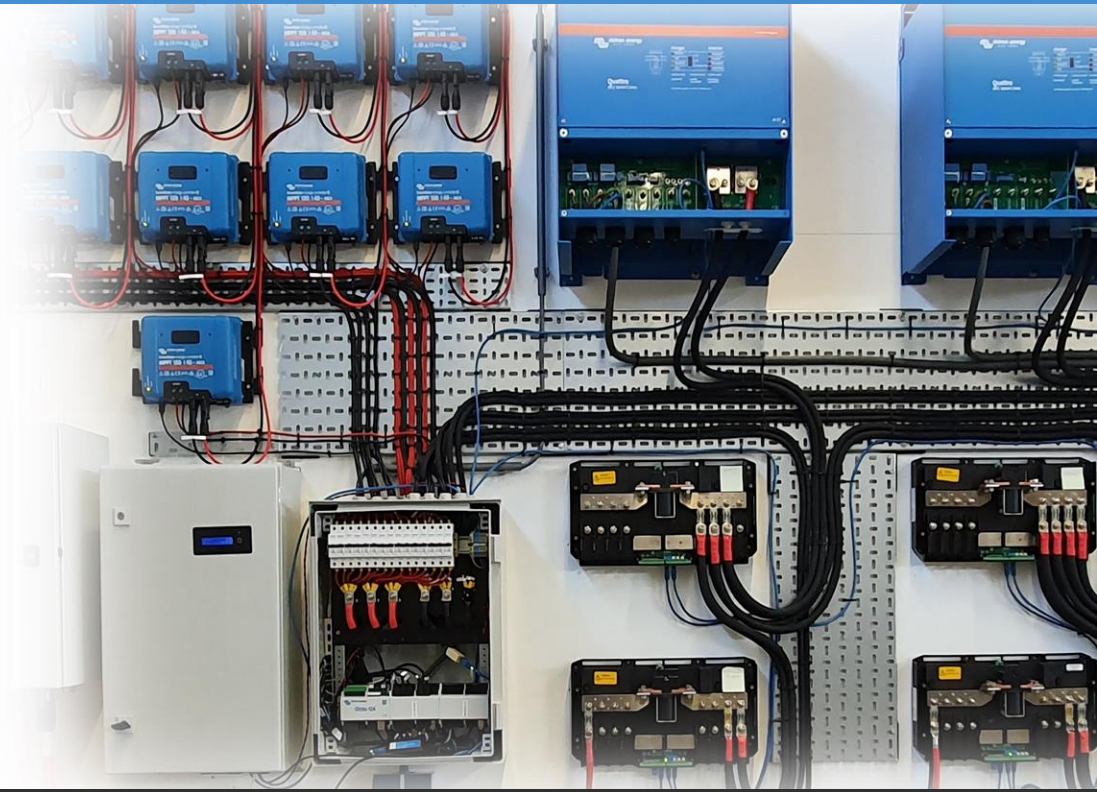
System design, calculations and commissioning

Solar and Windmill

Todays webinar

1. Introduction
2. Design
3. Calculations
4. Equipment sizing
5. Installation
6. Configuration
7. Commissioning
8. Training and more information



1. Introduction

Systems - from start to finish

Design	Design brief, component selection system diagram
Calculate	Power requirements Equipment, fuses and wire sizing
Install	Installation, wiring and configuring
Commission	Test and fix faults (if any) ☺

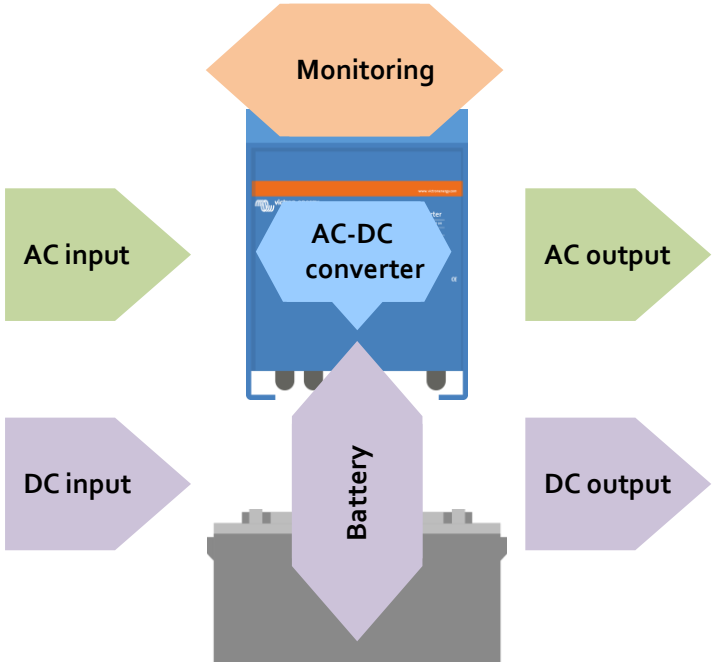
2. Design

The design brief

Talk to the customer and investigate

- New system or existing system ?
- Budget ?
- How often will the system be used ?
- Power consumption ?
- Is monitoring required or recommended?

Component selection



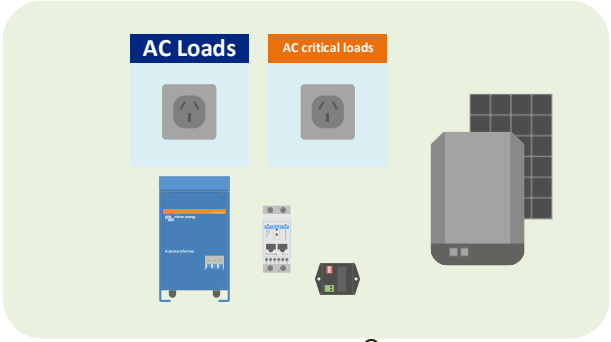
The Battery - the basis of a system

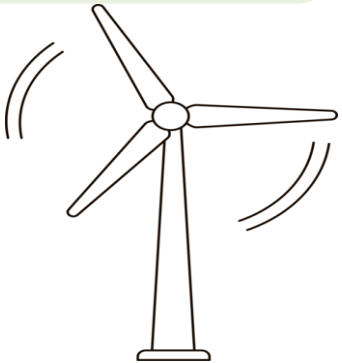
Considerations:

- System battery voltage - high loads, choose a higher voltage
- Battery chemistry - lead acid, lithium, flow battery or other chemistry?
- How much space is there for the battery?
- Are there weight restrictions?
- Budgetary constrains? - never try to save money on the battery, a too small battery means bad system
- Traditional battery (lead acid) or a self managed or a smart battery (Lithium or flow battery)?
- Is battery communication needed?
- Does the battery have or need a BMS?
- Is temperature sensing needed - to adapt the charge current or to prevent low temperature charging

AC output

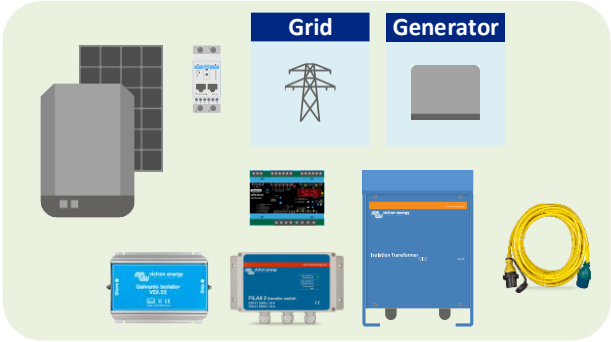
- AC load power ratings and their peak ratings (start up current)
- AC load running times - how long and when do they run?
- Will the AC source and/or the battery power the AC loads and when?
- Single phase, split phase or 3 phase AC loads?
- Is a PV inverter or windmill connect to the AC output - be aware that special settings are needed - consider using or adding MPPT for black start and good battery charging
- Divide loads in essential and non essential
- Is backup needed? - are there specific loads that always need power
- Auto transformer - for split phase systems (115Vac)





