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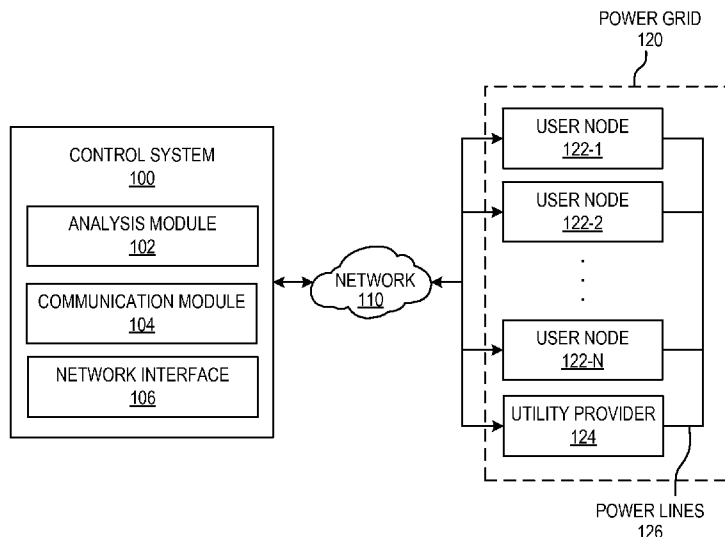


FIG. 1

- (57) Abstract: Example implementations may relate to a control system. The control system may predict a power disruption to a power grid that includes a plurality of interconnected user nodes. The control system may determine a power distribution plan to mitigate the power disruption based on a policy

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framework that includes profiles of the user nodes. The power distribution plan may be to route power between user nodes to mitigate the power disruption. The control system may transmit control signals over a network to the user nodes to implement the power distribution plan.

POWER DISTRIBUTION PLAN

BACKGROUND

[0001] An electrical utility provider may supply power from a power plant to residential and commercial consumers via a power grid. Consumers may experience power disruptions due to various causes, such as faults at the power plant, damage to the power grid, and high consumer demand. Individual consumers may maintain backup generators to privately mitigate power disruptions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Various examples will be described below with reference to the following figures.

[0003] FIG. 1 is a block diagram showing an example control system to determine a power distribution plan.

[0004] FIG. 2 is a block diagram showing an example control system to determine a power distribution plan.

[0005] FIG. 3 is a block diagram showing an example control system to determine a power distribution plan.

[0006] FIG. 4 is a flow diagram of an example method for determining a power distribution plan.

[0007] FIG. 5 is a flow diagram of an example method for determining a power distribution plan.

[0008] FIG. 6 is a flow diagram of an example method for determining a power distribution plan.

[0009] FIG. 7 is a block diagram showing a non-transitory, machine-readable medium encoded with example instructions to determine a power distribution plan.

DETAILED DESCRIPTION

[0010] A power plant operated by a utility provider may deliver power (e.g., electric power) to residential and commercial consumers by way of a power grid, which may include power lines, substations, and other related infrastructure. In some cases, the power grid or the power plant may operate abnormally due to conditions such as consumer demand in excess of utility provider supply capacity, equipment failure or weather related damage at the power grid or power plant, and faults within the power grid or the power plant. In such cases, consumers may experience power disruptions such as blackouts (a total loss of power) or brownouts (a drop in voltage of power). Some consumers may have local power sources to generate power independent of the utility provider and to privately mitigate a power disruption. Accordingly, a resilient system to predict power disruptions and to coordinate a power distribution among consumers may be useful to mitigate power disruptions.

[0011] Referring now to the figures, FIG. 1 is a block diagram showing an example control system 100 that may determine a power distribution plan. The control system 100 may be a computing device, such as, for example, a server, a desktop computer, a workstation, a laptop computer, or the like. The control system 100 may comprise various modules, such as an analysis module 102 and a communication module 104, which will be described further herein below. As used herein, the term "module" may refer to a set of instructions encoded on a machine-readable medium of a device (e.g., control system 100) and executable by a processor of the device. Additionally or alternatively, a module may include a hardware device comprising electronic circuitry for implementing the functionality described below. The control system 100 may include a network interface 106 suitable for communicating over a network 110, such as a local area network, a wide area network, a virtual private network, a dedicated intranet, the Internet, a wireless network, a satellite network, a cellular network, a cloud environment, or the like. For example, the network interface 106 may be a wired or wireless interface.

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[0012] The control system 100 may communicate by way of the network 110 with entities of a power grid 120. The power grid 120 may comprise a plurality of user nodes 122 (e.g., user nodes 122-1, 122-2, 122-N, etc.) and may also comprise a utility provider 124. In some implementations, the control system 100 acts as a separate and independent third-party with respect to the user nodes 122 and the utility provider 124. The utility provider 124 may include a power plant (e.g., a fossil fuel plant, a nuclear plant, a solar plant, a hydroelectric plant, a wind plant, a geothermal plant, or the like) or a company that controls the sale and distribution of power from a power plant. In some instances, a user node 122 may be a residential user node (also referred to as a residential consumer), such as a single-family home, a multi-family home, a mobile home, or the like. In other instances, a user node 122 may be a commercial user node (or commercial consumer), such as a retail establishment, a hospital, a transportation hub or facility, or any other user node that is not categorized as a residential user node. Each user node 122 may include various power consuming appliances, such as lighting, domestic appliances (e.g., HVAC system, refrigerator, washing machine, computer, television, etc.), an electric vehicle charging station, or other electrically powered equipment. Accordingly, the user nodes 122 generally may be deemed consumers of the power grid 120. In some instances, at least one of the user nodes 122 may generate power. For example, a user node 122 may include a local generator (e.g., a solar panel/array generator, a wind turbine generator, a back-up generator, or other similar sources of power), and the amount of power generated by the local generator may offset consumption at the user node, satisfy consumption at the user node, or exceed consumption at the user node. A user node that generates power may sell power to the utility provider 124 or share/sell to other ones of the user nodes 122, as will be described below.

[0013] The user nodes 122 and the utility provider 124 of the power grid 120 may be interconnected by power lines 126 (e.g., transmission lines and/or distribution lines). Power may be routed over the power lines 126, for example, from the utility provider 124 to various ones of the user nodes 122, from a user

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node 122 to the utility provider 124, or from a user node to another user node. In some implementations, each of the user nodes 122 may be individually addressable for the purpose of power delivery and routing, such as between user nodes, and more particularly, as coordinated by the control system 100 in a manner described below. For example, each user node 122 may include an addressable power gateway to interface with the power lines 126 and the power grid 120. In some implementations, the addressable power gateway may also include a network interface by which the user communicates with the network 110, as described above. Moreover, the power gateway may further control distribution of power within the user node 122, such as to different sockets, circuits, devices, equipment, or appliances. Such an addressable power gateway may be in addition to or in substitution of electric meters installed at many user nodes 122. Additionally, the power grid 120 may include power routers that can route power along the appropriate power lines 126 to reach an addressed one of the user nodes 122. Accordingly, in some implementations, the power grid 120 may be deemed to function in a manner analogous to a computing network for routing data between computing nodes.

[0014] As described above, the control system 100 may include an analysis module 102 and a communication module 104. The analysis module 102 may be to predict a power disruption to the power grid 120 (comprising the plurality of user nodes 122 and the utility provider 124, where at least one user node 122 generates power). In some implementations, the analysis module 102 may predict a power disruption by analysis of various factors individually or in any combination, in a manner described further herein below with respect to FIG. 4. Such factors for analysis may include, for example, power usage patterns of the power grid 120, power fluctuations of the power grid 120, and weather forecasts. As part of the power disruption prediction, the analysis module 102 may specify particular ones of the user nodes 122 that may be affected by the power disruption, the nature of the power disruption (e.g., estimated time and duration, blackout or brownout, etc.), and a likelihood or probability that those user nodes will be affected.

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[0015] The analysis module 102 also may be to determine a power distribution plan to mitigate (or prepare for) the power disruption based on a policy framework. In some implementations, the analysis module 102 may determine the power distribution plan in response to predicting a power disruption. As described above, a power disruption may be a condition wherein the user nodes 122 do not receive sufficient power, owing to failures, faults, or damage of the power grid 120 or the utility provider 124. As a general example then, the analysis module 102 is to coordinate distribution of available power on the power grid 120 among the user nodes 122. For example, distribution of available power may mean a load rebalancing or power rationing to make use of a reduced power supply from the utility provider 124 or may mean a distribution of power generated by some of the user nodes 122. Such distribution may be based on various premises, such as need-based or economic drivers. As a result of the distribution of available power according to the analysis module 102, some user nodes may receive uninterrupted or continuous supply of power when the predicted power disruption occurs and/or a number of user nodes affected by the power disruption may be minimized.

