Achieving the impossible

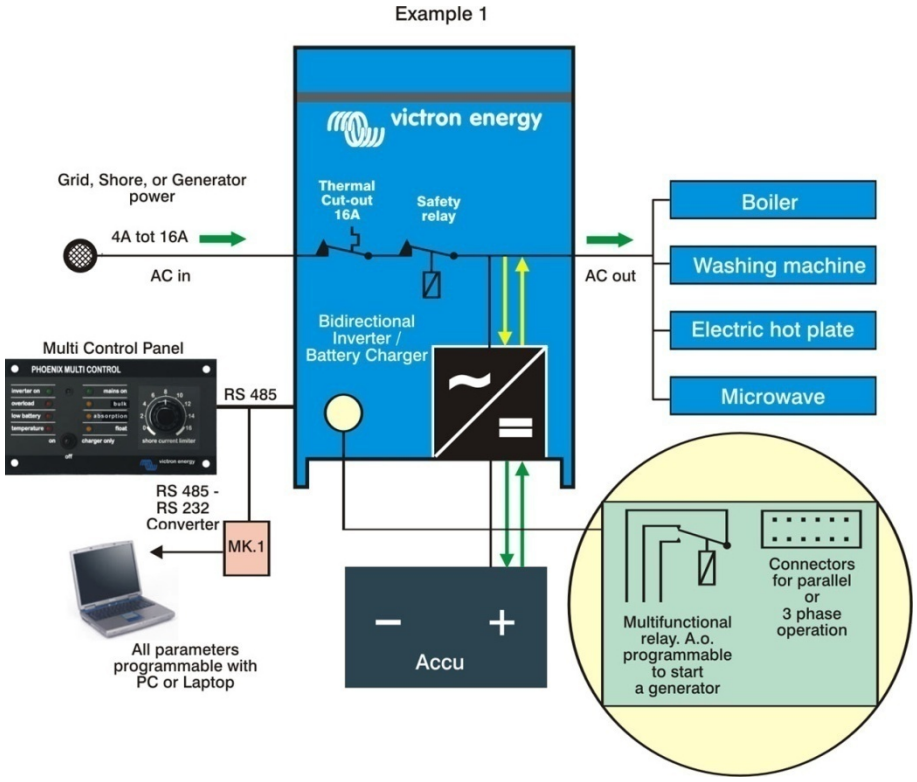
Taking control of shore power with the Phoenix Multi/MultiPlus fromVictron Energy

Sometimes the features of a new product are so unique that the benefits are difficult to understand or simply denied. The Phoenix MultiPlus is such a product.

The purpose of this paper is to step by step clarify the many features of the Phoenix Multi/MultiPlus.
Think of a situation where electricity from the grid or a generator is not available or limited in power. Think of boats, mobile homes, trucks, service vans, remote communication systems or off-grid houses. All too often shore power in the marina or on the camping ground is limited. All too often small gensets are a headache because of premature failure or frequent maintenance.
The Phoenix Multi/MultiPlus solves these problems.

1. The block diagram of the Phoenix Multi and MultiPlus (M/M+)

The most important components and features:



1.1 The bidirectional converter

The M/M+ is built around a bidirectional converter, that operates as an inverter or as a battery charger.
The converter of the M+ does more than a conventional bidirectional converter: it operates in parallel with the grid, with shore power or with a genset. It can add power to AC supply (with energy from the battery) and it will use surplus power to recharge. In most cases the M+ will also reduce the harmonic distortion of the genset voltage (this can be important for certain sensitive loads such as an induction cooker)

1.2 A multifunctional relay
This relay can a. o. be programmed to start a generator based on power demand and / or battery voltage.

1.3 A RS485 port
All parameters of the M/M+ are programmable.
The most important parameters can be programmed with a push button code, but it is much more convenient to use the MK.1 RS485 to RS232 converter, VEConfigure software (downloadable from our website) and a PC Notebook computer.
Examples of programmable parameters:
- inverter DC voltage cut out
- charge curve
- maximum charge current
- parallel operation and 3 phase operation
- programming the multifunctional relay

1.4 Connector for parallel operation and 3 phase operation
Up to 6 Multis can be parallel-connected to increase power to 15 kW.
In 3 phase configuration up to 18 Multis can be used to build a 45 kW inverter / charger!

1.5 AC input with 16 Amp thermal breaker and safety relay
The maximum AC input current of the M/M+ is 16 A. The safety relay makes sure that no dangerous AC voltage will be present on for example the shore power plug when disconnected.

