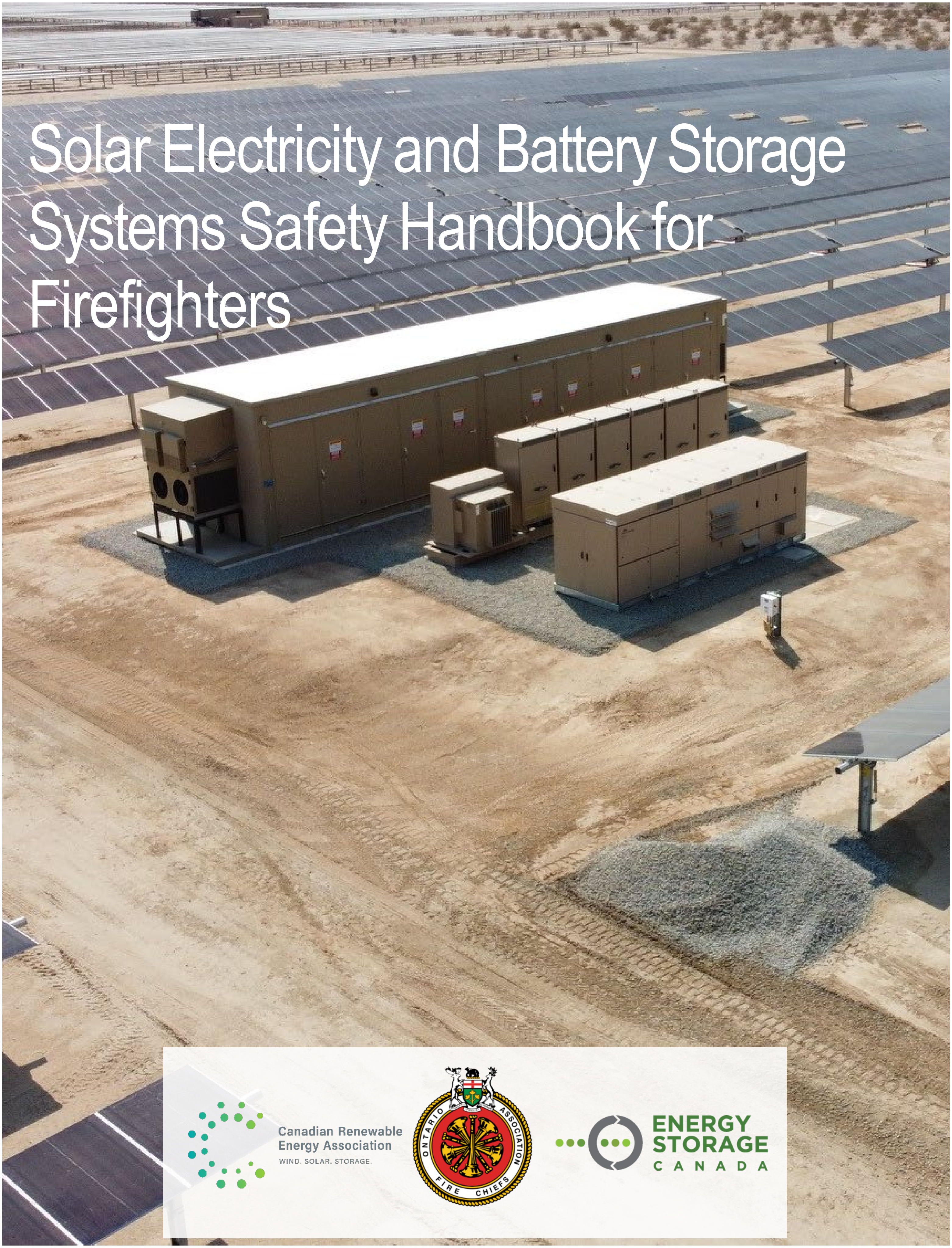
Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters



Canadian Renewable Energy Association
WIND. SOLAR. STORAGE.

Ontario Association Fire Chiefs

Energy Storage Canada


DC DISCONNECT SWITCH
INVERTER
PRIMARY PANELBOARD
AC DISCONNECT SWITCH

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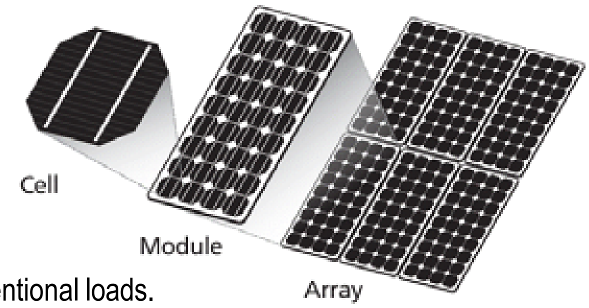
Definition - PV



Solar Photovoltaic (PV) Systems
The components and subsystems that in combination convert solar energy into electrical energy suitable for connection to conventional loads.

Grid-Tied PV System
A solar photovoltaic system that operates in parallel with, and that may deliver power to the utility grid.

Off-Grid System
A solar photovoltaic system that operates independent of a utility grid.

PV Module
A manufactured and complete environmentally protected assembly of interconnected solar cells, mechanically fastened together and prewired to form a self-contained unit.

PV String
An electrical circuit created by one or more series of connected PV Modules.

PV String Combiner
A piece of equipment that combines two or more PV Strings in parallel.

PV Inverter
Converts the direct current (DC) output of the PV Modules into alternating current (AC).

Utility-Interactive PV Inverter
An inverter intended for use in parallel with an electric utility, the output is fully synchronized with the utility power.

Off-Grid PV Inverter
PV inverter intended for use independent of the electric utility grid.

Distributed Generation (DG)
The name used by utilities and the Electrical Safety Authority (ESA) to identify renewable energy or other generators connected to the utility grid. This includes solar PV systems. Warning signs and labels identifying solar PV system and associated equipment will reference DG in most cases.

Backfeed
An electrical generator feeding power back to the electrical system. This can be hazardous when the system is thought to be de-energized.

Photovoltaic (PV) Array
A collection of PV modules located together.

References

Ontario Fire Service Section 21 Advisory Guidance Note 6-34 Solar Photovoltaic (PV) Systems www.oafc.on.ca/section-21-manual

Definitions - BESS

Battery Energy Storage System (BESS or ESS)
A device or group of devices assembled together, capable of storing energy in order to supply electrical energy at a later time.

Battery Cell
The smallest unit within a BESS. The cell is the electrochemical device which stores electrical energy and can discharge that electrical energy. Cells can be made up of different chemistries. Currently, a dominant cell chemistry used in residential, commercial, and utility grid connected storage systems is Lithium-Ion.