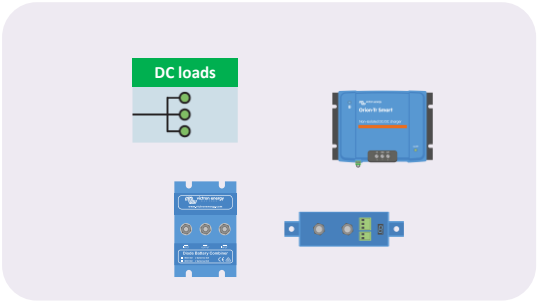
AC input

- Grid (shore power)
- Generator - ideally the same size or bigger than the inverter/charger
- AC current limit - how much power is available and when?
- AC Transfer switch - manual, automatic or use a Quattro
- Single phase, split phase or 3 phase - multiple phases need multiple inverter/chargers
- PV inverter connected to AC input?
- Feeding back into the grid - inverter/charger certification needed or use anti-islanding relay
- Isolation transformer or galvanic isolator - to stop galvanic corrosion in marine applications
- System bypass switch - what if there is a fault with the system?



DC output

- What is the power or current rating of the DC loads?
- When and how long do they run?
- Are there essential and non essential DC loads?



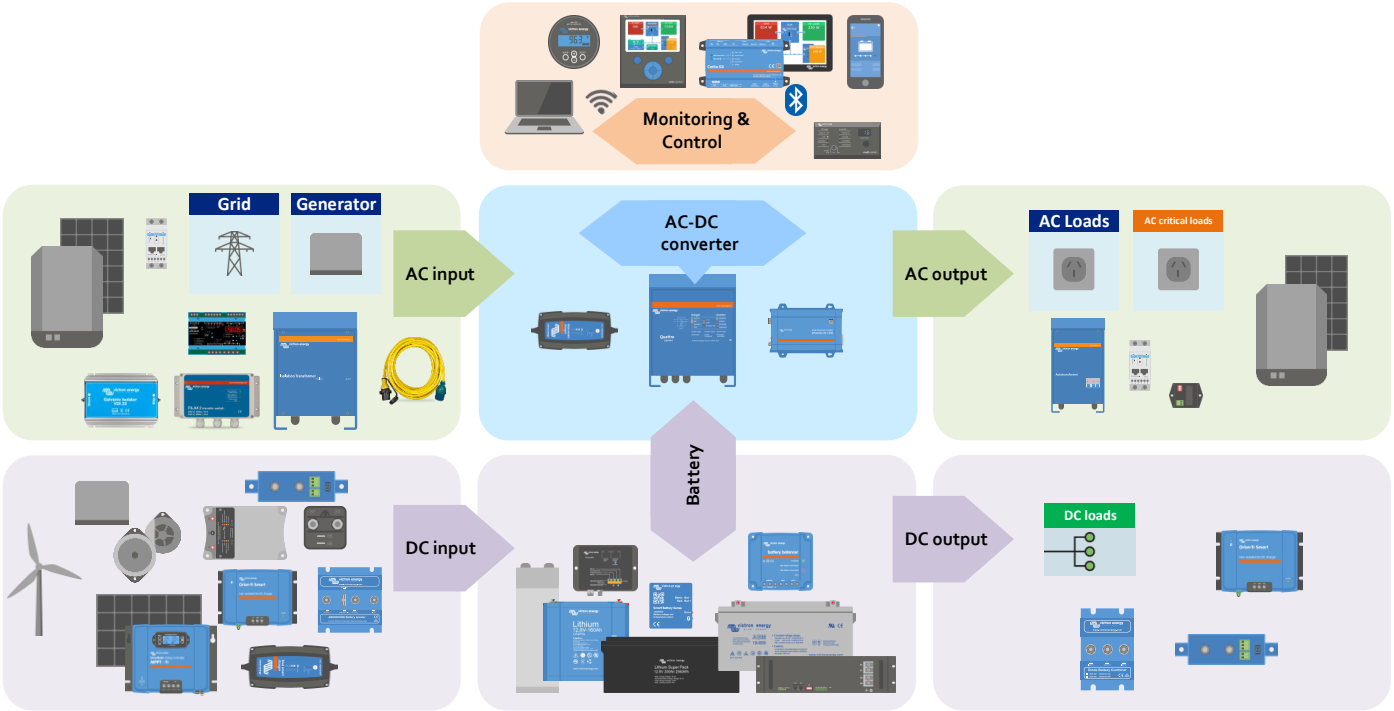
- Low battery protection - BatteryProtect
- Converting voltages, example 24VC system with 12V loads - Orion
- Are multiple battery banks powering the same DC load(s)?- diode combiner

Monitoring and control

- Full system monitoring
- Battery monitoring
- AC input monitoring - Energy meter
- PV inverter monitoring - Energy meter, current transformer or network communication
- Local or remote monitoring
- Is internet or a mobile phone network available

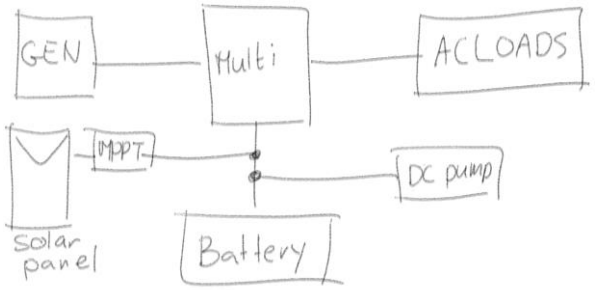
- Full control, limited control or multiple people access?
- Remotely control the system
- Do alarms need to be generated?
- Third party monitoring required - NMEA, Modbus or other systems
- Does equipment need to be turned on/or off by a remote signal?

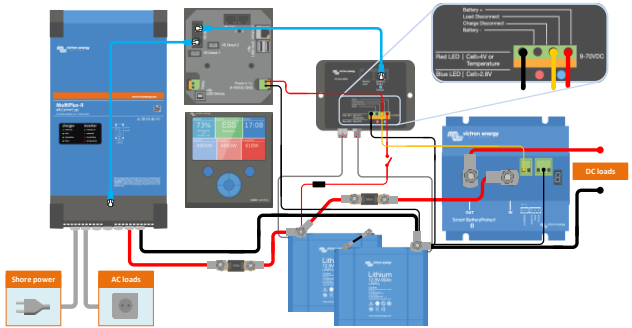
All system parts together



System block diagram

- A block diagram is needed to help you get the design right
- It can also be used to explain the system concept to the customer
- Perhaps add it to your quote?
- Can be a simple sketch or a properly drawn diagram





3. Calculations

Perform the calculations in this order

Step 1. Power out calculations:

- How big are the loads both AC and/or DC?
- When do they run?

Step 2. Inverter calculations:

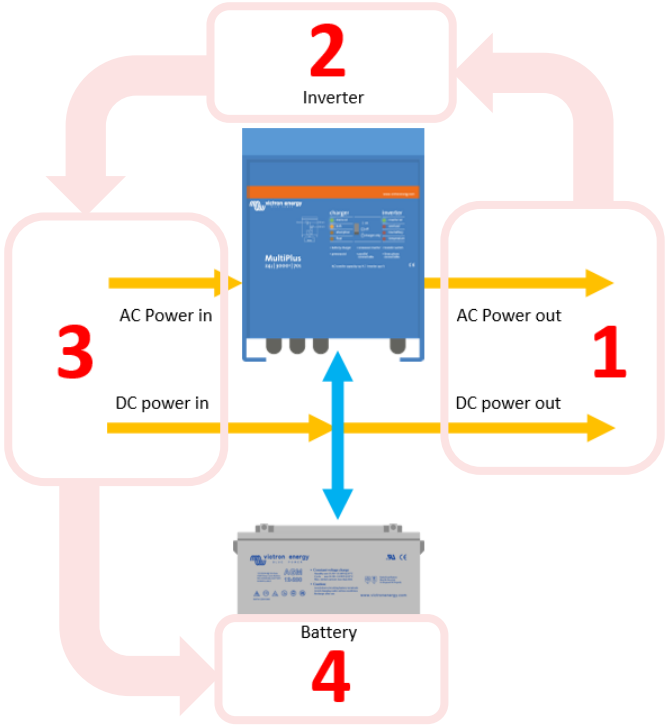
- The inverter needs to match the AC peak power requirements

Step 3. Power in calculations:

- How big are the AC
- When are they available?

