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(54) SYSTEMS AND METHODS FOR ELECTRIC VEHICLE POWER FLOW MANAGEMENT

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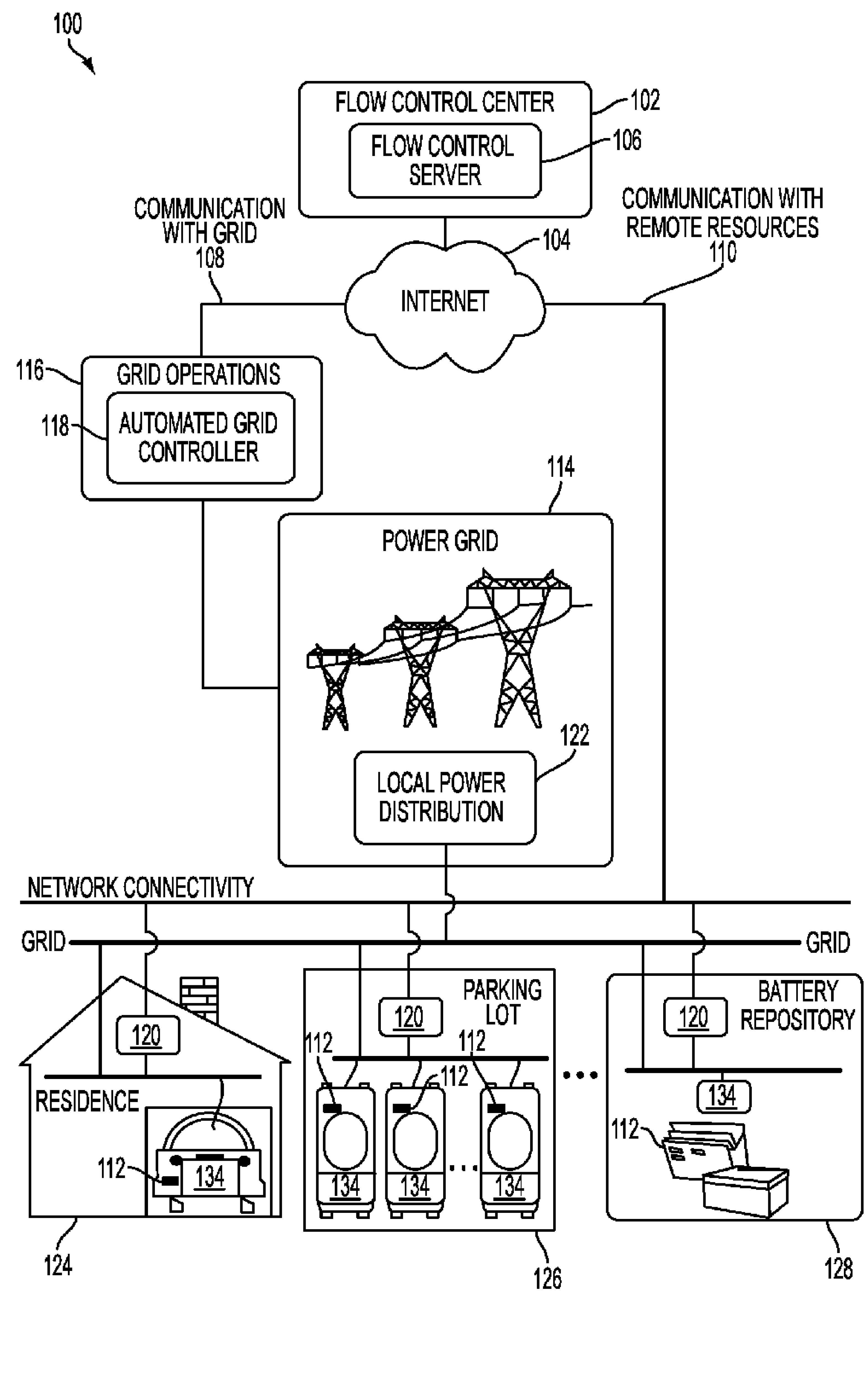
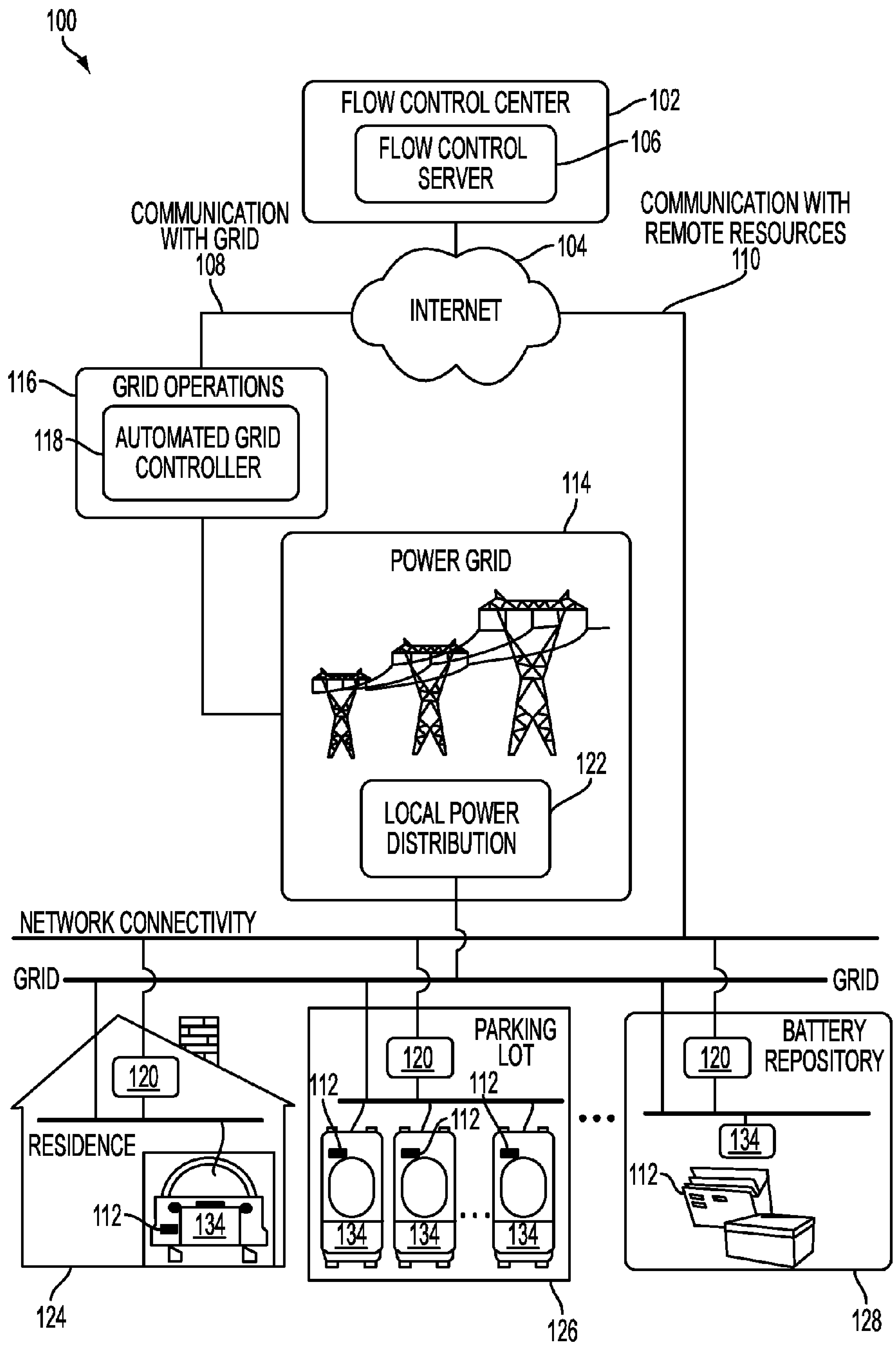
(57) ABSTRACT

A system and methods that enables power flow management at the local level. A power flow manager can coordinate the charging activities of electrical devices, such as electric vehicles. Power flow decisions may based on the site-level information. In addition, power flow management strategies may be optimized. An optimizer can choose a power flow management strategy and electrical devices for implementing a strategy. In the event of a system failure, power spikes may be avoided by using safe failure modes to provide that the charging activities be coordinated in a predictable and non-disruptive manner. The cost of providing power may be reduced using generation stacks of power production. As such, the total daily cost of providing energy generation may be minimized.

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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
PARKING LOT
120
112
112
112
134
134
134
BATTERY REPOSITORY
120
134
112
124
126
128

FIG. 1

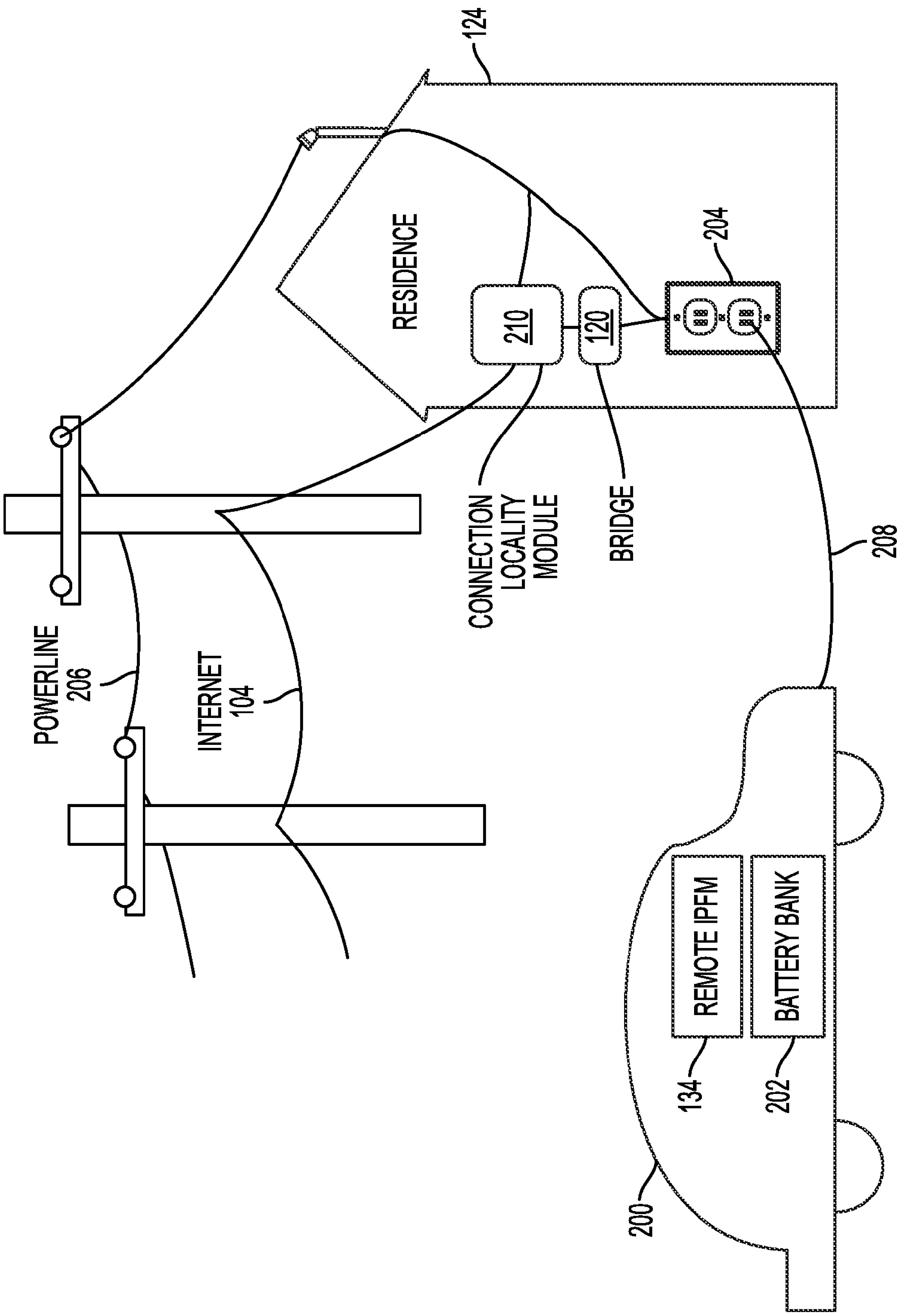
124
RESIDENCE
210
120
204
CONNECTION LOCALITY MODULE
BRIDGE
POWERLINE 206
INTERNET 104
208
REMOTE IPFM
BATTERY BANK
134
202
200