Battery Module
A collection of battery cells wired in series or parallel contained within an enclosure or frame. The module typically integrates module level monitoring and protections to ensure the battery cells within the module are operating within acceptable temperature and electrical limits.

Battery Rack
A collection of battery modules wired in series and/or parallel, typically housed within a metal rack(s).

Battery Management System (BMS)
A system that monitors, controls, and optimizes performance of an individual or multiple battery modules in an ESS and can control the disconnection of the module(s) from the system in the event of abnormal conditions.

Charge Controller
An electrical device that regulates the DC voltage and charge of a battery.

Power Conversion System (PCS) or Inverter
An electrical device that converts the Direct Current (DC) energy from a battery to Alternating (AC) current that can be exported to a typical building load and/or the electrical grid.

Energy Management System (EMS)
The energy management system handles the controls and coordination of ESS dispatch activity. The EMS communicates directly with the PCS and BMS to provide high-level coordination of the various components on-site.

Thermal Runaway
A term used for the rapid uncontrolled release of heat energy from a battery cell; it is a condition when a battery creates more heat than it can effectively dissipate. Thermal runaway in a single cell can result in a chain reaction that heats up neighbouring cells. As this process continues, it can result in a battery fire or explosion. This can often be the ignition source for larger battery fires.

Off-Gassing
A temperature, mechanical, or electrical damage event to a lithium-ion battery which may result in the release of volatile gases to the battery enclosure, battery room, and/or environment within which the battery is contained. The volatile gases may be flammable and may result very high pressure.

References

NFPA Energy Storage Systems Safety Fact Sheet

Energy Toolbase, The Primary Components of an Energy Storage System that you Need to Know

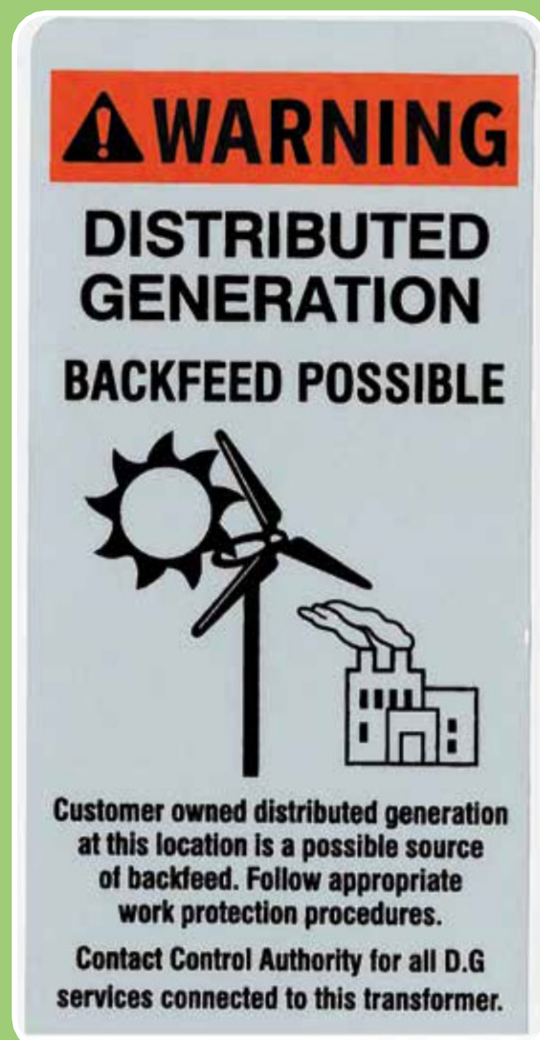
Introduction

This manual has been designed and developed jointly by firefighters, solar photovoltaic (PV) and battery storage industry and insurance professionals to educate and protect first responders who may attend an emergency situation where solar PV and battery storage installations are present.

This manual builds upon the 2015 Solar Electricity Safety Handbook for Firefighters, produced by the Ontario Association of Fire Chiefs (OAFC) in partnership with the Canadian Solar Industries Association (CanSIA) in March 2015. Since CanSIA's merger with the Canadian Wind Energy Association (CanWEA) to form the Canadian Renewable Energy Association (CanREA) in 2020, CanREA is pleased to have the opportunity to collaborate once again with OAFC and industry stakeholders on this important best practice guidance document.

Since then, Canada's solar PV industry has grown by more than 40%, and the number of on-site solar PV installations at homes, businesses, schools and other buildings has more than doubled, to an estimated 45,000 in 2020.

Meanwhile, significant cost decreases and improved performance have meant that on-site battery storage systems are an increasingly accessible and desirable source of back-up power for energy consumers of any size, from residential up to industrial-scale.



As the adoption of these technologies continues to accelerate, understanding solar electricity generation and battery storage, and potential hazards thereof, will only become more important to the health and safety of first responders. Fundamentally, these technologies are very safe, provided that they are properly installed and maintained – However, in the unlikely event that an emergency situation should arise, first responders must be informed and prepared.

One thing to keep in mind as you review this document is that despite the underlying technology being similar, BESS and PV arrays can vary by brand, and often have different disconnection and safe shutdown procedures, as well as different protections against thermal runaway. Because of this, the best way to ensure emergency personnel remain prepared is for Fire Departments to be aware of existing large-scale battery and solar projects operating within their jurisdiction, and work with operators to be sure they are aware of any unique safety and emergency response procedures for the projects in their area.

Going forward, CanREA and our members look forward to continued collaboration with first responders to help keep everyone safe.

What are Solar (PV) Modules (Panels)

Flat roof with ballasted or attached installation

Typical retrofit. Note: No clearances along edges

Stand alone system

Modules that are integrated into shingles

What is a Photovoltaic (Solar PV) Module?

A packaged, connected assembly of photovoltaic cells (think of solar garden light = one cell). Rated by its direct current (DC) output, (typically between 100-300 watts) and weighs approximately 2-7 lbs per square foot (1-3Kg per $30cm^2$).

Electricity Terms

Voltage = Pressure

Current (Amperage) = Flow Rate

Power (Watts) = Voltage X Current

How do they Work?

Photons (fundamental particles of light) in sunlight hit solar panels. If they are not in the right range (frequency), they are either reflected or dissipated as heat. Those in the right range are absorbed further into the panel and start a chain reaction with electrons (negative charge). These electrons start moving and create what we know as electricity.

What are Solar Thermal Collectors?