[0016] In some implementations, the power distribution plan may be to route power between the user nodes 122 (i.e., a peer-to-peer power sharing or power sale, as will be described below), which may mitigate the power disruption with respect to at least some of the user nodes 122. In some implementations, the power distribution plan may be to modify (e.g., reduce) power consumption of a user node 122, which may mitigate the power disruption at least with respect to the utility provider 124 by, for example, reducing load on the utility provider 124. In some implementations, the power distribution plan may be to instruct or control a user node 122 to store power in a storage device at the user node 122 (e.g., flywheels, batteries, capacitors, or the like) in preparation for the predicted power disruption.

[0017] More particularly, as described above, the analysis module 102 may determine (or develop) the power distribution plan based on a policy framework. The policy framework may include profiles of the user nodes 122 for power

sharing and/or profiles of the user nodes 122 for power consumption modification, and may be in the form of a database. The policy framework also may include a designation of each user node 122 as a power consumer and/or a power generator, and a power generation capacity for a user node designated as a power generator. The policy framework is flexible and may include other preferences of the user nodes 122 as pertains to power generation, consumption, and distribution, in addition or as an alternative to the profiles and preferences described herein. In some implementations, the policy framework may be stored at (or otherwise accessible by) the control system 100, in a machine-readable medium, memory, or storage, for example. The profiles included in the policy framework may be registered individually by each user node 122, for example, by way of a web-based interface or application. Some example user node profiles and preferences of the policy framework will now be described.

[0018] In some implementations, the profile of a user node 122 may include a priority level for power disruption mitigation at that particular node, the priority level being associated with a job of that particular node. For example, a life-critical or safety-critical user node, such as a medical facility or a transit system (e.g., railroad signaling systems, air traffic control towers, etc.), may indicate a high priority level for receiving power in the event of a predicted (or ongoing) power disruption. In comparison, a retail location user node (e.g., a store) or a residential user node may indicate a lower priority level for receiving power in response to a disruption to the power grid 120. In some implementations, the priority level at a particular node may be specified at finer levels of granularity, such as per subsystem within a user node 122 (e.g., emergency lighting, fire suppression system), per specific rooms within a user node building, per specific appliances or equipment at the user node, etc. The analysis module 102 may attempt to distribute power first to higher priority level user nodes when determining the power distribution plan.

[0019] In some implementations, the profile of a user node for power sharing may include a preference for a user node (e.g., 122-1) to provide power to another particular user node (e.g., 122-2), based on need or personal preference

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and either gratis or for a fee. The profile may include the identity of that another particular user node. To illustrate, a resident of a first user node (e.g., 122-1) may wish to share power with another user node (e.g., 122-2) because of a friendship or familial relationship. As another illustration, a resident at a first user node (e.g., 122-1) may be aware that a neighboring resident at a second user node (e.g., 122-2) is less tolerant of a power disruption (e.g., the neighboring resident may rely on electrically powered home medical equipment), and the resident of the first user node (e.g., 122-1) therefore may choose to indicate in their profile a preference to provide (by sharing or selling) power to the second user node (e.g., 122-2) in the event of a power disruption, thus mitigating the power disruption at least as to the second user node (e.g., 122-2). In order for the first user node (e.g., 122-1) to send power to the second user node (e.g., 122-2), the first user node (e.g., 122-1) may be a power generating user node in some examples. Additionally or alternatively, in other examples, the first user node (e.g., 122-1) may be unaffected by the power disruption experienced by the second user node (e.g., 122-2) and thus have power to route to the second user node (e.g., 122-2). The analysis module 102 may incorporate the above-described power sharing preferences when determining the power distribution plan.

[0020] In some implementations, the profile of a user node 122 for power sharing may include a power pricing model. A power pricing model may be used when, in the event of a power disruption, a user node (e.g., 122-1) that generates power is willing to sell generated power and another node wants to buy power (e.g., 122-2) in order to mitigate the power disruption, and such nodes may be deemed a seller user node and a buyer node, respectively. In some implementations, the selling user node (e.g., 122-1) may be willing to sell power that it receives from a utility provider 124. A power pricing model may include preferences and rules of a user node as a seller, a buyer, or both a seller and a buyer. Example aspects of the power pricing model of a user node 122 as a seller may include a desired sales price of shared power (e.g., a preferred, minimum, and/or target sales price), a time of day for selling (e.g., when a

resident of a seller user node is away and has less personal need for generated power), and an amount of power the user node is willing to sell. Example aspects of a power pricing model of a user node 122 as a buyer may include a maximum buy price, a time of day for buying, and a characteristic of received power (e.g., generated by another user node power or sourced from a utility provider, power quality, voltage magnitude, frequency stability, proximity of the seller user node, power conditioning, etc.). In some implementations, the analysis module 102 may determine the power distribution plan by matching a seller user node (e.g., 122-1) and a buyer user node (e.g., 122-2), from among many seller user nodes and buyer user nodes, according to an auctioning process or a cost-benefit analysis using the policy framework, as will be described in greater detail below.

[0021] In some implementations, the profile of a user node 122 for power consumption modification includes a prioritized schedule for modifying appliance power consumption at the particular user node. For example, appliance power consumption may be modified by shutting down an appliance, reducing an amount of power supplied to or consumed by an appliance, modifying the time or duration of operation of an appliance (and thus the time or duration of power consumption), or operating the appliance in an economy mode. Because a user node 122 may include or operate multiple appliances, power consumption modification of those appliances may be prioritized (e.g., at a residential user node, powering an HVAC system may be deemed more important than powering an electric vehicle charging station, and thus the corresponding profile may prioritize modifying/reducing power to the charging station before modifying/reducing power to the HVAC system). An analysis module 102 may use the prioritized schedules in the policy framework to determine a power distribution plan that rebalances load on the power grid 120 to mitigate a predicted power disruption (for example, when the power grid 120 is not damaged but user consumption is high, as during extreme hot or cold weather).

[0022] Accordingly, the analysis module 102 can determine or develop a power distribution plan to mitigate a power disruption of the power grid 102 based

on a policy framework. Various factors, which may be complementary or competing in nature, may be integrated in the policy framework, and analysis of the factors by the analysis module 102 may lead to an optimal power distribution outcome in some cases.

[0023] The communication module 104 may send a control signal to at least one of the user nodes 122 to implement the power distribution plan. For example, the communication module 104 can send the control signal to the user nodes 122 by way of the network interface 106 and the network 110. In some implementations, the control signal may instruct a user node (e.g., 122-1) to route power to another user node (e.g., 122-2) according to the power distribution plan. In some implementations, the control signal may instruct a user node 122 to modify its power consumption according to the power distribution plan. In some implementations, the control signal may instruct a user node 122 to store power.

[0024] In some implementations, the communication module 104 may also send a notification to a user device associated with a particular user node regarding the implementation of the power distribution plan. The user device may be, for example, a smart phone, a wearable device, a tablet computing device, a laptop computer, a desktop computer, an on-board vehicle-based computer, or the like. The notification may be to notify a user of the user device (and thus a user/resident of the particular user node) if the power distribution plan is to route power to or from the particular user node. The notification may be to notify the user of a user node if the power distribution plan is to modify power consumption of the user node.

[0025] In some implementations, the control system 100 may be independent from the user nodes 122 and the utility provider 124. Accordingly, in the event a utility provider 124 fails or goes offline, the control system 100 may be still able to mitigate disruption to the power grid 120, for example, by coordinating power sharing between the user nodes 122 over the network 110.

[0026] FIG. 2 is a block diagram of an example control system 200 that may determine a power distribution plan. The control system 200 may be a computing

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device, such as, for example, a server, a desktop computer, a workstation, a laptop computer, or the like. The control system 200 may include a network interface 206 for communicating, by way of a network 210, with user nodes 222 and/or a utility provider 224 of a power grid 220. The network interface 206, the network 210, the power grid 220, the user nodes 222, and the utility provider 224 may be analogous in many respects to the network interface 106, the network 110, the power grid 120, the user nodes 122, and the utility provider 124 of FIG. 1, respectively. For example, as with the user nodes 122 and the utility provider 124, the user nodes 222 and the utility provider 224 may be interconnected by power lines 226. Additionally, the user nodes 222 may be individually addressable for the purpose of power delivery and routing (e.g., by an addressable power gateway at each user node). In some implementations, the control system 200 may monitor or track the power routed through the power grid 220, by querying the power gateway at each user node 222 for example.

