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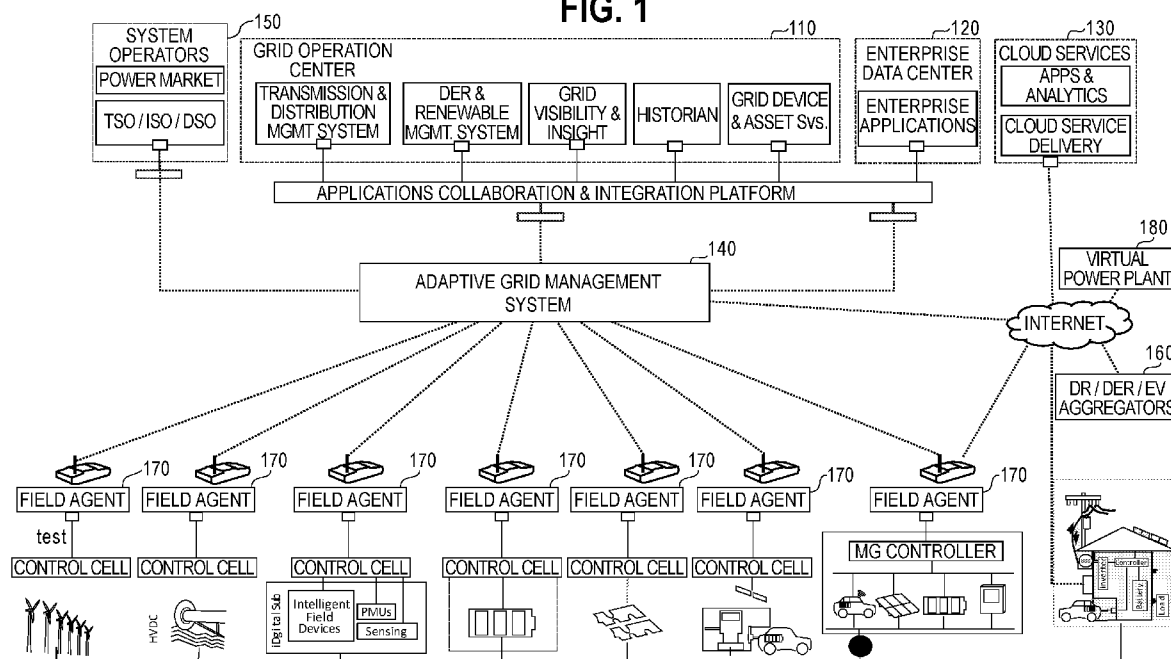
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(54) Title: ADAPTIVE POWER GRID MANAGEMENT SYSTEM

FIG. 1



(57) Abstract: Systems, apparatuses, and methods are provided herein for the adaptive management of a network of devices. The system is configured to train a context model, receive signals from the network of devices, determine, based on the context model, context data associate with a current condition of the network of devices, determine a formation plan based on the context data, configure one or more scout applications based on the formation plan and device information stored in the network device database, and cause the one or more scout applications to be executed by the one or more devices in the network of devices.

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ADAPTIVE POWER GRID MANAGEMENT SYSTEM

Cross-Reference To Related Application(s)

[0001] This application claims the benefit of U.S. Provisional Application No. 63/256,292 filed October 15, 2021, and U.S. Provisional Application No. 63/328,127 filed April 6, 2022, which are incorporated herein by reference in their entireties.

Technical Field

[0002] This invention relates generally to the management of a network of devices.

Background

[0003] Geographically distributed complex device networks, such as power grids, are often especially susceptible to various conditions that could lead to service interruptions due to the sheer number of components in the network. External causes such as weather and sabotage and internal causes such as device aging and malfunction can be difficult to identify, troubleshoot, and rectify in a timely manner.

Brief Description of the Drawings

[0004] Disclosed herein are embodiments of systems and methods for providing adaptive device network management. This description includes drawings, wherein:

[0005] FIG. 1 comprises a system diagram of a power grid system in accordance with some embodiments;

[0006] FIG. 2 comprises a block diagram of an adaptive grid management system in accordance with some embodiments;

[0007] FIG. 3 comprises a block diagram of the adaptive grid management system and operating cells in accordance with some embodiments;

[0008] FIG. 4 comprises a block diagram of a power grid system in accordance with some embodiments;

[0009] FIG. 5 comprises a flow diagram of a network management system in accordance with some embodiments;

[0010] FIG. 6 comprises a flow diagram of an operating cell in accordance with some embodiments;

[0011] FIG. 7 comprises a block diagram of a network management system in accordance with some embodiments;

[0012] FIG. 8 comprises a block diagram of modules the adaptive grid management system and operating cells in accordance with some embodiments; and

[0013] FIGS. 9A, 9B, 10A, 10B, and 11 comprises flow diagrams of modules of a network management system in accordance with some embodiments.

[0014] Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions and/or relative positioning of some of the elements in the figures may be exaggerated relative to other elements to help improve understanding of various embodiments of the present invention. Also, common but well-understood elements that are useful or necessary in a commercially feasible embodiment are often not depicted in order to facilitate a less obstructed view of these various embodiments of the present invention. Certain actions and/or steps may be described or depicted in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required. The terms and expressions used herein have the ordinary technical meaning as is accorded to such terms and expressions by persons skilled in the technical field as set forth above except where different specific meanings have otherwise been set forth herein.

Detailed Description

[0015] Generally speaking, pursuant to various embodiments, systems, apparatuses, and methods are provided herein for adaptively managing a network of devices.

[0016] In some embodiments, an adaptive power grid management system is provided. The system comprises a network device database, a network adapter, and a processor. The

processor is configured to train a context model with a machine learning algorithm using historical device signals and historical context information associated with a network of devices, receive signals from the network of devices, determine, context data associate with a current condition of the network of devices based on the context model, determine a formation plan based on the context data, the formation plan comprises tasks to be carried out by one or more devices in the network of devices, configure one or more scout applications based on the formation plan and device information stored in the network device database, and cause, via the network adapter, the one or more scout applications to be executed by the one or more devices in the network of devices.

[0017] In some embodiments, an operating cell device for power grid management is provided. The device comprises a network adapter configured to communicate with a device network management system and a processor coupled to the network adapter, the processor is configured to receive, via the network adapter and from a server, a scout application with an associated role assignment, authenticate the scout application and automatically execute the scout application upon authentication, and communicate, via the network adapter, with the device network management system or a plurality of devices in a network based on the role assignment of the scout application.

[0018] Referring now to FIG. 1, a power grid with an adaptive grid management system is shown. The power grid includes a grid operation data center 110, an enterprise data center 120, cloud services 130, an adaptive grid management system 140, and a plurality of field agent devices 170 each configured to monitor and/or control a control cell coupled to a power grid component and/or subsystem.

[0019] The grid operation data center 110 may comprise a transmission and distribution management system, a distributed energy resource (DER) and renewable management system, a grid visibility and insight system, a historian system, and a grid devices and asset services system communicating over an applications collaboration and integration platform. The components of the grid operation data center 110 may communicate with the enterprise data center 120 and system operators 150 over a network to perform their respective functions. The enterprise data center 120 generally comprises enterprise applications for enterprise-level management. System

operators 150 may include external systems such as systems associated with the power market, an electric power transmission system operator (TSO), an independent system operator (ISO), and a distributed system operator (DSO). The adaptive grid management system 140 may aggregate data from the system operators 150, the grid operation data center 110, and the enterprise data center 120. In some embodiments, the adaptive grid management system 140 may further aggregate data from cloud services 130 (including cloud applications and analytics and cloud service delivery), virtual power plants 180, and demand response/distributed energy response/electric vehicle (DR/DER/EV) aggregators 160 that aggregate power usage information.

[0020] The adaptive grid management system 140 is generally configured to aggregate data from devices and components of the network to detect alert conditions and determine a grid formation plan in response to the alert condition. In some embodiments, the grid formation plan is determined based on an artificial intelligence (AI) machine learning (ML) algorithm that compares the context data associated with an alert condition with historical context patterns to determine a formation to affect the formation of the grid. The adaptive grid management system 140 may further be configured to form and deploy scout applications to be executed on operating cells such as the field agent devices 170 to carry out the formation plan. In some embodiments, the adaptive grid management system 140 is further configured to receive additional data from the scout applications executed at the field agent devices 170 and generate new formation plans based on updated information from the power grid.

[0021] In some embodiments, the adaptive grid management system 140 may automatically and contextually adapt the grid to a new self-defined optimize operational formation in response to the changing power system operating conditions. Operating conditions may include physical stress, environmental hazards, social unrest, sabotage, pandemics, and shelter-in-place operating conditions. In some embodiments, the adaptive grid management system 140 includes a self-forming multi-dimensional, contextual, and cognitive state machine that is configured for driving the formation and operation of the self-acting grid. In some embodiments, the adaptive grid management system 140 includes a self-learning decision support system referred to as the grid-wide-mind module that is configured to provide dynamic,

condition-based context data and contextual construct in support of the grid artificer module. In some embodiments, the adaptive grid management system 140 includes a system-wide federated alerts correlation processing engine with unique assigned ownership and colorization utilizing grid-wide-mind distributed contextual sensing in support of the grid-wide-mind module. In some embodiments, the adaptive grid management system 140 includes a grid-wide federation command module functioning as a role-based command coordinator and executor, operating as grid-wide federation manager, grid foresight manager, and scouts command. The adaptive grid management system 140 according to some embodiments are described in further detail with reference to FIGS. 2-7 herein.

