US 20110001356A1

(19) **United States**

(12) **Patent Application Publication**

Pollack

(10) **Pub. No.: US 2011/0001356 A1**

(43) **Pub. Date: Jan. 6, 2011**

(54) **SYSTEMS AND METHODS FOR ELECTRIC VEHICLE GRID STABILIZATION**

(75) Inventor: **Seth B. Pollack**, Seattle, WA (US)

Correspondence Address:
GREENBERG TRAURIG, LLP (DC/ORL)
2101 L Street, N.W., Suite 1000
Washington, DC 20037 (US)

(73) Assignee: **GridPoint, Inc.**, Arlington, VA (US)

(21) Appl. No.: **12/751,845**

(22) Filed: **Mar. 31, 2010**

Related U.S. Application Data

(60) Provisional application No. 61/165,344, filed on Mar. 31, 2009.

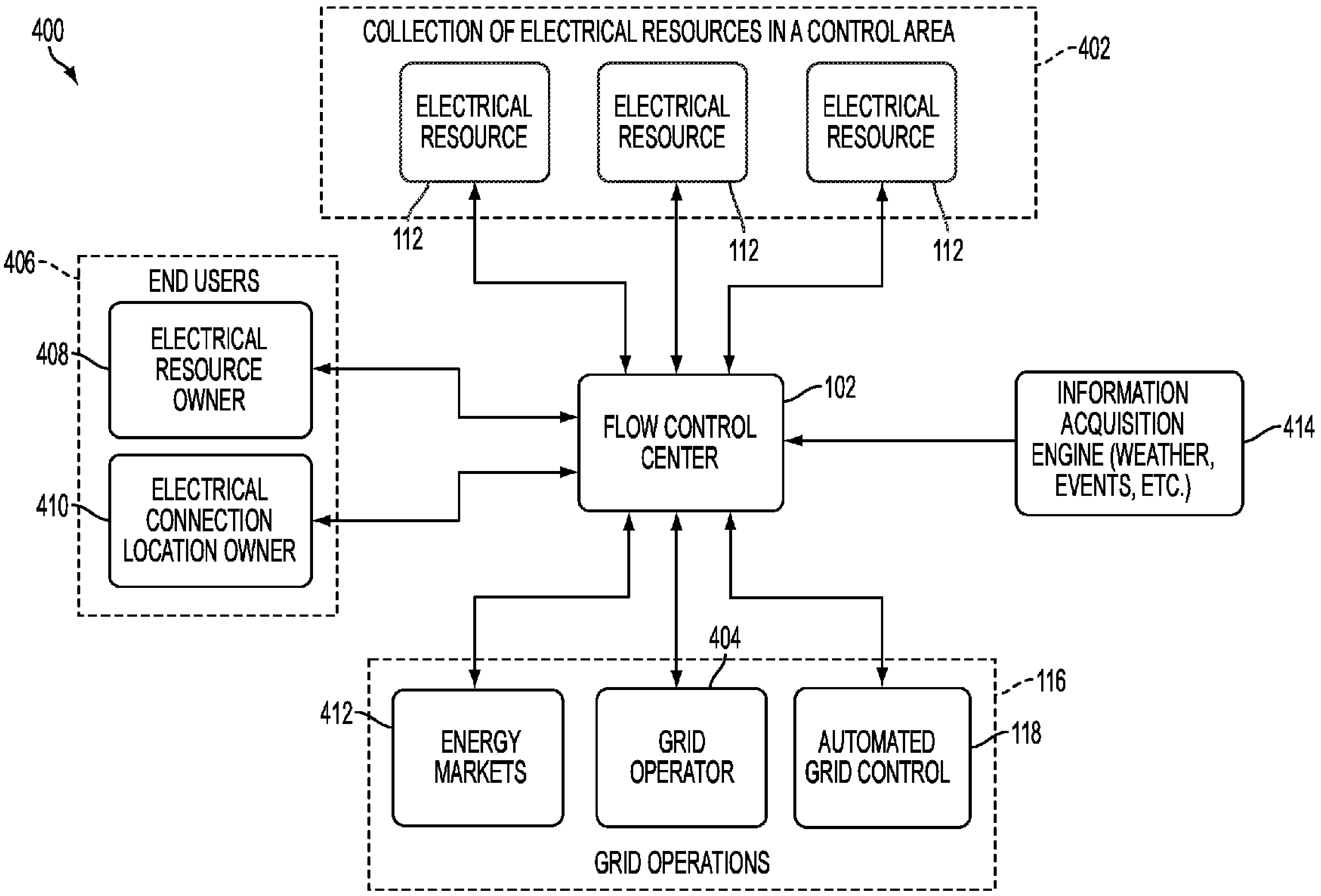
Publication Classification

(51) **Int. Cl.**
H02J 4/00 (2006.01)

(52) **U.S. Cl.** **307/31**

(57) **ABSTRACT**

A system and methods that enables power flow management using AGC commands to control power resources. Power regulation can be apportioned to the power resources. An AGC command requesting an apportioned amount of the power regulation may be transmitted to a power resource. The power flow manager can determine a power regulation range for a power resource, and transmit an AGC command based on the power regulation range. In addition, a power flow management system can detect a change in an intermittent power flow and implement a power flow strategy in response to the change in the intermittent power flow. The power flow strategy may be a smoothing strategy or a leveling strategy.



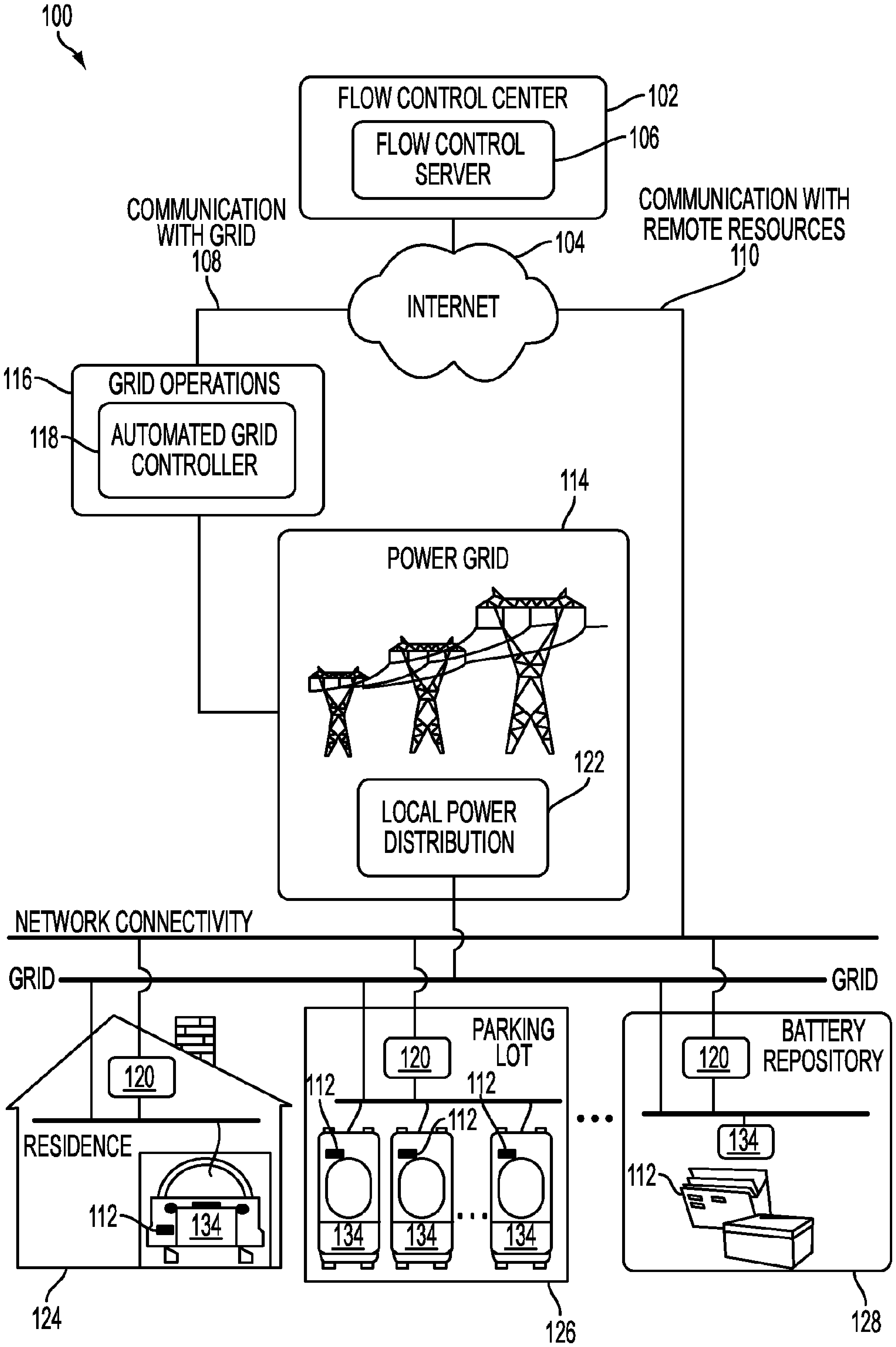

100
FLOW CONTROL CENTER
102
FLOW CONTROL SERVER
106
COMMUNICATION WITH GRID
108
104
INTERNET
COMMUNICATION WITH REMOTE RESOURCES
110
116
GRID OPERATIONS
118
AUTOMATED GRID CONTROLLER
114
POWER GRID
122
LOCAL POWER DISTRIBUTION
NETWORK CONNECTIVITY
GRID
GRID
120
RESIDENCE
112
134
124
PARKING LOT
120
112
112
112
134
134
134
126
BATTERY REPOSITORY
120
134
112
128

FIG. 1

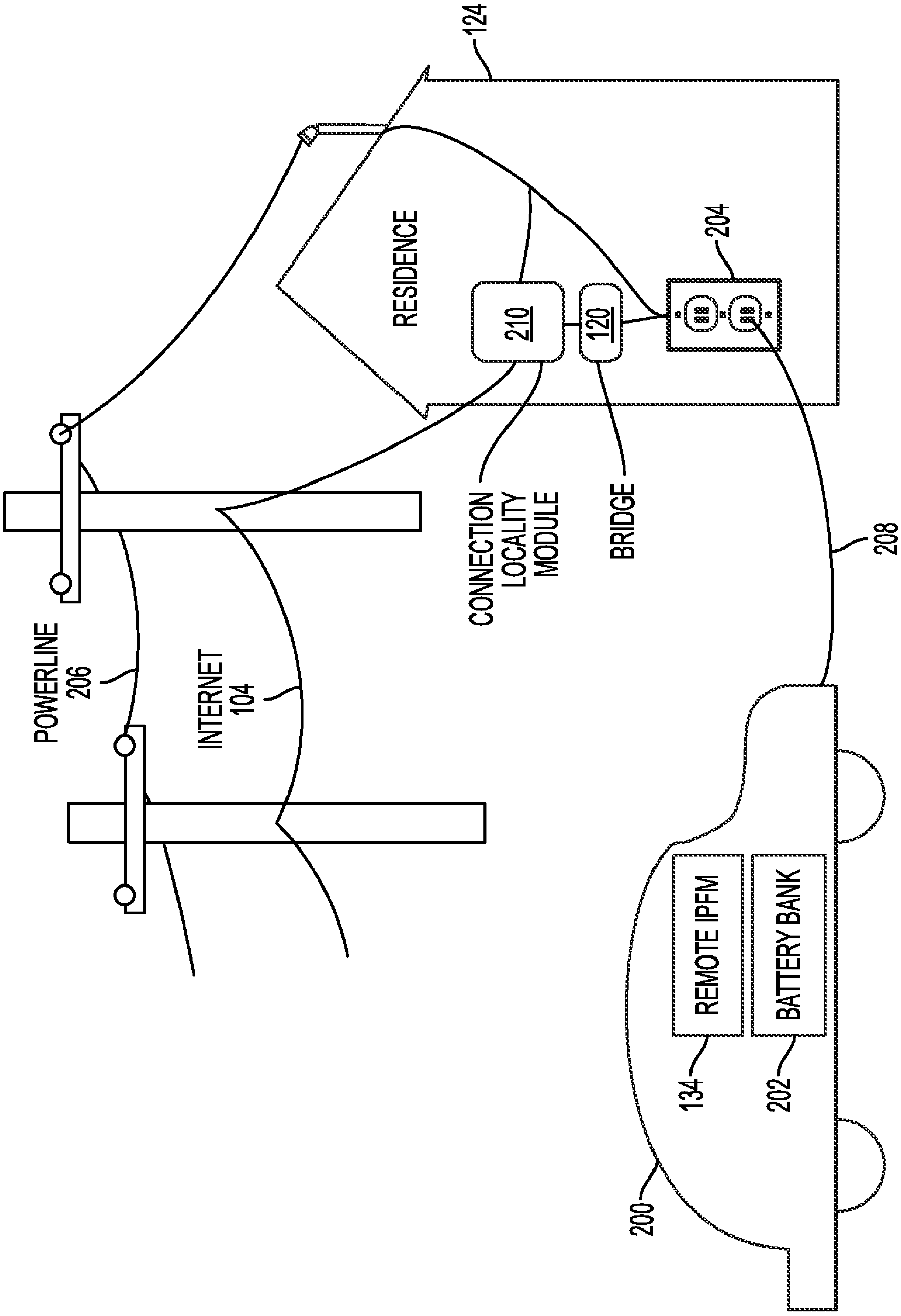

124
RESIDENCE
210
120
204
CONNECTION LOCALITY MODULE
BRIDGE
208
POWERLINE 206
INTERNET 104
REMOTE IPFM
BATTERY BANK
134
202
200

