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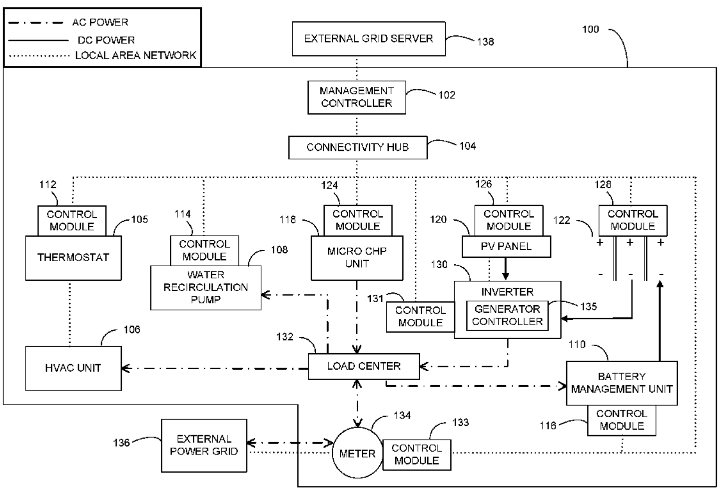

FIG. 1

(57) Abstract: Mechanisms and techniques for managing energy consumption within an energy management system are disclosed. In one embodiment, the energy management system includes a power generator and a management controller that controls activation of a plurality of load devices. The management controller is communicatively coupled to a meter that measures electrical energy transferred between the energy management system and an external power grid. The management controller monitors, using information from the meter, electrical energy transfer between the energy management system and the external power grid and receives a feed]out limit message from the external power grid. The management controller processes the feedout limit message and modifies activation scheduling of at least one of the plurality of load devices based, at least in part, on processing the feed]out limit message.

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VARIABLE FEED-OUT ENERGY MANAGEMENT

RELATED APPLICATIONS

[0001] This application claims priority to United States Provisional Application No. 62/120,239, filed on February 24, 2015, and United States Application No. 14/925,592, filed on October 28, 2015.

TECHNICAL FIELD

[0002] Embodiments of the disclosed subject matter generally relate to the field of distributed energy source management, and more particularly to systems and methods for managing transfer of energy between a variable output allocation and local energy loads.

BACKGROUND

[0003] Electrical grids form interconnected networks that deliver electrical power from suppliers to energy consumers. Traditionally, electrical grid power sources delivered energy from centralized, large-scale electrical generators to vast numbers of final electrical loads at consumer sites. Grid power supply management was designed to support and conform to this largely unidirectional flow of electrical energy.

[0004] Continued development of energy sources has resulted in changes in methods by which electric grids and energy utilities distribute electrical energy. Namely, technological advances have contributed to an emergence of on-site consumer energy control systems. These consumer energy control systems enable local energy generation systems, such as home-based photovoltaic systems, to supply electrical energy into the external, centralized electrical grid network. Local energy generation systems may comprise energy generators that generate electrical energy from relatively non-exhaustible sources. Such energy generators may include photovoltaic systems and wind turbine systems.

[0005] The increasing prevalence of decentralized electrical energy generators presents challenges relating to the stability of electrical grid supply. To maintain supply, energy suppliers have utilized consumer incentives to reduce energy intake from distributed sources and increase energy intake from localized sources. These consumer incentives are commonly referred to as feed-in tariffs.

SUMMARY

[0006] Various embodiments for managing energy consumption within an energy management system are disclosed. In one embodiment, the energy management system includes a management controller configured to control activation of a plurality of load devices. The management controller processes a feed-out limit message. The feed-out limit message indicates a power limit associated with a feed-out limit period. In one embodiment, the management controller determines a predicted average surplus power level over the feed-out limit period and modifies an activation schedule of at least one of the plurality of load devices based, at least in part, on the predicted average surplus power level.

[0007] In some embodiments, a method for managing loads within an energy management system that includes a management controller configured to control activation of a plurality of load devices comprises the management controller determining a power limit associated with a feed-out limit period based, at least in part, on a feed-out limit message; determining an average surplus power level over the feed-out limit period; and modifying an activation schedule of at least one of the plurality of load devices based, at least in part, on the average surplus power level and the feed-out limit message.

[0008] In some embodiments, determining the average surplus power level comprises estimating a first amount of energy to be generated by a power generator during the feed-out limit period; and estimating a second amount of energy to be consumed by the plurality of load devices over the feed-out limit period.

[0009] In some embodiments, determining the average surplus power level comprises comparing the first amount of energy to be generated with the second amount of energy to be consumed; and determining the average surplus power level over the feed-out limit period based, at least in part, on the comparing.

[0010] In some embodiments, estimating the second amount of energy to be consumed comprises identifying one or more of the plurality of load devices that are scheduled to be activated during the feed-out limit period.

[0011] In some embodiments, estimating the second amount of energy to be consumed comprises determining power consumption parameters associated with the one or more of the plurality of load devices; and estimating an unscheduled energy consumption value over the feed-out limit period.

[0012] In some embodiments, the method further comprises the management controller determining a feed-out power level based, at least in part, on real-time power generation by a power generator and real-time power consumption of the plurality of load devices; determining whether the feed-out power level exceeds the power limit; and adjusting an output power level of the power generator based, at least in part, on determining whether the feed-out power level exceeds the power limit.

[0013] In some embodiments, the method further comprises the management controller transferring power to an external power grid, the power generated by a power generator; and adjusting the power transferred to the external power grid based, at least in part, on the feed-out limit message and the modified activation schedule.

[0014] In some embodiments, modifying the activation schedule further comprises the management controller determining whether the average surplus power level exceeds the power limit by a specified margin; and determining to modify device activation scheduling based, at least in part, on determining that the average surplus power level exceeds the power limit by the specified margin.

[0015] In some embodiments, the plurality of load devices comprises a variable power level device and a constant power level device, and modifying the activation schedule comprises: determining whether the average surplus power level exceeds an adjustable load threshold; in response to determining that the average surplus power level exceeds the adjustable load threshold, selecting the constant power level device to be activated during the feed-out limit period; determining a second average surplus power level based, at least in part, on selecting the constant power level device to be activated during the feed-out limit period; and determining whether to schedule the variable power level device or another constant power level device based, at least in part, on the second average surplus power level.

[0016] In some embodiments, the method further comprises, following modifying the activation schedule, the management controller determining energy consumption by at least one unscheduled load device; and adjusting the activation schedule based, at least in part, on the energy consumption by the at least one unscheduled load device.

[0017] In some embodiments, the method further comprises determining a value of the average surplus power level, wherein modifying the activation schedule is further based, at least in part, on the value of the average surplus power level.

[0018] In some embodiments, a management controller that controls activation of a plurality of load devices within an energy management system, the management controller comprises a processor and memory to store instructions, which when executed by the processor, cause the management controller to: determine a power limit associated with a feed-out limit period based, at least in part, on a feed-out limit message; determine an average surplus power level over the feed-out limit period; and modify an activation schedule of at least one of the plurality of load devices based, at least in part, on the average surplus power level and the feed-out limit message.

[0019] In some embodiments, the instructions, which when executed by the processor, cause the management controller to estimate a first amount of energy to be generated by a power generator during the feed-out limit period; and estimate a second amount of energy to be consumed by the plurality of load devices over the feed-out limit period.

[0020] In some embodiments, the instructions, which when executed by the processor, cause the management controller to compare the first amount of energy to be generated with the second amount of energy to be consumed; and determine the average surplus power level over the feed-out limit period based, at least in part, on the comparing.

[0021] In some embodiments, estimating the second amount of energy to be consumed comprises identifying one or more of the plurality of load devices that are scheduled to be activated during the feed-out limit period.

[0022] In some embodiments, estimating the second amount of energy to be consumed comprises determining power consumption parameters associated with the one or more of the plurality of load devices; and estimating an unscheduled energy consumption value over the feed-out limit period.

[0023] In some embodiments, the instructions, which when executed by the processor, cause the management controller to determine a feed-out power level based, at least in part, on real-time power generation by a power generator and real-time power consumption of the plurality of load devices; determine whether the feed-out power level exceeds the power limit; and adjust an output power level of the power generator based, at least in part, on determining whether the feed-out power level exceeds the power limit.

[0024] In some embodiments, the instructions, which when executed by the processor, cause the management controller to transfer power to an external power grid, the power generated by a power generator; and adjust the power transferred to the external power grid based, at least in part, on the feed-out limit message and the modified activation schedule.

[0025] In some embodiments, the instructions, which when executed by the processor, cause the management controller to determine whether the average surplus power level exceeds the power limit by a specified margin; and modify device activation scheduling based, at least in part, on determining that the average surplus power level exceeds the power limit by the specified margin.

[0026] In some embodiments, the plurality of load devices comprises a variable power level device and a constant power level device, and wherein the instructions, which when executed by the processor, cause the management controller to determine whether the average surplus power level exceeds an adjustable load threshold; select, in response to determining that the average surplus power level exceeds the adjustable load threshold, the constant power level device to be activated during the feed-out limit period; determine a second average surplus power level based, at least in part, on selecting the constant power level device to be activated during the feed-out limit period; and determine whether to schedule the variable power level device or another constant power level device based, at least in part, on the second average surplus power level.

[0027] In some embodiments, the instructions, which when executed by the processor, cause the management controller to, following modifying the activation schedule, determine energy consumption by at least one unscheduled load device; and adjust the activation schedule based, at least in part, on the energy consumption by the at least one unscheduled load device.

[0028] In some embodiments, the instructions, which when executed by the processor, cause the management controller to determine a value of the average surplus power level, wherein modifying the activation schedule is further based, at least in part, on the value of the average surplus power level.

[0029] In some embodiments, a non-transitory machine-readable storage medium having machine executable instructions stored therein, the machine executable instructions comprises instructions to: determine a power limit associated with a feed-out limit period, the power limit based, at least in part, on a feed-out limit message; determine an average surplus power level over the feed-out limit period; and modify an activation schedule of at least one of a plurality of load devices based, at least in part, on the average surplus power level and the feed-out limit message.

[0030] In some embodiments, the instructions to determine the average surplus power level comprise instructions to estimate a first amount of energy to be generated by a power generator during the feed-out limit period; and estimate a second amount of energy to be consumed by the plurality of load devices over the feed-out limit period.

[0031] In some embodiments, the instructions to estimate the average surplus power level comprise instructions to compare the first amount of energy to be generated with the second amount of energy to be consumed; and determine the average surplus power level over the feed-out limit period based, at least in part, on comparing the first amount of energy to be generated with the second amount of energy to be consumed.

[0032] In some embodiments, the instructions to estimate the second amount of energy to be consumed comprise instructions to identify one or more of the plurality of load devices that are scheduled to be activated during the feed-out limit period.

[0033] In some embodiments, the instructions to estimate the second amount of energy to be consumed comprise instructions to determine power consumption parameters associated with the one or more of the plurality of load devices; and estimate an unscheduled energy consumption value over the feed-out limit period.

[0034] In some embodiments, the non-transitory machine-readable storage medium further comprises instructions to determine a feed-out power level based, at least in part, on real-time power generation by a power generator and real-time power consumption of the plurality of load devices; determine whether the feed-out power level exceeds the power limit; and adjust an output power level of the power generator based, at least in part, on determining whether the feed-out power level exceeds the power limit.

[0035] In some embodiments, the non-transitory machine-readable storage medium further comprises instructions to transfer power to an external power grid, the power generated by a power generator; and adjust the power transferred to the external power grid based, at least in part, on the feed-out limit message and the modified activation schedule.

