# Advantages and disadvantages of different types of battery and inverters

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# Overview

- Description of types of batteries
  - Flooded lead acid
  - VRLA lead acid
  - Lithium ion
- Description of types of inverters
  - Battery inverter
  - Inverter/charger
  - PV inverter
  - dc bus interactive inverter
  - ac bus interactive inverter

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# Common Battery technologies

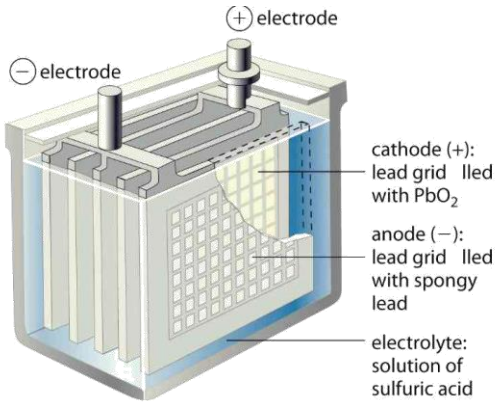
- Flooded lead acid battery
- Valve regulated lead acid (VLRA) battery
  - Gel
  - Amophorous glass mat (AGM)
- Lithium Ion batteries

# Lead Acid Batteries

- Lead-acid batteries are currently the most widely used battery type for PV systems with battery storage.
- This technology is generally cheaper than other battery technologies and has a long track record for various applications.
- However, lead-acid batteries are very heavy, and are susceptible to a variety of degradations
- Lead is toxic to human and batteries should be recycled at the end of life

# Flooded lead-acid batteries

- Comprises of positive and negative electrodes made out of lead
- Battery cell is flooded with sulfuric acid which acts as electrolyte
- Separator prevents accidental short circuit of electrodes
- During charging, some of the water in the electrolyte is converted into oxygen and hydrogen gas. This results in a loss of water in the electrolyte.

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# Flooded lead acid batteries

Pros:

- Old technology: Invented in 1859
- Familiar, cheap and reliable
- Easy to maintain

Cons:

- Lower energy density (heavier/bigger battery banks)
- Needs frequent maintenance (topping up with water)
- Contains hazardous liquid (corrosion risk if spilled)

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# Valve regulated lead-acid(VRLA) batteries

- Similar to flooded lead-acid batteries except that they are sealed in a leak-proof unit.
- Valve is for release of gases when overcharged
- The electrolyte in sealed batteries is restrained from moving, reducing problems with stratification, water loss and acid spillage.
- There is no mechanism to replace the lost gases/water in VRLA batteries, which could reduce their lifetime.

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# Valve regulated lead-acid battery- AGM

- AGM stands for Absorbed Glass Mat (AGM)
- Absorptive glass mats that have been soaked with sulfuric acid are placed between the electrodes instead of straight sulfuric acid.
- Glass mat reduces the amount of electrolyte needed resulting in a lighter battery.
- After cycling, the active material can stick onto the glass mat, which can result in a short circuit.
- AGM can provide high current discharge but not as good cycle life compared to gel batteries.

# Valve regulated lead-acid battery- Gel

- Also valve-regulated lead acid battery
- The electrolyte is combined with a gelling agent such as silica flour, which creates a thick gel, therefore immobilising the electrolyte.
- These batteries have better deep cycle and life cycle performance than AGM batteries.

# Valve regulated lead acid batteries

Pros:

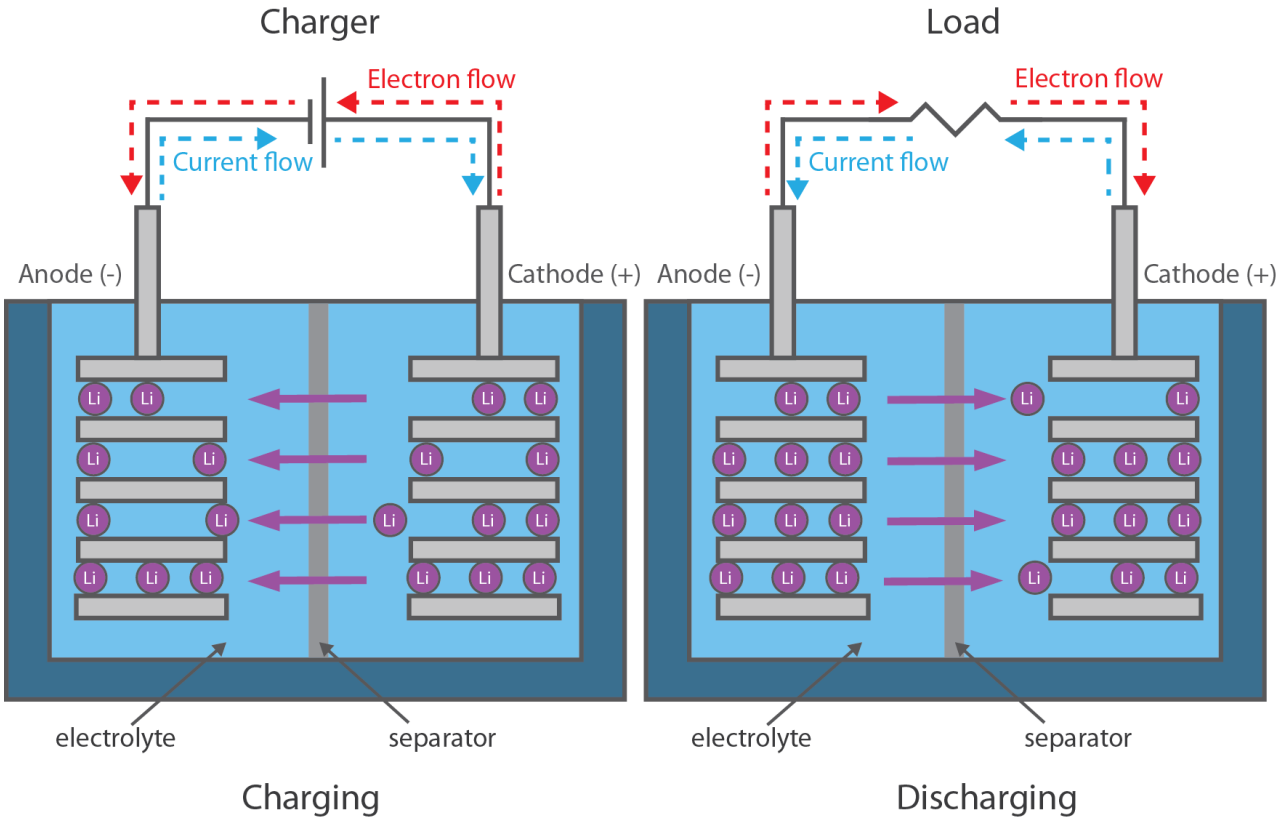
- Less stratification risk
- No fear of spillage
- Can be installed on their side
- Less maintenance
- Lighter (AGM)

Cons:

- More expensive
- Less tolerant of operation outside designed range than flooded lead acid

# Lithium ion technologies

- Structured similar to Lead-Acid Batteries: cathode, anode, separator, and electrolyte
- Very high energy density; more energy available for less weight and volume

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# Lithium Ion Risks

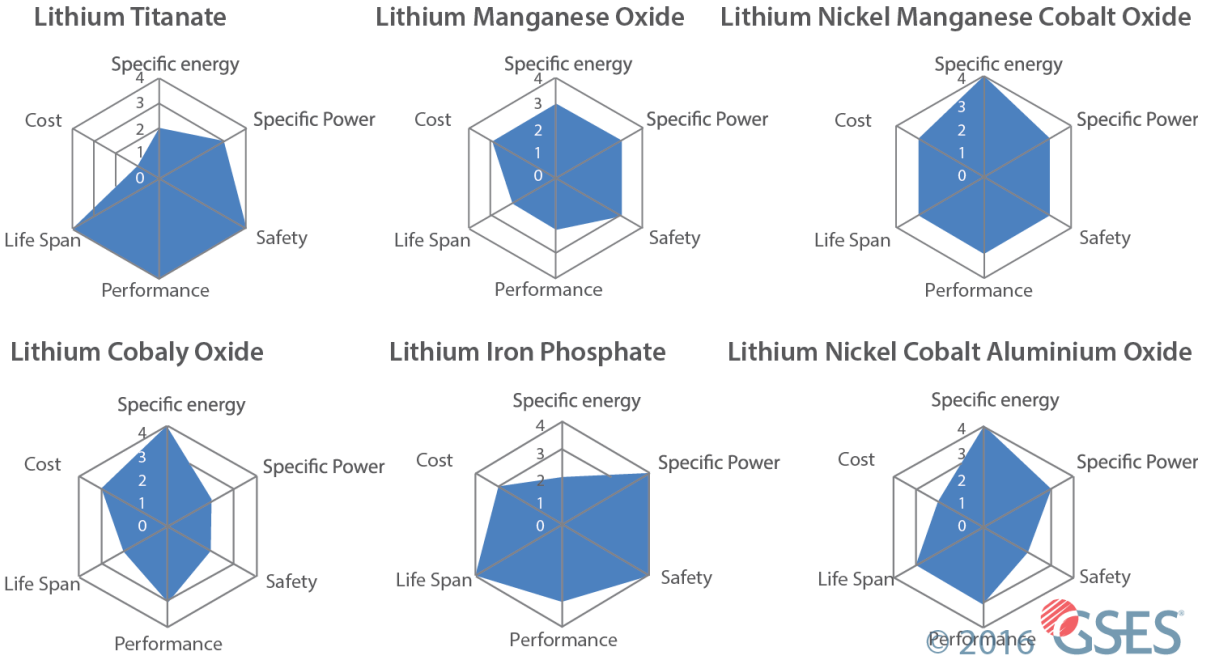
- Sensitive to overcharging and over-discharging
  - A dedicated battery management system (BMS) is required to ensure even charge within battery bank
- Overcharging, over-discharging, or puncturing of certain lithium ion chemistry can result in thermal runaway – a chain reaction when the battery gets too hot (from short circuit, external temperature, etc) which leads to the battery catching fire

# Different Types of Lithium Ion Chemistries

- Can be named after cathode or anode material
- These variations in the chemistry affect the operating characteristics and parameters of the battery.
- These materials are selected and manipulated to change the specific energy, energy density, cycle life, discharge rates or cost of the battery.

# Different Types of Lithium Ion Chemistries

- **LCO** – Lithium cobalt oxide ($LiCoO_2$)
- **LMO** – Lithium manganese oxide ($LiMn_2O_4$)
- **LFP** – Lithium iron phosphate ($LiFePO_4$)
- **NMC** – Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$)
- **NCA** – Lithium nickel cobalt aluminium oxide ($LiNiCoAlO_2$)
- **LTO** – Lithium titanate oxide ($Li_4Ti_5O_{12}$



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# Lithium Ion Batteries

Pros:

- High energy density – space saving device
- More cycle life than lead-acid battery
- Capable of high discharge current without voltage drop
- Can tolerate lower depth of discharge than lead-acid batteries

Cons:

- More expensive
- Very intolerant of operation outside designed range – can enter thermal runaway and combust
- Requires a battery monitoring system
- May lock up after long period of idling due to battery self discharge past internal safety point (“bricked” battery)

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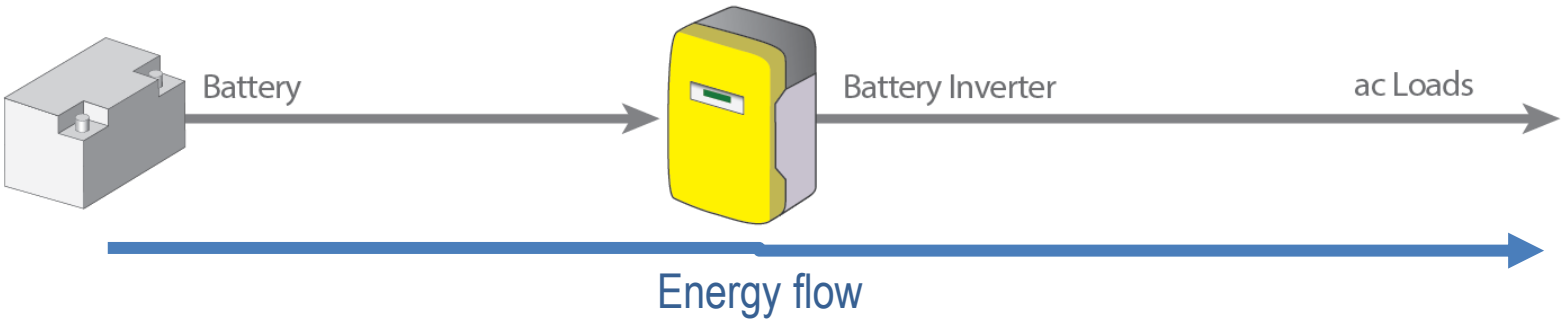
# Different types of Inverters

- Inverters convert DC to AC
- Not all inverters do the same thing
- Inverters can be categorised into different types depending on their capabilities:
  - Battery inverter only
  - Battery inverter + charger
  - PV inverter only
  - dc Bus interactive inverter
  - ac Bus interactive inverter

