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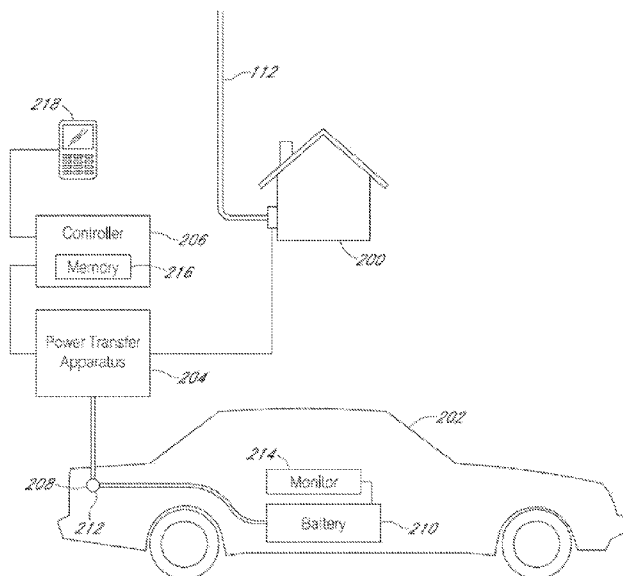


FIG. 2

(57) Abstract: An apparatus and method for transferring energy between a rechargeable battery and a power distribution network. The minimum final energy level may be determined at least in part from the historical energy levels and usage of the rechargeable battery. The time of day of charging the battery may be determined at least in part from information provided by the energy provider.



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POWER TRANSFER SYSTEM FOR A RECHARGEABLE BATTERY

BACKGROUND

Field of the Invention

5 The present disclosure relates to a device and method of transferring power between rechargeable batteries that may be used in Electric Vehicles (EVs) and an energy distribution network.

Discussion of the Related Art

EV batteries may be charged from an energy distribution network, the energy
10 distribution network is sometimes referred to as the energy grid. US patent numbers 5,642,270 and 7,590,472 as well as US patent applications 2008/0203973 entitled INTERACTIVE BATTERY CHARGER FOR ELECTRIC VEHICLE and 2009/0021213 entitled METHOD FOR PAY-PER-USE, SELF-SERVICE CHARGING OF ELECTRIC AUTOMOBILES address various methods and apparatus of recharging EV batteries,
15 however, each one of these references suffers from one or more disadvantages.

For the foregoing reasons there is a need for an improved system to transfer energy between the power distribution network and a rechargeable battery.

SUMMARY

20 Transportation using carbon based fuel vehicles contributes pollution to the environment. The cost of fuel for these vehicles is rising making alternatively fueled vehicles more attractive. EVs are one such alternatively powered vehicle. The present disclosure is directed to a power transfer system for a rechargeable battery and a method of transferring power for a rechargeable battery.

25 The present disclosure includes improvements of calculating the required final charge level of the battery based on historical usage data and a system communicating with an energy provider to maximize the use of renewable energy.

30 In one aspect of the disclosure, a power transfer system may comprise a power transfer apparatus electrically coupled to a rechargeable battery. The rechargeable battery includes an energy capacity and an energy level. A controller is communicatively coupled to the power transfer apparatus. The controller has a memory that contains temporal energy

usage data. The controller is configured to determine a predicted disconnect time when the battery is to be uncoupled from the power transfer apparatus based upon the temporal energy usage data. A monitor is electrically coupled to the battery and communicatively coupled to the controller. The controller receives the battery energy level from the monitor. The controller is configured to determine a minimum final energy level for the battery; the minimum final energy level is less than the energy capacity of the battery and based upon the temporal energy usage data. The controller is configured to determine an energy transfer rate and a minimum energy transfer interval. The minimum energy transfer interval is based upon the minimum final energy level, the energy transfer rate and the battery energy level. The controller communicates with the power transfer apparatus to initiate an energy transfer with the battery of duration of at least the minimum energy transfer interval. The energy transfer ending before the predicted disconnect time.

In another aspect of the disclosure, a method of transferring energy between a rechargeable battery and a power transfer apparatus comprises receiving an energy level from a rechargeable battery having an energy capacity. The method may further comprise storing temporal energy usage, and determining a predicted disconnect time when the rechargeable battery will be uncoupled from a power transfer apparatus. The method may include determining a minimum final energy level for the rechargeable battery, the minimum final energy level being less than the energy capacity and the minimum final energy level being determined based in part upon the stored temporal energy usage. The method may include determining an energy transfer rate. The method may include determining a minimum energy transfer interval based in part upon the minimum final energy level, the energy transfer rate, and the battery energy level. The method may include initiating an energy transfer, the energy transfer occurring for at least the minimum determined interval and ending before the predicted disconnect time.

BRIEF DESCRIPTION THE DRAWINGS

These and other features, aspects, and advantages of the present disclosure will become better understood with regard to the following description, appended claims, and accompanying drawings where:

FIG. 1 is a schematic diagram showing an energy distribution network and typical connections to the energy distribution network.

FIG. 2 is a schematic diagram of a energy transfer system.

FIG 3 is a graph depicting temporal energy usage data.

FIG 4. is a graph depicting a battery energy level over time.

FIG 5 is a graph depicting battery energy level over time in units of percentage of battery capacity, and energy demand on an energy distribution network in units of percentage of local generation capacity.

FIG 6 is a graph depicting battery energy level over time in units of percentage of battery capacity, energy demand on an energy distribution network in units of percentage of local generation capacity, and renewable energy supply in units of percentage of local generation capacity.

FIG 7 is a diagram of the method steps of transferring energy between a rechargeable battery and a power transfer apparatus.

FIG 8 shows a multi-mode display device using a monochrome liquid crystal display (LCD) module with a color overlay.

FIG. 9A and 9B show two different possible display patterns of the multi-mode display device of FIG 8.

DESCRIPTION

Aspects of the disclosure are disclosed in the following description and related drawings directed to specific embodiments of the disclosure. Alternate or modified embodiments may be devised without departing from the scope of the disclosure.

Additionally, well-known elements of the disclosure will not be described in detail or will be omitted so as not to obscure the relevant details of the disclosure.

FIG. 1 shows an energy provider 100 that may control multiple energy generating features. Several possible energy generating features are shown such as a coal power plant 102, solar panels 104, a wind farm 106, a nuclear plant 108, and a hydro electric plant 110. There may also be generating features not controlled by the energy provider. The generating features are connected to an energy distribution network 112. The energy distribution network 112 may also be known as the energy grid or the electric grid. If the generating features controlled by the energy provider 100 do not generate enough energy to meet the energy demand on the energy distribution network 112, the energy provider 100 may import power 114 from other energy utilities. Importing power is not optimal for the energy provider 100 as the energy provider 100 typically pays higher rates for imported energy 114 than it costs for the energy provider 100 to generate the power locally. One reason for the

higher rates may be transmission loss. The energy is distributed over the energy distribution network 112 to consumers of the energy. Several possible energy consumers are shown such as factories 116, businesses 118, and residential areas 120.