1.6 The Multi Control Panel (16 A or 30 A)
The rotary knob on this panel is crucial: with this knob the maximum AC input current can be set, to a maximum of 16 A or 32 A.

1.7 AC output
To connect the AC appliances

1.8 The drawbacks of a conventional combined inverter / charger
A conventional "combi" will operate as an inverter when there is no AC input voltage present, and as a battery charger when AC is available. That's it.
When AC is available the input current will be the current drawn by the battery charger **plus** the current taken by the connected AC appliances. A powerful battery charger draws a lot of current: a 24 V 70 A charger for example will take nearly 10 A from the AC supply. When connected to a 16 A socket only 6 A will be left for the remaining AC equipment on board.
The result is that a powerful combi will trip a 16 A circuit breaker as soon as some household equipment is switched on
(a high output battery charger will have the same effect)

1.9 PowerControl: how the Phoenix Multi solves the problem described in par. 1.8.
The Phoenix Multi measures the AC input current and gives priority to the connected AC equipment. The PowerControl function makes sure that only whatever current is "left over" is used to charge the batteries. This will be explained below with several examples.

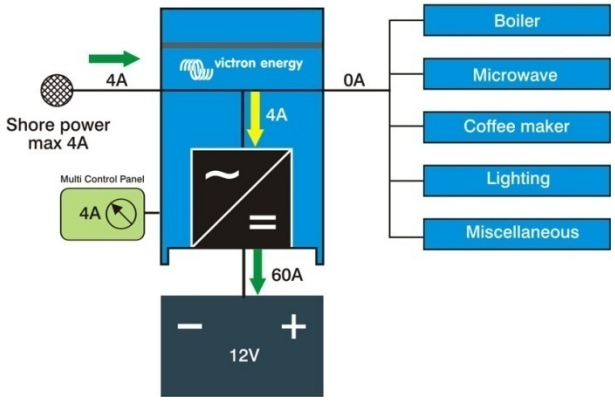
1.10 PowerAssist: this function, unique to the MultiPlus, takes PowerControl to a further dimension, allowing the MultiPlus to supplement the capacity of the AC source.
This is where we "achieved the impossible": the bidirectional converter of the MultiPlus operates in parallel with the AC input and will add current (with energy from the battery) whenever demand exceeds the capacity of the supply!

More power needed than the AC supply permits? The MultiPlus will supply the difference with power taken from the battery.
Has the load been reduced? The MultiPlus will use any surplus power to recharge the battery.

2. How it works in practice

Below are several examples to clarify the benefit of PowerControl (available on both the Multi and the MultiPlus) and of PowerAssist (MultiPlus only).
For the first examples we assume an AC supply limited to max. 4 A.
To make it work the input current limit should be set at 4 A on the Multi Control Panel.

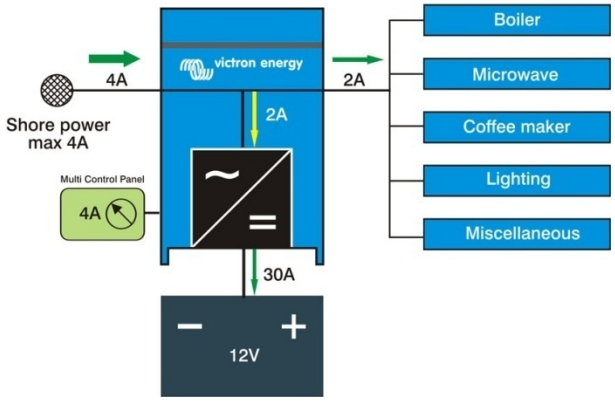
Example 2.1



Example 2.1

In this example all AC loads are off. With the Multi Control Panel set at 4 A the converter will not take more than 4 A, which limits the battery charge current to about 60 A.