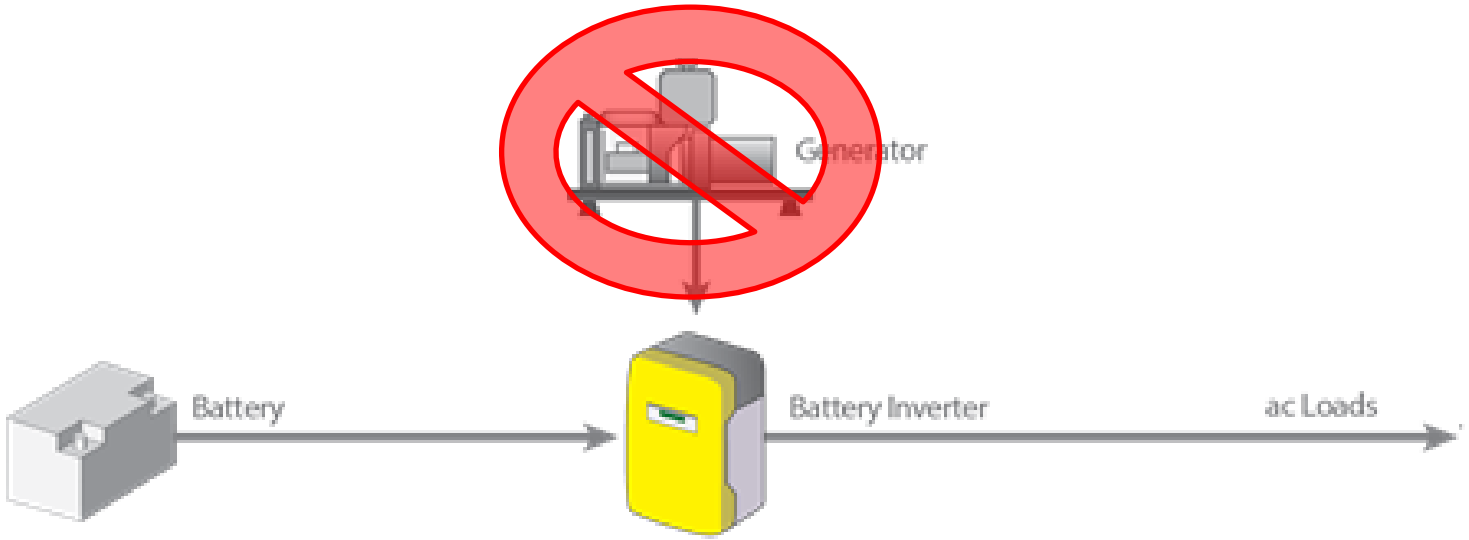
# Battery inverter

- Converts the dc power from the battery to provide ac power to the loads.
- Some manufacturers allow these inverters to parallel with a similar model inverter but one will have to be the master to ensure they are synchronised.



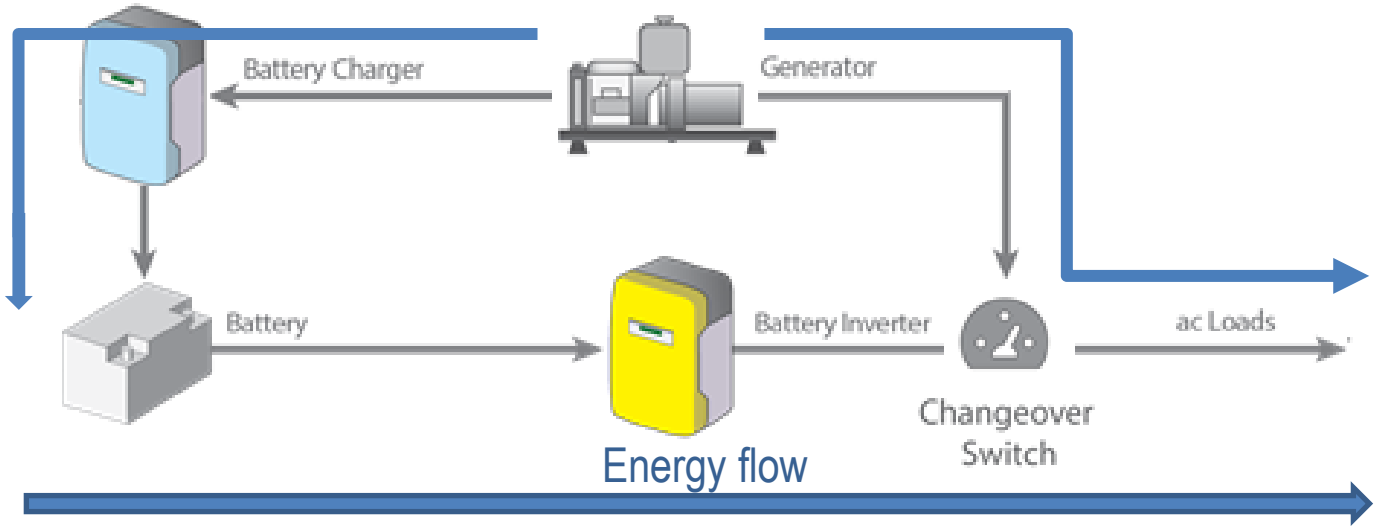
# Battery inverter

- Theses inverters cannot parallel to any other ac source like a generator.
- Battery can be charged by solar PV connected via a solar controller to the battery



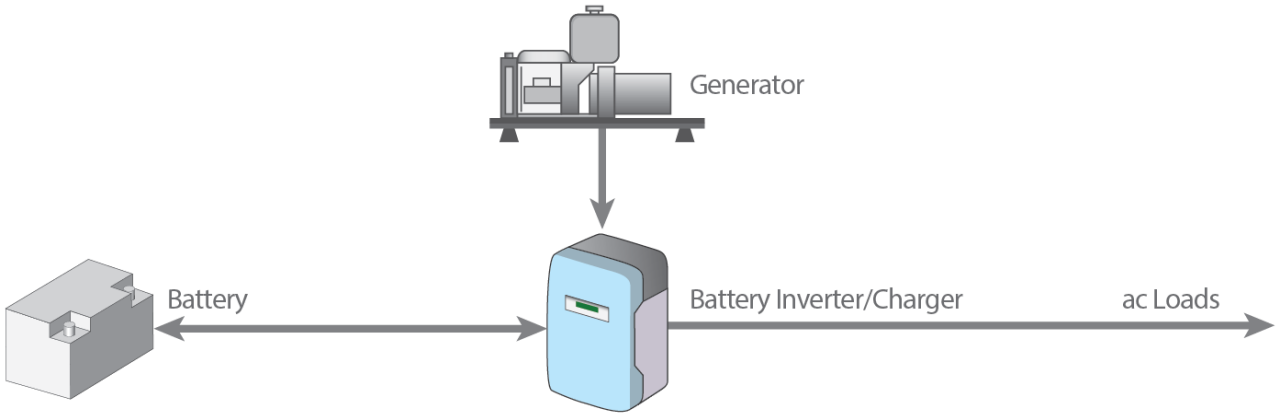
# Battery inverter

- If used in a hybrid system, battery inverters would require a separate battery charger.
- Battery inverter cannot charge the battery.