FIG. 2 shows the energy distribution network 112 distributing energy to a residence 200. The residence 200 may include a system to transfer energy to an electric vehicle 202. The electric vehicle 202 stores energy in a battery 210. The battery 210 may be composed of one enclosure containing one or more cells. In another embodiment the battery 210 may be composed of multiple enclosures each enclosure containing one or more cells. The cells may be lead-acid, lithium-ion, lithium iron phosphate, lithium sulfur, lithium titanate, nickel cadmium, nickel iron, nickel hydrogen, nickel metal hydride, nickel zinc, or other composition. It is also anticipated that the electric vehicle 200 may optionally use other energy storage devices such as capacitors, compressed air, inertial devices, or other energy storing devices. The battery 210 may be electrically connected to a battery connector 212. In one embodiment, the battery connector 212 is enclosed in a single unit. In some embodiments, the battery connector 212 has multiple connectors. In one embodiment, the battery connector 212 has a plurality of connectors, with a male connector connected to the positive battery connection and a female connector connected to the negative battery terminal. In other embodiments, the battery connector 212 has a plurality of connectors, with a female connector connected to the positive battery terminal and a male connector connected to the negative battery terminal. The battery 210 may be electrically coupled to a monitor 214. The monitor 214 may measure and report the energy level of the battery 210. The monitor 214 may calculate the energy usage and energy level of the battery 210 by measuring one of more of the following parameters of the battery 210: temperature, current, or voltage. Batteries that include such a monitor 214 are sometimes referred to as smart batteries. The monitor 214 may report the energy level of the battery 210 in energy units such as kilowatt hours or the monitor 214 may report the energy level of the battery 210 in percentage of the battery capacity. The monitor 214 may report the energy level of the battery to devices internal to the electric vehicle 202 allowing the driver of the electric vehicle 202 to assess the energy level of the battery 210.

A power transfer apparatus 204 is electrically coupled to the energy distribution network 112. The power transfer apparatus 204 facilitates the transfer of energy between the energy distribution network 112 and the battery 210. The power transfer apparatus 204 may include a transformer to match the voltage of the energy distribution network 112 and the

battery 210. The power transfer apparatus 204 may also include a rectifier to convert AC energy into DC energy. The power transfer apparatus 204 may also include an inverter to convert DC energy into AC energy. The power transfer apparatus 204 may include circuits such as relays, power field effect transistors (FETs) or other circuitry to control the voltage and current of the energy being transferred. In one embodiment, the power transfer apparatus both transfers energy from the energy distribution network 112 to the battery 210 and transfers energy from the battery 210 to the energy distribution network 112. Transferring energy from the energy distribution network 112 to the battery 210 may be referred to as charging the battery 210. Transferring energy from the battery 210 to the energy distribution network 112 may be referred to as a vehicle to grid transfer. The power transfer apparatus 204 may be electrically connected to a power transfer apparatus connector 208. The power transfer apparatus connector 208 may be designed to mate with the battery connector 212. In one embodiment an adapter may be used to facilitate mating between the battery connector 212 and the power transfer apparatus connector 208. In one embodiment, the power transfer apparatus connector 208 and the battery connector 212 are designed to be conductively coupled. In another embodiment, the power transfer apparatus connector 208 and the battery connector 212 are designed to be inductively coupled.

The controller 206 may be communicatively coupled to the power transfer apparatus 204. The controller 206 may signal the power transfer apparatus 204 when to start the energy transfer and the controller 206 may also signal the power transfer apparatus 204 when to stop the energy transfer. The controller 206 may also be communicatively coupled to the monitor 214. In an embodiment the coupling between the controller 206 and the monitor 214 is a wireless mesh network. The controller 206 may receive from the monitor 214 status information for the battery 210. The battery 210 status information may include, among other things, battery capacity, battery energy level, energy usage, and battery temperature. The controller 206 may include a memory 216 for storing temporal energy usage data 300. In one embodiment, the memory 216 may be DRAM (dynamic random access memory). In other embodiments, the memory 216 may be flash memory or a hard disk drive.

In other embodiments, the temporal usage data 300 may be stored in a location other than the memory 216 of the controller 206, at least between charging events. In some embodiments, the temporal usage data 300 may be stored in the vehicle 202 or in the monitor 214. In other embodiments, the temporal usage data 300 may be stored on internet based storage such as a website managed by the energy provider 100 to facilitate efficient use of

their energy distribution network 112. In other embodiments, the temporal usage data 300 may be stored on a mobile phone or on a smart card carried by the driver. The temporal usage data 300 may be stored anywhere and be retrieved by the controller 206 and may be stored in the memory 216 to facilitate efficient charging of the battery 210 in the vehicle 202.

5 The controller 206 may use the stored temporal energy usage data 300 to determine the minimum final energy level 406 of the battery 210. The minimum final energy level 406 is the calculated minimum charge level the battery 210 will have following the energy transfer. The minimum final energy level 406 is determined at least in part by the amount of energy typically used between energy transfers as reported by the temporal energy usage data
10 300. The minimum final energy level 406 may also include a constant offset allowing a safety margin. In one embodiment, the minimum final energy level 406 is determined by adding a constant offset to the amount of energy typically used between energy transfers as reported by the energy usage data 300.

 The controller 206 also has access to the energy transfer rate of the power transfer
15 apparatus 204. In one embodiment, the energy transfer rate of the power transfer apparatus 204 may be positive, indicating transfer of energy from the energy distribution network 112 to the battery 210, or negative, indicating transfer of energy from the battery 210 to the energy distribution network 112. The energy transfer rate may be dictated by, among other things, the current, voltage, internal resistance of the battery 210, and the power availability
20 from the energy distribution network 112.

 The controller 206 may provide data to a user interface 218. The data may be displayed on the user interface to provide information to a user about the current energy level of the battery 210, the minimum final energy level of the battery 210, the time remaining to charge the battery 210, the time that the battery 210 will reach its minimum final energy
25 level, costs related to charging the battery 210, or other information. The controller 206 may also receive information from the user interface 218, including, but not limited to, a user selected final energy level of the battery 210, a desired time for the battery 210 to reach the minimum final energy level, a time to start charging the battery 210, a preference for lowest cost charging or renewable energy charging, or other user entered information. The user
30 interface 218 may include input means, such as a touch screen, buttons, a keypad or keyboard, capacitive proximity switches, a touchpad, or some other type of human input device. Some embodiments may include more advanced input means including, but not limited to, a microphone for speech recognition or a camera for gesture recognition. In some

embodiments, the user interface 218 may allow an odometer reading of the vehicle 202 to be entered to help estimate the vehicle 202 range for a given charge level of the battery 210.

The user interface 218 may be an integral part of the power transfer apparatus 204 with a display and data entry device including, but not limited to, as a keypad or touch-
5 screen. In other embodiments, the user interface 218 may be a mobile phone such as an iPhone®, a Blackberry®, an phone running the Android® operating system, or other smart phone executing an application or using built-in functionality. In other embodiments, the user interface 218 may be general purpose computer running a program or communicating with an internet website. In other embodiments, the user interface 218 may be a multi-mode display
10 device or other separate user interface device. One embodiment of a multi-mode display device is shown in FIG. 8. In some embodiments, the controller 206 may be able to utilize more than one user interface 218 either selectively, or simultaneously.

The controller 206 may communicate with the user interface 218 by any communications method. In some embodiments, the controller 206 may have a direct, wired
15 communication path to the user interface. In other embodiments, the controller 206 may use a wireless mesh network such as Zigbee or Z-Wave to communicate with the user interface. Other networks, including, but not limited to, IEEE 802.11 WiFi, HomePlug® or other power line networks, or ethernet networking may be used. Some embodiments may use optical communication between the controller 206 and the user interface 218.

FIG 3 shows temporal energy usage data 300, shown in units of KW * Hr, which may include various time related aspects of the usage of energy by the battery over a period of time. In some embodiments, the temporal energy usage data 300 may include data on usage on a day by day basis, for each day of the week, each day of the month, or any other time
20 points in a given time period. The usage data 300 may extend over more than one time period, and thus may include daily usage amounts for multiple weeks, or multiple months. In this example, the energy usage values are listed by the day of the week for the past 5 weeks with MTWTFSS on the X axis representing time and labeled with the corresponding days of the week. In this example, a typical energy usage 302 is 12 KW*Hr. This value could be higher or lower depending on many factors one of which is a daily commute. In this
25 example, some days there is no energy usage 306. This may be weekend days when the electric vehicle is not used, or other days, such as holidays. In this example, some days are above the typical usage 304. The controller 206 processes the temporal energy usage data 300 in determining the minimum final energy level 406. In some embodiments, a user may
30

enter a minimum final energy level 406 using a user interface 218. The amount of energy usage data that is stored may vary.