FIG. 2A

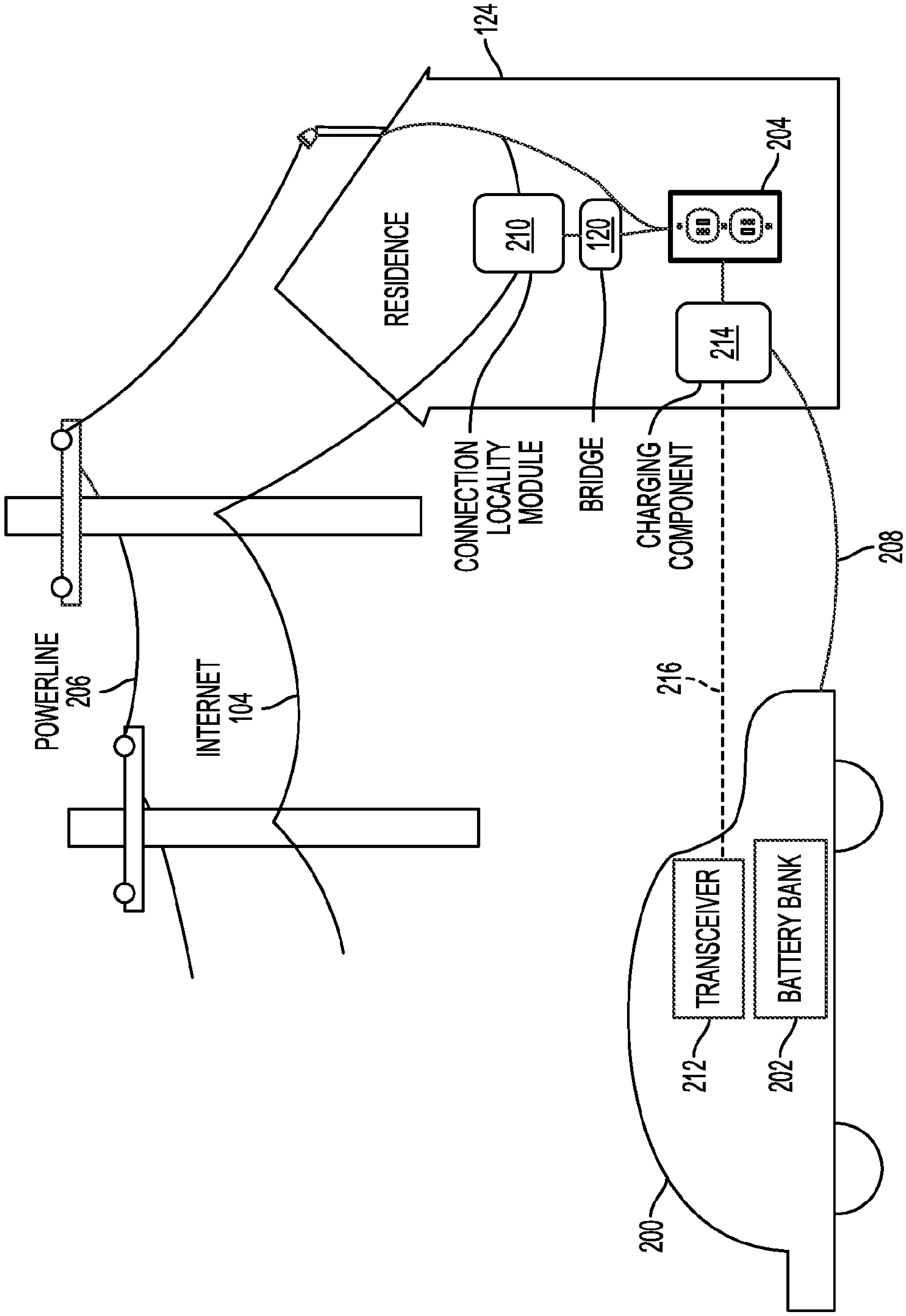

124
RESIDENCE
210
120
204
214
CONNECTION LOCALITY MODULE
BRIDGE
CHARGING COMPONENT
208
POWERLINE 206
INTERNET 104
216
TRANSCEIVER
BATTERY BANK
212
202
200

FIG. 2B

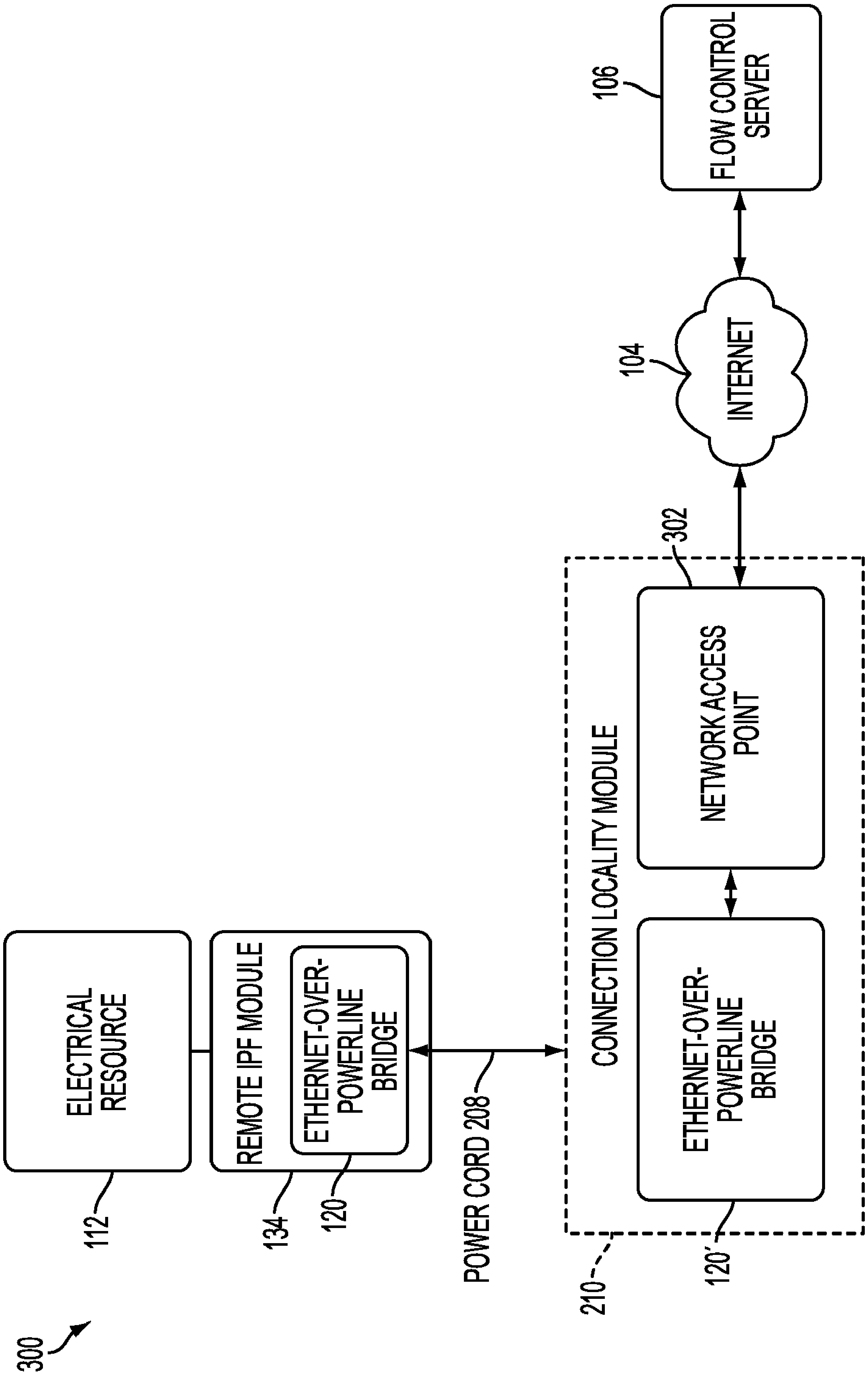

300
ELECTRICAL RESOURCE
112
REMOTE IPF MODULE
134
ETHERNET-OVER-POWERLINE BRIDGE
120
POWER CORD 208
CONNECTION LOCALITY MODULE
210
ETHERNET-OVER-POWERLINE BRIDGE
120'
NETWORK ACCESS POINT
302
INTERNET
104
FLOW CONTROL SERVER
106

FIG. 3

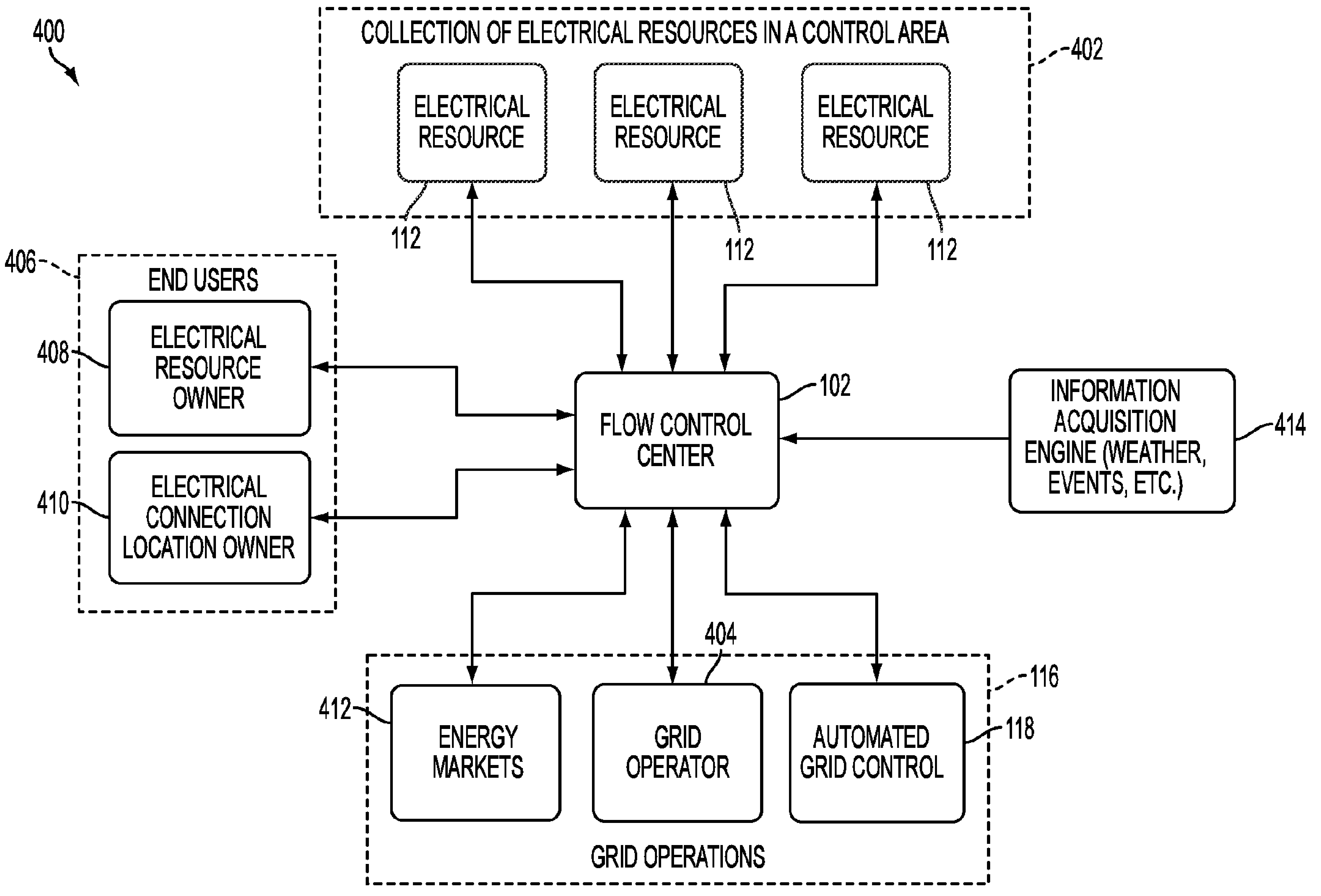

400
COLLECTION OF ELECTRICAL RESOURCES IN A CONTROL AREA
402
ELECTRICAL RESOURCE
ELECTRICAL RESOURCE
ELECTRICAL RESOURCE
112
112
112
406
END USERS
408
ELECTRICAL RESOURCE OWNER
410
ELECTRICAL CONNECTION LOCATION OWNER
FLOW CONTROL CENTER
102
INFORMATION ACQUISITION ENGINE (WEATHER, EVENTS, ETC.)
414
404
116
412
ENERGY MARKETS
GRID OPERATOR
AUTOMATED GRID CONTROL
118
GRID OPERATIONS