Step 4. Battery calculations:

- Autonomy
- Depth of discharge
- Charge rate
- Discharge rate



Calculate in Watts

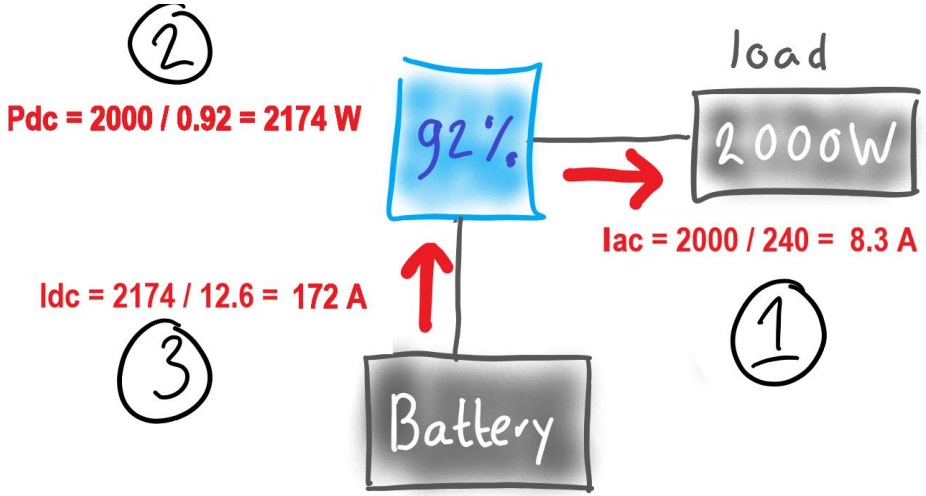
- When making system calculations, always calculate in power or energy
- In other words, always calculate in Watts or Watthours

Power:

- Watt = Volt x Amp
- kW = kilo Watt = 1000 W

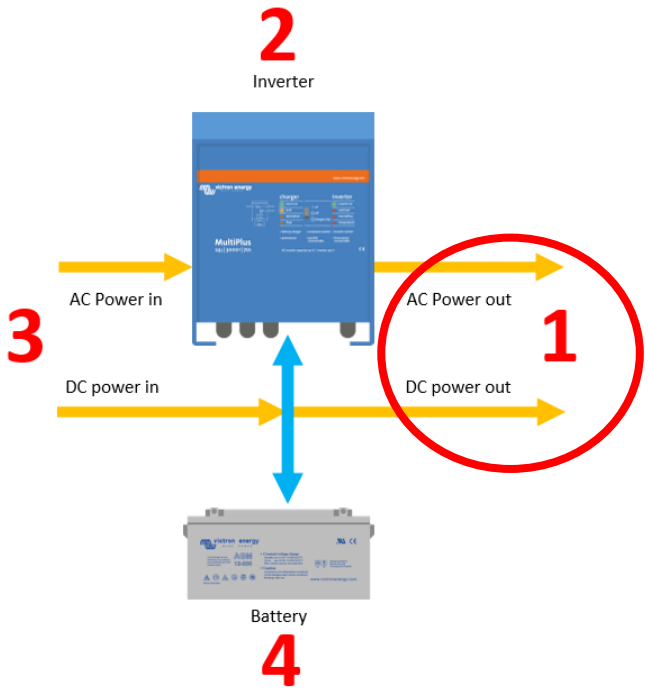
Energy

- Watthour = Watt x time
- kWh = kiloWatthour



Power out calculations

- Make a list of:
  - all AC loads
  - and all DC loads
- Determine how long these loads are running
- Ideally you will be able to get a kWh value



Calculation example

- Calculate the energy consumption of all loads over a 24h time span in Wh or kWh
- Do this for both the AC and the DC loads

AC microwave: 1200 W (from type plate on machine)
Running for 6 minutes a day
Energy usage 24 hours: 1200 x 0.1 = 120 Wh per 24h

AC fridge: yearly usage 279 kWh/annum (star rating)
Energy usage 24 hours: 279/365 = 764 Wh per 24h

DC Pump: 12V, 1.3A (from specification sheet)
running for 2 hours a day
Energy usage 24 hours: 12 x 1.3 x 2 = 46 Wh per 24h

Calculation example

- Add the 24h energy consumptions of all the AC and the DC loads
- This will result in the systems daily (24h) total energy consumption

AC Fridge	764 Wh per 24h
AC Microwave	120 Wh per 24h
AC lights	180 Wh per 24h
AC TV	300 Wh per 24h
DC radio	15 Wh per 24h
DC lights	400 Wh per 24h
DC pump	46 Wh per 24h
Total	1.8 kWh per 24h

Power consumption

- Be realistic on expected sources/loads
- Focus on major loads in the system and take the worst case scenario
- Be clear on budget and size and communicate this to you client before all work is started
- Talk about the systems limits with the customer and be aware of future loads being added
- To find out power consumption look at customers power bill or perhaps install an energy meter for a while
- For marine and RV system many online calculators exist

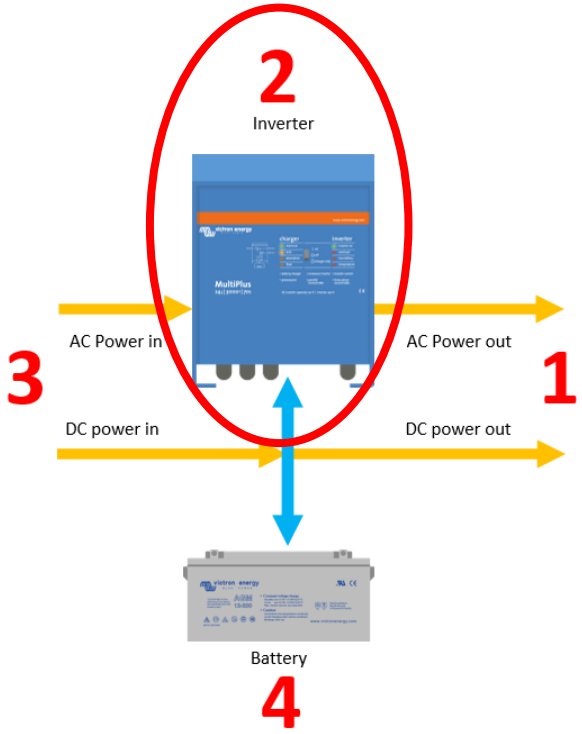
Load	Peak power (W)	Hours in use	Usage factor	Total energy (W/h)
Washing machine	2500	2	20%	1000
Lights	280	4	100%	1120
Fridge	120	24	30%	864
Pumps	7000	0.1	100%	700
Coffee maker	2000	0.3	100%	600
Total	11900		Total	4284