Regarding the example shown in FIG. 4, the predicted disconnect time 404 is the expected time when the battery is uncoupled from the power transfer apparatus 204. In one embodiment, this time is when the electric vehicle 202 is used for transportation. The
5 predicted disconnect time 404 may be calculated from previous disconnect times, or may be entered by a user interface 218. In one embodiment, the minimum final energy level 406, the initial battery energy level 408, and the energy transfer rate, are used to predict the amount to time the energy transfer will take. This time may be referred to as the energy transfer interval
10 402. In one embodiment the energy transfer interval 402 may be subtracted from the predicted disconnect time 404 so the minimum final energy level 406 is achieved before the predicted disconnect time 404. Using the numbers from the example the following values may be determined by the controller 206:

Energy transfer interval 402 = (Minimum Final Energy Level 406 – Initial Energy
15 Level 408) / energy transfer rate.

$$\text{Energy transfer interval 402} = (13 \text{ KW*Hr} - 1 \text{ KW*Hr}) / 7 \text{ KW}$$

$$\text{Energy transfer interval 402} \approx 1.7 \text{ hours.}$$

In this example the initial battery energy level 408 is about 1 KW*Hr. In this example, the minimum final energy level 406 is about 13 KW*Hr, the minimum final energy
20 level 406 being the typical weekday energy usage of 12 KW*Hr plus a 1 KW*Hr margin. In this example, the energy transfer rate is about 7 KW. In this example the predicted disconnect time 404 is about 8:00 am. An energy transfer interval 402 of 1.7 hours would therefore need an energy transfer start time 410 of no later than about 6:20 am.

In an embodiment, the controller 206 may be communicatively coupled with the
25 energy provider 100. In an embodiment, a Zigbee, or a Z-Wave network communicatively couples the controller 206 with the energy provider 100. This communication enables the energy provider 100 to provide the controller 206 with among other data, the customer energy demand, the local generation capacity, a cost of energy at various times, and the renewable energy percentage 600. FIG. 5 shows energy demand 500, as a percentage of local
30 generation capacity, of the energy provider 100. The energy demand 500 is sometimes referred to as the load of the energy distribution network 112. The energy transfer schedule of the vehicle may be responsive to the magnitude of the overall energy demand 500 placed upon the energy provider 100 at various times during the day, and in response to

communication from the energy provider 100 that the energy demand has exceeded a predetermined level or condition, such as the condition where energy demand has exceeded the provider's immediate ability to generate power, and must buy energy from other sources. In an example depicted in FIG. 5, the energy demand is shown in units of percentage of the generation capacity of the energy provider 100. An energy demand 500 value of more than 100% 502 indicates the demand for energy is greater than the local generation capacity of the energy provider 100. When the energy demand is greater than the local generation capacity 502 the energy provider must import power 114 from other utilities or sources. In this example, the energy demand 500 drops below 100% at about 8:00 pm and the energy demand 500 drops again at about 1:30 am. At about 2:00 am the controller 206 receives a signal from the energy provider 100 to start the energy transfer 410. At about 4:40 am, the minimum energy transfer interval 402 has been fulfilled and the energy level 504 has reached the minimum final energy level 506, because the energy demand 500 is still low, the energy transfer continues for an extended energy transfer interval 510. The energy transfer continues until the battery energy level 504 reaches approximately 100% of the battery capacity 512. In other examples, the energy transfer may continue after the minimum final energy level 506 has been reached and the energy transfer may stop before the battery energy level 504 reaches 100% of the battery capacity 512 if the energy demand 500 goes above a predetermined threshold level of energy demand.

FIG. 6 includes a renewable energy percentage 600 in units of percent of total generated energy. The energy transfer schedule of the vehicle may be responsive to the availability of energy from certain sources, such as sources considered to be renewable energy sources (which may include wind, solar, hydroelectric) as opposed to more conventional carbon fuel-based energy generation sources. Further, the degree to which the battery is charged may be dependent upon the availability of energy from the renewable energy sources. In an example depicted in FIG. 6, the energy demand information 500 and the percentage of renewal energy 600 may be received among other information by the controller 206. In alternative embodiments, the energy demand 500 and percentage of renewable energy may be utilized at least in part for the energy provider 100 to determine optimal energy transfer times and the energy transfer start time 410 is communicated to the controller 206. In an example depicted in FIG. 6, the energy demand 500 is relatively high at 4:00 pm, however there is a high percentage of renewable energy 600 meeting the energy demand 500. The high percentage of renewable energy 600 may for example be caused by a

sunny day causing solar panels 104 to generate power. The high percentage of renewable energy may for example be caused by a windy day causing wind farms 106 to generate power. In this example the percentage of renewable energy 600 drops at about 11:00 pm. One possible example of the renewable energy dropping may be that the wind stopped. In this example, at about 4:00 pm the controller 206 receives a signal from the energy provider 100 to start the energy transfer 410. In this example, at about 5:40 pm, the minimum energy transfer interval 402 has been fulfilled and the energy level 504 has reached the minimum final energy level 506. In this example, because the percentage of renewable energy 600 is still high, the energy transfer continues for an extended energy transfer interval 510. In this example the energy transfer continues until the battery energy level 504 reaches 100% of the battery capacity 512. In other examples, the energy transfer may continue after the minimum final energy level 506 has been reached and the energy transfer may stop before the battery energy level 504 reaches 100% of the battery capacity 512 if the percentage of renewable energy 600 goes below a threshold, or the if the energy demand 500 goes above a threshold. In this example, at about 6:00 am the energy demand 500 goes above 100% 502. Energy is transferred from the battery 210 to the energy distribution network 112 until the battery energy level 504 reaches the minimum final energy level 506. This allows the energy provider 100 to use the excess energy stored in the battery 210 to meet the energy demand effectively reducing the energy the energy provider 100 must import 114 to meet demand.

FIG. 7 depicts a method for transferring energy between a rechargeable battery 210 and a power transfer apparatus 204 that is coordinated by the controller 206. When actuated at 700, the controller 206 receives at 702 the initial battery energy level 408 from the monitor 214. In step 704 the controller 206 stores the energy usage in the memory 216. In one embodiment, the energy usage is calculated by subtracting the initial battery energy level 408 from the final energy level of the previous energy transfer. In another embodiment, the energy usage is received directly from the monitor 214. In step 706 the controller 206 determines the predicted disconnect time 404. The predicted disconnect time 404 may be calculated from previous disconnect times, or may be entered by a user interface 218. In step 708 the controller 206 calculates the minimum final energy level 406. As noted above, the minimum final energy level 406 is the level of energy typically used between energy transfers as reported by the temporal energy usage data 300, and may also include a constant offset. In step 710, a determination of the energy transfer rate may be made. The energy transfer rate may be dictated by, among other things, the current, voltage, internal resistance of the battery

210, and the power availability from the energy distribution network 112. Using the minimum final energy level 406 and the energy transfer rate, the minimum energy transfer interval 402 may be determined at step 712. In one embodiment, step 714, the controller 206 communicates with an energy provider 100. In another embodiment, the controller 206 receives data from the energy provider 100, and the data may include the energy demand 500 on the energy distribution network 112. In yet another embodiment, the data may include the amount of renewable energy available on the energy distribution network 112 allowing the controller 206 maximize the use of renewable energy at step 716. The renewable energy available on the energy distribution network 112 may be reported to the controller 206 as renewable energy percentage 600 in units of percent of total generated energy. In step 718, the energy transfer is initiated for a minimum duration of the minimum energy transfer interval 402. In step 720 the controller 206 monitors the energy transfer and determines if the energy transfer is complete. In one embodiment, the energy transfer is complete after the minimum energy transfer interval 402 has expired and the minimum energy transfer level 406 has been achieved. In another embodiment, the energy transfer continues after the minimum energy transfer interval has expired, until the battery energy level reaches approximately full capacity. In yet another embodiment, after the battery energy level reaches approximately full capacity, energy is transferred from the battery 210 to the energy distribution network 112. For example, charging the battery 210 to more than the minimum final energy level 406 using renewable energy sources allows energy from the battery 210 to be used on the energy distribution network 112 when demand exceeds local generation capacity 502. The energy transfer ends at or before the predicted disconnect time 404. When the controller 206 determines the energy transfer is complete, the recharging of the rechargeable battery 210 is substantially complete at step 722.

