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(54) **VEHICLE CHARGING, MONITORING AND CONTROL SYSTEMS FOR ELECTRIC AND HYBRID ELECTRIC VEHICLES**

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(57) **ABSTRACT**

A distributed charging system for electric and hybrid electric vehicles includes multiple battery packs of different voltages including high voltage battery packs and one or more low voltage battery packs, each having separate and independent charging systems and multiple sources of electric power. Electric power is distributed from the sources of electric power separately to each of the independent charging systems. A drive system for the electric or hybrid electric vehicle includes a stored energy system made up of these multiple battery packs and a master events controller controlling at least one of a) a traction drive system including a motor and controller for receiving driving electric energy from a stored energy system for propulsion of the vehicle, b), an auxiliary power system for recharging the battery packs and c) a vehicle monitoring and control network for controlling the operation of, and monitoring all bus systems in the vehicle.

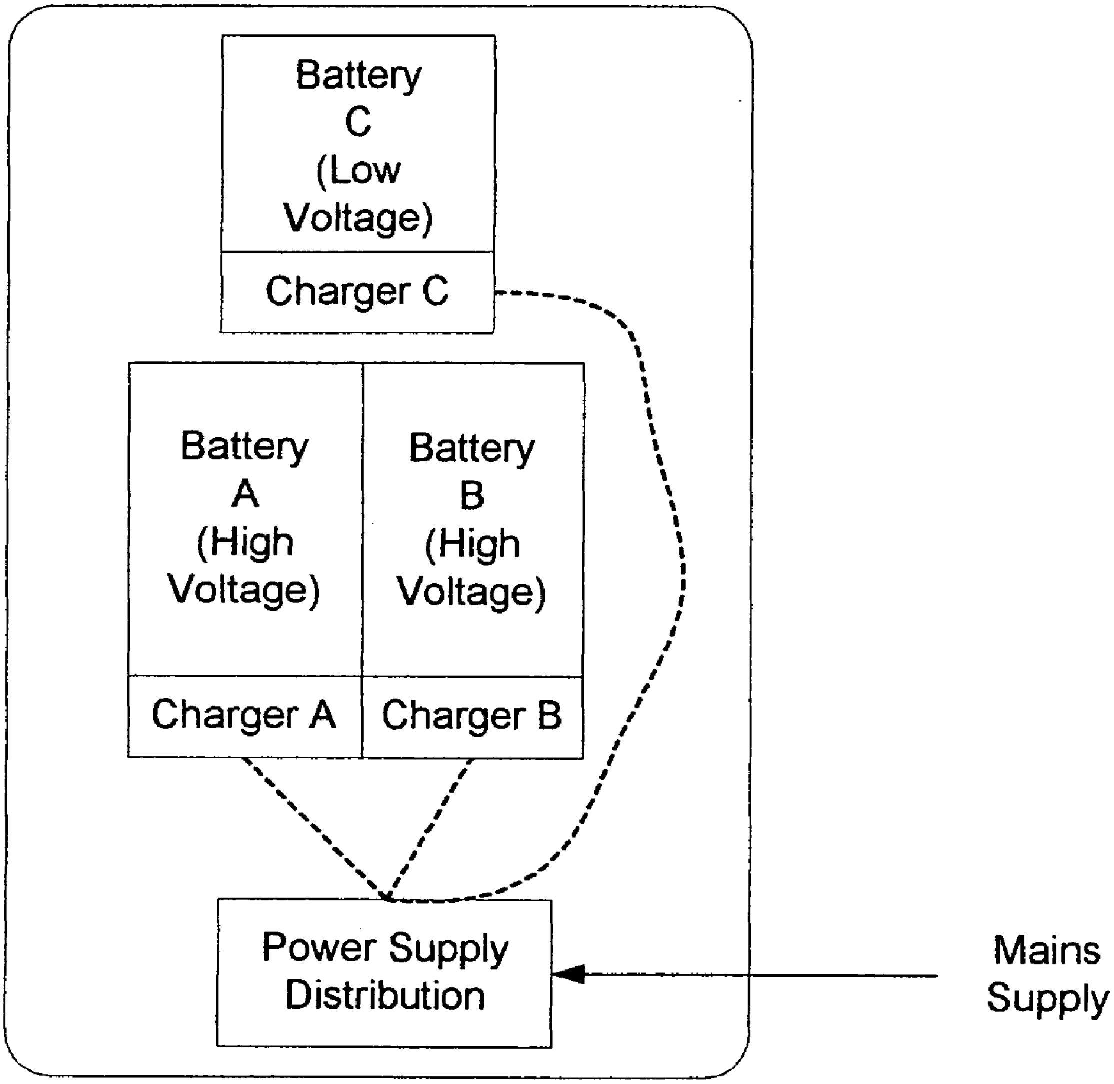
Battery
C
(Low
Voltage)
Charger C
Battery
A
(High
Voltage)
Battery
B
(High
Voltage)
Charger A
Charger B
Power Supply
Distribution
Mains
Supply