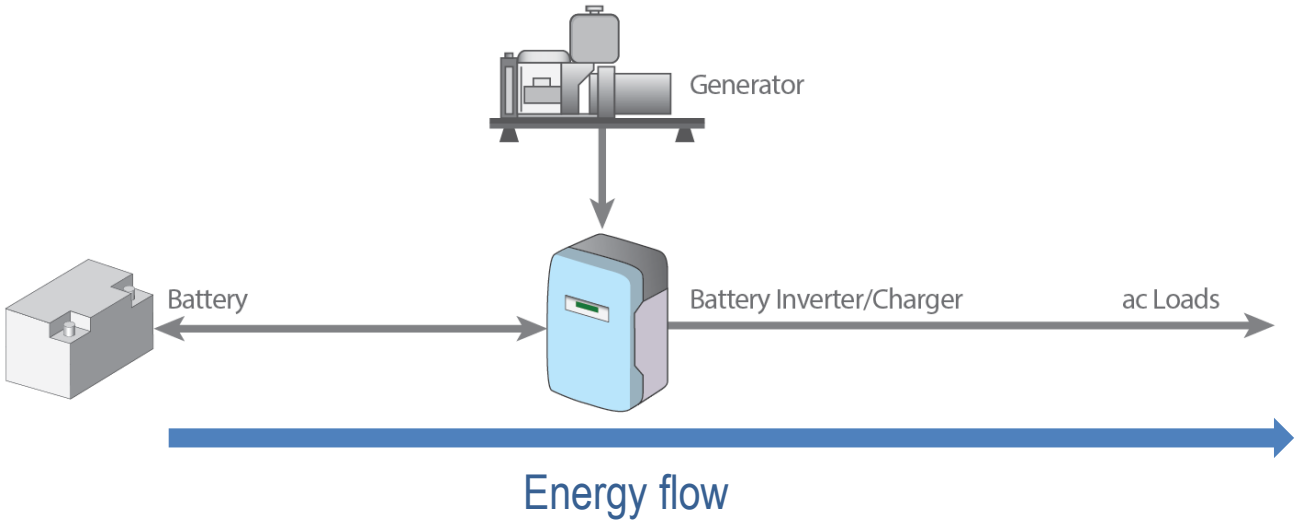
# Inverter/Charger

- Inverter/Chargers have ac inputs for generators.
- BUT! They do not parallel inverter output with the generator. They are either in inverter mode or charger mode.



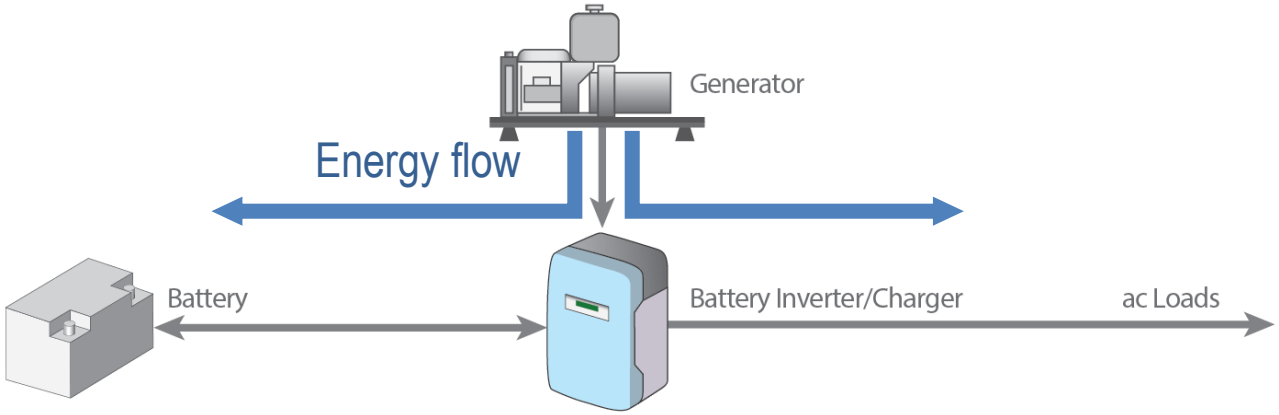
# Inverter/Charger

- When the generator is not operating, the inverter will convert the dc power from the battery to provide ac power to the loads. (Inverter Mode)



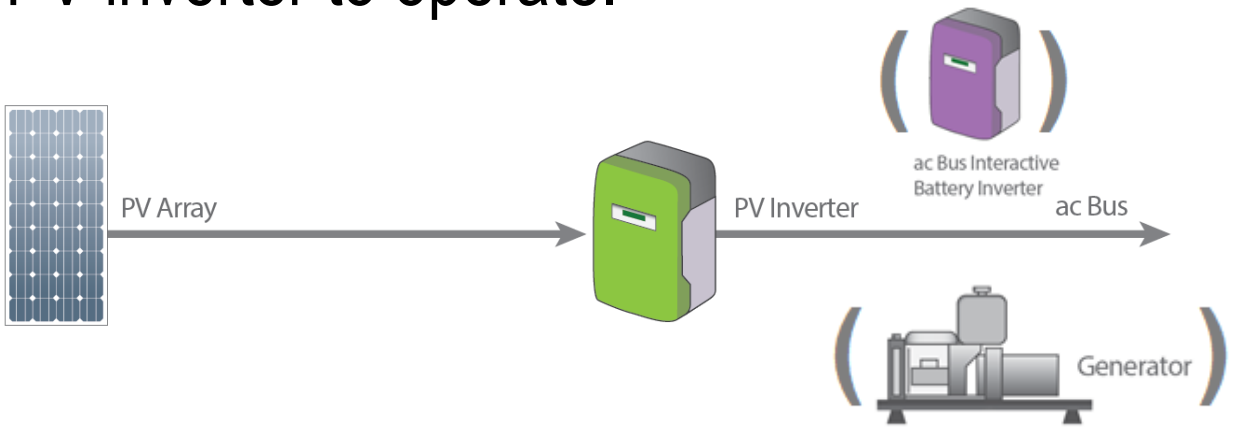
# Inverter/Charger

- When the generator starts, the inverter will switch the generator ac power to the loads, and the inverter will operate in charging mode converting the generators ac power to dc power and charge the battery. (Charger mode)