FIG. 4

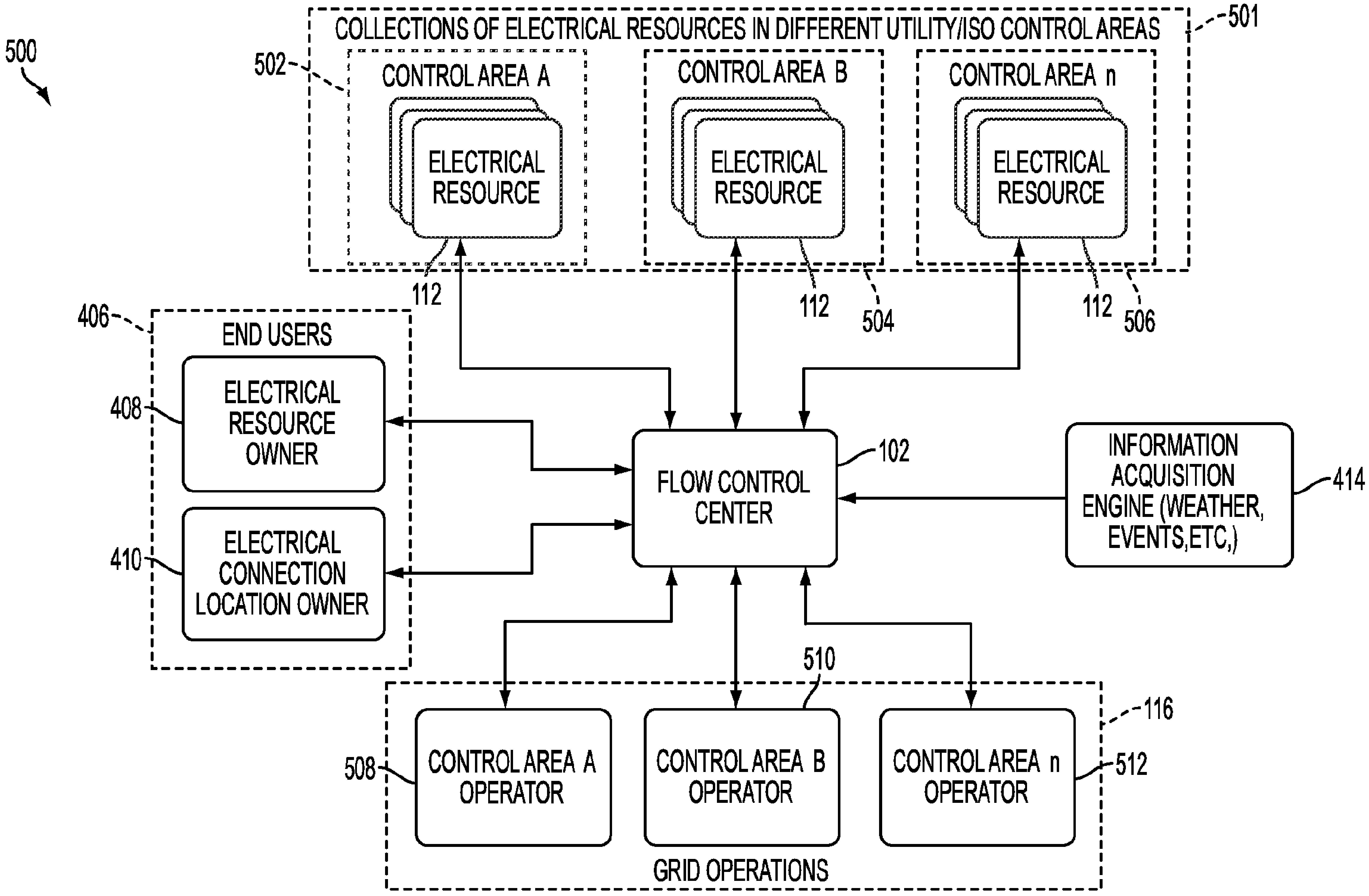

500
COLLECTIONS OF ELECTRICAL RESOURCES IN DIFFERENT UTILITY/ISO CONTROL AREAS
501
502
CONTROL AREA A
ELECTRICAL RESOURCE
112
CONTROL AREA B
ELECTRICAL RESOURCE
112
504
CONTROL AREA n
ELECTRICAL RESOURCE
112
506
406
END USERS
408
ELECTRICAL RESOURCE OWNER
410
ELECTRICAL CONNECTION LOCATION OWNER
FLOW CONTROL CENTER
102
INFORMATION ACQUISITION ENGINE (WEATHER, EVENTS,ETC,)
414
510
116
508
CONTROL AREA A OPERATOR
CONTROL AREA B OPERATOR
CONTROL AREA n OPERATOR
512
GRID OPERATIONS

FIG. 5

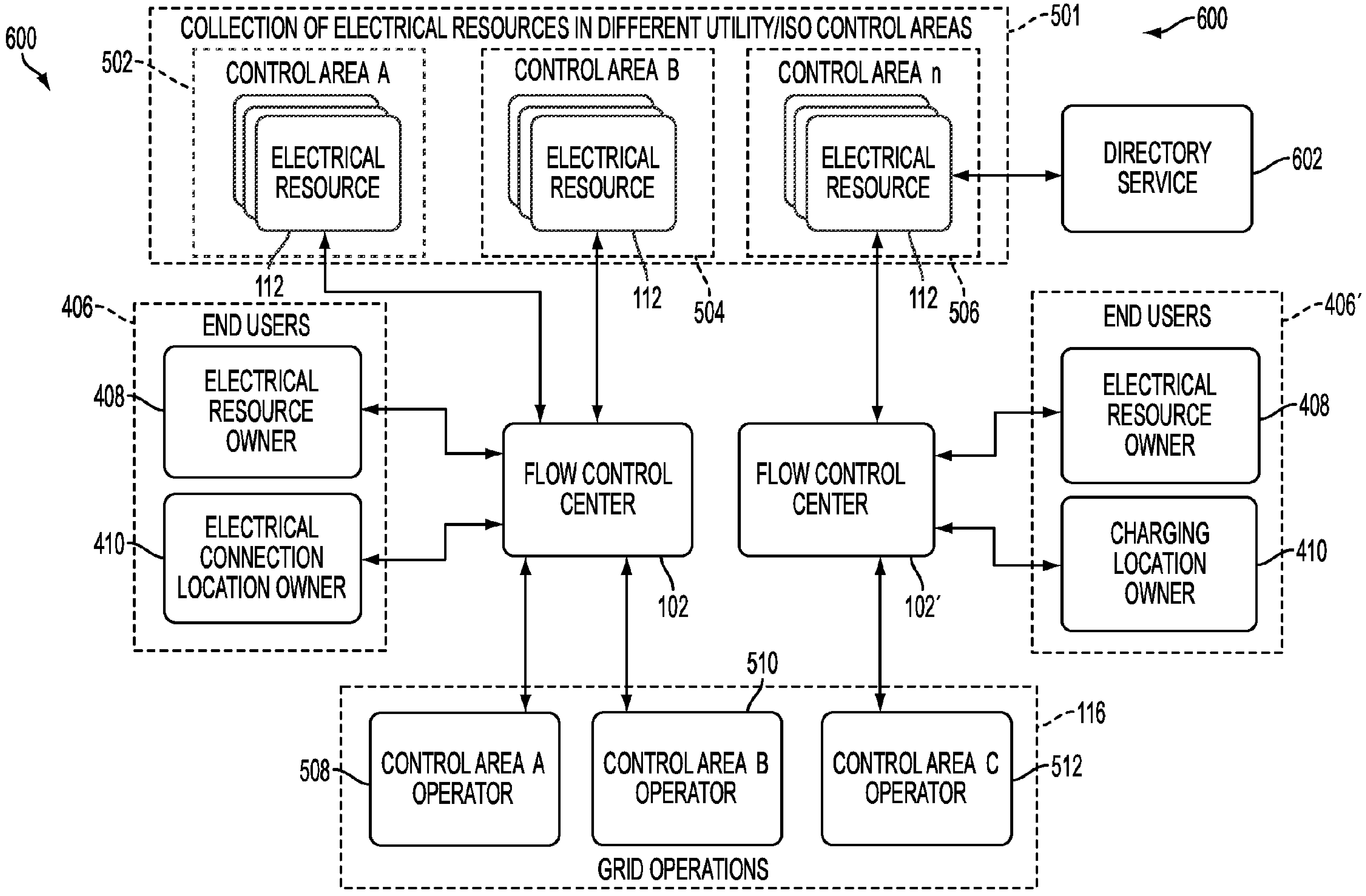

600
600
COLLECTION OF ELECTRICAL RESOURCES IN DIFFERENT UTILITY/ISO CONTROL AREAS
501
502
CONTROL AREA A
ELECTRICAL RESOURCE
112
CONTROL AREA B
ELECTRICAL RESOURCE
112
504
CONTROL AREA n
ELECTRICAL RESOURCE
112
506
DIRECTORY SERVICE
602
406
END USERS
408
ELECTRICAL RESOURCE OWNER
410
ELECTRICAL CONNECTION LOCATION OWNER
FLOW CONTROL CENTER
102
FLOW CONTROL CENTER
102′
406′
END USERS
ELECTRICAL RESOURCE OWNER
408
CHARGING LOCATION OWNER
410
510
116
508
CONTROL AREA A OPERATOR
CONTROL AREA B OPERATOR
CONTROL AREA C OPERATOR
512
GRID OPERATIONS

FIG. 6

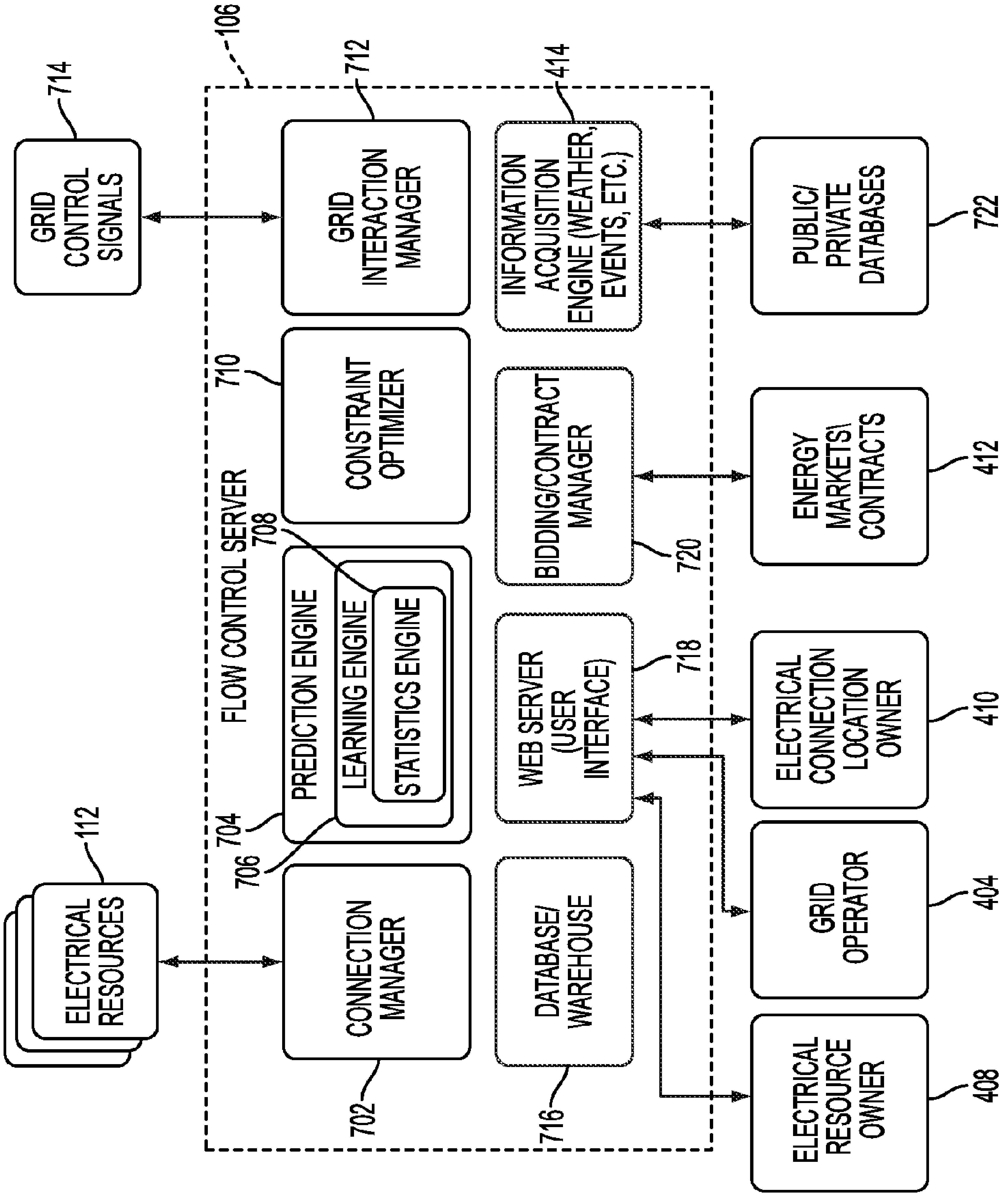

GRID CONTROL SIGNALS
714
106
FLOW CONTROL SERVER
GRID INTERACTION MANAGER
712
CONSTRAINT OPTIMIZER
710
PREDICTION ENGINE
704
LEARNING ENGINE
706
STATISTICS ENGINE
708
CONNECTION MANAGER
702
ELECTRICAL RESOURCES
112
INFORMATION ACQUISITION ENGINE (WEATHER, EVENTS, ETC.)
414
BIDDING/CONTRACT MANAGER
720
WEB SERVER (USER INTERFACE)
718
DATABASE/ WAREHOUSE
716
PUBLIC/ PRIVATE DATABASES
722
ENERGY MARKETS\ CONTRACTS
412
ELECTRICAL CONNECTION LOCATION OWNER
410
GRID OPERATOR
404
ELECTRICAL RESOURCE OWNER
408