Figure 1

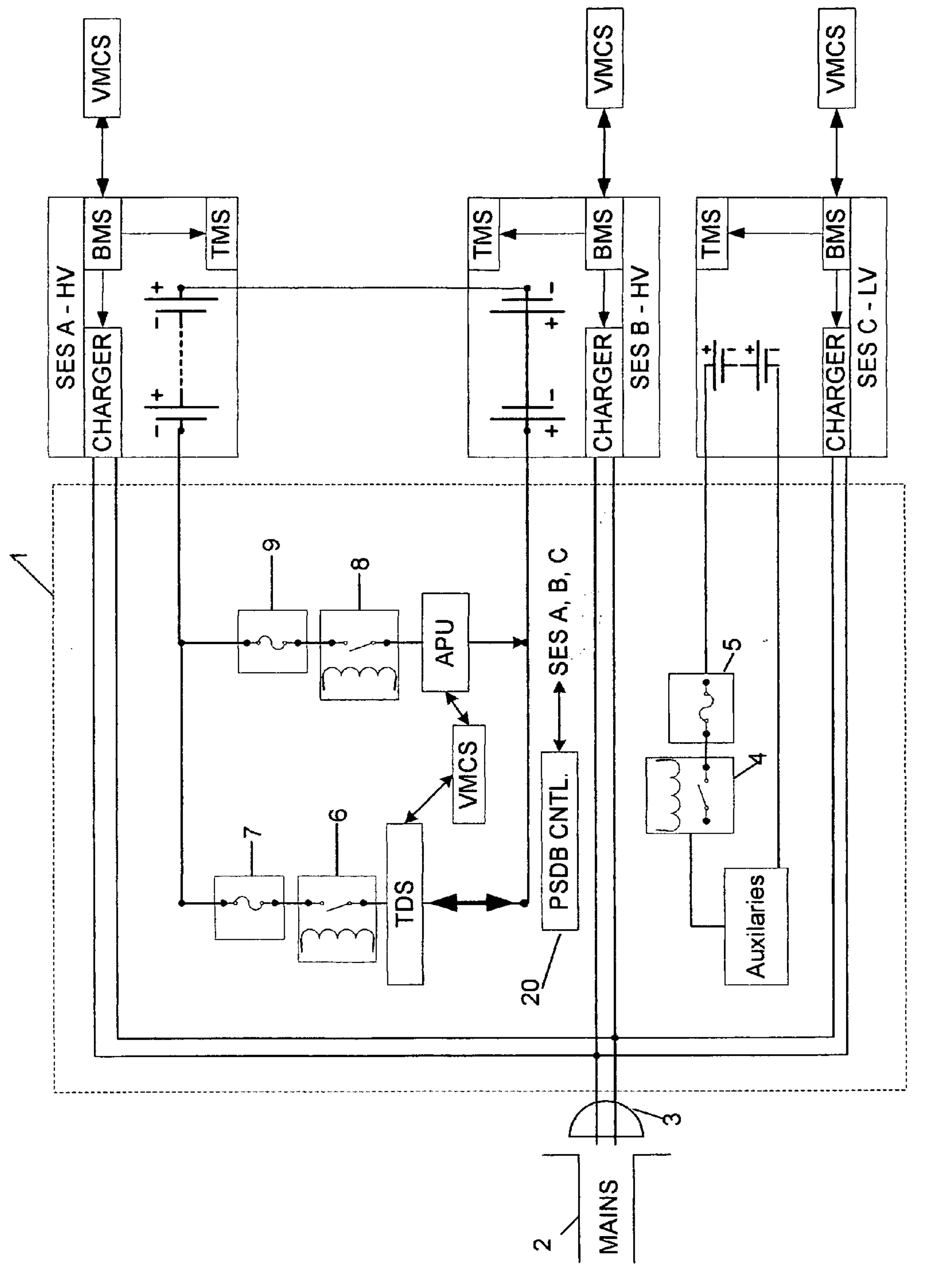

Figure 2A - SES in Series

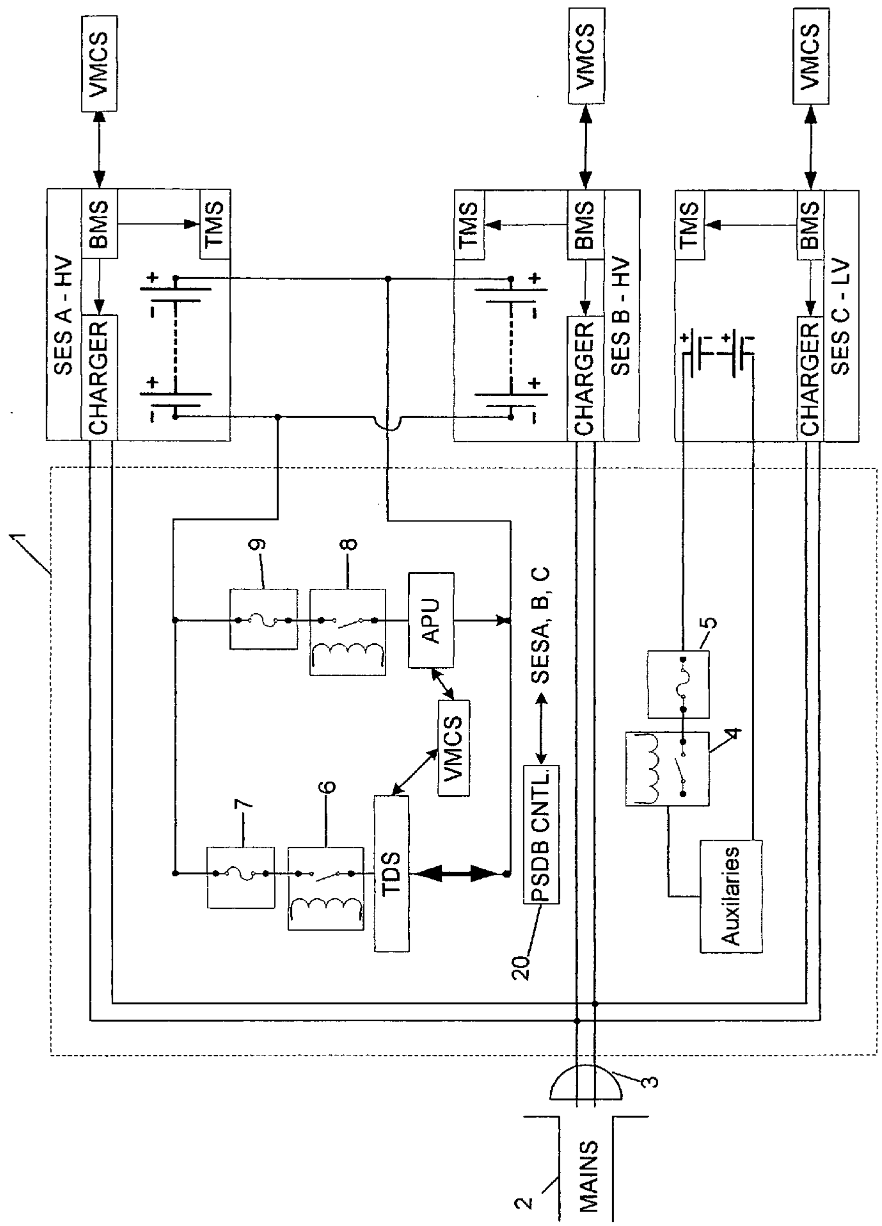

Figure 2B - SES in Parallel

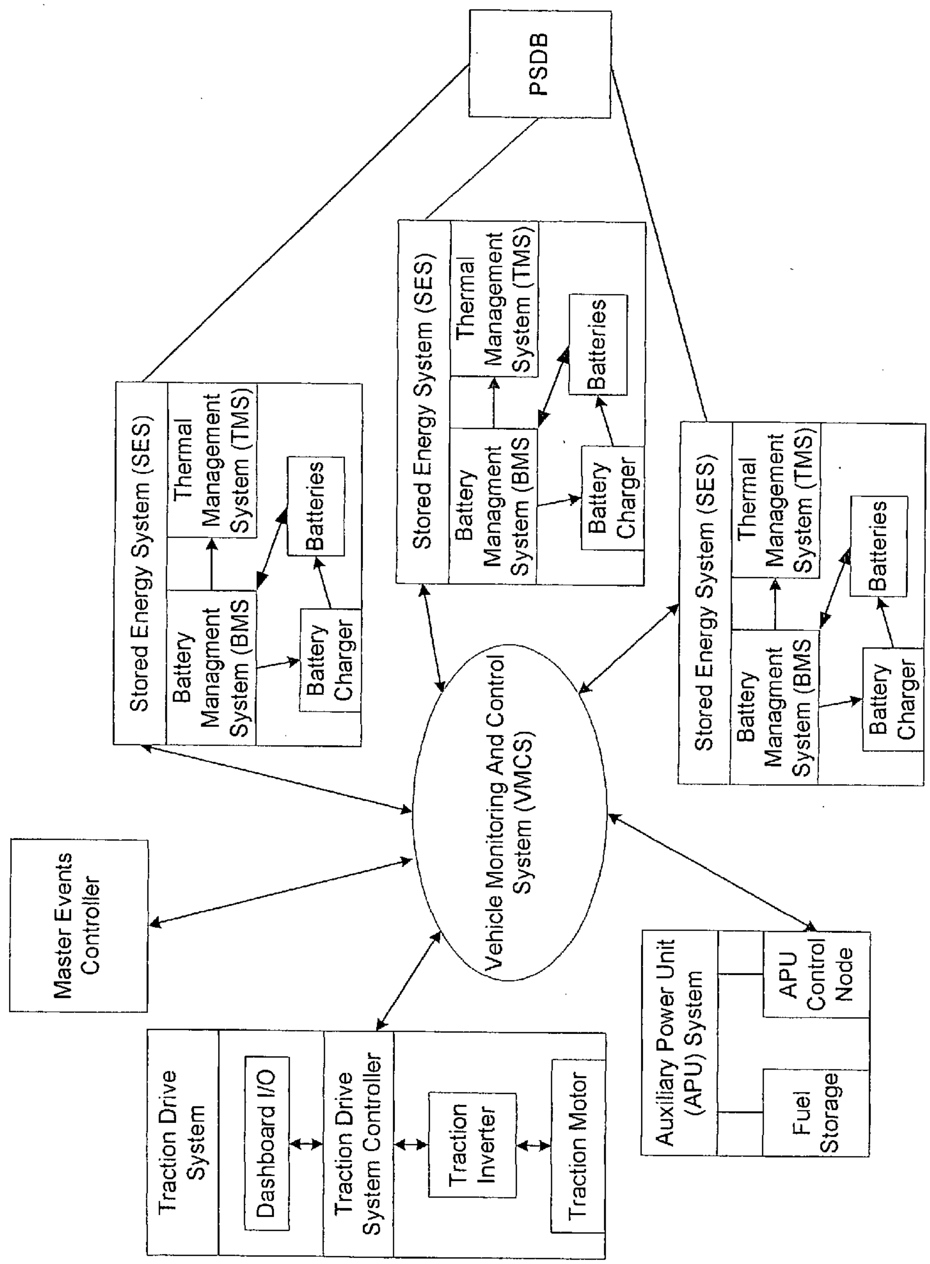
PSDB
Stored Energy System (SES)
Thermal Management System (TMS)
Battery Managment System (BMS
Batteries
Battery Charger
Stored Energy System (SES)
Thermal Management System (TMS)
Battery Managment System (BMS
Batteries
Battery Charger
Stored Energy System (SES)
Thermal Management System (TMS)
Battery Managment System (BMS
Batteries
Battery Charger
Vehicle Monitoring And Control System (VMCS)
Master Events Controller
Traction Drive System
Dashboard I/O
Traction Drive System Controller
Traction Inverter
Traction Motor
Auxiliary Power Unit (APU) System
APU Control Node
Fuel Storage

