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(54) **BATTERY CHARGING CONTROL METHODS, ELECTRIC VEHICLE CHARGING METHODS, BATTERY CHARGING APPARATUSES AND RECHARGEABLE BATTERY SYSTEMS**

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H01M 10/46 (2006.01)

(52) **U.S. Cl.** **320/107**

(58) **Field of Classification Search** 320/107, 320/109, 132, 149

See application file for complete search history.

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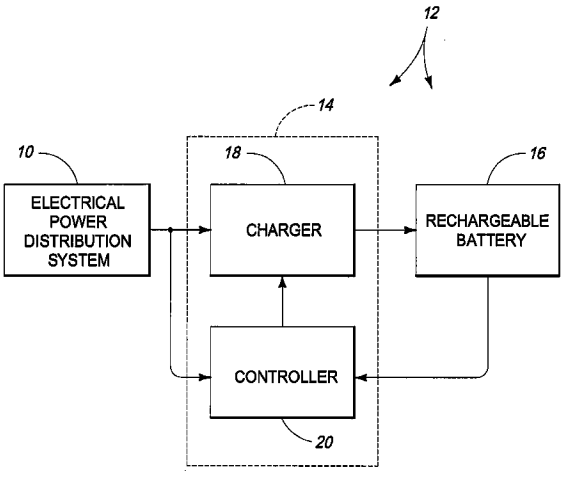
(57) **ABSTRACT**

Battery charging control methods, electric vehicle charging methods, battery charging apparatuses and rechargeable battery systems. According to one aspect, a battery charging control method includes accessing information regarding a presence of at least one of a surplus and a deficiency of electrical energy upon an electrical power distribution system at a plurality of different moments in time, and using the information, controlling an adjustment of an amount of the electrical energy provided from the electrical power distribution system to a rechargeable battery to charge the rechargeable battery.

52 Claims, 5 Drawing Sheets



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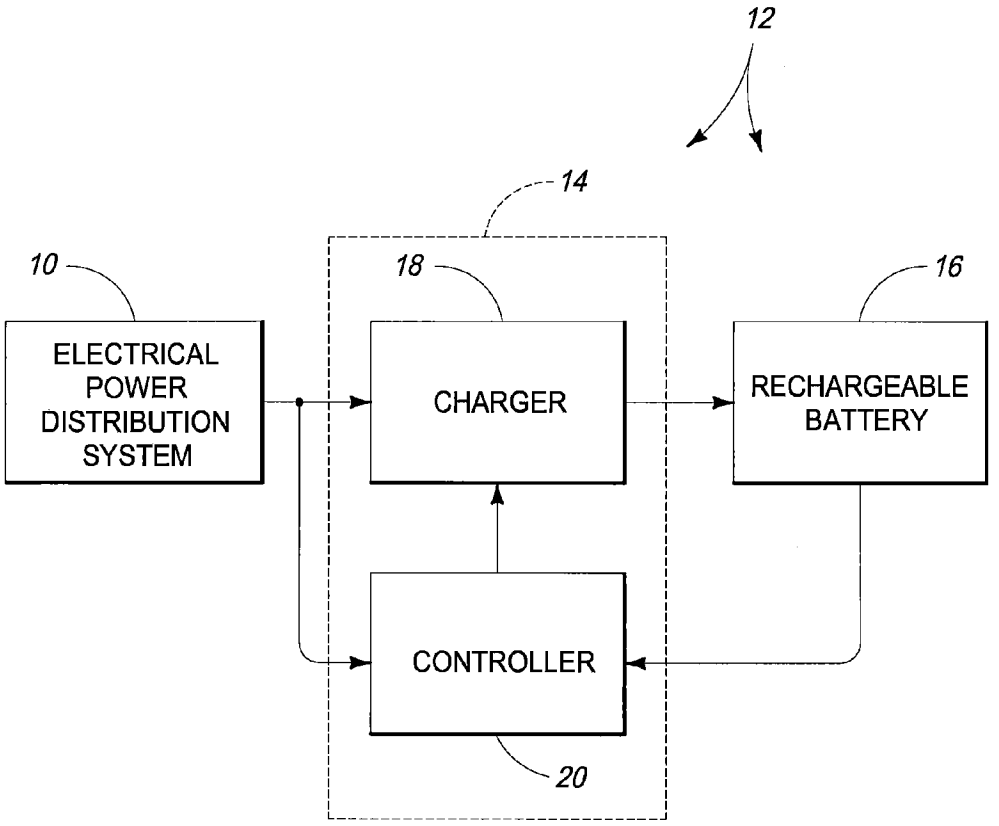
12
14
10
18
16
ELECTRICAL POWER DISTRIBUTION SYSTEM
CHARGER
RECHARGEABLE BATTERY
CONTROLLER
20

Fig. 1

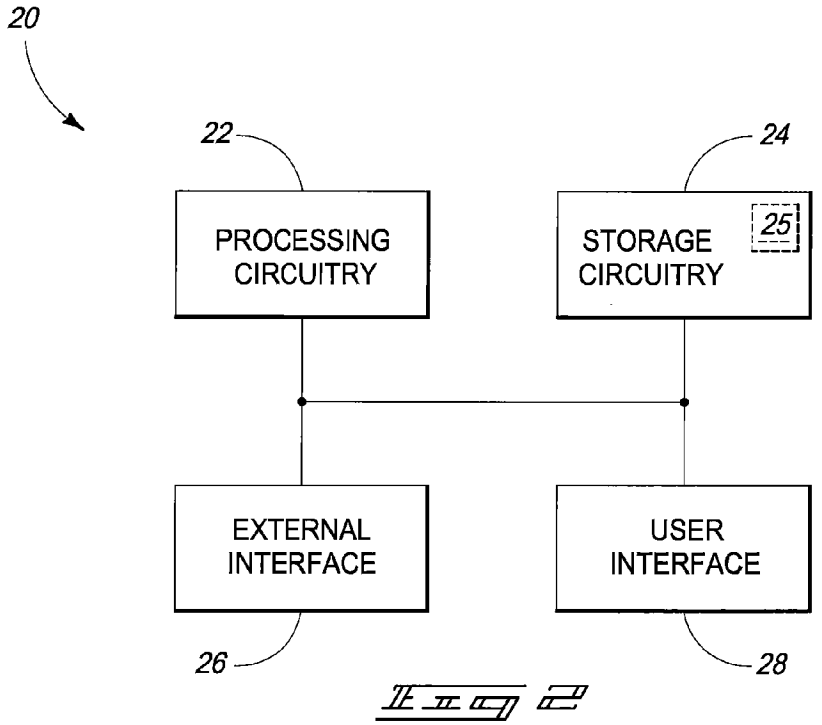
20
22
24
PROCESSING CIRCUITRY
STORAGE CIRCUITRY
25
EXTERNAL INTERFACE
USER INTERFACE
26
28