[0036] In some embodiments, the instructions to modify the activation schedule comprise instructions to determine whether the average surplus power level exceeds the power limit by a specified margin; and determine to modify device activation scheduling based, at least in part, on determining that the average surplus power level exceeds the power limit by the specified margin.

[0037] In some embodiments, the plurality of load devices includes a variable power level device and a constant power level device, and wherein the instructions to modify the activation schedule comprise instructions to determine whether the average surplus power level exceeds an adjustable load threshold; select, in response to determining that the average surplus power level exceeds the adjustable load threshold, the constant power level device to be activated during the feed-out limit period; determine a second average surplus power level based, at least in part, on selecting the constant power level device to be activated during the feed-out limit period; and determine whether to schedule the variable power level device or another constant power level device based, at least in part, on the second average surplus power level.

[0038] In some embodiments, the non-transitory machine-readable storage medium further comprises instructions to, following modifying the activation schedule, determine energy consumption by at least one unscheduled load device; and adjust the activation schedule based, at least in part, on the energy consumption by the at least one unscheduled load device.

[0039] In some embodiments, the non-transitory machine-readable storage medium further comprises instructions to determine a value of the average surplus power level, wherein modifying the activation schedule is further based, at least in part, on the value of the average surplus power level.

[0040] In some embodiments, a management controller that controls activation of a plurality of load devices within an energy management system, the management controller comprises: means for determining a power limit associated with a feed-out limit period, the power limit based, at least in part, on a feed-out limit message; means for determining an average surplus power level over the feed-out limit period; and means for modifying an activation schedule of at least one of the plurality of load devices based, at least in part, on the average surplus power level and the feed-out limit message.

[0041] In some embodiments, the management controller further comprises means for estimating a first amount of energy to be generated by a power generator during the feed-out limit period; and means for estimating a second amount of energy to be consumed by the plurality of load devices over the feed-out limit period.

[0042] In some embodiments, the management controller further comprises means for comparing the first amount of energy to be generated with the second amount of energy to be consumed; and means for determining the average surplus power level over the feed-out limit period based, at least in part, on comparing the first amount of energy to be generated with the second amount of energy to be consumed.

[0043] In some embodiments, the management controller further comprises means for identifying one or more of the plurality of load devices that are scheduled to be activated during the feed-out limit period.

[0044] In some embodiments, the management controller further comprises means for determining power consumption parameters associated with the one or more of the plurality of load devices; and means for estimating an unscheduled energy consumption value over the feed-out limit period.

[0045] In some embodiments, the management controller further comprises means for determining a feed-out power level based, at least in part, on real-time power generation by a power generator and real-time power consumption of the plurality of load devices; means for determining whether the feed-out power level exceeds the power limit; and means for adjusting an output power level of the power generator based, at least in part, on determining whether the feed-out power level exceeds the power limit.

[0046] In some embodiments, the management controller further comprises means for transferring power to an external power grid, the power generated by a power generator; and means for adjusting the power transferred to the external power grid based, at least in part, on the feed-out limit message and the modified activation schedule.

[0047] In some embodiments, the management controller further comprises means for determining whether the average surplus power level exceeds the power limit by a specified margin; and means for determining to modify device activation scheduling based, at least in part, on determining that the average surplus power level exceeds the power limit by the specified margin.

[0048] In some embodiments, the management controller further comprises means for determining whether the average surplus power level exceeds an adjustable load threshold;

means for selecting a constant power level device to be activated during the feed-out limit period in response to determining that the average surplus power level exceeds the adjustable load threshold; means for determining a second average surplus power level based, at least in part, on selecting the constant power level device to be activated during the feed-out limit period; and means for determining whether to schedule a variable power level device or another constant power level device based, at least in part, on the second average surplus power level.

[0049] In some embodiments, the management controller further comprises means for determining energy consumption by at least one unscheduled load device; and means for adjusting the activation schedule based, at least in part, on the energy consumption by the at least one unscheduled load device.

[0050] In some embodiments, the management controller further comprises means for determining a value of the average surplus power level; and means for modifying the activation schedule further based, at least in part, on the value of the average surplus power level.

BRIEF DESCRIPTION OF THE DRAWINGS

[0051] The present embodiments may be better understood by referencing the accompanying drawings.

[0052] **FIG. 1** is a block diagram depicting an architectural overview of a networked electrical energy transfer environment, in accordance with one embodiment;

[0053] **FIG. 2** is a block diagram illustrating features of a controller device, according to some embodiments;

[0054] **FIG. 3** is a diagram depicting a load management messaging protocol in accordance with one embodiment;

[0055] **FIG. 4A** is a flow diagram illustrating processing and communications performed during load management, in accordance with one embodiment;

[0056] **FIG. 4B** depicts a flow diagram showing processing and communications performed during load management, in accordance with one embodiment;

[0057] **FIG. 4C** depicts a flow diagram showing processing and communications performed during load management, in accordance with one embodiment; and

[0058] **FIG. 5** depicts an example computer system for implementing embodiments of the disclosure.

DESCRIPTION OF EMBODIMENT(S)

[0059] The following description discloses example techniques and structures that embody the subject matter herein. However, it is understood that the described embodiments may be practiced without these specific details. In other instances, well-known instruction instances, protocols, structures and techniques have not been shown in detail in order not to obfuscate the description.

[0060] **FIG. 1** is a block diagram depicting an architectural overview of a networked electrical energy transfer environment, in accordance with one embodiment. **FIG. 1** shows an energy management system (EMS) **100** and an external power grid **136**. The EMS **100** comprises multiple interconnected power generators and load devices. The EMS **100** may be implemented within a home, a business, or other environments. The EMS **100** may enhance energy efficiency of its load devices and subsystems, and reduce energy costs.

[0061] As shown in **FIG. 1**, the EMS **100** is connected to the external power grid **136,** which may be connected to one or more energy sources, such as electric power plants (not depicted). The EMS **100** may both receive and transmit electrical power from and to the external power grid **136**, with the exchange monitored by a meter **134**. The EMS **100** includes a management controller **102**, which functions as a centralized energy controller for the various energy-related devices associated with the EMS **100**.

[0062] The solid, dotted, and intermittent dot-dashed lines in **FIG. 1** represent communication and power transfer connections between various devices within the depicted energy transfer environment. The solid lines represent direct current (DC) power transfer. The intermittent dot-dashed lines represent alternating current (AC) power transfer. The dotted lines represent communication channels between devices. These power connections and communication channels may be unidirectional or bi-directional. For example, the devices within the EMS **100** may transmit their respective operational state information to the management controller **102** via the communication channels. The devices may determine whether to update their operational states based, at least in part, on the received data and/or control instructions.

[0063] The load devices include a heating, ventilation, and air conditioning (HVAC) unit **106** that provides temperature control within an enclosed structure, such as a home. Activation of the HVAC unit **106** is controlled by a thermostat **105**. The thermostat **105** is configured to monitor the operational state of the HVAC unit **106** with respect to air temperature. The thermostat **105** may receive scheduling instructions from the management controller **102**. The scheduling instructions enable scheduling of the HVAC unit **106** to coordinate scheduling with other load devices within the EMS **100**, as will be discussed further below. The load devices further include a water recirculation pump **108** and a battery management unit **110**.

[0064] The EMS **100** may supplement energy received from the external power grid **136** with power from local power generators. In the depicted embodiment, the EMS **100** is connected to two local power generators: a photovoltaic (PV) panel **120** and a micro combined heating and power (CHP) unit **118**. The PV panel **120** is controlled, in part, by an inverter **130**, which also functions to convert the direct current (DC) power generated by the PV panel **120** into alternating current (AC) power. The inverter **130** may implement maximum power point tracking and/or other techniques to improve utilization of the PV panel **120**. The inverter **130** may report, to the management controller **102**, an instantaneous and/or recorded energy generation rate (e.g., power measured in kW) and other power generation parameters associated with the PV panel **120**. In some embodiments, the inverter **130** receives control instructions from the management controller **102**.

[0065] The micro CHP unit **118** may utilize fuel from a fuel source (not shown) to generate power while simultaneously generating recoverable heat for a local enclosure. Generating power and recoverable heat may be known as cogeneration. The micro CHP unit **118** may similarly report an instantaneous and/or recorded energy generation rate and other parameters (such as the level of stored heat and/or water temperature) to the management controller **102**. The management controller **102** may change the operational state of the micro CHP unit **118** based on power consumption needs and power output limitations of the EMS **100**.

[0066] The EMS **100** further includes one or more local energy reserves, such as a battery **122** for storing energy locally. The battery **122** is connected to the battery management unit **110**, which may monitor, charge, and discharge the battery **122**. The battery management unit **110** may report, to the management controller **102**, an amount of charge stored by the battery **122,** an instantaneous charging or discharging rate, and recorded charging and charge levels and rates.

[0067] Local energy reserves, such as energy reserves store by the battery **122**, allow the EMS **100** to store excess energy that may be either received from the external power grid **136** or generated by local power generators (e.g., the PV panel **120**). The local energy reserves provided by the battery **122** can provide increased flexibility for coordinating energy consumption over a period of time. Furthermore, local energy reserves can also attenuate spikes in the net energy for be drawn from the external power grid **136** when numerous load devices are simultaneously active.

[0068] The meter **134** monitors and actuates energy transfer between the external power grid **136** and the EMS **100**. A load center **132** may receive AC power from the external power grid **136** through the meter **134** and may distribute this power to various load devices. The load center **132** may also receive AC power from local energy sources, such as the micro CHP unit **118** and the inverter **130**. In addition, the load center **132** may provide access for manually activating and deactivating loads and subsystems.

[0069] As further depicted in **FIG. 1**, the management controller **102** is connected to a connectivity hub **104**. In some embodiments, the connectivity hub **104** may be implemented as a router having Wi-Fi capability. The connectivity hub **104** may function to enable the management controller **102** to communicate with the various load devices (e.g., HVAC unit

106), energy reserves (e.g., battery **122**), and power generators (PV panel **120**). The connectivity hub **104** may further enable the management controller **102** to communicate with external network servers, such as an external grid server **138**.

[0070] For device connectivity, the loads, power generators, and energy reserves may include control modules to enable communication with the management controller **102**. In the depicted embodiment, power generators, such as micro CHP unit **118** and PV panel **120,** each have such control modules (**124** and **126** respectively as illustrated) to both receive instructions and send data to the management controller **102** through connectivity hub **104**. Similarly, load devices such as the thermostat **105**, the water recirculation pump **108**, and the battery management unit **110**, each have respective control modules **112**, **114**, and **116**. The inverter **130** has control module **131** and the meter **134** has control module **133**. The battery **122** has control module **128**. Communication may entail using established protocols for compatibility. These protocols may include Wi-Fi®, Bluetooth®, powerline communication, Zigbee®, Z-Wave, Ethernet and/or other communications protocols. The control modules may be external to or incorporated within their respective devices.

[0071] To simplify expansion of the EMS **100**, the management controller **102** may support ad-hoc discovery of power generator and load devices. For example, the management controller **102** may periodically (or upon user instruction) send out a request to discover non-configured devices that include system-compliant control modules.

[0072] In some embodiments, the management controller **102** may communicate with devices within the EMS **100** using the Smart Energy Profile 2.0 (SEP2.0) standard, also known as the Institute of Electrical and Electronics Engineers P2030.5 standard. This communications standard provides an application layer specifically designed to support communications between various smart energy devices within a local area network. The SEP2.0 standard functions independent of the media access control (MAC) and physical layers of end devices (e.g., devices in the EMS **100**), thereby promoting increased compatibility.

