Title of the Invention: Power supply apparatus and method

Abstract Title: Power supply apparatus

A power supply unit comprising a power generating unit 120, a power storage unit 110 for storing electrical power, a power switch and an output unit, connectable to a load 170. The switch is arranged in use to control a supply of electrical power to the output unit. The output unit is supplied with power from the power generating unit, the power storage unit or both the power 10 generating unit and power storage unit substantially at the same time. The power generating unit may comprise an engine and generator. The power generating unit and power storage unit may be located in a common housing, along with a liquid heat exchanger. The power supply unit may be for a marine or wheeled vehicle, or for building premises.
POWER SUPPLY APPARATUS AND METHOD

The present invention relates to a power supply apparatus and to a method of supplying power.

Marine vehicles, such as powered boats, typically use a diesel engine to provide power the propulsion system, and, via a generator, to supply electrical power to the boat’s other systems. Electricity is rarely used to power the propulsion system, despite its advantages of low noise and precise controllability. This is thought to be mainly because of a lack of affordable high efficiency batteries and also a perceived scarceness of recharging facilities.

These perceived drawbacks also affect the choice of battery power in a variety of other situations.

Embodiments of the present invention aim to provide a power supply apparatus and a method of supplying power which address, at least in part, the problems with the prior art.

The present invention is defined in the attached independent claims, to which reference should now be made. Further, preferred features may be found in the sub-claims appended thereto.

According to one aspect of the present invention, there is provided a power supply unit comprising a power generating unit, for generating electrical power, a power storage unit for storing electrical power, a power switch and an output unit, connectable to a load, wherein the switch is arranged in use to control a supply of electrical power to the
output unit so that the output unit is supplied with power from the power generating unit, the power storage unit or both the power generating unit and power storage unit substantially at the same time.

The power generating unit may comprise an engine and a generator, more preferably an internal combustion engine and a generator. Alternatively, or in addition, the power generating unit may comprise any of a group of electricity generating devices or systems for generating electricity from sources including but not limited to: solar, wind, wave, tide, geothermal, chemical or nuclear.

The power generating unit and power storage unit may be located within a common housing.

A heat exchanger, more preferably a liquid heat exchanger, may be located within the common housing.

The power supply unit preferably comprises a standard size, such as a standard pallet size. It may be sized and shaped so as to be accommodated in substantially the same space and using the same mounts as an internal combustion engine.

The power supply unit may comprise a power source for a marine vehicle.

The power supply unit may comprise a power source for a wheeled vehicle.

The power supply unit may comprise a power source for building premises, such as domestic or commercial premises.
The power supply unit may comprise a power source for a combined heat and power unit.

The power supply unit may be arranged to supply power to any of a range of power users including, but not limited to: single or three-phase electrical loads, farms, workshops, military bases, show grounds, exhibition centres, building sites, hospitals, homes, hotels, offices/data centres, back-up supply for critical facilities/equipment, camp sites, any other "off-highway" use that requires electrical energy power.

The invention also provides a method of supplying power, the method comprising generating electrical power using a power generator, storing the electrical power, and switching power to an output unit, connectable to a load, wherein the switch is controlled to supply electrical power to the output so that the output unit is supplied with power from the power generator, the power storage unit or both the power generator and power storage unit substantially at the same time.

The method may comprise generating electrical power using a generator, which may comprise an engine and a generator, more preferably an internal combustion engine and a generator. Alternatively or in addition, the power generator may comprise any of a group of electricity generating devices or systems for generating electricity from sources including but not limited to: solar, wind, wave, tide, geothermal, chemical or nuclear.
The invention also includes a vessel, vehicle or building powered by a power supply unit, or in accordance with a power supply method, according to any statement herein.

The invention may include any combination of the features or limitations referred to herein, except such a combination of features as are mutually exclusive, or mutually inconsistent.

A preferred embodiment of the present invention will now be described. By way of example only, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 shows schematically a power generation apparatus according to a first embodiment of the present invention;

Figure 2 shows schematically a power generation apparatus according to a second embodiment;

Figure 3 shows schematically a first variant of the embodiment of Figure 2;

Figure 4 shows schematically a second variant of the embodiment if Figure 2;

Figure 5 shows schematically an example of a physical arrangement of an apparatus of Figure 2;

Figure 6 shows schematically a boat including two of the apparatus of Figure 2;

Figure 7 shows an alternative configuration for marine use;
Figure 8 shows a comparison of an apparatus according to the embodiment of Figure 2 with a previously considered apparatus;

Figure 9 shows schematically a first generic apparatus according to the present invention;

Figure 10 shows schematically a second generic apparatus according to the present invention;

Figure 11 shows schematically a further generic embodiment of apparatus according to the present invention;

Figure 12 shows schematically a combined heat and power system employing an embodiment of the present invention;

Figure 13 shows schematically a control interface;

Figure 14 shows schematically a further generic apparatus;

Figure 15 shows a further embodiment of power generation apparatus;

Figure 16 shows schematically a cooling system; and

Figure 17 shows schematically a relationship between an embodiment of the power generation apparatus and alternative energy sources.