SOLAR THERMAL COLLECTORS SHOULD NOT BE CONFUSED WITH PV PANELS AS THEY PRESENT DIFFERENT HAZARDS.

Solar thermal collectors are characterized by tubing for circulating heat transfer fluid. Sunlight heats the circulating fluid.

THERE IS NO ELECTRICITY GENERATED THROUGH THIS PROCESS.

Solar thermal collectors do contribute added load to the roof.

SOLAR THERMAL SYSTEMS GENERATE VERY HOT FLUIDS. DAMAGE TO A SOLAR THERMAL SYSTEM MAY EXPOSE PERSONNEL TO A RISK OF SCALDING BURNS.

The Photovoltaic System

1. Solar Modules
2. Combiner Box
3. DC Disconnect
4. Inverter
5. AC Disconnect
6. Generation Meter

What are PV Strings and Combiners?

Photovoltaic panels are usually assembled in a “string” which means that multiple panels are joined together in series to increase the system voltage. Each string can generate a maximum output of up to 1000v DC. These strings are connected in parallel in combiners (junction boxes) to increase the system current and are usually located near the solar modules. In small systems, the combiners allow all the wires to come together and only one main set to continue down to the inverter. In larger systems, there can be recombiners and multiple wire sets down to the inverter. Combiners and re-combiners can have fuses, breakers or switches.

What is an AC Disconnect?

The alternating current (AC) disconnect is a switch that is used to shut off power from the building to the inverter.

The AC disconnect switch may contain breakers or fuses.

It is similar to the DC disconnect switch, even with the AC disconnect shut off, the solar panels, wires and cables with the conduit may be energized.

Operation of the AC disconnect will not de-energize the DC components. Panels and cables will still be energized.

EVEN WHEN THE AC DISCONNECT IS IN THE "OFF" POSITION, ALL SOLAR PANELS AND CONDUITS MAY BE ENERGIZED. OPERATE THE AC DISCONNECT BEFORE OPERATING THE DC DISCONNECT.

METALLIC CONDUITS MAY BECOME LIVE IF CABLES AND/OR CONDUIT DAMAGE HAS OCCURED.

What is Rapid Shutdown?

As of May 5, 2016 the Electrical Safety Authority (ESA) introduced a new rule to the Ontario Electrical Safety Code (OESC) mandating that solar photovoltaic (PV) installations on or in buildings must include 'rapid shutdown' in the protection of the system. It should be noted that systems installed before this date may not have rapid shutdown.

These new rapid shutdown requirements were introduced to reduce the shock hazard for first responders when attending to emergencies at buildings or facilities housing solar PV systems.

Rapid Shutdown Systems

DE-ENERGIZE PV SOURCE OR OUTPUT CONDUCTORS ON OR INSIDE A BUILDING THAT ARE MORE THAN 1 METRE IN LENGTH FROM A PHOTOVOLTAIC ARRAY TO <30V WITHIN 30 SECONDS OF INITIATION.

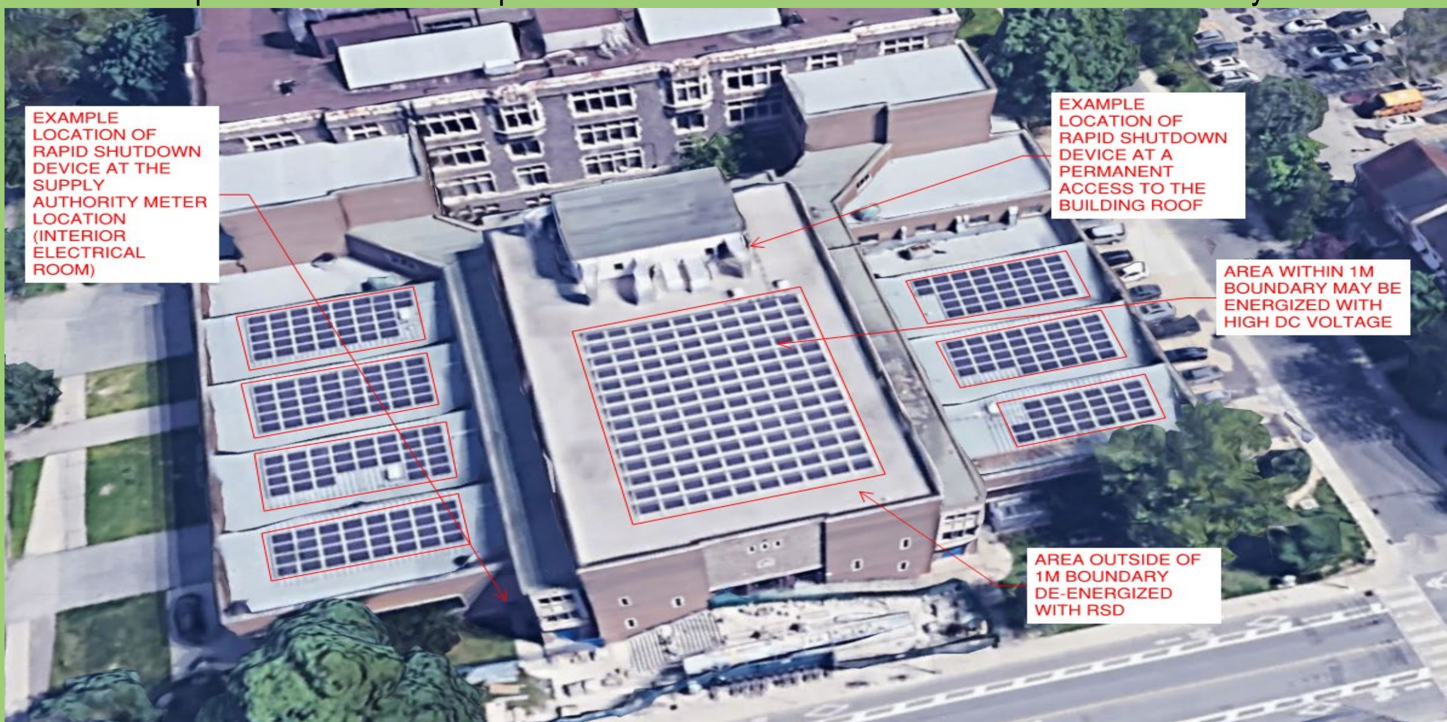
HAVE CLEARLY LABELLED DEVICE(S) USED TO INITIATE RAPID SHUTDOWN "RAPID SHUTDOWN INITIATOR.