[0073] Embodiments of the management controller **102** include memory that stores machine-executable instructions that cause the management controller **102** to perform the tasks and functionalities described herein. The management controller **102** may further include and/or communicate with a resource management application (not shown in **FIG. 1**). The resource management application may include program instructions and data associated with load device power and energy consumption parameters, configuration, and activation schedules. The resource management application will be described in more detail below, in the discussion of **FIG. 2**.

[0074] The EMS **100** further includes a generator controller **135**, which may be incorporated within or otherwise co-located with the inverter **130**. The generator controller **135** functions to control and adjust the output power level of the PV panel **120**. The generator controller **135** is communicatively coupled via the control module **131** or its own communication interface with the management controller **102**, the meter **134**, the external power grid **136**, and the load devices.

[0075] In some other embodiments, the management controller **102** is embedded in one of the load devices, such as the thermostat **105**. In some embodiments, the management controller **102** and/or the generator controller **135** is/are embedded in the connectivity hub **104**. In yet other embodiments, the management controller **102** and/or the generator controller **135** and their associated functionality are distributed over multiple devices. Additionally, the management controller **102** and/or the generator controller **135** may have distributed capabilities, such as those facilitated through cloud computing facilities.

[0076] **FIG. 2** is a block diagram illustrating features of a controller device, according to some embodiments. A controller device **200** may be representative of the management controller **102** and/or the generator controller **135** depicted in **FIG. 1**. In **FIG. 2**, the controller device **200** is a “smart” controller, having features extending beyond those associated with other interface-specific computer controllers. Although not shown, the controller device **200** can include user input/output systems, displays, and/or other suitable components. The controller device **200** includes a network interface **202,** which may be a wireless or wireline interface for communicating with an external grid server across a network, such as the Internet. The controller device **200** further includes a processor **204** and memory **210.** The memory **210** and the processor **204** cooperatively function to manage programs and data that enable the controller device **200** to perform various energy management tasks associated with local power generators and load devices. The controller device **200** further includes a communication interface **205**. The communication interface **205** may support one or more of Wi-Fi®, Zigbee®, Bluetooth®, etc. The communication interface **205** includes an interface controller **207** for communicating with various power generation and load devices directly or via a hub (e.g., the connectivity hub **104** in **FIG. 1**). The communication interface **205** also includes an antenna **206** for generating and maintaining wireless connectivity with other interface-enabled EMS devices.

[0077] The memory **210** comprises a non-transitory machine-readable storage medium that stores programs and supporting data that control operations of the controller device **200**. In the depicted embodiment, the memory **210** stores an operating system (OS) **230** and includes an application space **212** in which a resource management application **215** is maintained. OS **230** may be a flexible, multi-purpose OS such as that found in smartphones or may be an embedded OS having more limited and specialized functionality. The OS **230** generally comprises code for managing and providing services to hardware and software components within the controller device **200**. Among other code and instructions, the OS **230** may include process management code comprising instructions for interfacing application code with system hardware and software. The OS **230** may also include memory management code for allocating and managing memory for use by application and system-level programs. The OS **230** may further include I/O system management code including device drivers that enable the controller's hardware to communicate with external systems, such as a user's smartphone.

[0078] The resource management application **215** contains management code **225** (machine executable instructions) and associated data including load device power and energy consumption parameters, configuration, and activation schedules. For example, the resource management application **215** may be a user application for coordinating activation and deactivation of load devices, such as in a manner described with reference to **FIGS. 4** and **5**.

[0079] The resource management application **215** further includes load device entries **216**, **218**, and **220**, each associated with a respective load device. The depicted load device entries each comprise a load category field (*LDTYPE_1* for load device entry **216**, *LDTYPE_2* for load device entry **218**, and *LDTYPE_3* for load device entry **220**) concatenated with or otherwise logically associated with a power rating field (*RTG_1* for load device entry **216**, *RTG_2* for load device entry **218**, and *RTG_3* for load device entry **220**). Each of the load category fields includes data specifying an electrical load category that the controller device **200** may apply during load device scheduling. In one embodiment, the load categories include a Type 1 load for constant power level devices. A constant power level device is one that operates at a relatively constant power level independent of scheduling by the controller device **200**. For example, the water recirculation pump **108** may be in the Type 1 load. The load categories may further include a Type 2 load for devices that operate based on a duty cycle that is independent of management controller scheduling, such as the HVAC unit **106** depicted in **FIG. 1**. The load categories may further include a Type 3 load for variable power devices that operate at an adjustable or otherwise variable power level, such as the battery management unit **110** depicted in **FIG. 1**.

[0080] The resource management application **215** further comprises (or is logically associated with) generator output records **223** and unscheduled energy consumption records **219**. These records may be stored in any suitable data store, such as a relational database. The generator output records **223** may store energy and/or power output parameters associated with one or more power generators, such as the PV panel **120** and the micro CHP unit **118** depicted in **FIG. 1**. Such parameters may be manufacturer metrics and/or may include historical power/energy output metrics measured and recorded over time within an EMS. The unscheduled energy consumption records **219** may include historical power/energy consumption metrics associated with an EMS. These metrics may indicate a cumulative power and/or energy consumption and/or consumption patterns of all unscheduled electrical loads (e.g., manually activated lights) within the EMS.

[0081] The resource management application **215** may further comprise (or otherwise be logically associated with) a device activation schedule **227** that includes scheduling information. The scheduling information can include recorded activation schedules for load devices and power generators. The device activation schedule **227** may further include instructions for activating and/or deactivating the load devices and power generators in accordance with the scheduling information. During execution of the management code **225**, the controller device

200 can process the scheduling information in association with information within the load device entries **216**, **218**, and **220** to determine energy consumption patterns that may be processed in association with a feed-out limit message. The controller device **200** can schedule load devices based on the feed-out limit message, the energy consumption patterns, and real-time power output and energy consumption variations, as described in further detail with reference to **FIG 4**. It is noted that in this disclosure, “feed-out” refers to power or energy that is generated or produced locally and supplied to an external power grid or some other external energy or power consumer. The term “feed-out” may be used interchangeably with the term “feed-in” as commonly used in the industry.

[0082] Alternately, or in addition to maintaining the resource management application **215**, the application space **212** may maintain a generator management application **233**. The generator management application **233** may include management code for tracking the activation status of load devices to determine real-time collective power consumption level of load devices. The generator management application **233** may further include code for comparing the collective power consumption level with a power limit specified by a feed-out limit message. In some instances, the controller device **200** is configured as a generator controller, such as generator controller **135.** The generator management application **233** can provide control instructions for adjusting the output power level of a power generator (e.g., a PV panel), based on whether the current collective power consumption level exceeds a specified power limit. The discussion of **FIG. 4** describes this in further detail.

[0083] **FIG. 3** is a diagram depicting a load management messaging protocol in accordance with one embodiment. The entities operably involved in the example load management messaging protocol include a management controller **302**, a meter **304**, one or more load devices **306**, power generators **307**, and an external power grid **308**. The management controller **302** may include hardware and/or software for managing load activation and load activation scheduling within an energy management system. The external power grid **308** provides an external electrical power source to the energy management system that is managed by the management controller **302**. The meter **304** is a device for measuring transfer of electrical energy and a power level transferred between the external power grid **308** and the energy management system. The meter **304** is communicatively and electrically coupled to both the external power grid **308** and the management controller **302**. The load devices **306** are devices that consume electrical power supplied by either or a combination of power generators **307** and/or the external power grid **308**. The load devices **306** may include communication interfaces, such as local wireless interfaces for communicating with the management controller **302**.

[0084] As shown, the protocol begins with device discovery messages **312** between the management controller **302** and load devices **306**. The management controller **302** exchanges device discovery request and response messages with one or more of the load devices **306** to obtain system information regarding the composition and configuration of load devices.

[0085] The management controller **302** monitors electrical energy transfer between the energy management system and the external power grid **308** by exchanging power transfer status messages **314** with the meter **304**. While monitoring energy transfer between the energy management system and the external power grid **308**, the management controller **302** receives a feed-out limit message **316** from the external power grid **308**. In one embodiment, the management controller **302** receives the feed-out limit message **316** directly from the external power grid **308**. Alternatively, the management controller **302** may receive the feed-out limit message **316** via the meter **304**. The feed-out limit message **316** specifies a maximum power level (e.g., in kW) that may be fed-out from the energy management system to the external power grid **308**. Alternatively, the feed-out limit message **316** may comprise a message that specifies a maximum energy amount or power level to be fed-out from the energy management system to the external power grid **308** over a specified period.

[0086] After receiving the feed-out limit message **316**, the management controller **302** may transmit activation schedule messages **319** to one or more of the load devices **306**. The management controller **302** transmits the activation schedule messages **319** to obtain activation schedule and power consumption parameters. In response, the load devices **306** may transmit activation schedule messages **320** containing activation schedule and power consumption parameters. The management controller **302** processes the activation schedule messages **320** to determine power consumption parameters. Alternatively, the management controller **302** may access the load device information via an internal memory access **318**. The information received within the activation schedule messages **320** may include the identity of load devices that are currently scheduled to be activated during a feed-out limit period specified by the feed-out limit message **316**. The activation schedule messages **320** may further specify the portion(s) of the feed-out limit period in which the load devices **306** are scheduled to be activated. The activation schedule messages **320** may further include power/energy consumption parameters associated with each of the currently scheduled load devices. Based on the power limit and the feed-out limit period specified by the feed-out limit message **316,** and the load device schedule and power consumption parameters, the management controller **302** may modify the scheduling of one or more of the load devices over the feed-out limit period. The schedule modification may include modifying the activation periods of load devices currently scheduled to be activated during the feed-out limit period. The schedule modification may also or alternately include scheduling load devices not currently scheduled to be activated during the feed-out limit period. The management controller **302** may then generate and transmit the modified device activation schedule within a modified activation schedule message **321** to the load devices **306**.

[0087] Based on the modified activation schedule message **321** and the feed-out limit message **316**, the management controller **302** transmits to the power generators **307** a modified feed-out limit message **322** that may specify a limit on the power level to be generated by one of the power generators **307**. The management controller **302** may further exchange net energy transfer messages **324** with the meter **304** to monitor net energy transfer between the energy management system and the external power grid **308**. For example, the management controller **302** may request the net energy transferred between the energy management system and the external power grid **308** from the meter **304**. The net energy transfer messages **324** may include responses from the meter **304** specifying the net energy transferred between the energy management system and the external power grid **308**. The net energy transferred may be an amount of energy transferred over a period of time from the external power grid **308** to the energy management system. The net energy transferred may also or alternately be an amount of energy transferred over a period of time from the energy management system to the external power grid **308**.

[0088] Using the net energy transfer messages **324**, the management controller **302** can determine energy transfer metrics that enable the management controller **302** to track energy consumption of unscheduled load devices in the energy management system. An unscheduled load device may refer to load device that is not included in activation scheduling (e.g., manually activated lights and electronic devices). As described vis-à-vis **FIG. 4**, the unscheduled energy consumption can be determined by subtracting the scheduled energy consumption from the total energy consumption. The scheduled energy consumption may comprise the current energy consumption of scheduled devices (i.e., devices included in activation scheduling). The current energy consumption of scheduled devices may be determined by identifying which of the scheduled devices are currently activated. The activation schedule message **320** and/or the modified activation schedule message **321** may be accessed to identify which of the scheduled devices are currently activated.

[0089] The management controller **302** may process the unscheduled energy consumption and generator energy output to generate and send an adjusted activation schedule message **326** to the load devices **306**. The adjusted activation schedule message **326** specifies time intervals over which one or more load devices are scheduled to be activated for all or portions of the feed-out limit period. For example, the specified feed-out limit period may be a period of 8 hours beginning at 10:30 AM to 6:30 AM on January 3. The adjusted activation schedule message **326** may include data and instructions specifying that one or more load devices be activated for one or more time intervals between 10:30 AM and 6:30 AM on January 3.

