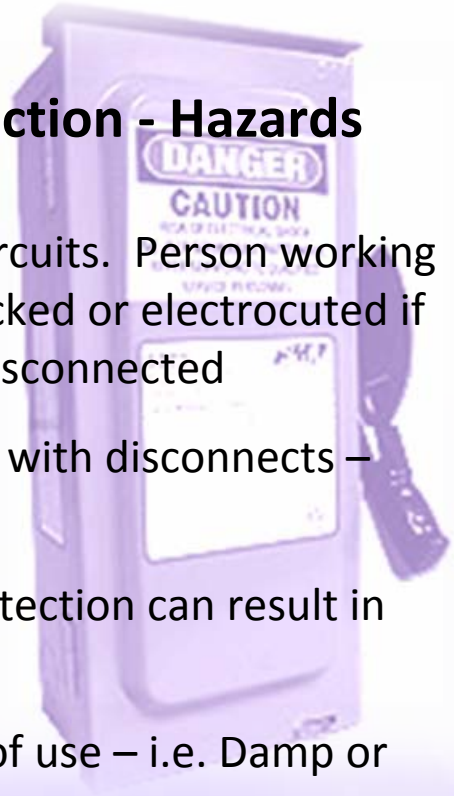


5. DC Disconnect and Circuit Protection

- Allows for safe disconnection of DC portions of the installation and protection against possible overcurrents or faults
- Disconnects often include integrated circuit protection
- Disconnect required to be installed on the DC side of the inverter – allows for isolation of PV output circuit
- Overcurrent Protection required at combiner box and between modules in the PV array – dependant on total short-circuit current and ampacity of cables

Part 3: Photovoltaic System Components and Hazards

5. DC Disconnect and Circuit Protection - Hazards



- Required to properly disconnect DC circuits. Person working on DC portion of system could be shocked or electrocuted if system or components not properly disconnected
- Typical fire related hazards associated with disconnects – connection failures or overloads
- Inappropriate overcurrent or fault protection can result in fire
- Must be appropriately rated for type of use – i.e. Damp or wet environments, if installed outdoors.

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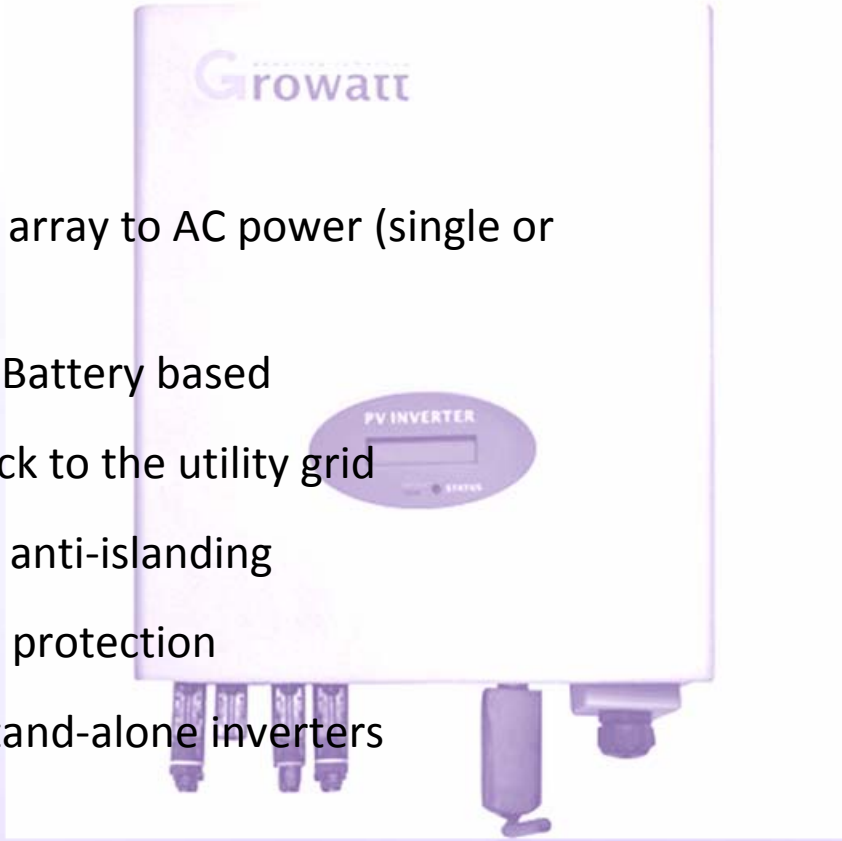
Part 3: Photovoltaic System Components and Hazards