Fig. 2

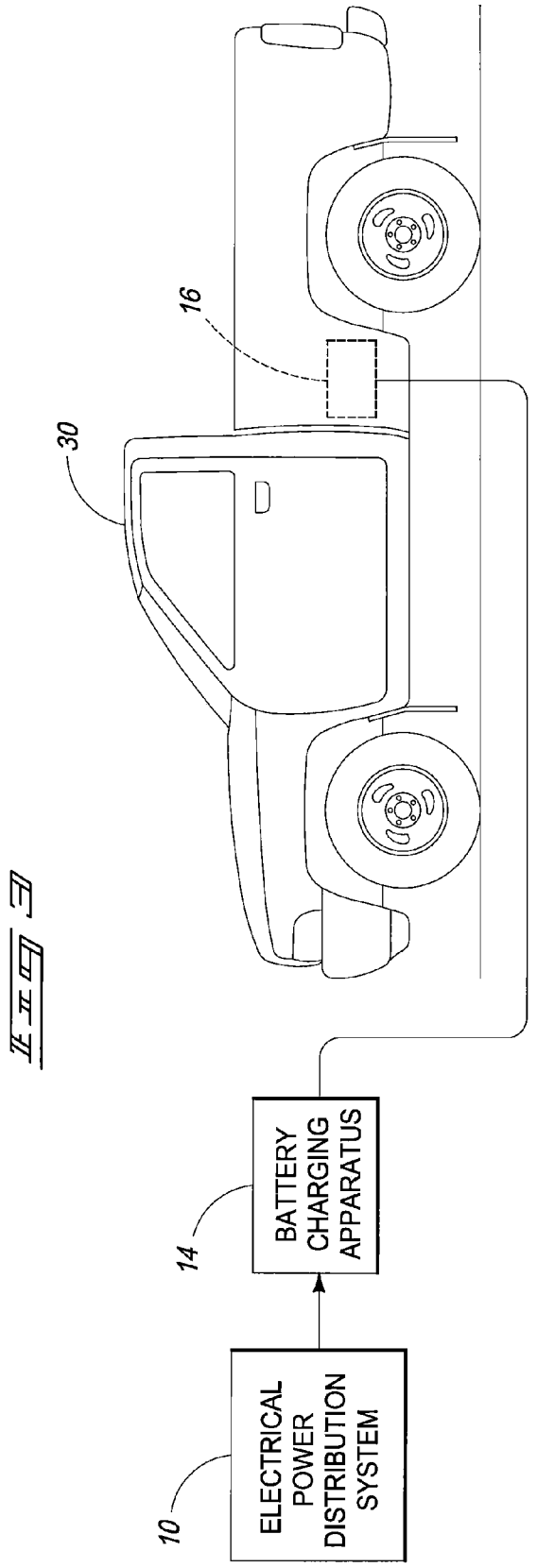
ELECTRICAL POWER DISTRIBUTION SYSTEM
10
BATTERY CHARGING APPARATUS
14
16
30

FIG. 3

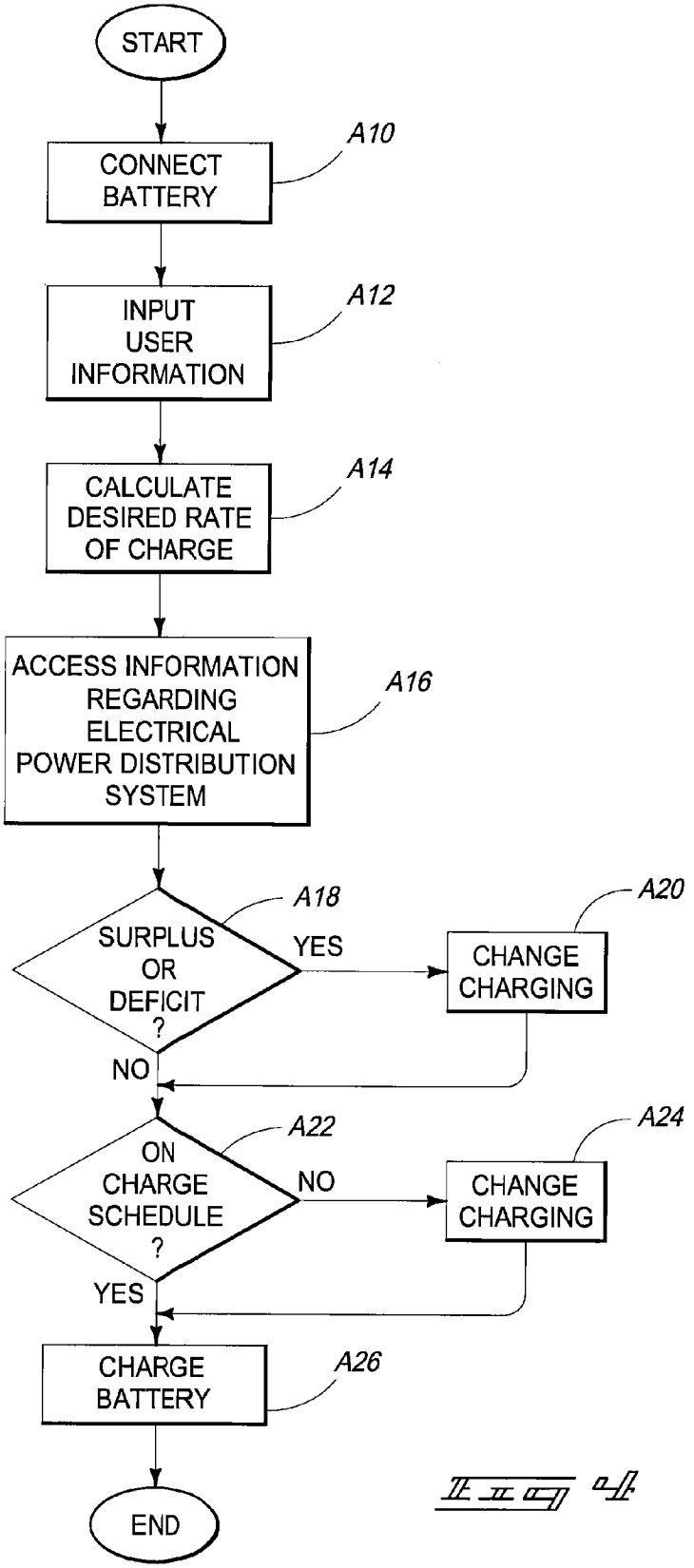
START
CONNECT BATTERY
A10
INPUT USER INFORMATION
A12
CALCULATE DESIRED RATE OF CHARGE
A14
ACCESS INFORMATION REGARDING ELECTRICAL POWER DISTRIBUTION SYSTEM
A16
SURPLUS OR DEFICIT ?
A18
YES
CHANGE CHARGING
A20
NO
ON CHARGE SCHEDULE ?
A22
NO
CHANGE CHARGING
A24
YES
CHARGE BATTERY
A26
END