[0090] **FIG. 4A** is a flow diagram illustrating processing and communications performed during load management, in accordance with one embodiment. At block **404**, a management controller communicates with a meter to monitor the transfer of electrical energy between an energy management system and an external power grid. The management controller can monitor the transfer of electrical energy in real-time which may include monitoring the power level measured by the meter (e.g., as measured by the meter in kilowatts (kW)). Alternately, the management controller may monitor energy transfer directly by monitoring the amount of energy measured by the meter (e.g., as measured by the meter in kilowatt hours (kWh)). Particularly, the management controller may monitor the net energy transferred into or out of the energy management system. The management controller can use the net energy amount to modify activation scheduling of load devices in the energy management system. In some instances, the management controller can use the net energy amount along with a feed-out limit message to modify activation scheduling of load devices within the energy management system.

[0091] At block **406**, the management controller receives or processes a feed-out limit message while monitoring energy transfer at the meter. In one embodiment, the feed-out limit message may be received at the management controller from an external source, for example, an external power grid. In another embodiment, the feed-out limit message may be installed in the management controller at a manufacturer or distributer of the management controller. In some embodiments, multiple feed-out limit messages may be received or installed and processed by the management controller. If the feed-out limit message is transmitted, the feed-out limit message may be transmitted from an electric grid server system, or some other external source, to the meter and/or to the management controller directly.

[0092] The feed-out limit message may specify a feed-out limit (e.g., in kW) to be fed-out from the energy management system to the external power grid over a feed-out limit period. The feed-out limit message may also indicate a maximum energy amount (e.g., in kWh) to be fed-out from the energy management system to the external power grid over a feed-out limit period. In one embodiment, the feed-out limit message may indicate that during a certain time period, e.g. 1PM-3PM, no energy may be fed out. In another embodiment, the feed-out limit message or some other message, may indicate a value of the energy to be fed-out, e.g. how much the consumer will be paid for the fed-out energy by the power company. In this case, the management controller may make a determination based on the value of the energy, whether to feed-out the energy or use it to power local loads. At block **406**, the management controller may further process the received feed-out limit message to determine the specified feed-out limit and associated feed-out limit period and in some cases may determine a value of the energy to be fed back to the external power grid.

[0093] The management controller may adjust the power level feed-out to the external power grid based on the feed-out limit message and an activation schedule, which may be modified as described herein. The schedule modification may begin with the management controller determining a predicted average surplus power level over the feed-out limit period. As shown at block **408**, the management controller may estimate an amount of energy to be generated by one or more power generators within the energy management system, during the feed-out limit period. The management controller may estimate the power generators' energy output by accessing power generator activation data, which may be stored in an activation schedule (e.g., see device activation schedule **227** in **FIG. 2**). The activation schedule specifies which power generator(s) are scheduled to operate during, and for what portion of, the feed-out limit period. The power generator energy output data can include historical power and/or energy output data for the respective power generator devices. The management controller may also estimate the power generator devices' energy output by accessing recorded generator energy output data (e.g., generator output records **223** in **FIG. 2**). The power generators' energy output may be further estimated based on data such as weather forecasts, historical consumption patterns, and occupancy information.

[0094] The average surplus power level may be predicted based on the energy generation estimate and on an estimated amount of energy to be consumed over the feed-out limit period. Estimating energy consumption begins at block **410**, where the management controller may access current load device activation schedule(s). At block **412**, the management controller may use the current load device activation schedule(s) to identify which load devices are scheduled for activation at some point during, and for what portion of, the feed-out limit period. The load device activation schedules for each load device may be centrally maintained in memory by the management controller. In some instances, load device activation schedules may be contained in individual records maintained by the load devices. The records may be accessible to the management controller.

[0095] As shown at block **414**, the management controller determines an estimate of the total scheduled and unscheduled energy consumption of the energy management system during the feed-out limit time period. The total scheduled energy consumption estimate may be computed based, at least in part, on power and/or energy rating data, such as may be obtained from the load device entries **216**, **218**, and **220** in **FIG. 2**. The total scheduled energy consumption computation may be further based on the load device activation schedule. The load activation schedule which is processed with the power and/or energy rating data to obtain the total scheduled energy consumption over the feed-out limit period. The total scheduled energy consumption may be further based on data such as weather forecasts, historical consumption patterns, and occupancy information. The management controller generates the estimated total scheduled and unscheduled energy consumption by adding the determined scheduled energy consumption with an unscheduled energy consumption value. The unscheduled energy consumption value may be estimated based on historical unscheduled power consumption data stored in unscheduled energy consumption records **219** in **FIG. 2**.

[0096] As shown at block **416**, the management controller can determine the net feed-out energy capacity over the feed-out limit period. To determine the net feed-out energy capacity, the management controller may compare the estimated amount of energy to be generated (block **408**) with the estimated total energy consumption (blocks **410-414**). In one embodiment, the net feed-out energy capacity may be determined as the amount of energy by which the energy generation estimate exceeds the estimated total scheduled and unscheduled energy consumption. The management controller may determine a predicted average surplus power level (block **417**) based on the determined net energy over the feed-out limit time period.

[0097] At block **432**, the management controller may determine whether the average surplus power level exceeds a feed-out limit by a specified margin. The feed-out limit may be specified in a feed-out limit message, which the management controller received or stored earlier in time. If the average surplus power level does not exceed the feed-out limit by the specified margin, the process may continue at block **460** (**FIG. 4C**), where the management controller (or a generator controller) performs real-time tracking of the power generation and consumption. Also at block **460**, the management controller may also determine a feed-out power level based on the real-time power level generated and the real-time power level consumed. If the real-time tracking reveals that the feed-out power level exceeds the feed-out limit (block **462**), the management controller (or generator controller) may issue a power reduction instruction to at least one of the power generators (block **464**).

[0098] In an embodiment, the specified margin may be related to a value of the energy. In this case, the management controller may determine what the costs associated with the surplus power are and how much the surplus power is worth to the external power grid. In some cases, the external power grid may offer little or no financial incentive to feed the power out to the external grid. When the specified margin is related to the value of the energy, the management controller may determine the cost of energy with and without modifying the activation schedule for the feed-out limit period in order to determine whether it is financially reasonable to modify the activation schedule. The management controller may determine to make modifications to the activation schedule that result in the most financial benefit to the consumer.

[0099] Returning to block **432** (**FIG. 4B**), if the average surplus power level exceeds the feed-out limit by the specified margin, the management controller determines whether the average surplus power level exceeds a power level threshold associated with an adjustable load type (block **434**). In some instances, the adjustable load type may be a load that draws electrical power in an adjustable variable manner (i.e., operates at an adjustable or otherwise variable power level). For example, a battery charger is a variable power level device that would be included in this load-type category. If the adjustable load threshold is not exceeded (block **434**), the management controller determines whether an adjustable load device is available to be scheduled for at least some portion of the feed-out limit period (block **442**). If an adjustable load device is available, the management controller selects the adjustable load device to be scheduled for at least a portion of the feed-out limit period (block **438**). From block 438, the management controller may then return to block 408 to estimate energy to be generated by the power generators.

[00100] Returning to block **434**, if the average surplus power level exceeds the adjustable load threshold, the management controller begins a scheduling sequence (blocks **436**, **438**, **440, 442**). The scheduling sequence may use load device categories to schedule loads by load types. In some embodiments, the management controller uses load types such as may be specified in load device entries **216**, **218**, and **220** in **FIG. 2.** The scheduling sequence begins at block **436**. At block **436**, the management controller determines whether a Type 1 load device is available to be scheduled during at least a portion of the feed-out limit period. In one embodiment, Type 1 load devices may be associated with devices that operate in a continuous manner, and at a relatively constant power level. For example, a water recirculation pump may be categorized as Type 1. The type information may be in load device records. If a Type 1 load device is available to be scheduled, the management controller schedules it for at least a portion of the feed-out limit period. If a Type 1 load device is not available to be scheduled during the feed-out limit period, the management controller determines whether a Type 2 load device is available to be scheduled during at least a portion of the feed-out limit period (block **440**). In one embodiment, Type 2 load devices operate based on a duty cycle that is independent of management controller scheduling (i.e., powers off and on during scheduled activation). For example, a thermostat controlled HVAC system may be categorized as a Type 2 load device. If a Type 2 load device is available to be scheduled, the management controller schedules it for at least a portion of the feed-out limit period. If a Type 2 load device is not available to be scheduled during the feed-out limit period, the management controller determines whether an adjustable load device is available to be scheduled during at least a portion of the feed-out limit period (block **442**). If an adjustable load device is not available to be scheduled during the feed-out limit period, the process continues to step 460. In some embodiments, more or less than three types of loads may be present and each type of load may be iteratively checked based characteristics of the load type.

[00101] The management controller may modify schedules in a modular manner that schedules Type 1 load devices before scheduling type 2 load devices. After each additional load device is scheduled (at block **438**), the predicted average surplus power level (determined at blocks **408-417**) incrementally decreases. After scheduling of Type 1 and Type 2 loads, the management controller schedules adjustable load devices for the feed-out limit period (blocks **442** and **438**) to consume at least a portion of the remaining surplus power level. In this embodiment, the management controller may schedule loads of known types (e.g., Type 1 and Type 2) prior to scheduling adjustable loads.

[00102] Returning to block **460** in **FIG. 4C**, the management controller may commence or continue real-time tracking of the power generation and consumption. If the real-time tracking indicates a feed-out power level that exceeds the feed-out limit specified by the feed-out limit message (block **462**) , the management controller or generator controller may issue a power reduction instruction to at least one of the generator devices (block **464**).

[00103] At blocks **466** the management controller monitors the amount of energy consumed by unscheduled load devices (e.g., personal electronic devices and other manually activated/deactivated devices). At block **468**, the management controller monitors the amount of energy generated by variable power generators, such as a PV panel. The management controller monitors these potentially variable energy metrics over a time interval, ΔT, (block **470**) to determine whether additional schedule modification is needed before the start of, and/or during, the feed-out limit period. In one embodiment, the management controller may determine the total energy consumption of all currently active/operating, scheduled and unscheduled, load devices over ΔT. The management controller may determine the currently active/operating unscheduled energy consumption by subtracting the energy consumption of all currently active/operating scheduled devices from the total energy consumption. The management controller may track the actual energy output of one or more power generators within the energy management system. In one embodiment, the management controller determines the actual energy output from one or more of the power generators based on measurement data from the meter or from generator-incorporated power/energy output measurement devices.

[00104] As shown at block **470**, the generator output and unscheduled energy consumption information may be collected over ΔT to determine actual energy generation and unscheduled energy consumption values. The unscheduled energy consumption value may refer to currently active devices that were not scheduled. At block **472**, the management controller compares the actual energy generation and unscheduled energy consumption values with the predictively estimated energy generation and unscheduled energy consumption values processed at blocks **408** and **414** in **FIG. 4A**. In response to the actual energy generation and unscheduled energy consumption values diverging from the predictively estimated values by a margin (block **474**), the average surplus power level is again predictively estimated (blocks **408-417**). This predictive estimation may be based, at least in part, on the determined actual energy generation and unscheduled energy consumption values. The activation schedule is adjusted accordingly (again modified) as shown with the process beginning again at block **432**. If the divergence between the actual and predicted values does not exceed the threshold, energy generation and unscheduled energy consumption tracking continues (block **466**).