FIG. 2A

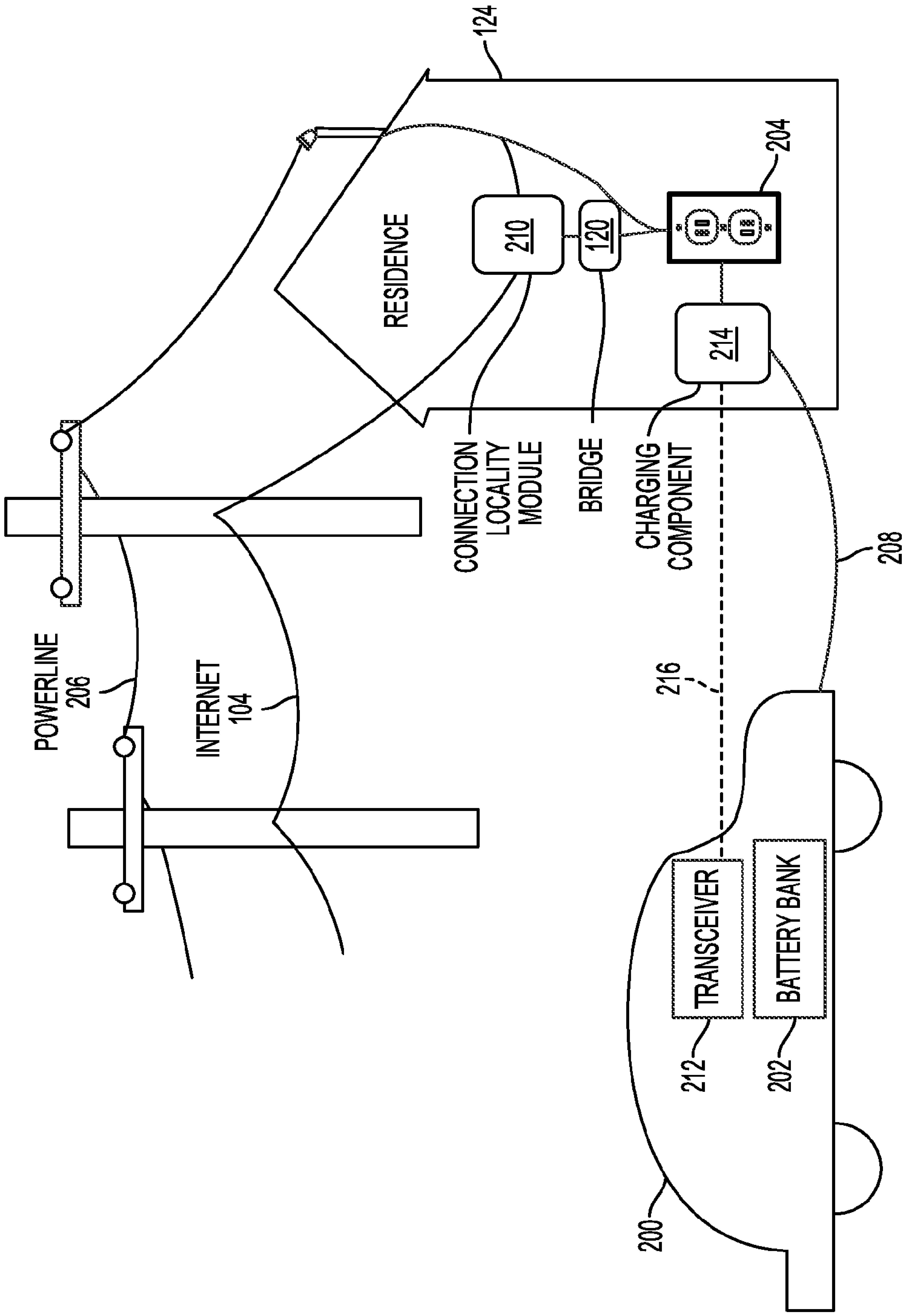
124
204
RESIDENCE
210
120
214
CONNECTION LOCALITY MODULE
BRIDGE
CHARGING COMPONENT
POWERLINE 206
INTERNET 104
208
216
TRANSCEIVER
BATTERY BANK
212
202
200

FIG. 2B

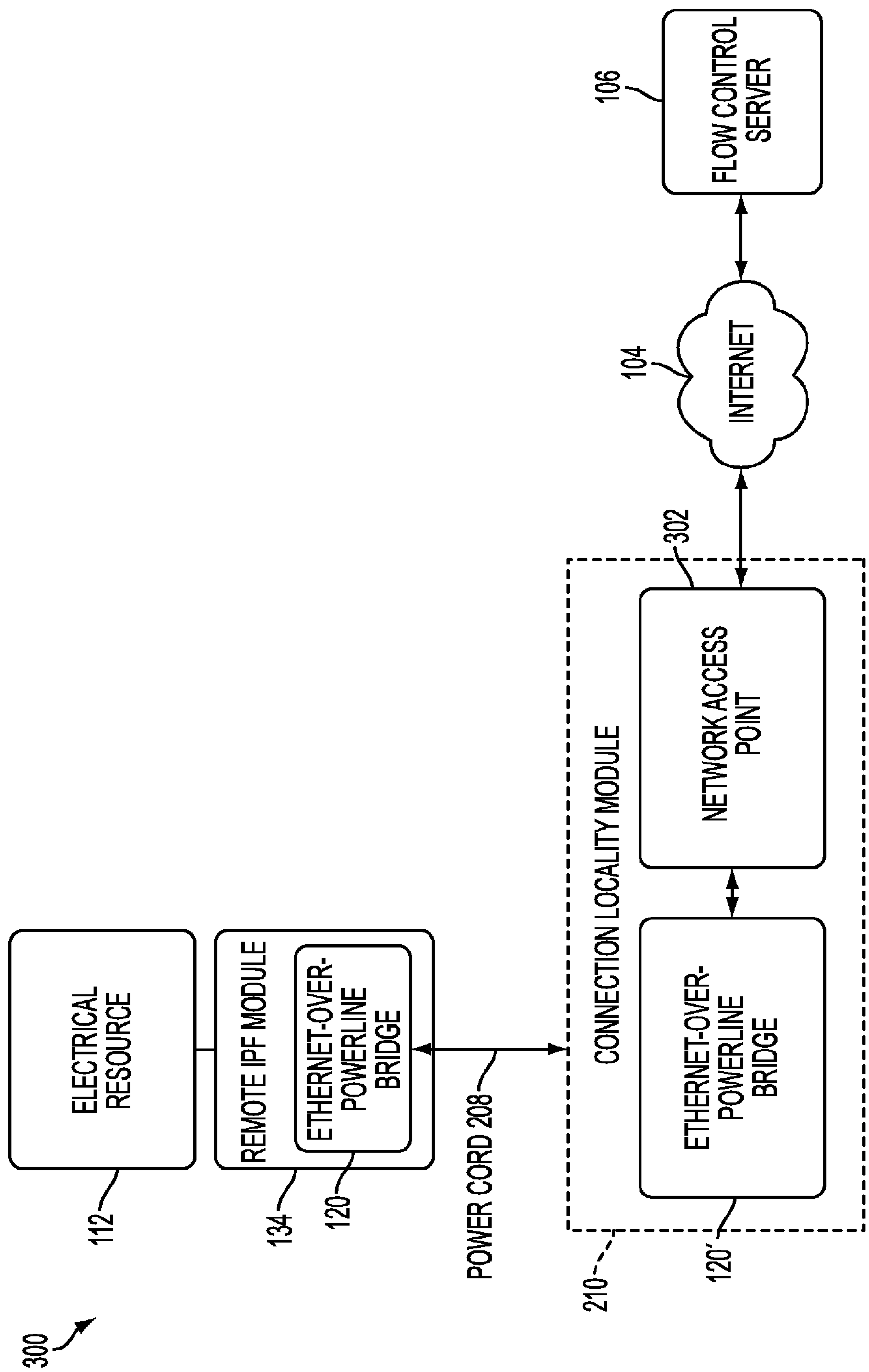
300
ELECTRICAL RESOURCE
112
REMOTE IPF MODULE
ETHERNET-OVER-POWERLINE BRIDGE
134
120
POWER CORD 208
CONNECTION LOCALITY MODULE
ETHERNET-OVER-POWERLINE BRIDGE
NETWORK ACCESS POINT
210
120'
302
INTERNET
104
FLOW CONTROL SERVER
106

FIG. 3

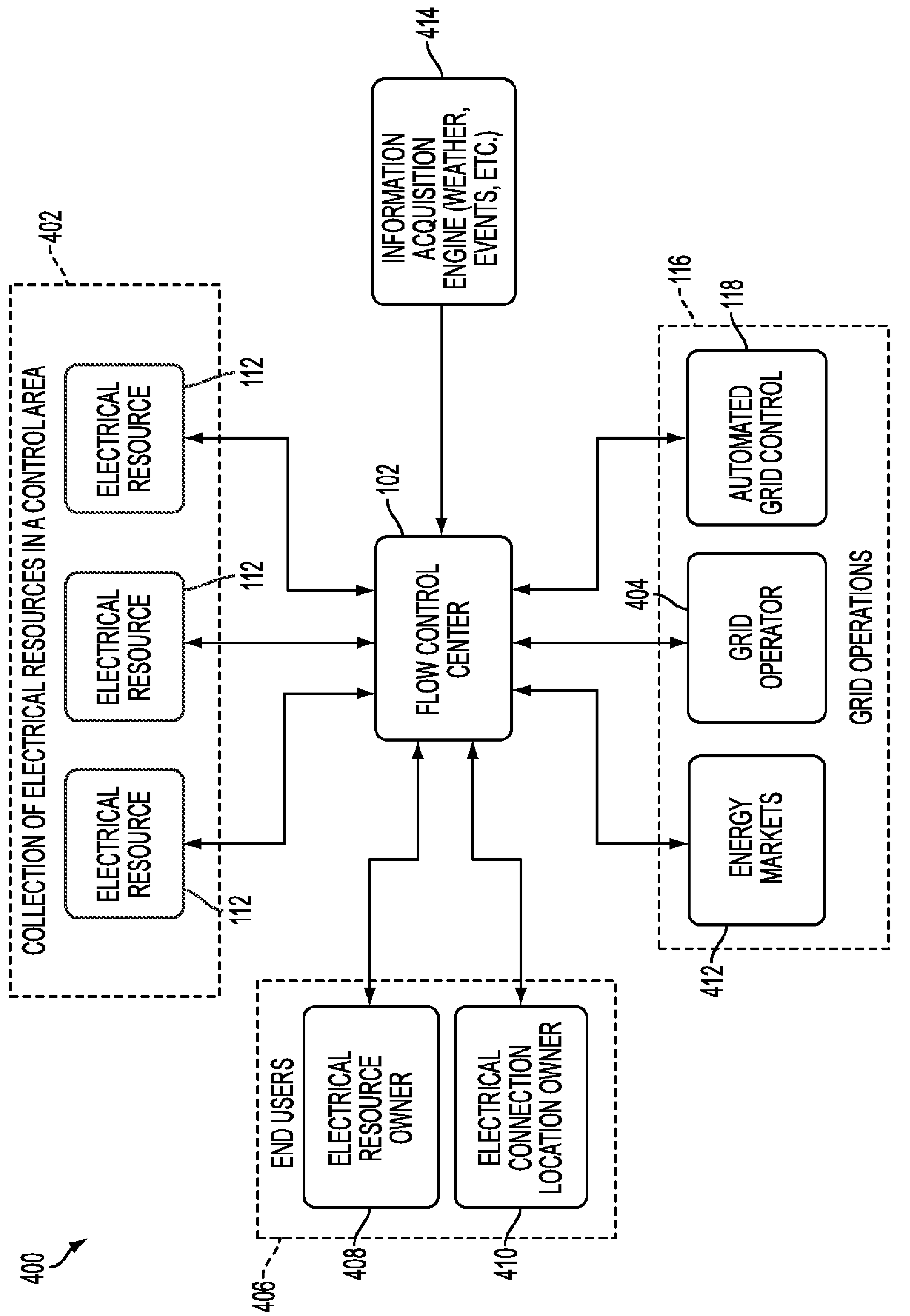
400
402
COLLECTION OF ELECTRICAL RESOURCES IN A CONTROL AREA
ELECTRICAL RESOURCE
ELECTRICAL RESOURCE
ELECTRICAL RESOURCE
112
112
112
414
INFORMATION ACQUISITION ENGINE (WEATHER, EVENTS, ETC.)
102
FLOW CONTROL CENTER
116
118
AUTOMATED GRID CONTROL
404
GRID OPERATOR
ENERGY MARKETS
412
GRID OPERATIONS
406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