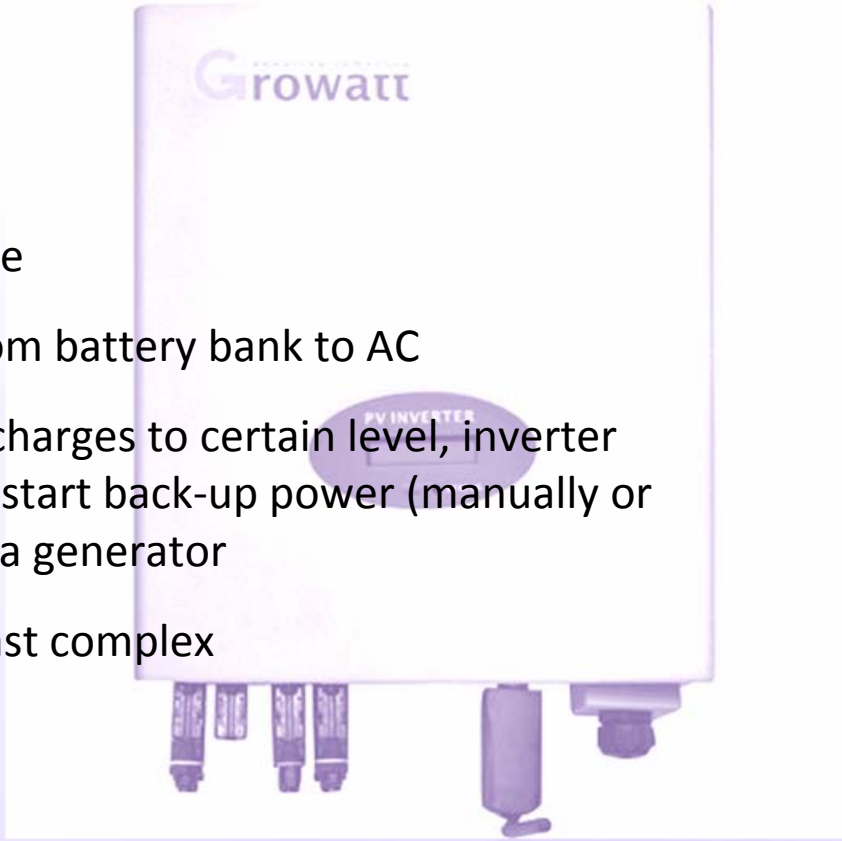
6. Inverter



- Convert DC power from PV array to AC power (single or three phase)
- Two types: Grid-direct and Battery based
- Grid-direct feeds power back to the utility grid
  - Must be equipped with anti-islanding
  - Integrated ground fault protection
  - More expensive than stand-alone inverters