[00105] **FIG. 5** depicts an example computer system for implementing embodiments of the disclosure. In **FIG. 5**, a computer system **500** having a resource management unit **510**. The computer system **500** includes a processor **502**, but may include multiple processors, multiple cores, and/or multiple nodes. The computer system **500** includes memory **504** which may be system memory (e.g., one or more of cache, SRAM, DRAM, zero capacitor RAM, Twin Transistor RAM, eDRAM, EDO RAM, DDR RAM, EEPROM, NRAM, RRAM, SONOS, PRAM, etc.) or any one or more of the above already described possible realizations of non-transitory machine-readable storage media. The computer system 600 also includes a bus **505** (e.g., PCI, ISA, PCI-Express, HyperTransport®, InfiniBand®, NuBus, etc.), a network interface **506** (e.g., an Ethernet interface, a Frame Relay interface, Synchronous Optical Network interface, wireless interface, etc.), and a storage device(s) **508** (e.g., optical storage, magnetic storage, etc.). Resource management unit **510** embodies functionality to implement features described above with reference to **FIGS. 1-4**. Resource management unit **510** may perform operations that facilitate energy management within an environment in which energy is transferred between an energy management system and an external power grid. Resource management unit **510** may perform system management operations including modifying device activation scheduling based on a received feed-out limit message. Any one of these operations may be partially (or entirely) implemented in hardware and/or on processor **502**. For example, the functionality may be implemented with an application specific integrated circuit, in logic implemented in processor **502**, in a co-processor on a peripheral device or card, etc. Further, realizations may include fewer or additional components not illustrated in **FIG. 5** (e.g., additional network interfaces, peripheral devices, etc.).

[00106] It should be understood that **FIGS. 1 – 5** are examples meant to aid in understanding embodiments and should not be used to limit embodiments or limit scope of the claims. Embodiments may perform additional operations, fewer operations, operations in a different order, operations in parallel, and some operations differently. In some embodiments, the management controller can implement the operations of **FIG. 4** individually or in combination with other devices.

[00107] As will be appreciated by one skilled in the art, aspects of the disclosed subject matter may be embodied as a system, method or computer program product. Accordingly, embodiments of the disclosed subject matter may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or one embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, embodiments of the disclosed subject matter may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

[00108] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[00109] While the embodiments are described with reference to various implementations and exploitations, it will be understood that these embodiments are illustrative and that the scope of the disclosed subject matter is not limited to them.

CLAIMS

1. A method for managing loads within an energy management system that includes a management controller configured to control activation of a plurality of load devices, the method comprising:

the management controller,

determining a power limit associated with a feed-out limit period based, at least in part, on a feed-out limit message;

determining an average surplus power level over the feed-out limit period; and

modifying an activation schedule of at least one of the plurality of load devices based, at least in part, on the average surplus power level and the feed-out limit message.

2. The method of claim 1, wherein determining the average surplus power level comprises:

estimating a first amount of energy to be generated by a power generator during the feed-out limit period; and

estimating a second amount of energy to be consumed by the plurality of load devices over the feed-out limit period.

3. The method of claim 2, wherein determining the average surplus power level comprises:

comparing the first amount of energy to be generated with the second amount of energy to be consumed; and

determining the average surplus power level over the feed-out limit period based, at least in part, on the comparing.

4. The method of claim 2, wherein estimating the second amount of energy to be consumed comprises identifying one or more of the plurality of load devices that are scheduled to be activated during the feed-out limit period.

5. The method of claim 4, wherein estimating the second amount of energy to be consumed comprises:

determining power consumption parameters associated with the one or more of the plurality of load devices; and

estimating an unscheduled energy consumption value over the feed-out limit period.

6. The method of claim 1, further comprising:

the management controller,

determining a feed-out power level based, at least in part, on real-time power generation by a power generator and real-time power consumption of the plurality of load devices;

determining whether the feed-out power level exceeds the power limit; and

adjusting an output power level of the power generator based, at least in part, on determining whether the feed-out power level exceeds the power limit.

7. The method of claim 1, further comprising:

the management controller,

transferring power to an external power grid, the power generated by a power generator; and

adjusting the power transferred to the external power grid based, at least in part, on the feed-out limit message and the modified activation schedule.

8. The method of claim 1, wherein modifying the activation schedule further comprises:

the management controller,

determining whether the average surplus power level exceeds the power limit by a specified margin; and

determining to modify device activation scheduling based, at least in part, on determining that the average surplus power level exceeds the power limit by the specified margin.

9. The method of claim 1, wherein the plurality of load devices comprises a variable power level device and a constant power level device, and modifying the activation schedule comprises:

determining whether the average surplus power level exceeds an adjustable load threshold;

in response to determining that the average surplus power level exceeds the adjustable load threshold, selecting the constant power level device to be activated during the feed-out limit period;

determining a second average surplus power level based, at least in part, on selecting the constant power level device to be activated during the feed-out limit period; and

determining whether to schedule the variable power level device or another constant power level device based, at least in part, on the second average surplus power level.

10. The method of claim 1, further comprising:

following modifying the activation schedule, the management controller,

determining energy consumption by at least one unscheduled load device; and

adjusting the activation schedule based, at least in part, on the energy consumption by the at least one unscheduled load device.

11. The method of claim 1, further comprising:

determining a value of the average surplus power level, wherein modifying the activation schedule is further based, at least in part, on the value of the average surplus power level.

12. A management controller that controls activation of a plurality of load devices within an energy management system, the management controller comprising:

a processor; and

memory to store instructions, which when executed by the processor, cause the management controller to:

determine a power limit associated with a feed-out limit period based, at least in part, on a feed-out limit message;

determine an average surplus power level over the feed-out limit period; and

modify an activation schedule of at least one of the plurality of load devices based, at least in part, on the average surplus power level and the feed-out limit message.

13. The management controller of claim 12, wherein the instructions, which when executed by the processor, cause the management controller to:

estimate a first amount of energy to be generated by a power generator during the feed-out limit period; and

estimate a second amount of energy to be consumed by the plurality of load devices over the feed-out limit period.

14. The management controller of claim 13, wherein the instructions, which when executed by the processor, cause the management controller to:

compare the first amount of energy to be generated with the second amount of energy to be consumed; and

determine the average surplus power level over the feed-out limit period based, at least in part, on the comparing.

15. The management controller of claim 13, wherein estimating the second amount of energy to be consumed comprises identifying one or more of the plurality of load devices that are scheduled to be activated during the feed-out limit period.

16. The management controller of claim 15, wherein estimating the second amount of energy to be consumed comprises:

determining power consumption parameters associated with the one or more of the plurality of load devices; and

estimating an unscheduled energy consumption value over the feed-out limit period.

17. The management controller of claim 12, wherein the instructions, which when executed by the processor, cause the management controller to:

determine a feed-out power level based, at least in part, on real-time power generation by a power generator and real-time power consumption of the plurality of load devices;

determine whether the feed-out power level exceeds the power limit; and

adjust an output power level of the power generator based, at least in part, on determining whether the feed-out power level exceeds the power limit.

18. The management controller of claim 12, wherein the instructions, which when executed by the processor, cause the management controller to:

transfer power to an external power grid, the power generated by a power generator; and

adjust the power transferred to the external power grid based, at least in part, on the feed-out limit message and the modified activation schedule.

19. The management controller of claim 12, wherein the instructions, which when executed by the processor, cause the management controller to:

determine whether the average surplus power level exceeds the power limit by a specified margin; and

modify device activation scheduling based, at least in part, on determining that the average surplus power level exceeds the power limit by the specified margin.

20. The management controller of claim 12, wherein the plurality of load devices comprises a variable power level device and a constant power level device, and wherein the instructions, which when executed by the processor, cause the management controller to:

determine whether the average surplus power level exceeds an adjustable load threshold;

select, in response to determining that the average surplus power level exceeds the adjustable load threshold, the constant power level device to be activated during the feed-out limit period;

determine a second average surplus power level based, at least in part, on selecting the constant power level device to be activated during the feed-out limit period; and

determine whether to schedule the variable power level device or another constant power level device based, at least in part, on the second average surplus power level.

21. The management controller of claim 12, wherein the instructions, which when executed by the processor, cause the management controller to:

following modifying the activation schedule,

determine energy consumption by at least one unscheduled load device; and

adjust the activation schedule based, at least in part, on the energy consumption by the at least one unscheduled load device.

22. The management controller of claim 12, wherein the instructions, which when executed by the processor, cause the management controller to:

determine a value of the average surplus power level, wherein modifying the activation schedule is further based, at least in part, on the value of the average surplus power level.

23. A non-transitory machine-readable storage medium having machine executable instructions stored therein, the machine executable instructions comprising instructions to:

determine a power limit associated with a feed-out limit period, the power limit based, at least in part, on a feed-out limit message;

determine an average surplus power level over the feed-out limit period; and

modify an activation schedule of at least one of a plurality of load devices based, at least in part, on the average surplus power level and the feed-out limit message.

24. The non-transitory machine-readable storage medium of claim 23, wherein the instructions to determine the average surplus power level comprise instructions to:

estimate a first amount of energy to be generated by a power generator during the feed-out limit period; and

estimate a second amount of energy to be consumed by the plurality of load devices over the feed-out limit period.

25. The non-transitory machine-readable storage medium of claim 24, wherein the instructions to estimate the average surplus power level comprise instructions to:

compare the first amount of energy to be generated with the second amount of energy to be consumed; and

determine the average surplus power level over the feed-out limit period based, at least in part, on comparing the first amount of energy to be generated with the second amount of energy to be consumed.

26. The non-transitory machine-readable storage medium of claim 24, wherein the instructions to estimate the second amount of energy to be consumed comprise instructions to identify one

or more of the plurality of load devices that are scheduled to be activated during the feed-out limit period.

27. The non-transitory machine-readable storage medium of claim 26, wherein the instructions to estimate the second amount of energy to be consumed comprise instructions to:

determine power consumption parameters associated with the one or more of the plurality of load devices; and

estimate an unscheduled energy consumption value over the feed-out limit period.

28. The non-transitory machine-readable storage medium of claim 23, further comprising instructions to:

determine a feed-out power level based, at least in part, on real-time power generation by a power generator and real-time power consumption of the plurality of load devices;

determine whether the feed-out power level exceeds the power limit; and

adjust an output power level of the power generator based, at least in part, on determining whether the feed-out power level exceeds the power limit.

29. The non-transitory machine-readable storage medium of claim 23, further comprising instructions to:

transfer power to an external power grid, the power generated by a power generator; and

adjust the power transferred to the external power grid based, at least in part, on the feed-out limit message and the modified activation schedule.

30. The non-transitory machine-readable storage medium of claim 23, wherein the instructions to modify the activation schedule comprise instructions to:

determine whether the average surplus power level exceeds the power limit by a specified margin; and

determine to modify device activation scheduling based, at least in part, on determining that the average surplus power level exceeds the power limit by the specified margin.

31. The non-transitory machine-readable storage medium of claim 23, wherein the plurality of load devices includes a variable power level device and a constant power level device, and wherein the instructions to modify the activation schedule comprise instructions to:

determine whether the average surplus power level exceeds an adjustable load threshold;

select, in response to determining that the average surplus power level exceeds the adjustable load threshold, the constant power level device to be activated during the feed-out limit period;

determine a second average surplus power level based, at least in part, on selecting the constant power level device to be activated during the feed-out limit period; and

determine whether to schedule the variable power level device or another constant power level device based, at least in part, on the second average surplus power level.

32. The non-transitory machine-readable storage medium of claim 23, further comprising instructions to:

following modifying the activation schedule,

determine energy consumption by at least one unscheduled load device; and

adjust the activation schedule based, at least in part, on the energy consumption by the at least one unscheduled load device.

33. The non-transitory machine-readable storage medium of claim 23, further comprising instructions to:

determine a value of the average surplus power level, wherein modifying the activation schedule is further based, at least in part, on the value of the average surplus power level.