Inverter calculations

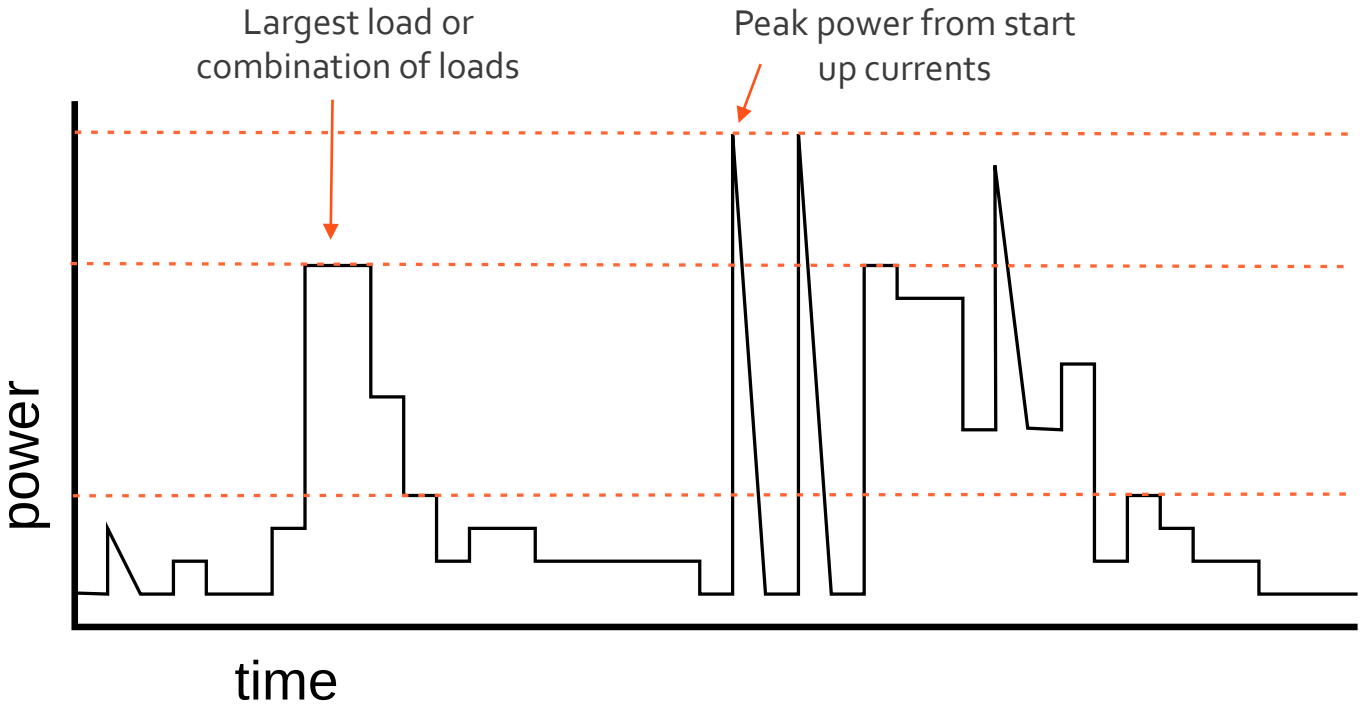
- Determine the peak power of the system
- This is equal to the loads that are running at the same time

- The peak load determines the inverter size

- Also look closer into loads that could have a high start up power, like compressors, air-conditioners and anything with an electromotor



System load graph



Peak load: This has to match the peak load capability of the Multi

Largest load: This determines the Multi size

Average daily load:

This average power consumed over 24 hours

Inverter size

- The inverter needs to be more powerful than the biggest load or a combination of loads that are running at the same time
- A good rule of thumb is to take the total peak power of a system and size the inverter to 80% of that

Example:

- 80% of 11,9 kW is 9kW.
- So select an 10 kVA inverter

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Washing machine	2500	2	20%	1000
Lights	280	4	100%	1120
Fridge	120	24	30%	864
Pumps	7000	0.1	100%	700
Coffee maker	2000	0.3	100%	600
Total	11900		Total	4284

Power in calculations

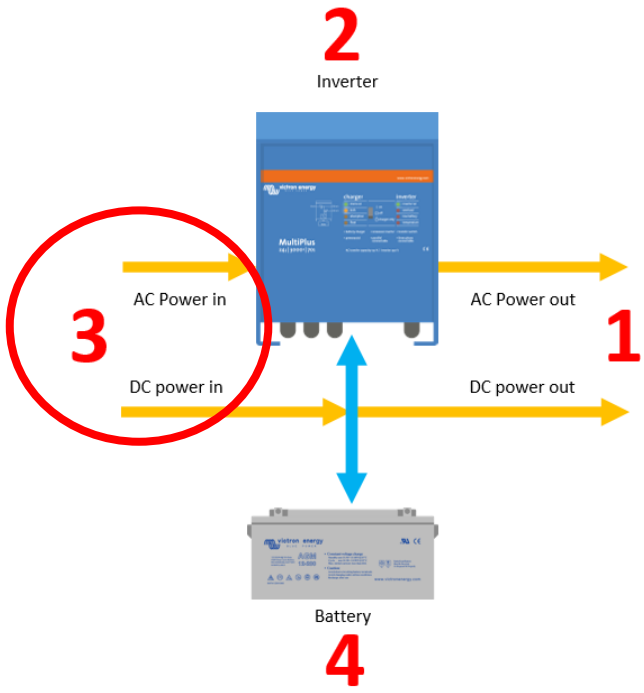
- Find out what type of power is coming into the system
- For how long is this available and at which times during a day

AC power:

- Generator, Grid or PV inverter

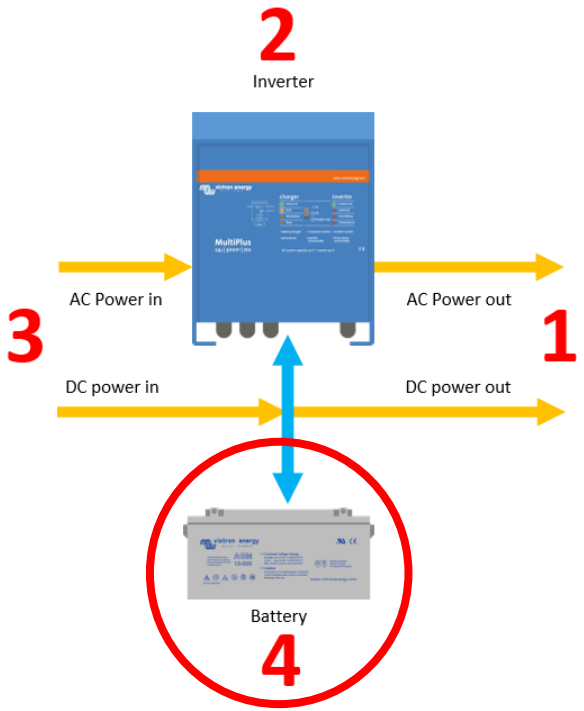
DC power

- Solar, wind, alternator, DC generator or other charge sources



Battery calculations

- System stand alone time
- Battery capacity
- Depth of discharge
- Charge and discharge rate
- How long to run AC and DC charge sources



Battery size is related to “stand alone” time

- The initial battery size is related to the stand alone time of the system
- This is the time during which there is no incoming power (AC or DC)
- This can be all the way from a few hours to a few days. It depends on the application

For example:

- A backup system that needs to ride out a small grid blackout
- A Marine or automotive system that is mobile and is only being charged when back at base
- A solar system that needs to have enough battery power to get past the night
- A fully autonomous solar system that needs to be able to ride out a few days of bad weather

Calculation example - Stand alone time is 24 hours

- Lead-acid batteries should generally not be discharged more than 50%
- Lithium batteries can be discharged lower

Using the earlier example system:

- The battery capacity that is needed to run the system for 24 hours without the need to charge is calculated as follows:

Power usage per day = 1800 Wh
This is for a 12V battery: 1800 / 12 = 150 Ah
Maximum 50 % discharge: 150 / 0.5 = 300Ah

Calculation example - Stand alone time is 3 days

- How long should this system be able to function without the need for charging?