THE RAPID SHUTDOWN INITIATOR(S) ARE LOCATED AT THE SUPPLY AUTHORITY METER LOCATION FOR SINGLE DWELLING UNITS, AND AT THE CONSUMER'S SERVICE EQUIPMENT OR SUPPLY AUTHORITY METER LOCATION FOR ANYTHING OTHER THAN SINGLE DWELLING UNITS.

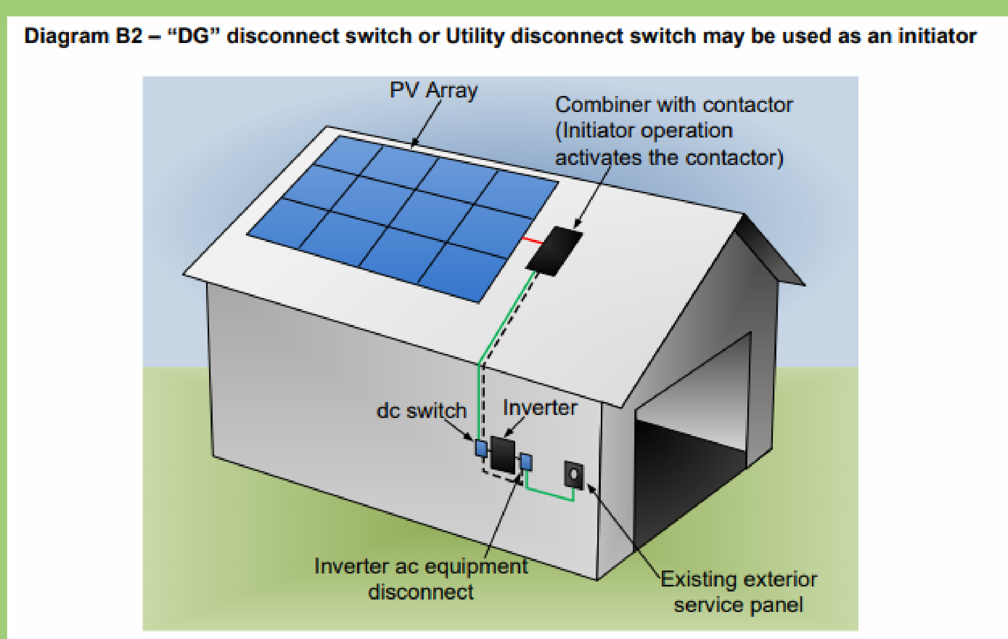
A RAPID SHUTDOWN INITIATOR(S) MAY ALSO BE LOCATED AT A PERMANENT ACCESS TO A BUIDLING ROOF WHERE THE SOLAR ARRAY IS INSTALLED OR WITHING SIGHT AND 9M OF THE ARRAY(S).

Rapid Shutdown Systems

The figure below provides an example of where a solar array will be de-energized to not more than 30V after the initiation of a rapid shutdown process, and where dangerous high voltage may still remain, as well as example locations of the Rapid Shutdown Initiator that can be used to shutdown a system:



The below diagram is included within the Ontario Electrical Safety Code Bulletin 64-6-1 and shows examples of disconnecting means that may be used as a rapid shutdown initiator:



What is a DC Disconnect?

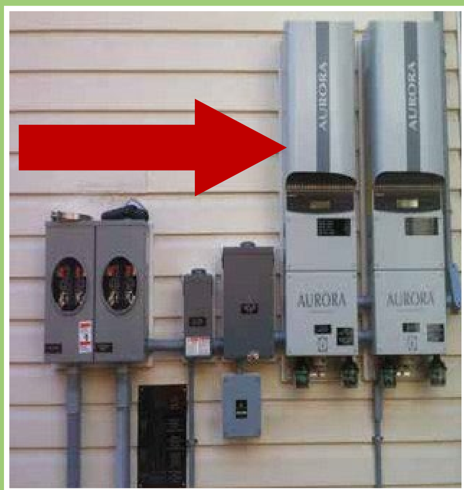
Photo provided by Ottawa Solar Power

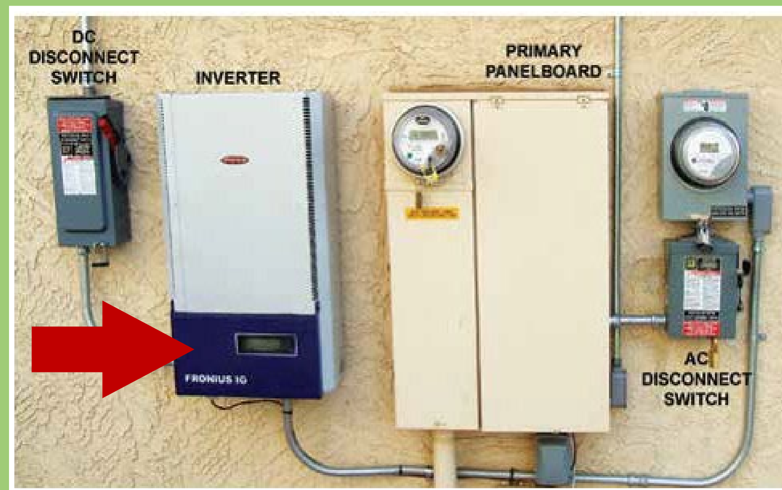
The primary function of the direct current (DC) disconnect switch is to shut down power from the solar panels to the inverter. The DC disconnect switch is usually located near the inverter but can also be attached directly on the inverter itself.

EVEN WHEN THE DC DISCONNECT IS IN THE "OFF" POSITION, ALL SOLAR PANELS AND CONDUIT LEADING INTO THE DC DISCONNECT WILL BE ENERGIZED.

OPERATE THE AC DISCONNECT BEFORE OPERATING THE DC DISCONNECT.

What is an Inverter





The inverter is a device that is used to convert the direct current (DC) being generated by the solar panels into alternating current (AC).

With Grid connected systems, the inverter must "see" power from the utility. It will not convert DC to AC without utility power.

Inverters can be found in various types and sizes such as central inverters, series string inverters and micro inverters.

THE INVERTER MAY BE LOCATED INSIDE THE BUILDING!

Various types of Inverters

Installation of PV Systems

The majority of photovoltaic systems are installed by qualified professionals, using certified components.

ONE OF THE BIGGEST CONCERNS IS "DO IT YOURSELF" INSTALLERS THAT PUT TOGETHER THEIR OWN SYSTEMS WITH HOME BUILT COMPONENTS AND NO UNDERSTANDING OF ELECTRIC SAFETY REQUIREMENTS, AND NO INSPECTION.

Who Inspects PV Systems?