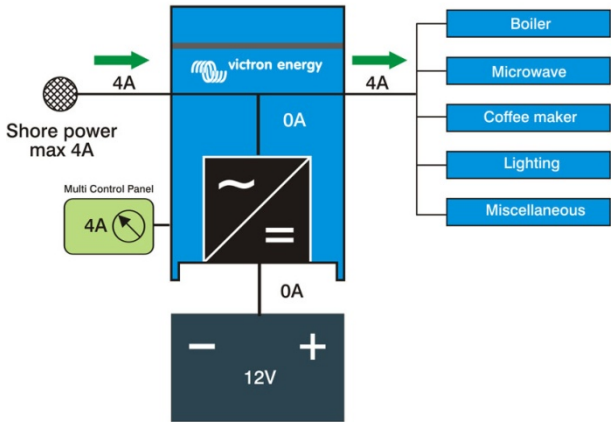
Example 2.2



Example 2.2

Now some small loads are switched on and the load increases to 2 A. Only 4 – 2 = 2 A is left to charge the batteries and the charge current is reduced to about. 30 A. Shore current is automatically limited to 4 A and the circuit breaker will not trip!

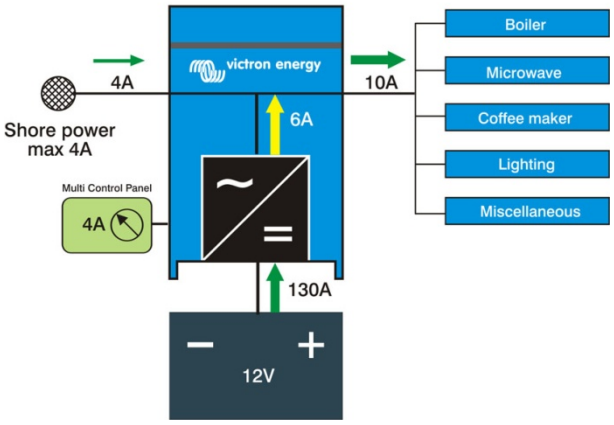
Example 2.3



Example 2.3

The coffee machine is switched on and current consumption increases to 4 A. Nothing is left to charge the batteries: the charge current is automatically reduced to 0. And again: the shore current circuit breaker does not trip!

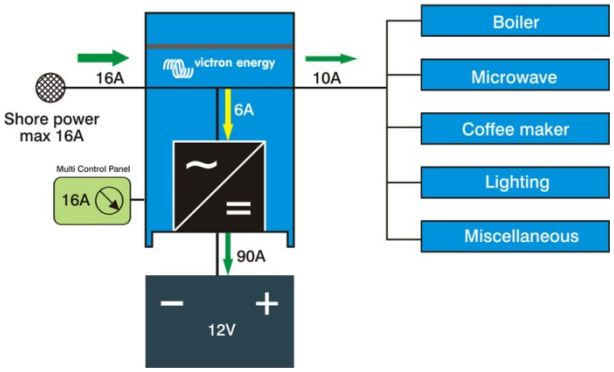
Example 2.4



Example 2.4

And now the impossible happens: the water heater switches on and the current increases to 10 A.
This is where PowerAssist (available on the MultiPlus only) is needed. The bidirectional converter starts operating as inverter to add 6 A to the 4 A that is available from the shore-side: total 6 + 4 = 10 A, and no overload on the AC supply!
As soon as the load reduces to less than 4 A any current that is left over will be used to recharge the battery.

Example 2.5



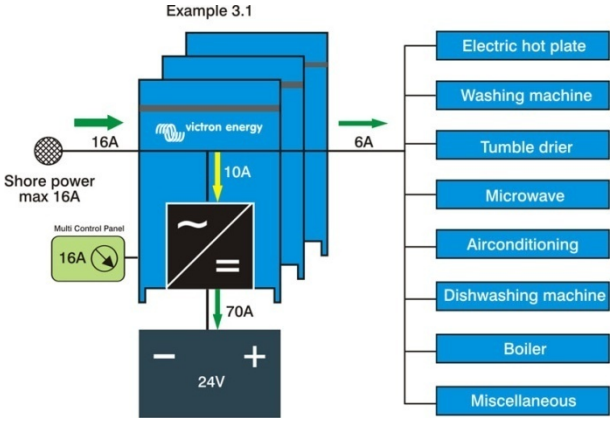
Example 2.5

In this example a 16 A supply is assumed. On the Multi Control Panel the current limit can now be set at 16 A.
The logic remains the same: with 16 A available and 10 A load, 6 – 10 = 6 A is left over, which results in a maximum charge current of 90 A.