Turning to Figure 1, this shows, in schematic form, a power generation apparatus, generally at 100, according to an
embodiment of the present invention. The power generation apparatus 100 comprises at its heart a high voltage battery pack 110, and includes an electrical generator 120 which is arranged to be driven by an internal combustion engine 130 connected to a fuel tank 140. The generator 120 is connected via a generator inverter/engine starter 150 to a high voltage bus 160. The high voltage battery pack 110 is also connected to the bus 160, as is an external load 170 via a load inverter 180.

A main electronic control unit 190 controls the battery pack 110, the generator inverter/engine starter 150 and the external load inverter 180 respectively via a Battery Management System (BMS) network 200 and a propulsion network 210 respectively. The main electronic control unit 190 is also connected to control inputs 220 and feedback display 230 via a display/control network 240.

A mains charger 250 is connected to an external mains power connection 260. When connected to a source of mains power the charger 250 supplies a low voltage to an outlet represented at 270, via a DC/DC converter 280, which is used to step down the DC voltage, for example from around 700 V to 12 V. The mains charger 250 is also connected to the Control Unit 190 via the bus 200.

The apparatus 100 is located within a self-contained acoustic safety enclosure 290. A multi-circuit closed loop heat exchanger 300 cools the components within the enclosure 290. The multi-circuit closed loop heat exchanger 300 may be a liquid-to-liquid heat exchanger. The heat exchanger 300 is connected to a cooling liquid intake 310
and a cooling liquid return 320. The liquid may be water, glycol, oil or refrigerant, but it will be appreciated other type of cooling liquid may be used.

The apparatus 100 is a self-contained power supply that can be used for a variety of purposes as will be described below. The load 170 can receive electrical power from the battery pack 110 or from the generator 120 directly. The generator can also charge the battery 110 via invertor 150 when driven by the internal combustion engine, which is typically a diesel engine.

As an example, Figure 2 represents schematically the use of the unit 100 to power a marine vessel. In this case the load 170 is actually an electrical propulsion motor that is used to drive a propeller/stern drive unit 330 and a power steering unit 340. In this case, the cooling water intake 310 and return 320 for the heat exchanger 300 use raw (i.e. untreated) water. The low voltage outlet 270 is used to provide a 12 Volt DC supply to the rest of the marine vessel. The internal combustion engine 130 would typically be a two-stroke diesel engine. Alternatively, or in addition, other engine types could be used, such as a four stroke diesel, or a gasoline engine or a turbine or a fuel cell for example.

Turning to Figure 3, this shows further detail of the marine propulsion unit of Figure 2. A closed loop, dual/multi core water heat exchanger 301 is supplied with raw cooling water from a water pump 321. A further pump 322 also supplies cooling water to the battery pack 110.
Figure 4 shows a variant in which the cooling is achieved using oil. This is convenient as some components use the lubrication oil for cooling. The same components as are shown in Figure 3 are labelled identically here. An oil coolant pump 322' replaces the cooling water pump 322 of Figure 3. Alternative and/or additional methods of heat recovery or cooling may be used such as ports or fins on or within the cylinder block of the engine.

Figure 5 is a schematic example of the physical arrangement of the power supply unit when used in a marine vessel. All of the components are installed inside the acoustic structural enclosure 270. All of the high voltage components and wiring connections are safely enclosed to protect personnel from direct contact. The components are labelled according to the reference numerals used in Figures 1-4.

A single integrated package may replace an existing internal combustion engine. The mounting strategy, volume and weight of the unit 100 are all comparable to that of typical existing V8 internal combustion engine. Application of the unit 100 is not limited to only stern drive, but can be used as, or together with, any in-boat propulsion & power requirement.

Figure 6 shows a marine vessel, generally at 400, in which both engines of a traditional twin-engine design have been replaced by the units 100. Multiple Installations can be fitted to match the existing number of internal combustion engines in a boat, e.g. single, twin or triple engines.
Alternatively the units 100 could be used alongside existing engines.