[0022] A field agent device 170 comprises a processor-based device configured to communicate with the adaptive grid management system 140 and other field agent devices 170 over a network such as a secured private network, a virtual private network, a wireless network, a power lines communication (PLC) network, and/or the Internet. In some embodiments, the field agent devices 170 may be geographically distributed and each associated with a component or sub-system of the power grid such as a windfarm, a digital substation, a solar farm, a power bank, an electric vehicle (EV) charging station, a 21339 controller, and the like. In some embodiments, the field agent device 170 may have a data connection with the control cell of the associated component of the network and be configured to exchange data, send requests, and/or change the configuration of the network component via the control cell. In some embodiments, a field agent device 170 may be a user interface device (e.g. portable computer, mobile phone) configured to provide instructions to human operators via a user interface (UI) based on an executed scout application. In some embodiments, the field agent device 170 is configured to execute one or more scout applications received from the adaptive grid management system 140 or from another field agent device to carry out functions specified by the scout application. In some embodiments, a field agent device 170 may be configured to operate for an extended period of time (e.g. hours, days) based on the directives of the scout application without communicating with the adaptive grid management system. In some embodiments, a group of field agent devices 170 may form a federation based on roles assigned to the scout applications executed on the devices. In some embodiments, a field agent device 170 executing a scout

application serving as the scout master of a federation may be configured to coordinate task executions and/or issue commands to other field agent devices 170 in the federation. In some embodiments, a field agent device 170 may be configured to cause a copy of an executed scout application to be installed and executed on another field agent device 170. In some embodiments, a field agent device 170 may be configured to automatically terminate the scout application after the completion of one or more tasks or after a set period of time.

[0023] In some embodiments, a field agent device 170 executing one or more scout applications may be referred to as an operating cell of the adaptive grid management system 140. In some embodiments, the adaptive grid management system 140 is configured to provide adaptive formation of the grid into geographically dispersed fit-for-purpose self-forming operating cells in response to dynamic grid internal and external imperatives. In some embodiments, each operating cell or federation of cells may be self-managed and can operate autonomously to achieve its assigned objectives. In some embodiments, an operating cell may further merge with other operating cells to create larger cells or join a federation to collectively achieve multiple assigned objectives. In some embodiments, operating cells under stress (e.g. physical threat, cyber threat, insufficient processing power, memory, power supply, network connection stability, etc.) can transfer authority to another cell. In some embodiments, the adaptive grid management system 140 may be configured to provide dynamic formation of lateral access fit-for-purpose distributed control in support of shelter-in-place and other emergency response operations. In some embodiments, the adaptive grid management system 140 may define a federated transaction processing enabling the transfer of authority and autonomous operation in relation to a plurality of operating cells in response to commands or stress conditions. In some embodiments, the adaptive grid management system 140 provides operation and lifecycle management of scout applications in support of self-acting grid adaptive formation, grid formation, grid foresight, and optimization. In some embodiments, the system further includes a grid-wide-eye module for providing grid-wide observability and foresight with an extended line of sight and condition-based point of view in support of grid formation.

[0024] In some embodiments, the adaptive grid management system 140 and the field agent devices 170 are added to an existing power grid with one or more of the components

shown in FIG. 1. Conventionally, components of the grid operation data center 110 may communicate with the services and control cells of the power grid based on a plurality of individually defined messaging formats and/or protocols such that the components of the grid operation data center 110 are required to each be configured to communicate with each type of control cell the grid operation center supports. In some embodiments, the adaptive grid management system 140 and the field agent devices 170 may serve as intermediaries that unify the communications between the components of the grid operation data center 110 and the various controllers in the system. In some embodiments, while each field agent may be configured to communicate with the associated controller, the communications between the field agent devices 170 and the adaptive grid management system 140 and/or the grid operation data center 110 may be based on a uniform messaging format and/or protocol.

[0025] Next referring to FIG. 2, an adaptive grid management system according to some embodiments is shown. In some embodiments, the adaptive grid management system 200 may comprise one or more processor-based devices executing computer-readable instructions stored on a computer-readable memory storage device. In some embodiments, the adaptive grid management system may be implemented with distributed and/or redundant server architecture on a plurality of networked processor-based devices. In some embodiments, the components of the adaptive grid management system 200 shown may comprise software and/or hardware modules.

[0026] In some embodiments, the adaptive grid management system 200 provides a self-acting grid that contextually adapts to new operational formations in response to changing power system operating conditions. Operating conditions may include physical stress, environmental hazards, social unrest, sabotage, pandemics, and shelter-in-place operating conditions. In some embodiments, the adaptive grid management system 200 includes an alert correlation engine 201 based on unique assigned ownership and colorization utilizing distributed contextual sensing 272. In some embodiments, the adaptive grid management system 200 includes a decision support module 202 that utilizes a machine-learning algorithm to provide dynamic, condition-based context data and contextual construct in support of a grid artificer module 210. In some embodiments, the adaptive grid management system 200 includes a self-forming grid artificer

module 210 configured to drive self-acting grid formation and operation to maintain grid physical and operational stability in response to system stress and changing operating conditions. In some embodiments, the adaptive grid management system 200 includes cognitive state machine (“CSM”) operator 213 for operating a self-forming multi-dimensional, contextual, and cognitive state machine to drive the formation and operation of the self-acting grid. In some embodiments, the adaptive grid management system 200 includes a grid federation command module 230 functioning as a role-based command coordinator and executor, operating as grid-wide federation manager, grid foresight manager, and scouts command.

[0027] In some embodiments, the adaptive grid management system 200 is configured to provide adaptive formation of the grid into geographically dispersed fit-for-purpose self-forming operating cells 270 in response to dynamic grid internal and external imperatives. In some embodiments, each operating cell 270 may be self-managed and may operate autonomously to achieve its assigned objectives. The operating cells 270 may further merge with other operating cells to create larger cells or join a federation to achieve multiple assigned objectives. In some embodiments, operating cells 270 under stress can transfer authority to another cell. In some embodiments, the system is configured to provide dynamic formation of lateral access fit-for-purpose distributed control in support of shelter-in-place and other emergency response operations. In some embodiments, the system may define a federated transaction processing enabling the transfer of authority and autonomous operation in relation to a plurality of operating cells in response to command or stress conditions.

[0028] The alert correlation engine 201 is configured to retrieve data from the grid operation data center 260 and other data sources, such as contextual sensing 272, for alert condition detection. The alert correlation engine 201 may include an alert coordination manager module for coordinating geographically dispersed alert acquisition processors. In some embodiments, the alert coordination manager module is configured to coordinate the processing and transformation of relevant system-wide alerts with unique system-wide assigned alert ownership. In some embodiments, the alert coordination manager further manages the ingestion and storage of relevant alerts to provide a dynamic and holistic view of the grid and its condition. The stored information may be used for historical recreation, pattern recognition, and situational

coordination. In some embodiments, the stored information is used to train an alerts and/or context model using a machine learning algorithm such as a deep neural network algorithm. The trained model may be configured to detect alerts and/or determine context information associated with the current condition of the grid by the alert correlation engine 201.

[0029] The alert correlation engine 201 receives signals from an alert coordination manager and/or a grid operation data center 260, analyzes the signal, and detects for an abnormal condition that is out of an acceptable band. If an abnormal condition is detected, the alert correlation engine 201 may generate an action stress frame comprising a unique ID and signal attributes that activates the alert correlation processing. In some embodiments, the alert correlation engine 201 initiates a pattern recognition analysis based on the unique ID of the stress frame and generates a pattern plate colorized based on the best-matched corresponding source, severity degree, and/or potential area of impact. In some embodiments, the alert correlation processing engine, upon receiving the analysis results of the pattern plate, activates an action stress frame constructor module to construct an action stress frame comprising a stress frame ID, pattern plates, and an associated time. In some embodiments, the alert correlation processing engine further creates a record in the learning engine 203 based on the lesson learned from the analysis. The alert correlation engine 201 may then send the action stress frame through a grid gatekeeper module to the decision support module 202 of the grid-wide-mind module. In some embodiments, the grid gatekeeper module is generally configured to provide authentication and security verifications for communications between the grid-wide-mind module and the grid artificer module.

[0030] The decision support module 202 is configured to validate the action stress frames through a grid-shaping analysis engine. In some embodiments, the grid-shaping analysis engine is configured to analyze an action stress frame through interactions with the learning engine 203 and send analysis results and context data to a context data builder. In some embodiments, the context data builder performs correlation analysis on the results received from the grid shaping analysis engine and determines the associated vital attribute with a value range. The context data builder may further create a context data ID and final vital attributes with associated severity degree (e.g. (for-id, (a₁,sd₁),(a₂, sd₂), ... ,(a_n, sd_n), t_i)). The decision support module 202 then

sends the “for-id, (attributes), t(x)” as context data to a grid artificer module 210 thru the grid gatekeeper module.

[0031] The grid management database 205 stores temporal data, experience data, data ownership, alert ownership, grid profile, resource view data, application portfolio data, DNA mapping information, scouts portfolio data, and launch plans for use by the alert correlation engine 201, the decision support module 202, the learning engine 203, and/or the simulation engine 204.

[0032] The grid artificer module 210 comprises a context construct engine 211, a contextual abstraction plane database, 212 a CSM operator 213, a CSM builder 214, and a Contextual and Cognitive State Machine (CaCSM) 215. In some embodiments, the grid artificer module 210 may validate the context data identifier and the request received from the decision support module 202. In some embodiments, the grid artificer module 210 validates “for-id, (attributes)” by extracting a historical pattern for “for-id, (attributes)” to create an activation key (“ga-authenticationkey”), and initiates grid formation upon validation.