Using the earlier example system:

- If a 3 day stand alone time is required this is the battery calculation:

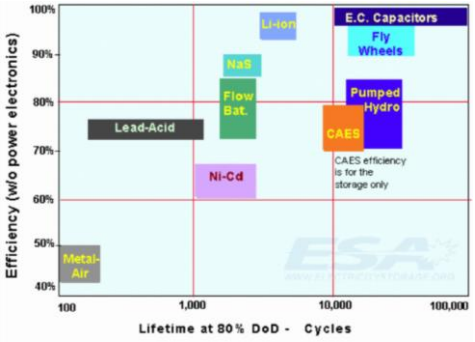
Stand alone time = 3 days:
Battery capacity for 1 day = 300 Ah
Battery capacity needed for 3 days = 3 x 300 = 900 Ah

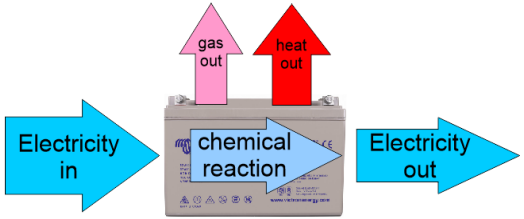
Battery recharging

- Eventually the battery needs to be recharged
- This is done by using the power in AC and DC sources, the main ones being Grid, Generator, Solar and/or Alternator

There are a few things to consider:

- AC battery charge efficiency
- Battery charge rate (maximum charge current)
- Battery charge and discharge efficiencies (round trip lead-acid is 75 to 85% and lithium is 95 to 99%)





Charge current calculation example

- For a lead acid battery the charge current should be 10-20% of the battery capacity C10 (= 0.1C)
- Lithium batteries can deal with much larger charge and discharge currents, close to 100% of the battery capacity (1C)

Calculation example for a 900Ah battery bank:

Charge current 10% of capacity: 900 x 0.1 = 90A

- This current will recharge the batteries in 5 hours if the battery was 50% discharged

Grid or Generator as charge source

- Charging from an inverter/charger or a battery charger connected to the grid or a generator

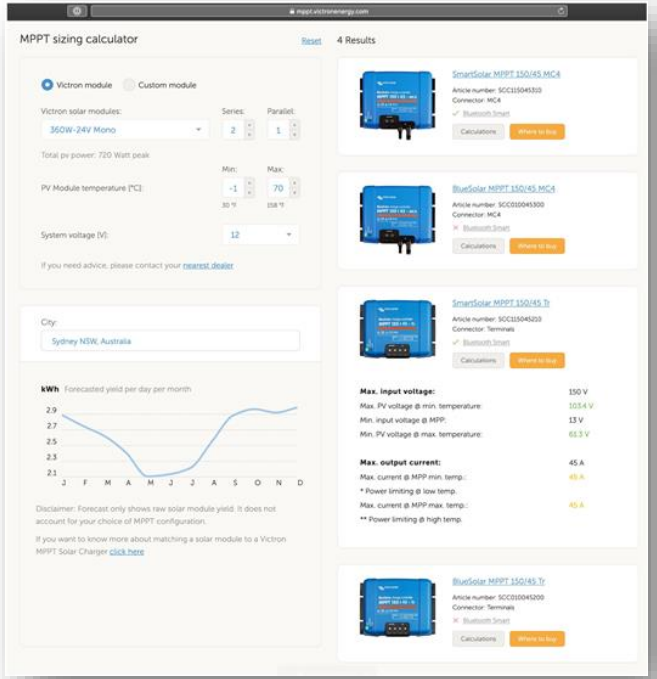
Calculation example:

A 900 Ah 12V battery is 50% discharged	900Ah x 0.5 = 450Ah
Recharging at 90A will take 5 hours	540Ah / 90A = 5h
Power needed is:	90A x 12V = 1080W
Energy needed is:	1080W x 5h = 5.4kWh
Battery charger efficiency is 80%	
Power rating of the AC source should at least be:	1080W x 1.2 = 1.3kW
AC current required is:	1.3kW / 230V = 5.7 A
Energy required from AC is	1.3kW x 5h= 6.5 kWh

Solar as charge source

- Sizing a solar array and MPPT is more difficult and variable
- The Victron MPPT calculator can help you with calculations
- In our calculation example, for 24h stand alone time, a minimum solar input of 2 kWh each day is required
- Always calculate for winter
- If a 3 day stand alone time is required you will need to generate 6kWh (needed for places with very bad weather)
- An alternative could also be to run a generator for longer

- For more information also see the: Victron off grid and backup system design planning tool



Equipment sizing

Datasheet

- Always consult the datasheets of all the equipment used in the system
- The nominal load rating has to match the actual load
- The nominal current rating has to match the actual current
- Maximum power, current or voltage requirements need to be adhered to

MultiPlus	12 Volt 24 Volt 48 Volt	C 12/800/35 C 24/ 800/16
PowerControl		Yes
PowerAssist		Yes
Transfer switch (A)		16
Input voltage range (V DC)		
Output		
Cont. output power at 25°C (VA) (3)		800
Cont. output power at 25°C (W)		700
Cont. output power at 40°C (W)		650
Cont. output power at 65°C (W)		400
Peak power (W)		1600
Maximum efficiency (%)		92 / 94
Zero load power (W)		8 / 10
Zero load power in AES mode (W)		5 / 8
Zero load power in Search mode (W)		2 / 3

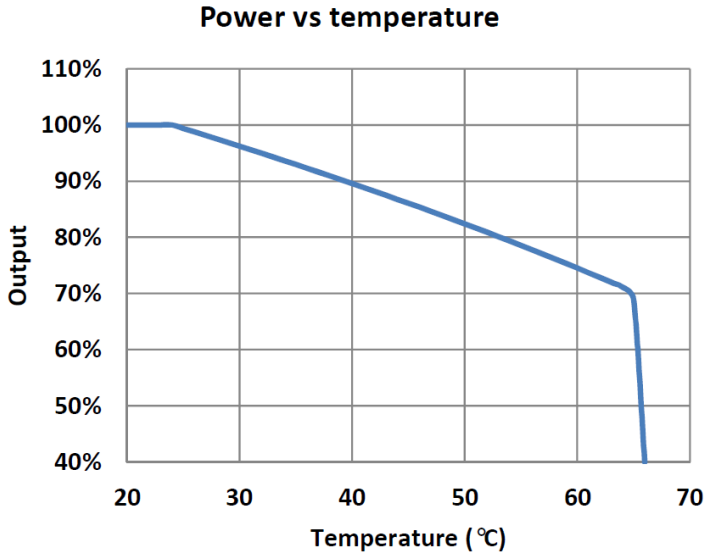
SmartSolar Charge Controller	150/45	150/60
Battery voltage		12 / 24 / 48V Auto Sele
Rated charge current	45A	60A
Nominal PV power, 12V 1a,b)	650W	860W
Nominal PV power, 24V 1a,b)	1300W	1720W
Nominal PV power, 36V 1a,b)	1950W	2580W
Nominal PV power, 48V 1a,b)	2600W	3440W
Max. PV short circuit current 2)		50A (max 30A per MC4 conn.)