Figure 7 shows an alternative arrangement. In larger vessels that have multiple subordinate craft, such as tender boats T, the units 100 can be used for propulsion in the tender boats when they are launched, and can be used to provide electrical power to the parent vessel PV when they are docked. These batteries can be recharged from the parent vessel when it is cruising. This arrangement could be useful for larger yachts or military vessels. It could provide emergency backup power, or else silent running capability for night-time berthing or manoeuvres.

Figure 8 includes an image of an existing V8 petrol engine at 500 and, for comparison, a similar propulsion system 510 utilising a power unit 100, which is of a similar size and weight, and can have similar mounting arrangements. The unit 100 is advantageously a single integrated package that can replace the engine 500. It is useful for stern drive or other in-boat propulsion power requirements.

Figure 9 is a schematic of the unit 100 specifically for use in marine propulsion applications. Fuel is supplied at 602, mains power (when a hook-up is available) is supplied at 604, helm controls connect at 606, an auxiliary power out is shown at 607, an exhaust outlet is shown at 608, cooling water is taken in at 610 and removed at 612.

The unit 100 is suitable both for after-market fitment and new OEM installations, and has few external connections, so is easy to install. The propulsion motor PM could be
mounted either inside or outside the unit 100 depending upon the application.

Embodiments of the invention are able to provide a highly efficient two stroke diesel or four stroke petrol engine mechanically connected via a flexible coupling to a 75kW, 700V axial flux motor (AFM), for example (other motor/generator options are possible). This may include in the future a gas turbine or Hydrogen fuel cell for example. Both engine types are substantially modified to reduce their weight and complexity, including removing the alternator, starter motor, super charger (where fitted) and engine control (ECU).

The AFM will run at near peak engine operating speed to start the engine. Once the engine is running, the AFM then works as a generator to charge the on board high voltage 700 V DC battery-pack. Two or more engine speeds will be available, namely to optimise fuel efficiency or to optimise the power.

The 700 V DC battery pack will likely be of lithium ion type chemistry with around 35 kWh capacity. The battery pack will have its own integrated battery management system (BMS) that will interface with the Main electronic control unit (ECU) on a dedicated controller area network (CAN) bus.

A 200kW, 700 V AFM will provide the propulsion to the craft, mechanically connected to the new or existing stern drive or propeller. Both AFM’s are controlled via their own motor controller, both of which are connected via their own
CAN bus to the Main ECU. The operation of the system and feedback is provided via the human-machine interface HMI. The HMI is connected to the Main ECU via its own CAN bus.

The torque of the propulsion motor can be limited and mapped to match the capability of the new or existing stern drive, so as not to cause premature damage.

The generator operation is invisible to the end user. The Main ECU controls the starting and stopping of the generator. A mains charger is also able to recharge the high voltage battery pack whilst the boat is berthed or in storage.

Propulsion may be inhibited whilst the mains charger is connected. An example of the cooling system design and thermal management strategy is described below. Different Charisma modes will be available at the helm for the user to be able to choose from. These will include: Economy/Normal, Sport, Electric Only and Restricted Power/Marina.

The power generation units described herein are suitable for a variety of other uses, beyond the examples of marine propulsion described above. Figure 10 is a schematic representation of the unit 100 suitable for a variety of purposes in which a rotational output 600 is required. Again, fuel is supplied at 602, mains power (when a hook-up is available) is supplied at 604, controls connect at 606, an auxiliary power out is shown at 607, an exhaust outlet is shown at 608, cooling water is taken in at 610 and removed at 612.
The rotational drive 600 can be utilised in several applications, including but not limited to: boats, such as military boats, lifeboats, leisure boats, commercial boats, trains, tractors, agricultural vehicles, excavators, dumpers, and other off-highway vehicles requiring rotational power. Energy recuperation can be utilised in certain applications. The apparatus can be used as a mobile dynamometer for torque and power measurement. In this guise it would offer the benefit of storing the energy that is usually wasted by previously considered dynamometers.

Figure 11 is a schematic representation of the unit 100 suitable for a variety of purposes where only an electrical supply is needed. The inputs and controls on the right hand side of the drawing include most of those shown in Figure 9. However, in the case where all that is required is a source of electrical power, the unit 100 can supply at an output 700 either single or three-phase electrical power, for use in a variety of applications, including but not limited to: on farms, in workshops, on military bases, show grounds exhibition centres, construction sites, campsites, hospitals and domestic and commercial premises, data centres, and can provide back-up supply for critical facilities and equipment.