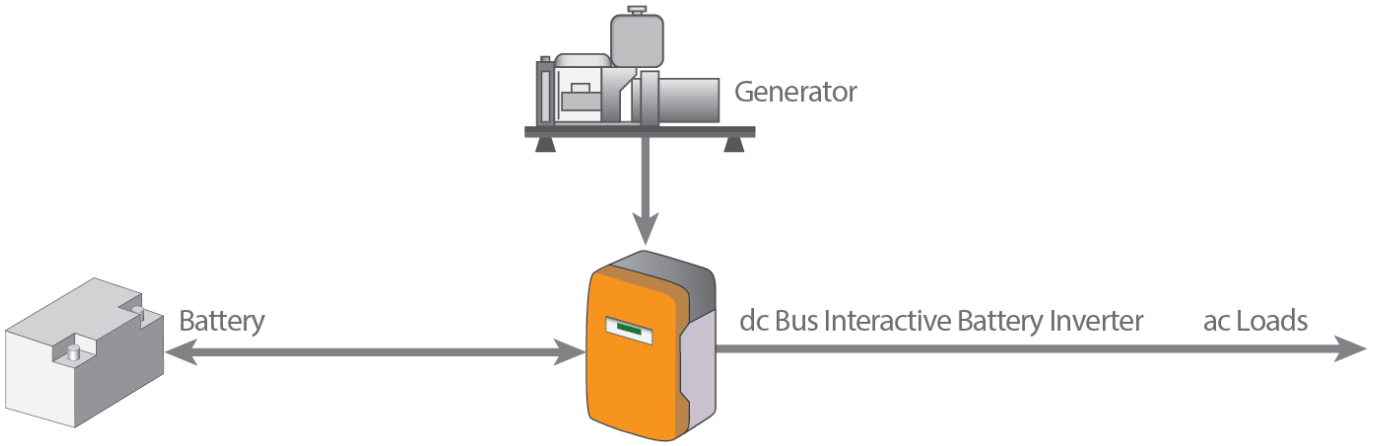
# PV Inverter

- The PV inverter converts the dc power from the PV array to provide ac power to the ac bus.
- However, there must already be ac power on the ac bus from another source (generator or ac bus hybrid inverter) for the PV inverter to operate.



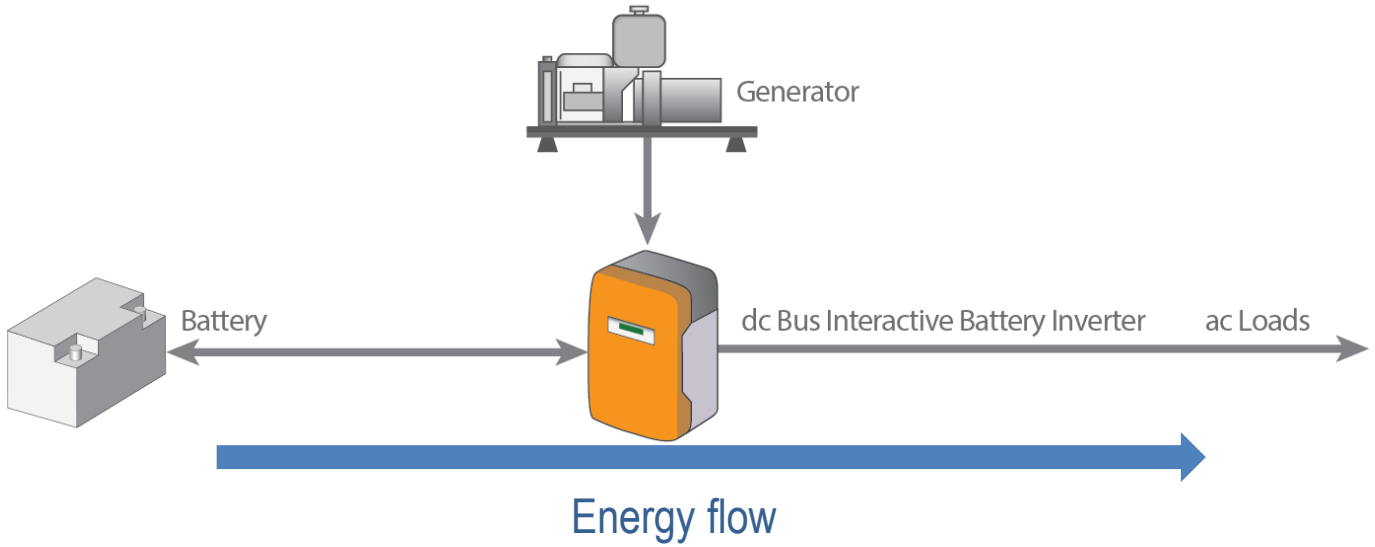
# dc Bus Interactive Inverter

- The dc bus interactive inverter is an inverter/charger that can parallel battery output with generator operation to supply energy to ac loads.



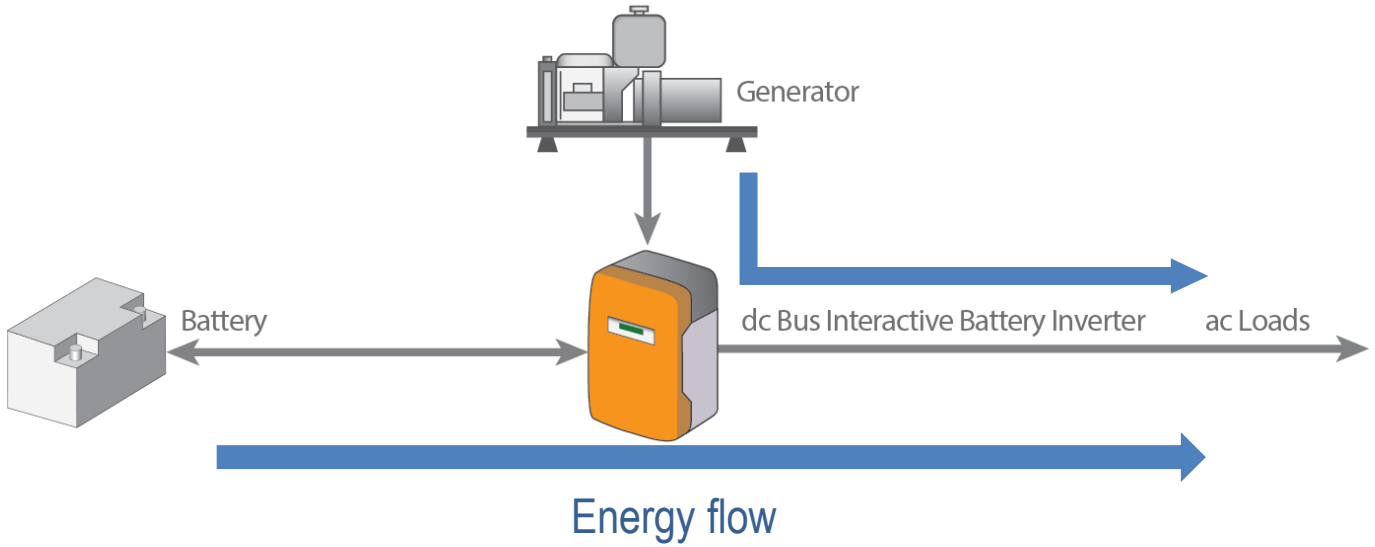
# dc Bus Interactive Inverter

- When the generator is not operating, the dc bus interactive inverter will convert the dc power from the battery to provide ac power to the loads.



# dc Bus Interactive Inverter

- When the generator starts, the inverter will synchronise with the generator so that the ac loads can be supplied by the generator and inverter in parallel.

