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(54) UNINTERRUPTIBLE POWER SUPPLY SYSTEM HAVING AN NIMH OR LI-ION BATTERY

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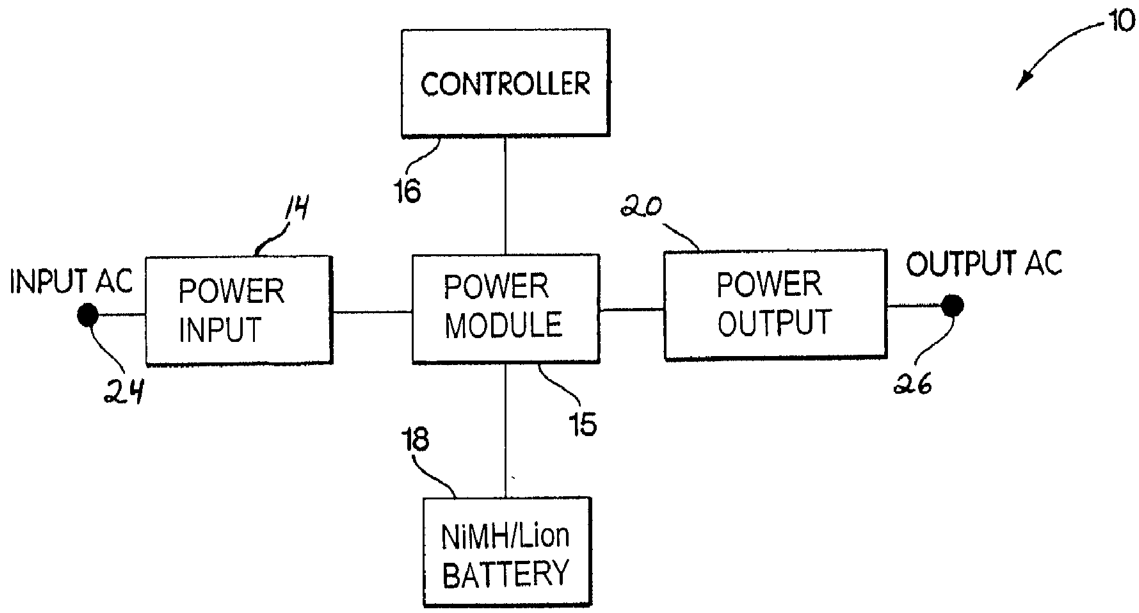
(57) **ABSTRACT**

An uniterruptible power supply (UPS) system that includes one or more NiMH or Li-ion batteries is provided. In one general aspect, the invention features a power supply system including a power input to receive input power from a power source, a power output to provide output power to a load, at least one NiMH or Li-ion battery having a battery output that provides battery power, at least one power module coupled to the power input to receive the input power, coupled to the battery output to receive the battery power and coupled to the power output to provide the output power, a controller, coupled to the at least one power module, constructed and arranged to monitor and control the output power from the at least one power module. A UPS system using a NiMH or Li-ion battery typically uses less space and weigh less than a UPS having a lead acid battery. Additionally, NiMH and Li-ion batteries perform better at temperature extremes than do comparable lead acid batteries.