Fig 4

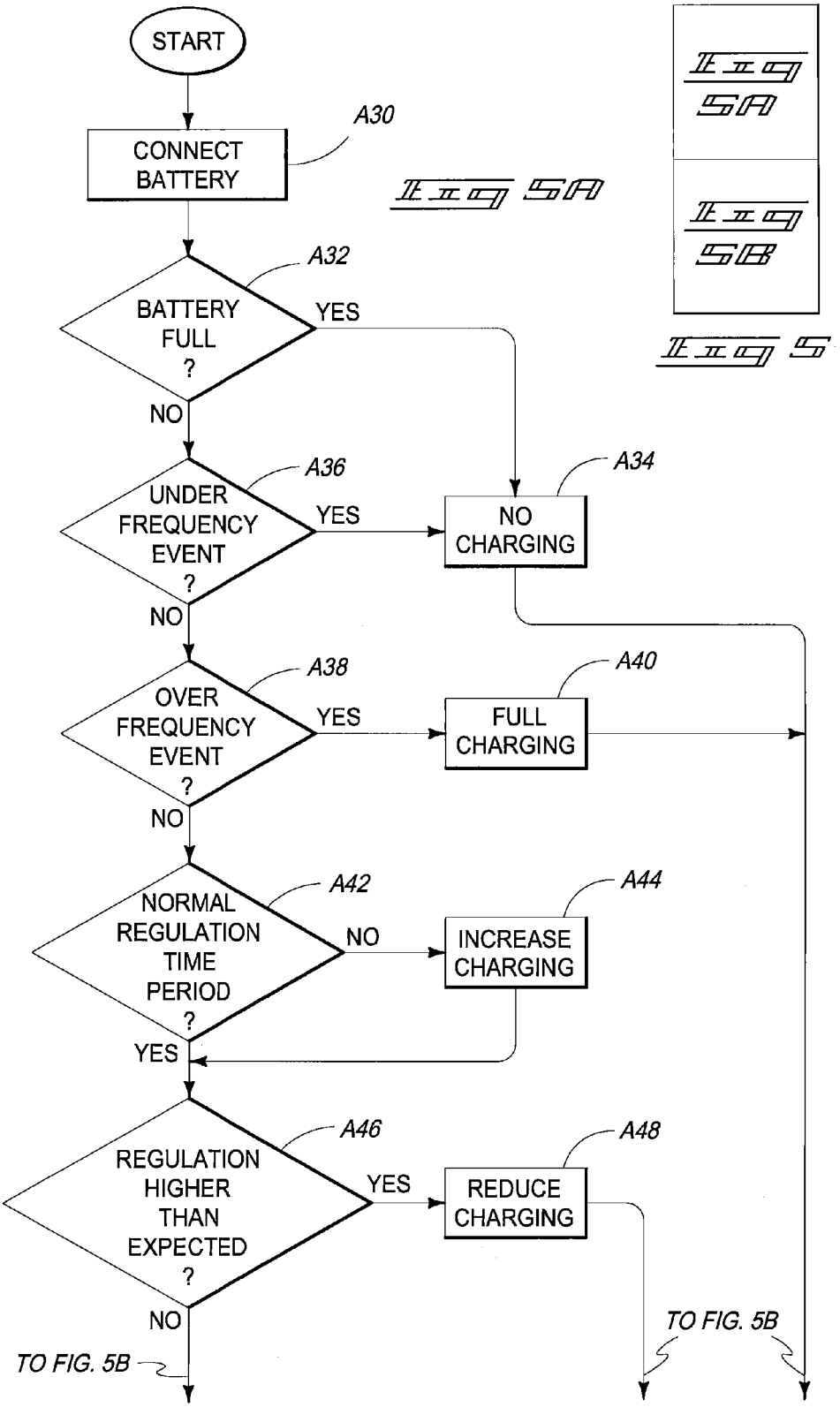

Fig 5A

Fig 5B

Fig 5

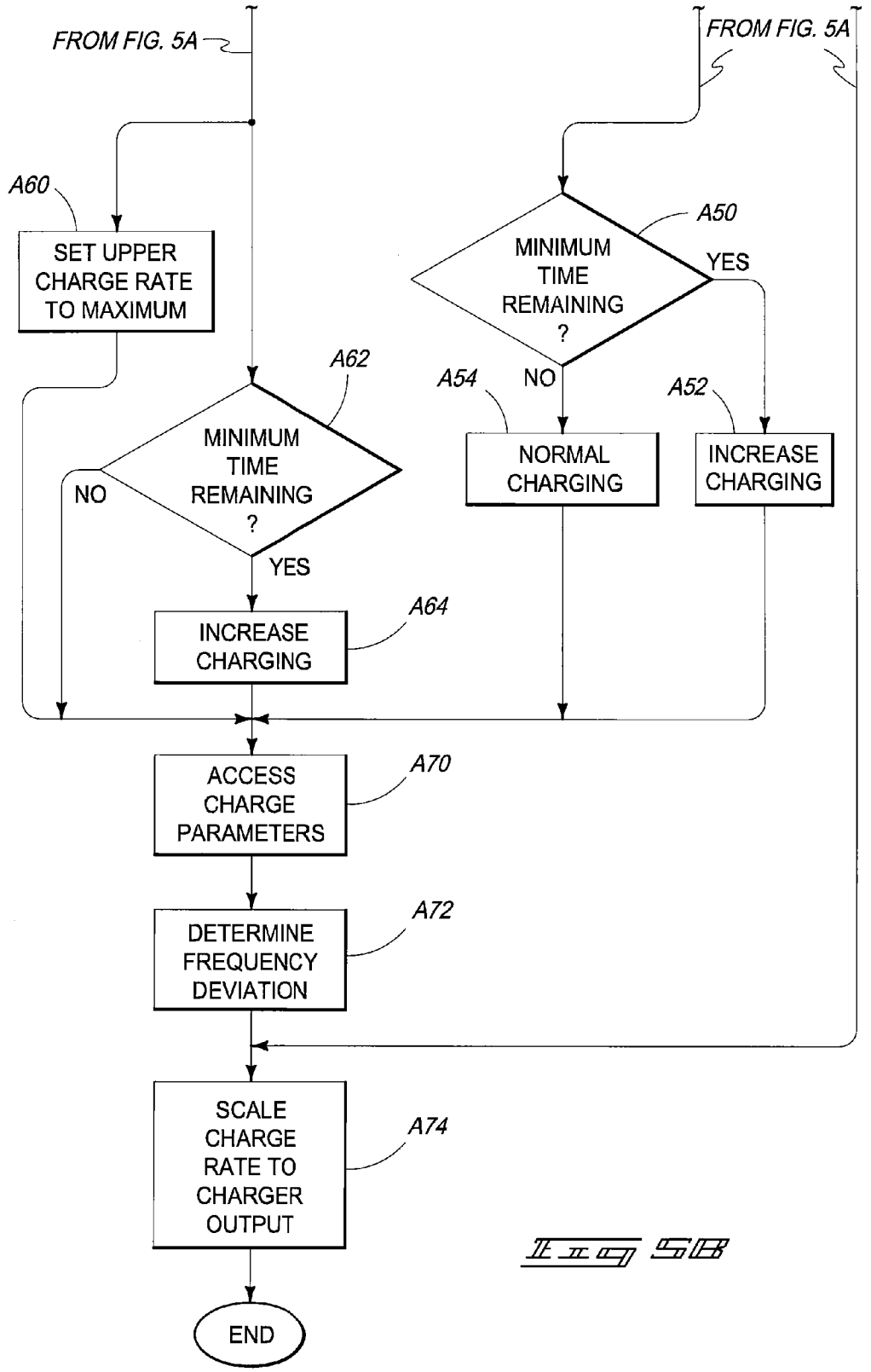
FROM FIG. 5A
FROM FIG. 5A
A60
SET UPPER CHARGE RATE TO MAXIMUM
A50
MINIMUM TIME REMAINING ?
YES
NO
A62
MINIMUM TIME REMAINING ?
NO
YES
A54
NORMAL CHARGING
A52
INCREASE CHARGING
A64
INCREASE CHARGING
A70
ACCESS CHARGE PARAMETERS
A72
DETERMINE FREQUENCY DEVIATION
A74
SCALE CHARGE RATE TO CHARGER OUTPUT
END

Fig 5B

BATTERY CHARGING CONTROL METHODS, ELECTRIC VEHICLE CHARGING METHODS, BATTERY CHARGING APPARATUSES AND RECHARGEABLE BATTERY SYSTEMS

GOVERNMENT RIGHTS STATEMENT

This invention was made with Government support under contract DE-AC0676RLO1830 awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

TECHNICAL FIELD

This disclosure relates to battery charging control methods, electric vehicle charging methods, battery charging apparatuses and rechargeable battery systems.

BACKGROUND OF THE DISCLOSURE

Consumption of and reliance upon electrical energy is ubiquitous in almost every aspect of life. Businesses, entertainment, communications, etc. are heavily dependent upon electrical energy for fundamental operation. More recently, use of electrical energy in transportation applications has increased and is expected to increase further. For example, some types of electric vehicles and hybrid electric vehicles use rechargeable batteries for power. Rechargeable batteries are also used with many other electrical devices apart from transportation devices (e.g., laptop computers, portable media devices, etc.). This expected increased usage of electrical energy for transportation and other applications using rechargeable batteries as well as increased usage in traditional applications may result in increased demands upon electrical power distribution infrastructure.

Power distribution systems or grids provide electrical energy to households, businesses, manufacturing facilities, hospitals, etc. Some electrical power distribution systems are ever-changing dynamic systems and operations are often concerned with balancing generation with load. Typically, control of the state of the electrical power distribution system is implemented by controlling operations of generators coupled with the system. For example, at times of increased demand, the output of generators may be increased and/or other generators may be brought on-line to assist with supplying the electrical energy. In addition, spinning reserves may be utilized to accommodate unexpected significant fluctuations in demand for electrical energy.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the disclosure are described below with reference to the following accompanying drawings.

FIG. **1** is a block diagram of a battery system and an electrical power distribution system according to one embodiment.

FIG. **2** is a block diagram of a controller according to one embodiment.

FIG. **3** is an illustrative representation of an electrical vehicle coupled with a battery charging apparatus and an electrical power distribution system according to one embodiment.

FIG. **4** is a flow chart of a battery charging method according to one embodiment.

FIG. **5** is a map showing how FIGS. **5**A and **5**B are to be assembled. Once assembled, FIGS. **5**A-**5**B depict a flow chart of a battery charging method according to another embodiment.

DETAILED DESCRIPTION OF THE DISCLOSURE

This disclosure is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

According to one embodiment, a battery charging control method comprises accessing information regarding a presence of at least one of a surplus and a deficiency of electrical energy upon an electrical power distribution system at a plurality of different moments in time, and using the information, controlling an adjustment of an amount of the electrical energy provided from the electrical power distribution system to a rechargeable battery to charge the rechargeable battery.

According to an additional embodiment, electric vehicle charging method comprises coupling an electrical vehicle having a depleted state of charge with an electrical power distribution system, charging the electrical vehicle using electrical energy from the electrical power distribution system, monitoring an electrical characteristic of the electrical energy from the electrical power distribution system, and adjusting an amount of the electrical energy provided from the electrical power distribution system to charge the electrical vehicle as a result of the monitoring.

According to another embodiment, a battery charging apparatus comprises processing circuitry configured to access information indicating at least one of a surplus and a deficiency of electrical energy upon the electrical power distribution system and to control an adjustment of an amount of electrical energy provided from the electrical power distribution system to a rechargeable battery to charge the rechargeable battery using the information.

According to an additional embodiment, a rechargeable battery system comprises a charger coupled with an electrical power distribution system and configured to provide electrical energy from the electrical power distribution system to a rechargeable battery to charge the rechargeable battery, and processing circuitry configured to monitor for a presence of at least one of a surplus and a deficit of electrical energy upon the electrical power distribution system and to control the charger to adjust an amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery as a result of the monitoring detecting the presence of the at least one of the surplus and the deficit of the electrical energy upon the electrical power distribution system.

At least some aspects of the present disclosure are directed towards methods and apparatus which may assist with balancing electrical power distribution systems. In some example embodiments discussed herein, operations of loads consuming electrical energy may be adjusted to implement the balancing. In more specific illustrative examples, operations with respect to charging rechargeable batteries may be adjusted. In at least one embodiment described herein, information regarding an electrical power distribution system is used during charging of the rechargeable batteries to implement balancing. In one arrangement described below, information regarding a surplus or a deficit of electrical energy upon the electrical power distribution system is used to control one or more charging operation of the rechargeable batteries. Other aspects and embodiments are described herein and encompassed by the claims.

Referring to FIG. **1**, one embodiment of a battery system **12** is shown coupled with an electrical power distribution system **10**. Although only one battery system **12** is shown in the embodiment of FIG. **1**, numerous additional battery systems **12** may be coupled with electrical power distribution system **10** in other embodiments. In one embodiment, electrical power distribution system **10** is arranged to provide electrical energy to the battery system **12** to charge one or more rechargeable battery **16** of the battery system **12**. In some embodiments described below, the rechargeable battery or batteries **16** may be utilized to power an electric vehicle (e.g., plug-in electric hybrid vehicle (PHEV), electric vehicle (EV) etc.). Rechargeable batteries **16** may be used in other loads, apparatus and/or in different applications in other embodiments.

In one embodiment, electrical power distribution system **10** comprises any appropriate electrical energy delivery system configured to deliver residential, commercial, industrial, and/or other electrical energy from a supply to customers or consumers. Electrical power distribution system **10** is arranged to provide electrical energy for consumption by battery system **12**, for example, for operation and for recharging the rechargeable batteries **16**. Electrical power distribution system **10** may be arranged as one or more source (e.g., generator or other construction) configured to generate electrical energy. Generators may be individually taken on-line or off-line, or the output thereof may be adjusted, according to the usage of the electrical energy. Electrical power distribution system **10** may include a distribution grid which may comprise a plurality of switching stations, transformers, and transmission lines arranged to transmit electrical energy from sources to the battery systems **12** and other loads. The transmission lines may transmit the electrical energy using high voltage lines spanning across vast distances (e.g., hundreds or thousands of miles) between geographically distant locations in some arrangements.

In one implementation, electrical power distribution system **10** is arranged to provide alternating current electrical energy at a system frequency of 50 or 60 Hz. System frequency is the frequency of system voltage in one embodiment. Electrical power distribution system **10** may provide electrical energy at exemplary voltages of 120/240 VAC (residential), 120/208 VAC (commercial), 277/480 VAC (industrial) or other appropriate voltages in example arrangements.

As mentioned above, battery system **12** includes one or more rechargeable battery **16** in the presently described embodiment. Rechargeable batteries **16** may be used in various electrical devices including electric vehicles, notebook computers, cellular telephones, other portable electronic devices, etc. Rechargeable battery **16** may have different configurations in different implementations (e.g., lead acid, nickel hydride, lithium ion in some examples). During use, the state of charge of the rechargeable battery **16** decreases, and electrical power distribution system **10** is configured to supply electrical energy for re-charging of the rechargeable battery **16** to an increased state of charge.

In addition, battery system **12** also includes a battery charging apparatus **14** in one embodiment. In the depicted embodiment, battery charging apparatus **14** is coupled between electrical power distribution system **10** and rechargeable battery **16**. Battery charging apparatus **14** is configured to implement charging operations of rechargeable battery **16** using the electrical energy from the electrical power distribution system **10** in one embodiment.

