Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2317045 C 2004/09/21

(11)(21) 2 317 045

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

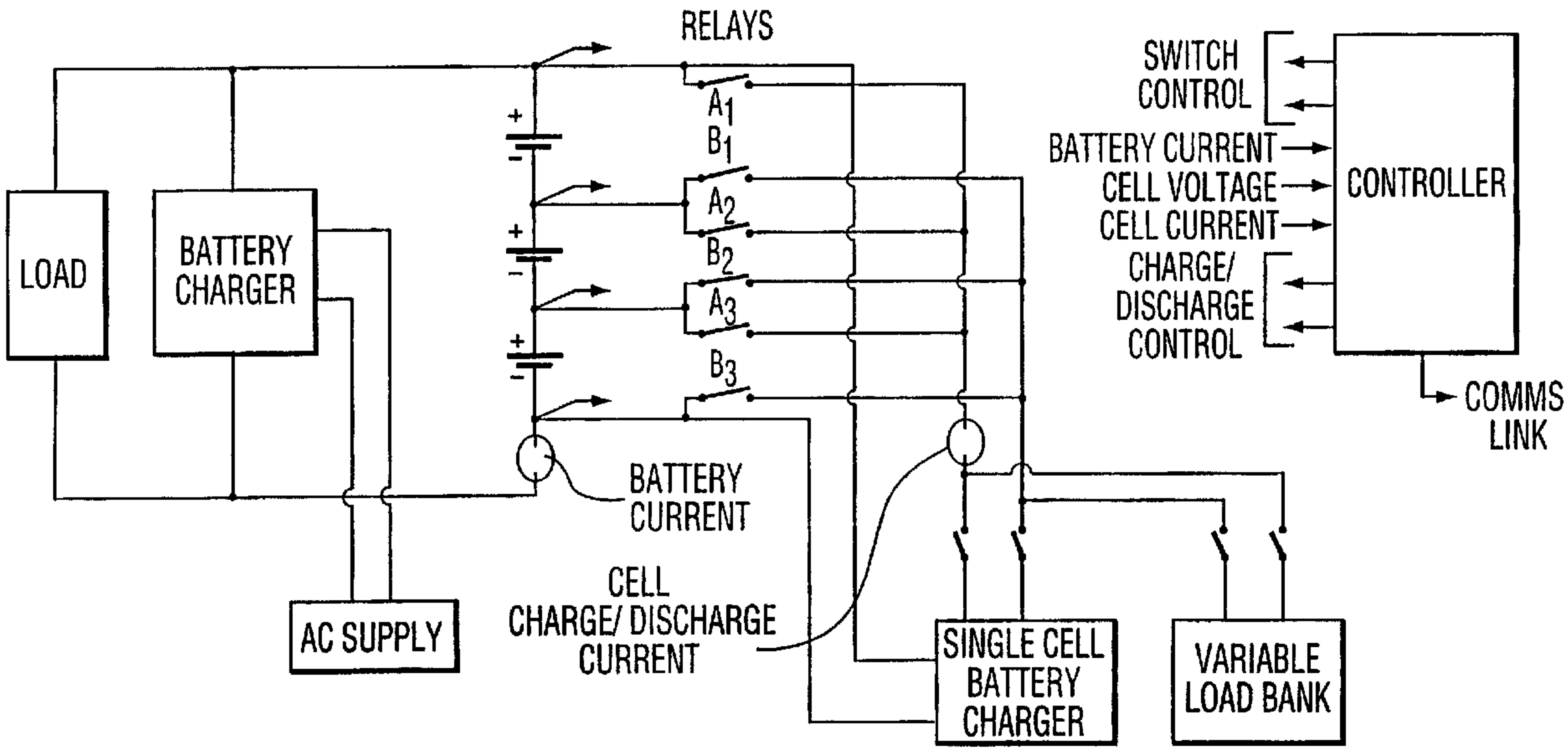
(86) Date de dépôt PCT/PCT Filing Date: 1998/07/03
(87) Date publication PCT/PCT Publication Date: 1999/01/14
(45) Date de délivrance/Issue Date: 2004/09/21
(85) Entrée phase nationale/National Entry: 2000/06/27
(86) N° demande PCT/PCT Application No.: CA 1998/000650
(87) N° publication PCT/PCT Publication No.: 1999/001918
(30) Priorités/Priorities: 1997/07/03 (08/887,844) US; 1997/07/04 (2,209,817) CA

(51) Cl.Int.^{6}/Int.Cl.^{6} H02J 7/00, G01R 31/36
(72) Inventeurs/Inventors:
DUNN, JAMES H., CA;
DE OLIVEIRA, JULIO C., CA;
GERWING, DAVID H., CA

(73) Propriétaire/Owner:
ESTCO BATTERY MANAGEMENT INC., CA

(74) Agent: BORDEN LADNER GERVAIS LLP

(54) Titre : DISPOSITIF ET SYSTEME DE GESTION D'UNE SOURCE D'ENERGIE DE BATTERIE DE SECOURS
(54) Title: DEVICE AND SYSTEM FOR MANAGEMENT OF BATTERY BACK UP POWER SOURCE



(57) Abrégé/Abstract:
The invention relates to a device for managing battery packs from which it is powered by measuring and monitoring the operating capacity of individual battery modules in a battery pack. A programmable logic controller directs the selective closing of relays to allow individual battery modules to be load-tested using a variable discharge load unit, without compromising useful battery pack capacity. In a further embodiment, the invention can include, for each user, a network of battery management devices with two-way communications links to a central management location with computer based monitoring and control of all battery packs. In addition, a centre of expertise on battery technology is linked to the user networks.

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [6] : **H02J 7/00, G01R 31/36**	A2	(11) International Publication Number: **WO 99/01918** (43) International Publication Date: 14 January 1999 (14.01.99)

(21) International Application Number: PCT/CA98/00650

(22) International Filing Date: 3 July 1998 (03.07.98)

(30) Priority Data:
08/887,844 3 July 1997 (03.07.97) US
2,209,817 4 July 1997 (04.07.97) CA

(71) Applicant *(for all designated States except US)*: ESTCO ENERGY INC. [CA/CA]; Unit 12, 21 Concourse Gate, Nepean, Ontario K2E 7S4 (CA).