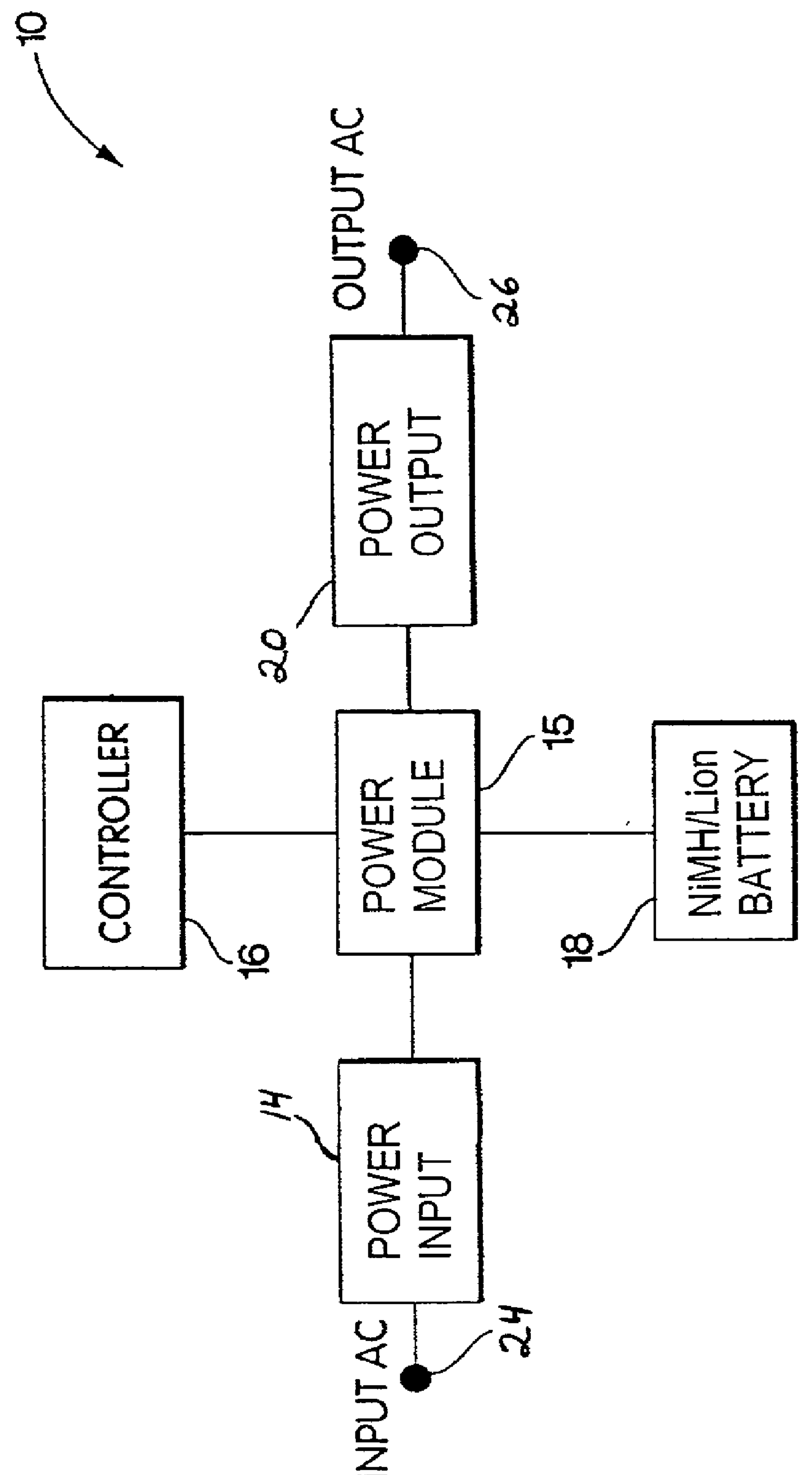

10
OUTPUT AC
26
POWER OUTPUT
20
CONTROLLER
16
POWER MODULE
15
NiMH/Lion BATTERY
18
POWER INPUT
14
INPUT AC
24

Fig. 1

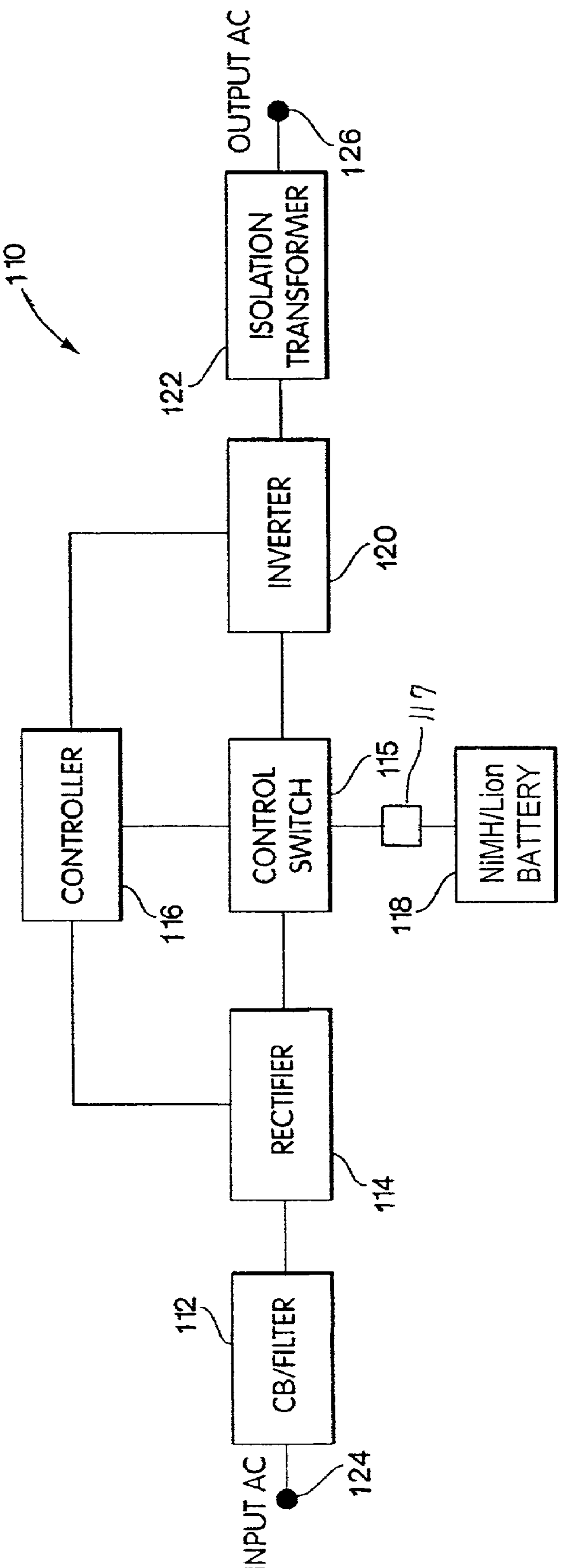

OUTPUT AC
126
110
ISOLATION TRANSFORMER
122
INVERTER
120
CONTROLLER
116
CONTROL SWITCH
115
117
NiMH/Lion BATTERY
118
RECTIFIER
114
CB/FILTER
112
INPUT AC
124

Fig. 2

UNINTERRUPTIBLE POWER SUPPLY SYSTEM HAVING AN NIMH OR LI-ION BATTERY

FIELD OF THE INVENTION

[0001] The present application relates generally to an apparatus for providing uninterruptible, regulated power to critical and/or sensitive loads. More specifically, the present application relates to providing battery power for an uninterruptible power supply (UPS) to ensure power system availability for critical and/or sensitive loads.

BACKGROUND OF THE INVENTION

[0002] The use of uninterruptible power supplies having battery back-up systems to provide regulated, uninterrupted power for critical and/or sensitive loads, such as computer systems, and other data processing systems is well known. Typically, most UPS systems use some type of lead acid battery to provide back-up power. Lead acid batteries, however, have performance limitations especially when they are discharged well above their rated rates or when they are operated at temperature extremes.

SUMMARY OF THE INVENTION

[0003] The uninterruptible power supply (UPS) system of the present application includes one or more NiMH or Li-ion batteries. NiMH and Li-ion battery chemistries are desirable because they are respectively about 2 and 5 times volumetrically and gravimetrically more energy dense than an equivalent lead-acid battery that is typically used in a UPS. Thus, the size of an NiMH or a Li-ion battery is much smaller and lighter than a similarly performing lead acid battery and makes the product into which it is installed more attractive, versatile and useful to customers. The extra volume required by similarly performing lead acid batteries typically requires extra floor space and costly hardware to install the batteries.

