

# Using the Phoenix MultiPlus to reduce operating cost of a generator

## 1. The traditional AC generator system

Per Watt ac-power, an inverter is generally more expensive than a generator. So why would one add an inverter to an ac-generator system?

Apart from the obvious advantage of “silent ac-power”, there are other major considerations why it is attractive to add a Multi inverter/charger to a system with ac-generator:

- Fuel savings
- Cost and time savings as a result of reduced maintenance
- Extended generator life
- 24/7 availability of ac power

Figure 1. shows a typical ac-power requirement schedule. In this example, there is a morning peak of 3 kW for two hours, a 3 kW peak around noon and the evening peak of 6 kW. Between morning- and noon peak and between noon- and evening peak, ac requirement is relatively low, around 500 W on average. After the evening peak, the average requirement is about 1 kW for some hours.

With a 7.5 kW ac-generator as the only source of ac-power, the generator needs to run for **17 hours** per day. 70% of the time the generator is loaded to **less than 15%** of its full capacity.

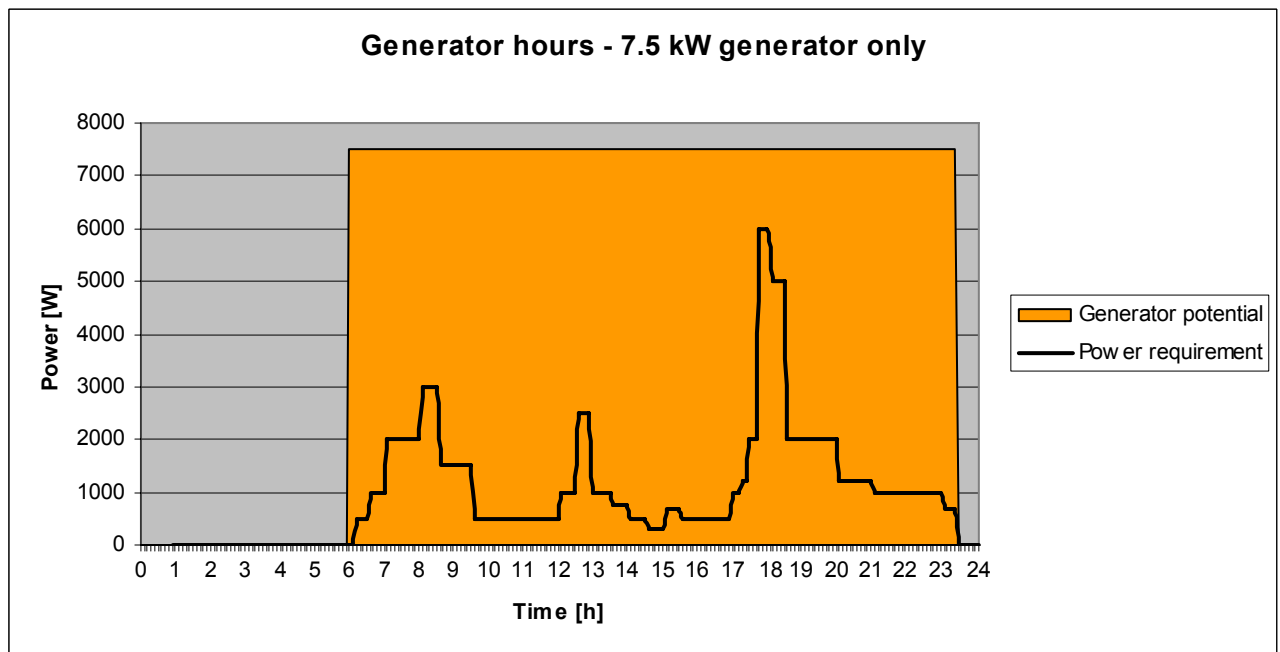
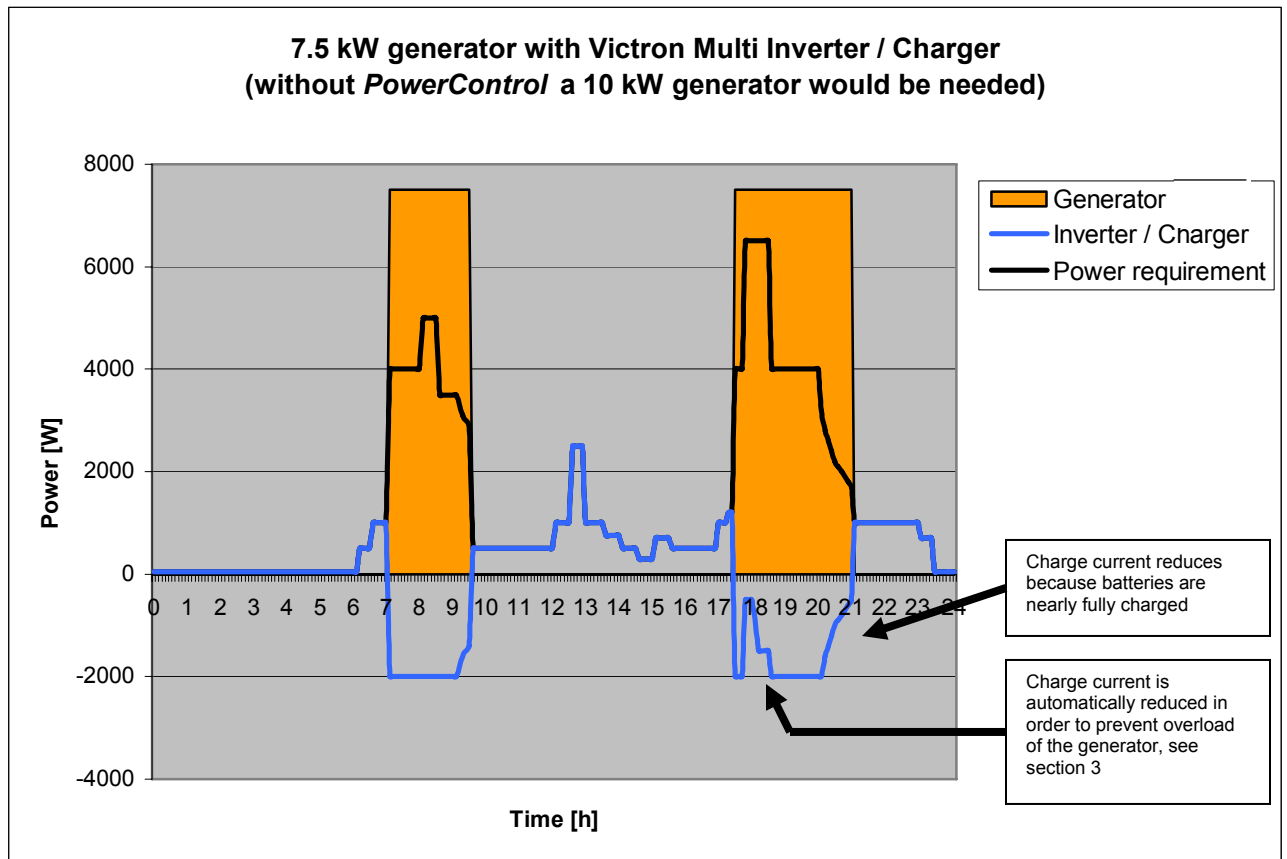


Figure 1. System with 7.5 kW generator only

## 2. Adding a Victron MultiPlus to the system

We now introduce a Victron Phoenix MultiPlus 24/3000/70 inverter/charger and a battery bank to the system. (see appendix for MultiPlus schematic) The inverter can supply the required ac-power most of the time. During the peak ac-requirement, the generator is started (preferably automatically by the Multi and/or a battery monitor) to supply peak ac demand. At the same time, the MultiPlus will use any ac-power from the generator which is not required by the ac-loads, to re-charge the batteries.