The Electrical Safety Authority (ESA) must inspect every solar photovoltaic installation in Ontario, that they are aware of. All electrical work must conform to standards outlined in the Ontario Electrical Safety Code. The ESA inspector may not go on the roof to inspect.

Not all municipalities require a building code inspection.

Battery Energy Storage Systems (BESS)

Battery Energy Storage System (BESS or ESS) is a device or group of devices assembled together, capable of storing energy in order to supply electrical energy at a later time.

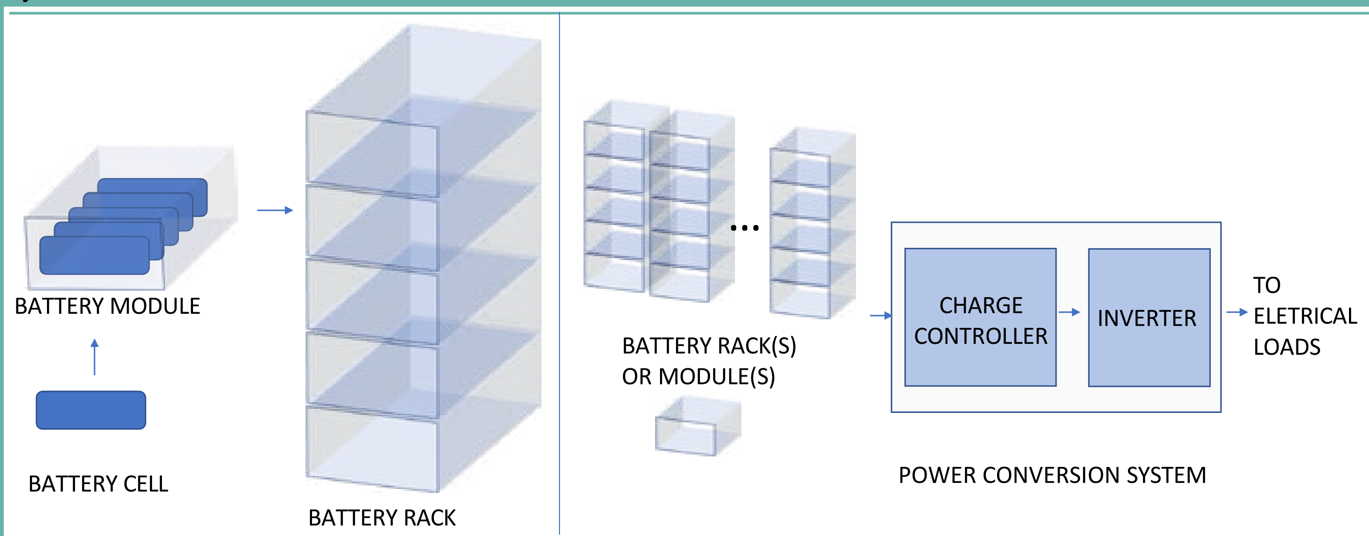
What makes up a BESS?

The fundamental building block of a battery energy storage system (BESS) is the battery cell. The battery module is a self-contained unit of series and/or parallel connected battery cells.

For large BESS systems, battery modules are typically installed in battery racks to increase the total energy storage capacity. For smaller BESS systems battery modules may be installed in a smaller manufacturer specific enclosure (e.g. a Tesla Powerwall).

Battery modules and battery racks are controlled and protected by a battery management system (BMS) that monitors important operational variables such as temperature and voltage and can disconnect battery module(s) in the event of abnormal conditions.

A BESS will also include power system equipment to convert the stored electrical energy into a useable form. For grid connected systems, this is typically a power conversion system or Inverter which in many respects looks and behaves similar to solar inverters. A charge controller is typically integrated into the PCS, but may exist as a standalone unit depending on the size and design of the system.



Types of Batteries in a BESS

There are 3 main types:

1. Flooded Lead Acid Batteries

Lead acid batteries have been the workhorse of the storage industry for almost a century. They are very basic in construction, consisting of layers of lead alloy plates surrounded by a sulphuric acid electrolyte. Flooded lead acid batteries, also known as vented lead acid, contain the sulphuric acid in liquid form and have vent caps allowing the release of hydrogen gas during charging, as well as allowing users to check/top up the electrolyte levels.

These batteries are very basic in construction, are low energy density and perform well through a wide range of temperatures. The main safety risks with flooded lead acid batteries are the buildup of hydrogen from improper ventilation and acid spills.

Types of Batteries in a BESS

2. Valve Regulated Lead Acid Batteries

Similar to flooded lead acid batteries, valve regulated lead acid are batteries that consist of lead alloy plates surrounded by a sulphuric acid electrolyte. However, the electrolyte is not in liquid form, thus being 'spill proof', also known as "sealed" lead acid and they come in different forms such as:

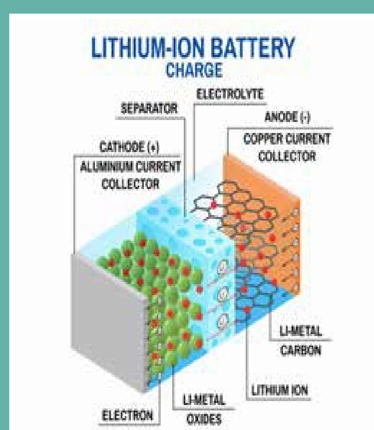
- **Absorbed Glass Mat (AGM):** These batteries contain electrolytes in glass mats surrounding the lead alloy plates; and
- **Gel Batteries:** Has silica in the electrolyte, creating a gel substance.

Types of Batteries in a BESS

3. Lithium Based Batteries

Lithium based batteries are a rechargeable battery used in electric vehicles, electronics and now home energy systems and large-scale grid storage. In the batteries, lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. A lithium-ion battery consists of four parts as shown in the middle picture below:

- **A Negative End (Anode)**: usually made up of graphite/carbon and has a current collector made up of copper;
- **A Positive End (Cathode)**: usually made of a lithium iron phosphate (LFP)/lithium nickel manganese cobalt oxide (NMC), and has a current collector made of aluminum. There are many other types on the market with slightly different materials;
- **An Electrolyte**: consists of salts, organic solvents and other additives; and
- **A Separator**: a synthetic barrier which separates the positive to the negative, usually made of polyethylene, polypropylene or other polyolefins.