[0004] Another advantage of both NiMH and Li-ion batteries is that they are relatively temperature immune. Their performance suffers little at the extremes of the lead acid limits, and their lifetime is not affected as dramatically by temperature as are lead acid batteries. It has been estimated that NiMH battery life times are around 10-15 years. Lead acid batteries can be designed to last similarly long, but compromise their energy density doing so.

[0005] In one general aspect, the invention features a power supply system including a power input to receive input power from a power source, a power output to provide output power to a load, at least one NiMH or Li-ion battery having a battery output that provides battery power, at least one power module coupled to the power input to receive the input power, coupled to the battery output to receive the battery power and coupled to the power output to provide the output power, a controller, coupled to the at least one power module, constructed and arranged to monitor and control the output power from the at least one power module.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] **FIG. 1** is a block diagram of a UPS system having a NiMH or a Li-ion battery in accordance with the invention.

[0007] **FIG. 2** is a block diagram of another embodiment of a UPS system having a NiMH or a Li-ion battery in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0008] One embodiment of the present invention is directed to an uninterruptible power supply (UPS) system that includes one or more NiMH or Li-ion batteries. Both NiMH and Li-ion battery chemistries are more energy dense than an equivalency rated lead acid battery chemistry. Thus, an NiMH or Li-ion battery typically uses less space than a comparable lead acid battery. Additionally, NiMH and Li-ion batteries perform better at temperature extremes than do comparable lead acid batteries.