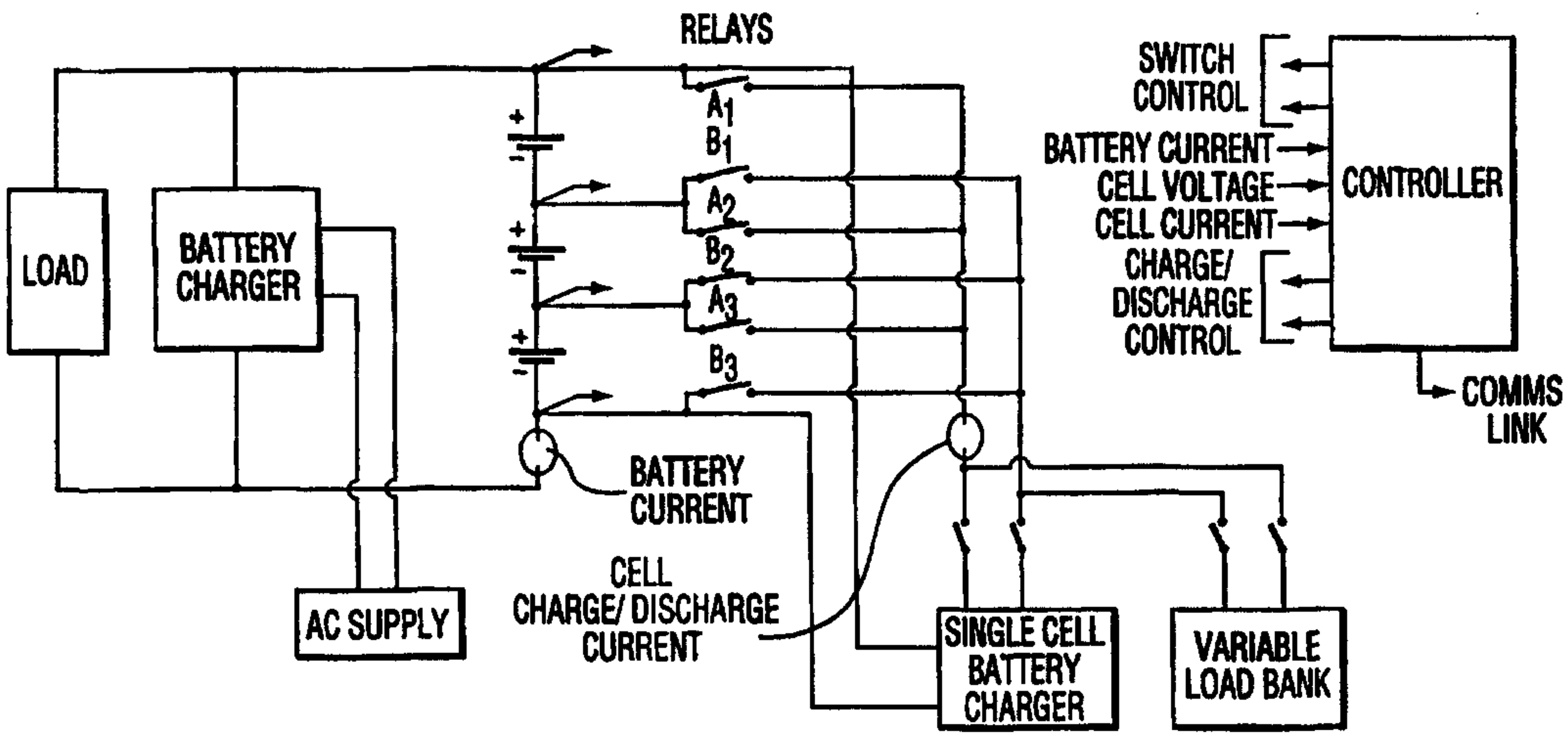
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: DUNN, James, H. [CA/CA]; 1389 King Street, Limoges, Ontario K0A 2M0 (CA). de OLIVEIRA, Julio, C. [CA/CA]; 6025 Pineglade Crescent, Gloucester, Ontario K1W 1G8 (CA). GERWING, David, H. [CA/CA]; 1367 Darcy Street, Greely, Ontario K4P 1A6 (CA).

(74) Agents: BEAUBIEN, Susan, D. et al.; Shapiro, Cohen, Suite 2001, 112 Kent Street, P.O. Box 3440, Station D, Ottawa, Ontario K1P 6P1 (CA).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: DEVICE AND SYSTEM FOR MANAGEMENT OF BATTERY BACK UP POWER SOURCE



(57) Abstract

The invention relates to a device for managing battery packs from which it is powered by measuring and monitoring the operating capacity of individual battery modules in a battery pack. A programmable logic controller directs the selective closing of relays to allow individual battery modules to be load–tested using a variable discharge load unit, without compromising useful battery pack capacity. In a further embodiment, the invention can include, for each user, a network of battery management devices with two–way communications links to a central management location with computer based monitoring and control of all battery packs. In addition, a centre of expertise on battery technology is linked to the user networks.

battery pack is intended to provide back up. In order for the operative capacity of the back-up battery pack to be accurately measured, an allowance must be made for the current which flows from the primary power source into the battery pack. Use of Kirchoff's law, where +/- ic = +/- ip + +/- im where +/- is positive for charge and negative for discharge, ic is module current, ip is current of the primary power circuit, and im is the current of the monitor device, enables the PLC to accurately and selectively measure the operative capacity of a given module within the battery pack without isolating or disengaging the module from the other modules which comprise the battery pack.

In operation, the controller selectively controls and co-ordinates the opening and closing of the switches which connect the battery charger and the variable discharge load. Where it is desired to measure the capacity of module or cell 1, isolation relays A1 and B1 are closed by command of the PLC, which then closes the relays which connect the variable discharge load with the battery. The discharge circuit which is thus created enables module or cell 1 to be discharged across the variable discharge load. Module current is measured by a reader within the circuit and fed back to the PLC. The PLC then causes the relays connecting the variable discharge load to the battery to open, and then closes the relays which connect the battery charger with the battery, thereby defining a charging circuit which recharges module 1 up to a threshold level which is consistent with the useful capacity of the other modules within the string. The procedure is then sequentially repeated for the remaining modules 2, 3,....n within the string.

The programmable logic controller comprises, or is connected to at least one module voltage reader; at least one battery pack current reader and module current reader; a switch controller to control the isolation relays; a controller for

AMENDED SHEET

said variable discharge load means and said single module battery charger (charger/discharger controller).

Both the variable discharge load and battery charger output are adjusted according to the ambient battery and module temperature present to prevent battery damage. As well, the computer calculates the a-h (ampere-hour) capacity of each battery cell by integrating the discharge current over the time taken to reach the cut-off voltage threshold, or the energy capacity by the above integration of current times voltage over discharge time in hours. An alternative to using computer control of the variable discharge load and battery charger is direct control using linear circuits.

The means used to discharge the module may be a use specific variable discharge profile, constant current, constant resistance, or constant power. The method chosen will depend on the battery technology and the normal usage. To implement these methods, a variable resistor or the like is typically used.

The battery charger used to recharge the module under scrutiny may operate with a variety of algorithms including constant voltage/current, constant power and fast charge methods, including pulse charging.

In another preferred embodiment, relays A, B and C shown in Figures 2 and 3 may be replaced with solid state switches. However, solid state devices have the following characteristics which affect their suitability as replacements for relays:

1) They tend to have a voltage drop when conducting current. In the inserted connection embodiment, the battery voltage under load would be reduced somewhat (a fraction of a volt). In the case of the bridged

AMENDED SHEET

connection, this problem could be reduced by sensing battery voltages at the connection to the invention;

2) Usually, two such solid state devices are needed for conducting in two directions. This increases the cost and complexity of the design;

3) Inputs are not isolated from outputs. This is somewhat problematic, since the monitor circuit needs to connect to points up and down the chain of modules making up the battery. If the battery voltage exceeds 30 volts, optical isolation is needed which further complicates the design.