In the depicted embodiment, battery charging apparatus **14** includes a charger **18** and a controller **20**. Charger **18** is configured to receive electrical energy from electrical power distribution system **10** and to provide the electrical energy to rechargeable battery **16** to charge the rechargeable battery **16**. As discussed herein according to one embodiment, charger **18** can apply different amounts of electrical energy to the rechargeable battery **16** to vary the rates of charging at different moments in time.

In one embodiment discussed in additional detail below, controller **20** is configured to access information regarding the electrical power distribution system **10** and rechargeable battery **16**. In some arrangements, the controller **20** may access the information at a plurality of moments in time during charging of a rechargeable battery **18**. Further, controller **20** may control the amount of electrical energy provided by the charger **18** to the battery **16** to implement various rates of charging using the accessed information. In one more specific example embodiment discussed below, controller **20** is configured to access information regarding a surplus or deficiency of electrical energy upon the electrical power distribution system **10** and to control an adjustment of an amount of electrical energy provided by the distribution system **10** via the charger **18** to charge battery **16** using the accessed information (e.g., surplus or deficiency information).

In addition, controller **20** may access other information for use in controlling the rate of charging. For example, controller **20** may access rate of charge information, state of charge information regarding a current state of charge of the rechargeable battery, and user inputted information (e.g., desired point in time in the future for the battery **16** to be fully charged) to control the amount of electrical energy provided to the battery **16** in illustrative examples. Additional information may also be used by the controller **20** in other embodiments to control the amount of electrical energy provided to the battery **16**.

Referring to FIG. **2**, one embodiment of controller **20** is shown. The illustrated example controller **20** includes processing circuitry **22**, storage circuitry **24**, an external interface **26** and a user interface in the depicted embodiment. Controller **20** may include more, less and/or alternative components in other embodiments.

In one embodiment, processing circuitry **22** is arranged to implement operations of controller **20** described below. For example, processing circuitry **22** may process data, control data access and storage, issue commands, and control other desired operations. For example, processing circuitry **22** is configured to access information regarding a surplus and/or deficiency of electrical energy upon the electrical power distribution system **10**, information regarding state of charge and rates of charge of rechargeable battery **16**, and user inputted information in one embodiment. Processing circuitry **22** may utilize the accessed information to control charging operations of charger **18** with respect to rechargeable battery **16** in one embodiment.

Processing circuitry **22** may comprise circuitry configured to implement desired programming provided by appropriate media in at least one embodiment. For example, the processing circuitry **22** may be implemented as one or more of processor(s) and/or other structure configured to execute executable instructions including, for example, software and/or firmware instructions, and/or hardware circuitry. Exemplary embodiments of processing circuitry **22** include hardware logic, PGA, FPGA, ASIC, state machines, and/or other structures alone or in combination with a processor. These examples of processing circuitry **22** are for illustration and other configurations are possible.

The storage circuitry **24** is configured to store programming such as executable code or instructions (e.g., software and/or firmware), electronic data, databases, or other digital

information and may include processor-usable media. For example, processing circuitry **22** may control storage circuitry **24** to store information accessed from system **10**, battery **16** and/or user inputted information in one embodiment.

Processor-usable media may be embodied in any computer program product(s) or article of manufacture(s) **25** which can contain, store, or maintain programming, data and/or digital information for use by or in connection with an instruction execution system including processing circuitry in the exemplary embodiment. For example, exemplary processor-usable media may include any one of physical media such as electronic, magnetic, optical, electromagnetic, infrared or semiconductor media. Some more specific examples of processor-usable media include, but are not limited to, a portable magnetic computer diskette, such as a floppy diskette, zip disk, hard drive, random access memory, read only memory, flash memory, cache memory, and/or other configurations capable of storing programming, data, or other digital information.

At least some embodiments or aspects described herein may be implemented using programming stored within appropriate storage circuitry **24** described above and configured to control appropriate processing circuitry. For example, programming may be provided via appropriate media including, for example, embodied within articles of manufacture **25**.

External interface **26** is arranged to implement external communications including data acquisition of controller **20** in one embodiment. For example, external interface **26** may be coupled with electrical power distribution system **10**, rechargeable battery **16** and charger **18** in one embodiment. External interface **26** may be implemented as a network interface card (NIC), serial or parallel connection, USB port, Firewire interface, flash memory interface, floppy disk drive, ZigBee interface, Home Plug interface, X-10 interface, or any other suitable arrangement.

User interface **28** is configured to interact with a user including conveying data to a user (e.g., displaying data for observation by the user, audibly communicating data to a user, etc.) as well as receiving inputs from the user (e.g., tactile input, voice instruction, etc.). Accordingly, in one exemplary embodiment, the user interface **28** may include a display (e.g., cathode ray tube, LCD, etc.) configured to depict visual information and an audio system as well as a keyboard, mouse and/or other input device. Any other suitable apparatus for interacting with a user may also be utilized. In one arrangement, a user may input information to control the charging by charger **18**. For example, the user may specify a point of time in the future in which the battery **16** is to be fully charged or obtain some other desired state of charge.

As discussed above with respect to FIG. **1**, controller **20** is configured to control the charging rate of charger **18** of battery charging apparatus **14** with respect to battery **16** in one embodiment. Battery charging apparatus **14** may use information from various sources to implement the control of the charging in one embodiment.

In one embodiment, controller **20** is configured to utilize one or more of: information regarding a state of electrical energy upon electrical power distribution system **10**, information regarding a rate of charging and a state of charge of the rechargeable battery **16**, and/or information regarding a desired point in time where the rechargeable battery **16** is to be fully charged to control the charging of the rechargeable battery **16** by charger **18**.

In one embodiment, controller **20** accesses information regarding the state of electrical energy upon the electrical power distribution system **10** which indicates whether there is a surplus or deficiency of electrical energy within the electrical power distribution system **10** at a plurality of moments in time. In one configuration, controller **20** is configured to monitor the electrical power distribution system **10** at different moments in time to determine the state of electrical energy upon the system **10** at the different moment in time.

For example, in one embodiment, controller **20** may access information regarding the distribution system **10** by monitoring electrical energy received from the distribution system **10** at the location of the battery system **12** and without data communications with the electrical power distribution system **10**. In other embodiments, battery charging apparatus **14** obtains information regarding the state of the electrical power distribution system **10** using different methods than by monitoring the electrical energy from the system **10**. For example, in another embodiment, controller **20** may receive information regarding the state of the distribution system **10** from the distribution system **10** itself (e.g., internet data communications from an appropriate utility entity indicating a surplus or deficiency of electrical energy upon the distribution system **10** at different moments in time) or from some other appropriate source. The above examples are some methods of accessing information regarding a state of the distribution system **10**. Controller **20** which is configured to monitor the energy upon the system **10** to determine the state of electrical energy **10** described above according to one embodiment may be considered to be a passive system. This implementation may have cost benefits compared with arrangements utilizing communications from an entity of the distribution system **10** or other source with the battery system **12** since communications infrastructure is not needed to implement the monitoring operations.

As mentioned above, the controller **20** may monitor the distribution system **10** in one implementation. In one more specific example, the controller **20** may monitor one or more electrical characteristic of electrical energy received from the system **10** at various moments in time to determine the state of electrical energy upon the system **10** at the different moments in time (e.g., determine information regarding a surplus or deficit of electrical energy upon system **10**).

As mentioned above, electrical power distribution system **10** provides electrical energy at a system frequency (of voltage of the electrical energy) which generally corresponds to a nominal frequency (e.g., 50 or 60 Hz). When the electrical power distribution system **10** is substantially balanced (i.e., the amount of electrical energy generated substantially matches the amount of electrical energy being consumed), then the system frequency of the electrical energy upon the system **10** is at the nominal frequency. However, due to fluctuations in power generation and consumption throughout a given day, the system frequency may vary and deviate from the nominal frequency. For example, the system frequency rises if the amount of produced electrical energy exceeds the amount of consumed electrical energy and the system frequency falls if the amount of produced electrical energy is less than the amount of consumed electrical energy.

Accordingly, in one embodiment, controller **20** is configured to monitor the system frequency of the electrical power distribution system **10** to access information regarding the state of electrical energy upon system **10** (e.g., the presence of a surplus or deficit of electrical energy upon the distribution system **10**). In another embodiment, controller **20** may access frequency information from another device such as a smart meter, advanced meter infrastructure (AMI) or the distribution system **10** itself, for example, via data communications. If data is obtained at a higher sample rate than desired, an averaging or low-pass filter may be utilized to effectively decimate the data to a desired sampling rate in one embodi-

ment. Additional details with respect to monitoring frequency of the electrical power distribution system **10** are described in U.S. Pat. No. 7,149,605, entitled "Electrical Power Distribution Control Methods, Electrical Energy Demand Monitoring Methods, And Power Management Devices", assigned to the assignee hereof and the teachings of which are incorporated herein by reference. Other electrical characteristics of electrical energy of the system **10** may be monitored to determine surpluses or deficiencies of energy on the system **10** in other embodiments. For example, voltages or harmonics may be monitored.

In one example, the controller **20** continually compares the instantaneous system frequency of the voltage of the electrical energy of the system **10** at a given moment in time (also referred to as current frequency) with respect to the nominal frequency of the voltage of the electrical energy of the system **10** to determine the state of the distribution system **10** at the corresponding moment in time. A fixed value (e.g., 60 Hz) may be used as the nominal frequency in one embodiment. In another embodiment described below, the nominal frequency may be calculated as an average of the system frequency over a period of time, for example using a sliding-window.

If the monitored frequency is above the nominal frequency at a given moment in time, there is a surplus of electrical energy upon the distribution system **10** at the given moment in time indicating the generation of electrical energy is exceeding the consumption of the electrical energy. If the monitored frequency is below the nominal frequency at the given moment in time, there is a deficit of electrical energy upon the distribution system **10** at the given moment in time indicating the consumption of electrical energy exceeds the generation of the electrical energy. Accordingly, in one embodiment, the controller **20** may compare information regarding the current frequency at different moments in time with the nominal frequency to determine if there is a surplus or a deficit of electrical energy upon the distribution system **10** at the different moments in time.