Part 3: Photovoltaic System Components and Hazards

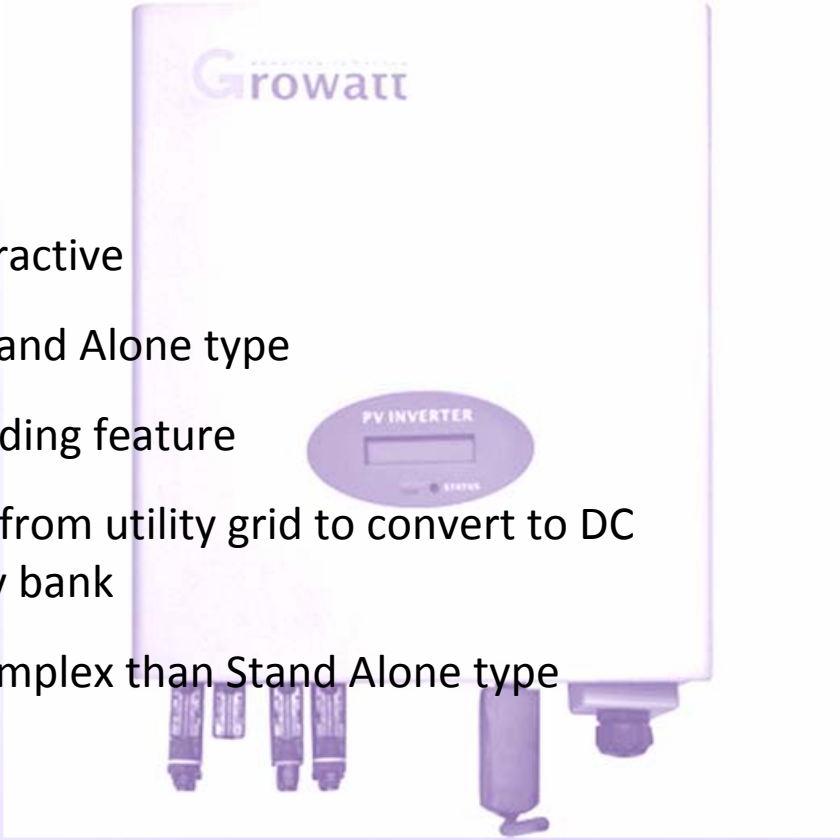
6. Inverter



- Battery Based – Stand Alone
  - Converts DC voltage from battery bank to AC
  - When battery bank discharges to certain level, inverter can alert the system to start back-up power (manually or automatically), such as a generator
  - Least expensive and least complex

Part 3: Photovoltaic System Components and Hazards

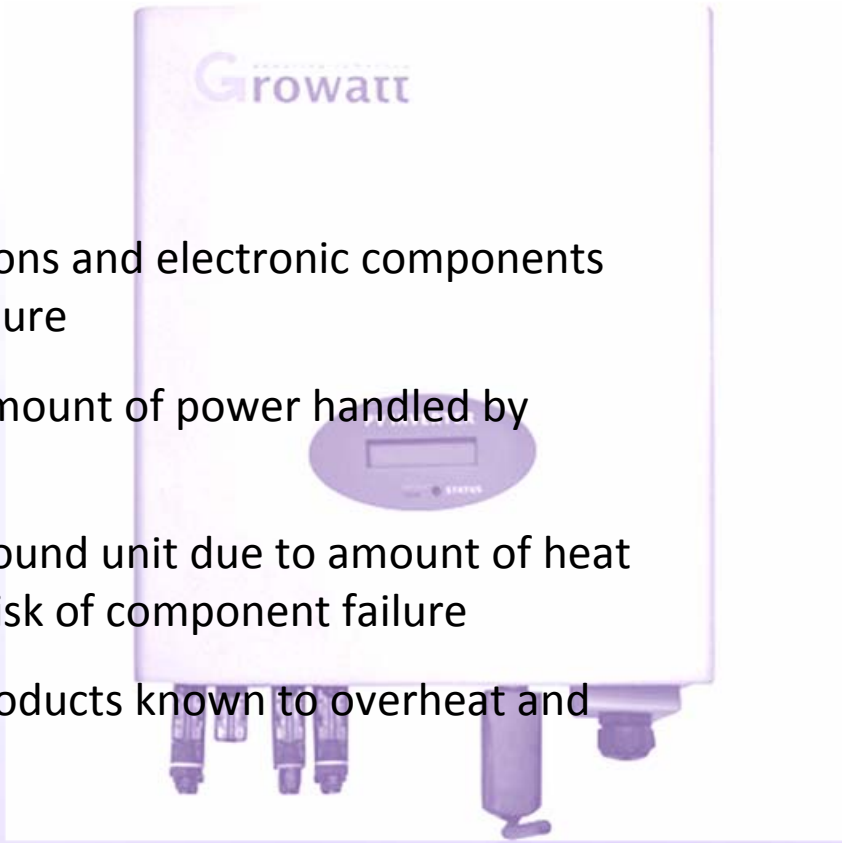
6. Inverter



- Battery Based – Utility Interactive
  - Operates similarly to Stand Alone type
    - Requires anti-islanding feature
    - Can accept power from utility grid to convert to DC and charge battery bank
  - More expensive and complex than Stand Alone type