Figure 12 illustrates schematically a use of the unit 100 as part of a combined heat and power (CHP) plant. A single or three-phase power supply can be provided with advance thermal recovery systems and electrical water heating. Waste heat, from the exhaust 608 and cooling 612 can be used to assist in the heating of a hot water system having
a cylinder 800, pipes 810 and radiators 820. Flow is controlled by a pump 830 and valves 840.

Either the main unit 100 or the “Hotel Pack” (see below) can make use of the rejected heat that is a by-product of the generated and stored electricity. This heat can be reclaimed and provided to a central heating and/or hot water system rather than being simply rejected to the air or into a water source.

In some embodiments, the CHP device may be used when applications do not need to use the heat energy produced as a by-product of the electrical power generation (e.g. it may be disposed of using the Hotel Pack or by discharging the water into the sea). Alternatively, as mentioned above, in some embodiments, the CHP may be used for applications where the electrical power is not the prime requirement but a heat source is. It will be understood that the CHP or power unit will produce heat when any energy transfer is taking place, such as during the operation of the engine, or when receiving power from an external source such as a battery. Similarly, heat will be produced when the CHP or power unit is delivering power from the engine and / or battery.

Figure 13 shows schematically a control interface architecture for the unit 100. The components have the same reference numerals as in Figures 1-4.

Figure 14 shows a variant of the apparatus which is for use where only mains electrical power is required. The same parts are labelled with the same reference numbers as in
the Figure 1 embodiment. There is no propulsion motor to provide a mechanical output and the DC/DC converter is omitted.

Figure 15 shows a support unit 1000, referred to here as a “Hotel Pack”. Where the Electrical Power Unit is installed to provide power and there is not a readily available cooling medium, such as a nearby lake, stream or canal, a Hotel Pack must be attached to the system. This Hotel Pack can also house an additional battery for extra capacity. It can also contain fuel tank for the ICE in the main unit. The Hotel Pack 1000 can either be located close to the unit 100 or remotely.

Once heat is taken from the heat exchanger within the Power Unit, if it is not discharged directly into a body of water, such as the sea, a lake, or a river, then variants of the Hotel Pack may be used to extract heat using a liquid-to-liquid, or liquid-to-air, heat exchanger. The use of a liquid-to-liquid or liquid-to-air heat exchanger depends on the application. The heat exchanger may be incorporated within or associated with, the main unit. The heat exchanger may take in liquid, such as sea water when in a boat, or alternatively it may take in liquid from the Hotel Pack to help dissipate the heat. The heated liquid in the Hotel Pack may be used for another purpose. The Hotel Pack may further comprise means of rejecting heat by a secondary means if it is being used as a CHP unit. For example, if the heat generated by the main pack cannot be used to heat a building, for example due to climatic reasons such as on a warm summer day, then the Hotel Pack may dissipate the heat to the air via a fan arrangement or
via a secondary heat exchanging mechanism, such as being able to discharge the heated liquid into a body of water.

Figure 16 shows schematically and in more detail a generic cooling system 3000 in accordance with an embodiment of the present invention. An internal combustion engine is represented at 3130, a generator inverter at 3004, an AFM generator at 3003, a high-voltage battery pack at 3014 and a propulsion inverter at 3006. A twin-circuit water/glycol heat exchanger is shown at 3301 and an oil heat exchanger is shown at 3301'. An ICE exhaust cooling portion is shown at 3500, a cooling water/raw water inlet at 3520 and an outlet at 3540.

A cooling water/raw water pump is shown at 3321 and a propulsion inverter circuit water pump is shown at 3560. A generator circuit water pump is shown at 3580 and propulsion AFM circuit oil pump and generator AFM circuit oil pump respectively at 3600 and 3620.

If a water source is available for cooling, such the sea, then the entire system is self-contained within the housing of the power supply unit 100. However, if it is necessary to cool to air, then the hotel pack support unit 1000 can facilitate this.

Figure 17 is a schematic showing the unit 100 in conjunction with a renewable mains recharge capability. The unit 100 can be connected to renewable energy sources such as wind W or solar S, for example, to provide an additional or alternative method of charging the battery pack in either the main system or a Hotel Pack.
Units of the kind described herein can be used as a primary interchangeable power source for military installations as follows. The Electrical power unit 100 can be viewed as a large-scale battery that can be quickly and easily interchanged from different apparatus. The same units can be installed in all of the applications listed herein as examples. Military examples would include personnel carriers, water-craft, medical bases and aircraft hangars and workshops. This reduces the number of spares required and units could even be re-deployed in times where fast recovery to operational status is required.