As discussed herein according to one embodiment, battery system **12** may be used as a regulation system in an attempt to balance generation and consumption of electrical energy upon the distribution system **10** which may minimize stresses upon the distribution system **10**. In one embodiment, controller **20** may use the information regarding the state of the distribution system **10** (e.g., using the results of the comparison of the current frequency with the nominal frequency) to control an adjustment of the amount of electrical energy provided by charger **18** to charge the battery **16** in an attempt to reduce an amount of deficit or surplus energy upon the system **10** to balance the system **10**. In a more specific example, controller **20** may control an increase in an amount of electrical energy used to charge battery **16** if accessed information indicates there is a surplus of electrical energy upon system **10** at one moment in time or decrease an amount of electrical energy used to charge battery **10** if accessed information indicates there is a deficit of electrical energy upon system **10** at another moment in time. Accordingly, battery system **12** including a battery charging apparatus **14** may be considered to be a regulation device which may be used to attempt to stabilize the system **10** by attempting to reduce a surplus or deficit of electrical energy upon system **10** in one embodiment.

As mentioned above, information regarding a rate of charging of the battery **16** may also be used to control charging operations with respect to battery **16** in one embodiment. In one embodiment, controller **20** may monitor a rate of charging of the battery **16** during a charge process of the battery **16**. For example, the controller **20** may access state of charge information of battery **16** at a plurality of different moments in time during the charge process to determine the actual rate of charging of the battery **16**. In some embodiments, it is desirable to avoid situations where the battery **16** is quickly brought to a full charge. More specifically, once the battery **16** is fully charged, the amount of electrical energy used by charger **18** may be greatly reduced (e.g., perhaps only a relatively small amount of energy is used for trickle charging) and the ability of battery charging apparatus **14** to function as a regulation device may be similarly reduced if there is a surplus of electrical energy present upon the system **10**.

According to one embodiment, controller **20** compares the actual rate of charge information with respect to a desired rate of charge of the battery **16** and may control operations of the charger **18** as a result of the comparison. More specifically, in one embodiment, a user may input a desired point in time in the future for the rechargeable battery to be fully charged (or otherwise charged to a different desired state of charge). Controller **20** may use this desired point in time to determine an amount of time remaining from the present time to the desired point in time to determine a desired rate of charge of battery **16** (e.g., referred to as a needed charge rate in examples below). If the battery **16** is charging too quickly with respect to the desired rate of charge as a result of the comparison, the controller **20** may control the charger **18** to reduce an amount of electrical energy used to charge the battery **16**. If the battery **16** is charging too slowly compared with the desired rate of charge, the controller **20** may control the charger to increase the amount of electrical energy used to the charge the battery **16**. The above-described example charging allows the battery system **12** to provide the battery charging functionality as a regulation device of system **12** for an extended period of time during the charging process compared with arrangements which do not monitor rate of charge.

In another embodiment, the controller **20** may also monitor the remaining amount of time until the battery **16** is to be charged to the desired state of charge at the desired point of time in the future in an attempt to accommodate the desires of the user. If the battery **16** is charging too slowly, the controller **20** may increase the rate of charge in an effort to provide the battery **16** in the desired state of charge at the desired point of time in the future.

Referring to FIG. **3**, one embodiment of charging operations of battery system **12** is described with respect to a load in the form of an electric vehicle **30** which includes one or more rechargeable battery **16**. The arrangement of the battery system **12** of FIG. **3** is illustrative for explanation of some aspects of the disclosure and other arrangements are possible. For example, the battery charging apparatus **14** of battery system **12** may be installed at home, work, or any other location where it is desirable to implement charging of rechargeable battery **16** and electrical energy from electrical power distribution system **10** is available for consumption. Furthermore, rechargeable batteries **16** may be utilized in different applications other than vehicles **30** and which may be charged by battery charging apparatus **14**. Additionally, one or more components of the battery system **12** may be implemented differently in other embodiments. For example, battery charging apparatus **14** may also be located within the vehicle **30** in some implementations. In some embodiments, the battery **16** may be removed from the device being powered and coupled with the battery charging apparatus **14**.

Referring to FIG. **4**, a method for charging a battery is shown according to one embodiment. The illustrated method may be executed or otherwise implemented by controller **20** in one arrangement. In one embodiment, the illustrated

method may be repeatedly executed during a charge cycle of a battery. Other methods are possible including more, less and/or additional acts.

At an act **A10**, a user connects the battery system to the electrical power distribution system. For example, the user may connect his electric vehicle to the electrical power distribution system for recharging when he arrives home from work. The controller detects the connection at step **A10**.

At an act **12**, the controller accesses user inputted information. For example, the inputted information may specify the desired point of time in the future when the vehicle is expected to be fully charged (or at some other desired state of charge).

At an act **14**, the controller accesses the present time, for example from an internal clock, and the desired point of time in the future when the vehicle is to be fully charged and may calculate a desired charge rate using the present time and the desired point of time in the future when the vehicle is to be fully charged.

At an act **16**, the controller accesses information regarding the electrical power distribution system. For example, the controller may access information regarding the instant frequency of the system and the average frequency of the system.

At an act **A18**, the controller determines whether there is a surplus or deficit of electrical energy upon electric power distribution system. For example, the controller may compare the information regarding the instant frequency of the system with respect to the average frequency of the system to determine if there is a surplus or deficit of electrical energy upon the system.

If act **A18** is affirmative, the controller proceeds to an act **A20**. At act **A20**, the controller changes the amount of electrical energy used to charge the battery according to the surplus or deficit of electrical energy upon the system. For example, if there is a surplus of electrical energy, the controller may increase the amount of electrical energy used to charge the rechargeable battery. If there is a deficit of electrical energy, the controller may decrease the amount of electrical energy used to charge the rechargeable battery.

In one embodiment, the controller may also refer to time of day information to implement charging. For example, if a user connects the battery at a critical peak time of the day (e.g., in the afternoon when air conditioners may be used), the controller may delay a start time of charging until the critical peak time has passed. The controller may access a schedule (e.g., internally or from the utility) of critical peak times to control when charging is started in one embodiment.

If act **A18** is negative, the controller proceeds to an act **A22** to determine whether the charging of the battery is on schedule. For example, the controller may compare the actual rate of charge with the desired rate of charge to determine whether the charging process for the current charge cycle is on schedule.

If act **A22** is negative, the controller proceeds to act **A24** to change the amount of electrical energy used to charge the battery according to the actual rate of charge. In one embodiment, the controller may decrease the amount of electrical energy used to charge the battery if the charging of the battery is faster than desired or the controller may increase the amount of electrical energy used to charge the battery if the charging of the battery is slower than desired.

If act **A22** is negative, the controller proceeds to an act **A26** to control the charging of the battery using the appropriate amount of electrical energy.

Referring to FIGS. **5**A and **5**B, another method for charging a battery is shown according to one embodiment. The illustrated method may be executed or otherwise implemented by controller **20** in one arrangement. In one embodiment, the illustrated method may be repeatedly executed during a common charge cycle of a battery. Other methods are possible include more, less and/or additional acts.

At an act **A30**, a user connects the battery system to the electrical power distribution system. The controller detects the connection at step **A30**.

At an act **A32**, the controller accesses information regarding the present state of the charge of the battery and determines whether the battery is fully charged.

If act **A32** is affirmative, the controller proceeds to an act **A34** where no charging is implemented using the battery charging apparatus.

If act **A32** is negative, the controller proceeds to an act **A36** to determine if the electrical power distribution system is experiencing an under frequency event. In one embodiment, the controller monitors for the presence of a significant under frequency event at act **A36**. In a specific example, the controller compares the current frequency with respect to a threshold corresponding to a deviation of the current frequency below the nominal frequency. For an example system having a nominal frequency of 60 Hz, the threshold may be 59.95 Hz in one embodiment indicative of a relatively significant under frequency event. Other thresholds may be used in other embodiments.

If act **A36** is affirmative, the controller proceeds to act **A34** where minimal charging is implemented using the battery recharging apparatus (e.g., the charger performs no charging in one arrangement).

If act **A36** is negative, the controller proceeds to an act **A38** to determine if the electrical power distribution system is experiencing an over frequency event. In one embodiment, the controller monitors for the presence of a significant over frequency event at act **A38**. In a specific example, the controller compares the current frequency of the electrical energy with respect to a threshold corresponding to a deviation of the current frequency above the nominal frequency. For an example system having a nominal frequency of 60 Hz, the threshold may be 60.05 Hz in one embodiment indicative of a relatively significant over frequency event. Other thresholds may be used in other embodiments.

If act **A38** is affirmative, the controller proceeds to an act **A40** where charging is implemented by the battery recharging apparatus using a maximum amount of electrical energy (e.g., the charger charges at its maximum rate).

If act **A38** is negative, the controller proceeds to an act **A42** to determine whether the recharging of the battery is presently charging within the normal regulation time period. In one embodiment, the normal regulation time period may correspond to the time period of a charging cycle which occurs after charging is initiated until a fixed period of time threshold (e.g., thirty minutes) before the point in time when the battery is desired to be fully charged. In one embodiment, the controller calculates the remaining amount of time for charging from the present time to the desired point of time in the future for full charge and compares the calculated remaining amount of time with the threshold to determine whether the charging is within the normal regulation time period (e.g., the remaining amount of time for charging is greater than the threshold).