FIG. 4

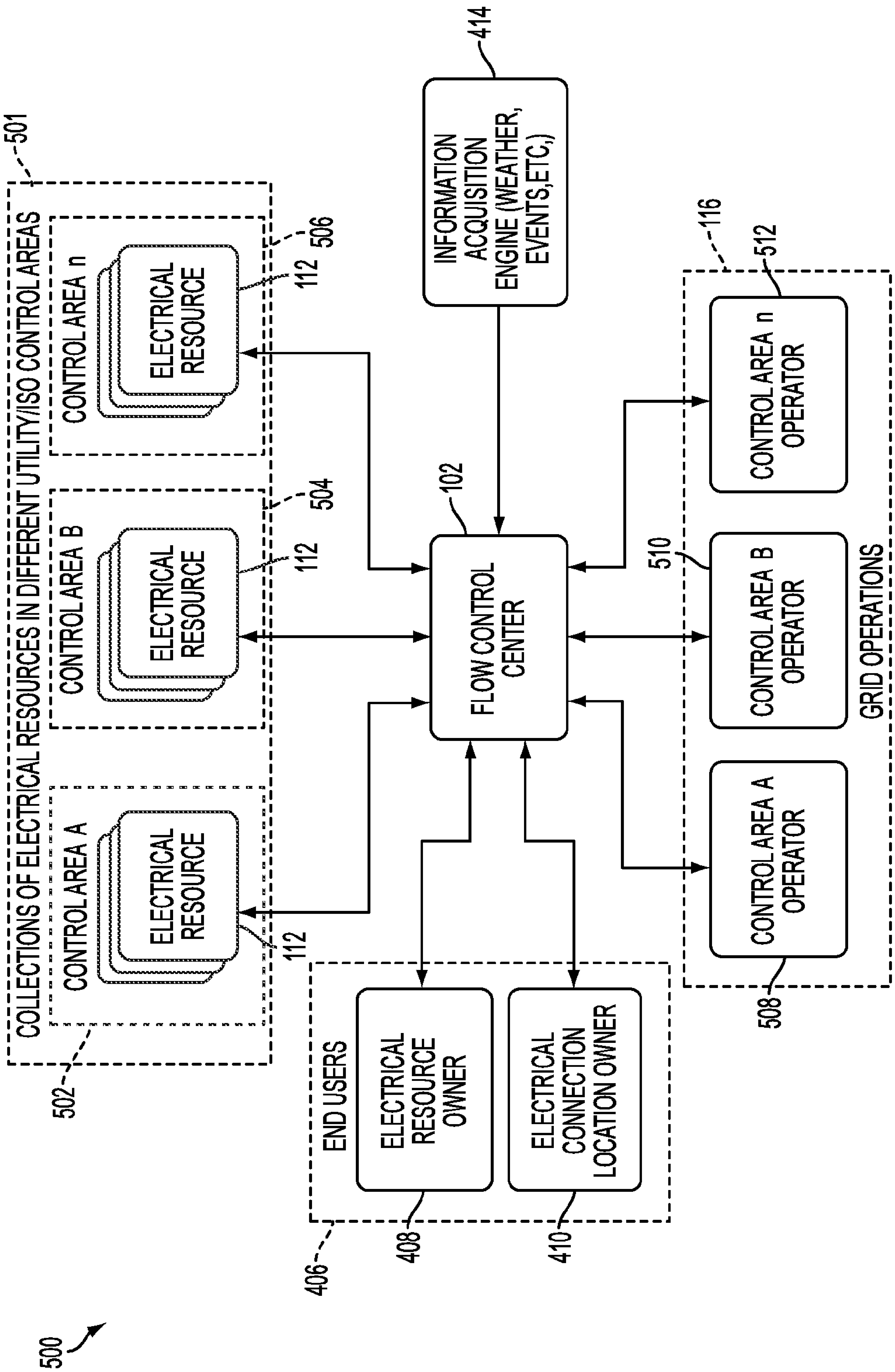
500
COLLECTIONS OF ELECTRICAL RESOURCES IN DIFFERENT UTILITY/ISO CONTROL AREAS
501
CONTROL AREA A
502
ELECTRICAL RESOURCE
112
CONTROL AREA B
504
ELECTRICAL RESOURCE
112
CONTROL AREA n
506
ELECTRICAL RESOURCE
112
INFORMATION ACQUISITION ENGINE (WEATHER, EVENTS,ETC,)
414
FLOW CONTROL CENTER
102
END USERS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

FIG. 5

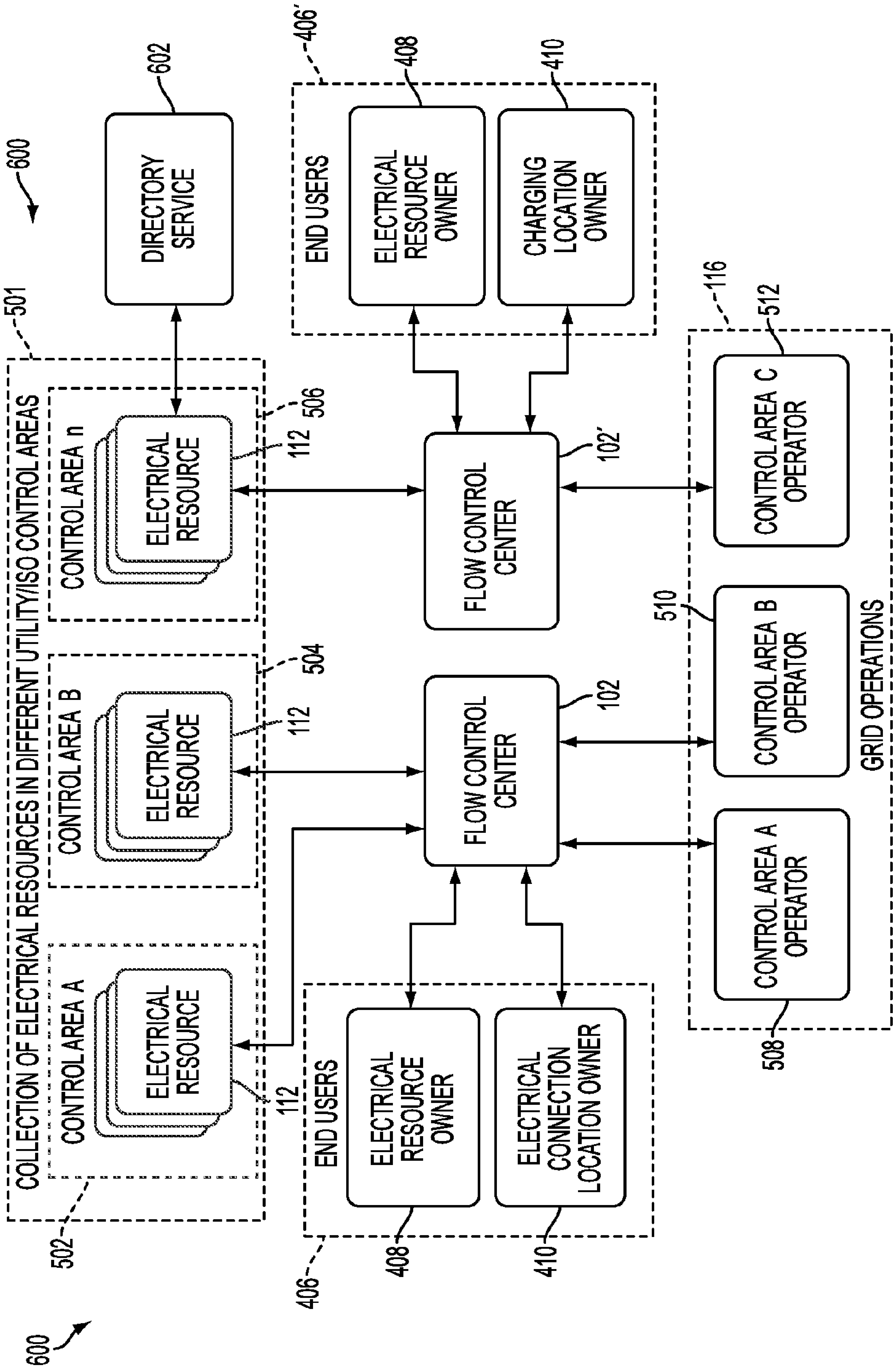
600
COLLECTION OF ELECTRICAL RESOURCES IN DIFFERENT UTILITY/ISO CONTROL AREAS
501
CONTROL AREA A
ELECTRICAL RESOURCE
112
502
CONTROL AREA B
ELECTRICAL RESOURCE
112
504
CONTROL AREA n
ELECTRICAL RESOURCE
112
506
DIRECTORY SERVICE
602
FLOW CONTROL CENTER
102
FLOW CONTROL CENTER
102'
END USERS
ELECTRICAL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

FIG. 6

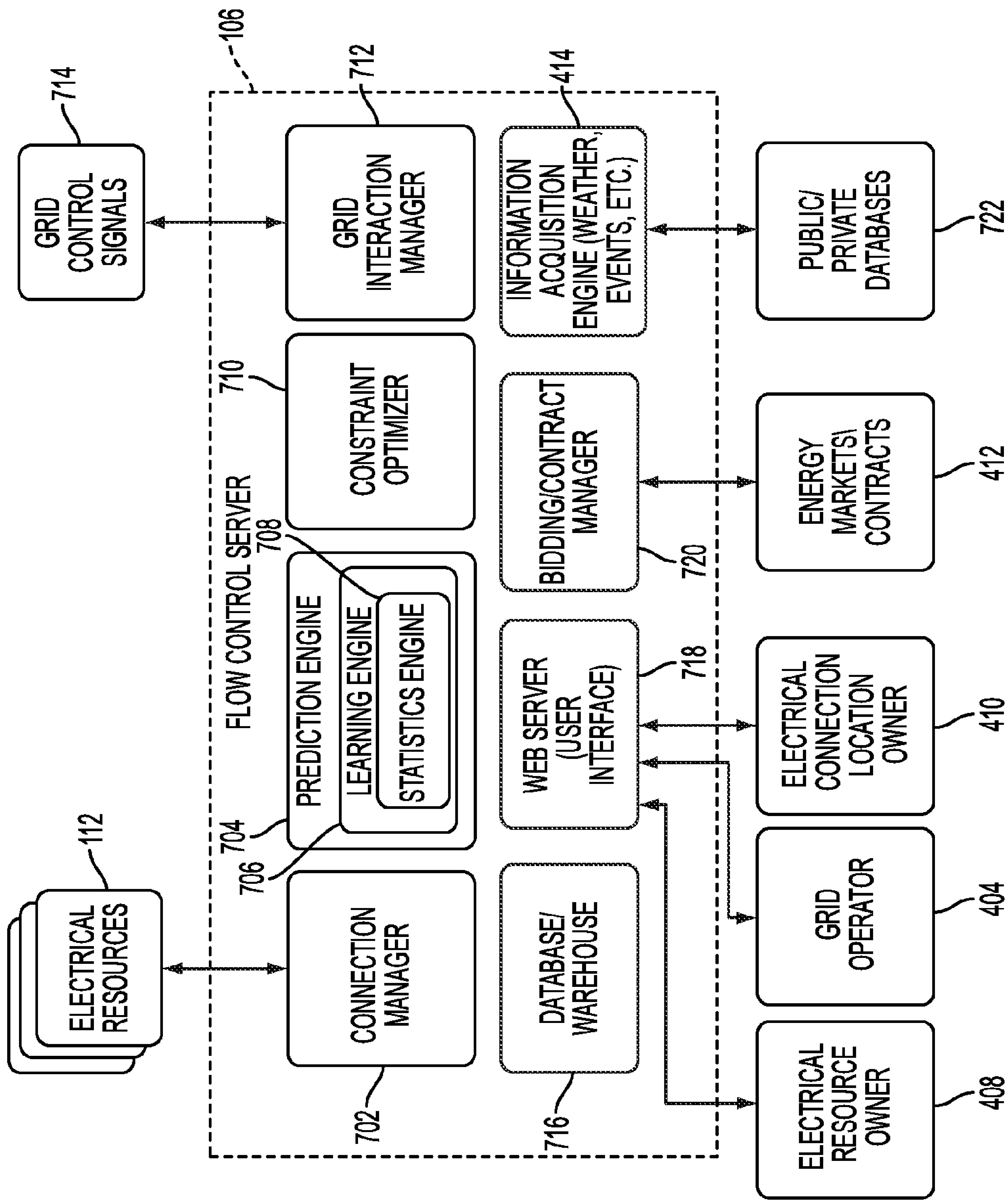
106
FLOW CONTROL SERVER
GRID CONTROL SIGNALS
714
ELECTRICAL RESOURCES
112
CONNECTION MANAGER
702
PREDICTION ENGINE
704
LEARNING ENGINE
706
STATISTICS ENGINE
708
CONSTRAINT OPTIMIZER
710
GRID INTERACTION MANAGER
712
DATABASE/ WAREHOUSE
716
WEB SERVER (USER INTERFACE)
718
BIDDING/CONTRACT MANAGER
720
INFORMATION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

FIG. 7

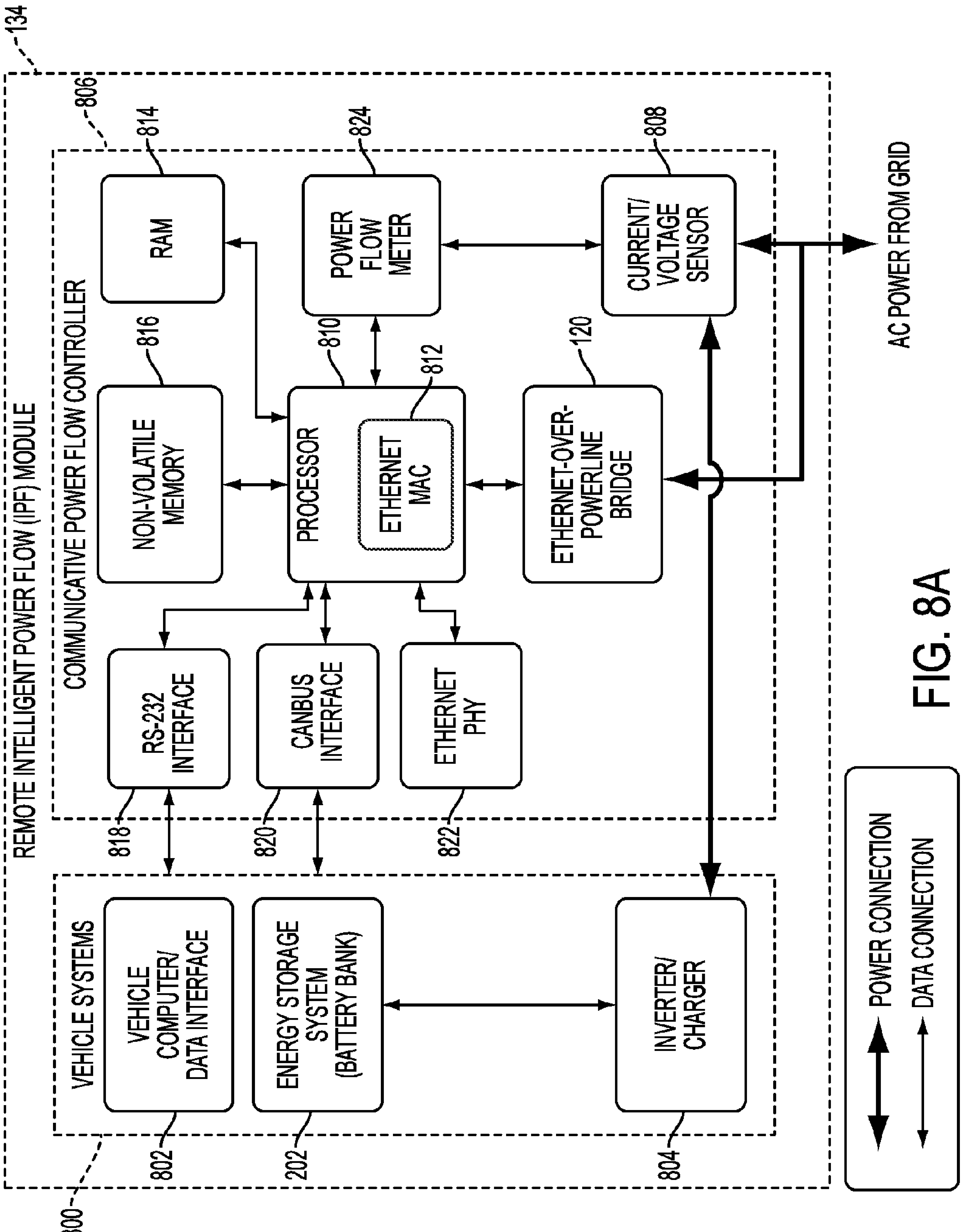
134
REMOTE INTELLIGENT POWER FLOW (IPF) MODULE
806
COMMUNICATIVE POWER FLOW CONTROLLER
814
RAM
816
NON-VOLATILE MEMORY
810
PROCESSOR
812
ETHERNET MAC
824
POWER FLOW METER
808
CURRENT/ VOLTAGE SENSOR
120
ETHERNET-OVER-POWERLINE BRIDGE
AC POWER FROM GRID
RS-232 INTERFACE
818
CANBUS INTERFACE
820
ETHERNET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