Because of the problems outlined above, the use of solid state switches as replacements for relays A, B and C would be determined on a case by case basis. The most likely applications would be for batteries having voltages below 30 volts or with currents below a few amperes, or where the battery power levels are not much larger than the relay drive requirements or where the use of electromechanical relays is undesirable for other reasons.

The invention works as an integral part of the battery and is designed to continue to operate in the event of an AC power failure, and is able to provide a full load current to substitute for a partially discharged module. This ensures that the useful capacity of the battery pack is available and that the module is protected from reverse-voltage damage.

So that no capacity is lost in the unlikely event of the module battery charger failing when the isolated battery is discharged, extra capacity is provided in the form of an external module. This module will normally be float charged by the invention. When the battery charger fails during a

AMENDED SHEET

discharge cycle, the external module or battery will be used to power the battery charger.

The device of the present invention may further comprise an alarm circuit which conveys an audible or visible warning signal that the capacity of the battery pack has fallen below useful level, which is particularly important where the battery pack is being used as a back-up power source. This provides the option of replacing individual batteries from the battery instead of the whole pack, thereby providing a substantial increase in battery pack life and a resulting decrease in battery cost to the user.
As depicted by Figure 4, a plurality of the devices of the present invention may be networked to permit the gathering of data required for the effective management of systems with multiple battery installations. The data collected from the network is collated in one central data center. This eases the problem of handling a large amount of data, enables the analysis of standby power in large, complex systems, which facilitates the making of rapid, well-informed decisions.

The embodiment shown in Figure 4 is a network of a plurality battery health management devices (shown in Figures 1 or 2 herein) installed in conjunction with the battery back up power sources for multiple, remote installations at sites on a telecommunications or other similar network or system. The remote battery health management devices are linked by multiple communications or sub-networks to one or more instations. The instation is equipped with suitable software to enable the instation to log data from the remote installations, generates alarms, produce statistics, group data in tables for comparison, plot trends, extrapolate data, generate reports and assist in record keeping.

The network shown in Figure 4 is application specific and focuses on assisting in the routine health management

AMENDED SHEET

(including monitoring or power outages) of a remote battery, such as remote cellular site. Because of the emphasis on routine maintenance, the instation presents information such as battery back time remaining, alarms, maintenance records, site down time and power outages records. The system is equipped with extensive database facilities that are used for trending or to provide historical evidence of battery system status.

A more sophisticated type of network is depicted in Figure 5 which comprises a plurality of individual battery health management installations and/or one or more application specific networks. All of the data collected at the individual installations or sites on this network are collated at a master control center which is equipped to manage battery maintenance of individual sites or systems by providing routine monitoring, and/or diagnostic assistance. The master control center may be staffed with personnel who are well acquainted with battery systems and maintenance and who are able to analyse problems as reflected by the incoming data, and who can further provide and implement constructive and remedial advice.

Optionally, a battery health management device shown as sites in the networks depicted in Figures 4 and 5 may use an inserted connection circuit, shown in Figure 6, in place of the bridged connection circuit shown in Figures 1 and 2.

An inserted connection circuit isolates one of the multiple modules in the battery pack (typically nine or eleven modules) by taking the cell out of the trickle/float charge circuit and then performing a discharge of the battery module which drains the energy of the module into variable discharge means such as a fixed resistance heater or similar device at the normal rated load capacity for that module. The PLC then records which module is being discharged, and how long it takes to discharge to a pre-programmed cut-off voltage. This information is then

AMENDED SHEET

used to calculate how much energy the module was able to deliver under actual loaded conditions, thereby providing a real measure of its useful capacity. The information on module capacity is provided by way of a liquid crystal display, or similar means, and is given in watt-hours, ampere-hours; % of "as new" or the time to failure under load in minutes, whichever is required by the end user. When the measured capacity falls below a predefined threshold an alarm will be triggered, signalling the need for battery or module replacement. The battery module charger will be engaged to recharge the discharged module.

In the inserted connection circuit shown in Figure 6, batteries B1, B2 and B3 operate a charge/load circuit V. Isolation relays or contacts A and B connect an individual module to a monitor circuit, while contact C closes the gap in the battery created by the removal of the module. When relay contact C is closed, the open circuit formed by the removal of the battery module is closed, thereby allowing current to flow through the charge/ load circuit. When isolation relays A, B are closed, an individual battery module can be isolated and connected to the monitor circuit. The monitor circuit discharges the isolated battery module and charges it as required using feedback provided by the current sensor and the preset voltage limits.

In the event of an AC mains failure, the relays must continue to operate, otherwise a discharged module would be re-introduced into the battery pack, reducing the useful capacity of the battery pack.

The battery voltage would normally be (Vc * N-1) where Vc is the nominal module voltage and N is the number of modules in the battery. As the monitor circuit moves from one module to the next, it causes a disruption in the battery pack voltage. The battery pack momentarily goes open-circuit, then the

AMENDED SHEET

voltage jumps to Vc* N, then the battery pack goes open-circuit again, then finally the voltage returns to (Vc * N-1).

The module to be measured is accordingly isolated from the other modules comprising the battery pack by the selective engagement of isolation relays. The module is then discharged, its capacity is measured by the PLC as a function of the discharge load, and it is then recharged. The isolated module is temporarily unable to contribute to the output of the battery. The procedure is sequentially repeated, at selectable times, for the remaining modules which comprise the battery pack.

Only one battery module at a time is discharged so that the system is never more than 1/9 or 11% short of its maximum ampere-hour or watt-hour energy capacity (in the case of a nine cell battery pack). In the event of an AC power outage (i.e. a situation where the DC battery pack is engaged), when one of the modules is not fully charged, this module is kept out of the circuit by the use of isolation relays.

As an alternative to this method, an identical module to the battery modules in the battery pack can be added to the battery pack; for example, making a 9 module battery pack into a 10 module battery pack. In this case, the module battery charger will be powered from the battery pack.

In the event that there is a battery module with less useful capacity than the other modules in the pack, the invention can assess the state of health of the reduced capacity module and electrically isolate it from the rest of the battery pack, until such time as the rest of the pack has a poorer performing module than the isolated, reduced capacity module.

AMENDED SHEET

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A battery management system for directly assessing the useful capacity of at least one battery module in a battery pack, the system comprising:

- a programmable logic controller for controlling the system and for calculating data regarding the useful capacity of the at least one battery module
- a monitor circuit connected to the programmable logic controller, the monitor circuit including:
  - charging means for charging the at least one battery module
  - discharging load means for discharging the at least one battery module
  - at least one current measurement means for measuring a current of the at least one battery module
- a plurality of relays connected between the monitor circuit and the battery pack

wherein

- the at least one current measurement means measures a current of the at least one battery module and the programmable logic controller calculates data regarding the useful capacity of the at least one battery module based on the current of the at least one battery module
- the programmable logic controller selectively opens and closes the plurality of relays to define a circuit chosen from the group comprising:
  - a discharge circuit which enables the at least one battery module to be discharged by the discharging load means
  - a charging circuit which enables the at least one battery module to be charged by the charging means

AMENDED SHEET

2. A system as claimed in claim 1 further including recording means for recording said data regarding the useful capacity of the at least one battery module.