If the condition of act **A42** is negative, the controller proceeds to an act **A44** where the controller increases the rate of the charging (e.g., increases the amount of electrical energy used to charge the battery). In one embodiment, the controller scales a needed charge rate (i.e., the needed charge rate may be defined as the charge rate needed to achieve full charge by

the desired point of time in the future for example using the capacity information of the battery, time remaining to reach full charge and the charger efficiency). At act **A44**, the controller may multiply the needed charge rate by 1.01 providing a new needed charge rate and which increases the rate of charging of the battery in one embodiment.

In one embodiment, if the result of **A42** is affirmative, the controller may reset the charging to the needed charge rate prior to proceeding to act **A46**. In one embodiment, the controller compares the actual charge rate with the desired charge rate at act **A46**. In a more specific example, the controller determines whether a regulation ratio value is greater than a regulation high deviation limit for the condition of act **A46**. In one embodiment, the regulation ratio value is calculated by (measured charge rate−needed charge rate) divided by the maximum charge rate of the charger where the measured charge rate is the average rate of charge of the charger measured over a period of time (e.g., 5 minutes). The result of this calculation may be multiplied by 100 for a percentage to provide the regulation ratio value. In one embodiment, the regulation high deviation limit is a limit above the needed charge rate to which charging can exceed the needed charge rate in one embodiment (e.g., a percentage such as 15% in one embodiment).

Following the processing in act **A46**, the controller follows plural routes via the yes and no branches out of act **A46** to set the average charge rate and the upper and lower charge rates which scale or map the charger output based upon the frequency of electrical energy of the distribution system deviating from the nominal frequency in the described example. In one embodiment, the upper and lower charge rates limit the adjustment to an average charge rate which controls the output of the charger using information regarding the system frequency of the electrical power distribution system. In one embodiment, the average charge rate is an output of the charger when the system frequency of the electrical power distribution system is at the nominal frequency in one embodiment. The average charge rate may be adjusted up or down in subsequent acts depending on whether the system frequency goes up or down relative to the nominal frequency, respectively as described further below. In other words, the upper and lower charge rates determine the minimum and maximum output of the charger based upon frequency deviation from the nominal frequency. The determination of the upper and lower charge rate may be determined using information regarding an amount of time left to charge the battery in one embodiment.

If the condition of act **A46** is affirmative, the controller proceeds to an act **A48** to reduce the rate of charge (e.g., decrease the amount of electrical energy used to charge the battery) which extends the length of time the battery charging apparatus **14** is available as a regulation device to assist balancing of electrical power distribution system. In one embodiment, the controller determines whether the needed charge rate is greater than the maximum charge rate of the charger and limits the needed charge rate to the maximum charge rate if the needed charge rate is greater than the maximum charge rate of the charger. The controller sets the average charge rate equal to the needed charge rate.

Following act **A48**, the controller proceeds to an act **A50** to determine whether a minimum time is remaining to charge the battery. For example, the controller can determine the time left ratio as an amount of time for the battery to be fully charged if the charger is set to maximum charging output compared with the remaining period of time to charge the battery. The controller determines whether the time left ratio is greater than a critical limit (e.g., 98.5% in one example).

If the condition of act **A50** is affirmative, the controller proceeds to an act **A52** to increase the charging by setting the upper and lower charge rates to allow an increased charge rate of the charger. For example, the upper charge rate is set to be the maximum charge rate minus the average charge rate and the lower charge rate is set to be the average charge rate*(1−time left ratio).

If the condition of act **A50** is negative, the controller proceeds to an act **A54** to implement normal charge scaling. At act **A54**, the controller limits upward adjustment of the rate of charging due to subsequent frequency analysis if the amount of time remaining to reach full charge is greater than a threshold, such as 30 minutes. If the amount of time remaining is greater than the threshold, the controller sets the upper charge rate to zero if the average charge rate is greater than the maximum charge rate. Otherwise, the upper charge rate is set to (maximum charge rate−average charge rate). The controller also sets the lower charge rate to the average charge rate. If the amount of time remaining is less than the threshold, the controller may restrict the upper and lower charge rates to be close to the average charge rate. In one specific example, the controller sets the lower charge rate to be the average charge rate divided by three. For the upper charge rate, the controller determines whether the maximum charge rate divided by two is greater than the average charge rate. If the answer is yes, the controller sets the upper charge rate to be equal to a value determined by (the maximum charge rate of the charger minus the average charge rate)/3. If the answer is no, the controller sets the upper charge rate to be the maximum charge rate minus the average rate.

Referring again to the condition of act **A46**, if the condition of act **A46** is negative, the controller sets the average rate to be the needed charge rate (capped by the maximum charge rate of the charger if appropriate) and proceeds to acts **A60** and **A62** in parallel.

At act **A60**, the upper charge rate is set to be the maximum charge rate minus the average charge rate.

At act **A62**, the controller determines whether a minimum time is remaining to charge the battery (similar to act **A50**). As discussed above, the controller can determine the time left ratio as an amount of time for the battery to be fully charged if the charger is set to maximum charging output compared with the remaining period of time to charge the battery. The controller determines whether the time left ratio is greater than a critical limit (e.g., 98.5% in one example).

If the condition of act **A62** is affirmative, the controller proceeds to an act **A64** to increase the charge rate by setting the lower charge rate to allow increased rate of charge of the charger. In one embodiment, the lower charge rate equals the average charge rate*(1−time left ratio) (similar to act **A52**).

If the condition of act **A62** is negative, in one embodiment, the lower charge rate is set to the average charge rate and the controller proceeds to an Act **A70**.

At an Act **A70**, the controller accesses the charger parameters. In the described example, these parameters include the previously determined average charge rate, and upper and lower charge rates.

At an Act **A72**, the frequency deviation of electrical energy on the distribution system is determined which compares the current frequency of the electrical energy of the distribution system with the nominal frequency of the electrical energy of the distribution system. In one embodiment, an average frequency of the electrical energy is calculated and used as the nominal frequency. One example method for obtaining the average frequency information from direct measurements of the electrical energy received at the location of the battery charging apparatus may use a simple recursive implementa-

tion of a finite-impulse response (FIR) filter. In one embodiment, this filter computes the average frequency for a predetermined amount of time prior to the execution of the described method. In one embodiment, the amount of time of taking measurements to determine the average frequency is five minutes. In some arrangements, the filter may be reinitialized if the system frequency has gone significantly under or over the average frequency (e.g., if the frequency exceeds the under frequency or over frequency thresholds mentioned earlier by a significant amount such as a measurement of 61.5 Hz when the threshold is 60.05 Hz).

At an Act A**74**, the controller scales the charge rate to the charger output. If the current frequency is greater than the average frequency, normalization of the current frequency measurement to a historical frequency measurement may be implemented according to (current frequency−average frequency)/(maximum frequency−average frequency) where the maximum frequency may be the maximum value of the system frequency during a previous amount of time, such as two minutes. The normalized output may then be multiplied by the upper charge rate previously calculated and added to the average charge rate to determine the appropriate rate of charging. If the current frequency is less than the average frequency, a normalization may be implemented according to (current frequency−average frequency)/(average frequency−the minimum frequency) where the minimum frequency may be the minimum value of the system frequency during a previous amount of time, such as two minutes. The normalized output may be multiplied by the lower charge rate previously calculated and added to the average charge rate to determine the appropriate charge rate to be applied to the battery.

Example programming comprising c-code for controlling controller **20** to implement the methods described herein according to one embodiment is shown below in Table A. Other programming may be used in other embodiments.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

Further, aspects herein have been presented for guidance in construction and/or operation of illustrative embodiments of the disclosure. Applicant(s) hereof consider these described illustrative embodiments to also include, disclose and describe further inventive aspects in addition to those explicitly disclosed. For example, the additional inventive aspects may include less, more and/or alternative features than those described in the illustrative embodiments. In more specific examples, Applicants consider the disclosure to include, disclose and describe methods which include less, more and/or alternative steps than those methods explicitly disclosed as well as apparatus which includes less, more and/or alternative structure than the explicitly disclosed structure.

TABLE A

```
/*********************************************************************
// Frequency regulation C function
// written based upon floating point being included
//
// Function has minimal UF/OF handling. Most of this is
// presumed to be handled in the external GFA chip.
*********************************************************************/
extern struct battery_mgmt_t battery;
extern struct gfa_control_t gfa;
extern long PeriodAvg, Period, FreqValue[128];
//Globals
uint8 FreqRegStatus;            //Status bits for frequency-regulation algorithm
/********************* Variable Descriptions ***************************
//Actual frequency regulation function
//All values in seconds - e.g. Batt_Cap = A-seconds, not A-hours
//PercentOut = 0 – 100 signal for final charger output
//TimeLeft = time left in charging period in seconds
//Batt_SOC = percent state of charge (5.0 = 5%)
//AvgRate = Average battery rate charge rate in Amps
//MaxChargeRate = Maximum battery charge rate in Amps
//ChargeEfficiency = ratio of efficiency (0.98 = 98% efficient)
//UpDevPercent = percent the average charge rate is allowed to exceed the
//    "nominal" rate before regulation up is restricted
//TimeRatioCritCharge - time ratio (Needed charge time over minimum necessary
//    charge time) before algorithm maxes rate to try and reach 100% SOC
//TimeLeftLimitReg - time in seconds before regulation algorithm starts
//    limiting itself so a 100% SOC can be reached in time
//
//Imported variables (globals elsewhere)
//FreqValue - Array of frequencies (period) stored for min/max calculations
//battery - Structure of battery information of interest are:
//    battSOC - battery state of charge as a % (e.g. 78 = 78%)
//    battCapacityAhr - total capacity in Amp Hours (convert to Amp-seconds)
//Period - current period measurement
//PeriodAvg - Average period measurement
*********************************************************************************/
int FreqRegulation(uint32 TimeLeft, float AvgRate, float MaxChargeRate, float
ChargeEfficiency, float UpDevPercent, float TimeRatioCritCharge, uint16
TimeLeftLimitReg)
{
float BattCapacityLeft, TimeRatio, RegRatio;
float NeededRate, SlopeDiffVal, AVGChargeRate, LowerChargeRate,
        UpperChargeRate;
```