FIG. 8A

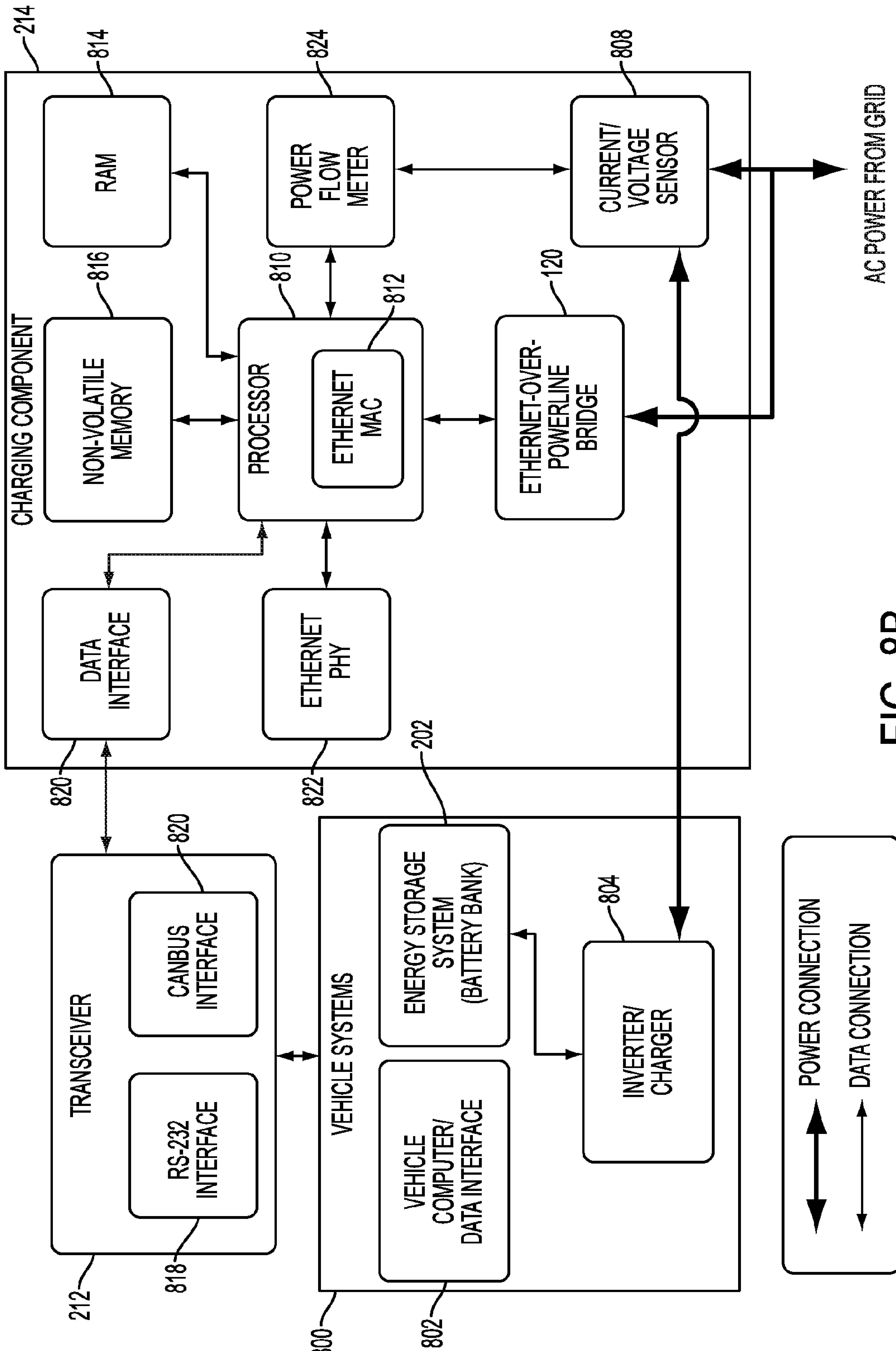
214
CHARGING COMPONENT
814
RAM
816
NON-VOLATILE MEMORY
810
PROCESSOR
812
ETHERNET MAC
824
POWER FLOW METER
808
CURRENT/ VOLTAGE SENSOR
120
ETHERNET-OVER-POWERLINE BRIDGE
DATA INTERFACE
820
ETHERNET PHY
822
AC POWER FROM GRID
212
TRANSCEIVER
820
CANBUS INTERFACE
818
RS-232 INTERFACE
800
VEHICLE SYSTEMS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

FIG. 8B

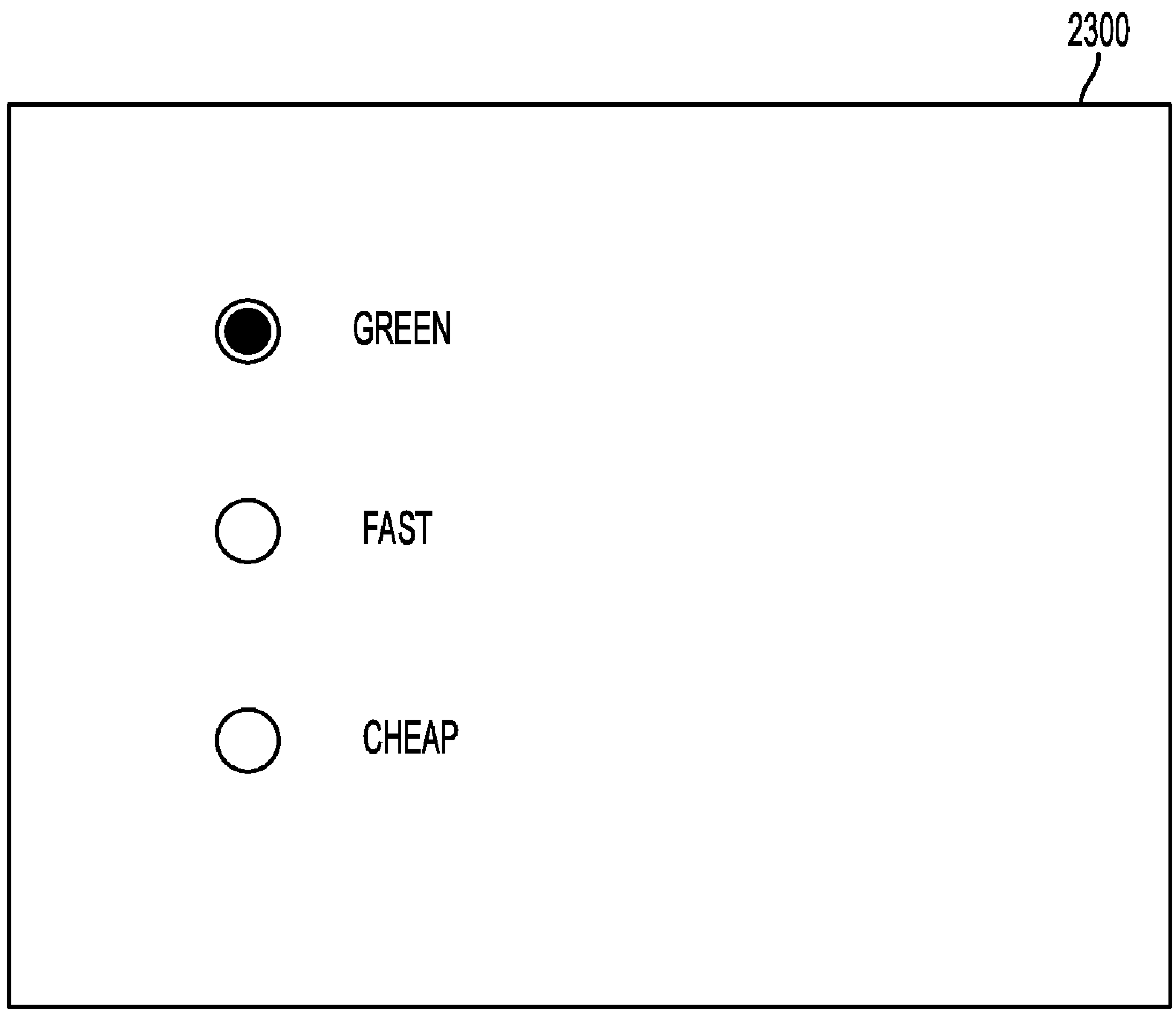

FIG. 8C

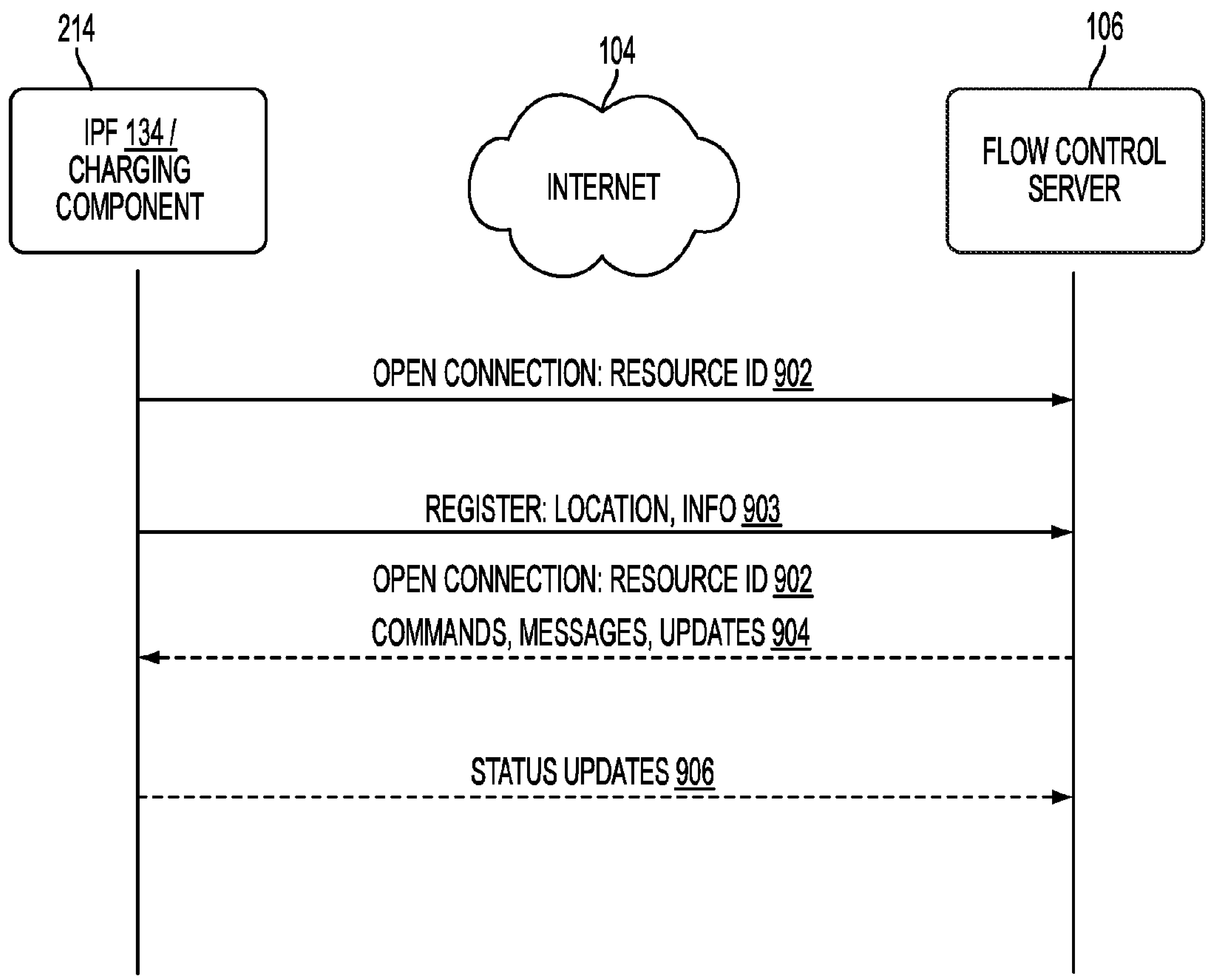
214
IPF 134 / CHARGING COMPONENT
104
INTERNET
106
FLOW CONTROL SERVER
OPEN CONNECTION: RESOURCE ID 902
REGISTER: LOCATION, INFO 903
OPEN CONNECTION: RESOURCE ID 902
COMMANDS, MESSAGES, UPDATES 904
STATUS UPDATES 906