Figure 2 shows the same system now with the Victron MultiPlus added. Generator running hours can be reduced to **5 hours/day**, while 12 hours of ac-consumption are enjoyed in silence. Whenever the generator is running, it is loaded up to **70%** of its capacity.



**Figure 2. System with 7.5 kW generator and Victron MultiPlus.** The blue line shows the power through the Victron Multi. When the blue line is above 0, the inverter of the Multi takes power from the batteries to supply ac-power to the ac-loads. When the blue line is below 0, the charger of the Multi takes ac-power from the generator to re-charge the batteries.

### 2.1 The Battery

The battery size needed is smaller than what may be expected.

In our example a 24 V battery would be discharged to 166 Ah just before the generator is started in the morning, and to 285 Ah just before the generator is started in the evening.

A 24 V / 600 Ah battery would therefore be a good choice, with ample reserve capacity.

If a 48 V system is chosen, 300 Ah will be needed.

The most rugged battery for the purpose is the type used in forklift trucks.

## 2.2. Fuel consumption

The typical 7.5 kW generator will consume about 1.5 l/h diesel at low load and 2.3 l/h at 75% load. So the generator only configuration requires 25.5 liters diesel per day, whereas the generator with the Victron Multi requires 11.5 l/day to provide the same ac power. **A savings of 5110 liters diesel per year.** At Euro 0.50 per liter, this equates to a savings of about Euro 2555 per year (not counting time and money saved on re-fuelling).

## 2.3. Periodic maintenance

Typical recommendation by the manufacturers is to change oil every 150 h of operation. For the generator-only scenario with 6205 running hours, this equates to 41 oil changes per year.

When the Multi inverter / charger is added to the system, running time is reduced to 1825 hours, this equates to 12 oil changes per year. **A savings of 29 oil changes per year.**

At a typical lube oil volume of 5 l, 145 liter of lube oil is saved each year. At Euro 5.00 per liter, this equates to a savings of Euro 725 per year (not counting time involved in performing the oil change and parts such as oil filters).

## 2.4. Generator life

Generators based on a fixed speed diesel engine will last longer when they are run under load compared to being run at no- or low load. Some manufacturers recommend operation at a minimum of 30% load to prevent premature failure.

By adding the Multi inverter/charger in our example, the load on the generator went up from less than 15% for 70% of the time, to a loading of 70%. A considerable longer generator life may be expected.

## 2.5. Summary

	Generator Only	Generator with Multi	Savings
Running hours/day	17 h	5 h	12 h (silence)
Diesel consumption/day	25.5 l/day	11.5 l/day	14 l/day
Diesel consumption/yr	9307 l/yr	4197 l/yr	5110 l/yr
Oil changes/yr	41	12	29
Lube oil consumption/yr	205 l/yr	60 l/yr	145 l/yr
Generator loading	15% load for 70% of running hours	70% load	
Annual savings in fuel and lube oil (3x longer service life of the generator not included)			Euro 3.280/yr
Dollar savings after 5 yrs			Euro 16.400

## 2.6. Conclusion

Apart from the obvious benefit of availability of "silent" ac-power, the fuel savings and cut-down in maintenance are significant when a Multi inverter/charger is added to the generator system. Also, not covered in this brief, the environmental impact as a result of reduction in harmful exhaust and oil waste will be significant.

Actual gain will vary per generator and actual power requirement profile. In general, the benefits will be larger when the ac-requirement profile shows a pattern of a few high peaks with significantly lower average power requirements between the peaks, which is a common profile for most ac generator systems.

### 3. Why should the inverter/charger be a Victron MultiPlus?

In the previous section we saw that there are potentially huge benefits and cost savings to be made when an inverter/charger is added to a system with ac-generator. There are many inverter/chargers on the market that cost a lot less than a Victron MultiPlus. In this section we will show that, to take full advantage of the potential benefits, the inverter/charger must be a Victron MultiPlus.