FIG. 7

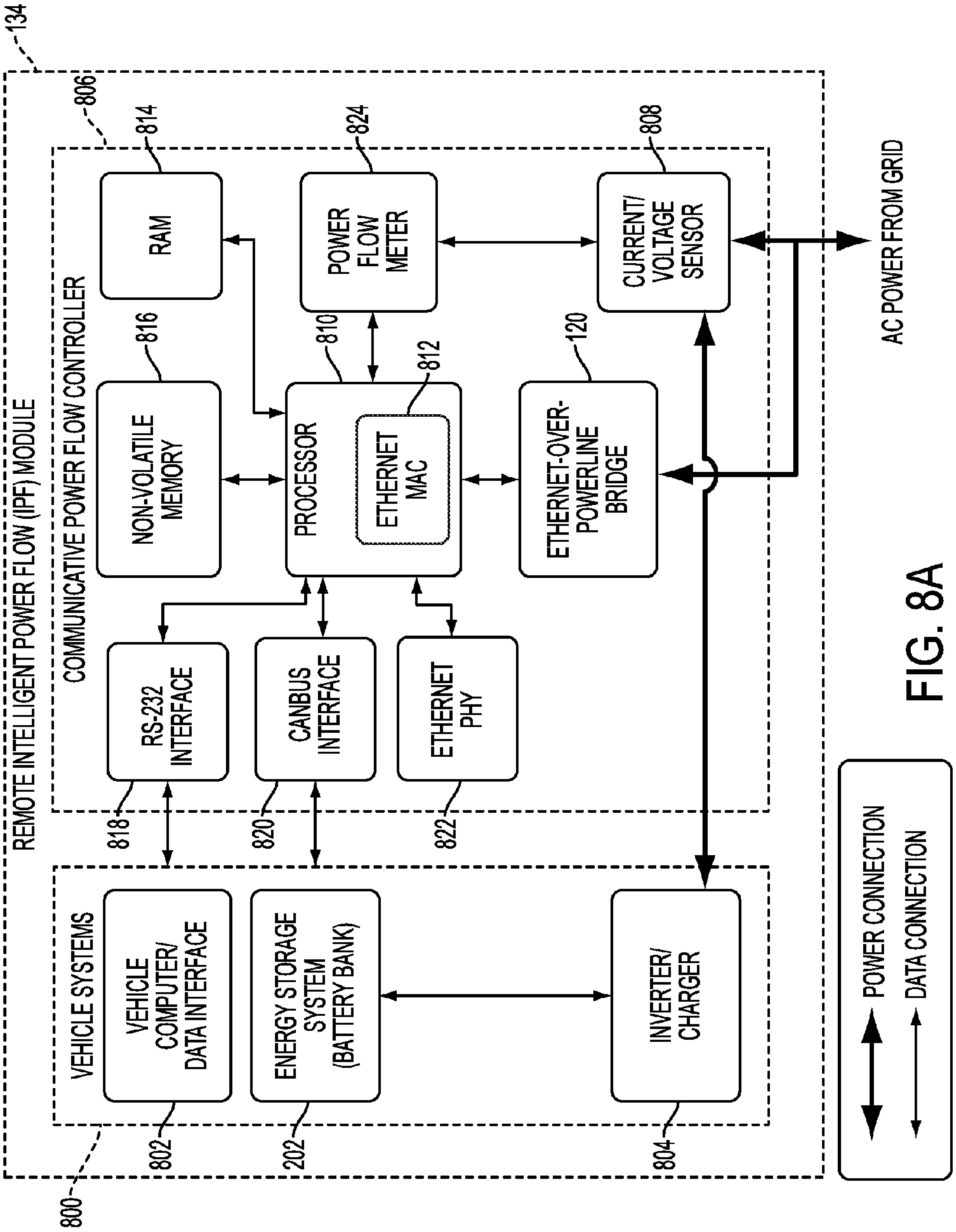

134
REMOTE INTELLIGENT POWER FLOW (IPF) MODULE
806
COMMUNICATIVE POWER FLOW CONTROLLER
814
RAM
824
POWER FLOW METER
808
CURRENT/ VOLTAGE SENSOR
816
NON-VOLATILE MEMORY
810
PROCESSOR
812
ETHERNET MAC
120
ETHERNET-OVER-POWERLINE BRIDGE
AC POWER FROM GRID
RS-232 INTERFACE
CANBUS INTERFACE
ETHERNET PHY
818
820
822
VEHICLE SYSTEMS
VEHICLE COMPUTER/ DATA INTERFACE
ENERGY STORAGE SYSTEM (BATTERY BANK)
INVERTER/ CHARGER
800
802
202
804
POWER CONNECTION
DATA CONNECTION

FIG. 8A

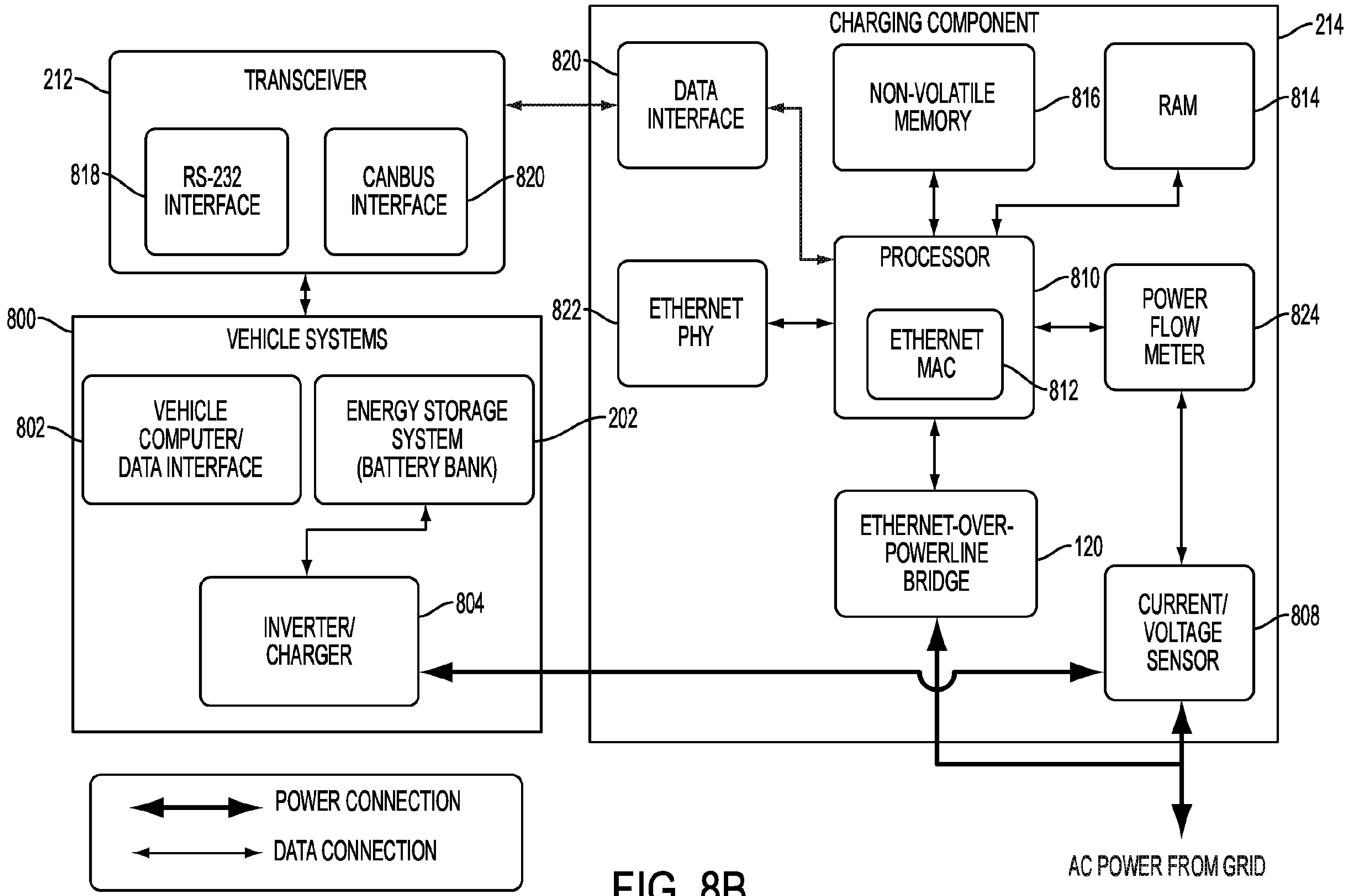

212
TRANSCEIVER
818
RS-232 INTERFACE
CANBUS INTERFACE
820
800
VEHICLE SYSTEMS
802
VEHICLE COMPUTER/ DATA INTERFACE
ENERGY STORAGE SYSTEM (BATTERY BANK)
202
INVERTER/ CHARGER
804
CHARGING COMPONENT
214
820
DATA INTERFACE
NON-VOLATILE MEMORY
816
RAM
814
822
ETHERNET PHY
PROCESSOR
810
ETHERNET MAC
812
POWER FLOW METER
824
ETHERNET-OVER-POWERLINE BRIDGE
120
CURRENT/ VOLTAGE SENSOR
808
AC POWER FROM GRID
POWER CONNECTION
DATA CONNECTION

FIG. 8B

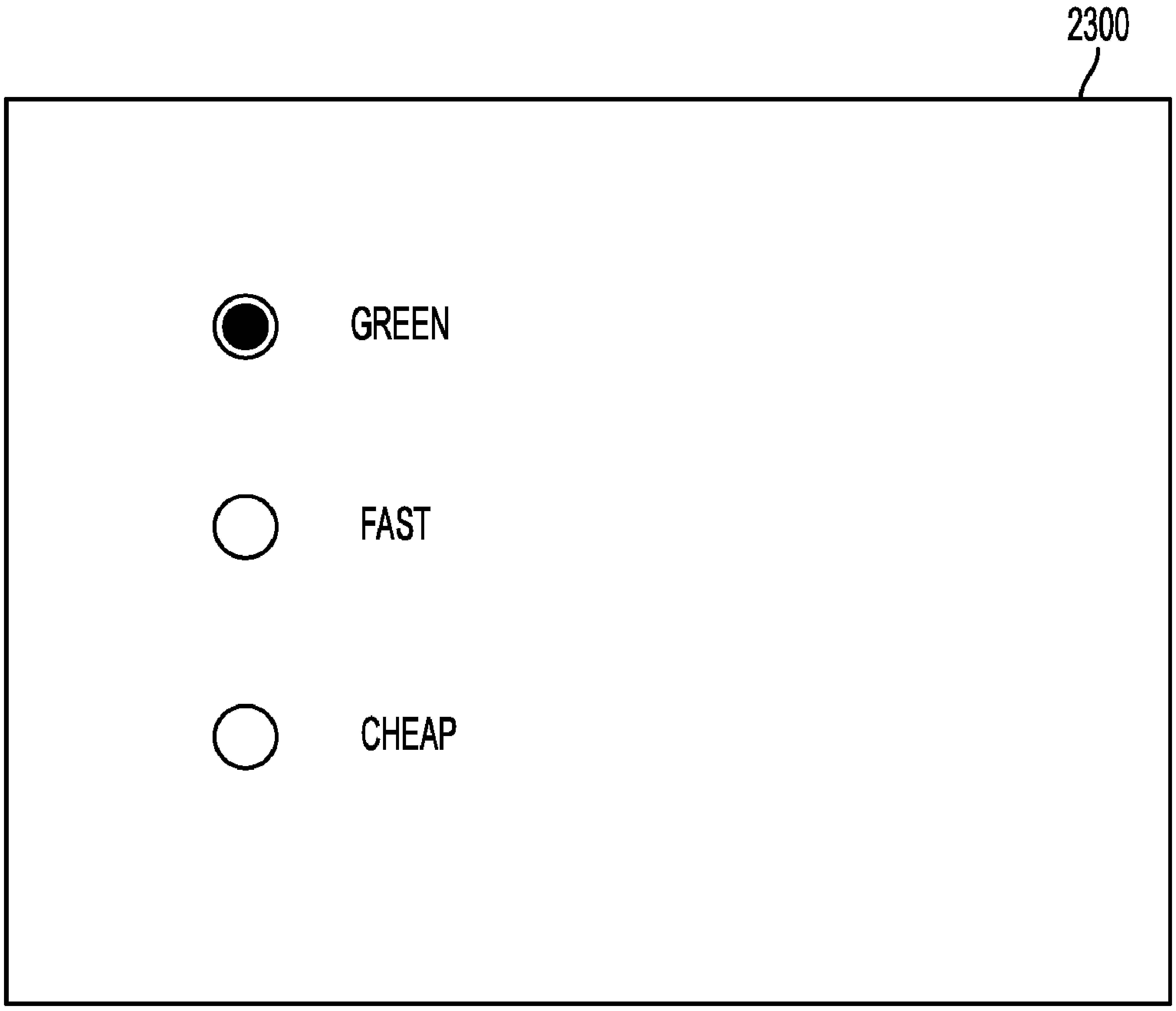


FIG. 8C

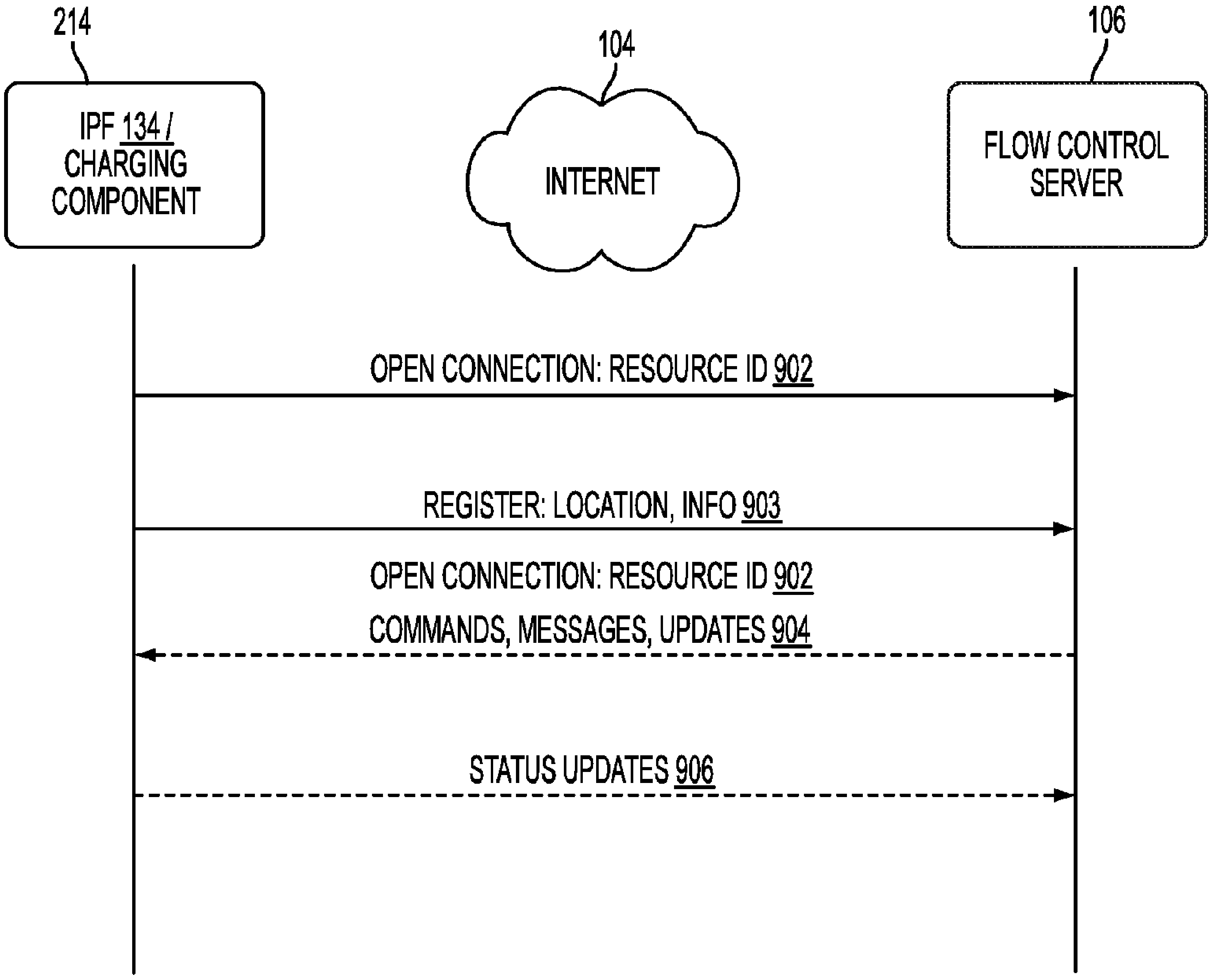

214
IPF 134 / CHARGING COMPONENT
104
INTERNET
106
FLOW CONTROL SERVER
OPEN CONNECTION: RESOURCE ID 902
REGISTER: LOCATION, INFO 903
OPEN CONNECTION: RESOURCE ID 902
COMMANDS, MESSAGES, UPDATES 904
STATUS UPDATES 906