[0009] The NiMH battery chemistry is about 2 times more volumetrically and gravimetrically dense than the equivalent lead-acid battery as typically used in a UPS. For example, a 7AH NiMH battery can deliver 6 ampere-hours of current-time when discharged at 10 times its rated rate (C) or when it is discharged in 6 minutes. A high rate 18 ampere-hour lead acid battery can deliver the same energy as the example above, but the comparable battery can take up more than twice the volume.

[0010] In an embodiment of the present invention, prior art UPS systems have been modified to include an NiMH battery rather than a lead acid battery. The power processing and control electronics of the UPS have been modified to accept a wider battery voltage range and have been selected to withstand higher charging voltages. The voltage gain components have been selected to deal with the lower discharge voltages.

[0011] Additionally, a controller's algorithm to detect the state of charge of the battery may be different for the NiMH battery than that used for a lead-acid battery. Because NiMH batteries have very flat voltage discharge curves, an NiMH battery's output voltage is an inaccurate gauge to determinate the remaining charge in the battery. Therefore, a current measuring device is preferably used such that the UPS microprocessor controller can calculate the state of charge of the batteries during charge, discharge and standby modes.

[0012] As an example, a NiMH battery has been retrofitted in a Legacy UPS system manufactured by the American Power Conversion, Corp. by making the following changes. The SLA batteries in the Legacy model have been retrofitted with one or more NiMH batteries that collectively have a 25% higher nominal voltage. For example, a 24V SLA system was replaced by 25 1.2V cells coupled together in series to create a 30V NiMH system. If a plurality of NiMH batteries are used in parallel, it is necessary that the batteries have equivalent voltage ratings.

[0013] The voltage rating on all the Legacy UPS electrical components connected to the DC bus are increased to accommodate the higher charging voltages of the NiMH batteries. It is sufficient to increase the voltage rating of the DC connected components in the Legacy UPS by at least 25% (corresponding to the higher charging voltages).

[0014] In an embodiment of the invention, the one or more NiMH batteries retrofitted in the Legacy system have been charged according to a method different than that typically used for lead acid batteries. For example, for about 0-99% of the charging capacity of the batteries, the batteries are charged at a constant current rate of between about 0.3C to about 1C*. The fast charge of one or more batteries is stopped when the temperature of the batteries starts to rise substantially, exceeds 40° C. or exceeds 20° C. above the ambient temperature. After the fast charge of the batteries is stopped, one or more batteries are "float" charged by applying a trickle current to achieve a slight positive temperature differential between the battery cases to the ambient temperature. This procedure keeps overcharging of the batteries to a minimum, yet adequately compensates for the loss of charge due to internal self-discharge.

*NOTE C is a constant equal to the AH rating of the battery in Amps. e g C for a 7AH battery is 7 Amps.

[**0015**] In another embodiment of the present invention, prior art UPS systems have been modified to include a battery from the Li-ion family rather than a lead acid battery. The Li-ion battery chemistry is desirable because the battery is about five times more volumetrically and gravimetrically energy dense than an equivalently rated lead-acid battery types. For example, a 10 ampere-hour Li-ion battery can deliver 9 ampere-hours of current-time when discharged at 2 times its rated rate (C) or when it is discharged in 30 minutes. A high rate 18 ampere-hour lead acid battery can deliver the same energy as example above but takes up more than 5 times the volume as the Li-ion battery in the above example.

[**0016**] The algorithm used for charging the Li-ion battery may be different and the discharge rate of the batteries should be lower than that used for a lead acid battery. Typically, a Li-ion based UPS will be used for long discharges, for example more than one hour, rather than shorter discharges.

[**0017**] As an example, a Li-ion battery has been used in a Legacy UPS system with SLA batteries by making the following changes. Similar to a NiMH battery, a Li-ion battery has a very flat voltage discharge curve, so it is not desirable to use a Li-ion battery's output voltage for determining the remaining charge in the battery. Therefore, a means for measuring the battery current was used such that the UPS microprocessor monitored the battery current, determined the state of charge of the battery and calculated the remaining run time in the batteries during discharge, charge and standby modes. The determination of the remaining run time from the state of charge is known to those of ordinary skill in the art. The current measuring means can be an ammeter connected in series with the battery, a volt meter for measuring the voltage across a resistor in series with a battery such that the current can be determined, or any other means for detecting or measuring current to and from the battery.