FIG. 8 shows an embodiment of a multi-mode display device 800 using a monochrome liquid crystal display (LCD) module with a color overlay. The multi-mode display device 800 may be back-lit or may use ambient light from the room for visibility. Other embodiments may use different display technology including, but not limited to, thin film transistor (TFT) color LCD, organic light emitting diode (OLED), cathode ray tube (CRT), plasma, or other display technologies. The multi-mode display device 800 may have several buttons for user control located in the bezel. In the embodiment shown, back button 801 and forward button 802 may be used to control the mode of the multi-mode display device 800. The Home/OK button 803, the Away/Cancel button 804, the Night/Down button

805 and Up/Settings button 806 may be used for various purposes within the user interface (UI) of the multi-mode display device 800.

The multi-mode display device 800 may include various independently addressable display elements, or a fixed set of displayable elements, that may vary between embodiments. Other embodiments may use a matrix addressable pixel-based display. Display elements above the UI buttons 803-806 may be included to allow the current function of the buttons 803-806 to be displayed. The embodiment shown in FIG. 8 includes a 15 character text line 821. Each character of the text line 821 may be made up of 15 segments that may be used to create a wide variety of symbols including representations of most letters used in languages using variations of the Latin alphabet, including, but not limited to, English, Danish, German, French, Spanish, Norwegian, Swedish, and others. Other embodiments may use other implementations for text such as a 5x7 dot matrix, a 7, 14, or 16 segment display or some other type of character display.

The multi-mode display device 800 also may include other delineated display areas such as the “actual” display area 822 and/or the target/average display area 823. The “actual” display area 822 and target/average display area 823 may include display elements for various currency symbols including, but not limited to US Dollars (\$), British Pounds (£), Euros (€) and/or Danish Kroner (Kr). The display areas 822, 823 may also include display elements for showing kW and/or kW-h to allow for energy and/or power readings to be displays. The display areas 822, 823 may also include a multi-character display allowing numbers and/or other characters to be displayed. In the embodiment shown, the “actual” display area 822 and the target/average display area 823 each include 5 characters.

The multi-mode display device 800 may also include a clock display 824 allowing the current time to be displayed in either 24 hour or 12 hour format and may have current value display 825 and a multi-purpose gauge display 826 that may be used to show the same value at some times and different values at other times. An electric vehicle (EV) icon 827 may also be included on the multi-mode display device 800. Other icons or symbols may also be included in some embodiments such as a fan indication, an snowflake, a thermometer, a wireless signal strength meter, a low battery indication and./or a company logo. Other embodiments may include other icons or symbols and yet other embodiments may not include all the elements shown in FIG. 8.

Each individual element of the display may be controlled to be either on or off although in some cases, not every combination of elements may be supported. For example,

in some embodiments, the 15 segment display may only support a limited number of characters, such as 828 or 256 different pre-determined characters, instead of the 32768 different possible combinations of the 15 elements. Some embodiments may support a display technology allowing for an intensity level or color to be set instead of having each element being only on or off.

The multi-mode display device 800 may have a variety of operating modes to allow different types of information to be displayed on a single display. In some embodiments, an electric vehicle charging station may be monitored. In some embodiments the multi-mode display device 800 may be used as a thermostat. In some embodiments the multi-mode display device 800 may be able to display a variety of information related to home energy usage. Other embodiments may have modes for displaying other information.

FIG. 9A and 9B show two different possible display patterns for the multi-mode display device 800. The display pattern 900 of FIG. 9A turns on the EV charging icon 827 to indicate that the multi-mode display device 800 is currently showing information related to charging an EV. Display pattern 900 may show the current battery charge level of 14.3% in the “Actual” display area 903 and a target charge level of 75% in the target/average display area 904. The gauge 902 may show both the actual battery charge and the target in a graphical manner. The character display 905 shows an amount of time left to charge the battery to the target level. The indicators at the top of the display show “LOW” to highlight that the battery is below a pre-determined charge level.

FIG. 9B shows a possible display pattern of the multi-mode display device 800 related to home energy usage. Display pattern 910 of FIG. 9B may show current power usage in the “Actual” display area 913 and the average power usage over a pre-determined period of time in the target/average display area 914. The current power usage as a percentage of the average power usage may be shown on the gauge 912 and the character display may show “WATTS” to indicate that a current power level is being displayed.

The disclosure has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the disclosure.

CLAIMS

What is claimed is:

1. A power transfer system for a rechargeable battery comprising:
a power transfer apparatus electrically coupled to
5 a rechargeable battery having an energy capacity and an energy level,
a controller communicatively coupled to the power transfer apparatus, the controller
having a memory containing temporal energy usage data, the controller being configured to
determine a predicted disconnect time when the rechargeable battery is to be electrically
uncoupled from the power transfer apparatus based upon the temporal energy usage data, and
10 a monitor electrically coupled to the battery, the monitor communicatively coupled to
the controller to send the battery energy level to the controller,
wherein the controller is configured to determine a minimum final energy level for the
battery, the minimum final energy level being less than the energy capacity of the battery, the
minimum final energy level being based upon the temporal energy usage data,
15 wherein the controller is configured to determine an energy transfer rate and a
minimum energy transfer interval, the minimum energy transfer interval being based upon
the energy transfer rate, the minimum final energy level, and the battery energy level,
wherein the controller is configured to communicate with the power transfer
apparatus to initiate an energy transfer with the battery of a duration of at least the minimum
20 energy transfer interval, the energy transfer ending before the predicted disconnect time.
2. The system of claim 1 wherein the controller is configured to communicate with an
energy provider to receive information regarding a capacity condition of an energy
distribution network of the energy provider and the controller is configured to determine an
energy transfer start time based upon the information regarding the capacity condition.
- 25 3. The system of claim 2 wherein the energy distribution network is characterized by a
level of energy available and a current level of energy demand, wherein the controller is
configured to receive information from the energy provider regarding the current level of
energy demand and the level of energy available, and wherein the controller is configured to
determine the energy transfer start time at least partially based upon the current level of
30 energy demand and the level of energy available.