FIG. 9

SYSTEMS AND METHODS FOR ELECTRIC VEHICLE GRID STABILIZATION

[0001] This non-provisional patent application claims priority to, and incorporates herein by reference, U.S. Provisional Patent Application No. 61/165,344 filed on Mar. 31, 2009. This application also incorporates herein by reference the following: U.S. patent application Ser. No. 12/252,657 filed Oct. 16, 2008; U.S. patent application Ser. No. 12/252,209 filed Oct. 15, 2008; U.S. patent application Ser. No. 12/252,803 filed Oct. 16, 2008; and U.S. patent application Ser. No. 12/252,950 filed Oct. 16, 2008.

[0002] This application includes material which is subject to copyright protection. The copyright owner has no objection to the facsimile reproduction by anyone of the patent disclosure, as it appears in the Patent and Trademark Office files or records, but otherwise reserves all copyright rights whatsoever.

FIELD OF THE INVENTION

[0003] The present invention relates in general to the field of electric vehicles, and in particular to novel systems and methods for power flow management and electrical grid stabilization for electric vehicles.

BACKGROUND OF THE INVENTION

[0004] The electric power grid has become increasingly unreliable and antiquated, as evidenced by frequent large-scale power outages. Grid instability wastes energy, both directly and indirectly, e.g. by encouraging power consumers to install inefficient forms of backup generation. While clean forms of energy generation, such as wind and solar, can help to address the above problems, they suffer from intermittency. Hence, grid operators are reluctant to rely heavily on these sources, making it difficult to move away from carbon-intensive forms of electricity.

[0005] With respect to the electric power grid, electric power delivered during periods of peak demand costs substantially more than off-peak power. The electric power grid contains limited inherent facility for storing electrical energy. Electricity must be generated constantly to meet uncertain demand, which often results in over-generation (and hence wasted energy) and sometimes results in under-generation (and hence power failures). The communications protocol by which an utility controls a power plant in regulation mode is known as Automatic Generation Control, or AGC. AGC signals have been sent to large scale conventional power plants, generally with a capacity of 1 Megawatt or more.

[0006] Significant opportunities for improvement exist in managing power flow and stabilizing electrical grids. More economical, reliable electrical power needs to be provided at times of peak demand. Power services, such as regulation and spinning reserves, can be provided to electricity markets to stabilize the grid and provide a significant economic opportunity. Technologies can be enabled to provide broader use of intermittent power sources, such as wind and solar. Novel grid stabilization systems and methods are needed that aggregate the power generation behavior of resources via Automatic Generation Control (AGC), that provide system frequency regulation via AGC, and that smooth and level power generation.

SUMMARY OF THE INVENTION

[0007] In an embodiment, a method for managing power flow includes controlling power resources via Automatic Generation Control (AGC) commands. The AGC commands are transmitted by a power flow manager to the power resources. The AGC commands request power regulation. The method includes apportioning the power regulation to the power resources based on an apportionment scheme. In addition, the method may include transmitting an AGC command to a power resource, wherein the AGC command requests an apportioned amount of the power regulation from the power resource.

[0008] The apportionment scheme may relate to various factors, including: power range of each power resource; power range of some power resources; minimization of communications to the power resources; fairness to the power resources; maximization future abilities to provide power services by the power resources; and/or, preferences or requirements of the power resources.

[0009] In another embodiment, the method for managing power flow also includes controlling a plurality of power resources via Automatic Generation Control (AGC) commands. The AGC commands are transmitted by a power flow manager to power resources, and the AGC commands request power regulation. Further, the method determines a power regulation range for a power resource, and transmits an AGC command to the power resource. The AGC command is based on the power regulation range for the power resource.

[0010] In yet another embodiment, a method for managing power flow may include detecting a change in an intermittent power flow. Accordingly, a power flow manager detects the change in the intermittent power flow. The power flow manager also coordinates power resources to respond to the change in the intermittent power flow by implementing a power flow strategy. The power flow strategy may be a smoothing strategy or a leveling strategy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of embodiments as illustrated in the accompanying drawings, in which reference characters refer to the same parts throughout the various views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating principles of the invention.

[0012] FIG. **1** is a diagram of an example of a power aggregation system.

[0013] FIGS. **2A-2B** are diagrams of an example of connections between an electric vehicle, the power grid, and the Internet.

[0014] FIG. **3** is a block diagram of an example of connections between an electric resource and a flow control server of the power aggregation system.

[0015] FIG. **4** is a diagram of an example of a layout of the power aggregation system.

[0016] FIG. **5** is a diagram of an example of control areas in the power aggregation system.

[0017] FIG. **6** is a diagram of multiple flow control centers in the power aggregation system and a directory server for determining a flow control center.

[0018] FIG. **7** is a block diagram of an example of flow control server.

[0019] FIG. **8**A is a block diagram of an example of remote intelligent power flow module.

[0020] FIG. **8**B is a block diagram of an example of transceiver and charging component combination.

[0021] FIG. **8**C is an illustration of an example of simple user interface for facilitating user controlled charging.

[0022] FIG. **9** is a diagram of an example of resource communication protocol.

[0023] FIG. **10** is a flow chart of an example for AGC virtualization.

[0024] FIG. **11** is a flow chart of an example for AGC for resources beyond generation.

[0025] FIG. **12** is a flow chart of an example of smoothing and leveling intermittent generation.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0026] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

[0027] Overview

[0028] Described herein is a power aggregation system for distributed electric resources, and associated methods. In one implementation, a system communicates over the Internet and/or some other public or private networks with numerous individual electric resources connected to a power grid (hereinafter, "grid"). By communicating, the system can dynamically aggregate these electric resources to provide power services to grid operators (e.g. utilities, Independent System Operators (ISO), etc).

[0029] "Power services" as used herein, refers to energy delivery as well as other ancillary services including demand response, regulation, spinning reserves, non-spinning reserves, energy imbalance, reactive power, and similar products.

[0030] "Aggregation" as used herein refers to the ability to control power flows into and out of a set of spatially distributed electric resources with the purpose of providing a power service of larger magnitude.

[0031] "Charge Control Management" as used herein refers to enabling or performing the starting, stopping, or level-setting of a flow of power between a power grid and an electric resource.

[0032] "Power grid operator" as used herein, refers to the entity that is responsible for maintaining the operation and stability of the power grid within or across an electric control area. The power grid operator may constitute some combination of manual/human action/intervention and automated processes controlling generation signals in response to system sensors. A "control area operator" is one example of a power grid operator.

[0033] "Control area" as used herein, refers to a contained portion of the electrical grid with defined input and output ports. The net flow of power into this area must equal (within some error tolerance) the sum of the power consumption within the area and power outflow from the area.

[0034] "Power grid" as used herein means a power distribution system/network that connects producers of power with consumers of power. The network may include generators, transformers, interconnects, switching stations, and safety equipment as part of either/both the transmission system (i.e., bulk power) or the distribution system (i.e. retail power). The power aggregation system is vertically scalable for use within a neighborhood, a city, a sector, a control area, or (for example) one of the eight large-scale Interconnects in the North American Electric Reliability Council (NERC). Moreover, the system is horizontally scalable for use in providing power services to multiple grid areas simultaneously.

[0035] "Grid conditions" as used herein, refers to the need for more or less power flowing in or out of a section of the electric power grid, in response to one of a number of conditions, for example supply changes, demand changes, contingencies and failures, ramping events, etc. These grid conditions typically manifest themselves as power quality events such as under- or over-voltage events or under- or over-frequency events.

[0036] "Power quality events" as used herein typically refers to manifestations of power grid instability including voltage deviations and frequency deviations; additionally, power quality events as used herein also includes other disturbances in the quality of the power delivered by the power grid such as sub-cycle voltage spikes and harmonics.

[0037] "Electric resource" as used herein typically refers to electrical entities that can be commanded to do some or all of these three things: take power (act as load), provide power (act as power generation or source), and store energy. Examples may include battery/charger/inverter systems for electric or hybrid-electric vehicles, repositories of used-but-serviceable electric vehicle batteries, fixed energy storage, fuel cell generators, emergency generators, controllable loads, etc.

[0038] "Electric vehicle" is used broadly herein to refer to pure electric and hybrid electric vehicles, such as plug-in hybrid electric vehicles (PHEVs), especially vehicles that have significant storage battery capacity and that connect to the power grid for recharging the battery. More specifically, electric vehicle means a vehicle that gets some or all of its energy for motion and other purposes from the power grid. Moreover, an electric vehicle has an energy storage system, which may consist of batteries, capacitors, etc., or some combination thereof. An electric vehicle may or may not have the capability to provide power back to the electric grid.

[0039] Electric vehicle "energy storage systems" (batteries, super capacitors, and/or other energy storage devices) are used herein as a representative example of electric resources intermittently or permanently connected to the grid that can have dynamic input and output of power. Such batteries can function as a power source or a power load. A collection of aggregated electric vehicle batteries can become a statistically stable resource across numerous batteries, despite recognizable tidal connection trends (e.g., an increase in the total number of vehicles connected to the grid at night; a downswing in the collective number of connected batteries as the morning commute begins, etc.) Across vast numbers of electric vehicle batteries, connection trends are predictable and such batteries become a stable and reliable resource to call upon, should the grid or a part of the grid (such as a person's home in a blackout) experience a need for increased or decreased power. Data collection and storage also enable the power aggregation system to predict connection behavior on a per-user basis.

[0040] An Example of the Presently Disclosed System

[0041] FIG. **1** shows a power aggregation system **100**. A flow control center **102** is communicatively coupled with a network, such as a public/private mix that includes the Internet **104**, and includes one or more servers **106** providing a centralized power aggregation service. "Internet" **104** will be used herein as representative of many different types of communicative networks and network mixtures (e.g., one or more wide area networks—public or private—and/or one or more local area networks). Via a network, such as the Internet **104**, the flow control center **102** maintains communication **108** with operators of power grid(s), and communication **110** with remote resources, i.e., communication with peripheral electric resources **112** ("end" or "terminal" nodes/devices of a power network) that are connected to the power grid **114**. In one implementation, power line communicators (PLCs), such as those that include or consist of Ethernet-over-power line bridges **120** are implemented at connection locations so that the "last mile" (in this case, last feet—e.g., in a residence **124**) of Internet communication with remote resources is implemented over the same wire that connects each electric resource **112** to the power grid **114**. Thus, each physical location of each electric resource **112** may be associated with a corresponding Ethernet-over-power line bridge **120** (hereinafter, "bridge") at or near the same location as the electric resource **112**. Each bridge **120** is typically connected to an Internet access point of a location owner, as will be described in greater detail below. The communication medium from flow control center **102** to the connection location, such as residence **124**, can take many forms, such as cable modem, DSL, satellite, fiber, WiMax, etc. In a variation, electric resources **112** may connect with the Internet by a different medium than the same power wire that connects them to the power grid **114**. For example, a given electric resource **112** may have its own wireless capability to connect directly with the Internet **104** or an Internet access point and thereby with the flow control center **102**.

[0042] Electric resources **112** of the power aggregation system **100** may include the batteries of electric vehicles connected to the power grid **114** at residences **124**, parking lots **126** etc.; batteries in a repository **128**, fuel cell generators, private dams, conventional power plants, and other resources that produce electricity and/or store electricity physically or electrically.

[0043] In one implementation, each participating electric resource **112** or group of local resources has a corresponding remote intelligent power flow (IPF) module **134** (hereinafter, "remote IPF module" **134**). The centralized flow control center **102** administers the power aggregation system **100** by communicating with the remote IPF modules **134** distributed peripherally among the electric resources **112**. The remote IPF modules **134** perform several different functions, including, but not limited to, providing the flow control center **102** with the statuses of remote resources; controlling the amount, direction, and timing of power being transferred into or out of a remote electric resource **112**; providing metering of power being transferred into or out of a remote electric resource **112**; providing safety measures during power transfer and changes of conditions in the power grid **114**; logging activities; and providing self-contained control of power transfer and safety measures when communication with the flow control center **102** is interrupted. The remote IPF modules **134** will be described in greater detail below.