3. A system as claimed in claim 1 wherein said relays are selected from the group consisting of multi-pole relays, contactors, or solid state switching devices.

4. A method of sequentially assessing a useful capacity of a plurality of battery modules which define a battery pack, the method comprising:

a) selecting a selected module from the plurality of battery modules for assessment;

b) connecting said selected module to a discharging load means for discharging a module

c) measuring parameters which are used to determine the useful capacity of said selected module while said selected module is under load;

d) determining whether the useful capacity meets a predefined threshold

e) disconnecting said selected module from said discharging load means

f) performing an action chosen from the group comprising:

- recharging said selected module by connecting said selected module to a charging means for charging a module
- generating an alarm signal if said useful capacity does not meet the predefined threshold

wherein the above method is coordinated by a programmable logic controller.

5. A device for cycling battery modules in a battery pack while the battery pack remains in service, the device including:

AMENDED SHEET

- charging means for charging a battery module
- discharging means for discharging a battery module
- a plurality of relays coupled between the charging means, the discharging means, and the battery modules
- a programmable logic controller for controlling the plurality of relays, the battery module recharging means, and the battery module charging means

wherein

- the programmable logic controller selectively opens and closes the plurality of relays to couple at least one battery module in the battery pack to a component chosen from the group comprising:
  - the charging means and
  - the discharging means.

6. A device as claimed in claim 5 wherein the charging means uses a plurality of different recharge methods to recharge the at least one battery module in the battery pack.

7. A networked system for managing the capacity of remote batteries, the system including:

- a central data center for receiving data regarding the capacity of a plurality of remote battery packs,
- a plurality of satellite nodes, each satellite node transmitting data regarding the capacity of at least one remote battery pack to the central data center
- a communications network connecting the satellite nodes to the central node
- a plurality of battery health management units which calculate and gather data regarding the capacity of individual modules in a battery pack such that a capacity of the battery pack is an aggregate of the capacity of the individual modules in the battery pack, each battery health management unit having:

AMENDED SHEET

- a monitor circuit for charging and recharging of battery modules and for measuring at least one measured parameter related to the capacity of a battery module
- a plurality of relays coupled between the monitor circuit and the battery pack
- a programmable logic controller
  - for calculating data regarding the capacity of individual modules in a battery pack based on the at least one measured parameter and
  - for controlling the monitor circuit and the plurality of relays to selectively charge and discharge individual modules in the battery pack

wherein each battery health management unit is connected to a node chosen from the group comprising:

- a satellite node
- a central data center.

8. A system as claimed in claim 1 wherein the discharging load means for discharging the at least one battery module further includes means for discharging the at least one battery module under a predefined load.

9. A system as claimed in claim 1 wherein the discharging load means for discharging the at least one battery module further includes means for variably discharging the at least one battery module.

10. A system as claimed in claim 1 wherein the programmable logic controller includes:

- a switch controller to control the plurality of relays
- a controller for the discharging load means and
- a controller for the charging means.

AMENDED SHEET

11. A system as claimed in claim 1 wherein the at least one current measurement means measures a discharge current of the at least one battery module.

12. A system as claimed in claim 1 wherein the at least one current measurement means measures a charge current of the at least one battery module.

13. A method as claimed in claim 4 wherein the discharging load means discharges the selected module under a predefined load.

14. A method as claimed in claim 4 wherein the discharging load means discharges the selected module under variable loads.

15. A method as in claim 4 wherein step d) further includes recording capacity data regarding the useful capacity of the selected module.

16. A method as claimed in claim 15 wherein the group in step f) further includes

- determining a capacity of other modules in the battery pack from recorded capacity data of other modules in the battery pack and recharging the selected module by connecting the selected module to the charging means, the selected module being recharged to a recharge level consistent with the capacity of other modules in the battery pack.

17. A method as claimed in claim 5 wherein the discharging means discharges the at least one battery module under a predefined load.

AMENDED SHEET

18. A method as claimed in claim 5 wherein the discharging means discharges the at least one battery module under variable loads.

19. A device as claimed in claim 6 wherein the plurality of different recharge methods are chosen from the group comprising:

a) constant voltage
b) constant current
c) constant power
d) fast charge
e) pulse charging
f) any other recharging profile algorithm.

20. A networked system as claimed in claim 7 wherein

- the central data center is a master control center which provides a plurality of services including routine monitoring and diagnostic assistance
- each satellite node is a node chosen from the group comprising
  - a battery health management device which gathers data regarding the health of at least one battery pack;
  - an instation node which receives battery pack health data from a plurality of battery health management devices.

21. A networked system as claimed in claim 7 wherein each instation node provides a plurality of services based on battery health pack data received from a plurality of battery health management devices, the services including:

- logging battery health pack data
- generating alarms
- producing statistics
- generating reports

- collating data to produce an instation data report wherein the instation data report is transmitted to the central data center

- providing historical database

- providing maintenance records

- providing and implementing constructive and remedial advice.

22. A networked system as claimed in claim 7 wherein

- the central data center is an instation node which provides a plurality of services based on data regarding the capacity of a plurality of remote battery packs

- each satellite node is a battery health management device which gathers and transmits to the central data center data regarding the health of at least one battery pack.