Part 3: Photovoltaic System Components and Hazards

6. Inverter – Hazards

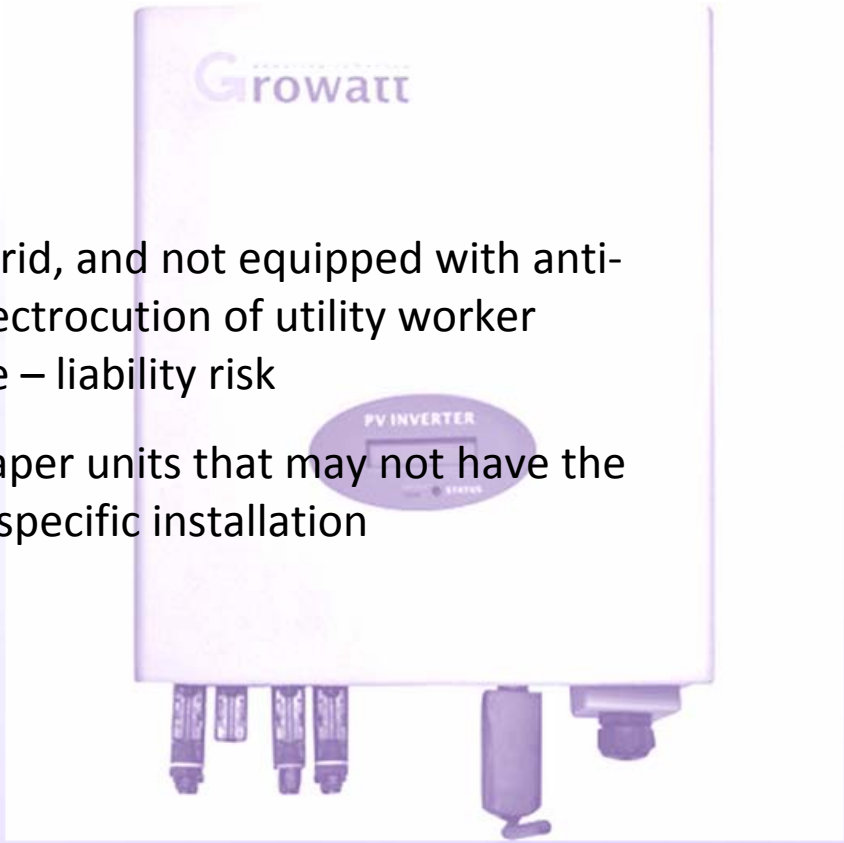


- Internal electrical connections and electronic components susceptible to electrical failure
  - Increased risk due to amount of power handled by inverters
  - Required clearances around unit due to amount of heat produced – increased risk of component failure
- Non-certified “cheaper” products known to overheat and melt/ignite

Part 3: Photovoltaic System Components and Hazards

6. Inverter – Hazards

- If connected to the utility grid, and not equipped with anti-islanding feature, shock/electrocution of utility worker during outage very possible – liability risk
- Owners may purchase cheaper units that may not have the required features for their specific installation



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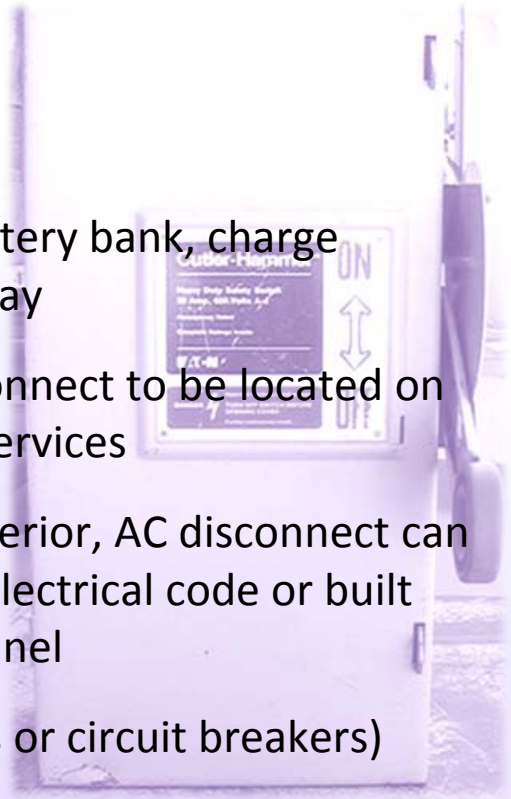
Part 3: Photovoltaic System Components and Hazards