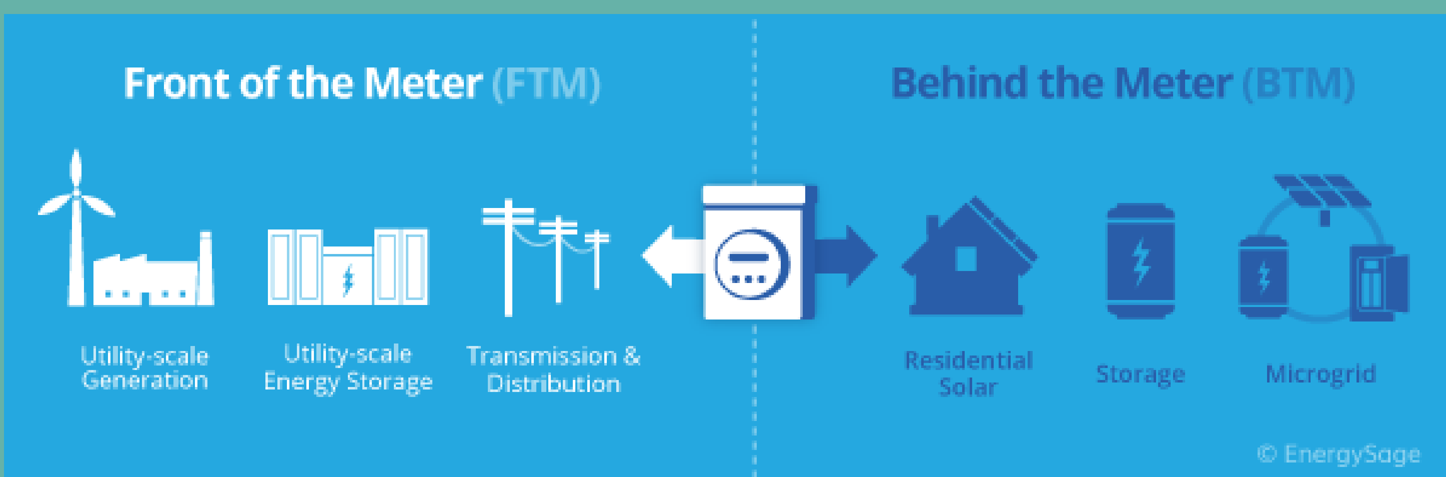
These batteries are high energy density, but have temperature limitations. There are more safety concerns with lithium-ion batteries since they contain flammable electrolytes, and if damaged or incorrectly charged can lead to explosions and fires.

BESS Located in Front of the Meter

Some Battery Energy Storage Systems are connected directly to the electrical grid. These systems are said to be connected "In front of the meter". These types of connections provide grid regulation services directly to the utility; and are often large in size as well as energy storage capacity. In front of the meter BES systems will also generally be connected to the grid at high voltage and be paired with transformers and other associated electrical substation equipment. These systems are typically located outdoors but could be contained within a building.

BESS Located Behind the Meter

The majority of BES systems are connected to the electrical systems of buildings. These include dwellings, as well as commercial and industrial facilities. These systems are said to be connected "Behind the Meter". Behind the meter systems provide services to the electrical customer such as peak shaving, backup power, and energy savings. Systems can range in size from a wall mounted device in a home storing a few kilowatt hours to large multi megawatt installations. These systems can be found indoors or outdoors.



MicroGrids

Behind the meter BES systems are often paired with other sources of energy, such as solar arrays and/or conventional generators in what's called a MicroGrid configuration. MicroGrids are capable of managing multiple sources to provide savings and reliability to customers and facilities.

Off-Grid Installations

Off-Grid BES systems provide electrical power to remote locations where there is no grid connection. These installations are usually paired with solar, fossil fuel generators, wind turbines, or other sources. These installations typically use lead-acid batteries; however, lithium type batteries are becoming more common.

In accordance with NFPA section 15.

References

[1] https://www.electronicspoint.com/research/lithium-ion-battery-basics-advantages-and-applications/

[2] https://www.rollsbattery.com/wp-content/uploads/2019/11/Rolls-Battery-User-Manual.pdf

[3] https://www.rollsbattery.com/wp-content/uploads/2019/11/SDS-Flooded_Lead_Acid_Battery.pdf

[4] https://www.rollsbattery.com/wp-content/uploads/2019/11/SDS-AGM_Battery.pdf

[5] https://www.eastpenncanada.com/unigy-ii.html

[6] https://www.lgchem.com/upload/file/product/LGChem_Catalog_Global_2018.pdf

[7] Standard for the Installation of Stationary Energy Storage Systems, NFPA Standard 855, 2020.

Who are the Primary Authorities Having Jurisdiction for BESS?

The body responsible for electrical safety inspection will be the primary Authority Having Jurisdiction (AHJ) for the BES system. This responsible body varies from province to province. In Ontario for example the primary responsible body is the Electrical Safety Authority.

There are some cases where a BESS may also fall into the jurisdiction of the local building department. This varies by location but would typically occur if the BESS is not listed to UL 9540, (please note certification of individual components to UL 9540 does not constitute certification of the entire BESS to UL 9540) is located below grade, requires HVAC, fire suppression, and/or structural upgrades to a building within which it is contained.

The primary authority for the Installation and Approval of Energy Storage Systems connected to the electrical grid in Ontario, is the Electrical Safety Authority (ESSA)
https://esasafe.com/assets/files/esasafe/pdf/Electrical_Safety_Products/ Bulletins/64-07-1.pdf

A Fire Services Portal listing the over 30,000 solar installation in Ontario can be accessed through
https://apps.esasafe.com/

NFPA 855 Standard for the Installation of Stationary Energy Storage Systems
https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=855

HAZARDS

THERE IS ALWAYS AN ELECTRICAL SHOCK HAZARD

- PV systems may energize metal structures or ground water when flooding occurs.
- Added weight (dead load) when installed on roofs.
- Potential uplift in extreme winds.
- Can mask potential collapse due to racking system holding areas of roof decking.
- Cables and panels can pose trip hazards.
- Smoke from burning panels or batteries may release extremely toxic fumes when involved in fire.
- If contact is made with direct current (DC) there is little or no ability to let go because of the constant flow.
- Battery storage areas can generate corrosive and explosive gasses when exposed to fire.
- Don't cover panels with tarps, salvage covers or foam.
- Backfeed generation (Islanding) is possible for these installations.

SOLAR PANELS AND BATTERIES CANNOT BE SHUT OFF!

PV Hazards – Electric Shock Potential

A SINGLE SOLAR PANEL PRODUCES ENOUGH ELECTRICITY TO KILL YOU.