Apart from obvious benefits such as the clean pure sine wave output, ultra fast ac-transfer switch, marinated construction, high quality built and an organization behind the product which has been committed to R&D and customer support for over 30 years, there are five specific features of the MultiPlus that are essential in achieving cost savings when using the inverter/charger with the ac-generator.

#### 3.1. AC input power manager

Unique to the Victron MultiPlus is the ability to set a power level that the unit will try to maintain at its ac-input terminals. The MultiPlus has 2 levels of ac power management. The first level is **PowerControl**.

##### **PowerControl**

The **PowerControl** functionality enables the MultiPlus to automatically increase and decrease the charge rate of its charger depending on the power demand at the ac-output of the Multi. The **PowerControl** functionality of the input power manager is best understood by looking more closely at fig. 2.

The blue line shows the power through the Victron Multi. When the blue line is above 0, the inverter of the Multi takes power from the batteries to supply ac-power to the ac-loads. When the blue line is below 0, the charger of the Multi takes ac-power from the generator to re-charge the batteries. This ac-power is an additional load of 2.2 kW for the generator. As can be concluded from fig. 1, this additional load would result in an overload of the generator between 18 hours and 19 hours, because the other ac loads do increase to 6 kW during that period (see fig. 1). Adding the 2.2 kW load of the charger would increase the load to  $6 + 2.2 = 8.2$  kW. This overload would stall the 7.5 kW generator.

To prevent this, the input power manager of the MultiPlus will automatically reduce its charge rate in order to limit the total load on the generator to the set maximum power level, 6.5 kW in this example.

If you are still reading, you are either an enthusiast or professionally involved with power systems. In that case we will let you in on one of our best-kept secrets.

**PowerAssist**: the secret of the MultiPlus

Figure 3 shows again our example power schedule with the 6 kW peak in the evening.

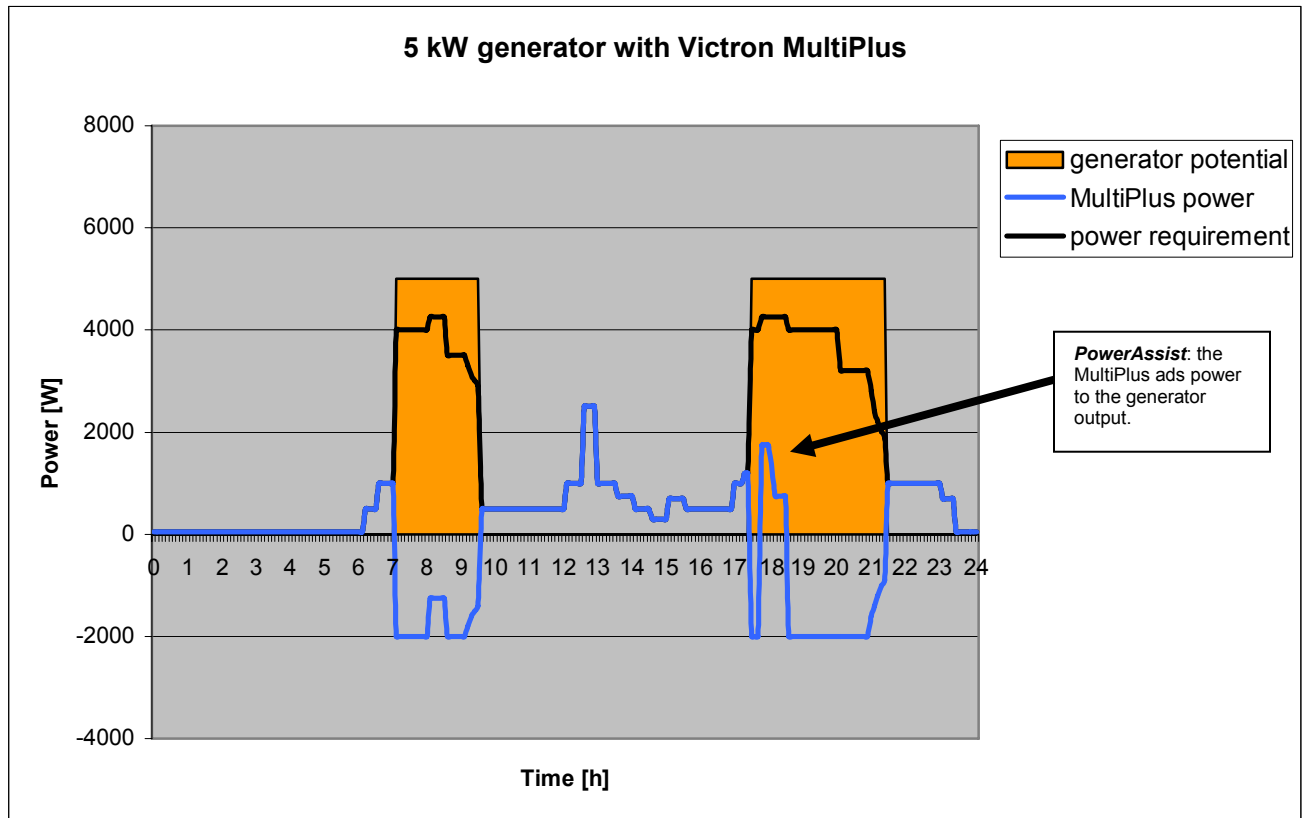
But now the generator has been downsized to 5 kW.