[0033] In some embodiments, when misalignment is detected by the artificer module 210, the artificer module 210 may send the context data ID, context data, and a time (tx1) to the decision support module 202 and request a correctness analysis. In response, the decision support module 202 may check with the alert correlation engine 201 for system condition variance between t(x) and t(x1) and perform a correctness analysis. If the confidence degree from the correctness analysis is within an acceptable range, the decision support module 202 sends an adjusted (for-id, (attributes), t(x), gwm-verificationkey, ga-authenticationkey) to the artificer module 210 thru a gatekeeper module. If the confidence degree is outside of an acceptable range due to changes in system condition, the decision support module 202 sends a new context data comprising (for-id, (attributes), t(x₂), gwm-verificationkey, ga-authenticationkey-x) to the grid artificer module 210. In some embodiments, when the grid artificer module 210 identifies an authentication mismatch, validation steps may be reinitiated. In some embodiments, the artificer module 210 may send the authentication key (“ga-authenticationkey”) to the federation command module 230, the federation manager, the foresight manager, the scouts command,

and/or a self-acting operator. In some embodiments, the artificer module 210 then sends the context data (e.g. for-id, (a₁,sd₁),(a₂, sd₂), ... ,(a_n, sd_n), t(y)) to the context construct engine 211.

[0034] The context construct engine 211 is configured to use the context data from the artificer module 210 to initiate context construction. The context construct engine 211 may send a request to the learning engine 203 to exact patterns and context associated with the received context data (e.g. for-id). In some embodiments, the context construct engine 211 may initiate context building by mapping to context patterns that are best matched with (for-id, (a₁,sd₁),(a₂, sd₂), ... ,(a_n, sdn), t(y)) per attribute (a_{1,n} and sd_{1,n}). On the best-matched context pattern, the context construct engine 211 constructs a contextual abstraction panel (e.g. subcontext data), each panel representing a separate problem domain perspective and relative dimension. In some embodiments, each panel may be assigned a “cap-id” and include panel positioning, operation classification, functional composition, and a severity index. The context construct engine 211 may then notify the artificer module 210 on the completion of the construct and send the context abstraction plane data (cap-id, abstraction panels attribute, ga-authenticationkey) to the artificer module 210.

[0035] In some embodiments, the grid artificer module 210, in response to receiving a signal (cap-id, abstraction panels attribute, ga-authenticationkey) from context construct engine 211, verifies the ga- authentication key and the corresponding “for-id, (attributes)” and activates a CSM entry creation. In some embodiments, the grid artificer module 210, using data from the decision support module 202, maps abstraction panels and the associated context, and determines the level of contextual interdependency and associated index between abstraction panels. In some embodiments, the grid artificer module 210 then determines the most relevant abstraction panel contexts in relation to “for-id, (attributes)” and marks the abstraction panel contexts based on the degree of relevancy (e.g. high (most probable root cause), medium, and low). The grid artificer module 210 then creates a new composite ID (for-id, primary-context-id, attributes, ga-authenticationkey) and activates the cognitive state machine builder (CSM-builder) 214. In some embodiments, the CSM builder 214, extracts the context ID with the highest relevancy index and (for-id, context-id, relevancy-index-high, attributes, ga-authenticationkey) from the signal received from the grid artificer module 210 and sends the exacted information to the

learning engine 203. The learning engine 203 then extracts the context ID and the most closely matched patterns CSM (number of states, initial states, trigger, self-forming trigger, final state with corresponding performance index) - (for-id, primary-context-id, attributes, ga-authenticationkey) and sends the data to the CSM-builder. In some embodiments, the CSM utilizes the template from the learning engine 203 and constructs a draft CSM entry. With the creation of a new draft CSM entry by the CSM-builder, the grid artificer module 210 activates the simulation engine 204 for the validation of the CSM. If the simulation engine 204 returns a satisfactory result, the grid artificer module 210 then sends a signal with authenticated simulation result to the CSM builder 214 to authorize the CSM builder 214 to move the CSM entry to production. The CSM builder 214 then updates the draft CSM entry with simulation results, creates the final blueprint, and sends the final blueprint with associated for-ID to learning engine 203. The CSM builder 214 further sends the final blueprint, the authenticated key, and an initiate command to the CSM operator 213. In some embodiments, the CSM operator 213 is configured to authenticate the signal from the CSM builder, on verification, verify that blueprint mapped to the CSM entry, activate self-forming capabilities in relevant cell(s), and send a signal to the federation.

[0036] The grid-wide-eye module 220 is configured to provided observability and foresight with an extended line of sight and condition-based point of view in support of grid formation. In some embodiments, the grid-wide-eye module 220 is configured to provide information to the alerts engine, including the alert correlation engine 201, an action stress frame constructor module, and the decision support module 202. In some embodiments, the adaptive grid management system 200 includes system-wide distributed contextual sensing 272 with embedded adaptive self-describing semantics and an embedded method for self-adjusting positioning coordination. In some embodiments, the adaptive grid management system 200 includes alert acquisition processors with built-in semantics deployed across the grid and configured with self-adjusting positioning.

[0037] The federation command module 230 is a role-based coordinator, functioning as grid formation manager, grid foresight manager. and scout coordinator. In some embodiments, a foresight manager creates an operation plan and optimizes the formation strategy based on

signals from the artificer module 210. The foresight manager may further interact with the decision support module 202 to simulate the formation plan via the simulation engine 204 and derive operational functional attributes. In some embodiments, based on the simulation result, the foresight manager may optimize the formation plan, create a manifest template, define operating cell DNA type, and log the manifest in a CSM cell with the corresponding DNA matches. In some embodiments, if an operating cell does not exist, federation command module 230 may request the CSM operator 213 to create a new operating cell. In some embodiments, upon completion of CSM state cell formation, the CSM operator 213 may set the cell as incubation ready for scouts command module to initiate scout inception, training, and deployment preparation. Upon the completion of incubation via the scout incubator 250, the CSM operator 213 updates the cell with a ready-to-deploy flag and assigns DNA.

[0038] In some embodiments, in response to a request from the grid foresight manager, the grid federation command module 230 may initiate the definition and coordination of a plurality of distributed operating cells 270. In some embodiments, the federation command module 230 may designate each cell as a virtual, physical, or hybrid base operation plan. In some embodiments, a cell is assigned operational DNA, defining operation characteristics of the cell. In some embodiments, a cell may have knowledge of other cells, their locality, and DNA types. In some embodiments, a cell may operate autonomously for an extended period of time. In some embodiments, a cell may be configured to determine to merge with another cell to create a larger cell with more operating power based on detecting associated triggering conditions. In some embodiments, a federation of a plurality of cells can form based on commands from the command hub and the cells may be configured to create a new federation or join an existing federation of cells. In some embodiments, each federation of cells may include a federation command hub that inherits relevant intelligence from the grid-wide-mind module of the adaptive grid management system 200. In some embodiments, a federation may be managed by a scout master cell assigned by the command hub coordinator and the cells in the federation may be configured to receive commands to be managed by the scout master.

[0039] The scout command module comprises a scout incubator 250 and a scout launch manager 251 operating based on commands received from the artificer module 210. In some

embodiments, a scout application may be assigned the role of a scout messenger for providing optimized ingestion, transformation, and storage of relevant data in motion. In some embodiments, a messenger scout application may be automatically configured by the system to be adaptive to the locality, people, assets, and applications. In some embodiments, a scout application may be assigned the role of a scout coordinator that is automatically configured by the adaptive grid management system 200 to provide coordination and management of operating cells for the duration of the assigned mission according to the mission plan. In some embodiments, a scout application may be assigned the role of a scout inspector that is automatically configured by the system to observe cell behavior in relation to interactions, asset/device performance, people interaction, historical recreation, pattern recognition, and machine learning, and provide the collected information to the decision support system. In some embodiments, the scout application may be assigned the role of a guard that is automatically configured by the system to provide cell defense against physical threats, cyber threats, and functional misalignments. In some embodiments, a scout application executed on an operating cell may be configured to clone itself to another operating cell in response to a trigger condition. In some embodiments, a scout application may be configured to change its configuration and/or tasks (i.e. self-form) after deployment in response to trigger conditions. In some embodiments, a scout application may be configured to self-terminate (i.e. demise) in response to a trigger condition or after a set period of time.

[0040] In some embodiments, the adaptive grid management system 200 may provide operation and lifecycle management of scout applications in support of the adaptive formation of the grid. In some embodiments, the scouts command module may be configured to retrieve assignments and directives from the CSM and map a received DNA description to a scout roster. In some embodiments, upon receiving a directive from the CSM, the scouts command module may retrieve the associated assignment from CSM operator 213. Based on the assigned DNA description, the scouts command module maps the DNA to scouts in the scouts roster, if a match is found and the matched scout is in an idle state, the scouts command module may update the DNA, upload mission plan, and designate responsibility tag and level of alterity to the matched scout. If the matched scout is not in an idle state, the scouts command module may initiate a

cloning process to replicate the scout, update the DNA, upload the mission plan, designate the responsibility tag, and level of alterity at the cloned scout application. If no existing scout matches the received DNA, the system may initiate a new scout incubation and training process and notify the CSM operator 213 to initiate cell creation. The new scout application may be deployed upon completion of incubation and training. In some embodiments, the scout command module may further manage assigned advance controllability and assign objective function in relation to local grid morphing at the cells via the federated edge transaction manager 240.

[0041] The block diagram of FIG. 2 is provided as an example configuration of an adaptive grid management system. In some embodiments, one or more modules may be combined in the functionality with another module or split into multiple modules. In some embodiments, additional modules not illustrated in FIG. 2 may be included to perform the functions described herein.