[0027] In some implementations, the control system 200 may be one of a plurality of control systems connected to the network 210. For example, as depicted in FIG. 2, another control system 230 may be connected to the network 210, in addition to the control system 200. As with the control system 200, each of the control systems (e.g., the another control system 230) may be a computing device, such as a server, a desktop computer, a workstation, a laptop computer, or the like. Each of the control systems may be in communication with other ones of the control systems by way of the network 210 (e.g., the control system 200 may communicate with the another control system 230). In some implementations, the control system 200 and at least one other control system (e.g., another control system 230) may operate together, over the network 210 for example, to determine the power distribution plan (and to perform other functionality described herein) in parallel, in a distributed manner, and/or for redundancy.

[0028] The control system 200 may comprise various modules, including an analysis module 202, a communication module 204, a failover module 207, and a billing module 208. The analysis module 202 and the communication module

204 may be analogous in many respects to the analysis module 102 and the communication module 104 of the control system 100, respectively. For example, as with the analysis module 102, the analysis module 202 may predict a power disruption to the power grid 220 and determine a power distribution plan to mitigate the power disruption based on a policy framework that includes profiles of the user nodes 222. Also, as with the communication module 104, the communication module 204 may send a control signal to at least one of the user nodes 222 to implement the power distribution plan and/or may also send a notification to a user device associated with a user node regarding the implementation of the power distribution plan.

[0029] Additionally, the analysis module 202 may match a seller user node (e.g., 222-1) and a buyer user node (e.g., 222-2) in a power routing transaction, based on their respective profiles for power sharing from the policy framework. As described above with respect to the control system 100, a profile for power sharing may include aspects such as: a desired sales price of shared power (e.g., a preferred, minimum, and/or target sales price), a time of day for selling, an amount of power the user node is willing to sell, a maximum buy price, a time of day for buying, and a characteristic of received power. The analysis module 202 may utilize a cost-benefit analysis, an auctioning process, or any other economic model to determine parameters of the power routing transaction, such as, for example, the parties to the transaction (seller and buyer user nodes) and a mutually acceptable price and amount of power to be routed from the seller user node (e.g., 222-1) to the buyer user node (e.g., 222-2). The communication model 204 may then send a control signal to the user nodes, particularly the seller user node (e.g., 222-1) and/or the buyer user node (e.g., 222-2), to route power according to the power routing transaction. The billing module 208 may track an amount of power routed from the seller user node to the buyer user node, by monitoring the power gateways at each user node, for example. The billing module 208 may bill the buyer user node (e.g., 222-2) on behalf of the seller user node (e.g., 222-1) for the amount of power routed, based at least in

part on the power routing transaction parameters determined by the analysis module 202.

[0030] In a case where the control system 200 itself or the network 210 (or a part thereof) is affected by the power disruption or fails for any other reason, another control system (e.g., another control system 230) may take up control of the power distribution plan, that is, the another control system 230 may determine the power distribution plan to mitigate the power disruption. In some implementations, the control system 200 includes a failover module 207 that may transfer at least partial control (up to complete control) of the power distribution plan to another control system 230 on the network 210. The another control system 230 may take up control of the power distribution plan either in response to the control system 200 (e.g., in response to instructions pushed by the failover module 207), automatically (e.g., by pulling information from the failover module 207), or semi-automatically. In some implementations, the functionality of the control system 200 may be deemed to be replicated on the another control system 230. By virtue of the control system 200 (and particularly the failover module 207) being in communication with another control system 230 over the network 210, mitigation for power disruptions to the power grid 220 may be performed in a resilient manner.

[0031] FIG. 3 is a block diagram of an example control system 300 that may determine a power distribution plan. The control system 300 may include a network interface 306 to communicate with a network. The control system 300 may include an analysis module 302 to predict a power disruption to a power grid comprising a plurality of user nodes and a utility provider interconnected by power lines, where at least one user node generates power. The analysis module 302 also may determine a power distribution plan to mitigate the power disruption based on a policy framework that includes profiles of the user nodes for power sharing and for power consumption modification, the power distribution plan to route power between the user nodes over the power lines or to modify power consumption of a user node. The control system 300 may include a communication module 304 to send a control signal through the network interface

306 and via the network to at least one user node to implement the power distribution plan, the user nodes being in communication with the network.

[0032] FIG. 4 is a flow diagram of an example method 400 for determining a power distribution plan for a power grid. Method 400 may be described below as being executed or performed by a control system such as control system 100 of FIG. 1. Various other suitable systems may be used as well, such as, for example, control system 200 of FIG. 2 or control system 300 of FIG. 3. Method 400 may be implemented in the form of executable instructions stored on at least one machine-readable storage medium and executed by at least one processor of the control system 100, and/or in the form of electronic circuitry. In some implementations of the present disclosure, one or more blocks of method 400 may be executed substantially concurrently or in a different order than shown in FIG. 4. In some implementations of the present disclosure, method 400 may include more or less blocks than are shown in FIG. 4. In some implementations, one or more of the blocks of method 400 may, at certain times, be ongoing and/or may repeat.

[0033] The control system described herein as performing at least some of the functionality of method 400 may communicate electronically over a network with a plurality of user nodes of a power grid. In some implementations, the power grid also includes at least one utility provider, and the control system may communicate with the utility provider over the network. In some implementations, at least one user node is a residential or a commercial customer, and at least one user node generates power (e.g., by a local solar panel/array generator, a wind turbine generator, or the like). The user nodes may be interconnected by power lines and may also be individually addressable, such that power may be delivered to a particular user node over the power lines. The utility provider also may be connected to the user nodes by the power lines.

[0034] Method 400 may start at block 402 and continue to block 404, where a control system (e.g., control system 100, and more particularly, the analysis module 102) may predict a power disruption to a power grid (e.g., power grid 120) comprising a plurality of interconnected user nodes (e.g., user nodes 122).

In some implementations, the control system 100 may predict a power disruption by analysis of various factors individually or in any combination, and more particularly, by analysis of patterns of the various factors and correlations between the various factors. Such factors for analysis may include, for example, power usage patterns of the power grid, power fluctuations of the power grid (e.g., transient electromagnetic events caused by lightning, over-voltage scenarios, over-current scenarios, etc.), and weather forecasts. Some of the various factors, particularly the power usage patterns and power fluctuations of the power grid, may be detected by the control system 100, or received by the control system 100 from power monitoring sensors on the power grid. As part of the power disruption prediction, the control system 100 may specify particular ones of the user nodes that may be affected by the power disruption, the nature of the power disruption (e.g., estimated time and duration, blackout or brownout, etc.), and a likelihood or probability that those user nodes will be affected. In one illustration, the control system 100 may detect and analyze transient power fluctuations on the power grid 120 and correlate (causally, temporally, and/or spatially) such fluctuations with weather events identified in weather forecasts to predict a highly likely and imminent (e.g., within a time scale of minutes to hours) power disruption to the power grid.

[0035] At block 406, the control system 100 may determine a power distribution plan based on a policy framework, to route power between user nodes to mitigate the power disruption, and more particularly, between a sharing user node and an at-risk user node, as will be described below. The policy framework may include profiles established (registered) by each of the user nodes, and each profile may include at least one of an attribute or preference of the user node. The profile framework may be analogous in many respects to the profile framework described above with respect to FIG. 1. Examples of the content of a profile include: a power consumer designation (i.e., indicating that the user node consumes power from the power grid), a power generator designation (i.e., indicating that the user node can generate power for distribution to other user nodes and/or the utility provider), a power generation capacity (i.e.,

indicating how much power the user node generates, when the user node generates power, etc.), an identity of another user node to which a particular node prefers to send power, a priority level for power disruption mitigation based on a job of the particular node (e.g., whether the user node performs a life-critical or safety-critical job), etc. Other examples of the user node profile content include preferences for power routing transactions (sales) between user nodes, such as a power pricing model and a desired characteristic of received power. In another example, a user node profile may also include a prioritized schedule for modifying appliance power consumption at a particular user node (e.g., indicating an order of powering off appliances at the user node, allowable times of day to reduce power consumed by appliances, economy modes of the appliances, etc.).