Electrical Shock from Firefighters Tools

Damage to panels from tools may result in both electrical and fire hazards. The hazard may occur at the point of damage or at other locations depending on the electrical path. Metal roofs and buildings present unique challenges in that the surface is conductive unlike other types such as shingle, ballasted or single ply.

Damaged Solar PV Panels

DAMAGED EQUIPMENT/SOLAR MODULES CAN BE LIVE!

Fire Hazard - Arc Fault

A fault in the wiring may cause an arc whenever the solar panel is exposed to light. DC arc is more dangerous than AC.

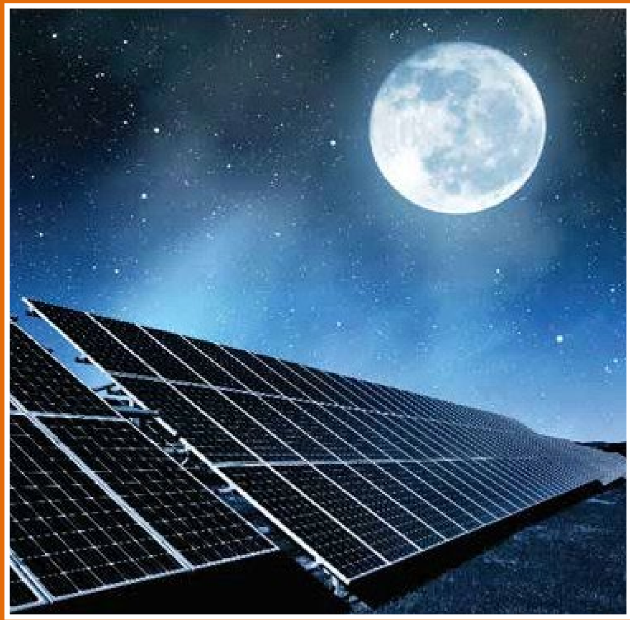
Always Treat as Live Because...

LIGHTING FROM FIRE APPARATUS OR STREET...
can produce dangerous electrical levels from solar panels.

LIGHT FROM FIRE...
can also produce dangerous levels of electricity.

THE MOON...
in certain conditions, especially with cold temperatures, the light from the moon can also produce dangerous levels of electricity.

THE MORE INTENSE OR DIRECT THE LIGHT, THE GREATER THE HAZARD.



BATTERY HAZARDS

Lithium-ion batteries deliver good energy density in a small, cost-effective footprint, however that comes with a risk. When a lithium-ion cell fails or is subjected to abuse, a potentially catastrophic event known as thermal runaway can occur, where chemical energy is converted to thermal energy. Once an ignition threshold is reached the process will continue to propagate, or spread, from cell to cell consuming the BESS, and where adjacent structures are present, potentially facility wide.

STAGES OF A BESS FIRE

Islanding (Backfeed) Hazards

Typically Grid connected BES systems are designed and configured to immediately shut down and stop producing energy when the utility grid is shut down or disconnected. However, some BES systems may be configured to provide backup power to a home or facility in case of a utility outage, much like a conventional backup generator. For this reason, it is important to always use lockout/tagout to ensure that electricity is completely isolated from electrical systems.

ISLANDING (BACKFEED) GENERATION IS POSSIBLE FOR THESE INSTALLATIONS.

FIREFIGHTERS AND FIRST RESPONDERS MUST BE AWARE OF THE DANGERS AND HAZARDS ASSOCIATED WITH BATTERY ENERGY STORAGE SYSTEMS.

Personal Protective Equipment – PPE

Full bunker gear must be worn when dealing with a photovoltaic emergency (coat, pants, boots, helmet, balaclava and gloves). Bunker gear is not designed or intended to provide protection from electrical current.

Full SCBA must be worn due to the fact that all fires are toxic, the potential of gas inhalation hazards and arc flash possibility.

Gloves and Boots, Electrical Insulation

Boots are only tested when they are new and dry. Dirt, water and damage (normal wear & tear) can reduce or negate the ability to provide electrical insulation.

Gloves are not tested for electrical insulation.

Rescue Considerations

Potential electrocution incident. How do we approach an injured person on, near, or under an array that could be live?.....

DON'T TOUCH ANYTHING METAL THAT MAY BE IN CONTACT WITH THE SOLAR SYSTEM

NO CONTACT WITH RACKING, METAL ROOF, OR METAL FRAMES OF THE SOLAR PANEL

CONTACT UTILITY OR CONTRACTOR, WAIT FOR ISOLATION

PV Tactical Considerations

- The first step is identifying the type of solar PV system in use.
- A 360 degree survey of the scene is key to the decision making process for the Incident Commander.
- Call the local utility company to disconnect the electrical service.
- If the roof is not involved and there is no flame impingement on the solar panels, consider treating the incident as a room and contents fire until the fire has extended into the roof. Watch for wires or conduits.
- Ventilation is to be directed by the Incident Commander, who may consider the opposite side of the roof, horizontal or positive pressure ventilation.
- Look at the meter entrance to the building – may have a distributed generation (DG) meter.
- Shut off switches on all disconnects found.

INVERTERS MAY NOT BE VISIBLE!

UL experiments found that with a 10 degree fog pattern, the nozzle could be as close as 5 feet (1.5 meters) on systems energized up to 1000 volts DC.

All systems are required to have a permanent label on the disconnect.

During nighttime, operations must be reviewed by the Incident Commander prior to sunrise to re-assess tactics - or when light conditions change such as less cloud, more scene lights.

During overhaul be aware that wiring may not be visible.

Fire departments should have a list of local installers to call for isolation of system in emergencies.

WHENEVER LIGHT IS PRESENT, TREAT ALL PANELS AND WIRING AS LIVE.

BESS Fire Safety Considerations

Considerations	Lithium-Ion Batteries	Flooded Lead-Acid Batteries	Valve Regulated Lead-Acid Batteries
Hazards	Thermal Runaway	Acid, Hydrogen gas	Hydrogen gas (over charge)
Requirements	Thermal runaway management, signage, seismic protection, smoke detection.	Venting caps, spill control, neutralization, ventilation, signage, seismic protection, smoke detection.	Self-resealing flame-arresting caps, neutralization, ventilation, signage, seismic Protection, Smoke detection.
Fire Methods	1. System isolation and shutdown 2. Hazard confinement and exposure protection 3. Fire suppression 4. Ventilation	1. System isolation and shutdown 2. Hazard confinement and exposure protection 3. Fire suppression 4. Ventilation	1. System isolation and shutdown 2. Hazard confinement and exposure protection 3. Fire suppression 4. Ventilation
Suppressing Agent Choice	Water is considered the preferred agent for suppressing lithium-ion battery fires.	**Small Fires:** • Water • Powders • Inert gases • Carbon dioxide **Large Fires:** • Water	**Small Fires:** • Water • Powders • Inert gases • Carbon dioxide **Large Fires:** • Water
Installation Restrictions	Temperature (0 to 40 C) Living spaces in a dwelling		

BESS Tactical Considerations

Strategic Considerations

- PV, BIPV, and BESS systems recognition or preferably pre-planning
- Hazard area
- ANYTHING that can be contacted electrically - building, fences, overhead or underground wires MUST be treated as LIVE
- Equipment involved
- Risk mitigation
- Equipment on fire is lost, adjacent equipment may be salvageable (heat and containment dependent)
- Do we need a specialist? If ANY part of the attached electrical/solar/battery system compromised, the answer is YES!