Smart BatteryProtect		Smart BP-65	Smart BP-100	Smart BP-220
Maximum continuous load current*		65A	100A	220A
Peak current (during 30 seconds)		250A	600A	600A
Operating voltage range		6 –35V		
Current consumption	BLE On	When on: 1,4 mA When off or low voltage shutdown: 0,9 mA		
	BLE Off	When on: 1,2 mA When off or low voltage shutdown: 0,7 mA		
Alarm output delay		12 seconds		
Maximum load on alarm output		50 mA (short circuit proof)		
Load disconnect delay		90 seconds (immediate if triggered by the VE.Bus BMS)		
Load reconnect delay		30 seconds		
Default thresholds		Disengage: 10,5V or 21V Engage: 12V or 24V		
Operating temperature range		Full load: -40°C to +40°C (up to 60% of nominal load at 50°C)		

Temperature deration

- When calculating equipment size always take the temperature deration into consideration
- Take the worst scenario ambient temperature that the system is going to be in
- The deration is based on equipment temperature
- Ambient heat also plays a role in this
- Keep in mind that the inverter generates heat during operation and this heat needs to dissipate

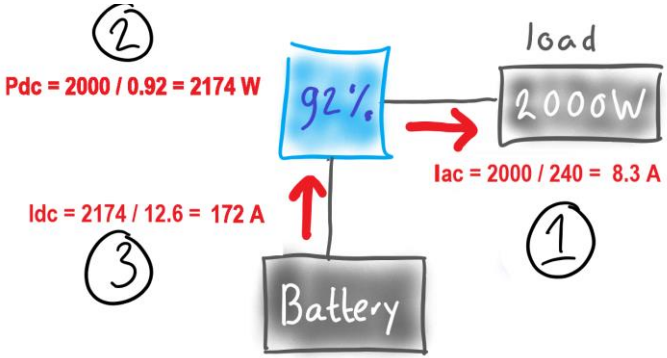
Cont. output power at 25°C (VA) (2)	1200
Cont. output power at 25°C (W)	1000
Cont. output power at 40°C (W)	900
Cont. output power at 65°C (W)	600



Fuses and circuit breakers

- Different currents at different voltages
- Both AC and DC need fuses
- Pick the correct fuse ratings
- See the product manual:

	24/5000/120	48/5000/70
Recommended battery capacity (Ah)	400–1400	200–800
Recommended DC fuse	400A	200A
Recommended cross section (mm^2) per + and - connection terminal		
0 – 5 m	2x 50 mm^2	1x 70 mm^2
5 – 10 m	2x 90 mm^2	2x 70 mm^2



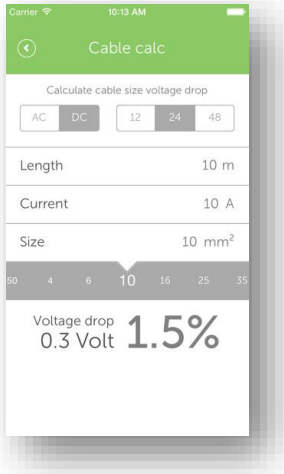
- Fuse according your local wiring regulations
- For background information see the Wiring unlimited book.

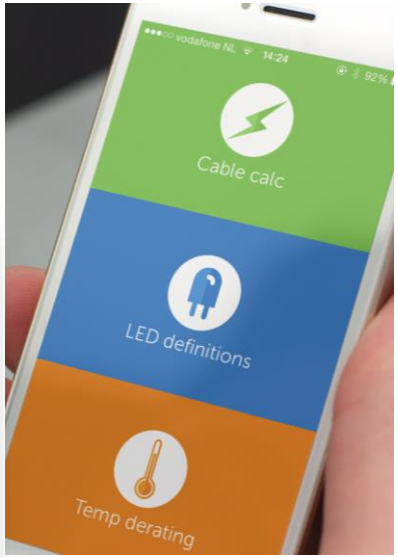
Cabling

- See the product manual for recommended cables:

	12/3000/120	24/3000/70	48/3000/35
Recommended battery capacity (Ah)	400–1200	200–700	100–400
Recommended DC fuse	400A	300A	125A
Recommended cross section (mm^2) per + and - connection terminal			
0 – 5 m	2x 50 mm^2	50 mm^2	35 mm^2
5 – 10 m	2x 70 mm^2	2x 50 mm^2	2x 35 mm^2

- If not in manual then use the Victron Toolkit App
- Wire according your local wiring regulations
- For background information see the Wiring unlimited book



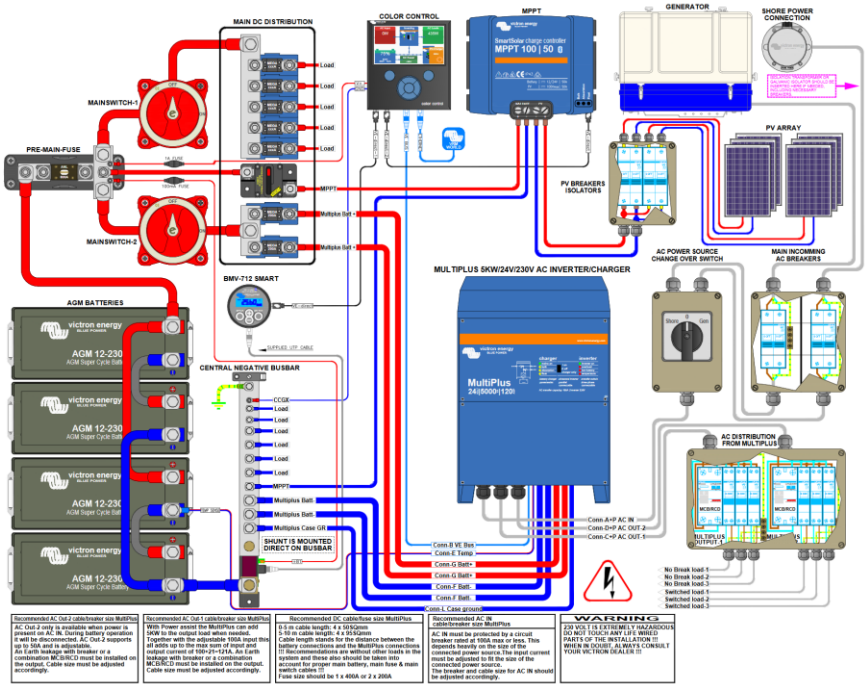


System wiring diagram

- Is used to specify the system
- Is used by the electrician to install system

Should contain:

- System components
- Wiring dimensions
- Fuses and circuit breakers
- Part lists



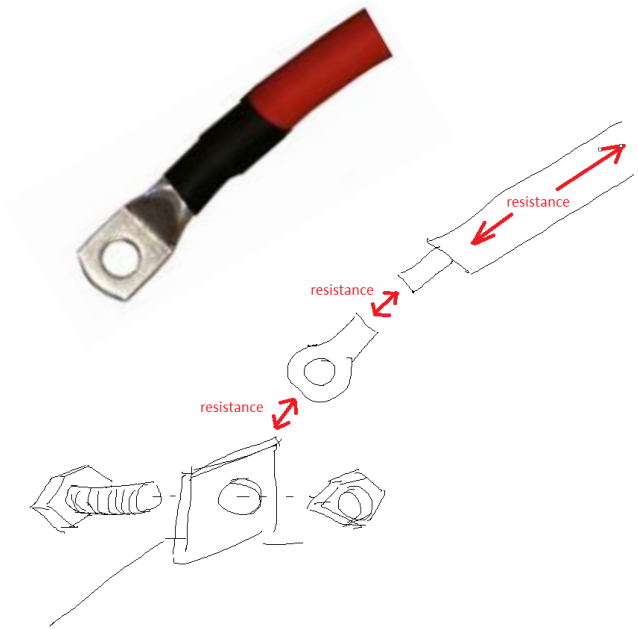
4. Installation

Wiring

- Always use correct cable with correct cable core thickness as recommended by the product manual

- Always use cable terminals suitable for the application
- Use correct crimping tools

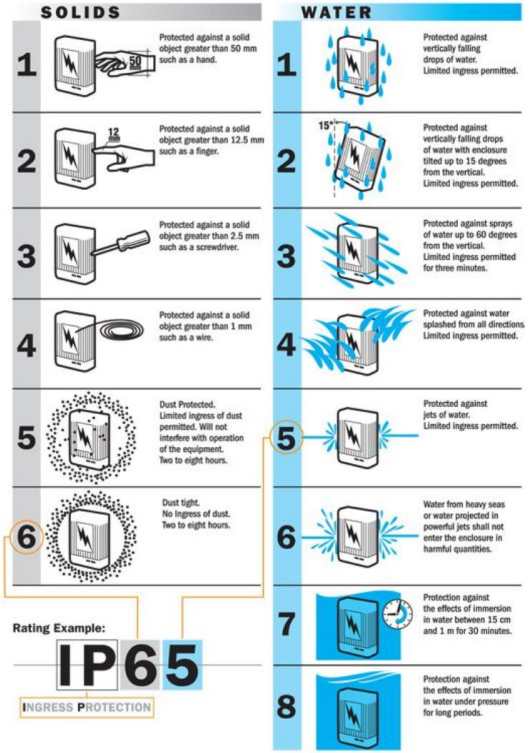
- When tightening connections, use correct torque (see manual)
- For background information see the Wiring unlimited book