[0036] The power distribution plan determined by the control system 100 at block 406 may be to route power from a sharing user node to an at-risk user node to mitigate the power disruption. For example, if the power grid is unable to meet power demand by a user node in a predicted power disruption, that user node may be deemed an at-risk user node (particularly if the at-risk user node has indicated a job-related high priority level in its corresponding policy framework profile). A sharing user node may be a user node that is able and willing (per its policy framework profile) to share or sell power with at-risk user nodes, from its own generated or stored power or by sharing some of the power the sharing user node receives from the power grid. The control system 100 may match sharing user nodes and an at-risk user nodes based on the policy framework and may compile the match or matches into the power distribution plan.

[0037] Additionally or alternatively, in some instances a predicted power disruption may be a result of the utility provider being unable to meet demand of the power grid, and the power distribution plan may be to modify power consumption of a user node, deemed a mitigating user node, according to the prioritized schedule associated with the mitigating user node in the policy framework in order to reduce demand for power and thus mitigate the power disruption with respect to the utility provider. The power distribution plan

determined at block 406 may further include other actions, such as the following examples, depending on the nature of the predicted power disruption.

[0038] Additionally or alternatively, the power distribution plan may be to store power at at least one of the user nodes to mitigate the power disruption (e.g., where the power disruption may be predicted based on a forecasted severe weather event). For example, a user node may be equipped with a power storage device, such as a battery, capacitor, flywheel, or the like.

[0039] At block 408, the control system 100 may transmit control signals over the network to the user nodes to implement the power distribution plan determined at block 406. As described above, the power distribution plan may vary depending on the policy framework and the predicted power disruption, and the control signals may vary accordingly. For example, a control signal may instruct a user node (a sharing user node) to route power to another user node (an at-risk user node), and more particularly, to an addressable power gateway of the another user node. A control signal may instruct the user node to modify power consumption of appliances at the user node. A control signal may instruct the user node to store power at a power storage device at the user node. After block 408, the method 400 may end at block 410.

[0040] FIG. 5 is a flow diagram an example method 500 for determining a power distribution plan for a power grid. Method 500 may be described below as being executed or performed by a control system such as control system 100 of FIG. 1, although other suitable systems may be used as well, such as, for example, control system 200 of FIG. 2 or control system 300 of FIG. 3. Method 500 may be implemented in the form of executable instructions stored on at least one machine-readable storage medium and executed by at least one processor of the control system 100, and/or in the form of electronic circuitry. In some implementations of the present disclosure, one or more blocks of method 500 may be executed substantially concurrently or in a different order than shown in FIG. 5. In some implementations of the present disclosure, method 500 may include more or less blocks than are shown in FIG. 5. In some implementations, one or more of the blocks of method 500 may, at certain times, be ongoing and/or

may repeat. In some implementations, some blocks of method 500 may be performed in parallel with, before, and/or after blocks of other methods described herein, such as method 400 and method 600. The control system, the power grid, the user nodes, and the utility provider described herein with respect to method 500 may be analogous in many respects to the similarly named elements described above with respect to method 400 (as well as FIGS. 1 and 2).

[0041] Method 500 may start at block 502 and continue to block 504, where the control system 100 may register a profile of a particular user node (e.g., any one of the user nodes 122) into a policy framework. For example, in some implementations, a user associated with the particular user node may complete and transmit a profile of the user node to the control system 100 through a web-based interface (accessible by a web browser), a smartphone application, or the like. The control system 100 may register the particular user node's profile in the policy framework, which may be stored as a database at (or otherwise accessible by) the control system 100. Block 504 may be performed for a plurality of user nodes. The contents of a profile of a particular user node may be analogous in many respects to the example contents described above with respect to FIG. 4, and may include: a power consumer designation, a power generator designation, a power generation capacity, an identity of another user node to which the particular node prefers to send power, a priority level for power disruption mitigation based on a job of the particular node, a power pricing model, a desired characteristic of received power, or a prioritized schedule for modifying appliance power consumption at the particular user node.

[0042] At block 506, the control system 100 may determine a power distribution plan in a manner analogous in many respects to block 406 of method 400. The control system 100 may determine the power distribution plan based on the policy framework, and more particularly, the profile(s) registered by performing block 504. The control system 100 may then implement the power distribution plan by sending control signals to the user nodes, as described above with respect to block 408 of FIG. 4.

[0043] At block 508, the control system 100 may send a notification to a user device associated with a user node affected by the power distribution plan determined at block 506. The user device may be, for example, a smart phone, a wearable device, a tablet computing device, a laptop computer, a desktop computer, an on-board vehicle-based computer, or the like. The notification may be to notify a user of the user device (and thus user/resident of the associated user node) if the power distribution plan is to route power to or from the user node. The notification may be to notify the user of the user device if the power distribution plan is to modify power consumption of the user node. After block 508, method 500 may end at block 510.

[0044] FIG. 6 is flow diagram of an example method 600 for determining a power distribution plan for a power grid. Method 600 may be described below as being executed or performed by a control system such as control system 200 of FIG. 2, although other suitable systems may be used as well, such as, for example, control system 100 of FIG. 1 or control system 300 of FIG. 3. Method 600 may be implemented in the form of executable instructions stored on at least one machine-readable storage medium and executed by at least one processor of the control system 200, and/or in the form of electronic circuitry. In some implementations of the present disclosure, one or more blocks of method 600 may be executed substantially concurrently or in a different order than shown in FIG. 6. In some implementations of the present disclosure, method 600 may include more or less blocks than are shown in FIG. 6. In some implementations, one or more of the blocks of method 600 may, at certain times, be ongoing and/or may repeat. In some implementations, some blocks of method 600 may be performed in parallel with, before, and/or after blocks of other methods described herein, such as method 400 and method 500. The control system, the power grid, the user nodes, and the utility provider described herein with respect to method 600 may be analogous in many respects to the similarly named elements described above with respect to method 400 (as well as FIGS. 1 and 2).

[0045] Method 600 may begin at block 602 and continue to block 604, where the control system 200 may register a profile of a particular user node into a

policy framework. Block 604 may be analogous in many respects to block 504. In particular, the user node profile registered at block 604 may include a power pricing model that describes the preferences and rules of a user node for buying power from another user node and/or for selling power to another user node. In some implementations, the power pricing model may be analogous to the power pricing model described above with respect to FIG. 1. For example sales-related aspects of the power pricing model may include a desired sales price of power (e.g., a preferred, minimum, and/or target sales price), a time of day for selling (e.g., when a resident of a seller user node is away and has less personal need for generated power), and an amount of power the user node is willing to sell. Example buying-related aspects of a power pricing model may include a maximum buy price, a time of day for buying, and a characteristic of received power (e.g., generated by another user node power or sourced from a utility provider, power quality, voltage magnitude, frequency stability, proximity of the seller user node, power conditioning, etc.).

[0046] At block 606, the control system 200 may analyze power pricing models of user node profiles of the policy framework to match a seller user node and a buyer user node for a power routing transaction. The control system 200 may also determine parameters of the power routing transaction, such as, for example, a mutually acceptable price and an amount of power to be routed from the seller user node to the buyer user node. In some implementations, the control system 200 may deem or classify, for example, user nodes that registered a power generator designation in their policy framework profiles, user nodes that registered sales-related aspects in a power pricing model of their policy framework profiles, or user nodes that are not currently or predicted to be affected by a power disruption, to be seller user nodes. The control system 200 may also deem or classify, for example, user nodes that are currently or predicted to be affected by a power disruption to be buyer user nodes.

[0047] In some implementations, the control system 200 may analyze the power pricing models, including the preferences and rules therein, using a cost-benefit analysis. In one illustration, a buyer user node may have configured its

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power pricing model to prefer or require buying power from the lowest cost/lowest priced provider, regardless of the source of the power, whether from the utility provider (e.g., directly or via another user node) or from another user node (e.g., solar power from a neighboring user node). Additionally or alternatively, the buyer user node may have configured its power pricing model to indicate a preference or a willingness to pay a premium (e.g., \$0.02/kWhr) for power from the utility provider over a non-guaranteed power supply from the another user node's solar array, for example. Depending on the situation (which the control system 200 may ascertain from network-connected data sources), such as weather-related conditions affecting solar power (e.g., cloud coverage), the control system 200 may find a seller user node for the illustrated buyer user node that balances the benefit of uninterrupted power against the monetary cost, as set forth in the buyer user node's profile (i.e., power pricing model). Accordingly, by analyzing power pricing models and the user node preferences and rules contained therein using a cost-benefit analysis at block 606, the control system 200 may possibly optimize the match of seller user nodes and buyer user nodes in different situations.