4. The system of claim 2 wherein the controller is configured to receive information from the energy provider regarding a level of renewable energy available on the energy distribution network, and wherein the controller is configured to determine the energy transfer start time at least partially based upon the information regarding the available level of renewable energy received.
- 5
5. The system of claim 1, further comprising:
a user interface communicatively coupled to the controller, said user interface having a display and input means, wherein the user interface is configured to receive a value for the minimum final energy level from the user.
- 10
6. The system of claim 5, wherein the user interface is a multi-mode display device.
7. The system of claim 1 further comprising a wireless network communicatively coupling the monitor and the controller.
8. The system of claim 2 wherein the energy transfer is from the energy distribution network through the power transfer apparatus to the battery.
- 15
9. The system of claim 2 wherein the energy transfer is from the battery to the energy distribution network.
10. A method of energy transfer between a rechargeable battery and a power transfer apparatus comprising:
receiving an energy level from a rechargeable battery having an energy capacity,
20 storing temporal energy usage of the rechargeable battery,
determining a predicted disconnect time when the rechargeable battery is to be electrically uncoupled from a power transfer apparatus,
determining a minimum final energy level for the rechargeable battery, the minimum final energy level being less than the energy capacity, the minimum final energy level being
25 determined based in part upon the stored temporal energy usage data,
determining an energy transfer rate,
determining a minimum energy transfer interval, based in part upon the minimum final energy level, the energy transfer rate, and the energy level, and

initiating an energy transfer, the energy transfer occurring for at least the minimum determined interval, the energy transfer ending before the predicted disconnect time.

- 5 11. The method of claim 10 further comprising communicating with an energy provider to aid in determining an energy transfer start time.
12. The method of claim 11 further comprising maximizing the use of renewable energy sources during the energy transfer.
13. The method of claim 10 further comprising overriding the minimum final energy level.
- 10 14. The method of claim 10 further comprising increasing the energy level of the battery by the energy transfer.
15. The method of claim 10 further comprising decreasing the energy level of the battery by the energy transfer.
- 15 16. A power transfer apparatus comprising:
a power input suitable to be electrically coupled to an energy distribution network;
a connector suitable for connecting to a vehicle to charge a rechargeable battery in the vehicle;
circuitry capable of transferring energy between the power input and the connector;
and
20 a controller communicatively coupled to said circuitry;
wherein the controller is configured to:
retrieve temporal energy usage data;
determine a predicted disconnect time for the connector to be unplugged from the vehicle based on the temporal energy usage data;
25 receive an energy capacity and a current energy level of the rechargeable battery;
determine a minimum final energy level for the rechargeable battery based on the temporal energy usage data, said minimum final energy level being less than the energy capacity of the rechargeable battery;

calculate a minimum energy transfer interval based on said minimum final energy level and the current energy level of the rechargeable battery; and

control the circuitry to transfer said energy from the power input to the connector for a time period of at least the minimum energy transfer interval, said transfer of said power ending before said predicted disconnect time.

5

17. The apparatus of claim 16, wherein the controller is further configured to: communicate with a provider of energy to the energy distribution network to receive information regarding the energy distribution network; and

determine an energy transfer start time based upon the information regarding the energy distribution network.

10

18. The apparatus of claim 17, wherein the information regarding the energy distribution network includes differing costs of said energy from the energy distribution network at different times.

19. The apparatus of claim 17, wherein the information regarding the energy distribution network includes a level of renewable energy available on the energy distribution network.

15

20. The apparatus of claim 16, wherein the controller is further configured to provide data to a user interface and to receive information from the user interface, said information received from the user interface used to override a parameter determined based on the temporal energy usage data.

20

21. The apparatus of claim 21, wherein the user interface is on a mobile phone.

22. The apparatus of claim 21, wherein the user interface is on a multi-mode display device.

23. The apparatus of claim 16, wherein the temporal energy usage data is retrieved from the vehicle.

25

24. The apparatus of claim 16, wherein the temporal energy usage data is retrieved from internet based storage.

25. The apparatus of claim 16, wherein the controller is further configured to control the circuitry to transfer said energy from the connector to the power input.