Choosing a smaller generator will of course reduce noise, size, weight, fuel consumption and initial investment.

The 5 kW generator will however not be able to supply the peak load of 6 kW, even if the charge current of the MultiPlus is reduced to zero during that period.

Now **PowerAssist**, the second level of ac power management is needed. With **PowerAssist** the MultiPlus can temporarily supplement the generator ac-power with power from the battery. In figure 3 this is visible between 18 hours and 19 hours: even though the generator is running, the MultiPlus is inverting (blue line above 0) instead of charging, thus providing the additional ac-power that is required on top of the generator output.

With one MultiPlus 24/3000/70 an additional 3 kW can be added to the generator output!



**Figure 3. System with 5 kW generator and MultiPlus inverter/charger.** When the blue line (MultiPlus) is below 0, energy is put into the battery bank (charging), when the blue line is above 0, the MultiPlus is generating ac from the battery bank (inverting).

### Dynamic range of ac power regulation

In the previous sections, we saw that the key to achieving savings by adding an inverter/charger to a generator system was the ability of the inverter/charger to dynamically control the ac power taken from the generator.

With the MultiPlus, 24/3000/70 the dynamic range of ac power regulation is more than 5 kW:

The first level of dynamic ac power regulation is **PowerControl**, which enables control of the ac power needed for battery charging between zero and a maximum power draw of about 2.3 kW. (= 70 A charge current times 30 V charge voltage at 90% efficiency)

On top of that PowerAssist, the second level of dynamic ac power regulation, extends power regulation with an additional 3kW (per unit), which may be **above** the maximum power of the generator. This implies that using a MultiPlus is particularly useful when the ac-power requirement profile shows large variations (high peaks short in duration, low average), that require a wide dynamic range of ac-power regulation.

### 3.2 Unity power factor

Simply said, the power factor of an ac-load is an indication of how much power needs to be supplied to the load relative to the power that the load consumes. The power consumed by the load is indicated in Watts, the power that needs to be supplied is indicated in VA. If the Power factor is PF, the following relationship exists:

$P_W = PF \times P_{VA}$ . The power in VA is equal to the product of rms voltage and rms current.

The power factor of some battery chargers can be as low as 0.7. This means that a charger that consumes 2 kW, requires about 2.8 kVA from the generator to make it work. If the generator voltage is 230 V, the generator must be able to supply 12.2 A to this charger. The generator would only need to supply 8.6 A for the same charge result if the power factor were to be 1.

One cause of non-unity power factor is that load current is not in phase with the voltage. The other major cause of non-unity power factor is a load current that is not sinusoidal. A non-sinusoidal load current will cause harmonic distortion in the ac system. Harmonic distortion can cause generator windings to burn out.