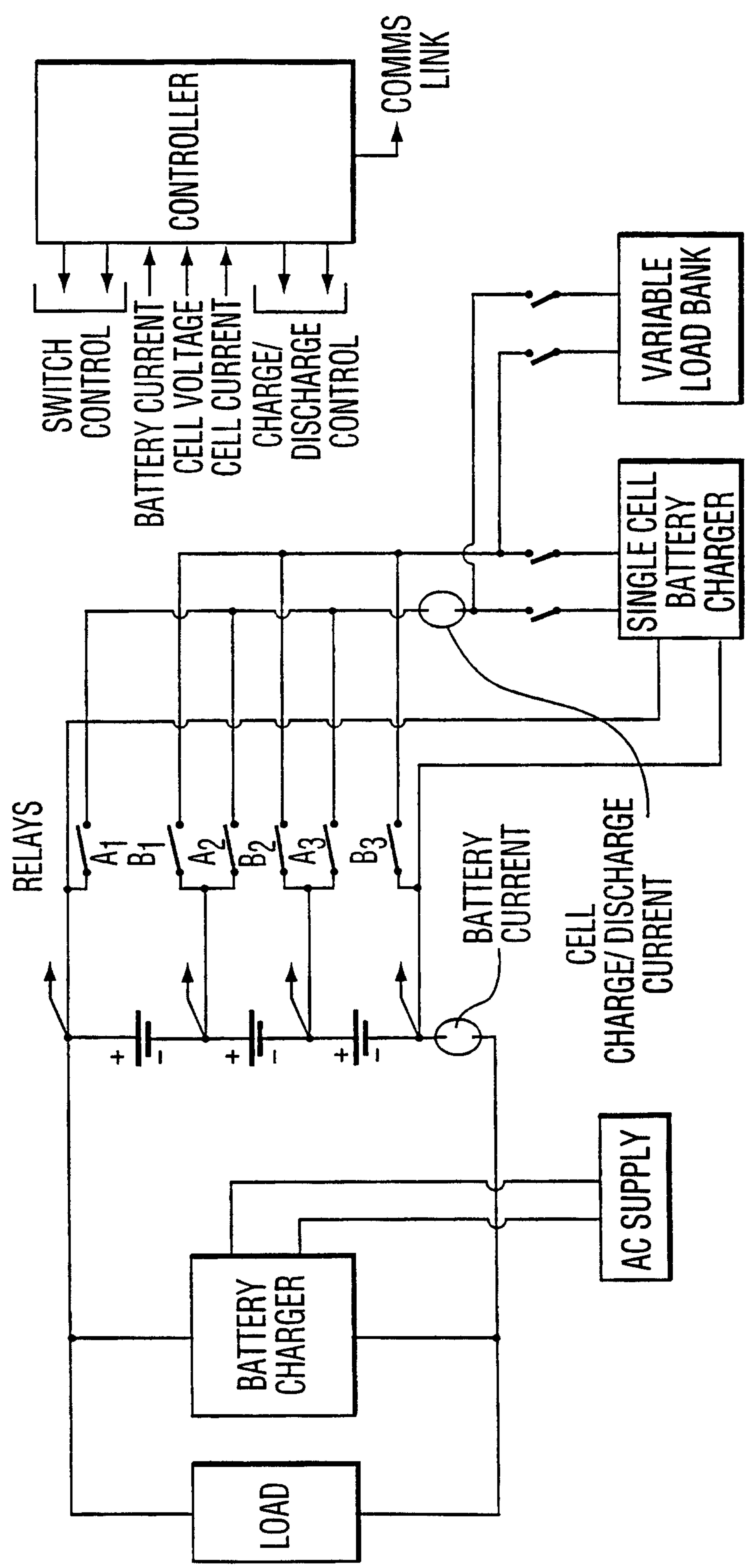

CONTROLLER
COMMS LINK
SWITCH CONTROL
BATTERY CURRENT
CELL VOLTAGE
CELL CURRENT
CHARGE/ DISCHARGE CONTROL
VARIABLE LOAD BANK
SINGLE CELL BATTERY CHARGER
RELAYS
A1
B1
A2
B2
A3
B3
BATTERY CURRENT
CELL CHARGE/ DISCHARGE CURRENT
AC SUPPLY
BATTERY CHARGER
LOAD

FIG. 1

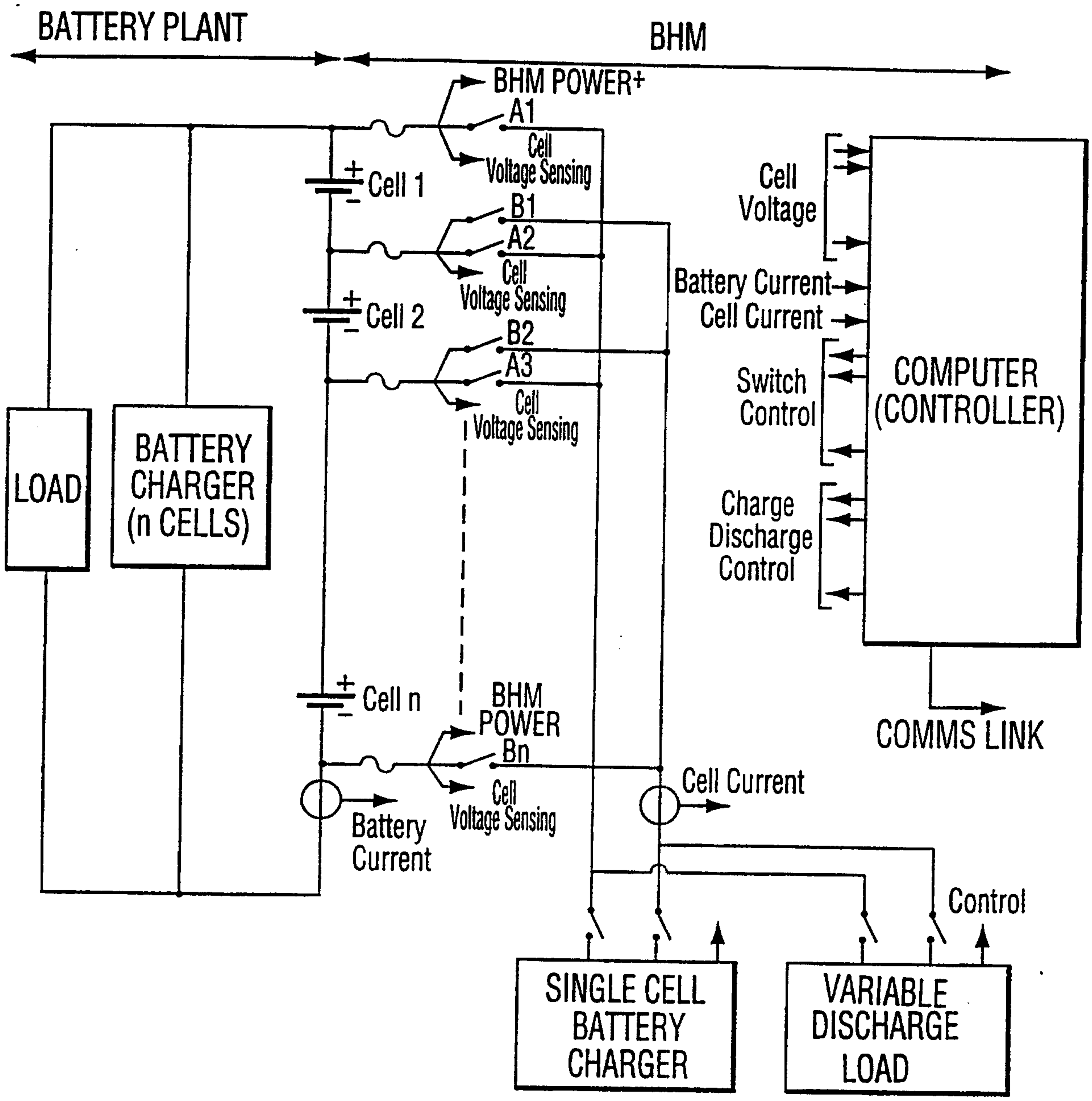

BATTERY PLANT
BHM
BHM POWER+
A1
Cell Voltage Sensing
Cell 1
B1
A2
Cell Voltage Sensing
Cell 2
B2
A3
Cell Voltage Sensing
LOAD
BATTERY CHARGER (n CELLS)
Cell n
BHM POWER
Bn
Cell Voltage Sensing
Battery Current
Cell Current
Cell Voltage
Battery Current
Cell Current
Switch Control
Charge Discharge Control
COMPUTER (CONTROLLER)
COMMS LINK
Control
SINGLE CELL BATTERY CHARGER
VARIABLE DISCHARGE LOAD