Figure 3

VEHICLE CHARGING, MONITORING AND CONTROL SYSTEMS FOR ELECTRIC AND HYBRID ELECTRIC VEHICLES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit, under 35 U.S.C. 119(e) of U.S. Provisional Application No. 60/642,501, filed Jan. 10, 2005 and U.S. Provisional Application No. 60/642,499, filed Jan. 10, 2005, which are hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to energy distribution, monitoring and control systems for hybrid electric and electric motor vehicles. More particularly, the present invention is directed to electric and hybrid electric off-road and on-road vehicles, which use solely a battery pack or a battery and electric generator combination to supply energy for propulsion.

BACKGROUND OF THE INVENTION

[0003] Electric and hybrid electric vehicles sometimes require the use of a plurality of battery compartments in order to meet the total voltage and/or capacity requirements or to supply auxiliary systems requiring a separate battery compartment. For example, two battery strings or battery packs may be connected in a series configuration in order to double the voltage or in a parallel configuration in order to double the current capacity. In addition a vehicle sub-system may require a completely different voltage than that of the main vehicle battery voltage thus requiring a lower or higher voltage battery pack or string.

[0004] Recharging batteries configured in the stated, segmented configuration with a bulk-charging device is not optimal, resulting in uneven battery charging and premature battery failure.

OBJECTS OF THE INVENTION

[0005] It is an object of the present invention to address the distribution of energy to a plurality of battery charging equipment, which are found in a plurality of battery compartments (also called battery packs), in electric and hybrid electric vehicles. The battery compartments or battery packs are part of a Stored Energy System, which includes a plurality of batteries connected in series, a Battery Management System, a battery charger and a Battery Thermal Management System.

[0006] It is another object of the present invention to address a variety of control challenges associated with reliable and long-term battery operation of electric and hybrid electric motor vehicles. Vehicles utilizing the present invention include, but are not limited to, electric and hybrid electric buses, trucks, material handling vehicles (forklifts and pallet jacks), neighborhood electric vehicles, and airport support equipment.

[0007] It is another object of the present invention to monitor and control the systems of electric and hybrid electric vehicles having differing voltages for different subsystems of the vehicle.

[0008] It is yet another object of the present invention to provide a distributed battery charging system and to prevent uneven battery charging and premature battery failure in electric and hybrid electric vehicles.

[0009] It is also an object of the present invention to monitor vehicle subsystems of electric and hybrid electric vehicles.

[0010] Other objects which become apparent from the following description of the present invention.

SUMMARY OF THE INVENTION

[0011] The present invention is a distributed charging system, specifically placing a separate battery charger for each of the varying voltage battery compartments or Stored Energy Systems (SES), found on the vehicle. Another object of the invention is the distribution of the supply power to each of the chargers from the mains supply, which may be an AC or DC supply. The AC and DC power source can be generated onboard or off-board, or can be obtained from the local power grid.

[0012] An individual battery compartment housing a battery pack or a battery string is a Stored Energy System, which completely, includes a plurality of batteries individually connected in series and/or parallel creating the battery pack or string, a Battery Management System, a battery charger and a Battery Thermal Management System managing the temperature of one or more batteries or cells within a battery pack. A vehicle may have multiple SES units either connected in series or in parallel creating the main vehicle voltage and current capacity, or stand alone, powering a vehicle sub-system, which may require a lower or higher voltage and current capacity, different from the main vehicle voltage and current capacity to operate.

[0013] The Vehicle Monitoring and Control System (VMCS) of this invention is used to control the operation of, and monitor all the bus sub-systems found in electric and hybrid electric vehicles (EV/HEV's). This system has been designed to accommodate the challenges associated with the operation of a variety of energy storage and propulsion technologies found within EV/HEV's.