[0044] In another implementation, instead of having an IPF module **134**, each electric resource **112** may have a corresponding transceiver (not shown) to communicate with a local charging component (not shown). The transceiver and charging component, in combination, may communicate with flow control center **102** to perform some or all of the above mentioned functions of IPF module **134**. A transceiver and charging component are shown in FIG. **2**B and are described in greater detail herein.

[0045] FIG. **2**A shows another view of electrical and communicative connections to an electric resource **112**. In this example, an electric vehicle **200** includes a battery bank **202** and a remote IPF module **134**. The electric vehicle **200** may connect to a conventional wall receptacle (wall outlet) **204** of a residence **124**, the wall receptacle **204** representing the peripheral edge of the power grid **114** connected via a residential powerline **206**.

[0046] In one implementation, the power cord **208** between the electric vehicle **200** and the wall outlet **204** can be composed of only conventional wire and insulation for conducting alternating current (AC) power to and from the electric vehicle **200**. In FIG. **2**A, a location-specific connection locality module **210** performs the function of network access point—in this case, the Internet access point. A bridge **120** intervenes between the receptacle **204** and the network access point so that the power cord **208** can also carry network communications between the electric vehicle **200** and the receptacle **204**. With such a bridge **120** and connection locality module **210** in place in a connection location, no other special wiring or physical medium is needed to communicate with the remote IPF module **134** of the electric vehicle **200** other than a conventional power cord **208** for providing residential line current at any conventional voltage. Upstream of the connection locality module **210**, power and communication with the electric vehicle **200** are resolved into the powerline **206** and an Internet cable **104**.

[0047] Alternatively, the power cord **208** may include safety features not found in conventional power and extension cords. For example, an electrical plug **212** of the power cord **208** may include electrical and/or mechanical safeguard components to prevent the remote IPF module **134** from electrifying or exposing the male conductors of the power cord **208** when the conductors are exposed to a human user.

[0048] In some embodiments, a radio frequency (RF) bridge (not shown) may assist the remote IPF module **134** in communicating with a foreign system, such as a utility smart meter (not shown) and/or a connection locality module **210**. For example, the remote IPF module **134** may be equipped to communicate over power cord **208** or to engage in some form of RF communication, such as Zigbee or Bluetooth.TM., and the foreign system may be able to engage in a different form of RF communication. In such an implementation, the RF bridge may be equipped to communicate with both the foreign system and remote IPF module **134** and to translate communications from one to a form the other may understand, and to relay those messages. In various embodiments, the RF bridge may be integrated into the remote IPF module **134** or foreign system, or may be external to both. The communicative associations between the RF bridge and remote IPF module **134** and between the RF bridge and foreign system may be via wired or wireless communication.

[0049] FIG. **2**B shows a further view of electrical and communicative connections to an electric resource **112**. In this example, the electric vehicle **200** may include a transceiver

212 rather than a remote IPF module **134**. The transceiver **212** may be communicatively coupled to a charging component **214** through a connection **216**, and the charging component itself may be coupled to a conventional wall receptacle (wall outlet) **204** of a residence **124** and to electric vehicle **200** through a power cord **208**. The other components shown in FIG. **2**B may have the couplings and functions discussed with regard to FIG. **2**A.

[0050] In various embodiments, transceiver **212** and charging component **214** may, in combination, perform the same functions as the remote IPF module **134**. Transceiver **212** may interface with computer systems of electric vehicle **200** and communicate with charging component **214**, providing charging component **214** with information about electric vehicle **200**, such as its vehicle identifier, a location identifier, and a state of charge. In response, transceiver **212** may receive requests and commands which transceiver **212** may relay to vehicle **200**'s computer systems.

[0051] Charging component **214**, being coupled to both electric vehicle **200** and wall outlet **204**, may effectuate charge control of the electric vehicle **200**. If the electric vehicle **200** is not capable of charge control management, charging component **214** may directly manage the charging of electric vehicle **200** by stopping and starting a flow of power between the electric vehicle **200** and a power grid **114** in response to commands received from a flow control server **106**. If, on the other hand, the electric vehicle **200** is capable of charge control management, charging component **214** may effectuate charge control by sending commands to the electric vehicle **200** through the transceiver **212**.

[0052] In some embodiments, the transceiver **212** may be physically coupled to the electric vehicle **200** through a data port, such as an OBD-II connector. In other embodiments, other couplings may be used. The connection **216** between transceiver **212** and charging component **214** may be a wireless signal, such as a radio frequency (RF), such as a Zigbee, or Bluetooth.TM. signal. And charging component **214** may include a receiver socket to couple with power cord **208** and a plug to couple with wall outlet **204**. In one embodiment, charging component **214** may be coupled to connection locality module **210** in either a wired or wireless fashion. For example, charging component **214** might have a data interface for communicating wirelessly with both the transceiver **212** and locality module **210**. In such an embodiment, the bridge **120** may not be required.

[0053] Further details about the transceiver **212** and charging component **214** are illustrated by FIG. **8**B and described in greater detail herein.

[0054] FIG. **3** shows another implementation of the connection locality module **210** of FIG. **2**, in greater detail. In FIG. **3**, an electric resource **112** has an associated remote IPF module **134**, including a bridge **120**. The power cord **208** connects the electric resource **112** to the power grid **114** and also to the connection locality module **210** in order to communicate with the flow control server **106**.

[0055] The connection locality module **210** includes another instance of a bridge **120**, connected to a network access point **302**, which may include such components as a router, switch, and/or modem, to establish a hardwired or wireless connection with, in this case, the Internet **104**. In one implementation, the power cord **208** between the two bridges **120** and **120'** is replaced by a wireless Internet link, such as a wireless transceiver in the remote IPF module **134** and a wireless router in the connection locality module **210**.

[0056] In other embodiments, a transceiver **212** and charging component **214** may be used instead of a remote IPF module **134**. In such an embodiment, the charging component **214** may include or be coupled to a bridge **120**, and the connection locality module **210** may also include a bridge **120'**, as shown. In yet other embodiments, not shown, charging component **214** and connection locality module **210** may communicate in a wired or wireless fashion, as mentioned previously, without bridges **120** and **120'**. The wired or wireless communication may utilize any sort of connection technology known in the art, such as Ethernet or RF communication, such as Zigbee, or Bluetooth.

[0057] System Layouts

[0058] FIG. **4** shows a layout **400** of the power aggregation system **100**. The flow control center **102** can be connected to many different entities, e.g., via the Internet **104**, for communicating and receiving information. The layout **400** includes electric resources **112**, such as plug-in electric vehicles **200**, physically connected to the grid within a single control area **402**. The electric resources **112** become an energy resource for grid operators **404** to utilize.

[0059] The layout **400** also includes end users **406** classified into electric resource owners **408** and electrical connection location owners **410**, who may or may not be one and the same. In fact, the stakeholders in a power aggregation system **100** include the system operator at the flow control center **102**, the grid operator **404**, the resource owner **408**, and the owner of the location **410** at which the electric resource **112** is connected to the power grid **114**.

[0060] Electrical connection location owners **410** can include:

[0061] Rental car lots—rental car companies often have a large portion of their fleet parked in the lot. They can purchase fleets of electric vehicles **200** and, participating in a power aggregation system **100**, generate revenue from idle fleet vehicles.

[0062] Public parking lots—parking lot owners can participate in the power aggregation system **100** to generate revenue from parked electric vehicles **200**. Vehicle owners can be offered free parking, or additional incentives, in exchange for providing power services.

[0063] Workplace parking—employers can participate in a power aggregation system **100** to generate revenue from parked employee electric vehicles **200**. Employees can be offered incentives in exchange for providing power services.

[0064] Residences—a home garage can merely be equipped with a connection locality module **210** to enable the homeowner to participate in the power aggregation system **100** and generate revenue from a parked car. Also, the vehicle battery **202** and associated power electronics within the vehicle can provide local power backup power during times of peak load or power outages.

[0065] Residential neighborhoods—neighborhoods can participate in a power aggregation system **100** and be equipped with power-delivery devices (deployed, for example, by homeowner cooperative groups) that generate revenue from parked electric vehicles **200**.

[0066] The grid operations **116** of FIG. **4** collectively include interactions with energy markets **412**, the interactions of grid operators **404**, and the interactions of automated grid controllers **118** that perform automatic physical control of the power grid **114**.

[0067] The flow control center **102** may also be coupled with information sources **414** for input of weather reports, events, price feeds, etc. Other data sources **414** include the system stakeholders, public databases, and historical system data, which may be used to optimize system performance and to satisfy constraints on the power aggregation system **100**.

[0068] Thus, a power aggregation system **100** may consist of components that:

- **[0069]** communicate with the electric resources **112** to gather data and actuate charging/discharging of the electric resources **112**;
- **[0070]** gather real-time energy prices;
- **[0071]** gather real-time resource statistics;
- **[0072]** predict behavior of electric resources **112** (connectedness, location, state (such as battery State-Of-Charge) at a given time of interest, such as a time of connect/disconnect);
- **[0073]** predict behavior of the power grid **114**/load;
- **[0074]** encrypt communications for privacy and data security;
- **[0075]** actuate charging of electric vehicles **200** to optimize some figure(s) of merit;
- **[0076]** offer guidelines or guarantees about load availability for various points in the future, etc.

[0077] These components can be running on a single computing resource (computer, etc.), or on a distributed set of resources (either physically co-located or not).

[0078] Power aggregation systems **100** in such a layout **400** can provide many benefits: for example, lower-cost ancillary services (i.e., power services), fine-grained (both temporal and spatial) control over resource scheduling, guaranteed reliability and service levels, increased service levels via intelligent resource scheduling, and/or firming of intermittent generation sources such as wind and solar power generation.

[0079] The power aggregation system **100** enables a grid operator **404** to control the aggregated electric resources **112** connected to the power grid **114**. An electric resource **112** can act as a power source, load, or storage, and the resource **112** may exhibit combinations of these properties. Control of a set of electric resources **112** is the ability to actuate power consumption, generation, or energy storage from an aggregate of these electric resources **112**.

[0080] FIG. **5** shows the role of multiple control areas **402** in the power aggregation system **100**. Each electric resource **112** can be connected to the power aggregation system **100** within a specific electrical control area. A single instance of the flow control center **102** can administer electric resources **112** from multiple distinct control areas **501** (e.g., control areas **502**, **504**, and **506**). In one implementation, this functionality is achieved by logically partitioning resources within the power aggregation system **100**. For example, when the control areas **402** include an arbitrary number of control areas, control area "A" **502**, control area "B" **504**, . . . , control area "n" **506**, then grid operations **116** can include corresponding control area operators **508**, **510**, . . . , and **512**. Further division into a control hierarchy that includes control division groupings above and below the illustrated control areas **402** allows the power aggregation system **100** to scale to power grids **114** of different magnitudes and/or to varying numbers of electric resources **112** connected with a power grid **114**.

[0081] FIG. **6** shows a layout **600** of a power aggregation system **100** that uses multiple centralized flow control centers **102** and **102'** and a directory server **602** for determining a flow control center. Each flow control center **102** and **102'** has its own respective end users **406** and **406'**. Control areas **402** to be administered by each specific instance of a flow control center **102** can be assigned dynamically. For example, a first flow control center **102** may administer control area A **502** and control area B **504**, while a second flow control center **102'** administers control area n **506**. Likewise, corresponding control area operators (**508**, **510**, and **512**) are served by the same flow control center **102** that serves their respective different control areas.

[0082] In various embodiments, an electric resource may determine which flow control center **102**/**102'** administers its control area **502**/**504**/**506** by communicating with a directory server **602**. The address of the directory server **602** may be known to electric resource **112** or its associated IPF module **134** or charging component **214**. Upon plugging in, the electric resource **112** may communicate with the directory server **602**, providing the directory server **112** with a resource identifier and/or a location identifier. Based on this information, the directory server **602** may respond, identifying which flow control center **102**/**102'** to use.

[0083] In another embodiment, directory server **602** may be integrated with a flow control server **106** of a flow control center **102**/**102'**. In such an embodiment, the electric resource **112** may contact the server **106**. In response, the server **106** may either interact with the electric resource **112** itself or forward the connection to another flow control center **102**/**102'** responsible for the location identifier provided by the electric resource **112**.

[0084] In some embodiments, whether integrated with a flow control server **106** or not, directory server **602** may include a publicly accessible database for mapping locations to flow control centers **102**/**102'**.

[0085] Flow Control Server

[0086] FIG. **7** shows a server **106** of the flow control center **102**. The illustrated implementation in FIG. **7** is only one example configuration, for descriptive purposes. Many other arrangements of the illustrated components or even different components constituting a server **106** of the flow control center **102** are possible within the scope of the subject matter. Such a server **106** and flow control center **102** can be executed in hardware, software, or combinations of hardware, software, firmware, etc.

[0087] The flow control server **106** includes a connection manager **702** to communicate with electric resources **112**, a prediction engine **704** that may include a learning engine **706** and a statistics engine **708**, a constraint optimizer **710**, and a grid interaction manager **712** to receive grid control signals **714**. Grid control signals **714** are sometimes referred to as generation control signals, such as automated generation control (AGC) signals. The flow control server **106** may further include a database/information warehouse **716**, a web server **718** to present a user interface to electric resource owners **408**, grid operators **404**, and electrical connection location owners **410**; a contract manager **720** to negotiate contract terms with energy markets **412**, and an information acquisition engine **414** to track weather, relevant news events, etc., and download information from public and private databases **722** for predicting behavior of large groups of the electric resources **112**, monitoring energy prices, negotiating contracts, etc.

[0088] Remote IPF Module

[0089] FIG. **8**A shows the remote IPF module **134** of FIGS. **1** and **2** in greater detail. The illustrated remote IPF module **134** is only one example configuration, for descriptive purposes. Many other arrangements of the illustrated components or even different components constituting a remote IPF module **134** are possible within the scope of the subject matter. Such a remote IPF module **134** has some hardware components and some components that can be executed in hardware, software, or combinations of hardware, software, firmware, etc. In other embodiments, executable instructions configured to perform some or all of the operations of remote IPF module **134** may be added to hardware of an electric resource **112** such as an electric vehicle that, when combined with the executable instructions, provides equivalent functionality to remote IPF module **134**. References to remote IPF module **134** as used herein include such executable instructions.