3. More power needed: parallel operation

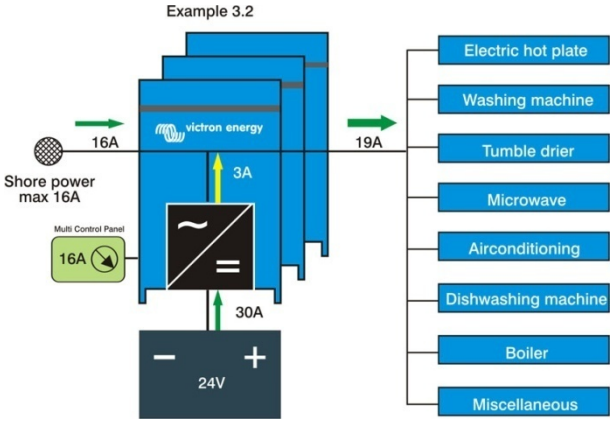
With a washing machine on board (and possibly also a dishwasher, electric cooker, oven and air conditioning) the current needed will increase to much more than 16 A.
What to do?
One solution is a stronger AC power supply. But more than 16 A shore power is not always easy to find, and berths for mega yachts are expensive!

Why not installing a set of parallel Multi's as shown in the examples below?



Example 3.1

In this example 3 Multis 24/3000/70 are operating in parallel. The AC supply is rated at 16 A and therefore the Multi Control Panel is also set at 16 A.
When power demand is low (during the night for ex.) the batteries will be charged. With 6 A needed for different loads, 16 – 6 = 10 A is left over. Therefore the batteries will be charged at max. 70 A. This is much less than the maximum charge current of 3 x 70 = 210 A the 3 Multis are capable of, but then the shore side circuit breaker would trip immediately!



Example 3.2

Turning on the washing machine (current 13 A) will, during a short period, increase the load to 6 + 13 = 19 A. PowerAssist is now needed to supply the missing 3 A. This is made possible by installing 1 MultiPlus (as Master) and 2 Multis (as Slave). The complete set of 3 units will then have PowerAssist functionality.
And again: the load is 19 A but the supply is only 16 !

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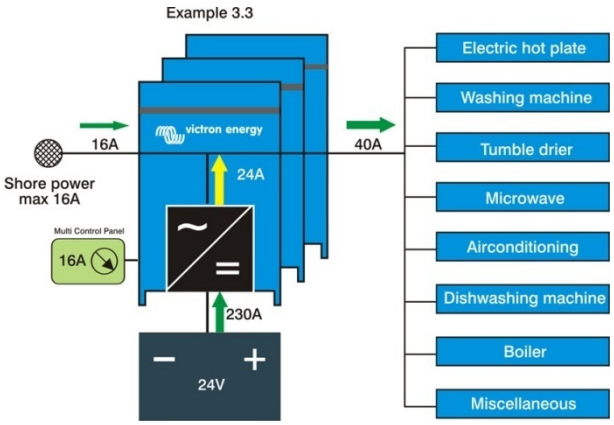
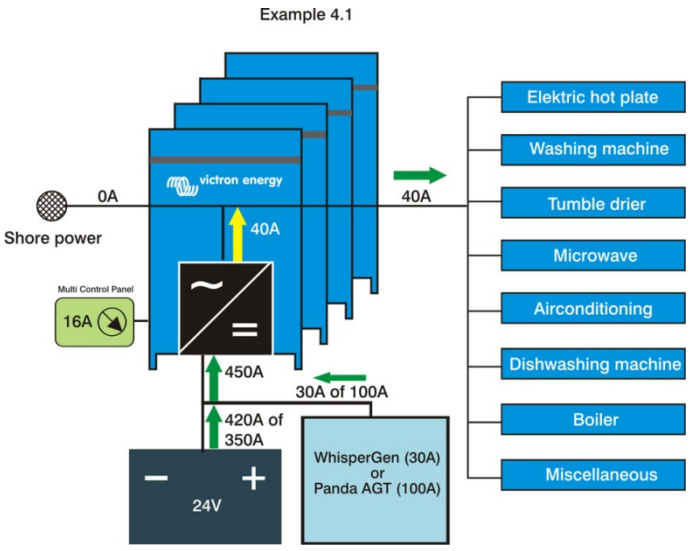


Example 3.3

The power needed will increase dramatically as soon as more household equipment is switched on, or when the electric cooker is in use. The AC current will peak to 40 A or more. Now the Multis must supply an additional 40 – 16 = 24 A to the AC source and the batteries will be discharged at a rate of some 230 A. It may be hard to believe but the total discharge of the batteries, measured in Ampere-hours (Ah), will nevertheless be limited. This is because a cooker or washing machine does need a lot of power during only a short period. Practice has shown that 16 A shore current is, on average, more than sufficient for big yachts and or luxury mobile homes. It is only when continuous power requirement increases (due for ex. to air conditioning) that a more powerful supply will be needed.
Please refer to our book "Electricity on Board" for detailed battery capacity calculations.