[0014] The major features of the system are:

- [0015] "Plug and Play" capability
- [0016] Modularity of components
- [0017] Upgradeable as subsystem technologies change
- [0018] Ethernet connectivity with embedded user interface software
- [0019] Unique software algorithms for overall system control, miles to empty indication (indicating how much remaining distance in travel miles is related to fuel capacity before the fuel tank is empty of fuel)
- [0020] Control strategies are based on individual battery module voltages

[0021] The system includes a central controller called the Master Events Controller (MEC) and three major subsystems: 1) Traction Drive System, 2) Stored Energy System, and, 3) Auxiliary Power Unit (APU). The VMCS may service one or more Stored Energy Systems, which can be connected in parallel or in series with each other or stand-alone. The network operates on a Controller Area Network-based (CAN) system using a higher-level protocol such as Odyne Corporation's O-NET™, over which the major subsystems communicate with the Master Events Controller (MEC).

Master Events Controller (MEC):

[0022] The MEC is the central control unit of the system. All of the overall operation software of the vehicle resides within the MEC. The MEC has two modes of operation: 1) driving mode and 2) stationary mode. During each mode, the MEC executes specific commands to interface with each sub-system, the driver, or off-board systems (when parked for charging).

[0023] The systems controlled by the Master Events Controller (MEC) include one or more of the following systems:

Stored Energy System (SES)

[0024] An SES preferably includes the batteries (which can be of any chemistry or type), battery enclosure/tray, thermal management system, battery charger and microprocessor-based Battery Management System (BMS). The BMS monitors the batteries, controls the charger and thermal management system and communicates via CAN with the MEC. The BMS reports critical information to the MEC on overall battery pack and individual battery modules. The BMS also performs its own "internal" operations such as battery monitoring, equalization and charging. The BMS provides the MEC with battery state of charge information, so that the MEC can provide the operator with a "miles to empty" indication and with any critical errors which may exist within the its SES. Multiple SES units of different voltages and current capacities can be used on a vehicle, either connected in series, parallel or stand-alone.

Traction Drive System (TDS)

[0025] The Traction Drive System (TDS) preferably includes the traction motor, motor controller with Inverter and a Driver Interface Node (DIN). The TDS is the part of the system, which creates the path between the driver and the wheels, specifically processing accelerator and brake pedal feedback, in order to move and stop the vehicle. The TDS receives critical information from the Master Events Controller (MEC), (as provided by the Stored Energy System (SES) units and other vehicle sub-systems connected to the VMCS), in order to maximize available acceleration and allowable regenerative braking, based on the condition of the SES units.

Auxiliary Power Unit (APU)

[0026] The Auxiliary Power Unit (APU) preferably includes a heat engine, alternator, fuel storage and power conversion electronics. The APU system can be configured to operate on a variety of fuels and generates electricity to charge the battery packs within the SES units. Alternatively, a fuel cell can be used. The MEC sends commands to the APU through the APU Control Node in order to establish the correct time and power level for APU operation. The APU provides the MEC with critical information such as current engine operating statistics along with fuel level so the MEC can provide the driver with a "miles to empty" indication and with any errors which may exist within the APU.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The present invention can best be understood in connection with the accompanying drawings. It is noted that the invention is not limited to the precise embodiments shown in drawings, in which:

[0028] **FIG. 1** is a block diagram showing the distributed charging system of this invention with a common power supply distribution block cabled to separate battery chargers incorporated into three separate battery packs on-board a vehicle;

[0029] **FIGS. 2A and 2B** are more detailed block diagrams of the charging system of **FIG. 1** showing interfaces to a Stored Energy Systems (SES) which is part of the Vehicle Monitoring and Control System (VMCS) of this invention, and

[0030] **FIG. 3** is a block diagram of the Vehicle Monitoring and Control System (VMCS) of this invention, showing the main vehicle-based communications loop with sub-branches within the various vehicle subsystems.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0031] **FIG. 1** is an illustration showing an example of the distributed charging system of this invention. The illustration of **FIG. 1** shows three battery packs A, B and C having different nominal voltages. Battery compartment A and battery compartment B are normally connected in series during vehicle operation in order to achieve a voltage double the rated voltage of each individual battery compartment. Battery compartment C is a low voltage battery pack, which is used to supply power to the vehicle auxiliaries.

[0032] Each battery compartment in **FIG. 1** is a complete Stored Energy System (SES), complete with Battery Management System (BMS) and other control, measurement and communication blocks, such as a Thermal Management System (TMS) and battery charger. During the period when the vehicle is charged, each Stored Energy System (SES) charges its own batteries by using its own charger, which is controlled by its own BMS. Battery charger A, charges batteries in Stored Energy System (SES) A, battery charger B charges the batteries in Stored Energy System (SES) B and battery charger C charges batteries in Stored Energy System (SES) C; all independent and having a separate and distinct mains supply.