IP rating

- Indoor or outdoor use?
- Choose the correct IP rating
- See the manual for recommendations

- IP21 and IP22 = indoor only
- IP44 = protected against water splashes
- IP65 = protected against jets of water
- IP 67 = protected against immersion

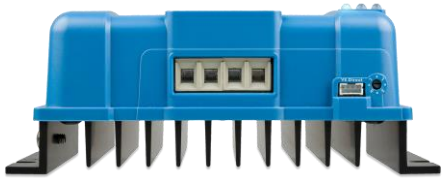


Mounting

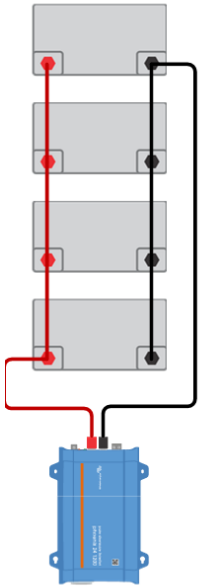
- Follow the product manual
- Do not mount electronics directly above lead-acid batteries
- Use provided mounting materials
- Some product have special mounting brackets
- Use shock mounts in severe vibrating environments

Cooling

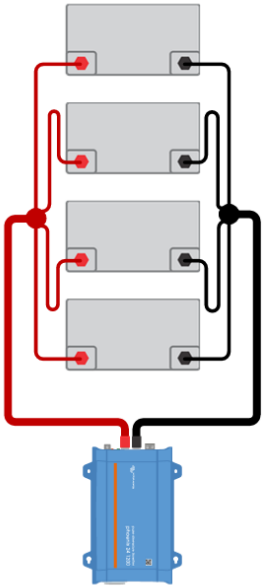
- Follow the product manual
- Keep things cool, this is important for all electronic equipment as well as for batteries
- Heat will reduce power output and will reduce lifetime
- Keep gaps between equipment and also between batteries in a battery bank
- Allow for airflow past and around electronic equipment
- Mount cooling fins in the right direction, remember hot air rises
- Install air conditioning
- Use natural convection or forced airflow
- Extract hot air from enclosures, use venting grills and /or mechanical air extraction
- Provide shade



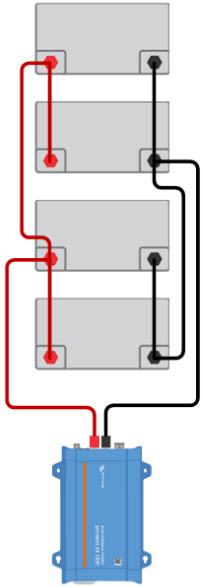
Correct battery bank wiring



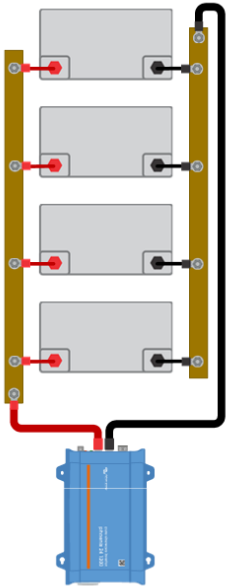
Diagonally



Posts



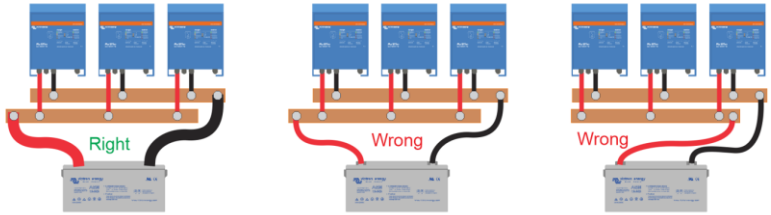
Halfway

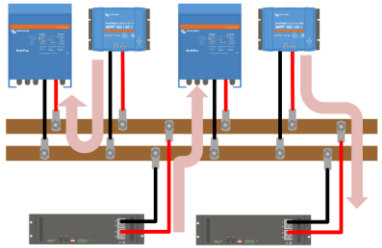


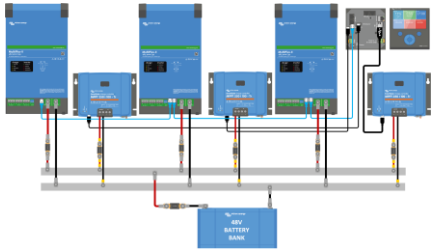
Busbars

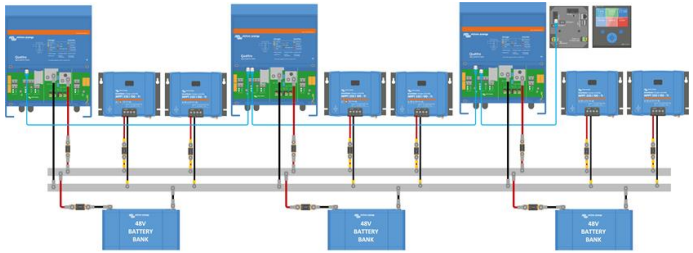
Busbars

- The core surface area of the cable from battery to busbar must equal the sum of the cables form busbar to DC equipment
- Cross connect the busbar
- Intermix batteries and DC loads on the bus









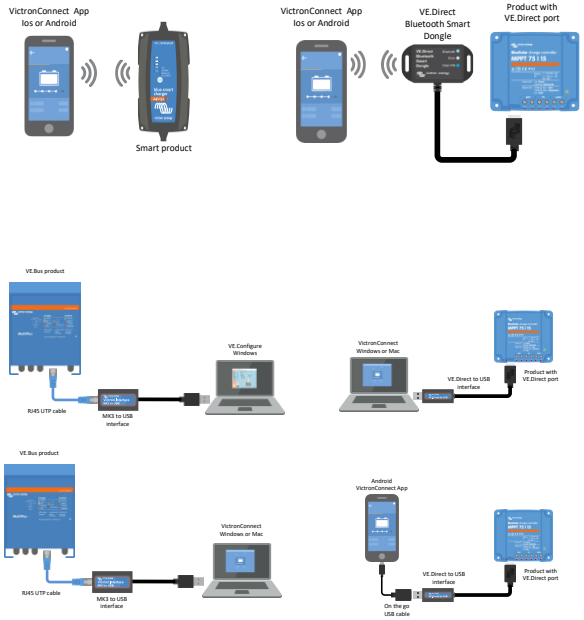
5. Configuration

Configurating and making settings

- See the manual on what settings can be made for each product and how to do this

Generally speaking:

- For VE.Direct, VE.Bus and Smart products use VictronConnect
- And for advanced Multiplus and Quattro settings use VE.Configure
- Be aware that a special interface might be needed
- For more info on configuration and setting see past webinars