[**0018**] It is preferable to replace the Legacy SLA lead acid batteries with one or more Liion batteries having a nominal voltage equivalent or somewhat more than that of the lead acid battery voltage. For example the Legacy's 24 volt SLA system was replaced by seven 3.7 volt cells coupled in series to create a 26 volt Li-ion battery system. To charge the Li-ion batteries, the float voltage setting point and temperature compensation slope was modified in the UPS microprocessor. As noted above, it is preferable to monitor current going into the battery for an indication of state of charge.

[**0019**] **FIG. 1** shows a exemplary UPS **10** system used to provide regulated uninterrupted power in which a NiMH or Li-ion battery can be used. The UPS **10** includes a power input **14**, a power module **15**, a controller **16**, an NiMH or Li-ion battery **18**, and a power output **20**. The UPS also includes an input **24** for coupling to an AC power source and an outlet **26** for coupling to a load. The power input **14** can include, for example, a circuit breaker or filter **112** and/or a rectifier. The power output **20** can include, for example, an inverter **120** and optionally an isolation transformer **122**. The controller **16** can be, for example, a microprocessor with code embedded therein for controlling the functions of the UPS. The power module **15** can include, for example, a control switch which is controlled by the controller **16**.

[**0020**] **FIG. 2** shows another exemplary UPS **110** used to provide regulated uninterrupted power in which a NiMH or Li-ion battery can be used. The UPS **110** includes an input circuit breaker/filter **112**, a rectifier **114**, a control switch **115**, a controller **116**, an NiMH or Li-ion battery **118**, an inverter **120** and optionally an isolation transformer **122**. The UPS also includes an input **124** for coupling to an AC power source and an outlet **126** for coupling to a load. The UPS can also include a current meter or other current measuring means to measure a current of the battery, such as, for example, an ammeter, a Hall sensor device or a voltmeter that measures the voltage across a current shunt **117**.

[**0021**] The exemplary UPS **110** can **8** operate as follows. The circuit breaker/filter **112** receives input AC power from the AC power source through the input **124**, filters the input AC power and provides filtered AC power to the rectifier **114**. The rectifier converts the filtered AC power to DC power having a predefined voltage value. The control switch **115** receives the DC power from the rectifier and also receives DC power from the NiMH or Li-ion battery **118**. The controller **116** determines whether the AC power available from the power input is within predetermined tolerances, and if so, controls the control switch to provide the DC power from the rectifier to the inverter **120**. If the AC power from the power input is not within the predetermined tolerances, which may occur because of "brown out" or "black out" conditions, or due to power surges, then the controller controls the control switch to provide the DC power from the NiMH or Li-ion battery **118** to the inverter **120**.

[**0022**] The inverter **120** of the exemplary UPS **110** receives DC power from the controller **116**, converts the DC power to AC power, and regulates the AC power to predetermined specifications. The inverter **120** provides the regulated AC power to the optional isolation transformer **122**. The isolation transformer may be used to increase or decrease the voltage of the AC power from the inverter and/or to provide electrical isolation between a load and the UPS. Depending on the capacity of the battery and the power requirements of the load, the UPS **110** can provide power to the load during brief power source "dropouts" or for extended power outages.

[**0023**] In the UPS system **110**. the controller, the control switch and/or the battery may also contain circuitry to charge the battery using the DC power supplied by the rectifier. The NiMH or Li-ion battery can be charged using one of the stated methods above. In addition, in some UPS systems, the controller provides operating status information to a user, either locally using, for example, indicating lights or a display system, or remotely by communicating with an external monitoring device.

[**0024**] It should be understood that the foregoing is illustrative and not limiting and that obvious modifications may be made by those skilled in the art without departing from the spirit of the invention. Accordingly, reference should be made primarily to the accompanying claims, rather than the foregoing specification, to determine the scope of the invention.

What is claimed is:

1. A power supply system comprising:

a power input to receive input power from a power source;

a power output to provide output power to a load;

at least one battery having a battery output that provides battery power, the at least one battery being selected from the group consisting of: nickel metal hydride and lithium ion polymer;

at least one power module coupled to the power input to receive the input power, coupled to each battery output to receive a power of each battery and coupled to the power output to provide the output power; and

a controller, coupled to the at least one power module, constructed and arranged to monitor and control the output power from the at least one power module.