[0042] In some embodiments, the systems and methods described herein are configured to increase grid reliability, stability, and resiliency to changing power system conditions both when operating under normal and abnormal conditions. In some embodiments, the system provides dynamic grid observability and situational awareness with an extended line of sight and condition-based point of view that allows for faster response times to dynamic system conditions. In some embodiments, the system increase grid abnormal condition predictivity based on historical re-creation, pattern recognition, and machine learning for operation optimization. In some embodiments, the system provides grid assistance health management that monitors, analyzes, and predicts failure. In some embodiments, the system provides decentralized control applications and distributed computing to avoid the vulnerabilities of centralized command and associated latencies. In some embodiments, the system enables a morphing grid with flexible integration and interoperability of diverse field devices, controllers, and communication paths at the edge. In some embodiments, the system further provides ecosystem value creation by allowing for seamless interaction and collaboration between applications, assets, and people across different system domains. In some embodiments, the system may include E2E secure connectivity such that the flows of information between disparate entities across multiple network domains are secured. In some embodiments, the

system provides full lifecycle device management, requiring minimum manual intervention. In some embodiments, the system provides optimized ingestion, transformation, and storage of relevant data in motion to fulfill grid functions and future anticipated needs.

[0043] In some embodiments, the systems and methods described herein provide a complex mission-critical machine that can transmute to new formations in response to system stress, abnormal conditions, environmental hazards, pandemics, and shelter in place operating conditions with minimum manual intervention, utilizing a grid-wide artificial intelligence (AI)-based decision support system.

[0044] Next referring to FIG. 3, an adaptive grid management system according to some embodiments is shown. In some embodiments, the adaptive grid management system 300 may comprise one or more processor-based devices executing computer-readable instruction stored on a memory storage device. In some embodiments, the adaptive grid management system 300 may be implemented with distributed and/or redundant server architecture on a plurality of networked processor-based devices. In some embodiments, the modules of the adaptive grid management system 300 may comprise software and/or hardware modules.

[0045] The adaptive grid management system 300 comprises a grid-wide-mind module 310, a grid artificer module 315, a grid-wide command hub 340, and federated grid data fabric 320. The grid-wide-mind module 310 comprises a federation alert correlation engine and a decision support module. In some embodiments, the federation alert correlation engine is configured to detect alert conditions based on data from a variety of sources including the grid operation data center 381 and enterprise data center and cloud services 382. In some embodiments, the decision support module is configured to generate context data based on the alert detected by the alert correlation engine. In some embodiments, context data may be referred to as frame of reference (“for”) data and may comprise alert type and vital attributes with severity degrees. In some embodiments, context data may be determined based on ML-based pattern recognition and matching using a context model trained on historical data. In some embodiments, the grid-wide-mind module 310 may comprise the alert correlation engine 201, the decision support module 202, the learning engine 203, and the simulation engine 204 described with reference to FIG. 2.

[0046] In some embodiments, the grid artificer module 315 may be configured to validate the context data from the grid-wide-mind module 310 and determine a formation plan via the context construction engine and a contextual and cognitive state machine. In some embodiments, the context construct engine is configured to extract patterns and context associated with the received context data and separate the context construct into abstraction panels representing separate problems. The grid artificer module 315 then matches each abstraction plane with historical constructs to determine a target grid formation and a formation plan for achieving the target formation through a cognitive state machine. In some embodiments, the grid artificer module 315 may comprise the grid artificer module 210, the context construct engine 211, the CSM operator 213, and the CSM builder 214 described with reference to FIG. 2.

[0047] The grid-wide command hub 340 comprises a grid-wide-eye module 342 and a grid-wide federation command module 344. The grid-wide-eye module 342 is configured to aggregate data from grid operation data center 381, the enterprise data center and cloud services 382, and operating cells, and organize data into points of view for various components of the adaptive grid management system 300. In some embodiments, the grid-wide-eye module 342 may comprise the grid-wide-eye module 220 described with reference to FIG. 2.

[0048] The grid-wide federation command module 344 may include a federation manager module, a foresight manager module, and a scout command module. The foresight manager creates an operation plan and optimizes the formation strategy based on signals from the grid-wide-mind module. The grid federation manager initiates the definition and coordination of the plurality of distributed operating cells. The scout command is configured to incubate and launch scout applications for execution at operating cells 391 and 392 and cells in the federation 390. The federated grid data fabric 320 may comprise a grid management system database providing data for use by the grid-wide-mind module 310 and the grid-wide federation command module 344. In some embodiments, the grid-wide federation command module 344 may comprise the federation command module 230 described with reference to FIG. 2.

[0049] The operating cells 391-395 each comprise a scout application executing on a device in the grid. In some embodiments, the device may be a physical field agent device or a virtual field agent device executed as a software component of another device. In some

embodiments, operating cells may form a scout federation 390 that shares communication and command. In some embodiments, one of the operating cells in the federation 390 may be designated as the scout master of the scout federation 390 and be configured to coordinate the task executions of cells in the federation 390 to achieve a common objective. In some embodiments, each of the operating cells may be assigned a role (e.g. coordinator, messenger, inspector, guard) by the adaptive grid management system 300 according to the characteristics of the executed scout application. The operating cells may then communicate with other operating cells and the adaptive grid management system 300 based on the assigned role. In some embodiments, each operating cell 391 may be associated with devices, sensors, or people. In some embodiments, an operating cell may be configured to provide instructions, collect data, relay messages, affect configurations, and provide security protection according to the scout application's assigned tasks.

[0050] Next referring to FIG. 4, an adaptive grid management system according to some embodiments is shown. In some embodiments, the adaptive grid management system 430 may comprise one or more processor-based devices executing computer-readable instruction stored on a memory storage device. In some embodiments, the adaptive grid management system 430 may be implemented with distributed and/or redundant server architecture on a plurality of networked processor-based devices. In some embodiments, the modules of the adaptive grid management system 430 may comprise software and/or hardware modules.

[0051] The adaptive grid management system 430 is coupled to a grid operation data center 410, cloud services 421, an enterprise data center 420, grid system operators 425, and market function systems 426. The grid operation data center 410 may comprise a transmission and distribution management system, a DER and renewable management system, a grid visibility and insight system, a historian system, a grid device and asset services system, and security services system. Cloud services 421 may comprise cloud applications and service delivery. The enterprise data center may comprise enterprise applications and services, DR/DER/EV aggregators, virtual power plant systems, and other external data and alerts. The grid system operators 425 may comprise transmission system operators and distribution system operators. The market function systems 426 may comprise energy market systems and peer-to-peer

electricity trading systems. In some embodiments, one or more components of the grid operation data center 410, the cloud services 421, the enterprise data center 420, the grid system operators 425, and the market function systems 426 includes a grid artificer virtual agent (“gAVA”) that allows the components to exchange data and commands with the adaptive grid management system 430. In some embodiments, the gAVA may standardize the communication messaging format of protocol between the components.

[0052] The adaptive grid management system 430 includes a grid-wide-mind module 431, a grid artificer module 432, and a grid-wide command hub. The grid-wide-mind module 431 comprises a decision support engine, a federated alert engine, and data storage and services. The grid-wide-mind module 431 is configured to detect alert conditions in the grid, determine context data based on ML pattern recognition and matching, and simulate a formation plan for execution based on current grid conditions. In some embodiments, the grid-wide-mind module 431 comprises the decision support module 202, the learning engine 203, the simulation engine 204, and the alert correlation engine 201 described with reference to FIG. 2. The grid artificer module 432 includes a contextual and cognitive state machine (CSM) for executing a formation plan determine based on context information received from the grid-wide-mind module. In some embodiments, the grid artificer module comprises the grid artificer module 210 described with reference to FIG. 2

[0053] The grid-wide command hub 439 comprises a grid-wide-eye module 435, a grid-wide federation command 436, a grid-wide formation manager 434, a grid-wide foresight manager 433, a scouts command 438, and a federated edge transaction manager 437. The grid-wide-eye module 435 is configured to aggregate data from grid operation data center 410, the enterprise data center 420, cloud services 421, grid system operators 425, and market function systems 426, and operating cells and organize data into points of view for use by various components of the adaptive grid management system 430.

[0054] In some embodiments, the grid-wide federation command 436 is configured to initiate the definition and coordination of a plurality of distributed operating cells. The grid-wide formation manager 434 is configured to define and coordinate the formation of the grid through the operating cells. The foresight manager 433 is configured to create an operation plan and

optimize formation strategy based on signals from the grid-wide-mind module 431. The scout command 438 is configured to incubate and launch scout applications for execution at operating cells. The federated edge transaction manager 437 is configured to assigned advance controllability and objective function in relation to local grid morphing at the cells.

[0055] An operating cell of the adaptive grid management system 430 may comprise a distributed operating cell 440 executing a scout application. The distributed operating cell 440 may comprise a processor-based device having a control circuit executing computer-readable instructions stored on a memory storage device. In some embodiments, the distributed operating cell 440 is configured to communicate with one or more field agent devices based on the directives of the scout applications running on and role assignments associated with the field agent devices. The distributed operating cell 440 may execute software-defined control, contextual reasoning, virtual sensing, alert collection, and security services. In some embodiments, the security services may be configured to provide cyber security to the distributed operating cell 440 and verify and validate scout applications before execution. In some embodiments, the distributed operating cell further comprises a data fabric storing data for decision making at the distributed operating cell 440. In some embodiments, the distributed operating cell 440 may be configured to coordinate the installation and execution of scout applications at a plurality of field agent devices. In some embodiments, the distributed operating cell 440 may be configured to performs its functions and make decisions based on the scout application and the stored data without communicating with the adaptive grid management system 430 for an extended period of time (e.g. hours, days).