6. Commissioning

Test the system before signing off

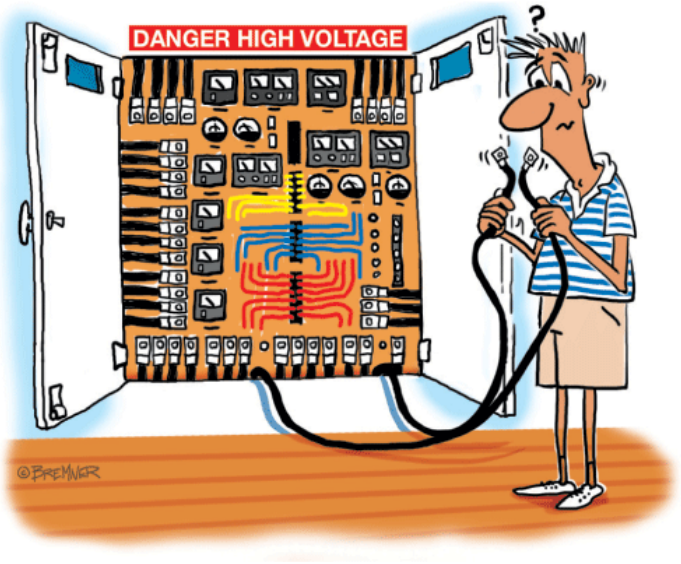
- Run system at full load - test run all individual AC and DC loads
- Fully charge the batteries - this is needed for SOC synchronisation
- Disconnect AC input and reconnect AC input - simulate a blackout
- Run generator at no load and full load - check that Multi keeps accepting the generator
- Run alternator and the other DC input sources
- Save a copy of all VictronConnect and/or VEConfigure settings
- Take photos of the installation once testing is complete
- Demonstrate the system to end user and get it signed-off

When seeking support

Contact your Victron dealer or distributor

Before seeking support:

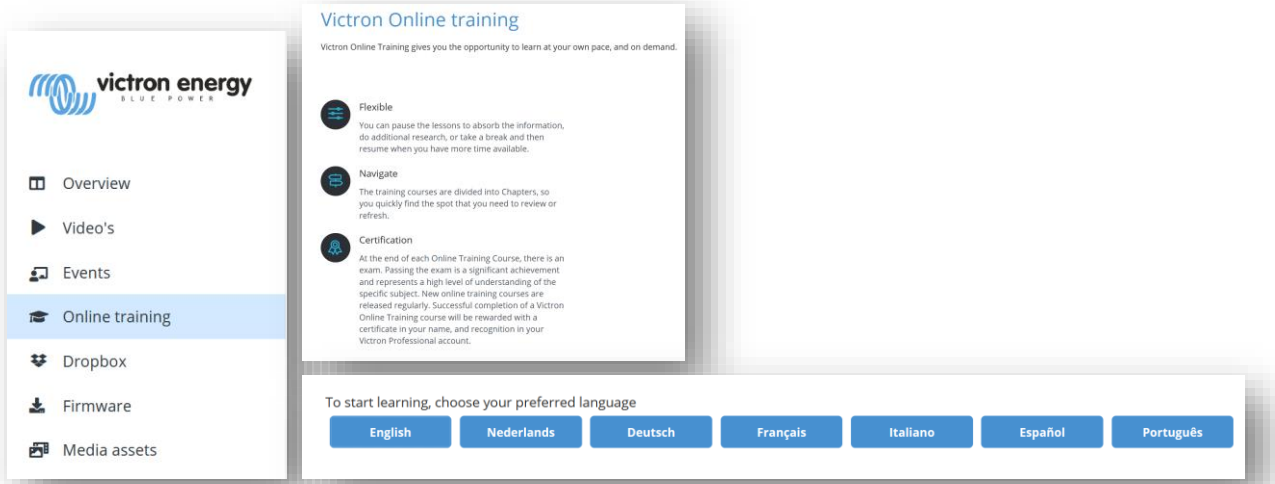
- Make sure all products have up to date firmware
- Save a copy of the VEConfigure and VictronConnect settings
- VRM site details
- Describe the system
- Describe the fault
- Make note of alarm LEDs and/ or CCGX error codes
- Prepare photos of the installation and the initial commissioning test results

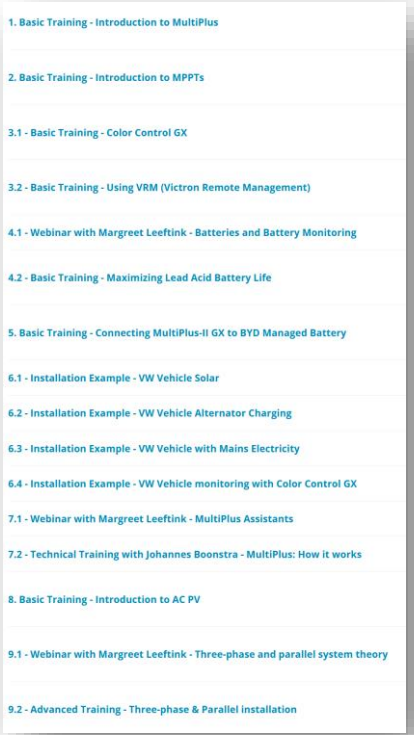


7. Training and more information

Victron Professional Training

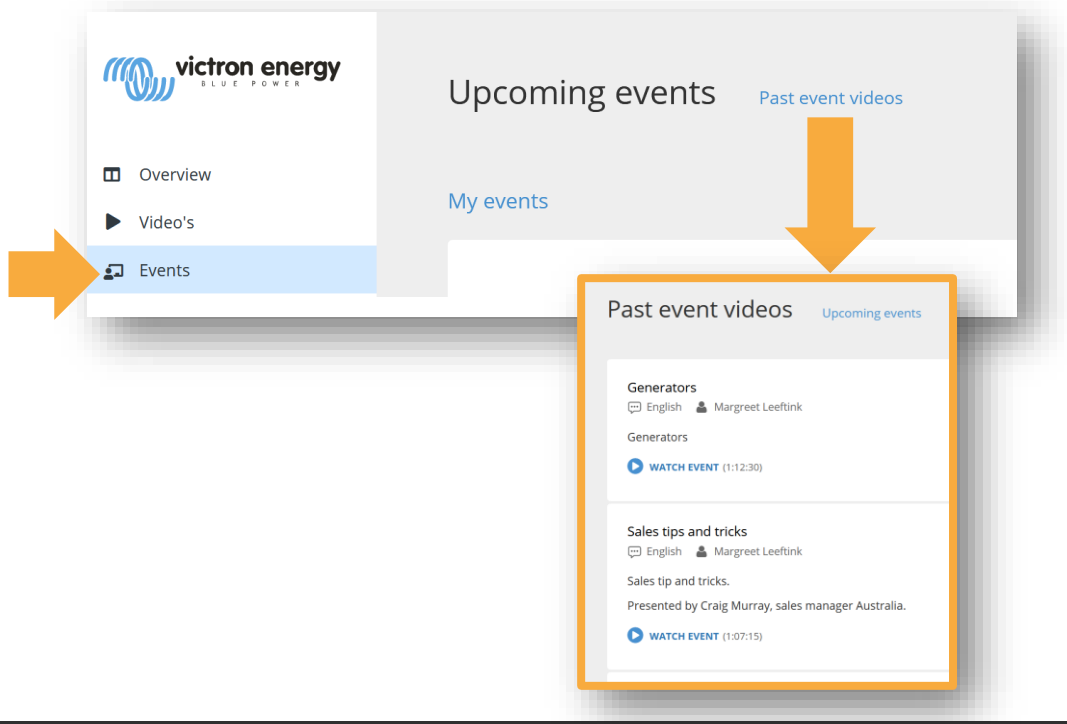
- Many to choose from
- Training is available in a variety of languages





Recordings of this webinar and past webinars

- Go to Victron Professional
- Click on events
- Click on “Past event videos” link in top right hand corner



UN system in Kazakhstan

Practical example microgrid Kathmandu, Nepal,

6 x 8 kVA Quattros

6 x 150/85 CAN MPPT

1 x CCGX

25 kW PV array

4000 Ah Battery bank

120 electricity poles, 4 kilometres of power lines

victron energy
BLUE POWER

Energy. Anytime. Anywhere.

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