To cope with the negative effects of non-unity power factor and non-sinusoidal current of most chargers, generator suppliers will recommend to oversize the generator by as much as a factor of 2 (note that only the generator needs to be oversized, not the diesel engine driving it).

The Victron MultiPlus inverter/charger has a unity power factor (PF = 1). A system with Multies does not require over sizing to cope with the chargers. It furthermore will not introduce harmonic distortion into the system. These are very important considerations when planning to add an inverter/charger to a generator system.

### 3.3 Scaling

Third reason to choose a Victron Multi, is because this is the only inverter/charger on the market that allows easy scaling of the system. A single 3 kW inverter/charger will have little impact on a 40 kW generator system. Because the Victron Multi is a modular unit, systems of up to 15 kW single phase or 45 kW 3-phase can easily be built by adding more units. The total system can easily be scaled for optimum performance / savings. (see fig. 4)

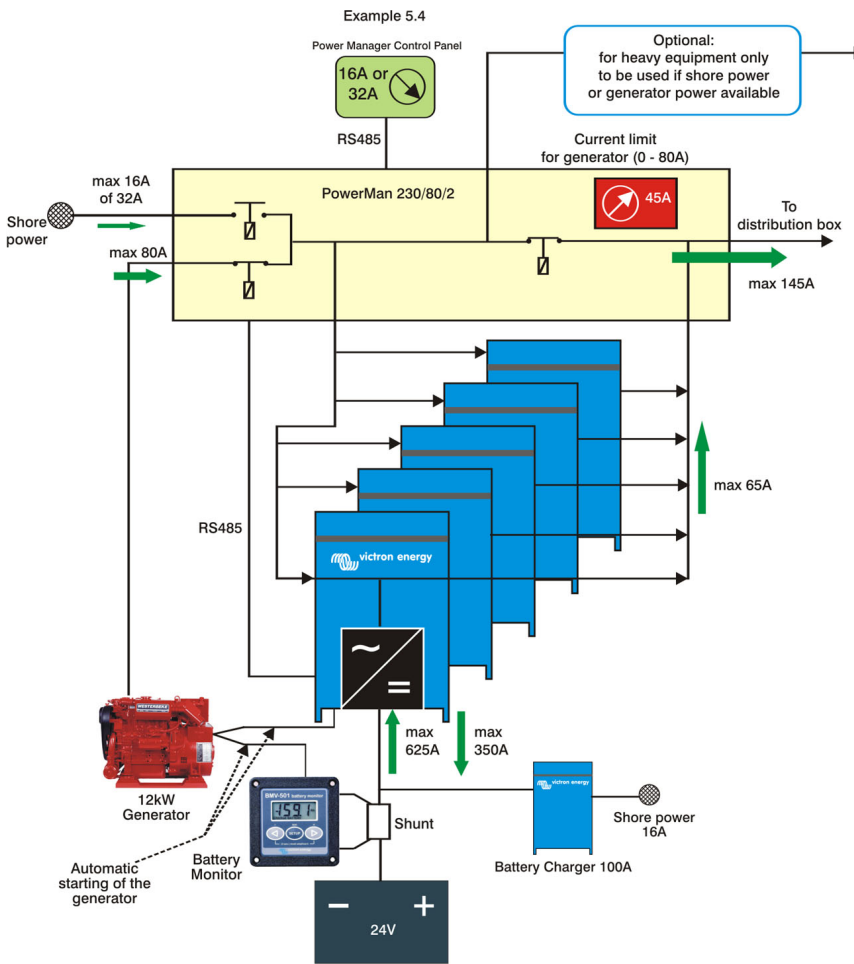


Figure 4: System with 5 Multies in parallel, a generator and an alternative supply.

**Note:**

At the other side of the power spectrum, A MultiPlus can also be used to boost the output of small gensets like the Honda "I" range for example. (The "I" range starts at 1 kVA)

**3.4 External ac power management module**

In the examples of fig. 2 and fig. 3 generators with 7.5 kW and 5 kW output power were used.