34. A management controller that controls activation of a plurality of load devices within an energy management system, the management controller comprising:

means for determining a power limit associated with a feed-out limit period, the power limit based, at least in part, on a feed-out limit message;

means for determining an average surplus power level over the feed-out limit period; and means for modifying an activation schedule of at least one of the plurality of load devices based, at least in part, on the average surplus power level and the feed-out limit message.

35. The management controller of claim 34 further comprising:

means for estimating a first amount of energy to be generated by a power generator during the feed-out limit period; and

means for estimating a second amount of energy to be consumed by the plurality of load devices over the feed-out limit period.

36. The management controller of claim 35 further comprising:

means for comparing the first amount of energy to be generated with the second amount of energy to be consumed; and

means for determining the average surplus power level over the feed-out limit period based, at least in part, on comparing the first amount of energy to be generated with the second amount of energy to be consumed.

37. The management controller of claim 35 further comprising means for identifying one or more of the plurality of load devices that are scheduled to be activated during the feed-out limit period.

38. The management controller of claim 37 further comprising:

means for determining power consumption parameters associated with the one or more of the plurality of load devices; and

means for estimating an unscheduled energy consumption value over the feed-out limit period.

39. The management controller of claim 34 further comprising:

means for determining a feed-out power level based, at least in part, on real-time power generation by a power generator and real-time power consumption of the plurality of load devices;

means for determining whether the feed-out power level exceeds the power limit; and

means for adjusting an output power level of the power generator based, at least in part, on determining whether the feed-out power level exceeds the power limit.

40. The management controller of claim 34 further comprising:

means for transferring power to an external power grid, the power generated by a power generator; and

means for adjusting the power transferred to the external power grid based, at least in part, on the feed-out limit message and the modified activation schedule.

41. The management controller of claim 34 further comprising:

means for determining whether the average surplus power level exceeds the power limit by a specified margin; and

means for determining to modify device activation scheduling based, at least in part, on determining that the average surplus power level exceeds the power limit by the specified margin.

42. The management controller of claim 34 further comprising:

means for determining whether the average surplus power level exceeds an adjustable load threshold;

means for selecting a constant power level device to be activated during the feed-out limit period in response to determining that the average surplus power level exceeds the adjustable load threshold;

means for determining a second average surplus power level based, at least in part, on selecting the constant power level device to be activated during the feed-out limit period; and

means for determining whether to schedule a variable power level device or another constant power level device based, at least in part, on the second average surplus power level.

43. The management controller of claim 34, further comprising:

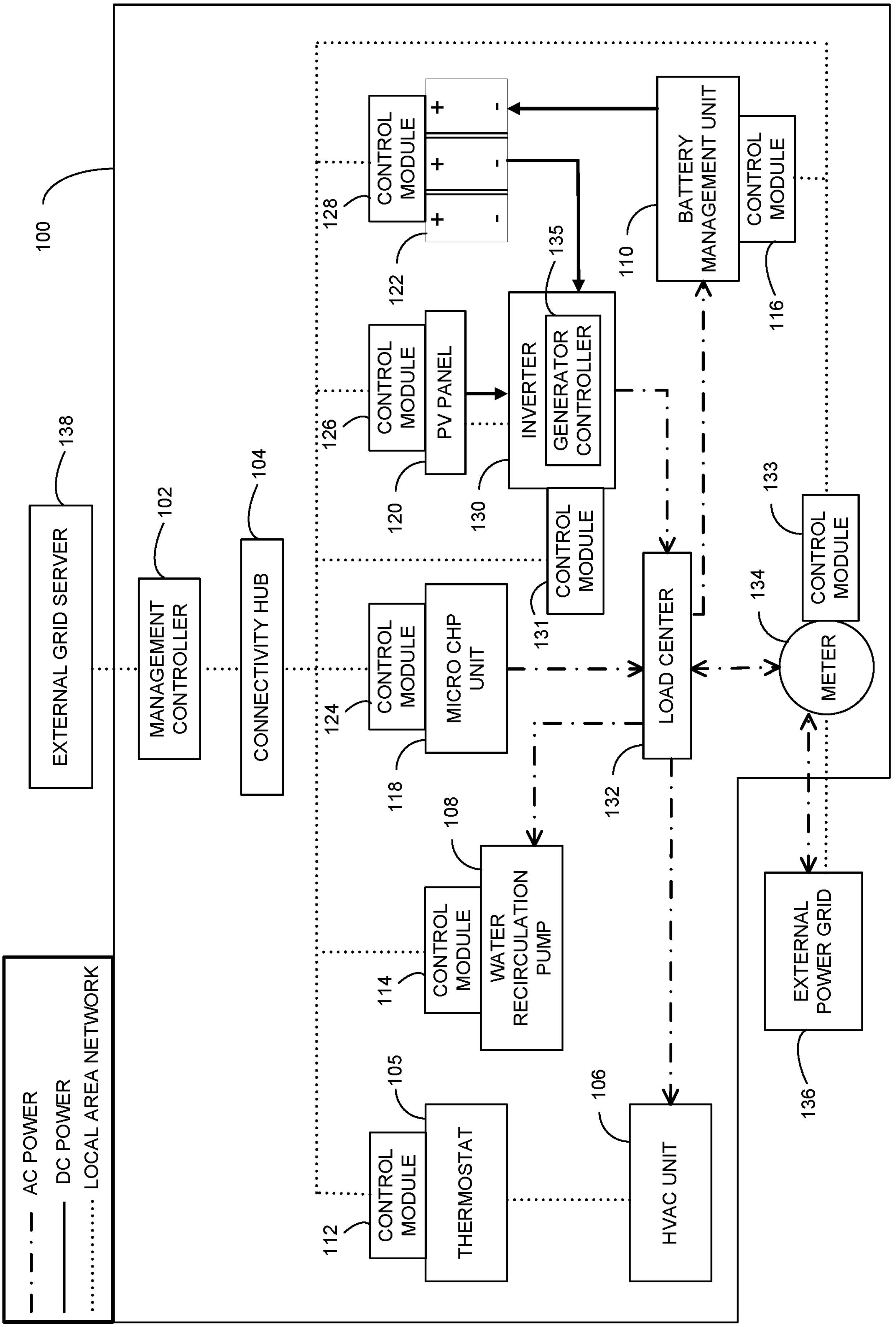
means for determining energy consumption by at least one unscheduled load device; and

means for adjusting the activation schedule based, at least in part, on the energy consumption by the at least one unscheduled load device.

44. The management controller of claim 34, further comprising:

means for determining a value of the average surplus power level; and

means for modifying the activation schedule further based, at least in part, on the value of the average surplus power level.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EXTERNAL GRID SERVER
138
MANAGEMENT CONTROLLER
102
CONNECTIVITY HUB
104
CONTROL MODULE
128
122
CONTROL MODULE
PV PANEL
126
120
INVERTER
GENERATOR CONTROLLER
135
130
CONTROL MODULE
131
BATTERY MANAGEMENT UNIT
110
CONTROL MODULE
116
CONTROL MODULE
MICRO CHP UNIT
124
118
LOAD CENTER
132
METER
134
CONTROL MODULE
133
CONTROL MODULE
WATER RECIRCULATION PUMP
108
114
CONTROL MODULE
THERMOSTAT
105
112
HVAC UNIT
106
EXTERNAL POWER GRID
136
AC POWER
DC POWER
LOCAL AREA NETWORK

FIG. 1

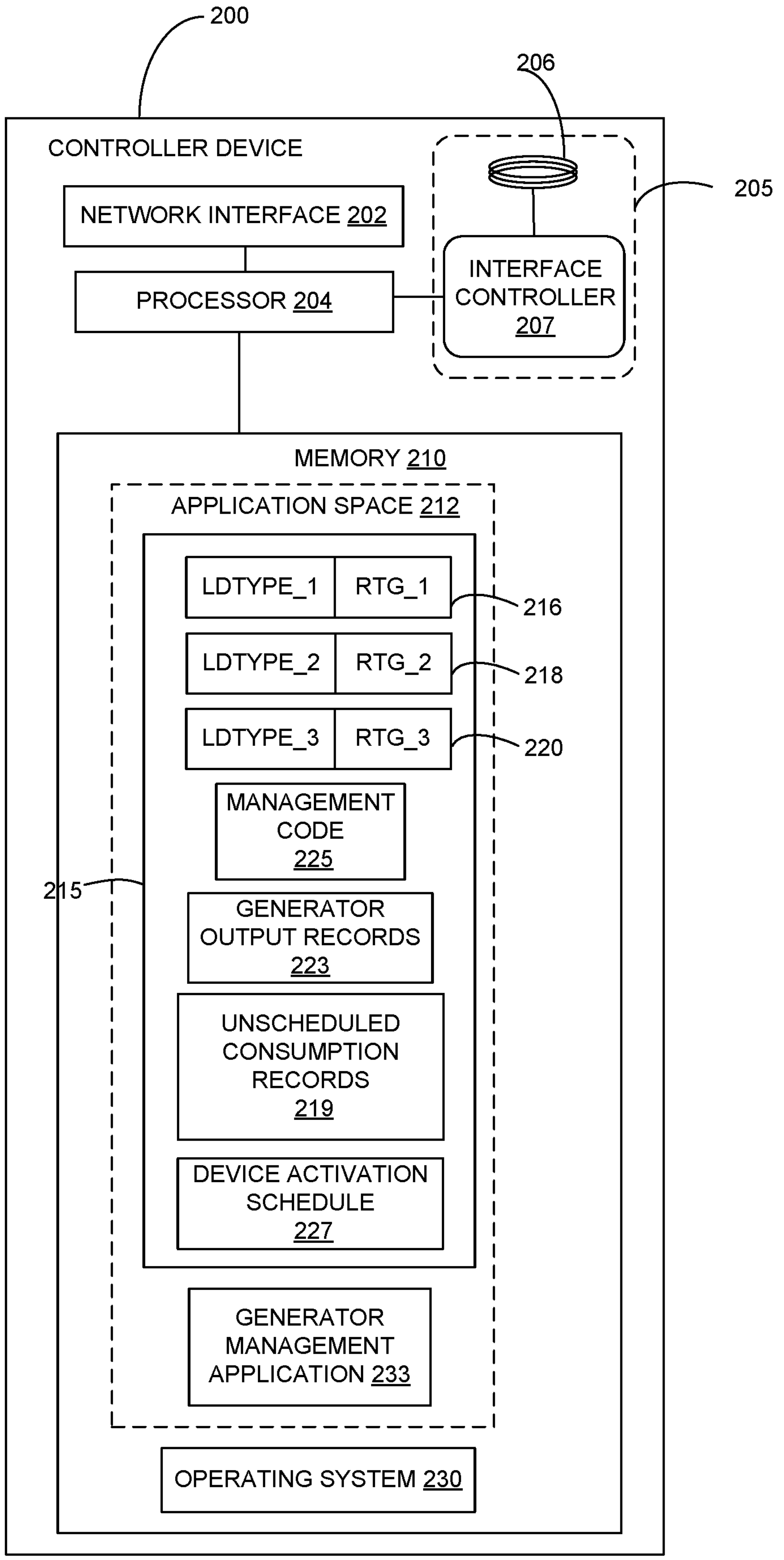
200
206
205
CONTROLLER DEVICE
NETWORK INTERFACE 202
PROCESSOR 204
INTERFACE CONTROLLER 207
MEMORY 210
APPLICATION SPACE 212
LDTYPE_1
RTG_1
216
LDTYPE_2
RTG_2
218
LDTYPE_3
RTG_3
220
MANAGEMENT CODE 225
215
GENERATOR OUTPUT RECORDS 223
UNSCHEDULED CONSUMPTION RECORDS 219
DEVICE ACTIVATION SCHEDULE 227
GENERATOR MANAGEMENT APPLICATION 233
OPERATING SYSTEM 230