[0056] An operating cell of the adaptive grid management system 430 may comprise an adaptive field agent device 450 executing a scout application. In some embodiments, the field agent device 450 may comprise a physical and/or a virtual device. The field agent device 450 may comprise a processor-based device having a control circuit executing computer-readable instructions stored on a memory storage device. The field agent device 450 may be assigned a role based on the executed scout application and perform tasks based on the directive of the scout application. The field agent device 450 may execute analytics, data services, semantic modeling, virtual sensing, and dynamic adaptation. In some embodiments, the security services may be

configured to verify and validate scout applications before execution. In some embodiments, a field agent device 450 may be associated with and/or communicate with components of a power grid such as plants 461, controllers 462, sensors 463, devices 464, assets 465, and electric vehicles 466. In some embodiments, a field agent device 450 may interface with a power grid component to aggregate data, send commands, provide security services, or perform inspections. Generally, a field agent device executing a scout application is configured to perform one or more tasks based on the directives of the scout application as part of the formation plan of the adaptive grid management system 430. Generally, an adaptive grid management system 430 may have any number of distributed operating cells 440 and adaptive field agent devices 450 executing scout applications. A distributed operating cell 440 may also be configured to command and coordinate any number of adaptive field agent devices 450.

[0057] While a network of devices in a power grid is generally referenced in the description of FIGS. 1-4, the teachings of the present disclosure are also applicable to other types of device networks such as a communications network, a transportation network, an Internet of Things (IoT) network, an enterprise network, etc.

[0058] Now referring to FIG. 5, a process for device network management is shown. In some embodiments, one or more steps of FIG. 5 may be performed by a processor-based device or system such as an adaptive grid management system described herein.

[0059] Prior to step 501, the system receives device signals from sources other than the devices executing scout applications in step 512. In some embodiments, the signals received in step 512 may comprise device status and system condition information provided by the devices or another system monitoring the network of devices. In some embodiments, the data received in step 512 may comprise other context data such as weather information, customer feedback information, incident reports, news services, web content, etc. In step 501, the system aggregates signals from devices in the network. In some embodiments, device signals may comprise status and alert data from various components of a network comprising information such as connectivity, throughput, response time, etc. In some embodiments, the signals may be ingested and processed through another system such as an operation center or an enterprise data center prior to step 501. In step 502, an alert condition is detected. In some embodiments, the system

may be configured to detect alert conditions based on detecting for signals that are outside of the expected band. In some embodiments, the alert condition may be detected based on an alert signal from one or more of the network devices or the operation center. In some embodiments, for a power grid, an alert signal may correspond to an outage or loss of connection to a component or a condition that is likely to lead to an outage or loss of connection. In step 503, the system performs alert correlation analysis by comparing the detected device signals with historical device network data. In some embodiments, the system may first train a context model using historical device signals and historical context information associated with the network of devices. The current signals from the network of devices are then used as input of the context model to determine context data associated with the current state of the network of devices. In some embodiments, the alert condition may correspond to a current issue or a predicted future issue (e.g. outage, overload, component failure).

[0060] In step 504, context data is determined based on the alert correlation analysis. In some embodiments, context data may comprise vital attributes and severities associated with each vital attribute. In some embodiments, context data may further comprise a control area identifier, a timing identifier, and an alert condition identifier determined based on the signals from the devices. For example, context data may identify a geographic area associated with the devices that generated the signals that led to the detection of the alert condition. In step 505, the context data is separated into sub-context data, each associated with a separate issue in the device network. In step 506, each sub-context data is compared with a historical context data pattern from a historical context pattern database to determine a formation plan for affecting the grid formation in response to the alert in step 507. In some embodiments, each historical context pattern may identify a particular issue associated with the sub-context and a target grid formation or one or more tasks for affecting the network formation in response to the issue. In some embodiments, the formation plan may comprise tasks to be executed by a plurality of operating cells in the device network. In some embodiments, the system may determine a state machine comprising a list of steps and trigger conditions for each step determined based on the context information for reconfiguring the device network from the current state to the desired state in stages, and the formation plan may be determined based on states defined in the state machine. In

some embodiments, the tasks may comprise one or more of a coordination task, a messenger task, an inspection task, or a guard task. In step 508, the system simulates the formation plan based on the updated signals from the network devices to verify that the execution of the formation plan would achieve the desired grid formation. If the formation plan passes simulation, the system configures scout federations and scout applications for incubation and deployment based on the formation plan and/or the state machine. In step 509, scout applications assigned to each operating cell may be configured based on the tasks and role of the operating cell assigned by the formation plan and characteristics of the operating cell such as device type, device capability, etc. In some embodiments, if the directives of the formation plan match a previously configured scout application, the previously configured scout application may be retrieved for deployment. In some embodiments, if no existing scout application matches the directive of the formation plan, the system may configure a new scout application based on stored application components (e.g. DNA). A newly formed scout application may be incubated and tested prior to deployment. In some embodiments, the system may further determine commands and/or reconfiguration of existing operating cells already executing a scout application based on the formation plan.

[0061] In step 510, the scout applications are deployed for execution at operating cells such as distributed control hubs and field agent devices. In some embodiments, scout applications may be deployed or triggered in phases based on the states of the state machine. In step 511, after the deployment of the scout applications, the system monitors for data from the operating cells executing the scout applications. In some embodiments, the system may further issue commands and instructions to the scout applications as needed based on updated data from the network of devices and/or the state machine. After the scout applications are deployed, the system continues to aggregate device signals to update the state machine and determine new formation plans in response to any remaining or new alert conditions. In some embodiments, a new formation plan may cause updates or terminations of deployed scout applications. In some embodiments, a scout application may be configured to cause an operating cell device to carry out tasks for an extended period of time in response to various trigger conditions without further commands or instructions from the network management system. Further details of an operating

cell device executing a scout application are described with reference to FIG. 6 herein. In some embodiments, a new formation plan may be directed to a different set of operating cells and device network components to address a different alert condition. In some embodiments, after successful execution of a formation plan that removes the alert condition, the detected device signal and the formation plan may be used to train a machine-learning algorithm model for future context construction and/or formation plan determinations.

[0062] Now referring to FIG. 6, a process for device network management with an operating cell is shown. In some embodiments, one or more steps of FIG. 6 may be performed by a processor-based device or system in a network of devices such as a field agent device and a distributed control hub described herein.

[0063] In step 601, a device in a power grid receives a scout application from the network management system or another device in the network such as a field coordinator device or a field agent device. In step 602, the device verifies the received scout application for authenticity and timeliness. In some embodiments, the authentication may be based on an authentication key. In step 603, the device executes the scout application and begins to carry out the directive of a formation plan based on tasks defined in the scout application. In some embodiments, the device may assume a role (e.g. coordinator, messenger, inspector, guard) based on the role assigned to the scout application. In step 604, the device detects for trigger conditions associated with various tasks and actions. In step 605, the device may begin to communicate with other field agent devices, a device federation, and/or the central device management system based on the role assigned to the scout application. For example, the device may begin to accept tasks assigned by a master of the federation or begin to transmit specified data to the central device management system. In some embodiments, the scout application may specify trigger conditions associated with actions and tasks. For example, a data transmission task may be triggered by a timestamp or upon detection of an abnormal condition in the data. In step 606, the device performs the task which may be a coordinator task, a messenger task, an inspector task, or a guard task. In step 607, upon detection of a cloning trigger, the device may send a copy of the scout application to be executed by another device. In some embodiments, the device may further transfer authority and role to the other device in step 607. For example, if the

device detects a stress condition (e.g. unstable power supply or data connection), the device may transfer its task and role to another device in the network that can complete the directive of the scout application. In step 608, upon detection of a termination trigger, the device may terminate the execution of the scout application. In some embodiments, the termination trigger may comprise the completion of one or more tasks or detection of a change in a specified condition. In some embodiments, the device may remove the scout application from its memory in step 608.

[0064] Next referring to FIG. 7, a network management system according to some embodiments is shown. The system comprises a network management system 710 accessing a context model 740, a device database 750, a context pattern database, a scout applications database 770, and a network operations system 720. The network management system 710 is further configured to communicate with a plurality of operating cell devices 780.

[0065] The network management system 710 comprises a control circuit 712, a memory 717, and a network interface device 713. The control circuit 712 may comprise one or more of a processor, a microprocessor, a central processing unit (CPU), a graphics processing unit (GPU), an application-specific integrated circuit (ASIC), and the like and may be configured to execute computer-readable instructions stored on a computer-readable storage memory 717. The computer-readable storage memory 717 may comprise volatile and/or non-volatile memory and have stored upon it, computer-readable instructions which, when executed by the control circuit 712, causes the control circuit 712 to detect for alert conditions in a network of devices, determine context data based on an ML trained model, determine a formation plan based on the context data, and cause a plurality of scout applications to carry out tasks at operating cells among the network of devices to affect a state of the network. In some embodiments, the network management system 710 may be implemented with a plurality of memory devices and/or processors at a central location or geographically distributed in multiple locations. In some embodiments, the computer-executable instructions may cause the control circuit 712 of the network management system 710 to execute one or more modules described with reference to FIGS. 2-4 herein and/or perform one or more steps described with reference to FIG. 5 herein.

[0066] The network interface device 713 may comprise a data port, a wired or wireless network adapter, and the like. In some embodiments, the network interface device 713 may communicate with the operating cell devices 780, and the network operations system 720 via a network such as a local network, a private network, or the Internet. In some embodiments, the network management system 710 may further access one or more of the context model 740, the device database 750, the context pattern database, and the scout applications database 770 via the network interface device 713.

[0067] An operating cell device 780 may comprise a processor-based device in the network of devices comprising a control circuit and a memory. The operating cell is generally configured to receive and execute one or more scout applications configured by the network management system 710 to carry out tasks specified by the network management system 710. In some embodiments, the tasks may cause the operating cell device 780 to collect data, send requests/instructions, or change a configuration of another component or subsystem of the network of devices. In some embodiments, the task may cause the operating cell to report collected data or other status information back to the network management system 710. In some embodiments, the task may cause the operating cell to form a federation with other cells and communicate with other operating cells based on roles associated with the executed scout application. In some embodiments, a control circuit executing a scout application stored on a computer-readable memory device may cause the operating cell device 780 to perform one or more steps described with reference to FIG. 6 herein. The network management system 710 is configured to communicate, directly or via another network device, with a plurality of devices in the network that may function as operating cell devices of the network management system 710.