FIG. 2

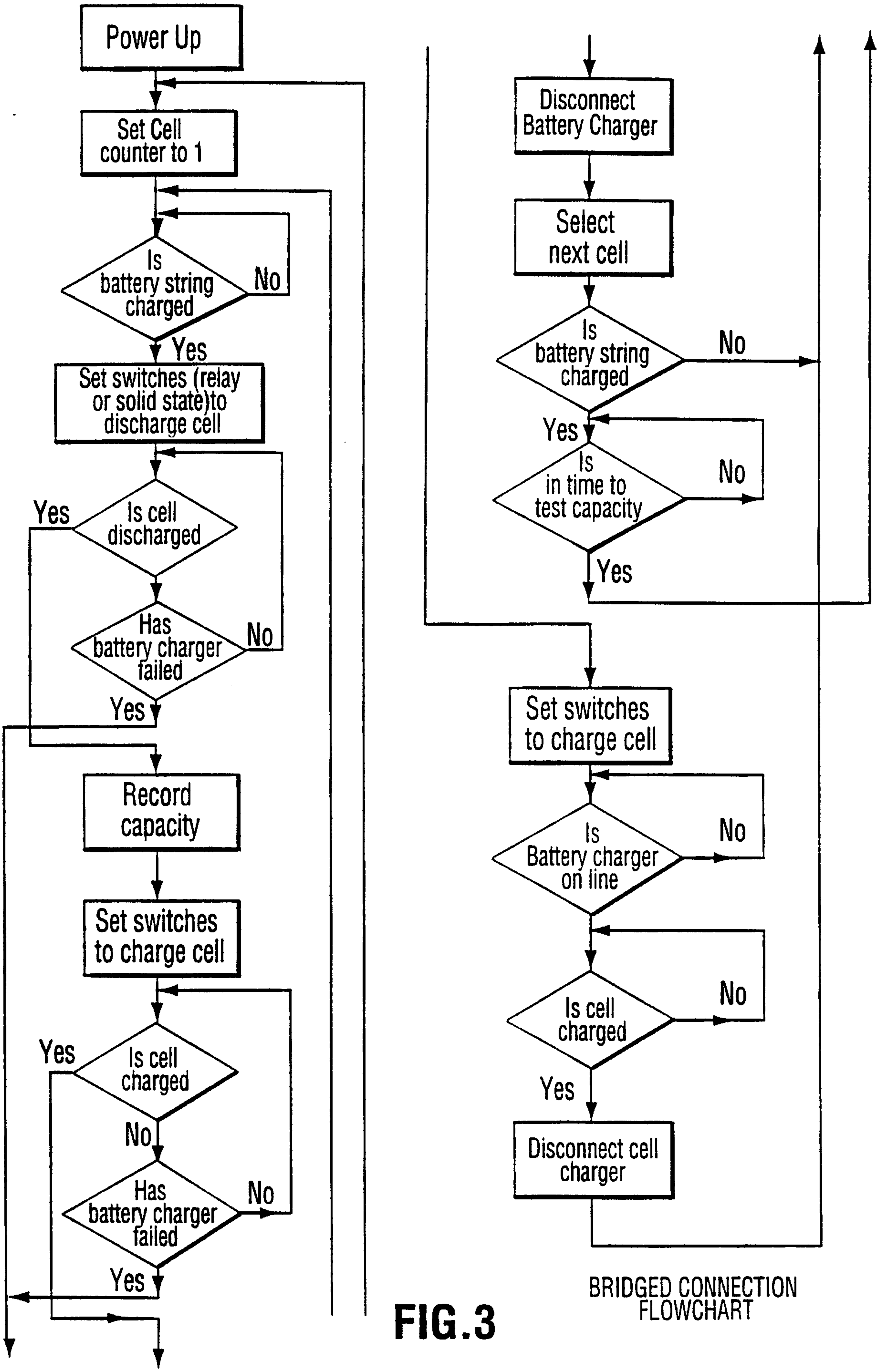

Power Up
Set Cell counter to 1
Is battery string charged
No
Yes
Set switches (relay or solid state)to discharge cell
Yes
Is cell discharged
Has battery charger failed
No
Yes
Record capacity
Set switches to charge cell
Yes
Is cell charged
No
Has battery charger failed
No
Yes
Disconnect Battery Charger
Select next cell
Is battery string charged
No
Yes
Is in time to test capacity
No
Yes
Set switches to charge cell
Is Battery charger on line
No
Is cell charged
No
Yes
Disconnect cell charger
BRIDGED CONNECTION FLOWCHART