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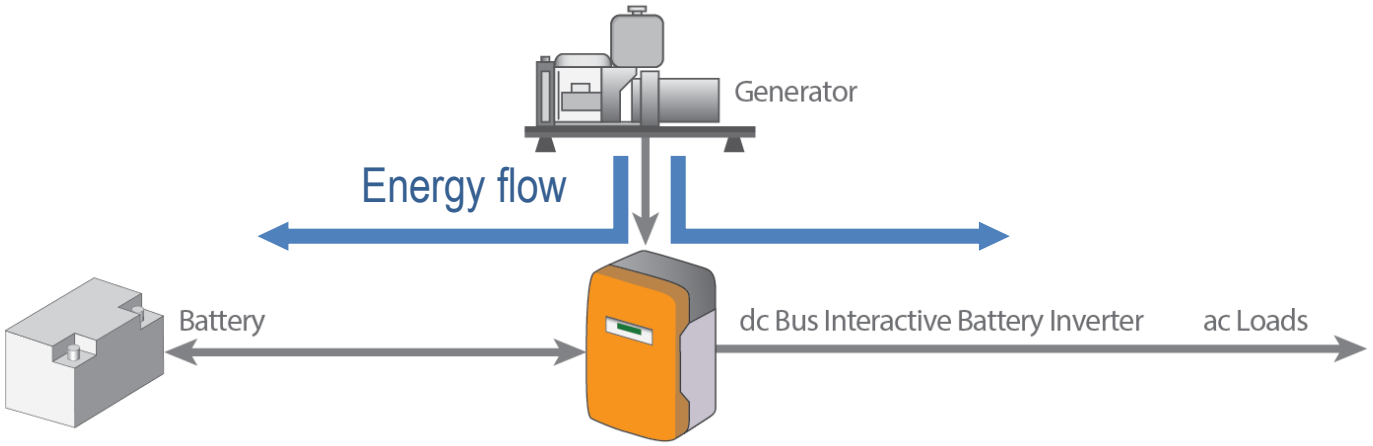
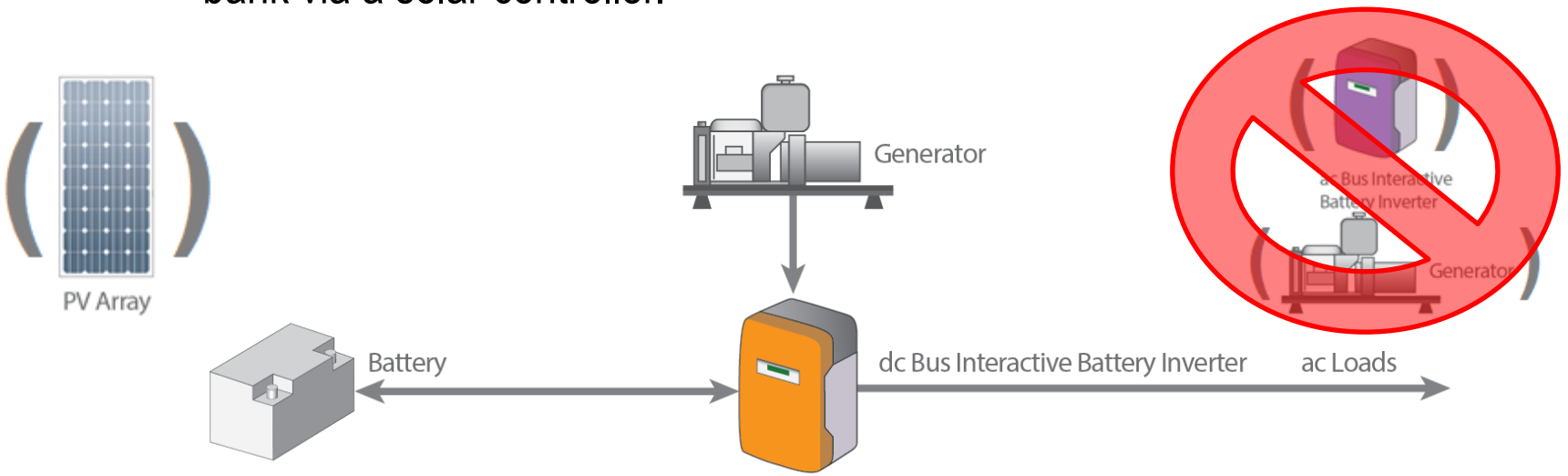
# dc Bus Interactive Inverter

- If there is excess generator power compared to the load, the dc bus interactive inverter will convert to a battery charger and charge the battery bank from the generator while the generator continues to provide ac power to the loads.



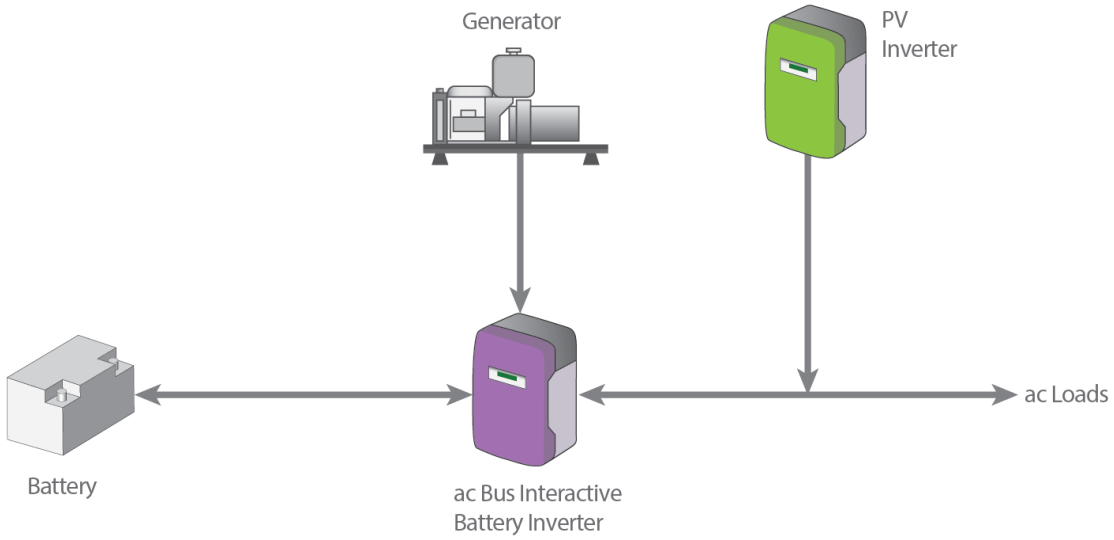
# dc Bus Interactive Inverter

- The dc bus interactive inverter will only parallel with the generator connecting to the inverter.
  - There can be no other sources of ac power on the ac load line from the inverter.
  - The PV array that is part of the hybrid system will be connected to the battery bank via a solar controller.