In case of larger systems (see fig. 4) with multiple paralleled Multies, it becomes unpractical to use the internal ac power management module of the Multies.

For larger systems an external current measuring system has been built in the PowerManager, and soon an even more sophisticated ac power management module will become available.

**3.5 Connectivity: a continuously increasing array of monitoring and control facilities**

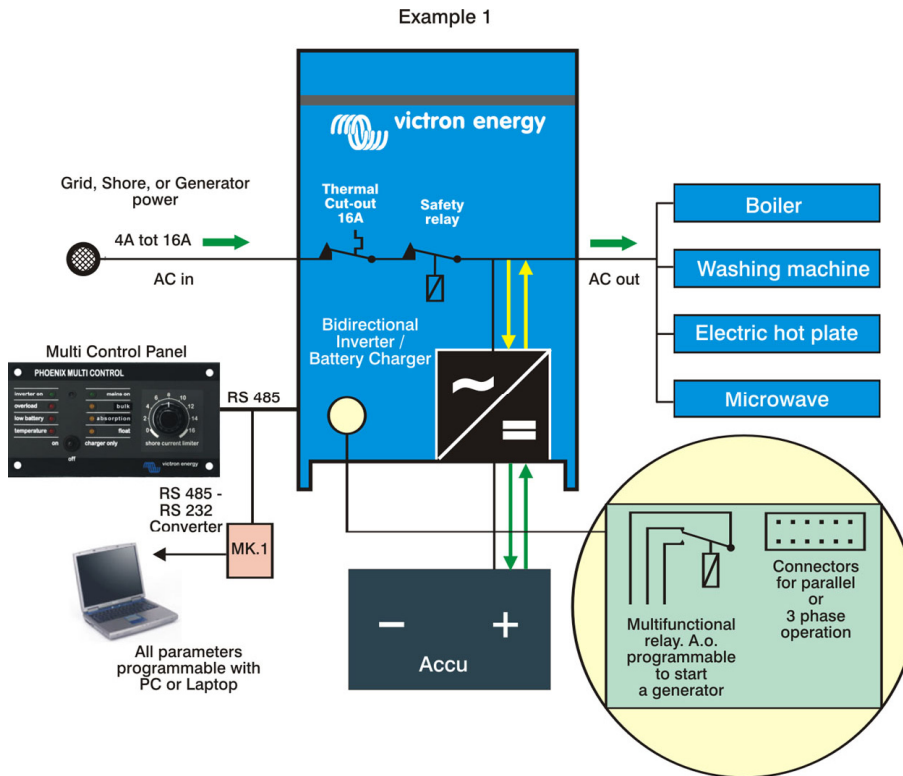
Next to the Multi Control panel and VEConfigure, VE.Bus and VE.Net connectivity will soon make any requirement regarding remote control (including mobile phone and satellite) a reality.

**4. Conclusion**

In the second section, we showed that adding an inverter charger to an ac-generator system could have huge potential benefits such as silent ac supply, fuel savings, maintenance reduction and extended generator life.

In the third section we saw that to be able to achieve these potential benefits, the inverter/charger must have certain specific features that are found only on the Victron MultiPlus: automatic ac input power control, unity power factor and modularity for scaling.

## Appendix : schematic diagram of the MultiPlus



### 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 output (this can be important for certain sensitive loads such as an induction cooker)

### A multifunctional relay

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

### 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.1b 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, split phase operation and 3 phase operation
- programming the multifunctional relay

**Connector for parallel operation and 3 phase operation**

Up to 6 Multi's can be parallel connected to increase power to 15 kW.

In 3 phase configuration up to 18 Multi's can be used to build a 45 kW inverter / charger!

**AC input with 16 Amp thermal breaker and safety relay**

The maximum AC input current of the M/M+ is 16 A. (optional 32 A).06/12/200406/12/2004

The safety relay makes sure that no dangerous AC voltage will be present on for example the shore power plug when disconnected.

**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.