FIG.3

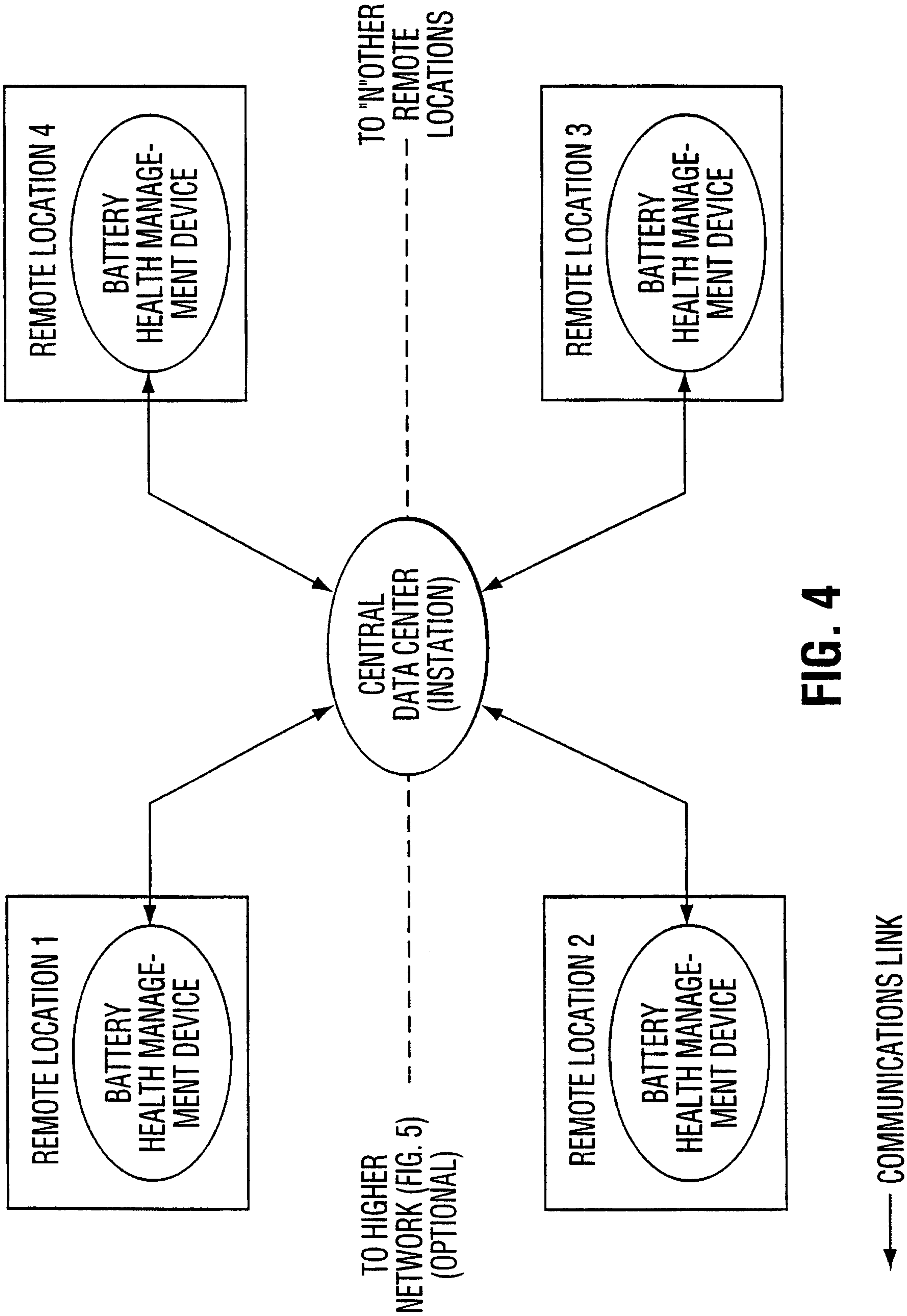

REMOTE LOCATION 4
BATTERY HEALTH MANAGE-MENT DEVICE
TO "N"OTHER REMOTE LOCATIONS
REMOTE LOCATION 3
BATTERY HEALTH MANAGE-MENT DEVICE
CENTRAL DATA CENTER (INSTATION)
REMOTE LOCATION 1
BATTERY HEALTH MANAGE-MENT DEVICE
TO HIGHER NETWORK (FIG. 5) (OPTIONAL)
REMOTE LOCATION 2
BATTERY HEALTH MANAGE-MENT DEVICE
COMMUNICATIONS LINK