FIG. 9

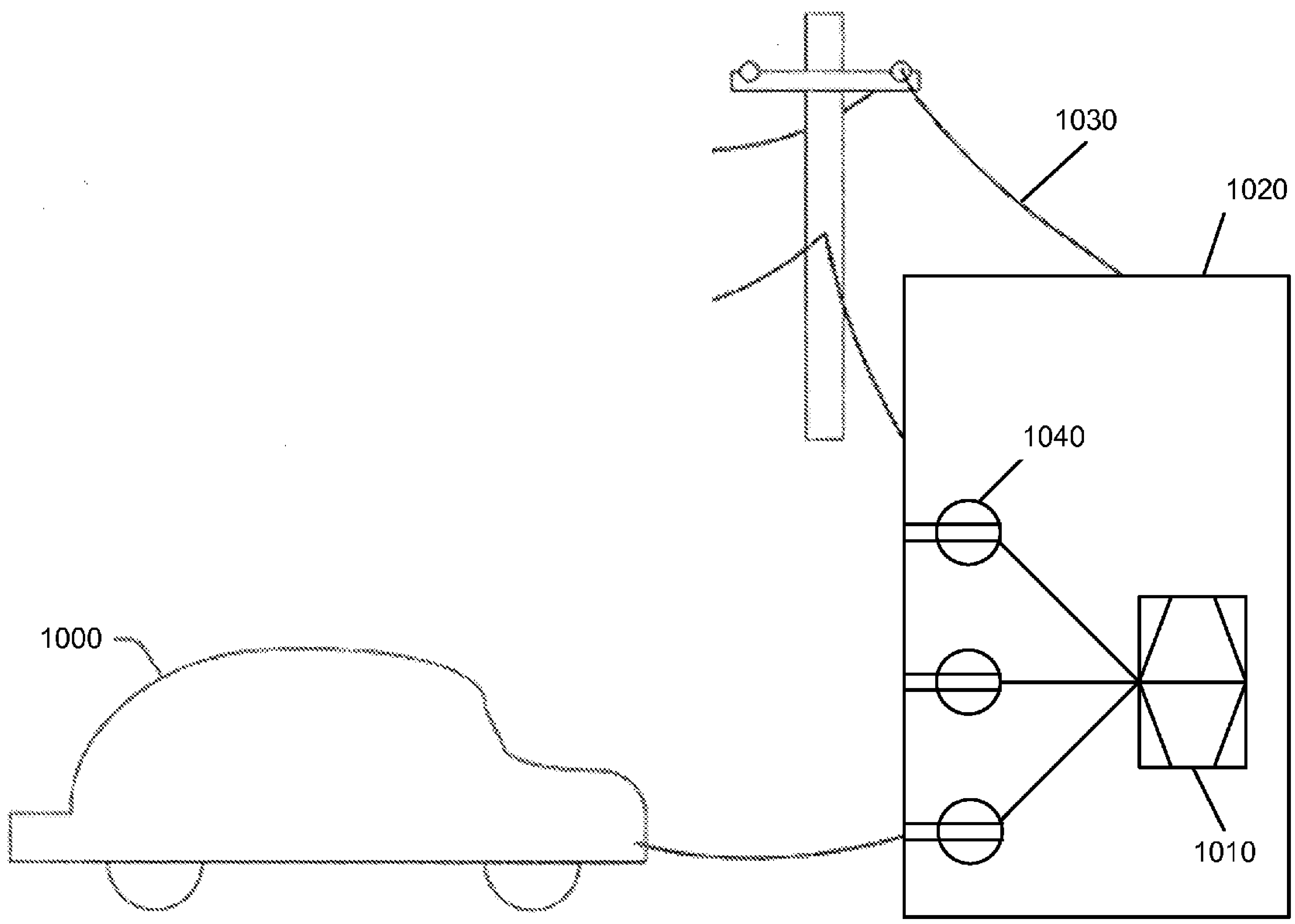

FIG. 10

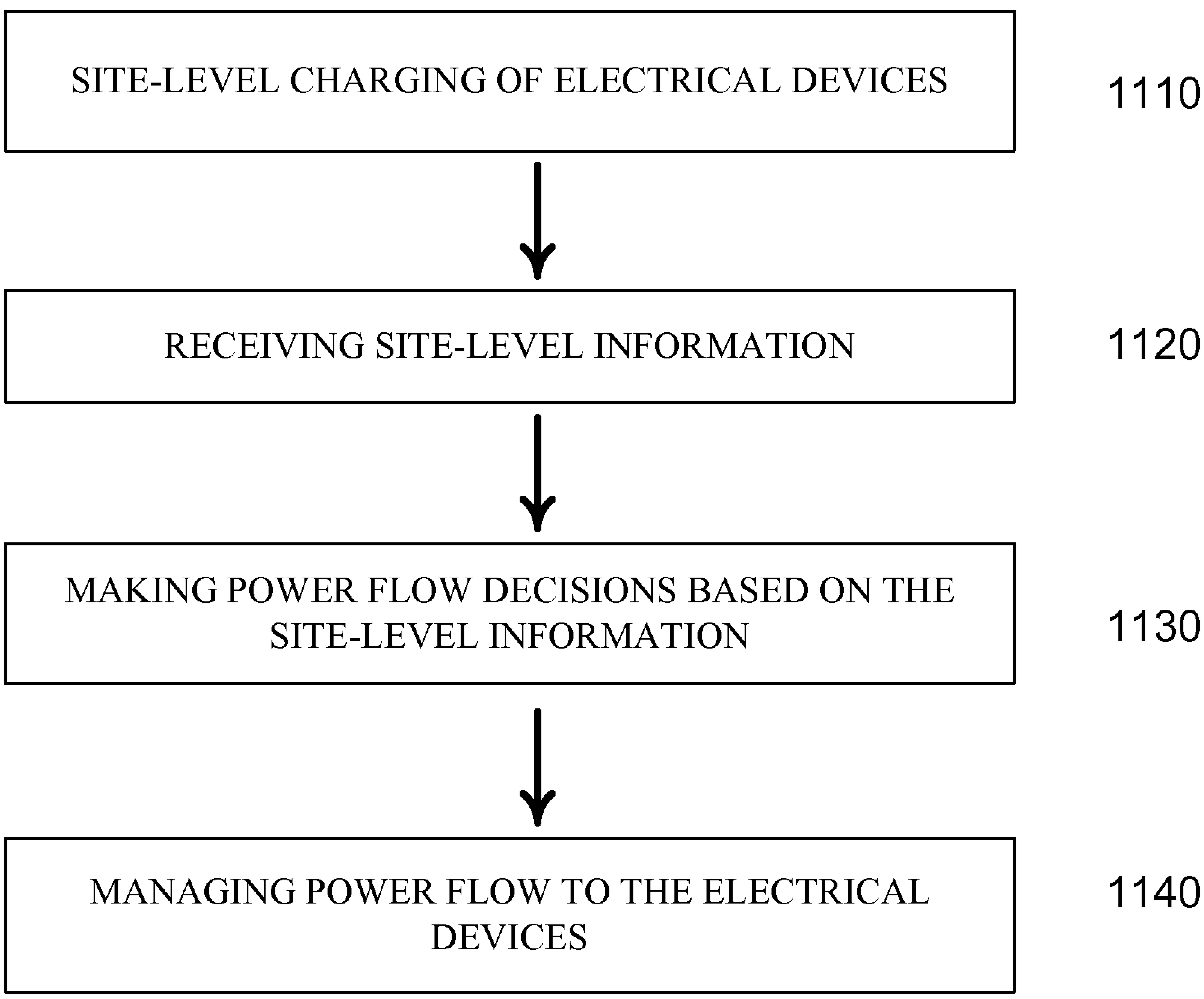
SITE-LEVEL CHARGING OF ELECTRICAL DEVICES
1110
RECEIVING SITE-LEVEL INFORMATION
1120
MAKING POWER FLOW DECISIONS BASED ON THE SITE-LEVEL INFORMATION
1130
MANAGING POWER FLOW TO THE ELECTRICAL DEVICES
1140

FIG. 11

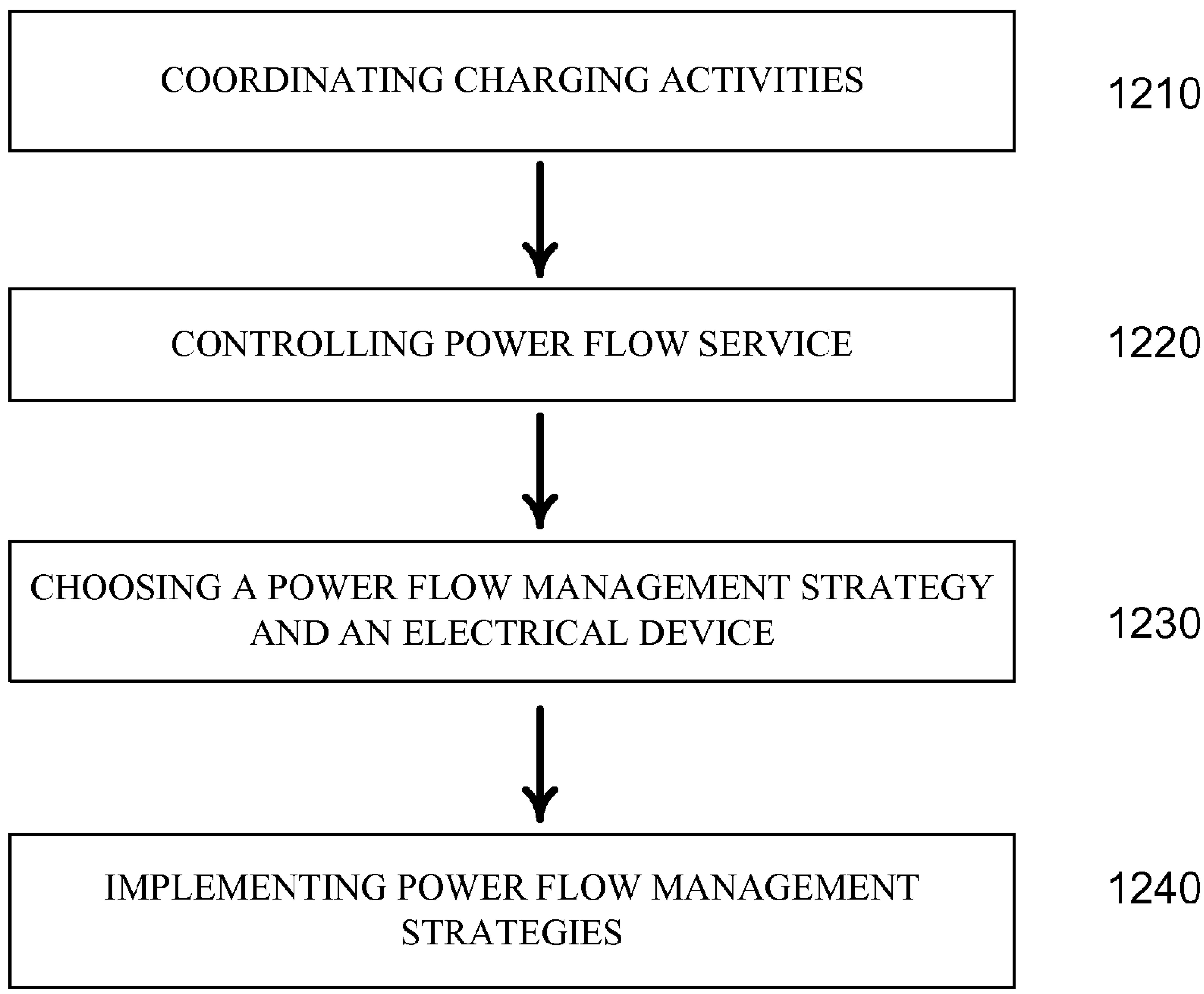
COORDINATING CHARGING ACTIVITIES
1210
CONTROLLING POWER FLOW SERVICE
1220
CHOOSING A POWER FLOW MANAGEMENT STRATEGY AND AN ELECTRICAL DEVICE
1230
IMPLEMENTING POWER FLOW MANAGEMENT STRATEGIES
1240