[0068] The network operations system 720 may comprise an operations system of the network of devices that aggregate data from various sources and coordinate commands and requests with the network of devices under normal operation. In a power grid, for example, a network operations system 720 may comprise the grid operation data center 110 and enterprise data center 120 described with reference to FIG. 1. In some embodiments, the network operations system 720 may be an existing control system of a device network that the network management system 710 communicates with to provide added capability of automatic

reconfiguration of the network of devices in response to alert conditions through tasks executed at operating cells. In some embodiments, the network management system 710 may further communicate with other cloud services or network data sources such as third-party data services for alert detection and context determination.

[0069] The context model 740 comprises a pattern recognition model trained based on an ML learning algorithm such as a neural network algorithm. In some embodiments, the context model is trained using historical signals from devices in the network as input and historical context data as categorization. In some embodiments, the historical context data may be manually inputted, derived from device signals from an earlier or later point of time, or supplied from another data source such as outage reports, news services, etc. The network management system 710 may use the context model to determine context data associated with the current state of the network of devices.

[0070] The device database 750 comprises parameters and/or status information associated with the devices in the network. In some embodiments, the device database 750 may store information such as unique identifier, device type identifier, geographic location, IP address, memory capacity, processing capacity, bandwidth capacity, operating system, etc. associated with devices in the device network, including devices that can be used as an operating cell device of the network management system 710. In some embodiments, the network management system 710 may use the information stored in the device database 750 to select devices for executing particular tasks and scout applications. In some embodiments, the network management system 710 may further configure scout applications based on information associated with the device such that the scout applications are suited for execution at the selected devices.

[0071] The context pattern database 760 comprises context patterns each associated with a different problem domain. In some embodiments, each context pattern may be associated with one or more vital attributes and associated severity degree that may be matched to context data associated with a current network state. In some embodiments, context patterns may further be associated with a geographic region. In some embodiments, the context pattern may identify a target network state or a response associated with the problem domain. In some embodiments,

the network management system 710 may use the context patterns in the context pattern database 760 to determine a formation plan and/or a state machine for affecting the state of the network of devices in response to the problem domain and/or alert condition associated with the context pattern.

[0072] The scout applications database 770 comprises scout applications and/or application components (e.g. application DNA). In some embodiments, a scout application may comprise codes for executing one or more tasks based on one or more trigger conditions. In some embodiments, a scout application may be configured based on a role assigned to the application and/or operating cell and the configurations and constraints of the operating cell. In some embodiments, the scout applications database 770 may store previously configured applications and the network management system 710 may retrieve an existing application for deployment at an operating cell based on a formation plan. In some embodiments, the network management system 710 may use the application components in the scout applications database 770 to configure new applications for deployment. In some embodiments, newly formed scout applications may first be tested in a simulation or incubation environment prior to deployment. In some embodiments, successfully simulated or executed scout applications may be stored in the scout applications database 770 for future use.

[0073] In some embodiments, one or more of the context model 740, the device database 750, the context pattern database 760, and the scout applications database 770 may be implemented on the same one or more memory storage devices. In some embodiments, one or more of the context model 740, the device database 750, the context pattern database 760, and the scout applications database 770 may be implemented on the memory 717 of the network management system 710 or be accessed through a network by the network management system 710. In some embodiments, one or more of the context model 740, the device database 750, the context pattern database 760, the scout applications database 770, network operations system 720 may be accessed and updated by a plurality of network management system 710, for example, distributed network management systems serving different geographic areas.

[0074] Now referring to FIG. 8, a flow diagram of an artificer module according to some embodiments is shown. In some embodiments, one or more steps of FIG. 8 may be performed by

a processor-based device or system such as an adaptive grid management system described herein.

[0075] In step 801, the artificer module receives context data associated with an alert condition from a decision support module. The context data may be determined by the decision support module based on signals received from a plurality of devices on a network of devices. In step 802 the system forms a context meta object. In some embodiments, the context data comprise a plurality of vital attributes each associated with a severity degree and a time stamp. In some embodiments, the context meta object is determined based on a machine learning model trained on historical context data associated with devices on the network of devices. In some embodiments, the context meta object is determined based on a stress force evaluation module that determines possible underlying causes based on a deterministic algorithm. In some embodiments, context meta object comprises a plurality of likely contexts ranked based on probability as determined by a machine learning model.

[0076] In step 803, the system determines a plurality of context abstraction panel based on parsing the context meta object into a plurality of context groups and assigning an abstraction problem domain to each context group based on a machine learning algorithm. In some embodiments, a contextual abstraction panel comprises panel positioning, operation classification, functional composition, and/or a severity index.

[0077] In step 805, the system determines the interdependency of one or more abstraction panels based on a machine learning model trained on contextual historical archive database, wherein the context meta object further comprises composite abstraction panel data with an associated relevancy index. In step 806, the system forms a provisional cognitive state machine and validates the provisional cognitive state machine with a simulation engine in step 807. Based on the result of the validation, one or more states of the provisional cognitive state machine may be calibrated in step 808. In step 809, the systems form a cognitive state machine based on the context meta object for execution by a cognitive state machine operator to affect operations of one or more devices on the network via the network adapter, the cognitive state machine comprises a plurality of states each defining at least a task for execution by at least one network device. In some embodiments, the cognitive state machine defines a number of states, initial

states, trigger conditions for each state, a final state with corresponding performance index, and recalibration conditions for one or more states.

[0078] Now referring to FIGS. 9A, 9B, 10A, 10B, and 11, flow diagrams according to some embodiments are shown. In some embodiments, one or more steps of FIGS. 9A, 9B, 10A, 10B, and 11 may be performed by a processor-based device or system such as an adaptive grid management system described herein. The variable in FIGS. 9A, 9B, 10A, and 10B may be defined as follows:

[0079] **for-ID - frame of reference -ID**

va_n - Vital attributes (va_1 to n)

sd_n - severity degree (sd_1, n)

t_i - time of recording of event

ga - grid artificer

ga-authenticationkey - grid artificer authentication key

ca - context abstraction

ca-id_{1,n} - context abstraction ID (1-to-n)

apd - abstraction problem domain

apd-id_n - abstraction problem domain ID (1,n)

C_n - context _{1,n}

pd - panel domain

h_n - historical pattern

sc_{n,n} - sub context (1, n)

for-id_{h(1,n)} - series if historical for -id (1,n) with similar context /variation in relation of for-id

pp_n - panel positioning in relation to other panels

oc - operational classification associated to panel

fc_n - function composition

pad_n - panel abstraction domain

$ri_{1,n}$ - relevancy index

Ccap - Composite contextual abstraction panel

s_n - state (1,n)

a_n - action (1,n)

t_n - transition

Sf (1,0) - self forming (1=on, 0=off) -state with self-forming

CaCSM_{bp} - Contextual and Cognitive State Machine – base production

CaCSM_p - Contextual and Cognitive State Machine - provisional

[0080] Now referring to FIGS. 9A and 9B, a pre-formation workflow is shown. The grid federated alerts engine 951 detects for alert conditions based on data from a grid operation data center and a grid-wide-mind sensing system. An action stress frame constructor 952 then constructs an action stress frame (including an action stress frame ID, pattern plate, and time (t)) based on the network device data associated with the detected alert. The action stress frame is passed to a decision support (ds) gatekeeper 953 for validation. If the action stress frame passes validation, the action stress frame is passed to a ds grid shaping analysis and machine learning module 954. The ds grid shaping analysis and machine learning module 954 sends a pattern recognition request to a learning engine 955 trained on historical action stress frame data. The learning engine 955 is configured to output a pattern mapping to the ds grid shaping analysis engine and machine learning module 954 in response to the pattern recognition request. The ds grid shaping analysis engine and machine learning module 954 then provides the analysis data and context data to a ds context model builder 956. The ds context model builder 956 applies correlation analysis and contextual reasoning to the data received from the ds grid-shaping analysis engine and machine learning module 954 to determine context or frame of reference information, including a frame of reference ID (for-ID), vital attributes (va_n), severity degrees (sd_n), and time (t_n). The frame of reference data is passed to a ds gatekeeper 953 for validation. If

the frame of reference information passes validation, the frame of reference data (e.g. for-id, $(va_1, sd_1), (va_2, sd_2), \dots, (va_n, sd_n), ti$) are passed to a grid artificer module 960. In some embodiments, the grid artificer module 960 may comprise one or more of the grid artificer modules 210, 315, and 432 described herein.

[0081] In step 961, the grid artificer module 960 creates a grid artificer (ga) authentication key. In step 962, the grid artificer module 960 validates the frame of reference data against historical patterns. In step 963, the grid artificer module 960 calculates a misalignment factor on the context. If the misalignment is within an acceptable range (e.g. predetermined threshold), the output of the grid artificer module 960 is passed to a ga-control and command module 970 and a context construct engine 980. If misalignment exceeding a threshold is detected, a correctness analysis request is generated and sent to the ds gatekeeper 953, the correctness analysis request includes for-id, (attributes), tx_1 , ga authentication key, and misalignment factor. The ds gatekeeper 953 then sends a request for system condition variance analysis from an initial time to the grid federated alerts engine 951 which in turn sends a request for correctness analysis including system condition variance analysis results for $t(x)$ to $t(x_1)$ to the grid wide decision support module 966. In step 967, the system then calculates a confidence degree on the recommendation. If the confidence degree is not within an acceptable range (e.g. below a predetermined threshold), the process returns to ds gatekeeper 953 for validation. If the confidence degree is in an acceptable range (e.g. exceeds a predetermined threshold) the output of the grid artificer module 960 is passed to a ga-control and command module 970 and a context construct engine 980.