FIG. 2

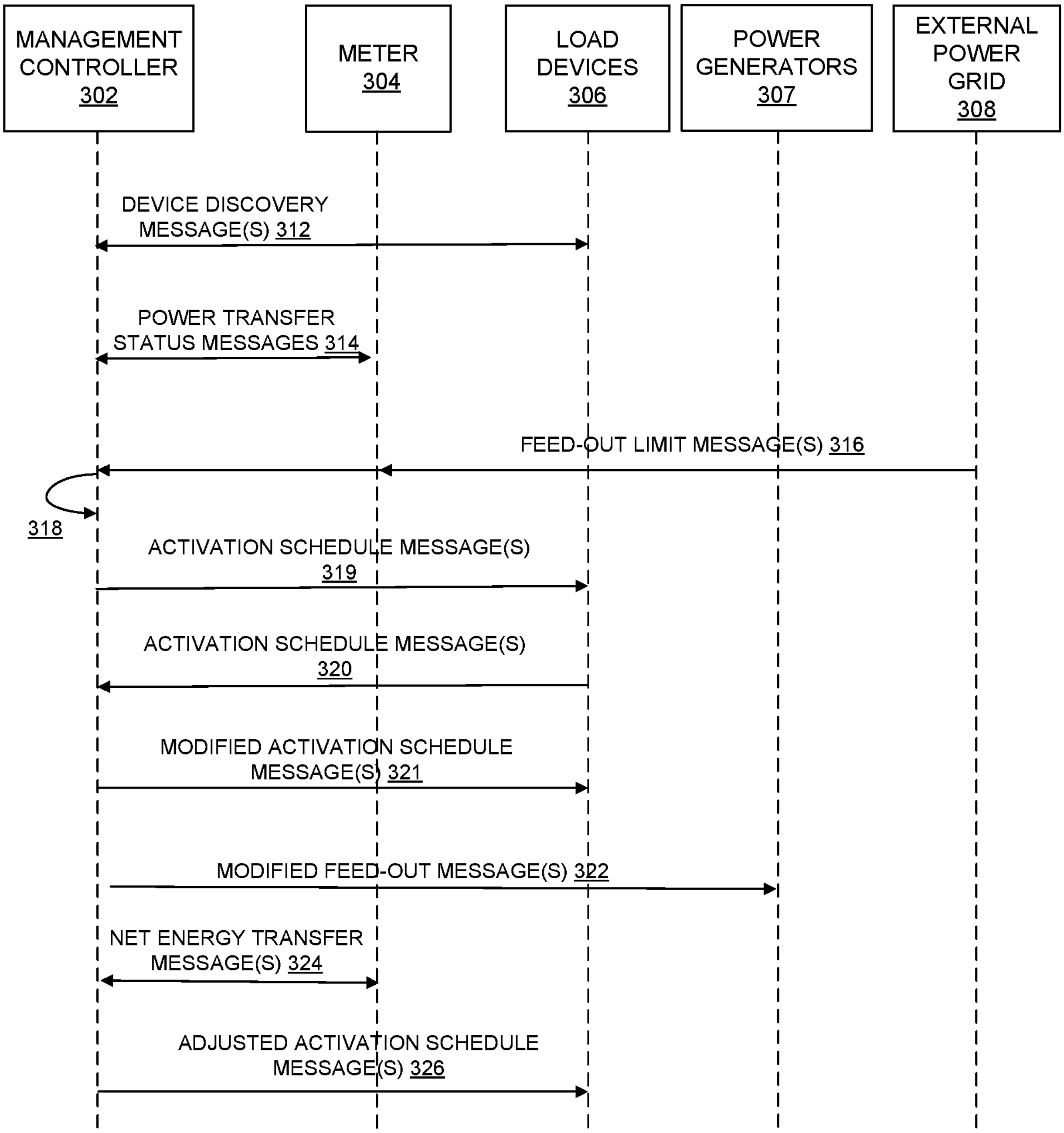
MANAGEMENT CONTROLLER 302
METER 304
LOAD DEVICES 306
POWER GENERATORS 307
EXTERNAL POWER GRID 308
DEVICE DISCOVERY MESSAGE(S) 312
POWER TRANSFER STATUS MESSAGES 314
FEED-OUT LIMIT MESSAGE(S) 316
318
ACTIVATION SCHEDULE MESSAGE(S) 319
ACTIVATION SCHEDULE MESSAGE(S) 320
MODIFIED ACTIVATION SCHEDULE MESSAGE(S) 321
MODIFIED FEED-OUT MESSAGE(S) 322
NET ENERGY TRANSFER MESSAGE(S) 324
ADJUSTED ACTIVATION SCHEDULE MESSAGE(S) 326

FIG. 3

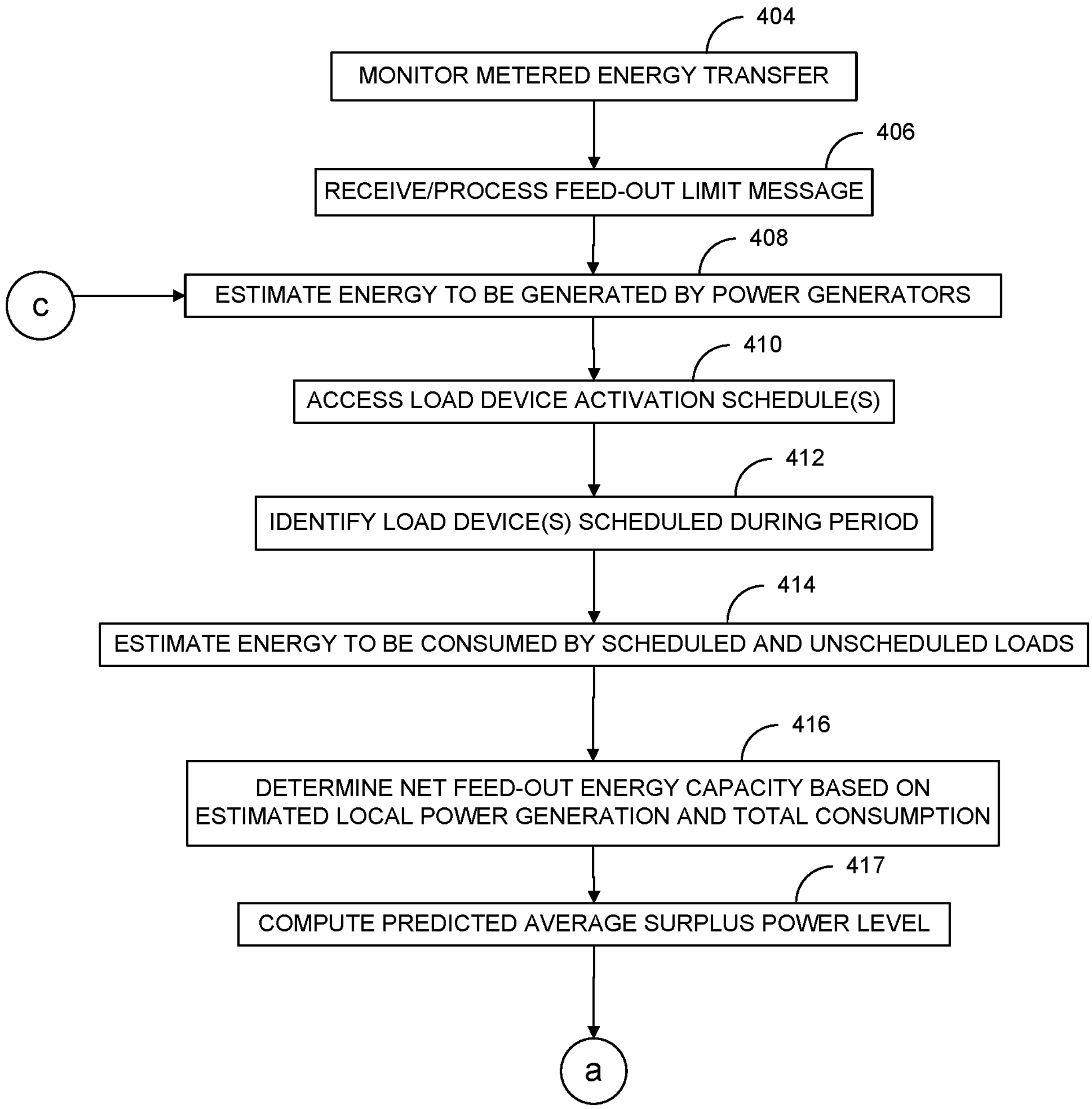
404
MONITOR METERED ENERGY TRANSFER
406
RECEIVE/PROCESS FEED-OUT LIMIT MESSAGE
408
c
ESTIMATE ENERGY TO BE GENERATED BY POWER GENERATORS
410
ACCESS LOAD DEVICE ACTIVATION SCHEDULE(S)
412
IDENTIFY LOAD DEVICE(S) SCHEDULED DURING PERIOD
414
ESTIMATE ENERGY TO BE CONSUMED BY SCHEDULED AND UNSCHEDULED LOADS
416
DETERMINE NET FEED-OUT ENERGY CAPACITY BASED ON ESTIMATED LOCAL POWER GENERATION AND TOTAL CONSUMPTION
417
COMPUTE PREDICTED AVERAGE SURPLUS POWER LEVEL
a

FIG. 4A

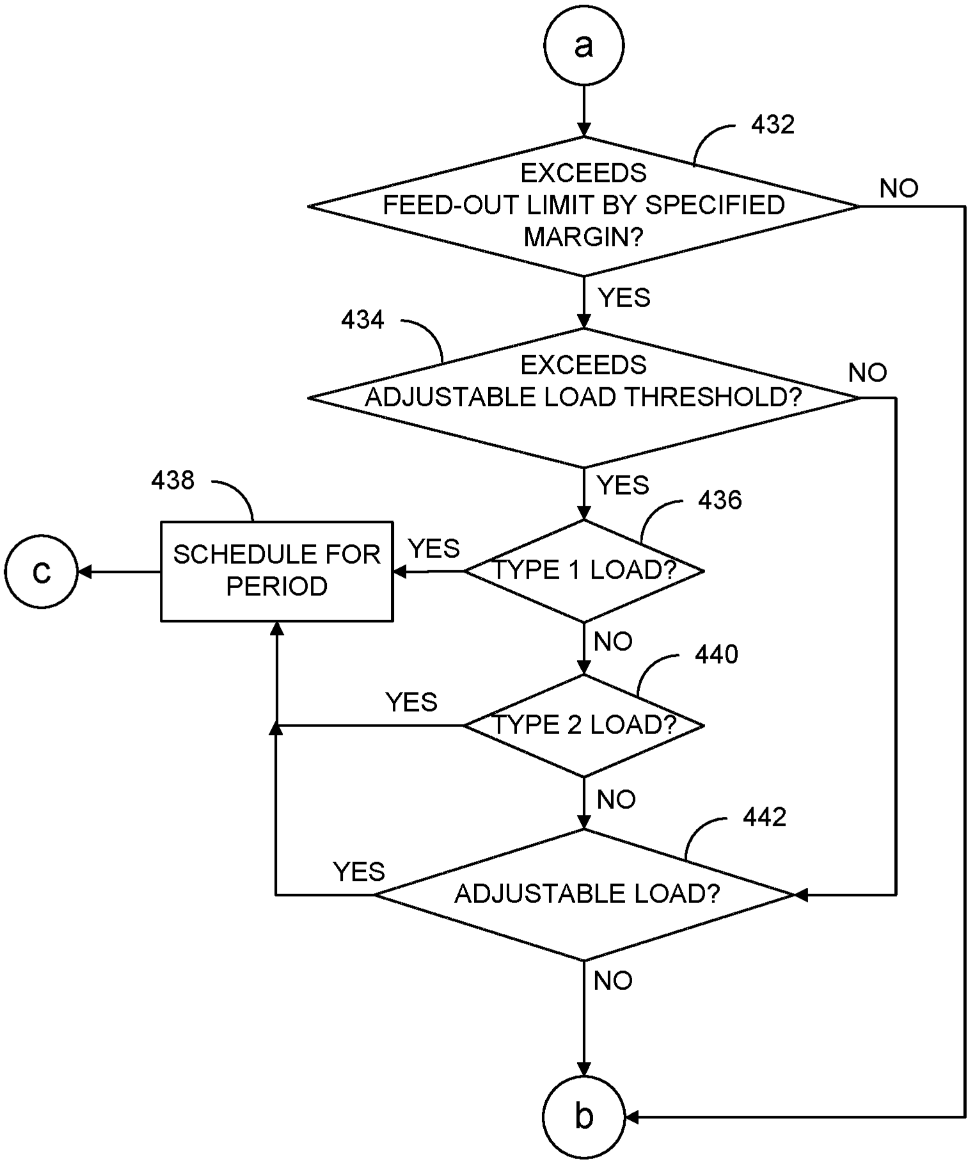
a
432
EXCEEDS FEED-OUT LIMIT BY SPECIFIED MARGIN?
NO
YES
434
EXCEEDS ADJUSTABLE LOAD THRESHOLD?
NO
YES
438
436
SCHEDULE FOR PERIOD
YES
TYPE 1 LOAD?
c
NO
440
YES
TYPE 2 LOAD?
NO
442
YES
ADJUSTABLE LOAD?
NO
b