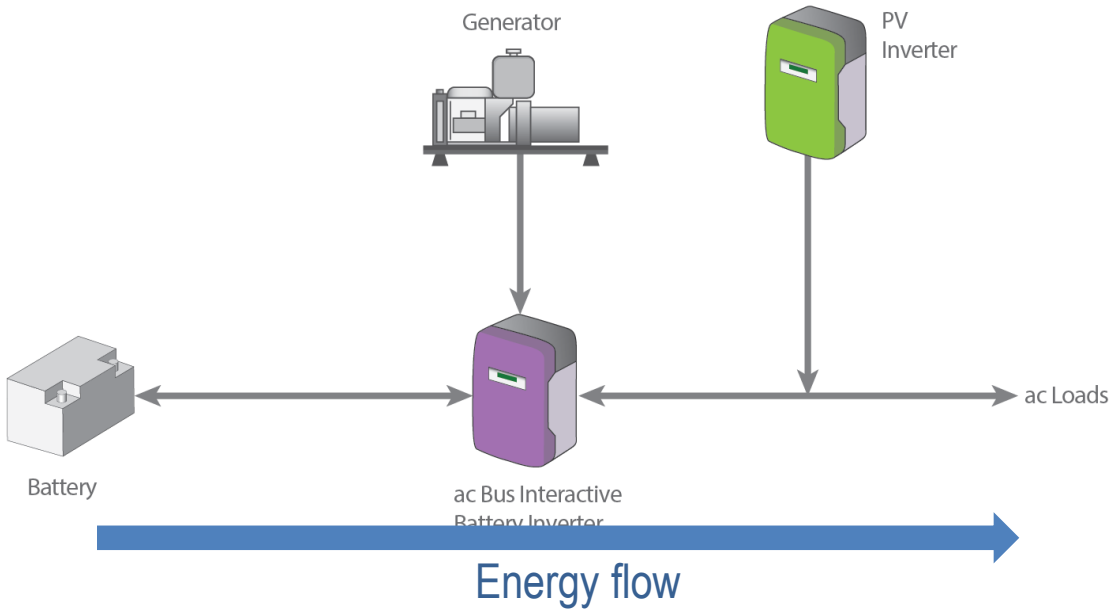
# ac Bus Interactive Inverter

- The ac bus interactive inverter is an inverter/charger that can parallel battery output with generator operation and another ac source (e.g. PV array via PV inverter) to supply energy to ac loads.



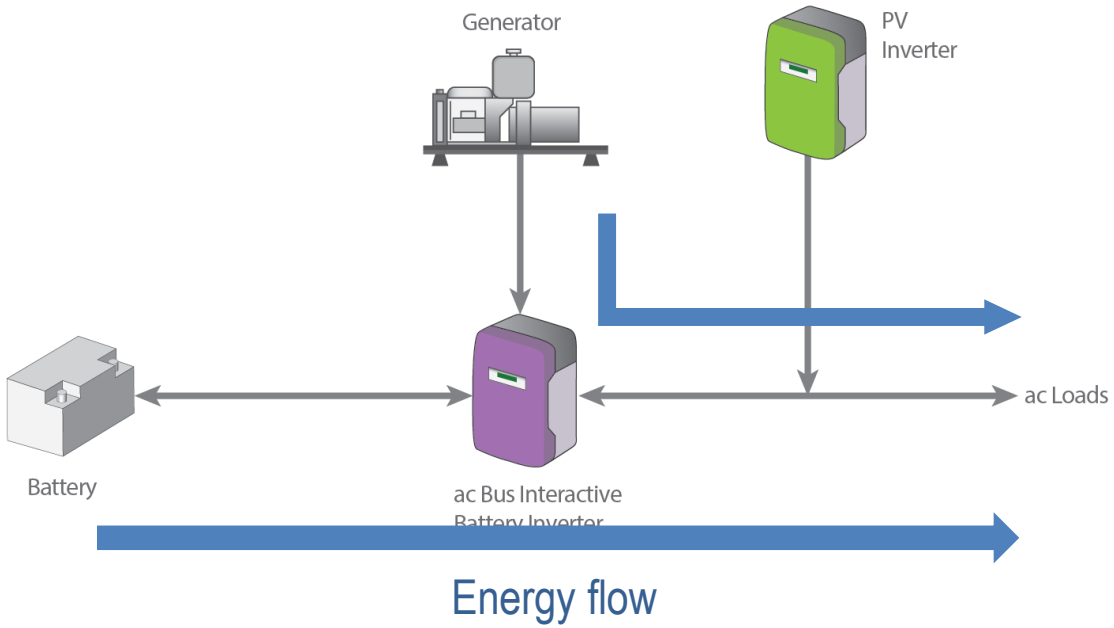
# ac Bus Interactive Inverter

- When the generator is not operating, the ac bus interactive inverter will convert the dc power from the battery to provide ac power to the loads.



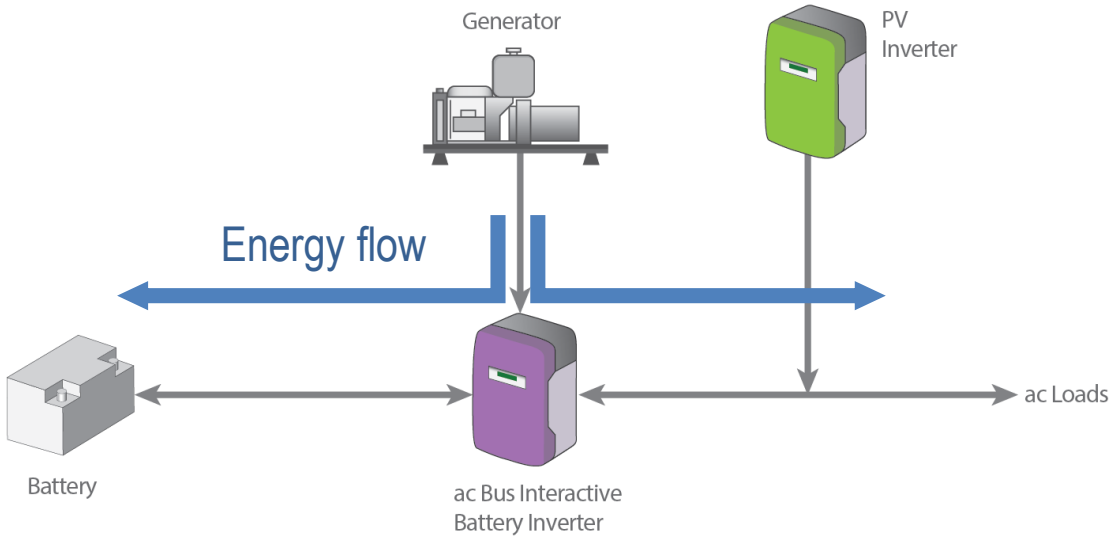
# ac Bus Interactive Inverter

- When the generator starts, the inverter will synchronise with the generator so that the ac loads can be supplied by the generator and inverter in parallel.