4. A DC genset on board

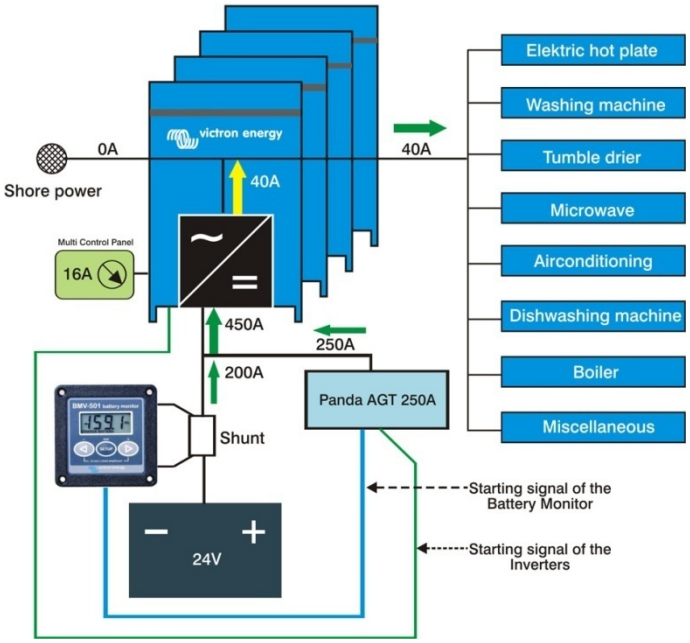
When no AC supply is available (no shore current, because the yacht is sailing) the Multis will operate as inverters and the DC genset will charge the batteries.



Example 4.1: maximum power required 7 kW, average load 700 W

If a lot of power is required for a short period only, a WhisperGen or a small Fischer Panda DC generator will easily supply the average load. Please refer to our book "Electricity on Board" for more examples

Example 4.2

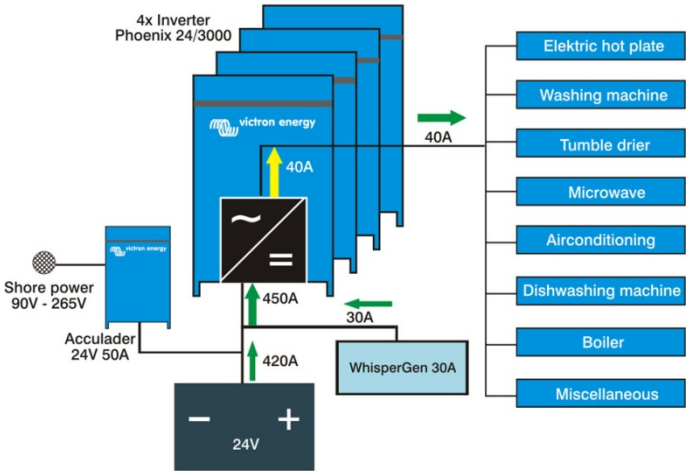


Example 4.2: maximum power required 7 kW, average load 2 kW

Intensive use of air conditioning will raise power consumption beyond the capacity of the WhisperGen. A powerful DC generator will be needed to keep running hours and noise within acceptable limits.
The multifunctional relay of the Multi can be used to automatically start the generator in case of high power demand. In addition our BMV-501 battery monitor may be used to start the generator once the batteries have been discharged to a pre-set percentage.
Complete wiring diagrams can be found on our website www.victronenergy.com.

A remark about 3 phase electric motors to drive pumps, a diving compressor or air conditioning:
Three phase motors of up to 3 kW can be connected to a single phase supply by adding a 3 phase motor drive with single phase input. The motor drive then takes care of 3 phase to 1 phase conversion and will also reduce start-up current.