[0033] **FIGS. 2A and 2B** are more detailed block diagrams of a vehicle distributed charging system as in **FIG. 1**; **FIG. 2A** illustrates two high voltage Stored Energy Systems (SES's) in series, while **FIG. 2B** shows them in parallel. Both **FIGS. 2A and 2B** show routing of power to the battery chargers through a single power supply distribution block **1**. Although this is illustrated as a two-wire AC or DC power distribution network, the power can be distributed via a common output to the distributed chargers as 3-wire or 4-wire three phase AC. Three complete Stored Energy Systems (SES) are illustrated in **FIGS. 2A and 2B** for the electric vehicle shown, however as few as one, or more than three such battery packs may be configured in any given vehicle.

[0034] **FIGS. 2A and 2B** also show that each of the chargers within its given SES is controlled by its associated battery management system (BMS) which, in turn, communicates with the VMCS. Each of the SES units has its own Thermal Management System (TMS), which is also controlled by the BMS.

[0035] **FIGS. 2A and 2B** also show that distribution block **1** has a control block **20** which communicates with the each of the Stored Energy Systems (SES) and controls the switching elements, while monitoring and controlling overload components. The mains power supply **2** is connected via connector **3** and provides power to the chargers individually. Switching elements **4**, **6** and **8** are illustrated as electromagnetic relays; they may be solid-state relays instead. Overload elements **5**, **7** and **9** are illustrated as fuses for clarity. Note that switching elements can be solid-state, and may range from steering diodes to IGPT's (isolated gate power transistors), MOSFET's or other AC or DC switching components. The overload elements can be circuit breakers, and not just fuses shown in **FIGS. 2A and 2B**.

[0036] Other elements shown in **FIGS. 2A and 2B** are the Auxiliary Power Unit (APU), shown connected via relay **8** and fuse **9**, and Traction Drive System (TDS), shown connected via relay **6** and fuse **7**. Auxiliaries include such items as lights, radio, power windows, HVAC systems, power seats, and many more. They are shown connected to a low voltage Stored Energy System (SES) C through relay **4** and fuse **5**.

[0037] **FIG. 3** shows the Vehicle Monitoring and Control System of this invention. Although other isolated expandable bus types and protocols can be used as the vehicle communications network, the Controller Area Network, or CAN, is illustrated in **FIG. 3**. One of the attributes of this network is the "plug and play" feature, where the network uses a self-discovery procedure which identifies a newly "plugged-in" element and then establishes communications with it. The network is configured as a main loop establishing bi-directional communications between the Master Events Controller (MEC), and at least one of the Stored Energy Systems (SES), the Traction Drive System (TDS) and the Auxiliary Power Unit (APU).

[0038] In addition, in **FIG. 3**, the Auxiliary Power Unit (APU) has a direct link to the Fuel Storage unit; the Traction Drive System has two direct links (or a local loop) to each of the Dashboard I/O Interface and the Traction Motor and Controller element, and each Stored Energy System (SES) has a local loop or a local star network to communicate to its local Battery Management System (BMS) and Thermal Management System (TMS). Each Stored Energy System (SES) also communicate with the Power Supply Distribution Block (PSDB).

[0039] In the foregoing description, certain terms and visual depictions are used to illustrate the preferred embodiment. However, no unnecessary limitations are to be construed by the terms used or illustrations depicted, beyond what is shown in the prior art, since the terms and illustrations are exemplary only, and are not meant to limit the scope of the present invention.

[0040] It is further known that other modifications may be made to the present invention, without departing the scope of the invention, as noted in the appended Claims.

We claim:

1. A distributed charging system for electric and hybrid electric vehicles comprising:

multiple battery packs;

said battery packs having separate and independent charging systems;

multiple sources of electric power for said independent charging systems; and

means for distributing said electric power from said sources of electric power separately to each of said independent charging systems.