[0090] The illustrated example of a remote IPF module **134** is represented by an implementation suited for an electric vehicle **200**. Thus, some vehicle systems **800** are included as part of the remote IPF module **134** for the sake of description. However, in other implementations, the remote IPF module **134** may exclude some or all of the vehicles systems **800** from being counted as components of the remote IPF module **134**.

[0091] The depicted vehicle systems **800** include a vehicle computer and data interface **802**, an energy storage system, such as a battery bank **202**, and an inverter/charger **804**. Besides vehicle systems **800**, the remote IPF module **134** also includes a communicative power flow controller **806**. The communicative power flow controller **806** in turn includes some components that interface with AC power from the grid **114**, such as a powerline communicator, for example an Ethernet-over-powerline bridge **120**, and a current or current/voltage (power) sensor **808**, such as a current sensing transformer.

[0092] The communicative power flow controller **806** also includes Ethernet and information processing components, such as a processor **810** or microcontroller and an associated Ethernet media access control (MAC) address **812**; volatile random access memory **814**, nonvolatile memory **816** or data storage, an interface such as an RS-232 interface **818** or a CANbus interface **820**; an Ethernet physical layer interface **822**, which enables wiring and signaling according to Ethernet standards for the physical layer through means of network access at the MAC/Data Link Layer and a common addressing format. The Ethernet physical layer interface **822** provides electrical, mechanical, and procedural interface to the transmission medium—i.e., in one implementation, using the Ethernet-over-powerline bridge **120**. In a variation, wireless or other communication channels with the Internet **104** are used in place of the Ethernet-over-powerline bridge **120**.

[0093] The communicative power flow controller **806** also includes a bidirectional power flow meter **824** that tracks power transfer to and from each electric resource **112**, in this case the battery bank **202** of an electric vehicle **200**.

[0094] The communicative power flow controller **806** operates either within, or connected to an electric vehicle **200** or other electric resource **112** to enable the aggregation of electric resources **112** introduced above (e.g., via a wired or wireless communication interface). These above-listed components may vary among different implementations of the communicative power flow controller **806**, but implementations typically include:

- **[0095]** an intra-vehicle communications mechanism that enables communication with other vehicle components;
- **[0096]** a mechanism to communicate with the flow control center **102**;
- **[0097]** a processing element;
- **[0098]** a data storage element;
- **[0099]** a power meter; and
- **[0100]** optionally, a user interface.

[0101] Implementations of the communicative power flow controller **806** can enable functionality including:

- **[0102]** executing pre-programmed or learned behaviors when the electric resource **112** is offline (not connected to Internet **104**, or service is unavailable);
- **[0103]** storing locally-cached behavior profiles for "roaming" connectivity (what to do when charging on a foreign system, i.e., when charging in the same utility territory on a foreign meter or in a separate utility territory, or in disconnected operation, i.e., when there is no network connectivity);
- **[0104]** allowing the user to override current system behavior; and
- **[0105]** metering power-flow information and caching meter data during offline operation for later transaction.

[0106] Thus, the communicative power flow controller **806** includes a central processor **810**, interfaces **818** and **820** for communication within the electric vehicle **200**, a powerline communicator, such as an Ethernet-over-powerline bridge **120** for communication external to the electric vehicle **200**, and a power flow meter **824** for measuring energy flow to and from the electric vehicle **200** via a connected AC powerline **208**.

[0107] Power Flow Meter

[0108] Power is the rate of energy consumption per interval of time. Power indicates the quantity of energy transferred during a certain period of time, thus the units of power are quantities of energy per unit of time. The power flow meter **824** measures power for a given electric resource **112** across a bidirectional flow—e.g., power from grid **114** to electric vehicle **200** or from electric vehicle **200** to the grid **114**. In one implementation, the remote IPF module **134** can locally cache readings from the power flow meter **824** to ensure accurate transactions with the central flow control server **106**, even if the connection to the server is down temporarily, or if the server itself is unavailable.

[0109] Transceiver and Charging Component

[0110] FIG. 8B shows the transceiver **212** and charging component **214** of FIG. 2B in greater detail. The illustrated transceiver **212** and charging component **214** is only one example configuration, for descriptive purposes. Many other arrangements of the illustrated components or even different components constituting the transceiver **212** and charging component **214** are possible within the scope of the subject matter. Such a transceiver **212** and charging component **214** have some hardware components and some components that can be executed in hardware, software, or combinations of hardware, software, firmware, etc.

[0111] The illustrated example of the transceiver **212** and charging component **214** is represented by an implementation suited for an electric vehicle **200**. Thus, some vehicle systems **800** are illustrated to provide context to the transceiver **212** and charging component **214** components.

[0112] The depicted vehicle systems **800** include a vehicle computer and data interface **802**, an energy storage system, such as a battery bank **202**, and an inverter/charger **804**. In some embodiments, vehicle systems **800** may include a data port, such as an OBD-II port, that is capable of physically coupling with the transceiver **212**. The transceiver **212** may then communicate with the vehicle computer and data interface **802** through the data port, receiving information from electric resource **112** comprised by vehicle systems **800** and, in some embodiments, providing commands to the vehicle computer and data interface **802**. In one implementation, the vehicle computer and data interface **802** may be capable of charge control management. In such an embodiment, the vehicle computer and data interface **802** may perform some or all of the charging component **214** operations discussed below. In other embodiments, executable instructions configured to perform some or all of the operations of the vehicle computer and data interface **802** may be added to hardware of an electric resource **112** such as an electric vehicle that, when combined with the executable instructions, provides equivalent functionality to the vehicle computer and data interface **802**. References to the vehicle computer and data interface **802** as used herein include such executable instructions.

[0113] In various embodiments, the transceiver **212** may have a physical form that is capable of coupling to a data port of vehicle systems **800**. Such a transceiver **212** may also include a plurality of interfaces, such as an RS-232 interface **818** and/or a CANBus interface **820**. In various embodiments, the RS-232 interface **818** or CANBus interface **820** may enable the transceiver **212** to communicate with the vehicle computer and data interface **802** through the data port. Also, the transceiver may be or comprise an additional interface (not shown) capable of engaging in wireless communication with a data interface **820** of the charging component **214**. The wireless communication may be of any form known in the art, such as radio frequency (RF) communication (e.g., Zigbee, and/or Bluetooth.TM. communication). In other embodiments, the transceiver may comprise a separate conductor or may be configured to utilize a powerline **208** to communicate with charging component **214**. In yet other embodiments, not shown, transceiver **212** may simply be a radio frequency identification (RFID) tag capable of storing minimal information about the electric resource **112**, such as a resource identifier, and of being read by a corresponding RFID reader of charging component **214**. In such other embodiments, the RFID tag might not couple with a data port or communicate with the vehicle computer and data interface **802**.

[0114] As shown, the charging component **214** may be an intelligent plug device that is physically connected to a charging medium, such as a powerline **208** (the charging medium coupling the charging component **214** to the electric resource **112**) and an outlet of a power grid (such as the wall outlet **204** shown in FIG. 2B). In other embodiments charging component **214** may be a charging station or some other external control. In some embodiments, the charging component **214** may be portable.

[0115] In various embodiments, the charging component **214** may include components that interface with AC power from the grid **114**, such as a powerline communicator, for example an Ethernet-over-powerline bridge **120**, and a current or current/voltage (power) sensor **808**, such as a current sensing transformer.

[0116] In other embodiments, the charging component **214** may include a further Ethernet plug or wireless interface in place of bridge **120**. In such an embodiment, data-over-powerline communication is not necessary, eliminating the need for a bridge **120**. The Ethernet plug or wireless interface may communicate with a local access point, and through that access point to flow control server **106**.

[0117] The charging component **214** may also include Ethernet and information processing components, such as a processor **810** or microcontroller and an associated Ethernet media access control (MAC) address **812**; volatile random access memory **814**, nonvolatile memory **816** or data storage, a data interface **826** for communicating with the transceiver **212**, and an Ethernet physical layer interface **822**, which enables wiring and signaling according to Ethernet standards for the physical layer through means of network access at the MAC/Data Link Layer and a common addressing format. The Ethernet physical layer interface **822** provides electrical, mechanical, and procedural interface to the transmission medium—i.e., in one implementation, using the Ethernet-over-powerline bridge **120**. In a variation, wireless or other communication channels with the Internet **104** are used in place of the Ethernet-over-powerline bridge **120**.

[0118] The charging component **214** may also include a bidirectional power flow meter **824** that tracks power transfer to and from each electric resource **112**, in this case the battery bank **202** of an electric vehicle **200**.

[0119] Further, in some embodiments, the charging component **214** may comprise an RFID reader to read the electric resource information from transceiver **212** when transceiver **212** is an RFID tag.

[0120] Also, in various embodiments, the charging component **214** may include a credit card reader to enable a user to identify the electric resource **112** by providing credit card information. In such an embodiment, a transceiver **212** may not be necessary.

[0121] Additionally, in one embodiment, the charging component **214** may include a user interface, such as one of the user interfaces described in greater detail below.

[0122] Implementations of the charging component **214** can enable functionality including:

[0123] executing pre-programmed or learned behaviors when the electric resource **112** is offline (not connected to Internet **104**, or service is unavailable);

[0124] storing locally-cached behavior profiles for "roaming" connectivity (what to do when charging on a foreign system or in disconnected operation, i.e., when there is no network connectivity);

[0125] allowing the user to override current system behavior; and

[0126] metering power-flow information and caching meter data during offline operation for later transaction.

[0127] User Interfaces (UI)

[0128] Charging Station UI. An electrical charging station, whether free or for pay, can be installed with a user interface that presents useful information to the user. Specifically, by collecting information about the grid **114**, the electric resource state, and the preferences of the user, the station can present information such as the current electricity price, the estimated recharge cost, the estimated time until recharge, the estimated payment for uploading power to the grid **114** (either total or per hour), etc. The information acquisition engine **414** communicates with the electric resource **112** and with public and/or private data networks **722** to acquire the data used in calculating this information.

[0129] The types of information gathered from the electric resource **112** could include an electric resource identifier (resource ID) and state information like the state of charge of the electric resource **112**. The resource ID could be used to obtain knowledge of the electric resource type and capabilities, preferences, etc. through lookup with the flow control server **106**.

[0130] In various embodiments, the charging station system including the UI might also gather grid-based information, such as current and future energy costs at the charging station.

[0131] User Charge Control UI Mechanisms. In various embodiments, by default, electric resources **112** may receive charge control management via power aggregation system **100**. In some embodiments, an override control may be provided to override charge control management and charge as soon as possible. The override control may be provided, in various embodiments, as a user interface mechanism of the remote IPF module **134**, the charging component **214**, of the electric resource (for example, if electric resource is a vehicle **200**, the user interface control may be integrated with dash controls of the vehicle **200**) or even via a web page offered by flow control server **106**. The control could be presented, for example, as a button, a touch screen option, a web page, or some other UI mechanism. In one embodiment, the UI may be the UI illustrated by FIG. **8**C and discussed in greater detail below. In some embodiments, the override would be a one-time override, only applying to a single plug-in session. Upon disconnecting and reconnecting, the user may again need to interact with the UI mechanism to override the charge control management.

[0132] In some embodiments, the user may pay more to charge with the override on than under charge control management, thus providing an incentive for the user to accept charge control management. Such a cost differential may be displayed or rendered to the user in conjunction with or on the UI mechanism. This differential could take into account time-varying pricing, such as Time of Use (TOU), Critical Peak Pricing (CPP), and Real-Time Pricing (RTP) schemes, as discussed above, as well as any other incentives, discounts, or payments that might be forgone by not accepting charge control management.

[0133] UI Mechanism for Management Preferences. In various embodiments, a user interface mechanism of the remote IPF module **134**, the charging component **214**, of the electric resource (for example, if electric resource is a vehicle **200**, the user interface control may be integrated with dash controls of the vehicle **200**) or even via a web page offered by flow control server **106** may enable a user to enter and/or edit management preferences to affect charge control management of the user's electric resource **112**. In some embodiments, the UI mechanism may allow the user to enter/edit general preferences, such as whether charge control management is enabled, whether vehicle-to-grid power flow is enabled or whether the electric resource **112** should only be charged with clean/green power. Also, in various embodiments, the UI mechanism may enable a user to prioritize relative desires for minimizing costs, maximizing payments (i.e., fewer charge periods for higher amounts), achieving a full state-of-charge for the electric resource **112**, charging as rapidly as possible, and/or charging in as environmentally-friendly a way as possible. Additionally, the UI mechanism may enable a user to provide a default schedule for when the electric resource will be used (for example, if resource **112** is a vehicle **200**, the schedule would be for when the vehicle **200** should be ready to drive). Further, the UI mechanism may enable the user to add or select special rules, such as a rule not to charge if a price threshold is exceeded or a rule to only use charge control management if it will earn the user at least a specified threshold of output. Charge control management may then be effectuated based on any part or all of these user entered preferences.

[0134] Simple User Interface. FIG. **8**C illustrates a simple user interface (UI) which enables a user to control charging based on selecting among a limited number of high level preferences. For example, UI **2300** includes the categories "green", "fast", and "cheap" (with what is considered "green", "fast", and "cheap" varying from embodiment to embodiment). The categories shown in UI **2300** are selected only for the sake of illustration and may instead includes these and/or any other categories applicable to electric resource **112** charging known in the art. As shown, the UI **2300** may be very basic, using well known form controls such as radio buttons. In other embodiments, other graphic controls known in the art may be used. The general categories may be mapped to specific charging behaviors, such as those discussed above, by a flow control server **106**.