TABLE A-continued

```
float PercentMax = 0;
long MaxFreqVal = 0x7FFFFFFF, MinFreqVal = 0;          // 1,250,000 / Freq
static int PercentOut;
int i;
//Find min and max frequency (period)
for (i = 0; i < 64; i++) {
        if (MinFreqVal > FreqValue[i]) MinFreqVal = FreqValue[i];
        if (MaxFreqVal < FreqValue[i]) MaxFreqVal = FreqValue[i];
}
//Initial time keeping
MaxChargeRate /= 10;
// Figure out battery capacity we need to charge – Amp-sec
BattCapacityLeft = (float)((100 – battery.battSOC) *
        battery.battCapacityAhr * 36);
// Calculate average charge rate (Amps)
NeededRate = BattCapacityLeft / (float)TimeLeft / ChargeEfficiency;
//BMS returning a lull, no sense going through code
if (MaxChargeRate == 0) return 0;
// Find minimum time needed to finish charge
TimeRatio = BattCapacityLeft / ChargeEfficiency / MaxChargeRate;
//Find ratio of time left to min time left (use a weighting of constants)
TimeRatio /= TimeLeft;
//Event Management
if              ((FreqRegStatus & 0x04)==0x04)
        PercentOut=0;//UF Event, make sure output zerod
else if ((FreqRegStatus & 0x08)==0x08)
        PercentOut=100; //OF event, max us
else if (BattCapacityLeft <= 0)
        PercentOut=0; //we're charged
else {                          //Normal algorithm
        //Don't let exceed 1
        if ((TimeRatio > 1) || ((FreqRegStatus & 0x01)==0x01))
                TimeRatio=1;
        //Prior to critical regulation time, let adjust
        if (TimeLeft > TimeLeftLimitReg)    {
                // See how close our average rate is to the current rate
                SlopeDiffVal = (AvgRate – NeededRate);
                // Adjust the average rate accordingly opposite
                NeededRate = NeededRate – SlopeDiffVal;
        }
        //Otherwise, bias it up a little just to ensure we finish in time
        //(if there is headroom)
        else
                NeededRate += NeededRate / 100;
        //See if we've exceeded our upper limit
        RegRatio=((AvgRate – NeededRate) / MaxChargeRate) * 100;
        //If lower – continue as normal
        if (RegRatio <= UpDevPercent)    {
                //Clear flag just in case
                FreqRegStatus = (uint8)(FreqRegStatus & 0x01);
                //Limit needed rate to maximum rate if it has exceeded it
                if (NeededRate > MaxChargeRate)
                        AVGChargeRate=MaxChargeRate;
                else if (NeededRate < 0)
                        AVGChargeRate=0;   //Should never go below 0, but just in case
                else
                        AVGChargeRate=NeededRate;
                if (TimeRatio > TimeRatioCritCharge)        {
                        UpperChargeRate = (MaxChargeRate – AVGChargeRate);
                        LowerChargeRate = AVGChargeRate * (1 – TimeRatio);
                        //Set critical flag
                        FreqRegStatus = (uint8)(FreqRegStatus | 0x01);
        }
                else            {
                        UpperChargeRate = (MaxChargeRate – AVGChargeRate);
                        LowerChargeRate = AVGChargeRate;
                }
        }
        else    {       //Over rate, throttle us back...unless we are in time trouble
                //Flag as overage condition
                FreqRegStatus = (uint8)(FreqRegStatus | 0x02);
                //Limit needed rate to maximum rate if it has exceeded it
                if (NeededRate > MaxChargeRate)
                        AVGChargeRate = MaxChargeRate;
                else if (NeededRate < 0)
                        AVGChargeRate = 0;     //Should never go below 0, but just in case
                else
                        AVGChargeRate = NeededRate;
                //Critical zone check
                if (TimeRatio > TimeRatioCritCharge) {
```

TABLE A-continued

```
                UpperChargeRate = (MaxChargeRate – AVGChargeRate);
                LowerChargeRate = AVGChargeRate * (1 – TimeRatio);
                //Set critical flag
                FreqRegStatus    = (uint8)(FreqRegStatus | 0x01);
        }
        //Non-critical.    Limit Reg up – limit to average
        else        {
        //If plenty of regulation time, business as usual
        if (TimeLeft > TimeLeftLimitReg) {
                if (AvGChargeRate > MaxChargeRate)
                        UpperChargeRate = 0;
                else
                        UpperChargeRate = MaxChargeRate – AVGChargeRate;
                LowerChargeRate = AVGChargeRate;
                }
                //Less than critical amount, pull up the base and
                //expand the top limit
        else {
                if ((MaxChargeRate/2) > AVGChargeRate)
                        UpperChargeRate = (MaxChargeRate – AVGChargeRate) / 3;
                else
                        UpperChargeRate = (MaxChargeRate – AVGChargeRate);
                        LowerChargeRate = AVGChargeRate / 3;
        }
        //Clear all flags except possible critical
        FreqRegStatus = (uint8)(FreqRegStatus & 0xFE);
        }
    }
    //Determine percentage out
    if (PeriodAvg > Period)        {            //Regulation up
        //Avg Freq = Max Freq?
        if (PeriodAvg == MaxFreqVal)
                PercentMax = UpperChargeRate;
        else    {
                PercentMax = (float)MaxFreqVal / (float)Period;
                PercentMax *= (PeriodAvg – Period);
                PercentMax /= (PeriodAvg – MaxFreqVal);
                PercentMax *= UpperChargeRate;
        }
    }
    else { // Regulation down
        //Avg Freq = Min Freq?
        if (MinFreqVal == PeriodAvg)
                PercentMax = 0;
        else    {
                PercentMax = (float)MinFreqVal / (float)Period;
                PercentMax *= (PeriodAvg – Period);
                PercentMax /= (MinFreqVal – PeriodAvg);
                PercentMax *= LowerChargeRate;
        }
    }
    PercentMax += AVGChargeRate;
    PercentMax *= (100 / MaxChargeRate);
    if (PercentMax > 100)
            PercentOut = 100;
    else if (PercentMax < 0)
            PercentOut = 0;
    else
            PercentOut = (int)(PercentMax);
}
return PercentOut;
}
```

What is claimed is:

1. A battery charging control method comprising:

accessing information regarding a presence of at least one of a surplus and a deficiency of electrical energy upon an electrical power distribution system at a plurality of different moments in time;

monitoring a rate of charging of a rechargeable battery;

using the information and the rate of charging of the rechargeable battery, controlling an adjustment of an amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery to charge the rechargeable battery.

2. The method of claim **1** wherein the accessing comprises monitoring an electrical characteristic of the electrical energy provided from the electrical power distribution system.

3. The method of claim **1** wherein the monitoring comprises monitoring the electrical characteristic of the electrical energy comprising frequency, and further comprising comparing the frequency of the electrical energy with respect to a nominal frequency of the electrical power distribution system, and wherein the controlling comprises controlling the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the comparing.

4. The method of claim 1 wherein the accessing comprises receiving the information from the electrical power distribution system.

5. The method of claim 1 wherein the controlling comprises controlling an increase in the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the information indicating that the surplus of electrical energy exists on the electrical power distribution system.

6. The method of claim 5 further comprising detecting that the surplus of the electrical energy exceeds a threshold, and wherein the controlling comprises controlling the adjustment of the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery to be a maximum amount as a result of the detecting the surplus of the electrical energy exceeding the threshold.

7. The method of claim 1 wherein the controlling comprises controlling a decrease in the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the information indicating that the deficiency of electrical energy exists on the electrical power distribution system.

8. The method of claim 7 further comprising detecting that the deficiency of the electrical energy exceeds a threshold, and wherein the controlling comprises controlling the adjustment of the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery to be a minimum amount as a result of the detecting the deficiency of the electrical energy exceeding the threshold.

9. The method of claim 1 further comprising:

accessing a desired point in time in the future for the rechargeable battery to reach a desired state of charge;

monitoring a remaining amount of time until the desired point in time; and

controlling the adjustment of the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the monitoring of the remaining amount of time.

10. The method of claim 1 wherein the controlling comprises controlling the adjustment of the amount of the electrical energy at a plurality of different moments in time during a common charge cycle of the rechargeable battery, and wherein the controlling further comprises controlling an increase of the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery at a first of the moments in time of the common charge cycle and controlling a decrease in the amount of electrical energy provided from the electrical power distribution system to the rechargeable battery at a second of the moments in time of the common charge cycle.

11. The method of claim 1 wherein the monitoring comprises monitoring an average rate of charging of the rechargeable battery.

12. An electric vehicle charging method comprising:

coupling an electrical vehicle having a depleted state of charge with an electrical power distribution system;

charging the electrical vehicle using electrical energy from the electrical power distribution system;

monitoring an electrical characteristic of the electrical energy from the electrical power distribution system;

monitoring a remaining amount of time until a desired point in time in the future for the electric vehicle to have a desired amount of stored energy;

adjusting an amount of the electrical energy provided from the electrical power distribution system to charge the electrical vehicle as a result of the monitoring of the electrical characteristic and the monitoring of the remaining amount of time.

13. The method of claim 12 wherein the monitorings individually comprise monitoring passively at the location of the electrical vehicle without data communications to the electrical power distribution system.

14. The method of claim 12 wherein the monitoring the electrical characteristic comprises monitoring the electrical characteristic of the electrical energy comprising frequency, and further comprising comparing the frequency of the electrical energy with respect to a nominal frequency of the electrical power distribution system, and wherein the adjusting comprises adjusting the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the comparing.