[0082] The ga control and command module 970 receives the output of the grid artificer module 960 (e.g. (for-id, $(a_1, sd_1), (a_2, sd_2), \dots, (a_n, sd_n), t(y)$)) and sends a formation alert (for-id, authentication key) to a . In some embodiments, the grid wide federation command module 975 may comprise one or more of the federation command module 230, 344, and 436. The federation command module 975 authenticates the information then sends a notification to the grid wide federation manager, the grid wide foresight manager, the grid scouts command, and the grid edge federated transaction manager 977.

[0083] The output of the grid artificer module 960 (e.g. (for-id, (a₁,sd₁),(a₂, sd₂), ... ,(a_n, sd_n), t(y))) is also provide to a context construct engine 980. In some embodiments, the context construct engine 980 may comprise the context construct engine 211. In step 901, the context construct engine 980 sends a request for historical patterns and contexts in correlation with received frame of reference data (e.g. (for-id, (a₁,sd₁),(a₂, sd₂), ... ,(a_n, sd_n), t(y))) to a learning engine 983. In step 902, the frame of reference data ((for-id, (a₁,sd₁),(a₂, sd₂), ... ,(a_n, sd_n), t(y))) is sent to a contextual reasoning module 985 which utilizes machine learning. In step 903, for-id, (a_n, sd_n) is sent to the stress force evaluation module 984 which, in step 904, determines underlying cause for (a_n,sd_n) based on a deterministic algorithm. In step 905, (a_n,sd_n) is sent to the context historical archive 987 which provides (a_nh_n,sd_n) in return in step 906. The stress force evaluation module 984 then provides (for-id, (a_nh_n,sd_n) + (dc₁ .. dc_n)) to the contextual reasoning module 985 in step 907. The context historical archive 987 also provides pattern extraction to the contextual reasoning module 985 in step 907a. In step 908, the contextual reasoning module determines the most probable context and rank. In step 909, the contextual reasoning module 985 then output the contexts to the context meta object builder 986 which sends a context meta object ((for-id, ((c₁,pd₁, (sc_{1.1}, ... sc_{1.n})), (c₂, pd₂, (sc_{2.1}, ... sc_{1.n}))), ... ,((c_n, pd_n, (sc_{2.1}, ... sc_{1.n}))), t(y)) + (for-id, (a₁,sd₁),(a₂, sd₂), ... ,(a_n, sd_n), t(y))) + ((for-id, (for-id_{h1,n}))) to the context construct engine 980 in step 911. The meta object (id) is also stored into the context historical archive 987 in step 910 for model training.

[0084] In step 912, the output of the grid artificer module 960 is sent to a grid artificer parser 981 which, in step 913, pars context meta object from the learning engine(s), determines coloration and grouping, creates context abstraction ID (ca-id_{1,n},) for each context group, and assigns abstraction problem domain ID (apd-id_n). In step 914, the parsed data ((for-id, (ca-id₁ (c₁, ... c_n), ad-id_n), ... (ca-id_n (c₁, ... c_n), ad-id_n), t(y))) is passed to a context abstraction panel builder 982 which, for corresponding correlated contexts and associated problem domain, creates individual abstraction panels with unique ID, ranks the abstraction panels based on probability degree provided by learning engine, and determines panel positioning in relation to each other in step 915. In step 916, the context abstraction panel builder 982 then passes context abstraction panel data (e.g. cap-id,(panel positioning, operation classification, functional composition,

severity index) to the context construct engine 980. In step 917, the cap-id, abstraction panels attribute, and ga-authentication key are sent from the context construct engine 980 to the grid artificer module 960 for CaCSM creation.

[0085] Now referring to FIGS. 10A and 10B, CaCSM creation stage of a formation workflow is shown. In step 917, the context construct engine 980 initiates CaCSM creation by sending for-id, (cap-id_{1,n}, (panel-positioning(pp_n), operation-classification (oc_n), functional-composition (fc_n), severity-degree (sd_n), pad_n), ga-authenticationkey) to the grid artificer module 960. In step 917a, the ga gatekeeper 1003 authenticates (ga-authenticationkey). In step 917b, if the authentication is rejected, a rejection with cap-id, ga-authenticationkey are sent back to the context construct engine 980. If the authentication is accepted, the ga gatekeeper notifies the grid artificer module 960 in step 917c.

[0086] In step 918, the grid artificer module 960 establishes an abstraction panel (AP) interdependency based on an AP interdependency analyzer 1004 which maps abstraction panels, and associated context, determine level of contextual interdependency and associated index between abstraction panels. The cap-id_{1,n}, ((pp_n), (oc_n), (fc_n), (sd_n), pad_n), and metaobject(id) outputted by the AP interdependency analyzer 1004 are sent to a ds correlator engine 1005 that verifies the relevancy of the correlation. The information are then sent to a learning engine 965 trained on data from context historical archive 987 to output contextual abstraction panel (cap) with high dependency (cap-id_{1,n}, relevancy index (ri_{1,n}), metaobject(id)) to a composite cap builder 969. The composite cap builder 969 outputs composite-cap- (Ccap-id) and relevancy index - (ri_{h,m,l}) to a context meta object builder 986 that builds meta objects (e.g. ((for-id, ((c₁,pd₁, (sc_{1.1}, ... sc_{1,n})), (c₂, pd₂, (sc_{2.1}, ... sc_{2,n})), ... ,((c_n, (sc_{n.1}, ... sc_{n,n}), pd_n)), t(y)) + (for-id, (a₁,sd₁),(a₂, sd₂), ... ,(a_n, sd_n), t(y))) + ((for-id, (for-id_{h1,n}))) + composite-cap (Ccap-id, relevancy index (ri_{h,m,l})) and sends ((for-id, (Ccap-id, relevancy index (ri_{h,m,l})), meta-object(id) to the grid artificer module 960 in step 919.

[0087] In step 920, ((for-id, (Ccap-id, relevancy index (ri_{h,m}), t_x)) is passed to the CSM builder 1010 which extract cap id with highest relevancy index and forwards for-id, ((context-id, ri_(high), attributes)) to a learning engine 1011. In some embodiments, the CSM builder 1010 may comprise the CSM builder 214. The learning engine 1011 determines the best matched CaCSM

pattern from the state machine historical archive 1013 and sends CaCSM template and for-id, ((context-id,, attributes) to a provisional CaCSM builder 1012 which determines parameters of the state machine such as the number of states, initial states, triggers, functional compositions, self-forming triggers, and final states with corresponding performance index based on the context ID and attributes stored in the state machine historical archive 1013. The provisional CaCSM template is then sent to the context state machine meta object builder 1014 and the meta object ID is stored into the state machine historical archive 1013 for use in training the learning engine 1011.

[0088] In step 921, the context state machine meta object builder 1014 sends for-id, ((context-id, attributes), CaCSM_p-id, ((s₁, a₁, t₁, sf_(1,0)), (s_n, a_n, t_n, sf_(1,0)), Meta-object (id) to the CSM builder 1010. In step 922, the CSM builder 1010 sends a CaCSM validation request with for-id and t_y to the grid artificer module 960 which sends Validate (CaCSM_p-id,), Meta-object (id) to the simulation engine 1020 in step 923. In some embodiments, the simulation engine 1020 may comprise the simulation engine 204. Simulation scenarios may be stored and retrieved from the simulation scenarios historical archive 1025. In step 923a, the simulation engine forwards Validate (CaCSM_p-id,), Meta-object (id) to the SM historical archive 1013 as query. In step 924, for-id, ((context-id, attributes), CaCSM_p-id, ((s₁, a₁, t₁, sf_(1,0)), (s_n, a_n, t_n, sf_(1,0)), Meta-object (id), are retrieved from the state machine historical archive 1013. In step 925, a CaCSM state calibration request including (s_n, a_n, t_n, sf_(1,0)) are sent to a learning engine 1021 and, in step 925a, calibrated state (sn, an, tn, sf(1,0)) are sent back to the simulation engine 204 to run the provisional CaCSM in simulation mode and calibrate each state as needed. In step 926, the simulation engine 1020 validates the states (s_n, a_n, t_n, sf_(1,0)) and forward the validated states to a production CaCSM builder 1022, which is configured to build, for each CaCSM_{bp} -ID, number of states, initial states, trigger, functional composition, self-forming trigger, and final state with corresponding performance index in step 927. In step 928, CaCSM_{bp} -id, (attributes) are stored in the state machine historical archive 1013. In step 929a, the calibrated for-id, ((context-id, attributes), CaCSM_p-id, ((s₁, a₁, t₁, sf_(1,0)), (s_n, a_n, t_n, sf_(1,0)), Meta-object (id) are provided to the simulation engine 1020. In some embodiments, the simulation and calibration steps may be repeated on the provisional CaCSM. In step 929, the simulation engine 1020 sends a operation-

ready notification with (CaCSM_p-id,) and Meta-object (id) to the grid artificer module 960. In step 930, the grid artificer module 960 signals the CSM builder 1010 for initiation of formation and operation. The initiation of formation and operation, including for-id, ((CaCSM_{bp}-id), Meta-object (id), ga-authenticationkey) are sent to a CSM operator 1040 to begin the operation stage of the formation workflow.

[0089] Now referring to FIG. 11 an operation stage of a formation workflow is shown. In step 931, the CSM builder 1010 sends for-id, ((CaCSM_{bp}-id), Meta-object (id), ga-authentication key) to a CSM operator 1040. In step 932, the CSM operator 1040 sends an authentication request (ga-authentication key) to a ga gatekeeper 1003 for verification. Verified for-ids are forward to the grid artificer module 960 in step 932a and rejected for-ids are sent back to the CSM builder 1010. In step 932b, the grid artificer module 960 activates CaCSM_{bp}-id and sends the data to the CSM operator 1040. In step 933, the grid artificer also sends for-id, Meta-object (id), Context(id) to a command logistic builder 1023 which creates a preparation action list and sends command logistic data to the grid wide federation command module 975 in step 933a.