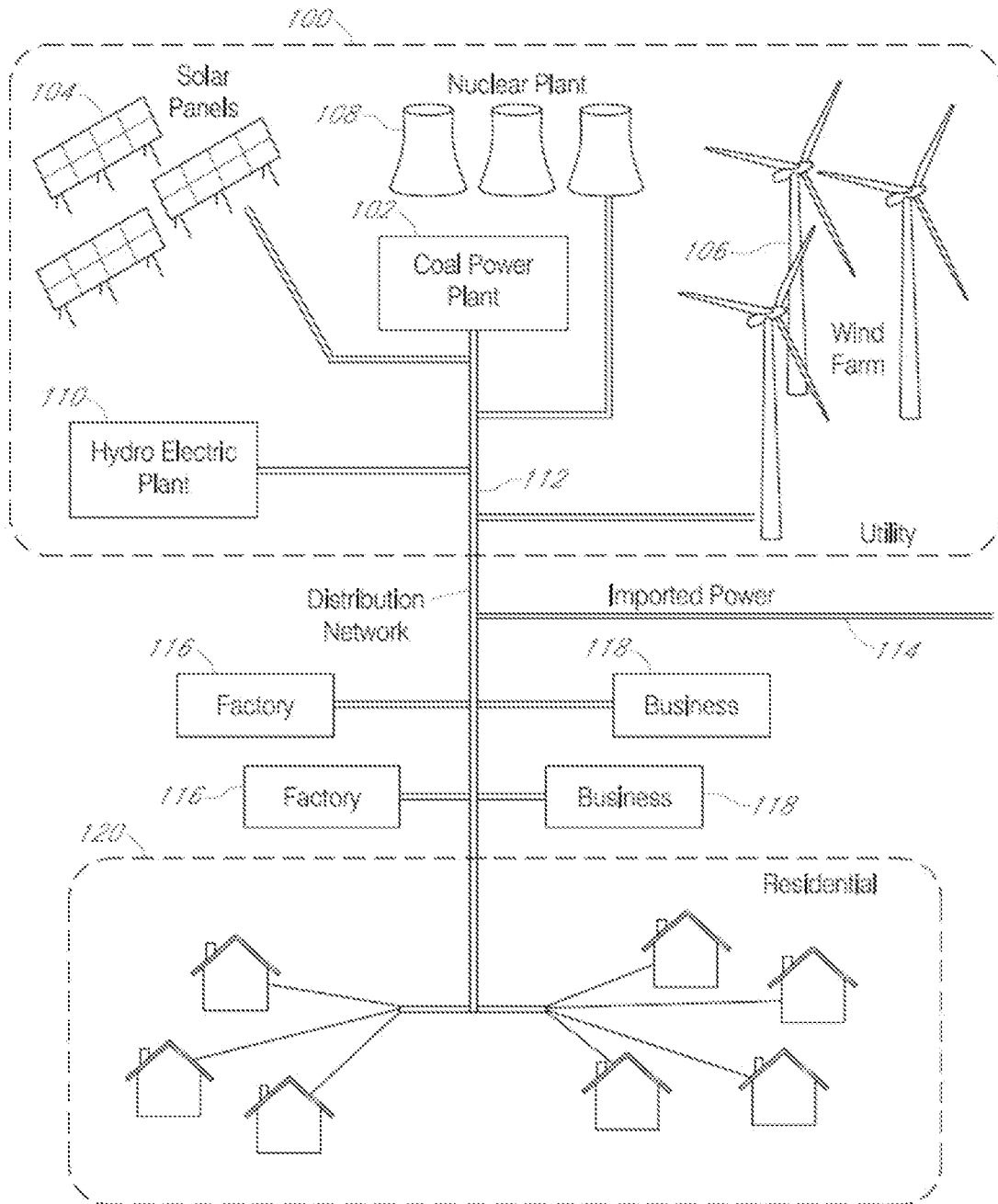


FIG. 1

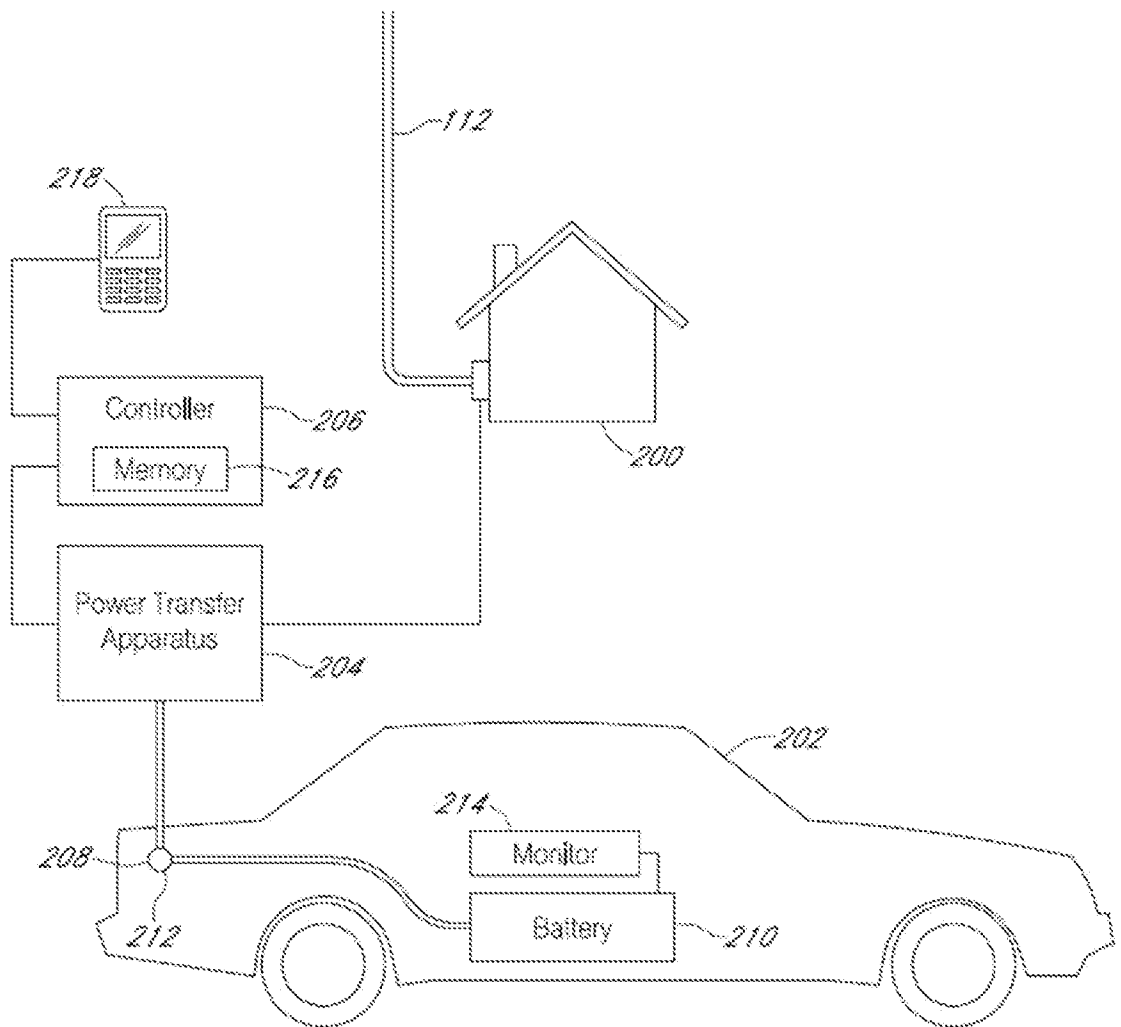


FIG. 2

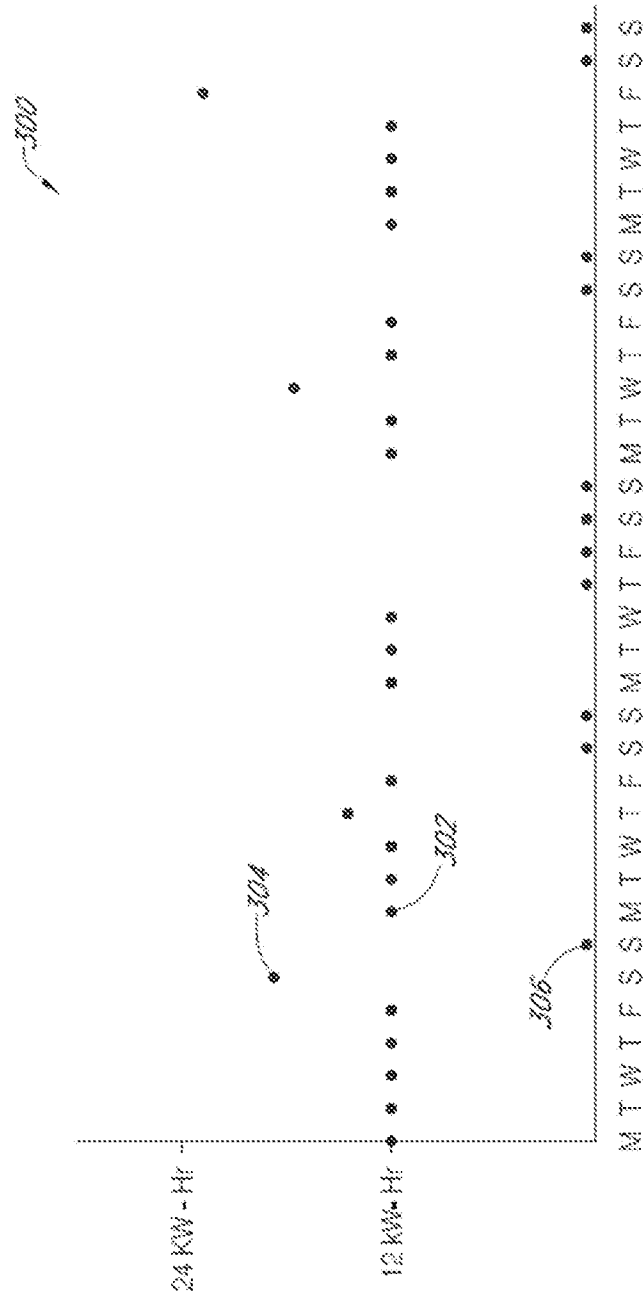


FIG. 3

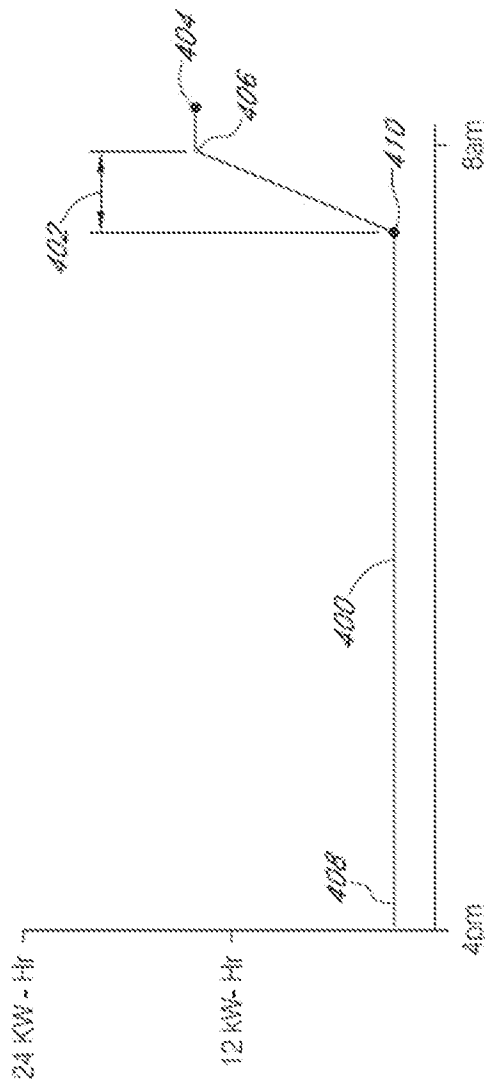


FIG. 4