15. The method of claim 14 wherein the adjusting comprises increasing the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery at a first moment in time as a result of the comparing detecting that the frequency of the electrical energy is greater than a nominal frequency at the first moment in time, and decreasing the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery at a second moment in time as a result of the comparing detecting that the frequency of the electrical energy is less than the nominal frequency at the second moment in time.

16. The method of claim 12 wherein the monitoring comprises monitoring the remaining amount of time for the electric vehicle to have the desired amount of stored energy comprising a desired state of charge.

17. The method of claim 12 wherein the coupling comprises coupling the electrical vehicle with the electrical power distribution system which is an electrical grid.

18. The method of claim 12 wherein the electrical characteristic of the electrical energy which is monitored is frequency of the electrical energy.

19. A battery charging apparatus comprising:

processing circuitry configured to access information indicating at least one of a surplus and a deficiency of electrical energy upon the electrical power distribution system and to control an adjustment of an amount of electrical energy provided from the electrical power distribution system to a rechargeable battery to charge the rechargeable battery using the information; and

wherein the processing circuitry is configured to monitor a rate of charging of the rechargeable battery and to control the adjustment of the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery as a result of the monitoring of the rate of charging of the rechargeable battery.

20. The apparatus of claim 19 wherein the processing circuitry is configured to monitor an electrical characteristic of the electrical energy received from the electrical power distribution system to access the information.

21. The apparatus of claim 20 wherein the processing circuitry is configured to monitor the electrical characteristic of the electrical energy comprising frequency, to compare the frequency of the electrical energy with respect to a nominal frequency of the electrical power distribution system, and to control the adjustment of amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the comparison.

22. The apparatus of claim 19 wherein the processing circuitry is configured to control an increase in the amount of the electrical energy provided from the electrical power distribu-

tion system to charge the rechargeable battery as a result of the information indicating that the surplus of electrical energy exists on the electrical power distribution system at a first moment in time and to control a decrease in the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the information indicating that the deficiency of electrical energy exists on the electrical power distribution system at a second moment in time.

23. The apparatus of claim **22** wherein the processing circuitry is configured to control the adjustment of the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery to be a maximum amount as a result of the surplus of the electrical energy exceeding a first threshold and to control the adjustment of the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery to be a minimum amount as a result of the deficiency of the electrical energy exceeding a second threshold.

24. The apparatus of claim **19** wherein the processing circuitry is configured to access a desired point in time in the future for the rechargeable battery to have a desired state of charge, to monitor a remaining amount of time until the desired point in time, and to control the adjustment of the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the monitoring of the remaining amount of time.

25. The apparatus of claim **19** wherein the processing circuitry is configured to control the adjustment of the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery at a plurality of different moments in time during a common charge cycle of the rechargeable battery, and wherein the processing circuitry is configured to control an increase of the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery at a first of the moments in time of the common charge cycle and to control a decrease in the amount of electrical energy provided from the electrical power distribution system to the rechargeable battery at a second of the moments in time of the common charge cycle.

26. The apparatus of claim **19** wherein the processing circuitry is configured to access the information indicating at least one of a surplus and a deficiency of electrical energy upon the electrical power distribution system which is an electrical grid.

27. A rechargeable battery system comprising:

a charger coupled with an electrical power distribution system and configured to provide electrical energy from the electrical power distribution system to a rechargeable battery to charge the rechargeable battery; and

processing circuitry configured to monitor for a presence of at least one of a surplus and a deficit of electrical energy upon the electrical power distribution system and to control the charger to adjust an amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery as a result of the monitoring detecting the presence of the at least one of the surplus and the deficit of the electrical energy upon the electrical power distribution system; and

wherein the processing circuitry is configured to monitor a remaining amount of time until a desired point in time in the future for the rechargeable battery to have a desired amount of stored energy, and to control the charger to adjust the amount of the electrical energy provided from the electrical power distribution system to the rechargeable battery as a result of the monitoring of the remaining amount of time.

28. The system of claim **27** wherein the processing circuitry is configured to monitor for the presence of the at least one of the surplus and the deficit passively at the location of the rechargeable battery system without data communications to the electrical power distribution system.

29. The system of claim **28** wherein the processing circuitry is configured to monitor an electrical characteristic of the electrical energy to monitor for the presence of the at least one of the surplus and the deficit of electrical energy.

30. The system of claim **27** wherein the processing circuitry is configured to monitor an electrical characteristic of the electrical energy comprising frequency to monitor for the presence of the at least one of the surplus and the deficit of electrical energy, to compare the frequency of the electrical energy with respect to a nominal frequency of the electrical power distribution system, and to control the charger to adjust the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery as a result of the comparison.

31. The system of claim **30** wherein the processing circuitry is configured to control the charger to provide an increase in the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery at a first moment in time as a result of the comparison detecting that the frequency is greater than a nominal frequency of the electrical power distribution system at the first moment in time, and to control the charger to provide a decrease in the amount of the electrical energy provided from the electrical power distribution system to charge the rechargeable battery at a second moment in time as a result of the comparison detecting that the frequency is less than the nominal frequency at the second moment in time.

32. The system of claim **27** further comprising the rechargeable battery.

33. An energy storage apparatus comprising:

circuitry configured to receive electrical energy from an electrical grid which is external of the energy storage apparatus and to use the received electrical energy to provide energy to an energy storage device which is configured to store the energy; and

wherein the circuitry is further configured to access information regarding a state of balance of consumption and generation of electrical energy upon the electrical grid and to control an adjustment of an amount of the energy which is provided to the energy storage device for storage using the information regarding the state of balance of the consumption and generation of electrical energy upon the electrical grid; and

wherein the circuitry is configured to monitor a remaining amount of time until a desired point in time in the future for the energy storage device to have a desired amount of stored energy, and to control the adjustment of the amount of the energy which is provided to the energy storage device for storage as a result of the monitoring of the remaining amount of time.

34. The apparatus of claim **33** further comprising the energy storage device which is configured to store energy.

35. The apparatus of claim **34** wherein the energy storage device is a rechargeable battery and the circuitry comprises charging circuitry which is configured to provide the energy comprising charging electrical energy to the rechargeable battery to charge the rechargeable battery.

36. The apparatus of claim **33** wherein the circuitry is configured to adjust the amount of the energy which is pro-

vided to the energy storage device to reduce a difference between the consumption and generation of the electrical energy upon the electrical grid.

37. The apparatus of claim **33** wherein the circuitry is configured to monitor an electrical characteristic of the electrical energy upon the electrical grid to access the information regarding the state of balance of consumption and generation of electrical energy upon the electrical grid.

38. The apparatus of claim **37** wherein the circuitry is configured to monitor the electrical characteristic of the electrical energy comprising frequency, to compare the frequency of the electrical energy with respect to a nominal frequency of the electrical grid, and to control the adjustment of the amount of energy which is provided to the energy storage device as a result of the comparison.

39. The apparatus of claim **33** wherein the circuitry is configured access the information from the electrical grid.

40. The apparatus of claim **33** wherein the circuitry is configured to control an increase in the amount of the energy which is provided to the energy storage device as a result of the information indicating that the generation of electrical energy exceeds the consumption of electrical energy upon the electrical grid.

41. The apparatus of claim **33** wherein the circuitry is configured to control an increase in the amount of the electrical energy which is provided to the energy storage device to a maximum amount as a result of the information indicating that a surplus of the electrical energy upon the electrical grid exceeds a threshold.

42. The apparatus of claim **33** wherein the circuitry is configured to decrease the amount of the energy which is provided to the energy storage device as a result of the information indicating that the consumption of electrical energy exceeds the generation of electrical energy upon the electrical grid.

43. The apparatus of claim **33** wherein the circuitry is configured to monitor frequency of the electrical energy upon the electrical grid to access the information regarding the state of balance of consumption and generation of the electrical energy upon the electrical grid.

44. An energy storage method comprising:

using electrical energy received from an electrical grid, providing energy to an energy storage device which is configured to store the energy to charge the energy storage device;

accessing information regarding a state of balance of consumption and generation of electrical energy upon the electrical grid;

monitoring a rate of charging of the energy storage device; and

controlling an adjustment of an amount of the energy provided to the energy storage device using the information regarding the state of balance of the consumption and generation of electrical energy upon the electrical grid and the rate of charging of the energy storage device.

45. The method of claim **44** wherein the energy storage device is a rechargeable battery and the providing comprises charging the rechargeable battery using the electrical energy received from the electrical grid.

46. The method of claim **44** wherein the controlling comprises controlling the adjustment to reduce a difference between the consumption and generation of the electrical energy upon the electrical grid.

47. The method of claim **44** wherein the accessing comprises monitoring an electrical characteristic of the electrical energy upon the electrical grid which is indicative of the state of balance of the consumption and generation of the electrical energy upon the electrical grid.

48. The method of claim **47** wherein the monitoring the electrical characteristic comprises monitoring the electrical characteristic of the electrical energy comprising frequency, and further comprising comparing the frequency of the electrical energy with respect to a nominal frequency of the electrical grid, and wherein the controlling comprises controlling using the comparing.

49. The method of claim **44** wherein the accessing comprises accessing the information from the electrical grid.

50. The method of claim **44** wherein the controlling comprises increasing the amount of the energy which is provided to the energy storage device as a result of the information indicating that the generation of electrical energy exceeds the consumption of electrical energy upon the electrical grid.

51. The method of claim **44** wherein the controlling comprises increasing the amount of the energy which is provided to the energy storage device to a maximum amount as a result of the information indicating that a surplus of the electrical energy upon the electrical grid exceeds a threshold.

52. The method of claim **44** wherein the controlling comprises decreasing the amount of the energy which is provided to the energy storage device as a result of the information indicating that the consumption of electrical energy exceeds generation of electrical energy upon the electrical grid.

* * * * *