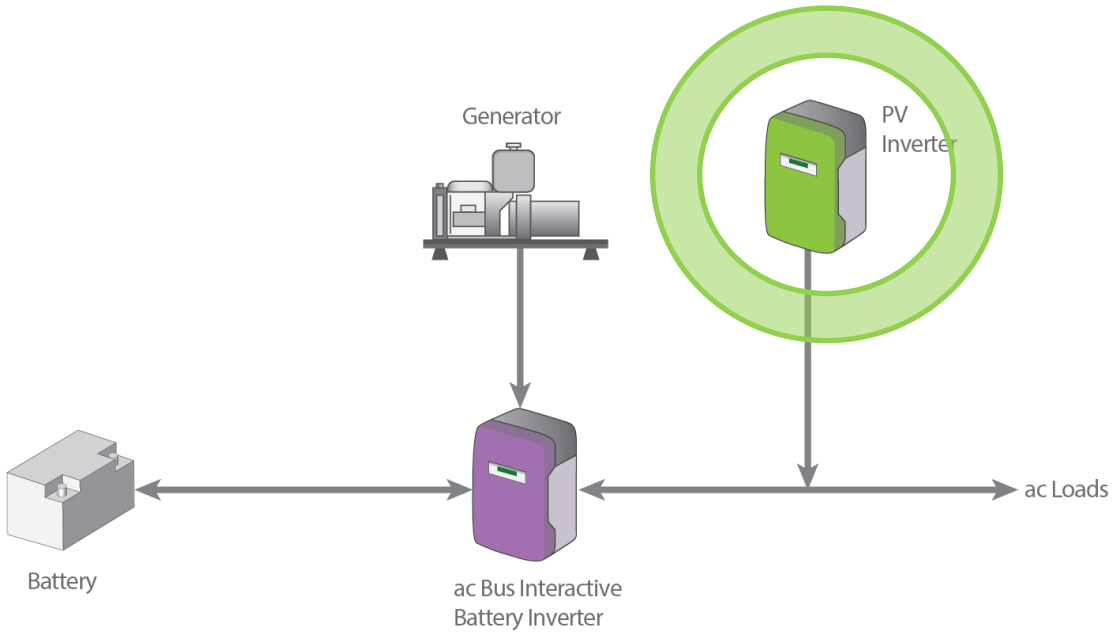
# ac Bus Interactive Inverter

- If there is excess generator power compared to the load, the ac bus interactive inverter will convert to a battery charger and charge the battery bank from the generator while the generator continues to provide ac power to the loads.



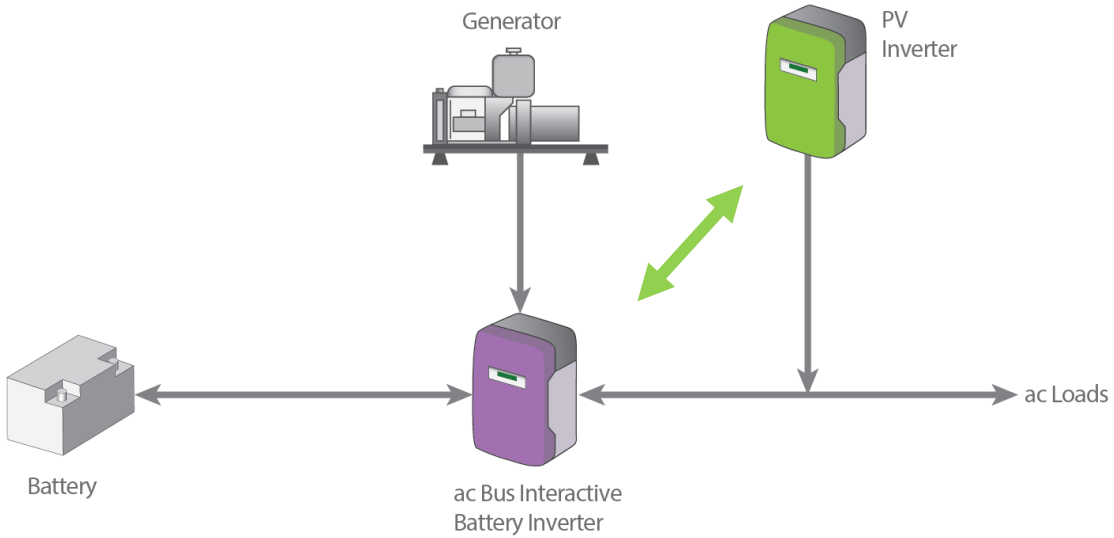
# ac Bus Interactive Inverter

- The ac bus interactive inverter will allow PV inverters to be connected to the ac bus.



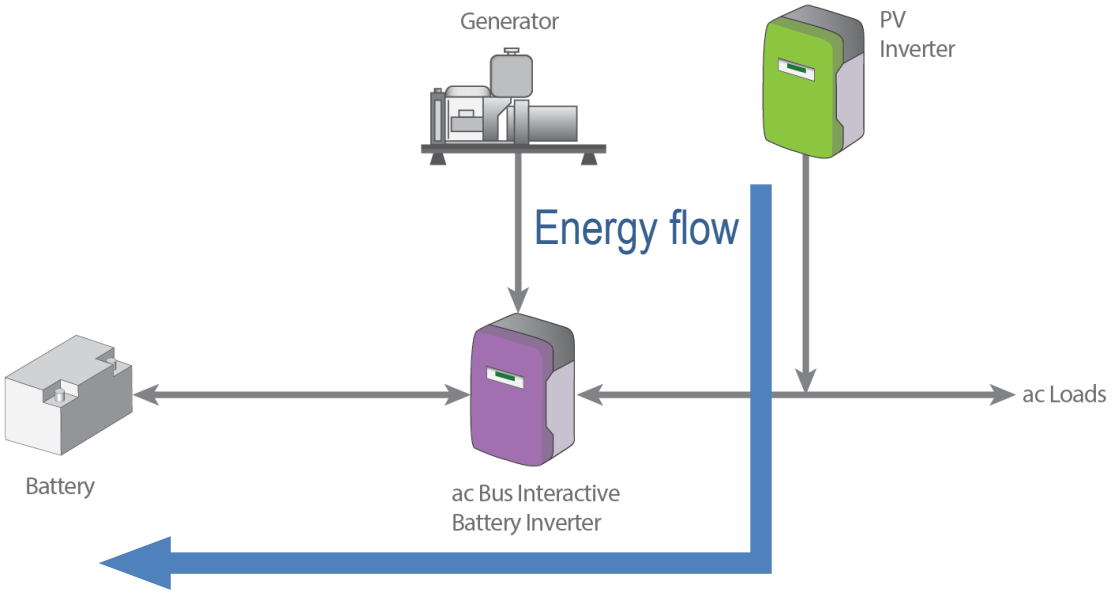
# ac Bus Interactive Inverter

- The ac bus inverter and PV inverters must be compatible and be able to communicate with each other.
- This is so their output can be synchronised.



# ac Bus Interactive Inverter

- If there is excess ac power from the PV array (and PV inverter) compared to the load, the ac bus interactive inverter will convert to a battery charger and charge the battery bank from the PV array via the PV inverter.



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