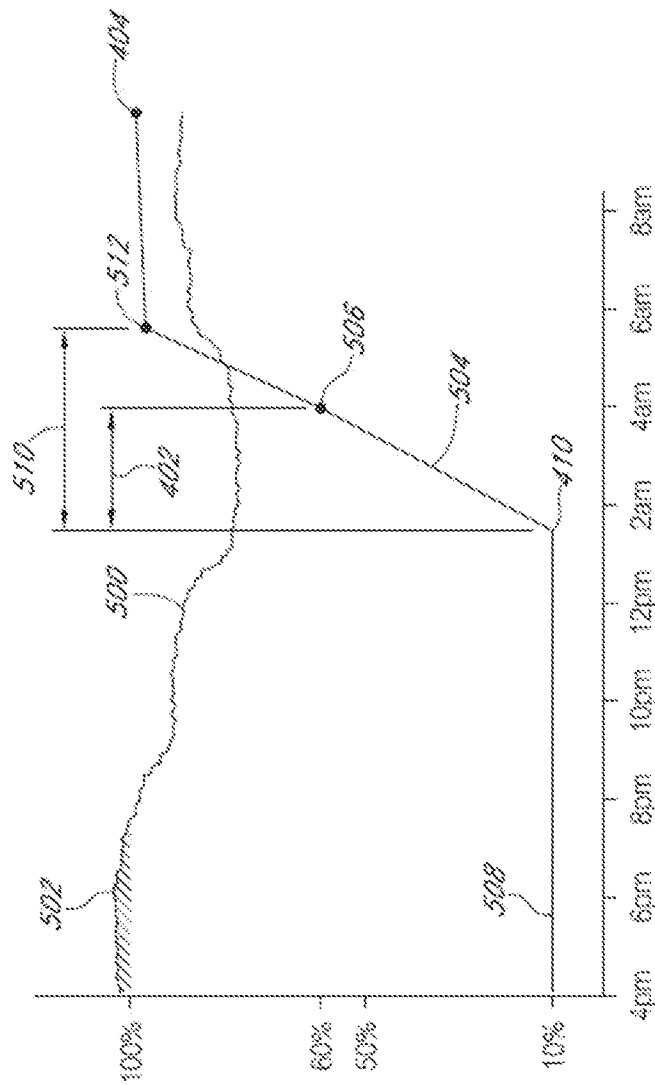


FIG. 5

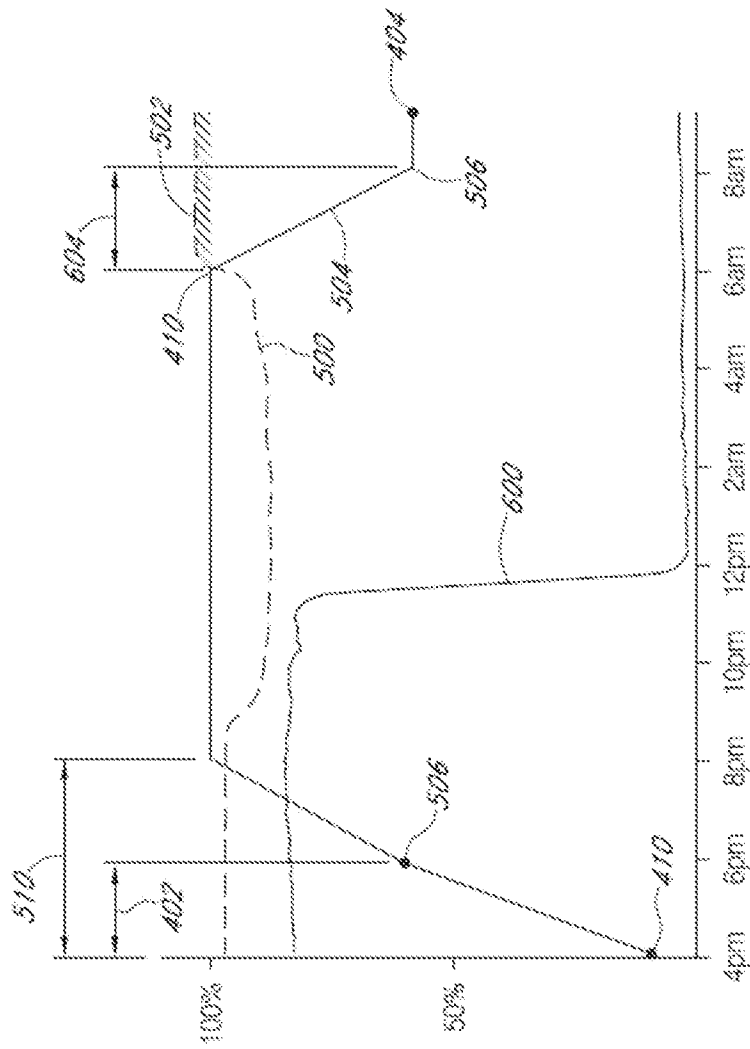


FIG. 6

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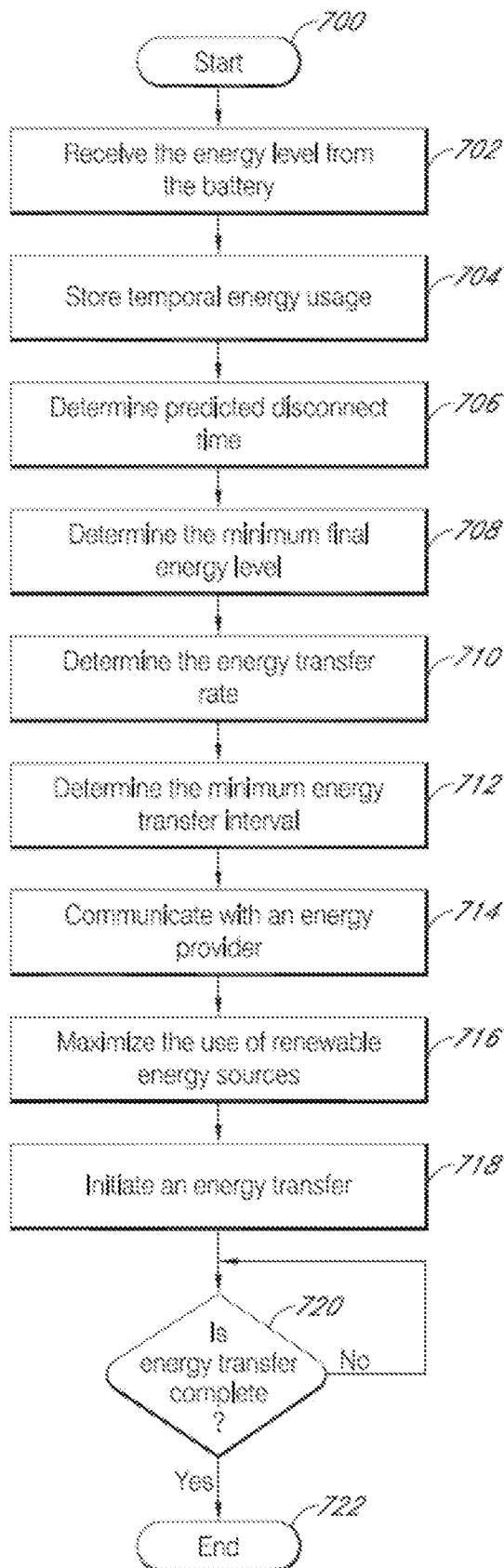