[0048] In some implementations, the control system 200 may analyze the power pricing models at block 606 using an auctioning process (e.g., an automated sealed-bid second-price auction, a Dutch auction, a reverse auction, or the like). In one non-limiting example scenario, if the seller user nodes outnumber the buyer user nodes, the control system 200 may auction off units of available power of the buyer user nodes to the highest bidding seller user nodes, based on the maximum buy price in the policy framework profiles of each seller user node. In another non-limiting example scenario, if the buyer user nodes outnumber the seller user nodes, the control system 200 may match a buyer user node to a seller user node offering the lowest price bid, based on a minimum sales price of power in the policy framework profiles of the seller user nodes.

[0049] Other aspects in the policy framework may affect the analysis performed at block 606. For example, a power characteristic preference in the user node profiles of the policy framework may impact, for example, the proximity

of user nodes that are matched for power sharing. A time of day for sharing, buying, or selling power may also affect which users may be matched. Block 606 may be performed as part of the power distribution plan determining step at block 406 of method 400 or block 506 of method 500.

[0050] At block 608, the control system 200 may track an amount of power routed from the seller user node to the buyer user node matched at block 606. For example, by virtue of each user node being individually addressable for the purpose of power delivery as described above (e.g., via an addressable power gateway), the amount of power routed from the seller user node to the buyer user node may be reported by those nodes to the control system 200.

[0051] At block 610, the control system 200 may bill the buyer user node on behalf of the seller user node for the amount of power routed. For example, the billed price may be calculated by multiplying an agreed-upon power sales price determined at block 606 by the amount of routed power as tracked by block 608. In some implementations, blocks 606, 608, 610 may be performed by the billing module 208 of the control system 200. After block 610, the method 600 may end at block 612.

[0052] FIG. 7 is a block diagram illustrating a control system 700 that includes a machine-readable medium encoded with instructions to determine a power distribution plan according to an example implementation. In some example implementations, the control system 700 may be or form part of a computing device, such as a server, a desktop computer, a laptop computer, a workstation, a laptop computer, or the like. In some implementations, the control system 700 may communicate with at least some entities of a power grid, including user nodes and a utility provider. The entities of the power grid may be interconnected by power lines, such that power may be routed between different ones of the entities (e.g., utility provider to user node, user node to user node, or user node to utility provider).

[0053] In some implementations, the control system 700 is a processor-based system and may include a processor 702 coupled to a machine-readable medium 704. The processor 702 may include a central processing unit, a multiple

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processing unit, a microprocessor, an application-specific integrated circuit, a field programmable gate array, and/or other hardware device suitable for retrieval and/or execution of instructions from the machine-readable medium 704 (e.g., instructions 706, 708, 710, 712, 714) to perform the various functions discussed herein. Additionally or alternatively, the processor 702 may include electronic circuitry for performing the functionality described herein, including the functionality of instructions 706, 708, 710, 712, and/or 714. With respect to the executable instructions represented as boxes in FIG. 7, it should be understood that part or all of the executable instructions and/or electronic circuits included within one box may, in alternate implementations, be included in a different box shown in the figures or in a different box not shown.

[0054] The machine-readable medium 704 may be any medium suitable for storing executable instructions, such as random access memory (RAM), electrically erasable programmable read-only memory (EEPROM), flash memory, hard disk drives, optical discs, and the like. In some example implementations, the machine-readable medium 704 may be a tangible, non-transitory medium, where the term “non-transitory” does not encompass transitory propagating signals. The machine-readable medium 704 may be disposed within control system 700, as shown in FIG. 7, in which case the executable instructions may be deemed “installed” on the control system 700. Alternatively, the machine-readable medium 704 may be a portable (e.g., external) storage medium, for example, that allows control system 700 to remotely execute the instructions or download the instructions from the storage medium. In this case, the executable instructions may be part of an “installation package.” As described further herein below, the machine-readable medium 704 may be encoded with a set of executable instructions 706, 708, 710, 712, 714.

[0055] Instructions 706, when executed by the processor 702, may register, into a policy framework, profiles of user nodes for power sharing and for power consumption modification. A profile of a user node for power consumption modification may, for example, include a prioritized schedule for modifying power consumed by appliances at the user node (e.g., by modifying a time, duration or

amount of power consumed). Instructions 708, when executed by the processor 702, may predict a power disruption to a power grid comprising user nodes and a utility provider. Instructions 710, when executed by the processor 702, may determine a power distribution plan to mitigate the power disruption based on the policy framework. For example, the power distribution plan may be to route power between the user nodes or to modify power consumption of a user node. Instructions 712, when executed by the processor 702, may send a control signal to the user nodes to implement the power distribution plan. Instructions 714, when executed by the processor 702, may send a notification to a user device associated with a particular user node affected by the power distribution plan.

[0056] In view of the foregoing description, it can be appreciated that interconnected residential and commercial user nodes may be coordinated by a control system so as to mitigate or prepare for a predicted (or ongoing) power disruption to a power grid by distributing power between user nodes based on need and/or economic factors. Moreover, the control system may mitigate power disruptions in a robust and resilient manner by virtue of being independent from utility provider(s) of the power grid and/or by virtue of having a failover module to transfer control to another control system.

[0057] In the foregoing description, numerous details are set forth to provide an understanding of the subject matter disclosed herein. However, implementation may be practiced without some or all of these details. Other implementations may include modifications and variations from the details discussed above. It is intended that the following claims cover such modifications and variations.

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What is claimed:

1. A method comprising:

predicting, at a control system, a power disruption to a power grid comprising a plurality of interconnected user nodes;

determining, at the control system, a power distribution plan based on a policy framework that includes profiles established by the user nodes, the power distribution plan to route power from a sharing user node to an at-risk user node to mitigate the power disruption; and

transmitting, by the control system, control signals over a network to the user nodes to implement the power distribution plan,

wherein at least one user node is a residential or a commercial customer, and the at least one user node generates power.

2. The method of claim 1, further comprising registering, by the control system, a profile of a particular user node of the user nodes into the policy framework, the profile including at least one of: a power consumer designation, a power generator designation, a power generation capacity, an identity of another user node to which the particular node prefers to send power, a priority level for power disruption mitigation based on a job of the particular node, a power pricing model, a desired characteristic of received power, or a prioritized schedule for modifying appliance power consumption at the particular user node.

3. The method of claim 2, wherein the power grid further comprises at least one utility provider, the control system communicates with the utility provider over the network, and the power distribution plan is to modify power consumption of a mitigating user node according to the prioritized schedule associated with the mitigating user node in the policy framework to mitigate the power disruption with respect to the utility provider.

4. The method of claim 2, further comprising:

analyzing power pricing models of user node profiles of the policy framework to match a seller user node and a buyer user node for a power routing transaction;

tracking, at the control system, an amount of power routed from the seller user node to the buyer user node; and

billing the buyer user node on behalf of the seller user node for the amount of power routed.

5. The method of claim 1, wherein the power distribution plan is to store power at at least one of the user nodes to mitigate the power disruption.

6. The method of claim 1, wherein the predicting is performed by analyzing power usage patterns of the power grid, power fluctuations of the power grid, or weather forecasts.

7. The method of claim 1, further comprising sending, by the control system, a notification to a user device associated with a user node affected by the power distribution plan.

8. A control system comprising:

a network interface to communicate with a network;

an analysis module to:

predict a power disruption to a power grid comprising a plurality of user nodes and a utility provider interconnected by power lines, where at least one user node generates power, and

determine a power distribution plan to mitigate the power disruption based on a policy framework that includes profiles of the user nodes for power sharing and for power consumption modification, the power distribution plan to route power between the user nodes over the power lines or to modify power consumption of a user node; and

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a communication module to send a control signal through the network interface and via the network to at least one user node to implement the power distribution plan, the user nodes being in communication with the network.

9. The control system of claim 8, wherein the analysis module predicts a power disruption by analysis of power usage patterns of the power grid, power fluctuations of the power grid, or weather forecasts.

10. The control system of claim 8, wherein the communication module is to send a notification to a user device associated with a particular user node if the power distribution plan routes power to or from the particular user node or modifies power consumption of the user node.

11. The control system of claim 8, wherein a profile of a user node for power consumption modification includes a prioritized schedule for modifying a time, duration, or amount of power consumed by appliances at the user node, and
a profile of a user node for power sharing includes a power pricing model or a preference for the user node to provide power to another user node.

12. The control system of claim 8, further comprising a failover module to transfer at least partial control of the power distribution plan to another control system on the network.