FIG. 12

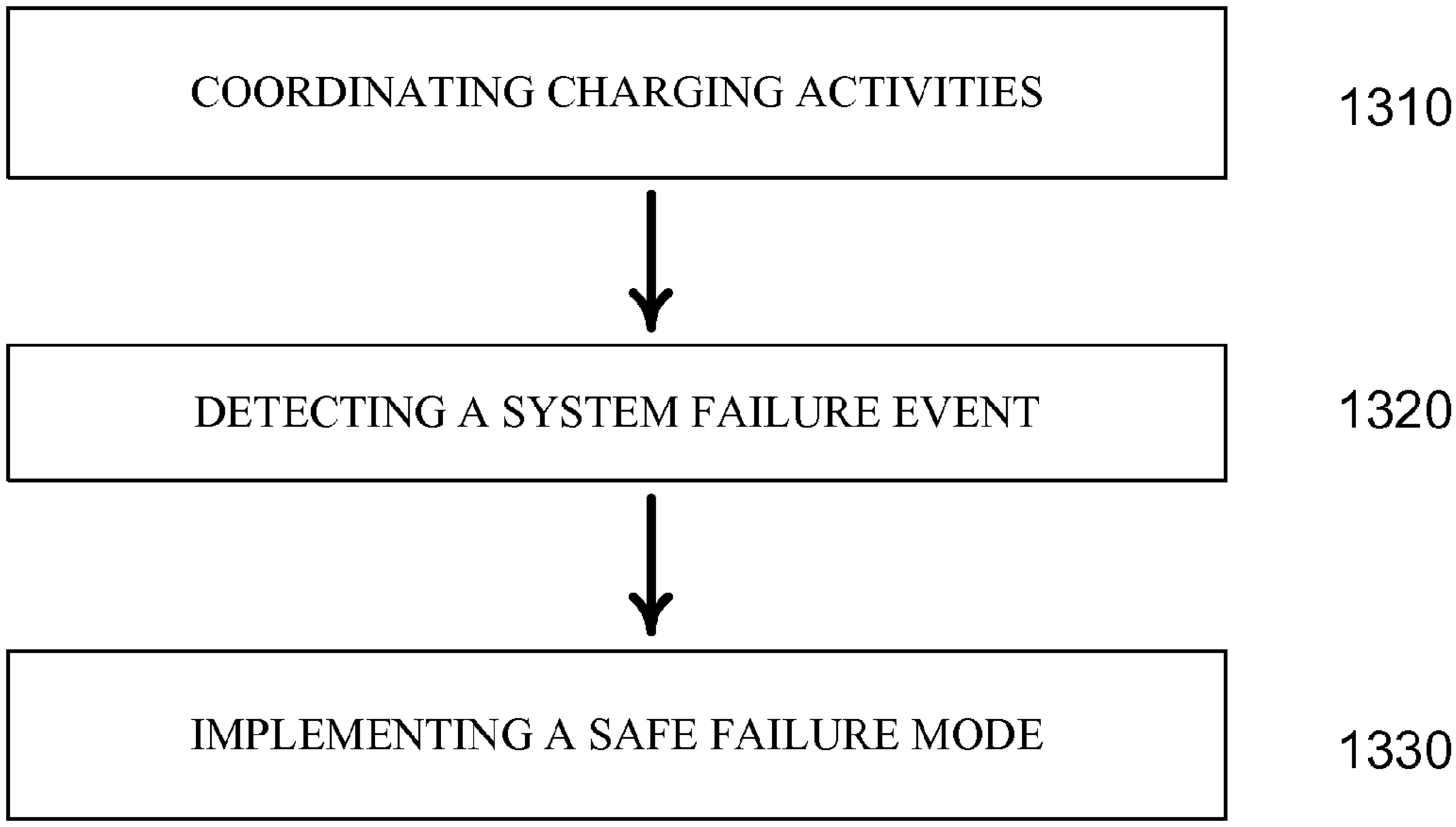
COORDINATING CHARGING ACTIVITIES
1310
DETECTING A SYSTEM FAILURE EVENT
1320
IMPLEMENTING A SAFE FAILURE MODE
1330

FIG. 13

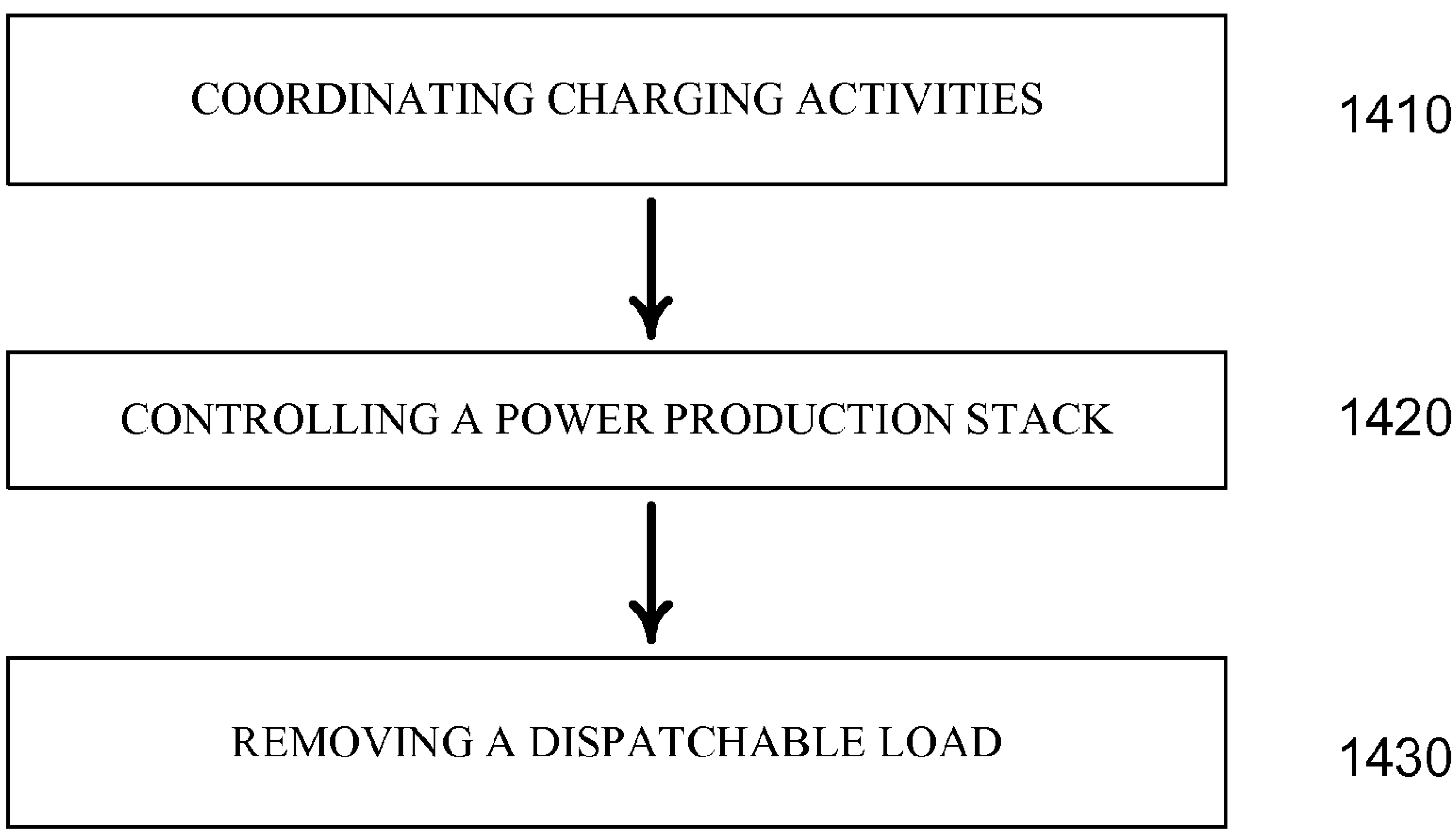
COORDINATING CHARGING ACTIVITIES
1410
CONTROLLING A POWER PRODUCTION STACK
1420
REMOVING A DISPATCHABLE LOAD
1430

FIG. 14

SYSTEMS AND METHODS FOR ELECTRIC VEHICLE POWER FLOW MANAGEMENT

[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.

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 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). Distributed electric resources, en masse can, in principle, provide a significant resource for addressing the above problems. However, current power services infrastructure lacks provisioning and flexibility that are required for aggregating a large number of small-scale resources, such as electric vehicle batteries, to meet large-scale needs of power services.

[0006] Modern Electric vehicles could benefit in a variety of ways from a centrally controlled smart charging program, wherein a central server coordinates the charging activities of a number of vehicles. Significant opportunities for improvement exist in managing power flow at local level. 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 provide a significant economic opportunity. Technologies can be enabled to provide broader use of intermittent power sources, such as wind and solar. What is needed are power flow management systems and methods that manage power flow at the site-level, that implement various power flow strategies for the optimizing how to dispatch the resources under management, that avoid power spikes, and that minimize the total daily cost of providing energy generation.

SUMMARY OF THE INVENTION

[0007] In an embodiment, a method for managing power flow at a local site includes site-level charging of electrical devices by a power flow manager. The power flow manager runs a smart charging program, and coordinates charging activities of the electrical devices. The electrical devices may be located at the local site. The method includes receiving site-level information, which is received by the power flow manager. In addition, power flow decisions are made, by the power flow manager, based on the site-level information. Further, power flow to the electrical devices is managed by the power flow manager, wherein the power flow manager responds to requests.

[0008] In another embodiment, a method for managing power flow by optimizing multiple power flow management strategies includes coordinating charging activities of electrical devices. The charge activities are coordinated by a power flow manager. Power flow services are also controlled by the power flow manager. A power flow management strategy is chosen by a meta-optimizer, which also chooses the electrical devices to utilize for implementing the power flow management strategy. The power flow management strategies are implemented by the power flow manager.

[0009] In one embodiment, a method for managing power flow using safe failure modes includes coordinating charging activities of electrical devices by a power flow manager. The method includes detecting a system failure event by a power flow manager, and implementing a safe failure mode. The safe failure mode implemented by the power flow manager provides that the charging activities be coordinated in a predictable and non-disruptive manner.

[0010] In another embodiment, a method for managing power flow uses generation stacks of power production to reduce cost of providing power to electrical devices. This method also includes coordinating charging activities of electrical devices by a power flow manager. In addition, the power flow manager controls a power production stack, which orders available power. A dispatchable load is listed in the power production stack. The dispatchable load is removed based on a cost reduction 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. **2**A-**2**B 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 diagram of an example of a site power flow manager.

[0024] FIG. **11** is a flow chart of an example of a site power flow manager.

[0025] FIG. **12** is a flow chart of an example of optimization across multiple power flow management strategies.

[0026] FIG. **13** is a flow chart of an example of avoiding power spikes during energy management failures using safe failure modes.

[0027] FIG. **14** is a flow chart of an example of generation-stack-aware dispatch of resources.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0028] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

[0029] Overview

[0030] 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).

[0031] "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.

[0032] "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.

[0033] "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.

[0034] "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.

[0035] "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.

[0036] "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.

[0037] "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.

[0038] "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.

[0039] "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.

[0040] "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.

[0041] 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.

[0042] An Example of the Presently Disclosed System

[0043] 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**.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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**.

[0048] 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**.

[0049] 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.

[0050] 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™, 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.

[0051] 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.

[0052] 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.

[0053] 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**.

[0054] 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™ 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.

[0055] Further details about the transceiver **212** and charging component **214** are illustrated by FIG. **8**B and described in greater detail herein.

[0056] 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**.

[0057] 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**.

[0058] 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.

[0059] System Layouts

[0060] 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.

[0061] 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**.

[0062] Electrical connection location owners **410** can include:

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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**.

[0068] 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**.

[0069] 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**.

[0070] Thus, a power aggregation system **100** may consist of components that:

[0071] communicate with the electric resources **112** to gather data and actuate charging/discharging of the electric resources **112**;

[0072] gather real-time energy prices;

[0073] gather real-time resource statistics;

[0074] 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);

[0075] predict behavior of the power grid **114**/load;

[0076] encrypt communications for privacy and data security;

[0077] actuate charging of electric vehicles **200** to optimize some figure(s) of merit;

[0078] offer guidelines or guarantees about load availability for various points in the future, etc.

[0079] 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).

[0080] 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.

[0081] 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**.

[0082] 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**.

[0083] 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.

[0084] 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.

[0085] 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**.

[0086] 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'**.

[0087] Flow Control Server

[0088] 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.

[0089] 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.

[0090] Remote IPF Module

[0091] 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.

[0092] 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**.

[0093] 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.

[0094] 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**.

[0095] 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**.

[0096] 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:

[0097] an intra-vehicle communications mechanism that enables communication with other vehicle components;

[0098] a mechanism to communicate with the flow control center **102**;

[0099] a processing element;

[0100] a data storage element;

[0101] a power meter; and

[0102] optionally, a user interface.

[0103] Implementations of the communicative power flow controller **806** can enable functionality including:

[0104] executing pre-programmed or learned behaviors when the electric resource **112** is offline (not connected to Internet **104**, or service is unavailable);

[0105] 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);

[0106] allowing the user to override current system behavior; and

[0107] metering power-flow information and caching meter data during offline operation for later transaction.

[0108] 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**.

[0109] Power Flow Meter

[0110] 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.

[0111] Transceiver and Charging Component

[0112] FIG. **8**B shows the transceiver **212** and charging component **214** of FIG. **2**B 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.

[0113] 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.

[0114] 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.

[0115] 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™ 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**.

[0116] 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.

[0117] 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.

[0118] 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**.

[0119] 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**.

[0120] 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**.

[0121] 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.

[0122] 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.

[0123] 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.

[0124] Implementations of the charging component **214** can enable functionality including:

- **[0125]** executing pre-programmed or learned behaviors when the electric resource **112** is offline (not connected to Internet **104**, or service is unavailable);
- **[0126]** 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);
- **[0127]** allowing the user to override current system behavior; and
- **[0128]** metering power-flow information and caching meter data during offline operation for later transaction.

[0129] User Interfaces (UI)

[0130] 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.

[0131] 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**.

[0132] 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.

[0133] 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.

[0134] 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.

[0135] 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.

[0136] 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**.

[0137] Electric Resource Communication Protocol

[0138] 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**.

[0139] 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).

[0140] 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.

[0141] 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.

[0142] 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.

[0143] 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**.