Tactical considerations

- Proximity to voltage carrying / producing / storage devices
- Type of extinguishing agent - CO2 best or other inert gas, water, or dry chemical
- Water pattern to be 30-degree fog, 700kPa (or nozzle manufactures' recommendation) at the nozzle sprayed from 3m away or more if water used
- DO NOT use foam unless electrical hazards are removed
- Shutting off switches must be done using PPE and one hand method
- "Hidden" main switches, battery rooms
- Wires in locations not normally found in traditional structures
- Vent gases from batteries are toxic and explosive
- Anything metallic touching energized equipment may also be energized
- Water from drafting or wells maybe more conductive especially if from winter roadway run-off due to contaminants, including those dissolved in the water

FIREFIGHTERS AND EMERGENCY RESPONDERS MUST BE FAMILIAR WITH AND RECOGNIZE THE HAZARDS AND DANGERS WHEN DEVELOPING AND IMPLEMENTING AN INCIDENT ACTION

Pre-Incident Considerations

Collecting information regarding where and what these installations are prior to an incident is by far the best way as it allows pre-incident planning.

Information regarding where these installations can be collected from:

- The municipal building department as permits are needed
- Contact the Electrical Safety Authority
- Look for these in your area when travelling. Contact the owner to arrange a site visit to allow pre-incident planning. Many owners will share lots of information in the interest of loss mitigation.

Post-Incident Considerations

Electrical

- Batteries and Solar panels not totally destroyed could still be electrically hazardous
- Anything conductive connected to these could also be hazardous

Off-gassing

- Both batteries and solar system components will off-gas hazardous fumes
- Batteries may also still off-gas explosive fumes if the electrolyte was not burned off

Mechanical hazards

- Broken parts and wiring could cause slip and trip hazards

Tactics

- Check area using multi-gas monitor to ensure there are no hazardous fumes
- Use of ventilation is recommended to provide fresh air to the area
- If fumes are present, use of SCBA is required

Have a solar/BESS specialist/installer or electrician familiar with these systems verify there are no electrical hazards, or to mitigate them. This may include disconnecting devices and removing them from the area.

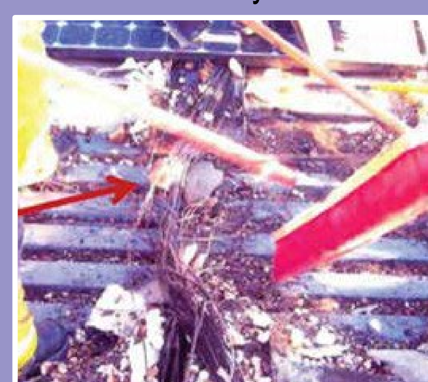
Example of Solar PV Fire Damage

HOT ENOUGH TO BURN THROUGH THE STEEL ROOF DECK

Post Fire Hazard

Photovoltaic systems on a burning building may not be the cause of the fire but may be damaged as a result.

During clean up damaged wires may still be arcing.

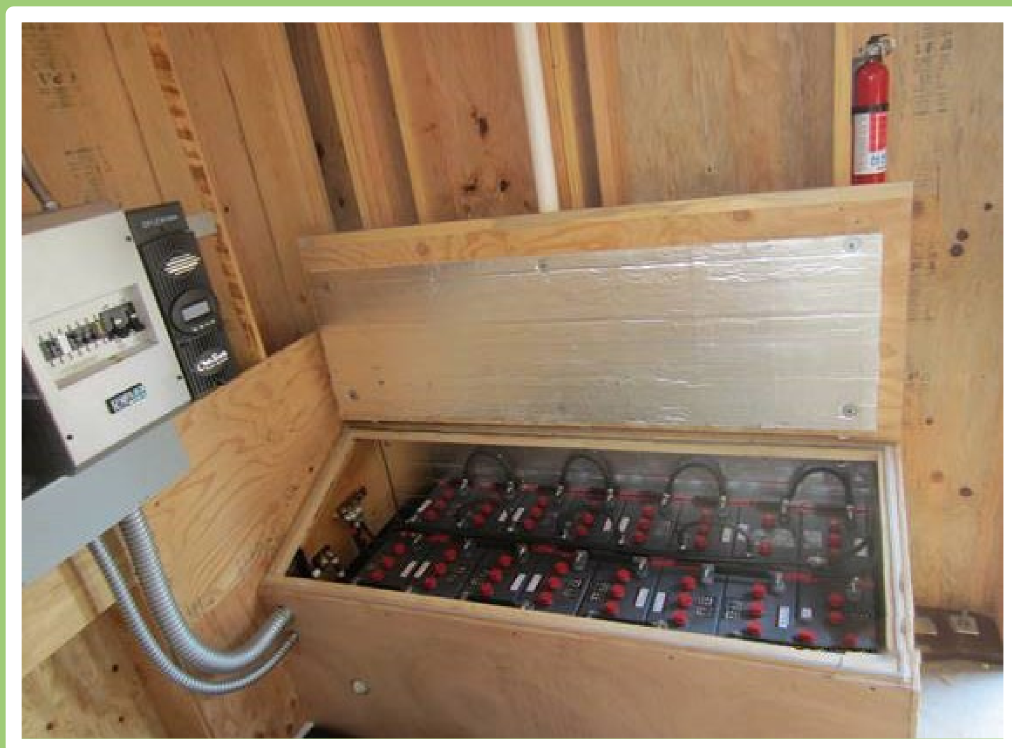


FIREFIGHTERS SHOULD TREAT ALL WIRES AS LETHAL SHOCK HAZARDS

Example of BESS Fire Damage

IMAGE INDEX

Example of a very neat and tidy battery installation



Solar Electricity and Battery Energy Storage Safety Handbook for Firefighters

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