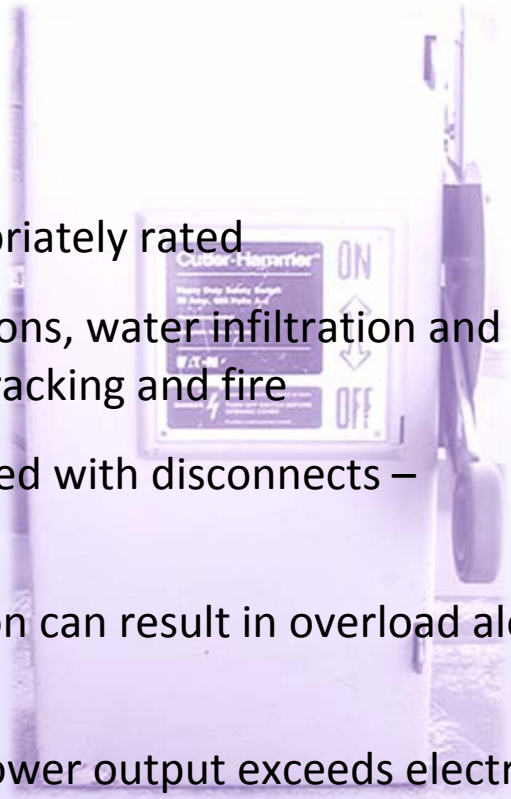
7. AC Disconnect



- Required to isolate the inverter, battery bank, charge controller, combiner box and PV array
- Some jurisdictions require this disconnect to be located on building exterior for access by fire services
- If not required to be on building exterior, AC disconnect can be located inside in accordance to electrical code or built into inverter or main distribution panel
- Can include circuit protection (fuses or circuit breakers)

Part 3: Photovoltaic System Components and Hazards

7. AC Disconnect - Hazards



- If located outdoors, must be appropriately rated
  - If not rated for wet/damp locations, water infiltration and contamination can lead to arc-tracking and fire
- Typical fire related hazards associated with disconnects – connection failures or overloads
- Inappropriate overcurrent protection can result in overload along circuit
- Expansion of PV system - system power output exceeds electrical ratings of original equipment/circuit protection

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Part 3: Photovoltaic System Components and Hazards

8. Cables

- Path for current to travel to/from the various system components
  - Run between PV modules and to combiner box
  - From combiner box to charge controller (if applicable)
  - From charge controller to battery bank and DC disconnect (if applicable)
  - Interconnecting batteries
  - From the inverter to the main distribution panel

Part 3: Photovoltaic System Components and Hazards

8. Cables – Hazards

- Ampacity (current carrying capacity) voltage rating of cable must be appropriate
- Cable must be rated for specific use
  - *Outdoor cables – more expensive*
    - Resistant to sunlight, temperature, moisture, etc.
    - If not appropriate, may degrade and result in failure/fire/shock/electrocution hazard
    - Outdoor PV cables may not be permitted for indoor use because insulation may not possess the required fire retardants*

Part 3: Photovoltaic System Components and Hazards

8. Cables – Hazards

- *Battery cables*
  - Some more flexible than others for use in confined spaces. If cable too stiff, stresses put on connections
  - Must be rated for use in corrosive environment
- Appropriate connectors for use with specific cables
  - Aluminum cables require connectors that are appropriately rated
  - Connectors must also be compatible with gauge of cable(s) being connected

Part 4: Additional Information

Ontario Electrical Safety Code – 2012

Applicable sections include:

- *Section 50 – Solar Photovoltaic Systems* **additions from previous edition*
- *Section 64 – Renewable Energy Systems* **new section*
- *Section 4 – Conductors*
- *Section 10 – Grounding and Bonding*
- *Section 12 – Wiring Methods*
- *Section 14 - Protection and Control*
- *Section 28 – Motors and Generators (if generator installed)*
- *Section 84 – Interconnection of Electric Power Production Sources*

Part 4: Additional Information

Recommendations:

- **All equipment used in an installation should be appropriately certified for its use**
  - Increase in popularity of Solar PV systems has led to an increase in uncertified and potentially unsafe products at much cheaper prices
  - AC disconnects and circuit protection may be utilized in place of their DC counterparts due to cost. These AC devices do not provide the required means of disconnect and circuit protection.
  - Inappropriate inverters may be used with grid-connected systems due to cheaper cost. May not include anti-islanding feature

Part 4: Additional Information

Recommendations:

- **Ensure installer of the system has adequate training and experience in Solar PV installations and that the installation has passed ESA inspections**
  - Increasing popularity of systems may result in unqualified installers taking on jobs to meet the demand for these systems

Part 4: Additional Information

Recommendations:

- **If installation occurred prior to most recent edition of Ontario Electrical Safety Code taking effect, have system inspected to determine if all new requirements are satisfied**
  - A system that satisfies the code requirements will not be free of risk, but this will help to minimize it

Questions?