[0144] Site Power Flow Manager

[0145] Modern electric vehicles benefit in a variety of ways from a centrally controlled smart charging program where a central server coordinates the charging activities of a number of vehicles. While many such smart charging programs may be operated by electric utilities to control electric vehicles over a wide area, many of the benefits of a smart charging program can be realized at a local level by the operator of a facility operating in isolation from the any other entity. In a place where multiple plug-in vehicles may park and connect to the grid, it is valuable to have site-level charging management.

[0146] As shown in FIG. **10**, the charging process of electric vehicles **1000** is managed by a site power flow manager **1010** at the site-level **1020**. Site-level charging management is an important feature at charging locations where multiple plug-in electric vehicles **1000** may park and connect to the grid **1030**. Such locations/sites **1020** may include public or private parking lots, or the base of operations for a fleet.

[0147] There are a number of benefits for managing the power flow at the site-level. Having control over the flow of power is useful when, for example, the grid connection **1030** at the site **1020** is not capable of supporting every electric vehicle **1000**, and/or other devices on site, that is simultaneously drawing power. In some instances, the wiring to specific charge points **1040** at the site, or to banks of charge points at the site **1020**, may not be capable of supporting every vehicle **1000** drawing power at the same time. Many sites are subject to demand charges based on peak power draw during a time period (e.g. month), so avoiding power spikes can also save money. Furthermore, power usage can be tuned to the specific electric rate structure of the site.

[0148] A site power flow manager **1010** could address these issues, inter alia. Providing a power flow management system at the site-level allows important information to be taken as input, including but not limited to: electrical meter data for the site **1020** as a whole, and/or electrical meter data for specific charge points **1040** or banks of charge points. In addition, the system can consider information from devices, such as plug-in vehicles **1000**, at the site that are connected to the electric grid **1030**. Such information might be transmitted in a variety of ways, including by a power-line carrier or a wireless means. This information may include a unique identifier, resource type, current state of charge, and max power in/out levels. Further, the system can receive information about the electric rate structure of the site, and information about the electrical topology and power limitations of various circuits within the site. A connection to a power flow manager **1010** operates at a higher level of the grid topology, i.e. at the substation level or the control area level, so that the site power flow manager **1010** can receive information and also respond to requests, such as a demand response event, a reserves call, renewable resource following, or system regulation. In one embodiment, the site power flow manager **1010** and the higher level site controller can have priority rules, e.g. not overloading local circuits takes priority over remote requests.

[0149] A site power flow manager **1010** can analyze the current, and the predicted future, state of the world. In doing so, the site power flow manager **1010** can make various determinations, including whether or not to allow certain devices/vehicles **1000** to draw power. In addition, site power flow manager **1010** can request that the devices/vehicles **1000** provide power, and further control the power levels of the devices/vehicles **1000**. These decisions could be made within constraints, such as not overloading a circuit or going over a certain total power draw. Such constraints may be performed, as in one embodiment, with prioritization, such as optimizing to get power to certain devices versus others. For example, the site power flow manager **1010** may charge vehicles **1000** that are at the lowest state of charge, that have been plugged in the longest, or that have priority for recharge. In an embodiment, the site power flow manager **1010** may allow for optimizing with regard to the overall site electric cost minimization or total cost minimization, or to recharge in the greenest, most efficient meaner.

[0150] Decisions made by the site power flow manager **1010** can be carried out in several ways, including controlling relays to open or close certain circuits. In addition, the site power flow manager **1010** can communicate with smart charging points **1040** or smart banks of charging points **1040** to control certain circuits or devices **1000** on those circuits. The site power flow manager **1010** may also communicate with the devices **1000** to give them a request or command for their power flow behavior, such as telling a vehicle **1000** to charge at half power or to recharge in an efficient manner. Such communications may traverse via a smart charging point **1040** or bank thereof. The site power flow manager **1010** may be located at the site **1020** being managed, but can also located remote to the site **1020**.

[0151] FIG. **11** illustrates the site-level charging of electrical devices by a power flow manager **1110**. The power flow manager receives site-level information **1120**, and makes power flow decisions based on the site-level information **1130**. In addition, power flow to the electrical devices is managed by the power flow manager **1140**, such that the power flow manager responds to requests including demand response event, reserves call, renewable resource following, or system regulation.

[0152] Meta-Optimization Across Multiple Power Flow Management Strategies

[0153] Managing one or an aggregation of power resources (such as load, generation, storage, plug-in vehicles), power flow manager can use the combined capabilities of the assets under its control to implement a variety of beneficial services. These services may include regulation, spinning reserve, and/or peak avoidance. Regulation involves increasing or decreasing the load present on the grid in real time in order to maintain balance between power production and power consumption in the entire grid. Spinning reserve provides the ability to quickly make up a large amount of missing power after the failure of a generation or transmission asset within the grid. Peak avoidance results in reducing peak power consumption for the day, which is typically the most expensive power for the utility to provide.

[0154] There are many other similar services, such as to provide capacity or to provide renewable generation following. As the power flow manager may use any number of different strategies to decide how to dispatch the resources under management, it will be understood by those skilled in the art that other strategies, and combinations thereof, may be implemented in various embodiments. In one embodiment, the power flow manager may be a site power flow manager **1010**, as shown in FIG. **10**.

[0155] Such services provide a substantial cost savings to an electric utility. In many circumstances, it is also possible for a utility or other operator to sell these services through an energy market. While each of these services have very distinct characteristics from the perspective of the electric utility, the services are each implemented in fundamentally the same way on the power resource endpoint. That is, by selectively flowing power in to or out of the power resource in response to commands from the central power flow manager.

[0156] Because the same pool of resources can be used to implement each of the possible services, a conflict arises. As an example, If an entire population of electric vehicles is committed entirely to regulation services, that population not be able to fully participate in a peak avoidance program. Because the relative costs and benefits of the various services change over time, it is undesirable to simply pick the most valuable service and commit all the assets to it all of the time.

[0157] Given a set of such strategies, a meta-optimizer decides which strategy to use at appropriate times. The meta-optimizer may be located within the power flow manager. The meta-optimizer determines which resources are to be used in implementing a strategy. The determination may be based on a variety of factors, such as maximizing value generated and/or minimizing environmental impact. In an embodiment, the meta-optimizer chooses the strategy that is likely to generate the most value for a given time period, e.g. the next hour. The implementation may have a value function associated with each strategy, and then take the maximum value across all strategies.

[0158] The decision may vary by grid topological location. For example, if a given feeder is overloaded, the best decision for resources on that feeder may be to reduce the load, even if elsewhere on the grid a different strategy or action may be best.

[0159] The decision may also take into account multiple component requirements. For example, in managing plug-in vehicle recharging, it may be desirable to get vehicles recharged in a timely fashion, while also maximizing value created through other services provided.

[0160] In one embodiment, the decision may be based on predictions about the future. For example, it may be worth a certain amount at hour N to take some action, such as charging plug-in vehicles to provide down regulation. However, if that means the resources might be unavailable at hour N+1, when the resource may be worth more than at hour N, then the meta-optimizer might delay the action so that the resource is available to provide more value.

[0161] FIG. **12** shows an embodiment of a method for managing power flow by optimizing multiple power flow management strategies including coordinating charging activities **1210** and controlling power flow service **1220**. A meta-optimizer can choose a power flow management strategy and an electrical device **1230** such that the power flow manager may implement the power flow management strategies **1240**.

[0162] Avoiding Power Spikes During Energy Management Failures

[0163] Historically, utilities had to depend on the independent and random nature of electrical loads on the grid. While an individual electrical load is unpredictable and can be switched on or off at any time, each load is only a small part of total power consumption. The large number of individual loads on the electrical system provides a form of smoothing. Electrical consumption increases and decreases over time, but the overall change fluctuates along a somewhat predictable curve and power companies are able to adjust power production to match consumption.

[0164] In distributed energy management systems where communications are not 100% reliable, it is important that no loss of communications between the elements of the system or unexpected system controller failure cause unexpected system behavior. One particular behavior to be avoided is an unexpected, coordinated action across distributed resources that results from a failure mode. For example, when a controller suffers a failure, it could be detrimental to the electrical grid if all distributed resources started drawing power from the grid simultaneously.

[0165] The introduction of a smart charging or energy management system causes otherwise isolated loads to potentially operate in concert. This creates the possibility of adverse coordinated action in the event of system failure. In particular, if each electrical load is designed to revert to a maximum energy consumption level in the case of communications loss, then a failure of the management system may result in an instantaneous and coordinated spike in electricity demand. When the population of controlled devices is sufficiently large, the spike in demand can exceed the utility's capacity for rapid adjustment and result in a blackout.

[0166] An example of a failure mode includes failed communications between individual resources and the master controller or controllers. Communications can also fail between a controller and some or all of the resources. In addition, a controller or a set of controllers can fail in a non-network related way that renders such controllers incapable of communicating with the resources. A failure mode may also be a design defect shared by a large population of resources causing the population to simultaneously lose communications capabilities when an unexpected event occurred.

[0167] In the case of any failure mode, the system behavior should be predictable and non-disruptive. To prevent disruptive impacts on the grid as a whole, endpoints normally controlled by a central energy management server may employ a variety of safe failure modes. A system for maintaining predictable behavior may include a distributed resource with various capabilities, including the ability to receive/enact a sequence of commands to be executed at one or various points in time.

[0168] An example of a safe failure mode includes maintaining stable (non-changing) behavior for a defined period of time around a failure event. For example, after communications is lost, an isolated EVSE can continue charging at the rate last specified by the charge management controller. After some period of time, the EVSE may slowly transition to a different autonomous strategy.

[0169] Another safe failure mode includes executing a pre-arranged behavior in the event of a failure condition. As an example, if a group of EVSE's was connected to a electrical circuit that was only capable of providing 70% of the combined maximum power draw of the group, each EVSE could be pre-programmed to operate at 70% of capacity in the event of communications failure.

[0170] Yet another safe failure mode includes executing state transitions in pre-arranged behaviors at the determined time offset by a random interval of time. As an example, EVSE's that are off when communications fail could wait a random amount of time between 0 and 30 minutes before powering on. This random startup causes the increase in power consumption to be spread over time, allowing the utility the opportunity to respond.

[0171] A safe failure mode may also include using predictions about resource behaviors, such as the comings and goings from the system, to further enhance the estimate of the state of the world. As an example, if an EVSE is normally commanded to consume power along a curve (to harmonize with grid conditions), the EVSE could be programmed to follow type-based typical curve in the absence of communications. Since the central smart charging system would know the curve the detached EVSE was following, its behavior could still be input in to the charge management algorithms.

[0172] FIG. **13** illustrates an embodiment for managing power flow using safe failure modes including coordinating charging activities of electrical devices **1310** and detecting a system failure event **1320**. The power flow manager implements a safe failure mode **1330** that provides predictable and non-disruptive system behavior.

[0173] Generation-Stack-Aware Dispatch of Resources

[0174] One potential goal of a distributed energy management system is to dispatch resources to minimize cost. A basic cost reduction strategy is to reduce electricity consumption when electricity prices are high. This basic strategy reduces the cost of electricity consumed by the endpoints under active management.

[0175] A more advanced strategy could manipulate the electricity consumed by controlled endpoints in a way that impacts the market price of power. Such a system can reduce the cost of providing power to all devices within a utility's service area, not just those under active management.

[0176] In many regions, power production is managed by separate entities from the utilities responsible for distribution. Utilities purchase electricity from Power producers, and re-sell it to their customers.

[0177] Often, the transactions between power producers and distribution utilities take place in formalized market. Such a market typically operates as a single price auction. In such a market, each power producer states the price at which they are willing to provide power, and power production is allocated to the cheapest producers first, moving up the stack to more expensive produces until sufficient power has been obtained. The last (highest) price selected set the price that all power producers are paid.

[0178] Each type of generation asset in an energy generation system, such as the electrical grid, has a marginal cost. Generation assets are dispatched in the order of increasing marginal cost. The most expensive generator dispatched at any time sets the cost basis for energy generation.

[0179] Different types of power plants have sharply different marginal costs of operation. For example, Hydroelectric is often much cheaper than gas turbines. As a result, there may be a sharp increase in the cost of electricity as available hydro is exhausted, and the gas turbines begin coming online.

[0180] At times, a distributed energy manager can remove enough load from the system to eliminate the need for higher cost generation, thereby decreasing the total cost to provide service.

[0181] The distributed energy manager can minimize the total daily cost to provide energy generation by forecasting total system and dispatchable load. The distributed energy manager schedules dispatchable load to draw power from the grid at times that will minimize cost based on the available generation stack. Altering the total price of power paid has a larger financial impact than the amount paid specifically for automotive power. Also, moving the market may be easier at one time of day than another. As a result, dispatchable load will not always be scheduled to the lowest-cost time of day, but rather when it will have the most beneficial overall effect to the utility.

[0182] Further, the generation stack can change from region to region, and load profiles and consumption can change daily. Therefore, the present method will produce different dispatch patterns in different regions.

[0183] FIG. **14** shows an embodiment of managing power flow using generation stacks of power production to reduce cost of providing power to electrical devices. Charge activities are coordinated by a power flow manager **1410**. A power production stack is controlled the power flow manager **1420** such that the power production stack orders available power. Based on a cost reduction strategy, a dispatchable load is removed **1430**. The dispatchable load is listed in the power production stack.

[0184] Business Model of Selling Aggregated Power Resource Management Services to Power Generators or Others

[0185] Power resource management services include aggregating the following: plug-in vehicles, thermostats, residential or commercial/industrial load, or fixed energy storage. Such services provide regulation, reserves, load shifting, renewable resource following, or peak avoidance. A power flow manager is able to provide a variety of services that can improve the stability of the electric grid. For example, electricity consumption of distributed resources can be increased and decreased as necessary to absorb the differences between electricity production and consumption on the grid.