Power supply units according to the present invention have a number of benefits when compared with previously considered power units. For example, they have an integrated internal power storage in the form of the battery pack, which allows the delivery of power virtually silently, which is particularly useful at night. Secondly, the units of the present invention couple a highly efficient internal combustion engine with a highly efficient, compact generator which is able to provide levels of power and costs comparable with the UK National Grid.

The apparatus is designed to replace a higher power internal combustion engine in the various applications, with no additional components required outside of the package. It can do so in the form of only one box. For example, when replacing a V8 engine in a powerboat, it is necessary only to install the unit for it to be used. There is no need for large items to be sited around the boat in a
complex redesign. A boat manufacturer can just fit one or more of the units described above as a propulsion option, optionally alongside/instead of the usual engines. The units are lighter and self-contained for the boat type application, unlike previously considered solutions, and the hotel pack option is also available, which is the enabler for the other installations and again differs from previously considered apparatus.

In summary, embodiments of the present invention described above are able to provide a single unit, as a common package, that can generate, store and supply electricity for multiple uses.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance, it should be understood that the applicant claims protection in respect of any patentable feature or combination of features referred to herein, and/or shown in the drawings, whether or not particular emphasis has been placed thereon.
CLAIMS

1. A power supply unit comprising a power generating unit, for generating electrical power, a power storage unit for storing electrical power, a power switch and an output unit, connectable to a load, wherein the switch is arranged in use to control a supply of electrical power to the output unit so that the output unit is supplied with power from the power generating unit, the power storage unit or both the power generating unit and power storage unit substantially at the same time.

2. A power supply unit according to Claim 1, wherein the power generating unit comprises an engine and a generator.

3. A power supply unit according to Claim 1 or 2, wherein the power generating unit comprises any of a group of electricity generating devices or systems for generating electricity from sources including but not limited to: solar, wind, wave, tide, geothermal, chemical or nuclear.

4. A power supply unit according to any of the preceding claims, wherein the power generating unit and power storage unit are located within a common housing.

5. A power supply unit according to Claim 4, wherein a liquid heat exchanger is located within the common housing.

6. A power supply unit according to any of the preceding claims, wherein the power supply unit comprises a power source for a marine vehicle.
7. A power supply unit according to any of the preceding claims, wherein the power supply unit comprises a power source for a wheeled vehicle.

8. A power supply unit according to any of the preceding claims, wherein the power supply unit comprises a power source for building premises, such as domestic or commercial premises.

9. A power supply unit according to any of the preceding claims, wherein the power supply unit comprises a power source for a combined heat and power unit.

10. A power supply unit according to any of the preceding claims, wherein the power supply unit is arranged to supply power to any of a range of power users including, but not limited to: single or three-phase electrical loads, arms, workshops, military bases, show grounds, exhibition centres, building sites, hospitals, homes, hotels, offices /data centres, back-up supply for critical facilities/equipment, camp sites, any other “off-highway” use that requires electrical energy power.

11. A method of supplying power, the method comprising generating electrical power using a power generator, storing the electrical power, and switching power to an output unit, connectable to a load, wherein the switch is controlled to supply electrical power to the output so that the output unit is supplied with power from the power generator, the power storage unit or both the power generator and power storage unit substantially at the same time.
12. A method according to Claim 11, wherein the method comprises generating electrical power using an engine and a generator.

13. A method according to Claim 11 or 12, wherein the power generator comprises any of a group of electricity generating devices or systems for generating electricity from sources including but not limited to: solar, wind, wave, tide, geothermal, chemical or nuclear.

14. A vessel, vehicle or building powered by a power supply unit according to any of Claims 1 to 10, or in accordance with a power supply method according to any of Claims 11 to 13.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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<tr>
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<td>1-14</td>
<td>US2012/0193988 A1 ESCHRICH et al See figure 1, abstract, paragraphs 3-5, 14-29 and 33</td>
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<td>X</td>
<td>1-14</td>
<td>US6624533 B1 SWANSON et al See figures 1-5, abstract, columns 1-5</td>
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<td>US2002/0190695 A1 WALL et al See figures 1-5 and 19, abstract, paragraphs 29-50 and 190</td>
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<td>US2003/0015873 A1 KHALIZADEH et al See figures 2-7, abstract, paragraphs 34-89</td>
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<td>US2010/0248562 A1 DAIKOKU See abstract and paragraphs 87-99</td>
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<td>1-14</td>
<td>US4150300 A1 VAN WINKLE See figure 1, abstract, columns 1-3</td>
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| X | Document indicating lack of novelty or inventive step |
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:

Worldwide search of patent documents classified in the following areas of the IPC:

H02J

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC
### International Classification:

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