2. The distributed charging system of claim 1 wherein said battery packs are of different voltages.

3. The distributed charging system of claim 2 wherein said battery packs are high voltage battery packs.

4. The distributed charging system as in claim 1 further comprising at least one low voltage power pack.

5. The distributed charging system of claim 1 in which the high voltage battery packs are connected in series during motor vehicle operation.

6. The distributed charging system as in claim 1 in which the battery packs are connected in parallel during motor vehicle operation.

7. The distributed charging system of claim 1 in which at least one of said sources of electric power is an onboard auxiliary power unit comprising an internal combustion engine.

8. The distributed charging system of claim 1 in which at least one of said sources of electric power is an off-board power supply.

9. The distributed charging system of claim 1 in which at least one of said sources of electric power is an AC power supply.

10. The distributed charging system of claim 1 in which at least one of said sources of electric power is a DC power supply.

11. The distributed charging system of claim 1 in which power is supplied to each of said battery packs from a mains supply.

12. The distributed charging system of claim 1 in which one of said sources is solar energy.

13. The distributed charging system of claim 1 in which all said sources of electric power are integrated into a single power supply distribution block.

14. The distributed charging system of claim 1 in which each of said independent charging systems has, and is controlled by, its own integrated battery management system.

15. The distributed charging system of claim 14 in which each battery management system is in communication with a vehicle monitoring control system.

16. The distributed charging system of claim 15 in which each battery pack has a thermal management system controlled its respective battery management system.

17. The distributed charging system of claim 1 in which each said battery pack of a battery compartment has associated therewith at least one sub-system requiring a different voltage than that of a main battery voltage for said battery pack, thereby requiring at least one of a lower and/or higher voltage battery compartment for said battery compartment.

18. A drive system in an electric or hybrid electric vehicle comprising:

stored energy systems comprising multiple batteries for providing driving electric energy;

a traction drive system including a motor, an inverter, controller and dashboard I/O for receiving driving electric energy from said stored energy systems for propulsion of said vehicle;

an auxiliary power system for recharging said voltage battery packs within said stored energy systems;

a vehicle monitoring and control network for controlling the operation of, and monitoring all bus systems in said vehicle; and,

a master event controller interfaced through said vehicle monitoring and control network with each system in said vehicle, said master event controller containing all overall operational software for said vehicle and executing specific commands relating to each of said systems; wherein said vehicle monitoring and control network is configured as a main loop establishing bi-directional communications among the master events controller, the stored energy system, traction drive system and the auxiliary power system.

19. The drive system of claim 18 in which said master event controller has two modes of operation, a drive mode and a stationary mode, said master event controller executing specific commands in each mode to interface with each system, to a driver of the vehicle, and to an off-board system when said vehicle is parked for charging.

20. The drive system of claim 19 in which said auxiliary power system includes one or more of an internal combustion engine, a solar power source, a fuel cell or an AC or DC power source.

21. The drive system of claim 18 further comprising at least one low voltage battery pack for operating accessories within said vehicle.

22. A drive system in an electric or hybrid electric vehicle comprising:

a) at least one of:

i) stored energy systems comprising multiple batteries for providing driving electric energy;

ii) a traction drive system including a motor, inverter, controller and dashboard I/O for receiving driving electric energy from said stored energy systems for propulsion of said vehicle;

iii) an auxiliary power system for recharging said voltage battery packs within said stored energy systems;

b) a vehicle monitoring and control network for controlling the operation of, and monitoring all bus systems in said vehicle;

c) a master event controller interfaced through said vehicle monitoring and control network with each system in said vehicle, said master event controller containing all overall operational software for said vehicle and executing specific commands relating to each of said systems;

d) wherein said vehicle monitoring and control network is configured as a main loop establishing bi-directional communications among the master events controller and at least one of said stored energy system, said traction drive system and said auxiliary power system.

23. The drive system of claim 22 in which said master event controller has two modes of operation, a drive mode and a stationary mode, said master event controller executing specific commands in each mode to interface with each system, to a driver of the vehicle, and to an off-board system when said vehicle is parked for charging.

24. The drive system of claim 23 in which said auxiliary power system includes one or more of an internal combustion engine, a solar power source, a fuel cell or an AC or DC power source.

25. The drive system of claim 22 further comprising at least one low voltage battery pack for operating accessories within said vehicle.

26. The drive system of claim 25 in which said master controller further controls at least one additional subsystem.

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