[0186] Customers for aggregated power resource management services include electric utilities, ISOs, and TSOs. Such entities are primarily responsible for the stability of the grid. But aggregated power resource management services may be sold to various types of power generators.

[0187] Some classes of electricity generation suffer from a high degree of intermittency, meaning that their power production is irregular. By bundling this irregular power production with the smoothing/stabilizing abilities of aggregated power resource management assets, it is possible to produce a higher grade of wholesale power, which may be more easily sold in energy markets.

[0188] In one example, a wind farm is the buyer of aggregated power resource management services. Wind farms are susceptible to fluctuations in the supply and demand of energy. For example, prices for energy may drop drastically when the amount of wind is great, or unexpectedly high. In addition, wind farms may be temporarily disconnected from a grid when there is not enough transmission or other capacity to absorb the power.

[0189] Economical issues resulting from such instability in the supply or demand of energy can be effectively addressed by providing owners of intermittent renewable generation with aggregated power resource management services. Power generators may increase their net load from the aggregated power resources when there is a large and/or unexpectedly high amount of wind, and decrease net load with there is a small and/or unexpectedly low amount of wind.

[0190] In an embodiment, power generators can use aggregated power resource management to smooth sudden ramping events in power output, or to firm the power output to a desired level. The sum of power generation plus net load from the aggregated power resources can be made constant, or less susceptible to changes in the supply or demand of energy.

[0191] As a result, power generators such as power plants may retain the value of the energy they create. Such an integration allow the operator of the generation asset to take direct action to address the intermittency issues associated with their type of generation. In some markets, this may be far more desirable than waiting for other parties to provide such services through the marketplace.

CONCLUSION

[0192] 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 at a local site, comprising the steps:

site-level charging of a plurality of electrical devices by a power flow manager, wherein the power flow manager runs a smart charging program, wherein the power flow manager coordinates charging activities of the plurality of electrical devices, wherein the plurality of electrical devices are located at the local site;

receiving site-level information, wherein the site-level information is received by the power flow manager;

making power flow decisions based on the site-level information, wherein the power flow decisions are made by the power flow manager; and,

managing power flow to the plurality of electrical devices by the power flow manager, wherein the power flow manager responds to requests.

2. The method of claim **1**, wherein the power flow manager is a central server.

3. The method of claim **1**, wherein the power flow manager is located at the local site.

4. The method of claim **1**, wherein the power flow manager is located remotely from the local site.

5. The method of claim **1**, wherein the electrical devices are electric vehicles.

6. The method of claim **1**, wherein the site-level information is selected from a group consisting of the following: electrical meter data for the local site, electrical meter data for at least one charge point; information from at least one of the plurality of electrical devices; electric rate information for the local site; electrical topology information; power limitation information; or priority rules.

7. The method of claim **1**, wherein the requests are selected from the group consisting of the following: demand response event, reserves call, renewable resource following, or system regulation.

8. The method of claim **1**, wherein the power flow manager communicates with at least one of the plurality of electrical.

9. The method of claim **1**, wherein the power flow manager communicates with at least one charge point.

10. The method of claim **1**, wherein the power flow decisions are selected from the group consisting of the following: to provide power, to draw power, to control power levels.

11. The method of claim **1**, wherein the power flow decisions are made based on constraints, priorities, optimizations, or efficiencies.

12. The method of claim **1**, wherein the power flow decisions are implemented by an action selected from the group consisting of the following: controlling relays to open close circuits; communicating to charging points to control circuits or devices on the circuits; communicating to at least one of the plurality of devices to provide a command for power flow behavior.

13. A system for managing power flow at a local site, comprising:

a power flow manager, wherein the power flow manager coordinates charging activities of a plurality of electrical devices, wherein the plurality of electrical devices are located at the local site;

a plurality of charge points connected to the power flow manger, wherein the plurality of charge points are operable to connect to the plurality of electrical devices, wherein the plurality of charge points are located at the local site;

site-level information, wherein the site-level information is received by the power flow manager; and,

power flow decisions based on the site-level information, wherein the power flow decisions are made by the power flow manager.

14. The system of claim **13**, wherein the power flow manager is a central server.

15. The system of claim **13**, wherein the power flow manager is located at the local site.

16. The system of claim **13**, wherein the power flow manager is located remotely from the local site.

17. The system of claim **13**, wherein the electrical devices are electric vehicles.

18. The system of claim **13**, wherein the site-level information is selected from a group consisting of the following: electrical meter data for the local site, electrical meter data for at least one charge point; information from at least one of the plurality of electrical devices; electric rate information for the local site; electrical topology information; power limitation information; or priority rules.

19. The system of claim **13**, wherein the power flow manager communicates with at least one charge point.

20. The system of claim **13**, wherein the power flow manager communicates with at least one of the plurality of electrical.

21. The system of claim **20**, wherein the power flow manager communicates with at least one of the plurality of electrical via at least one charge point.

22. The system of claim **20**, wherein the power flow manager communicates with at least one of the plurality of electrical via a wireless connection.

23. A system for managing power flow for optimization of multiple power flow management strategies, comprising:

a power flow manager, wherein the power flow manager coordinates charging activities of a plurality of electrical devices;

power flow services, wherein the power flow services are controlled by the power flow manager;

power flow management strategies, wherein the power flow management strategies are implemented by the power flow manager; and,

a meta-optimizer, wherein the meta-optimizer chooses at least one of the power flow management strategies, wherein the meta-optimizer chooses at least one of the electrical devices to utilize for implementing the at least one of the power flow management strategies.

24. The system of claim of **23**, wherein the power flow services are selected from a group consisting of the following: regulation, spinning reserve, peak avoidance, or renewable generation following.

25. The system of claim of **23**, wherein the meta-optimizer choices are based on maximizing value generated.

26. The system of claim of **23**, wherein the meta-optimizer choices are based on minimizing environmental impact.

27. The system of claim of **23**, wherein the meta-optimizer choices are based on a value function associated with the at least one of the power flow management strategies.

28. The system of claim of **23**, wherein the meta-optimizer choices are based on a grid topological location.

29. The system of claim of **23**, wherein the meta-optimizer choices are based on multiple component requirements.

30. The system of claim of **23**, wherein the meta-optimizer choices are based on predictions.

31. The system of claim of **23**, wherein the electrical devices are electric vehicles.

32. A method for managing power flow by optimizing multiple power flow management strategies, comprising:

coordinating charging activities of a plurality of electrical devices, wherein the charge activities are coordinated by a power flow manager;

controlling power flow services, wherein the power flow services are controlled by the power flow manager;

choosing at least one of the power flow management strategies, wherein the at least one of the power flow management strategies is chosen by a meta-optimizer;

choosing at least one of the electrical devices to utilize for implementing the at least one of the power flow management strategies, wherein the at least one of the electrical devices is chosen by the meta-optimizer; and,

implementing power flow management strategies, wherein the power flow management strategies are implemented by the power flow manager.

33. The method of claim of **32**, wherein the power flow services are selected from a group consisting of the following: regulation, spinning reserve, peak avoidance, or renewable generation following.

34. The method of claim of **32**, wherein the meta-optimizer choices are based on factors selected from a group consisting of the following: maximizing value generated; minimizing environmental impact; a value function associated with the at least one of the power flow management strategies; a grid topological location; multiple component requirements; or predictions.

35. The method of claim of **32**, wherein the meta-optimizer is the power flow manager.

36. The method of claim of **32**, wherein the power flow manager is a site power flow manager that managing power flow at a local site.

37. The method of claim of **32**, wherein the electrical devices are electric vehicles.

38. A system for managing power flow using safe failure modes, comprising:

a power flow manager, wherein the power flow manager coordinates charging activities of a plurality of electrical devices;

a system failure event; and,

a safe failure mode, wherein the safe failure mode is implemented by the power flow manager, wherein the safe failure mode provides that the charging activities be coordinated in a predictable and non-disruptive manner.

39. The system of claim of **38**, wherein the system failure event is generated as a result of an introduction of a smart charging or energy management system.

40. The system of claim of **38**, wherein the system failure event results in a spike in electricity demand.

41. The system of claim of **38**, wherein the system failure event occurs as a result of a failure in communications between the plurality of electrical devices and a master controller.

42. The system of claim of **38**, wherein the system failure event occurs as a result of a failure in a controller, wherein the controller is incapable of communicating with the plurality of electrical devices.

43. The system of claim of **38**, wherein the system failure event occurs as a result of a design defect shared by the plurality of electrical devices causing the plurality of electrical devices to simultaneously lose communications capabilities.

44. The system of claim of **38**, wherein the safe failure mode comprises maintaining a stable non-changing behavior for a defined period of time around a failure event.

45. The system of claim of **38**, wherein the safe failure mode comprises executing a prearranged behavior in the event of a failure condition.

46. The system of claim of **38**, wherein the safe failure mode comprises executing state transitions in prearranged behaviors at a determined time offset by a random interval of time.

47. The system of claim of **38**, wherein the safe failure mode comprises using predictions about resource behaviors.

48. The system of claim of **38**, wherein the electrical devices are electric vehicles.

49. A method for managing power flow using safe failure modes, comprising:

coordinating charging activities of a plurality of electrical devices, wherein the charge activities are coordinated by a power flow manager;

detecting a system failure event, wherein the system failure event is detected by a power flow manager; and,

implementing a safe failure mode, wherein the safe failure mode is implemented by the power flow manager, wherein the safe failure mode provides that the charging activities be coordinated in a predictable and non-disruptive manner.

50. The method of claim of **49**, wherein the system failure event is generated as a result of an introduction of a smart charging or energy management system.

51. The method of claim of **49**, wherein the system failure event results in a spike in electricity demand.

52. The method of claim of **49**, wherein the system failure event occurs as a result of a failure in communications between the plurality of electrical devices and a master controller.

53. The method of claim of **49**, wherein the system failure event occurs as a result of a failure in a controller, wherein the controller is incapable of communicating with the plurality of electrical devices.

54. The method of claim of **49**, wherein the system failure event occurs as a result of a design defect shared by the plurality of electrical devices causing the plurality of electrical devices to simultaneously lose communications capabilities.

55. The method of claim of **49**, wherein the safe failure mode comprises maintaining a stable non-changing behavior for a defined period of time around a failure event.

56. The method of claim of **49**, wherein the safe failure mode comprises executing a prearranged behavior in the event of a failure condition.

57. The method of claim of **49**, wherein the safe failure mode comprises executing state transitions in prearranged behaviors at a determined time offset by a random interval of time.

58. The method of claim of **49**, wherein the safe failure mode comprises using predictions about resource behaviors.

59. The method of claim **49**, wherein the electrical devices are electric vehicles.

60. A system for managing power flow using generation stacks of power production to reduce cost of providing power to electrical devices, comprising:

- a power flow manager, wherein the power flow manager coordinates charging activities of a plurality of electrical devices;
- a power production stack, wherein the power flow manager controls the power production stack, wherein the power production stack orders available power; and,
- a dispatchable load, wherein the dispatchable load is listed in the power production stack, wherein the dispatchable load is removed based on a cost reduction strategy.

61. The system of claim **60**, wherein the available power is ordered based on power prices ordered from cheapest to most expensive.

62. The system of claim **60**, wherein the dispatchable load is the most expensive load listed in the power production stack.

63. The system of claim **60**, wherein the available power is provided by a plurality of power producers.

64. The system of claim **60**, wherein the cost reduction strategy is to decrease a cost of providing power services to the plurality of electrical devices.

65. The system of claim **60**, wherein the cost reduction strategy is to decrease a cost of providing power services to the plurality of electrical devices, wherein the cost is a daily cost.

66. The system of claim **60**, wherein the cost reduction strategy is to minimize a cost based on the power production stack.

67. The system of claim **60**, wherein the cost reduction strategy is to dispatch the most expensive load.

68. The system of claim **60**, wherein the cost reduction strategy is based on a region.

69. The system of claim **60**, wherein the cost reduction strategy comprises forecasting the dispatchable load.

70. The system of claim **60**, wherein the electrical devices are electric vehicles.

71. A method for managing power flow using generation stacks of power production to reduce cost of providing power to electrical devices, comprising:

- coordinating charging activities of a plurality of electrical devices, wherein the charge activities are coordinated by a power flow manager;
- controlling a power production stack, wherein the power flow manager controls the power production stack, wherein the power production stack orders available power;
- removing a dispatchable load, wherein the dispatchable load is listed in the power production stack, wherein the dispatchable load is removed based on a cost reduction strategy.

72. The system of claim **71**, wherein the available power is ordered based on power prices ordered from cheapest to most expensive.

73. The system of claim **71**, wherein the dispatchable load is the most expensive load listed in the power production stack.

74. The system of claim **71**, wherein the available power is provided by a plurality of power producers.

75. The system of claim **71**, wherein the cost reduction strategy is to decrease a cost of providing power services to the plurality of electrical devices.

76. The system of claim **71**, wherein the cost reduction strategy is to decrease a cost of providing power services to the plurality of electrical devices, wherein the cost is a daily cost.

77. The system of claim **71**, wherein the cost reduction strategy is to minimize a cost based on the power production stack.

78. The system of claim **71**, wherein the cost reduction strategy is to dispatch the most expensive load.

79. The system of claim **71**, wherein the cost reduction strategy is based on a region.

80. The system of claim **71**, wherein the cost reduction strategy comprises forecasting the dispatchable load.

81. The system of claim **71**, wherein the electrical devices are electric vehicles.

82. The method of claim **71**, wherein the electrical devices are electric vehicles.

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