FIG. 4B

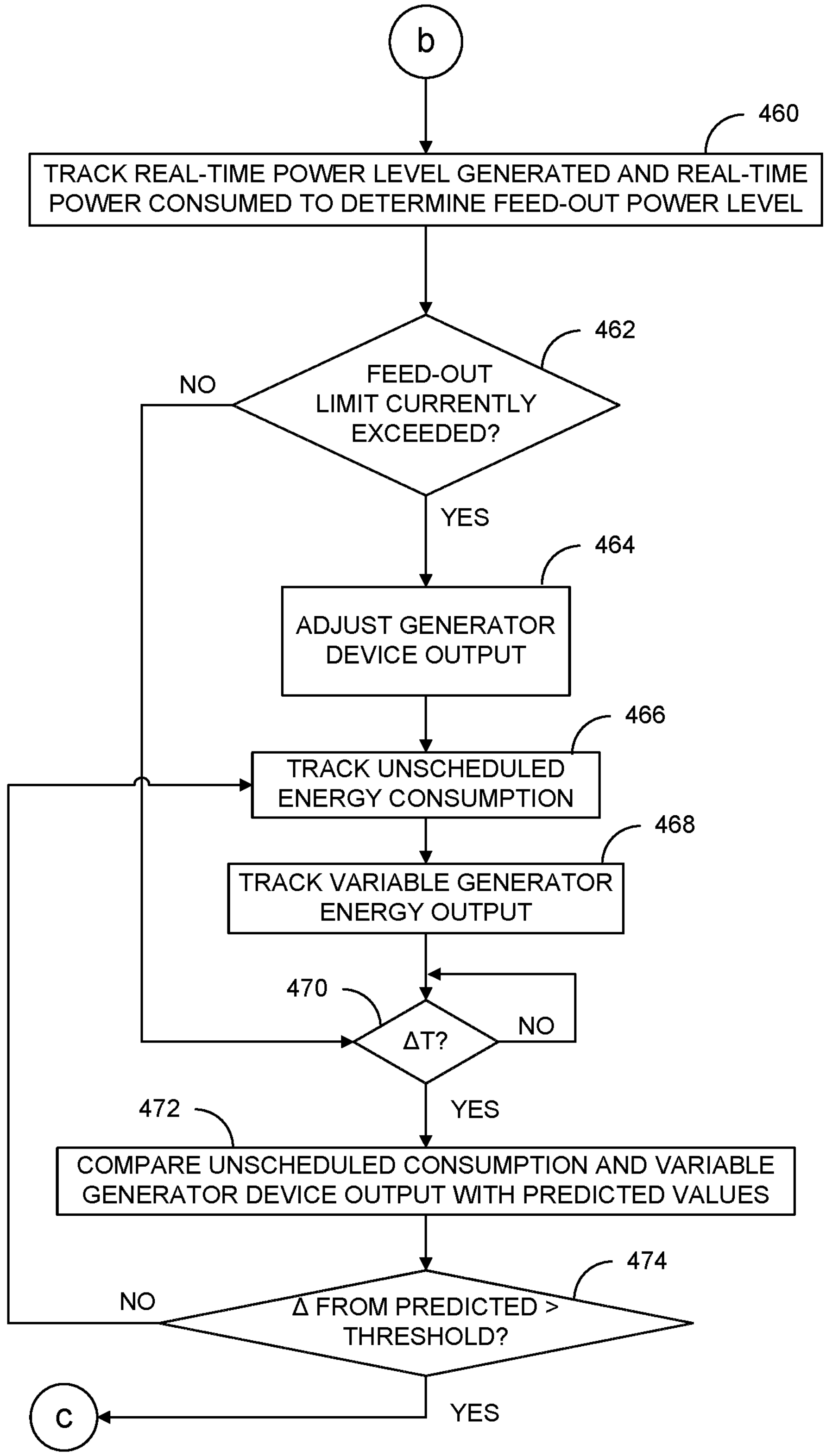
b
460
TRACK REAL-TIME POWER LEVEL GENERATED AND REAL-TIME POWER CONSUMED TO DETERMINE FEED-OUT POWER LEVEL
462
FEED-OUT LIMIT CURRENTLY EXCEEDED?
NO
YES
464
ADJUST GENERATOR DEVICE OUTPUT
466
TRACK UNSCHEDULED ENERGY CONSUMPTION
468
TRACK VARIABLE GENERATOR ENERGY OUTPUT
470
ΔT?
NO
YES
472
COMPARE UNSCHEDULED CONSUMPTION AND VARIABLE GENERATOR DEVICE OUTPUT WITH PREDICTED VALUES
474
Δ FROM PREDICTED > THRESHOLD?
NO
YES
c

FIG. 4C

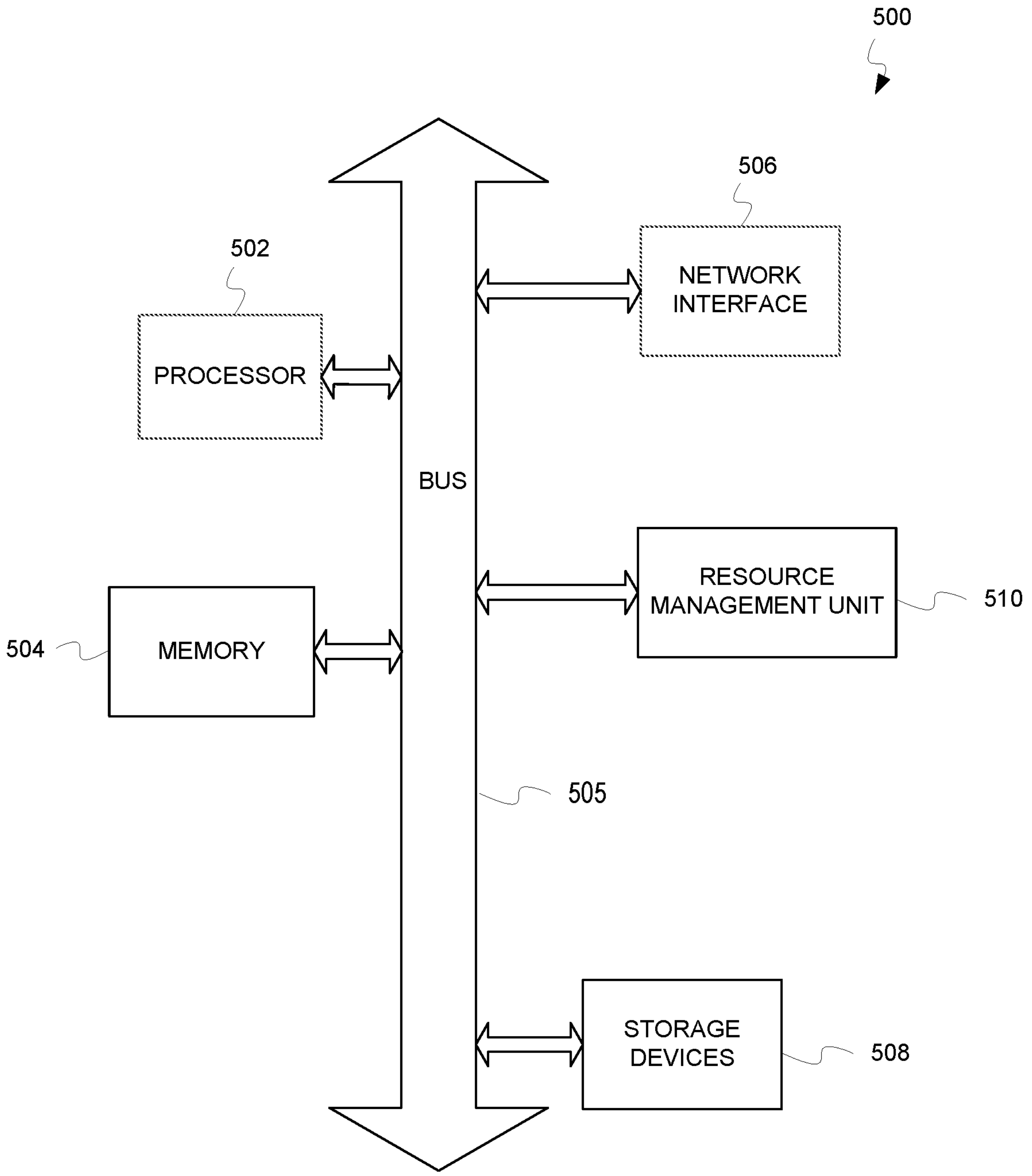
500
506
502
NETWORK INTERFACE
PROCESSOR
BUS
RESOURCE MANAGEMENT UNIT
510
504
MEMORY
505
STORAGE DEVICES
508

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/014668

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J3/14 H02J13/00 H02J3/38
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 8 548 637 B2 (LENOX CARL J S [US]) 1 October 2013 (2013-10-01) the whole document	1-44
A	EP 2 660 943 A1 (PANASONIC CORP [JP]) 6 November 2013 (2013-11-06) abstract; claim 1; figure 2 paragraph [0066] - paragraph [0070]	1-44
A	US 2010/017045 A1 (NESLER CLAY G [US] ET AL) 21 January 2010 (2010-01-21) abstract; claim 1; figures paragraph [0061] - paragraph [0066] paragraph [0006] - paragraph [0008] paragraph [0024] - paragraph [0027]	1-44

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 April 2016	02/05/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rother, Stefan

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/014668

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 8548637	B2	01-10-2013	AU	2010282850	A1	02-02-2012
			EP	2465178	A2	20-06-2012
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			EP	2660943	A1	06-11-2013
			JP	5807201	B2	10-11-2015
			JP	2012152093	A	09-08-2012
			US	2013270911	A1	17-10-2013
			WO	2012091113	A1	05-07-2012
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			WO	2010042550	A2	15-04-2010