13. The control system of claim 8, wherein the analysis module is to match a seller user node and a buyer user node in a power routing transaction, based on respective profiles for power sharing from the policy framework,

the communication module is to send a control signal to the user nodes to route power according to the power routing transaction, and

the control system further comprises a billing module to track an amount of power routed from the seller user node to the buyer user node and to bill the buyer user node on behalf of the seller user node for the amount of power routed.

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14. A non-transitory machine readable medium storing instructions executable by a processor of a control system, the non-transitory machine readable medium comprising:

instructions to register, into a policy framework, profiles of user nodes for power sharing and for power consumption modification;

instructions to predict a power disruption to a power grid comprising user nodes and a utility provider;

instructions to determine a power distribution plan to mitigate the power disruption based on the policy framework, the power distribution plan to route power between the user nodes or to modify power consumption of a user node;

instructions to send a control signal to the user nodes to implement the power distribution plan; and

instructions to send a notification to a user device associated with a particular user node affected by the power distribution plan.

15. The non-transitory machine readable medium of claim 14, wherein a profile of a user node for power consumption modification includes a prioritized schedule for modifying a time, duration, or amount of power consumed by appliances at the user node.

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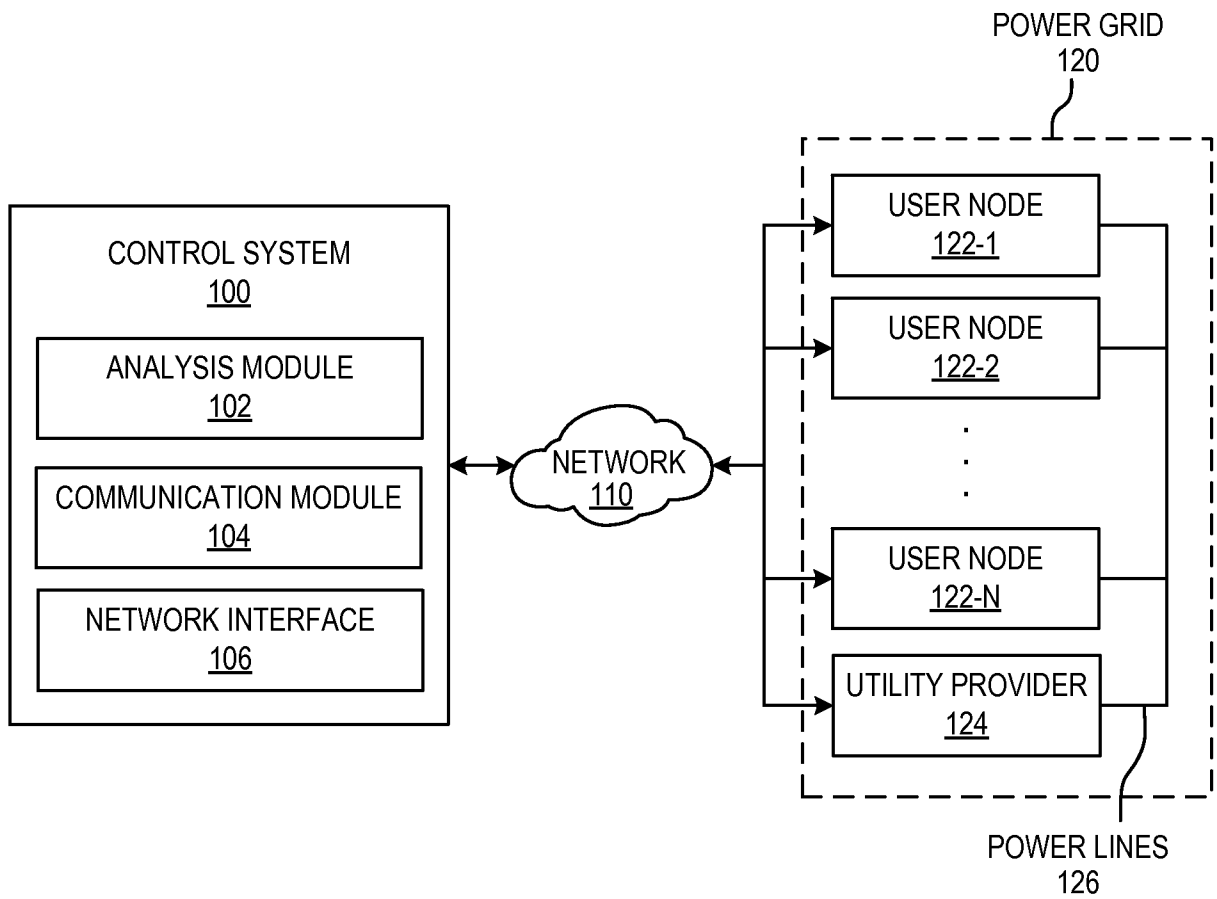


FIG. 1

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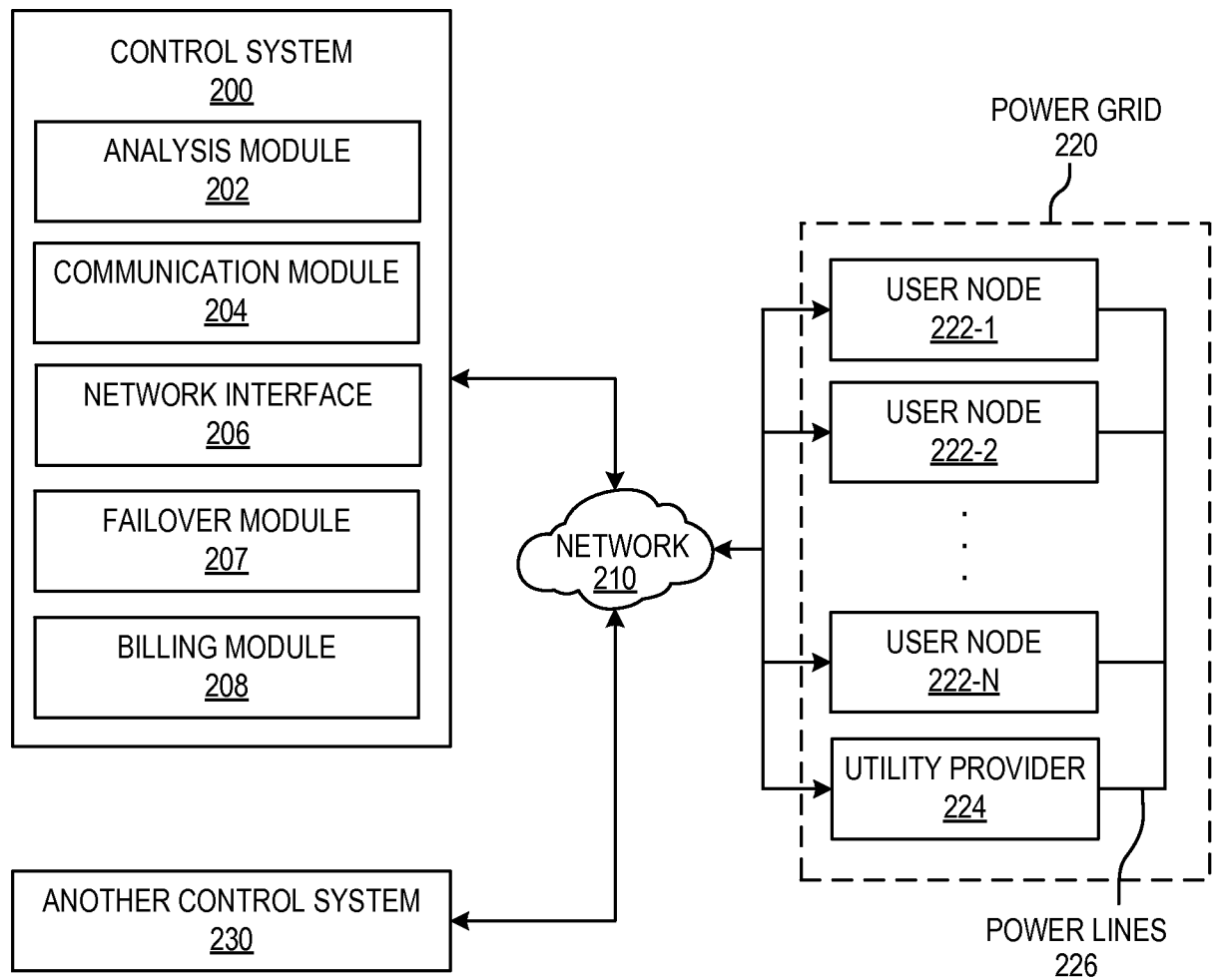