FIG. 7

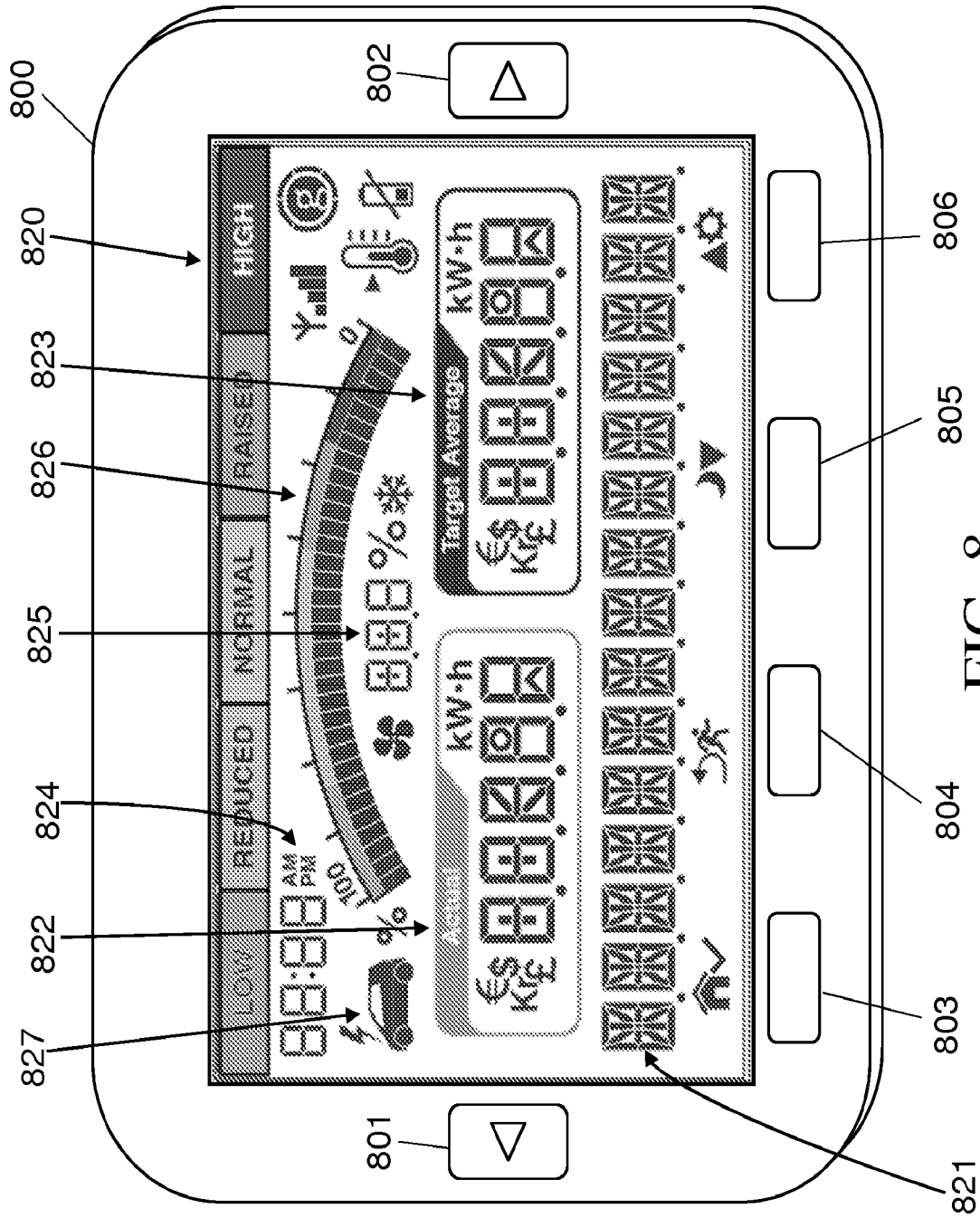


FIG. 8

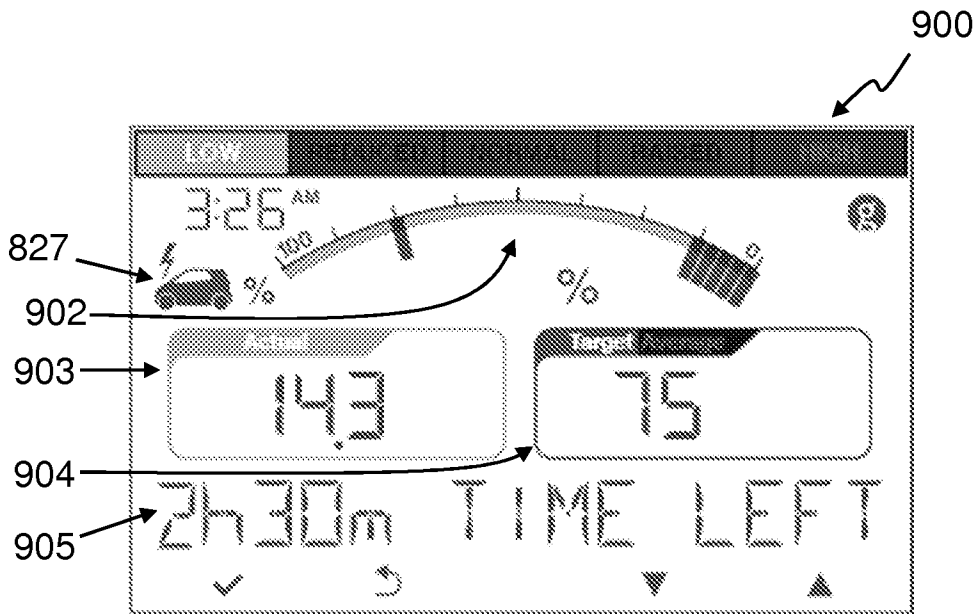


FIG. 9A

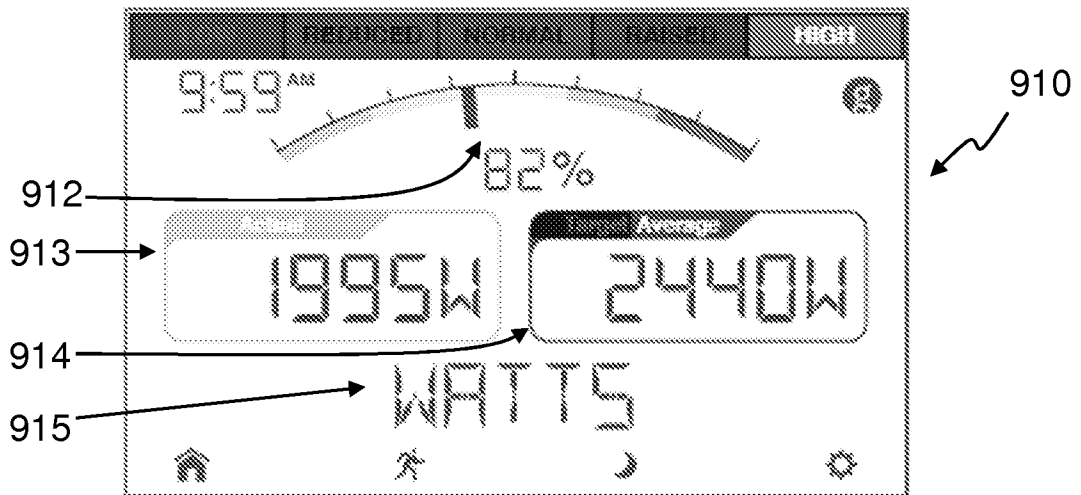


FIG. 9B