Example 4.3



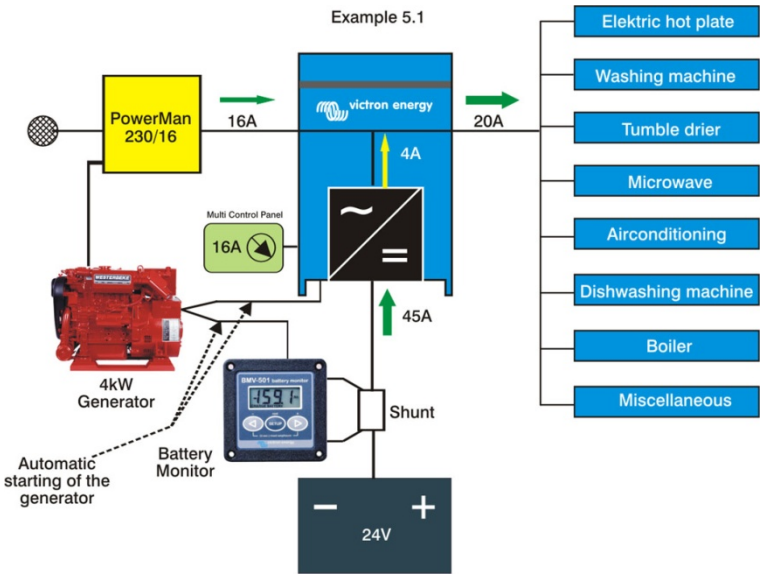
Example 4.3: An alternative solution, using inverters and battery chargers

The maximum AC supply current can also be controlled when only battery chargers are connected to it. All AC equipment should then be supplied by the inverters and the batteries are again used to absorb periods of high power demand.
Using battery chargers with universal 90 to 265 V input capability will make sure that a yacht can connect to any shore power supply anywhere in the world.

5. **How it works with an AC generator**

PowerAssist can also be used to boost the output of an AC genset. Next to reducing size and weight of the genset this also has the following advantages:

- In most cases the harmonic distortion of the genset output will be reduced (this can be important for certain sensitive loads such as an induction cooker)
- Because the generator can be reduced in size the load in % of its rated power will increase. This will improve efficiency and increase service life.



Example 5.1: maximum power required 2.5 kW

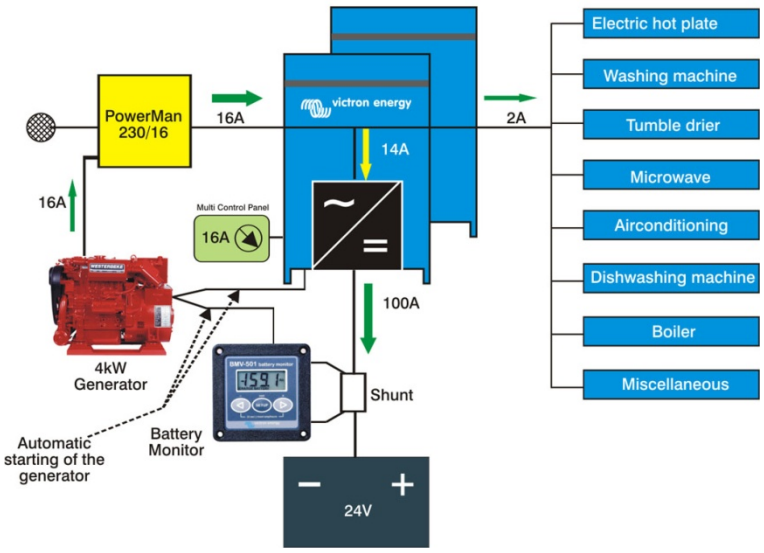
A lot can be achieved with a simple and compact system. As long as either the shore supply is available or the generator is running, the system can supply up to 26 A of AC current, which amounts to 6 kW. (the shore or genset supplies up to 16 A, to which the Phoenix MultiPlus will add up to 10 A)
And the batteries will be recharged as soon the load reduces to less 16 A.

Important building blocks of the system:

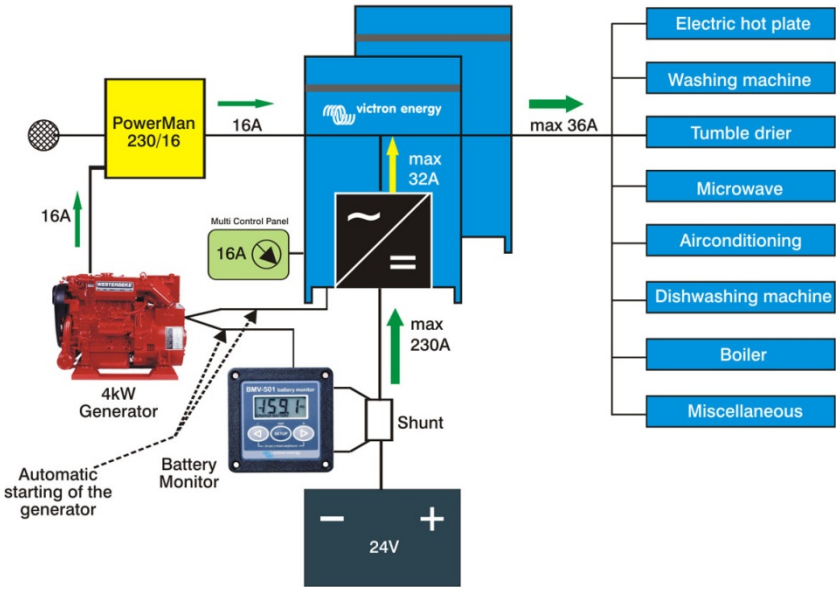
a) PowerMan 230/16-0
An automatic 16 A transfer switch.

b) Battery Monitor BMV 501
The BMV 501 keeps track of the state of charge of the battery. The BMV 501 can be programmed to generate a generator start signal when the batteries have been discharged to a pre-set percentage. Together with the start signal from the Multi the generator will start both in case of a high power requirement and when the batteries have been discharged to a pre-set percentage.