FIG. 2

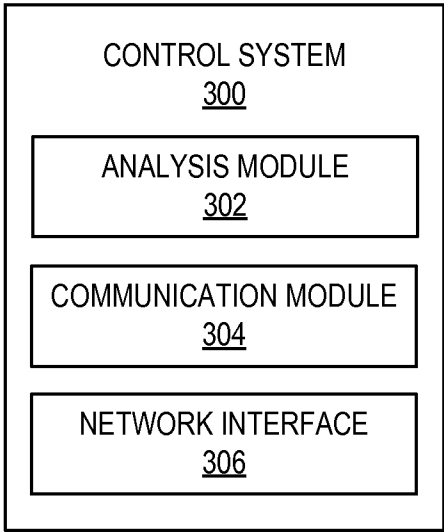


FIG. 3

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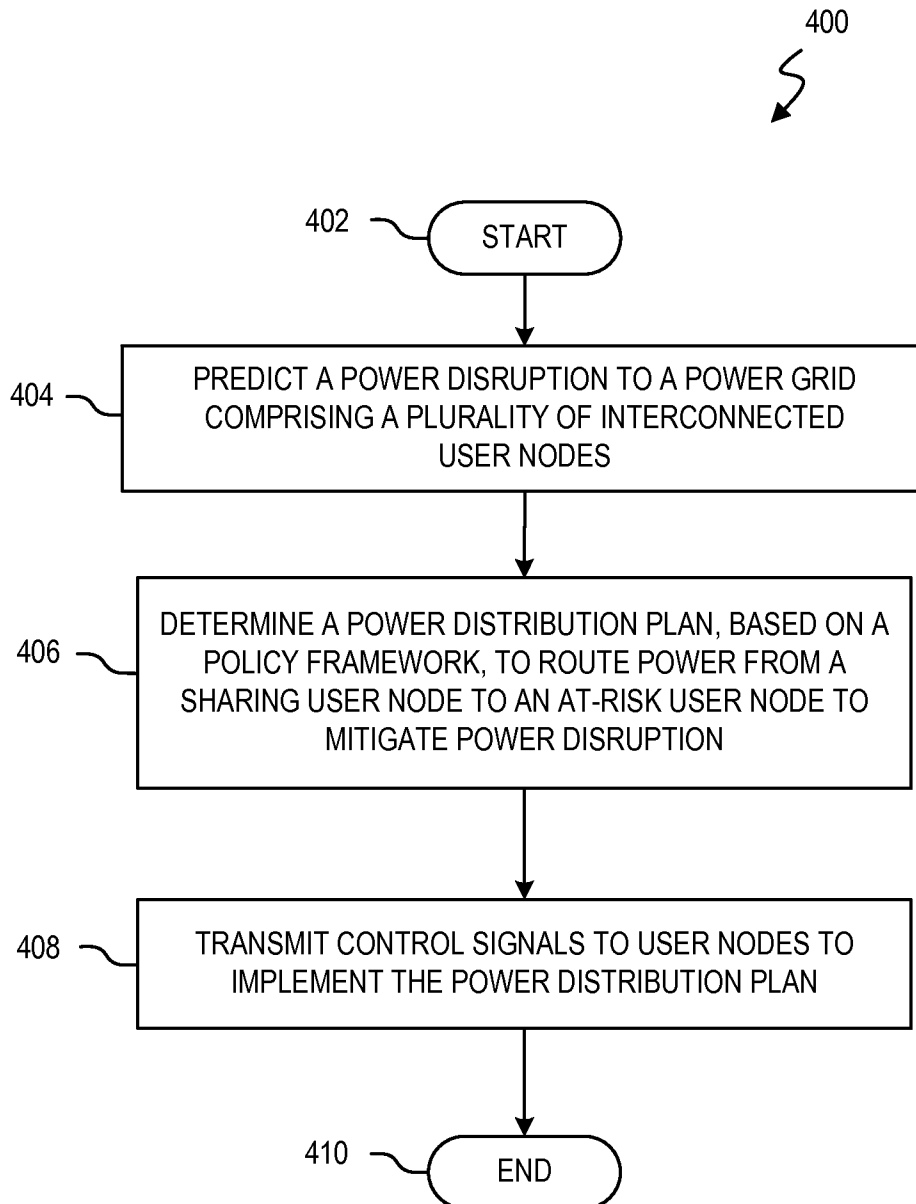


FIG. 4

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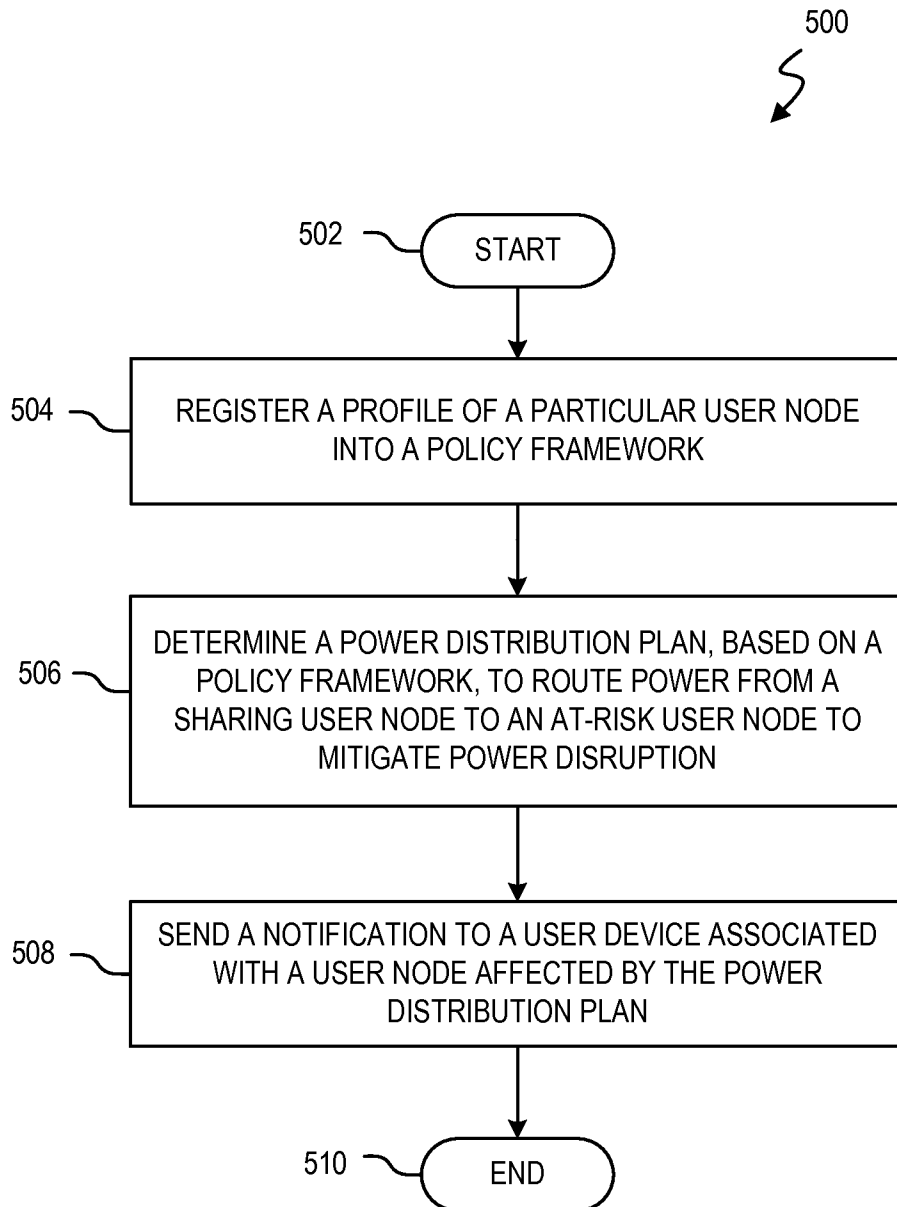