FIG. 4

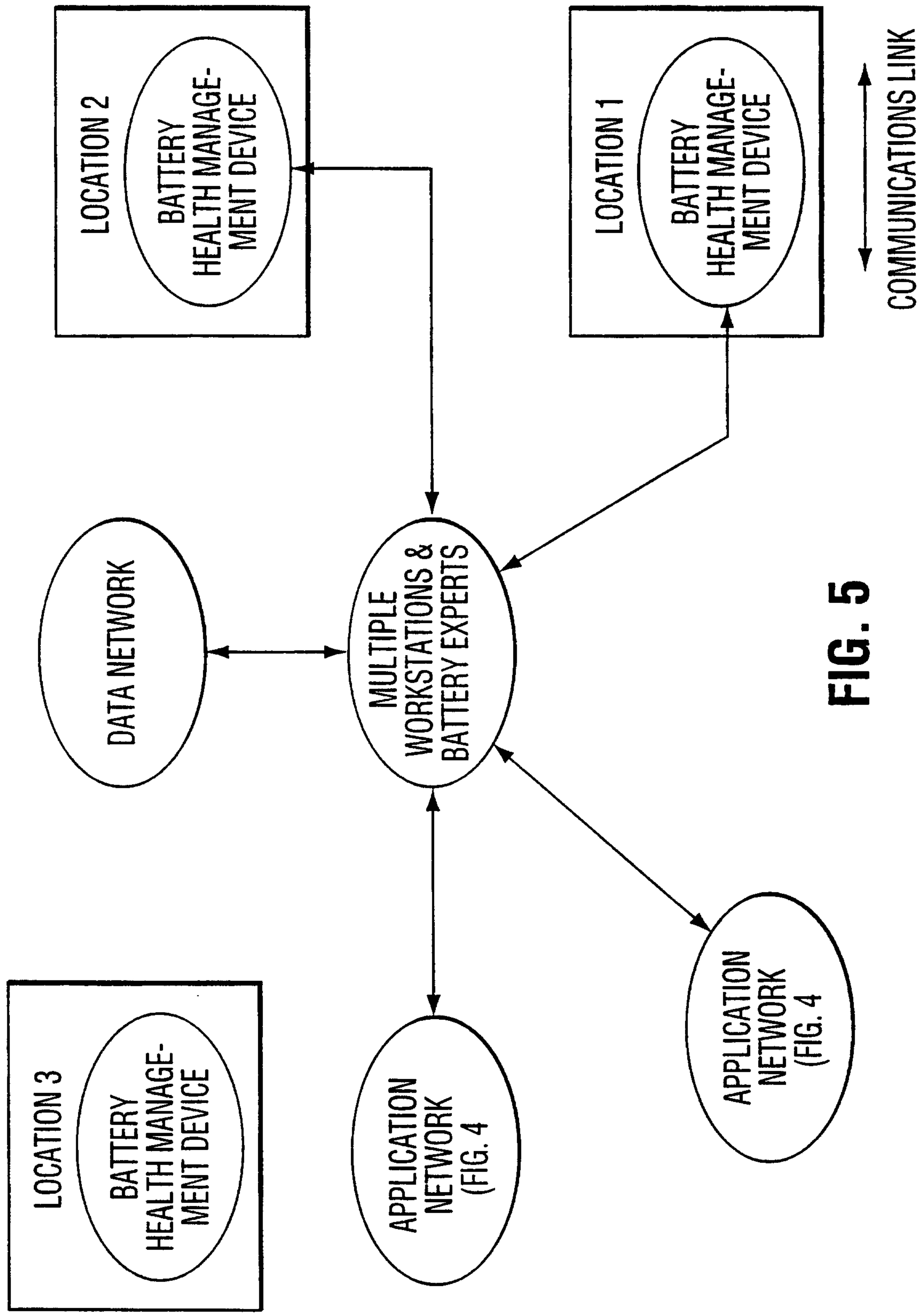
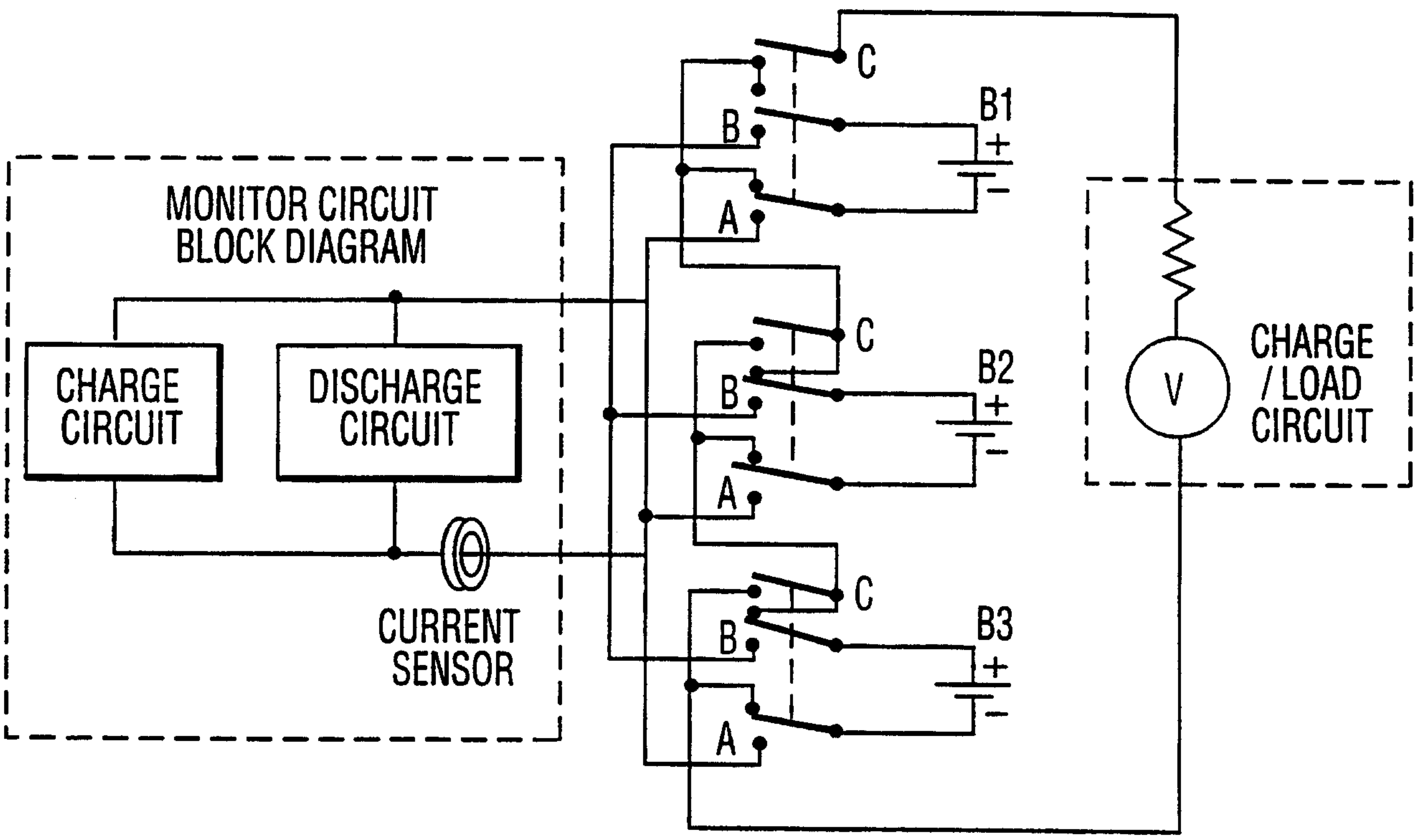
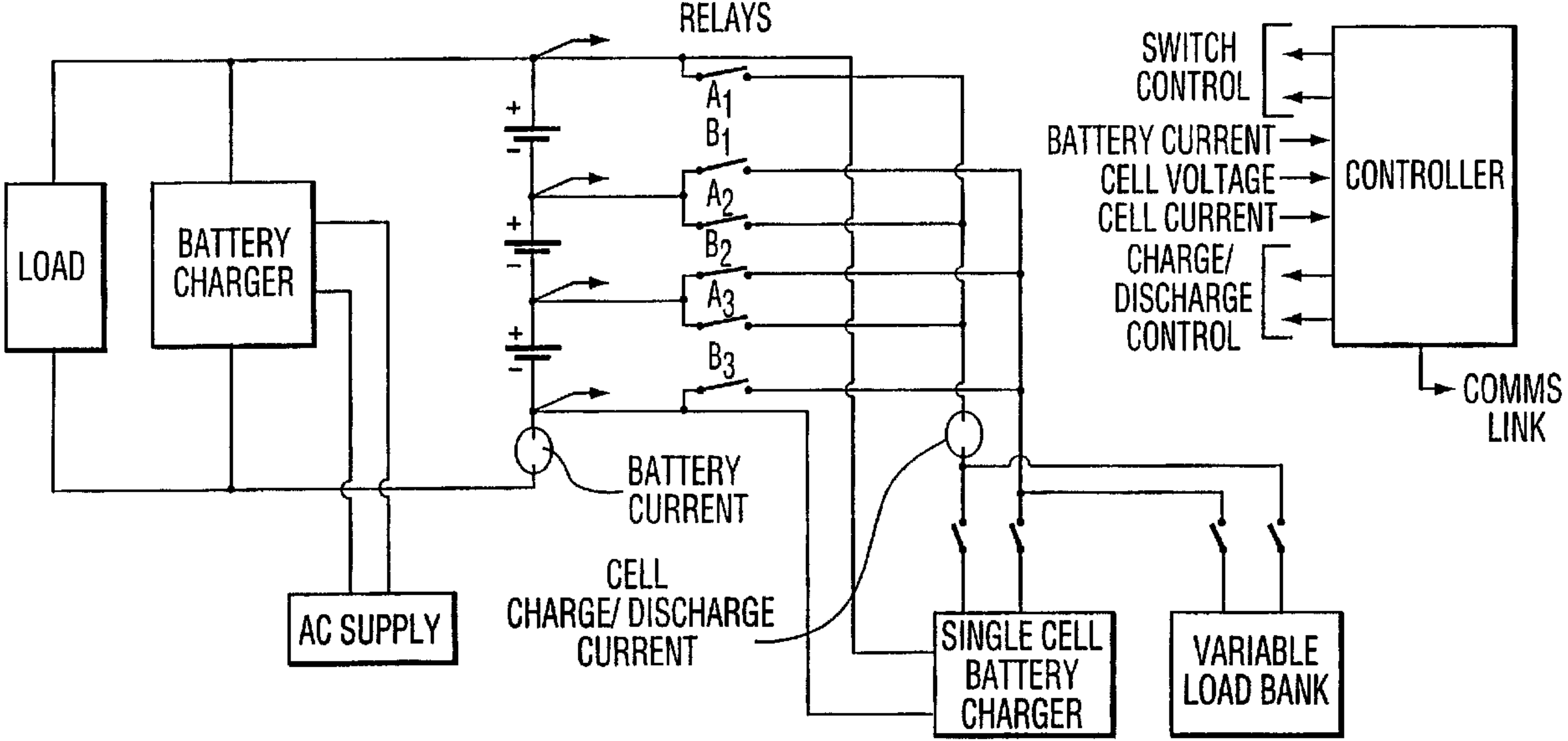

LOCATION 2
BATTERY HEALTH MANAGE-MENT DEVICE
LOCATION 1
BATTERY HEALTH MANAGE-MENT DEVICE
COMMUNICATIONS LINK
DATA NETWORK
MULTIPLE WORKSTATIONS & BATTERY EXPERTS
APPLICATION NETWORK (FIG. 4
APPLICATION NETWORK (FIG. 4
LOCATION 3
BATTERY HEALTH MANAGE-MENT DEVICE

FIG. 5



INSERTED CONNECTION CIRCUIT

FIG. 6


RELAYS
SWITCH CONTROL
BATTERY CURRENT
CELL VOLTAGE
CELL CURRENT
CHARGE/ DISCHARGE CONTROL
CONTROLLER
COMMS LINK
LOAD
BATTERY CHARGER
A1
B1
A2
B2
A3
B3
BATTERY CURRENT
CELL CHARGE/ DISCHARGE CURRENT
AC SUPPLY
SINGLE CELL BATTERY CHARGER
VARIABLE LOAD BANK