Example 5.2 a

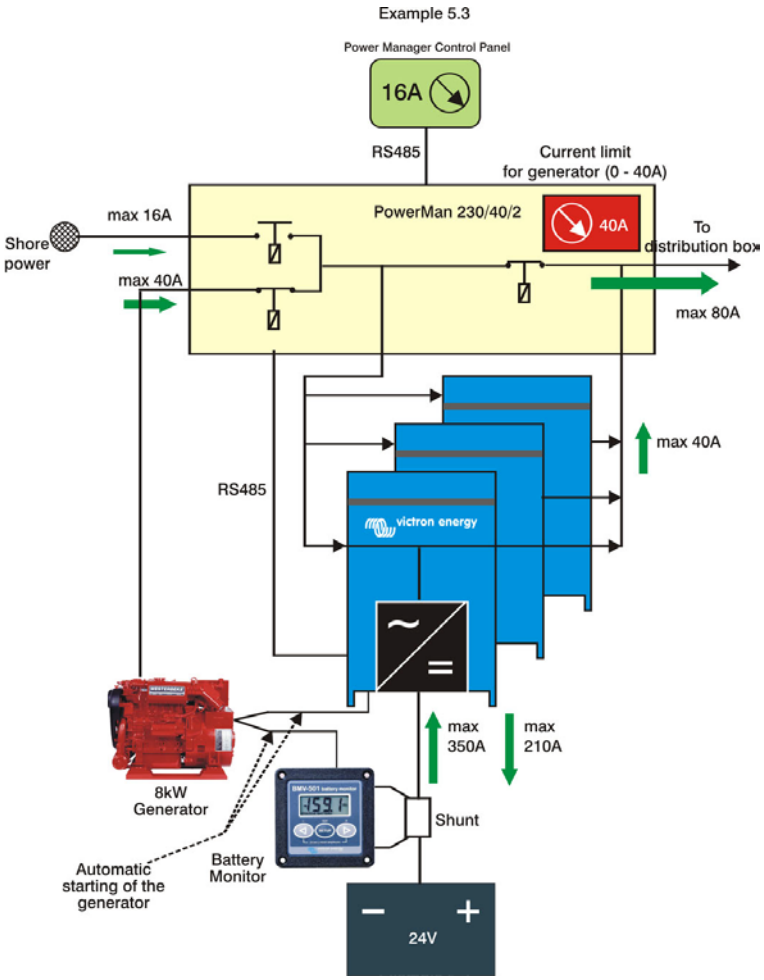


Example 5.2b



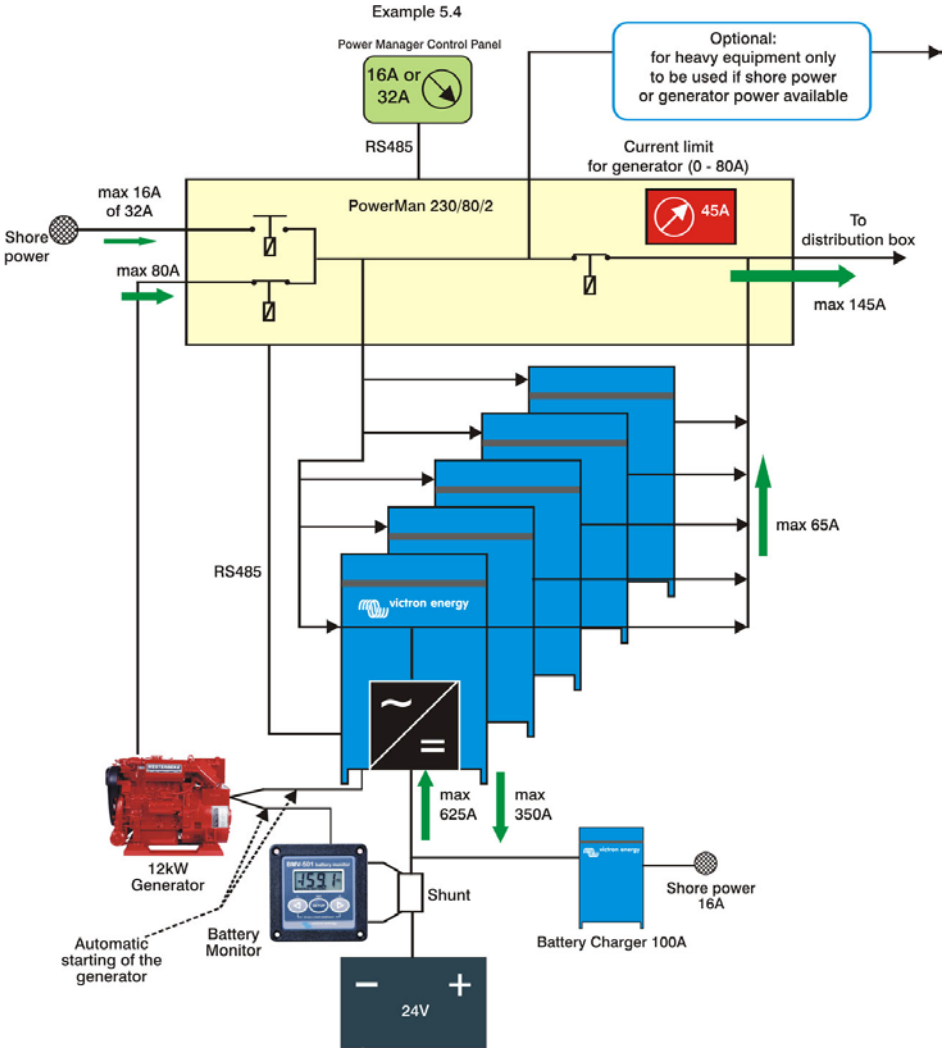
Example 5.2a and 5.2b: maximum power required 5 kW

A much more robust system is obtained by installing 2 Multis. The 2 Multis (of which 1 unit should be a MultiPlus to have PowerAssist functionality) can supply sufficient power even when several AC loads are switched on simultaneously. And once the generator is running the system will supply up to 16 + 2 x 10 = 36 A. Moreover the 2 Multis will easily absorb all available power from the generator when recharging the batteries, reducing running hours of the genset to the bare minimum.
Please note that a small 3000 rpm genset has limited service life and is in general not made to run at full load for long periods of time. (reduce output to 70 % of full load with the Multi Control Panel!). A 1500 rpm model is the better choice if intensive use is expected



Example 5.3: maximum power required 7 kW, and average power 2 kW (intensive use of air conditioning)

It is now time to install a bigger genset, unless a substantial generator free period is not required.
In this example transfer switch model PowerMan 230/40-2 has been used. This transfer switch will accept up to 40 A of AC input current. The genset current limit can be set inside the cubicle (indicated in red in the schematic diagram above) and is independent from the shore current setting on the PowerMan Control Panel (indicated in green in the schematic diagram above). The PowerMan Control Panel is similar but not identical to the Multi Control Panel.
Up to 3 Multis can be connected directly to the PowerManager.



Example 5.4: maximum power required 12 kW, and average power 4 kW (intensive use of air conditioning)

By connecting to 2 shore outlets of 16 A each, up to 32 A (7 kW) of shore current is available. The trick is to connect the AC system to one outlet, and a 100 A battery charger to the other. The transfer switch is a PowerMan 230/80-2, suitable for up to 80 A input.
Up to 6 Phoenix Multis can be connected to this Power Manager.

3 phase systems
Phoenix Multis and Phoenix inverters can also be configured for 3 phase operation. We will be pleased to make a proposal for a 3 phase system.