FIG. 5

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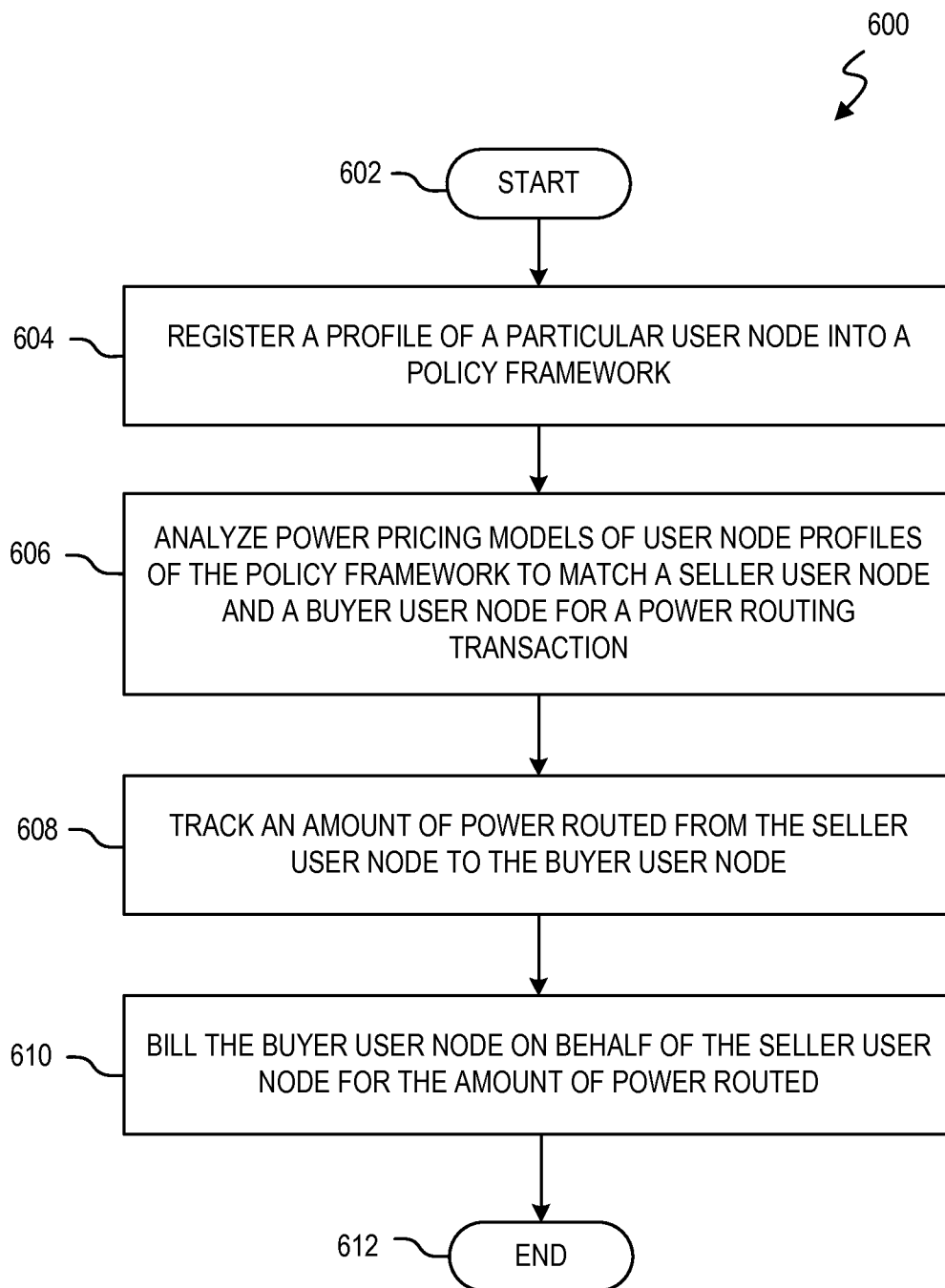


FIG. 6

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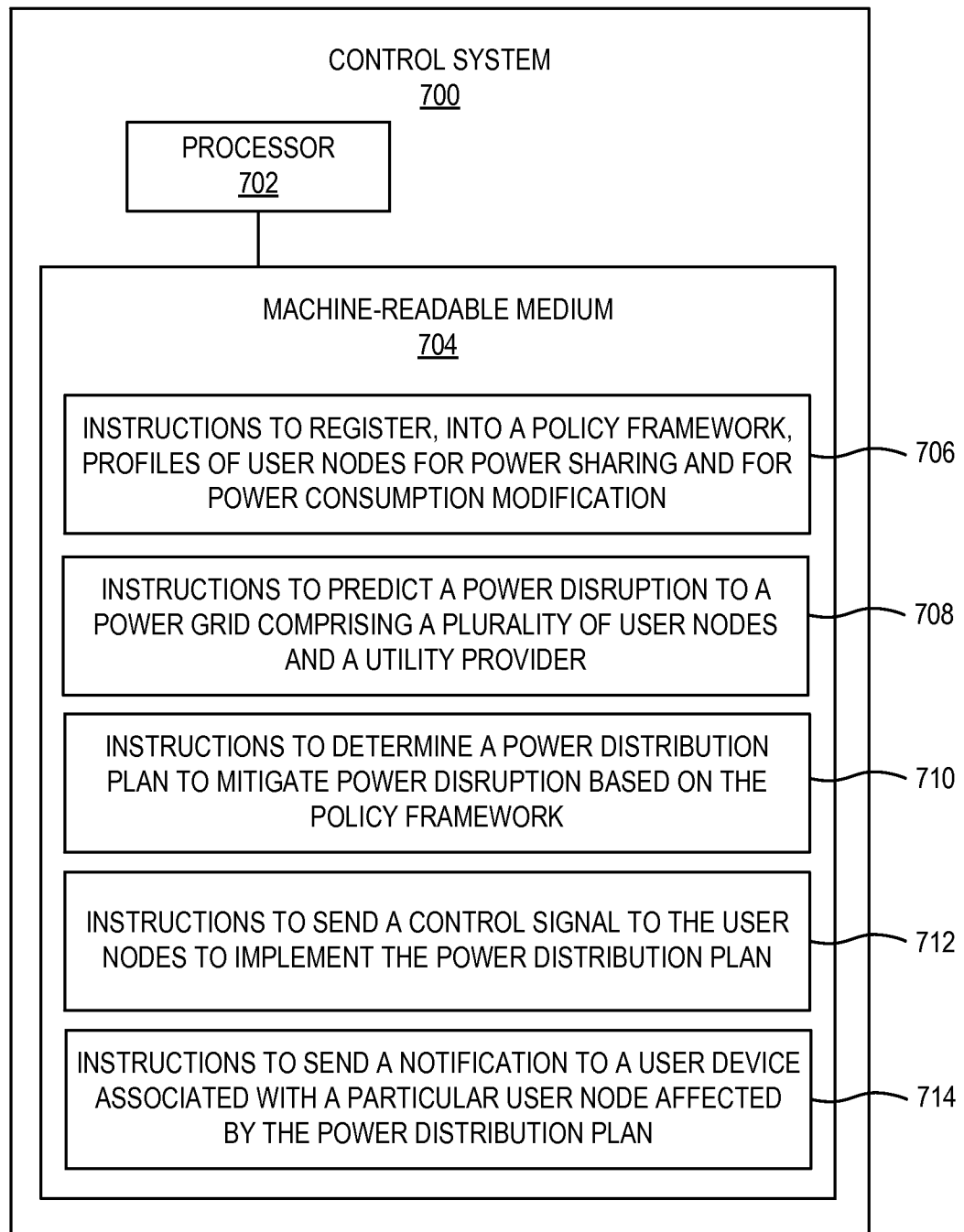


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/020085**A. CLASSIFICATION OF SUBJECT MATTER****H02J 3/00(2006.01)i, G06Q 50/06(2012.01)i**

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 3/00; G05B 15/02; G06Q 50/00; H02J 4/00; G06Q 50/06

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & keywords: plan, power distribution, disruption, node, profile, policy, consumption

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2011-002929 A (NIPPON TELEGR. & TELEPH. CORP.) 06 January 2011 See paragraphs 17-23, claim 1, and figures 1-2.	1-15
Y	US 2014-0088783 A1 (MATTHIAS ROEBKE) 27 March 2014 See paragraphs 25, 60, claims 24-25, and figures 1-2.	1-15
A	WO 2012-142586 A1 (POWER TAGGING TECHNOLOGIES, INC. et al.) 18 October 2012 See pages 6-9, claim 1, and figure 1.	1-15
A	US 2014-0125125 A1 (VIRTUAL ELECTRIC INC.) 08 May 2014 See paragraphs 78-81, claims 1-3, and figure 5.	1-15
A	WO 2013-098233 A2 (THOMSON LICENSING) 04 July 2013 See page 9, lines 4-15, claims 1-5, and figure 1.	1-15

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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"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

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"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

11 December 2015 (11.12.2015)

Date of mailing of the international search report

11 December 2015 (11.12.2015)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/020085

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