[0135] Electric Resource Communication Protocol

[0136] FIG. **9** illustrates a resource communication protocol. As shown, a remote IPF module **134** or charging component **214** may be in communication with a flow control server **106** over the Internet **104** or another networking fabric or combination of networking fabrics. In various embodiments, a protocol specifying an order of messages and/or a format for messages may be used to govern the communications between the remote IPF module **134** or charging component **214** and flow control server **106**.

[0137] In some embodiments, the protocol may include two channels, one for messages initiated by the remote IPF module **134** or charging component **214** and for replies to those messages from the flow control server **106**, and another channel for messages initiated by the flow control server **106** and for replies to those messages from the remote IPF module **134** or charging component **214**. The channels may be asynchronous with respect to each other (that is, initiation of messages on one channel may be entirely independent of initiation of messages on the other channel). However, each channel may itself be synchronous (that is, once a message is sent on a channel, another message may not be sent until a reply to the first message is received).

[0138] As shown, the remote IPF module **134** or charging component **214** may initiate communication **902** with the flow control server **106**. In some embodiments, communication **902** may be initiated when, for example, an electric resource **112** first plugs in/connects to the power grid **114**. In other embodiments, communication **902** may be initiated at another time or times. The initial message **902** governed by the protocol may require, for example, one or more of an electric resource identifier, such as a MAC address, a protocol version used, and/or a resource identifier type.

[0139] Upon receipt of the initial message by the flow control server **106**, a connection may be established between the remote IPF module **134** or charging component **214** and flow control server **106**. Upon establishing a connection, the remote IPF module **134** or charging component **214** may register with flow control server **106** through a subsequent communication **903**. Communication **903** may include a location identifier scheme, a latitude, a longitude, a max power value that the remote IPF module **134** or charging component **214** can draw, a max power value that the remote IPF module **134** or charging component **214** can provide, a current power value, and/or a current state of charge.

[0140] After the initial message **902**, the protocol may require or allow messages **904** from the flow control server **106** to the remote IPF module **134** or charging component **214** or messages **906** from remote IPF module **134** or charging component **214** to the flow control server **106**. The messages **904** may include, for example, one or more of commands, messages, and/or updates. Such messages **904** may be provided at any time after the initial message **902**. In one embodiment, messages **904** may include a command setting, a power level and/or a ping to determine whether the remote IPF module **134** or charging component **214** is still connected.

[0141] The messages **906** may include, for example, status updates to the information provided in the registration message **903**. Such messages **906** may be provided at any time after the initial message **902**. In one embodiment, the messages **906** may be provided on a pre-determined time interval basis. In various embodiments, messages **906** may even be sent when the remote IPF module **134** or charging component **214** is connected, but not registered. Such messages **906** may include data that is stored by flow control server **106** for later processing. Also, in some embodiments, messages **904** may be provided in response to a message **902** or **906**.

[0142] AGC Virtualizer

[0143] An attribute of the electrical grid is that power production must always be closely matched to power consumption. As such, electric utilities predict power consumption in advance using a variety of techniques in order to schedule power production to match consumption. Because these predictions are never entirely accurate, the electric utility is left with a shortfall or surplus of produced electricity.

[0144] To address this mismatch between predicted and actual power consumption, utilities arrange for some power generation plant to operate in a regulation mode. This is sometimes called system regulation, or frequency regulation. In regulation mode, the power output of a power plant can be increased or decreased in near real time. In the event of a power surplus, the utility orders the power plant in regulation mode to decrease power production. In the event of a power shortage, the utility orders the power plant to increase power production. Not all power plants are capable of operating in this mode, and the power plants that are often incur increased costs while in this mode. Issues such as fuel efficiently and mechanical stress must be accounted for when figuring the cost of regulation mode.

[0145] A power flow manager can provide system frequency regulation via Automatic Generation Control (AGC) commands. As such, the system may appear to behave as an ISO/TSO or a grid operator, such as a power plant, even though it is not actually a power plant. The power flow manager coordinates the behavior of power resources, such as the following: load, generation, or storage. The power resources can include plug-in vehicles, fixed energy storage, loads such as HVAC, or other devices. The AGC commands can be translated by the power flow manager into commands to specific devices, or sets of devices within its pool, in order to achieve aggregate behavior across the set of resources that matches the AGC request.

[0146] In an embodiment, the AGC command can be transmitted to all power resources. The magnitude of the command can be divided up among the power resources in proportion to the power range of each resource, accordingly to one embodiment. For example, a command for 1 MW of down regulation can be divided up such that a device with a 2 kW potential power swing between max power in and max power out would be asked to provide half as much contribution as a device with a 4 kW potential power swing. More complex schemes can optimize dispatch based on a variety of factors, including: minimizing communication to resources; fairness; maximizing ability to provide services in the future, e.g. not filling up a plug-in vehicle that can only be charged; or, resource owner preferences or requirements.

[0147] AGC allows for regulation in two directions. Up regulation is a request for additional power, while down regulation is the request for a reduction in power. A power flow manager can implement bi-directional regulation (both up and down) using only power resources that are capable of unidirectional power flow. This is accomplished by setting a population of power resources to consume power at a rate less than their maximum (e.g. 50%), and then adjusting power consumption up and down in accordance with AGC commands. During periods of power shortage (resulting in up regulation requests), the power resources could curtail energy use and/or increase energy output. During periods of power surplus (resulting in down regulation requests), the power resources could increase energy use and/or decrease energy output relative to their initial rate.

[0148] FIG. **10** shows an embodiment of power flow management using AGC commands to control power resources **1010**. Power regulation is apportioned to the power resources **1020**. An AGC command, which requests an apportioned amount of the power regulation, is transmitted to a power resource **1030**.

[0149] AGC for Resources Beyond Generation

[0150] Automatic Generation Control (AGC) can be utilized to control power plants so that they may provide system frequency regulation. In an embodiment, a power plant might be scheduled to provide 30 MW of power during a certain hour, while also being available to provide 10 MW of down regulation and 20 MW of up regulation during that hour. As such, the plant output might vary anywhere from 20 MW to 50 MW. In an embodiment, AGC typically transmits a power level set point within this range, e.g. 37 MW, or may send relative power request, i.e. increase power or decrease power relative to the current level.

[0151] Given a load or energy-storage based power resource, or an aggregation of such power resources, system frequency regulation can also be provided by adjusting the net balance of supply and demand for energy. Energy storage in discharge mode can output power much like a generation plant. Load, or energy storage in charge mode, can consume power like negative generation. When a number of vehicles/resources are grid-connected and charging, an up regulation request can be serviced by temporarily reducing the rate of vehicle charge. Additionally, generation based power resources can be part of an aggregate of other load or energy-storage based power resources.

[0152] In one embodiment, AGC systems and protocols can be extended to handle power level set points that can be negative. As such, the power flow manager receiving the request can treat negative values as requests for energy consumption, and positive values as requests for energy production. When the AGC system does not support negative numbers, the entire power range can be shifted to start at zero, such that the shift amount becomes a separate load amount within the system. For example, a power range of −5 MW to 10 MW can be shifted to be 0 MW to 15 MW with the offset amount becoming a separate load amount of 5 MW.

[0153] FIG. **11** illustrates an embodiment of power flow management using AGC commands to control power resources **1110** where a power regulation range for a power resource is determined **1120**. An AGC command based on the power regulation range is transmitted to the power resource **1130**.

[0154] Intermittent Generation Smoothing and Leveling

[0155] Intermittent generation resources, such as wind or solar, can suffer from sudden ramping up or down in output, as well as somewhat unpredictable output levels over time. For example, the wind speed or direction can shift rapidly or a cloud can temporarily obscure the sun over a solar generation asset. Since power production must always be closely matched to power consumption, it is very difficult to integrate unreliable generation resources in to the grid, particularly as the percentage of power being provided by such resources increases in the generation mix.

[0156] In some situations, utilities are forced to provision conventionally fueled standby power generation assets to provide backup to the intermittent generation resources. For example, natural gas turbines are often used in this way. Other rapidly adjustable generation such as hydro may also be used to provide this firming of intermittent generation. This substantially increases the real cost of renewable energy sources. To address these issues, a single power source or an aggregated collection of power resources can be controlled. Such resources may include load, generation, or storage.

[0157] In the case of unexpected drop-off in electricity production, managed power resources can reduce their electricity consumption. Power resources capable of reverse energy flow may also contribute electricity back to the grid. In the case of an unexpected spike in electricity production, managed power resources can consume the surplus electricity by increasing their rate of energy consumption, or by other means. A collection of power resources could be managed using at least two distinct strategies: smoothing and leveling.

[0158] In a smoothing method, the rate of change of power output can be limited. When a sudden increase or decrease in power production occurs, the managed power resources can be used to spread this sudden change over more time. As an example, a sudden drop-off in wind production from 10 MW to 0 MW could be spread out over 20 minutes (using stored power, deferred charging, and other shifts in net power draw), affording the utility additional time to locate replacement power sources or otherwise address the shortfall.

[0159] In a leveling method, the overall contribution of the generation resources to the grid can be balanced by the power resources to provide a desired level of net generation. In an embodiment, such methods are used when output from a wind farm falls below a desired level. A collection of aggregated resources, such as plug-in vehicles, are dispatched to absorb the power drop. Some of the plug-in vehicles are requested to stop charging, or to charge at a lower rate. With a sufficiently large and capable collection of distributed power resources, leveling could increase the reliability of renewables to the same level as conventional power sources.

[0160] In an embodiment, leveling may be more valuable than smoothing to an utility or other operator. However, leveling may require a large amount of reserve capacity relative to the amount of renewable energy being managed. Smoothing can provide substantial benefit while requiring a smaller population of distributed energy resources.

[0161] FIG. **12** illustrates an embodiment of power flow management that detects a change in an intermittent power flow **1210** and implements a power flow strategy in response to the change in the intermittent power flow **1220**. The power flow strategy may be a smoothing strategy or a leveling strategy.

CONCLUSION

[0162] Although systems and methods have been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as examples of implementations of the claimed methods, devices, systems, etc. It will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A method for managing power flow, comprising the steps of:
- controlling a plurality of power resources via Automatic Generation Control (AGC) commands, wherein the AGC commands are transmitted by a power flow manager to the plurality of power resources, wherein the AGC commands request power regulation;
- apportioning the power regulation to the plurality of power resources based on an apportionment scheme; and,
- transmitting an AGC command to at least one of the plurality of power resources, wherein the AGC command requests an apportioned amount of the power regulation from the at least one of the plurality of power resources.

2. The method of claim **1**, wherein the power regulation is frequency regulation.

3. The method of claim **1**, wherein the power regulation is power generation.

4. The method of claim **1**, wherein the power regulation is power consumption.

5. The method of claim **1**, wherein the power regulation is requested in response to a power surplus event, and wherein the power regulation requests a decrease in power.

6. The method of claim **1**, wherein the power regulation is requested in response to a power shortage event, and wherein the power regulation requests an increase in power.

7. The method of claim **1**, wherein the power regulation is bi-directional, wherein the power regulation requests an increase in power from a first power resource and requests a decrease in power from a second power resource.

8. The method of claim **1**, furthering comprising:
- setting at least one of the plurality of power resources to consume or generate at a maximum rate; and,
- adjusting power consumption or power generation for the at least one of the plurality of power resources in response to the AGC commands, wherein the power consumption is decreased or the power generation is increased during a power shortage, wherein the power consumption is increased or the power generation is decreased during a power surplus.

9. The method of claim **1**, wherein the apportionment scheme relates to factor selected from a group consisting of the following: power range of each of the plurality of power resources; power range of a portion of the plurality of power resources; minimization of communications to the plurality of power resources; fairness to the plurality of power resources; maximization future abilities to provide power services by the plurality of power resources; preferences of the plurality of power resources; or, requirements of the plurality of power resources.

10. The method of claim **1**, wherein the power resources are electric vehicles.

11. A method for managing power flow, comprising the steps of:

controlling a plurality of power resources via Automatic Generation Control (AGC) commands, wherein the AGC commands are transmitted by a power flow manager to the plurality of power resources, wherein the AGC commands request power regulation;

determining a power regulation range for at least one of the plurality of power resources; and,

transmitting an AGC command to the at least one of the plurality of power resources, wherein the AGC command is based on the power regulation range for the at least one of the plurality of power resources.

12. The method of claim **11**, wherein the AGC command comprises a power level set point, wherein the power level set point is within the power regulation range for the at least one of the plurality of power resources.

13. The method of claim **12**, wherein the power level set point is negative.

14. The method of claim **13**, wherein the power flow manager treats the negative power level set point as requests for power consumption.

15. The method of claim **13**, wherein the power regulation range for the at least one of the plurality of power resources shifts, whereby the negative power level set point is set to zero, wherein the an offset amount becomes a load amount.

16. The method of claim **11**, wherein the AGC command comprises a relative power request, wherein the relative power request increases or decreases power relative a current power level, and wherein the power increase or power decrease is within the power regulation range for the at least one of the plurality of power resources.

17. The method of claim **11**, furthering comprising:

adjusting a net balance of power supply and power demand for the plurality of power resources; and,

aggregating power from the plurality of power resources.

18. The method of claim **11**, wherein the power resources are electric vehicles.

19. A method for managing power flow, comprising the steps of:

detecting a change in an intermittent power flow, wherein a power flow manager detects the change in the intermittent power flow; and,

implementing a power flow strategy in response to the change in the intermittent power flow, wherein the power flow manager coordinates a plurality of power resources to respond to the change in the intermittent power flow.

20. The method for claim **19**, wherein the power flow strategy is a smoothing strategy, wherein the plurality of power resources are utilized to spread the change in the intermittent power flow over a time period.

21. The method for claim **20**, wherein the smoothing strategy utilizes stored power, deferred charging, or shifts in net power draw.

22. The method for claim **19**, wherein the power flow strategy is a leveling strategy, wherein the plurality of power resources are utilized to balance the change in the intermittent power flow.

23. The method for claim **22**, wherein the leveling strategy requests an adjustment to charging rates of a portion of the plurality of power resources.

24. The method of claim **19**, wherein the power resources are electric vehicles.

* * * * *