2. The power supply system according to claim 1, wherein the at least one battery is a nickel metal hydride battery.

3. The power supply system according to claim 1, wherein the at least one battery is a lithium ion battery.

4. The power supply system according to claim 2, further comprising means for measuring a current of the battery, wherein the controller has program code means embodied therein for determining a state of charge of at least one battery by monitoring the current of at least one battery.

5. The power supply system according to claim 3, further comprising means for measuring a current of the battery, wherein the controller has program code means embodied therein for determining a state of charge of the battery by monitoring the current of the battery.

6. The power supply system according to claim 2, further comprising means for measuring a current, a voltage and a temperature of at least one of the nickel metal hydride batteries, wherein the controller has program code means embodied therein for completing the method of charging the at least one nickel metal hydride battery, the method comprising:

determining a state of charge of the battery by monitoring the current of the battery;

for between about 0% to about 99% of a charging capacity each battery, charging each battery at a constant current rate of between about 0.3C to about 1C;

stopping the charge of each battery if the temperature of each battery starts to rise substantially;

stopping the charge if a temperature of each battery rises above about 40° C. or about 20° C. above an ambient temperature; and

applying a trickle current to each battery such that a slight temperature differential is achieved between each battery case and the ambient temperature.

7. A power supply system comprising:

a filter to receive and filter input power from a power source;

a rectifier coupled to the filter

at least one battery having a battery output that provides battery power, the at least one battery being selected from the group consisting of: nickel metal hydride and lithium ion polymer;

at least one control switch coupled to the rectifier to receive the input power, coupled to each battery output to receive a power of each battery and coupled to an input to provide the output power; and

a controller, coupled to the at least one control switch, constructed and arranged to monitor and control the output power from the at least one control switch.

8. The power supply system according to claim 7, further comprising an inverter coupled between the at least one control switch and the transformer, wherein the inverter is coupled to the controller.

9. The power supply system according to claim 7, wherein the at least one battery is a nickel metal hydride battery.

10. The power supply system according to claim 7, wherein the at least one battery is a lithium ion battery.

11. The power supply system according to claim 9, further comprising means for measuring a current of the battery, wherein the controller has program code means embodied therein for determining a state of charge of the battery by monitoring the current of the battery.

12. The power supply according to claim 11, wherein the means for measuring a current of the battery comprises a current shunt.

13. The power supply system according to claim 10, further comprising means for measuring a current of the battery, wherein the controller has program code means embodied therein for determining a remaining run time of the battery by monitoring the current of the battery.

14. The power supply according to claim 13, wherein the means for measuring a current of the battery comprises a current shunt.

15. The power supply system according to claim 7, wherein the rectifier is coupled to the controller.

16. The power supply system according to claim 7, further comprising a transformer coupled between the battery and the output.

17. A power supply system comprising:

a power input to receive input power from a power source;

a power output to provide output power to a load;

at least one battery having a battery output that provides battery power, the at least one battery being selected from the group consisting of: nickel metal hydride and lithium ion polymer;

at least one power module coupled to the power input to receive the input power, coupled to each battery output to receive a power of each battery and coupled to the power output to provide the output power;

means for measuring a current of at least one the batteries; and

a controller, coupled to the at least one power module, constructed and arranged to monitor and control the output power from the at least one power module, the controller having program code means embodied therein for completing a method of charging the at least one Nickel Metal Hydride battery, the method comprising:

for between about 0% to about 99% of a charging capacity each battery, charging each battery at a constant current rate of between about 0.5C to about 1C;

stopping the charge of each battery if the temperature of each battery starts to rise substantially;

stopping the charge if a temperature of each battery rises above about 40° C. or about 20° C. over an ambient temperature; and

applying a trickle current to each battery such that a slight temperature differential is achieved between each battery case and the ambient temperature.

18. A method of charging at least one Nickel Metal Hydride battery in an uninterruptible power supply system having at least one power module coupled to a power input to receive input power, coupled to each battery output to receive power from each battery and coupled to a power output to provide output power to a load, and a controller, coupled to the at least one power module, constructed and arranged to monitor and control the output power from the at least one power module, the method comprising:

measuring a current of each battery;

for between about 0% to about 99% of a charging capacity each battery, applying a current to each battery to charge each battery at a constant current rate of between about 0.5C to about 1C;

stopping the applied current of each battery if the temperature of each battery starts to rise substantially;

stopping the applied current if a temperature of each battery rises above about 40° C. or above 20° C. over an ambient temperature; and

applying a trickle current to each battery such that a slight temperature differential is achieved between each battery case and the ambient temperature.

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