[0090] The CaCSM 1030 receives $r(1, (sf=1, 0, (sf=0)))$ from the CSM operator and outputs the corresponding $(t, r(1,0), f)$ in each state to the grid wide federation manager, foresight manager, scouts command, and/or edge federated task manager. The CaCSM 1030 is further configured to send a CaCSM state calibration request to a learning engine 1045 to calibrate states $(s_n, a_n, t_n, sf(1,0))$. The CaCSM 1030 also provides state operation results back to the CSM operator 1040.

[0091] The grid wide federation command module 975 is configured to communicate with the CSM operator 1040 to perform state machine command executions in an operation loop. The grid wide federation command module 975 communicates with the grid wide federation manager, foresight manager, scouts command, and edge federate task manager based on logistics preparation notification (Context(id), Logistics(id)). The grid wide federation command module 975 is further configured to communicate with the grid artificer module 960 to respond to status requests with status reports as a state machine is executed.

[0092] In some embodiments, an adaptive power grid management system is provided. The system comprises a network device database, a network adapter, and a processor. The processor is configured to train, with a machine learning algorithm using historical device signals and historical context information associated with a network of devices, a context model, receive signals from the network of devices, determine, based on the context model, context data associate with a current condition of the network of devices, determine a formation plan based on the context data, the formation plan comprises tasks to be carried out by one or more devices in the network of devices, configure one or more scout applications based on the formation plan and device information stored in the network device database, and cause, via the network adapter, the one or more scout applications to be executed by the one or more devices in the network of devices.

[0093] In some embodiments, a decision support system for network management is provided. The system comprises a network device database and a processor coupled to the network device database. The processor executes a decision support module and is configured to detect an alert condition based on signals from a network of devices, determine context data associated with the alert condition and provide the context data to an artificer module, receive a formation plan from an artificer module, perform a simulation of the formation plan and a current network condition, and configure a plurality of scout application based on the simulation, the plurality of scout application being for execution on a plurality of devices on the network. In some embodiments, the alert condition is detected based on determining whether signals from the network of devices correspond to an abnormal condition exceeding an acceptable band. In some embodiments, detecting the alert condition comprises training, with a learning engine, an alert model based on historical signals from the network of devices and context data. In some embodiments, detecting the alert condition comprises aggregating signals from the network into a stressed frame and performing pattern recognition analysis on the stress frame based on historical stress frame data. In some embodiments, the processor is further configured to determine a set of select vital attributes each associated with a severity degree associated with the alert condition and wherein the context data comprises the set of vital attributes and the associated severity degrees.

[0094] In some embodiments, an artificer system for device network management is provided. The system comprises a contextual construct database and a processor coupled to the contextual construct database. The processor executes an artificer module and is configured to receive context data associated with an alert condition from a decision support module, wherein the context data comprises a plurality of vital attributes and is determined based on signals received from a plurality of devices on a network, for each vital attribute of the context data, match a context pattern in the context pattern database to determine a contextual abstraction panel and determine a formation plan for execution by a decision support module. In some embodiments, the system is further configured to determine a misalignment between the context data and subsequent context data; and request new context data from the decision support module in the event that of misalignment. In some embodiments, wherein the contextual abstraction panel comprises one or more of panel positioning, operation classification, functional composition, and a severity index.

[0095] In some embodiments, a decision support system for device network management is provided. In some embodiments, the system comprises a scout applications database and a processor coupled to the scout database. The processor executes a decision support module is configured to receive a formation plan from an artificer module, derive operation and functional attributes based on simulating the formation plan, determine, with a cognitive state machine, scout application configurations for a plurality of scout applications based on the operation and functional attributes, and configure one or more scout applications for executing on one or more devices of the network based on the attributes. In some embodiments, scout application configurations are determined based on selecting at least one stored scout application configuration from the scout database based on the formation plan. In some embodiments, the processor is further configured to perform incubation and training of a newly configured scout application prior to transmitting the newly configured scout application to a device on the network.

[0096] In some embodiments, an operating cell device for power grid management is provided. The device comprises a network adapter configured to communicate with a device network management system and a processor coupled to the network adapter, the processor

being configured to receive, via the network adapter and from a server, a scout application with an associated role assignment, authenticate the scout application and automatically execute the scout application upon authentication, and communicate, via the network adapter, with the device network management system or a plurality of devices in a network based on the role assignment of the scout application. In some embodiments, the scout application is assigned the role of a messenger and is configured for ingestion, transformation, and storage of data associated with one or more of locality, persons, assets, and applications associated with the cell device. In some embodiments, the scout application is assigned the role of a coordinator configured for providing coordination and management of one or more other cell devices in a federation. In some embodiments, the scout application is assigned the role of an inspector and is configured to collect data associated with the operation of the cell device or a federation comprising the cell device. In some embodiments, the scout application is assigned the role of a guard and is configured to prevent a physical threat, a cyber threat, and functional misalignment. In some embodiments, the scout application executing on the cell device is configured to cause another instance of the scout application to be installed and executed on another cell device. In some embodiments, the scout application is configured to automatically terminate in response to a termination condition being met. In some embodiments, the scout application is configured to perform an assigned role without communicating with the server or another cell device.

[0097] In some embodiments, a federation command system for device network management is provided. The system comprises a network device database and a processor. The processor executing a federation command module and configured to form, based on the formation plan and the device database, a federation comprising a plurality of cell devices each executing at least one of a plurality of scout applications each associated with a role in the federation, cause, the plurality of scout application to be executed on the plurality of cell devices, and transmit a command to a cell device the plurality of cell devices based on a role associated with a scout application executed by the cell device. In some embodiments, the processor is further configured to simulate, with a decision support module, the formation plan prior to configuring the plurality of scout applications.

[0098] Further aspects of the disclosure are provided by the subject matter of the following clauses:

[0099] An adaptive power grid management system, the system includes a network device database; a network adapter, and a processor coupled to the network device database and the network adapter, the processor being configured to: train, with a machine learning algorithm using historical device signals and historical context information associated with a network of devices, a context model; receive signals from the network of devices; determine, based on the context model, context data associate with a current condition of the network of devices; determine a formation plan based on the context data, the formation plan includes tasks to be carried out by one or more devices in the network of devices; configure one or more scout applications based on the formation plan and device information stored in the network device database; and cause, via the network adapter, the one or more scout applications to be executed by the one or more devices in the network of devices.

[00100] The adaptive power grid management system of any preceding clause wherein the one or more devices includes field agent devices associated with one or more of a power plant, a solar farm, a windfarm, a digital substation, a microgrid controller, and an electric vehicle charging station.

[00101] The adaptive power grid management system of any preceding clause wherein the context data includes a set of select vital attributes each associated with a severity degree.

[00102] The adaptive power grid management system of any preceding clause wherein the context data includes a control area identifier, a timing identifier, and an alert condition identifier.

[00103] The adaptive power grid management system of any preceding clause wherein the formation plan is determined based on: matching the context data with context patterns in a context pattern database; separating the context data into contextual abstraction panels each corresponding to a separate problem domain perspective; and determining the tasks and the one or more devices associated with each contextual abstraction panel.

[00104] The adaptive power grid management system of any preceding clause wherein the formation plan is determined based on a state machine including a list of steps and trigger conditions determined based on the context data.

[00105] The adaptive power grid management system of any preceding clause wherein configuring the one or more scout applications includes selecting a stored scout application matching the formation plan.

[00106] The adaptive power grid management system of any preceding clause wherein the one or more scout applications are each assigned a role and is configured based on the role.

[00107] The adaptive power grid management system of any preceding clause wherein configuring the one or more scout applications includes: generating a new scout application using stored application components based on the formation plan; and testing the new scout application prior to deployment.

[00108] The adaptive power grid management system of any preceding clause wherein the processor is further configured to simulate the formation plan based on updated signals from the network of devices prior to causing the one or more scout applications to be executed by the one or more devices in the network of devices.

[00109] A method for adaptive management of a power grid includes: training, with a machine learning algorithm executing on a processor using historical device signals and historical context information associated with a network of devices, a context model; receiving signals from the network of devices; determine, with the processor and based on the context model, context data associate with a current condition of the network of devices; determine, with the processor, a formation plan based on the context data, the formation plan includes tasks to be carried out by one or more devices in the network of devices; configure, with the processor, one or more scout applications based on the formation plan and device information stored in the network device database; and cause the one or more scout applications to be executed by the one or more devices in the network of devices.

[00110] A method for adaptive management of a power grid of any preceding clause wherein the one or more devices includes field agent devices associated with one or more of a

power plant, a solar farm, a windfarm, a digital substation, a microgrid controller, and an electric vehicle charging station.

[00111] A method for adaptive management of a power grid of any preceding clause wherein the context data includes a set of select vital attributes each associated with a severity degree.

[00112] A method for adaptive management of a power grid of any preceding clause wherein the context data includes a control area identifier, a timing identifier, and an alert condition identifier.

[00113] A method for adaptive management of a power grid of any preceding clause wherein the formation plan is determined based on: matching the context data with context patterns in a context pattern database; separating the context data into contextual abstraction panels each corresponding to a separate problem domain perspective; and determining the tasks and the one or more devices associated with each contextual abstraction panel.

[00114] A method for adaptive management of a power grid of any preceding clause wherein the formation plan is determined based on a state machine including a list of steps and trigger conditions determined based on the context data.

[00115] A method for adaptive management of a power grid of any preceding clause wherein configuring the one or more scout applications includes selecting a stored scout application matching the formation plan.

[00116] A method for adaptive management of a power grid of any preceding clause wherein the one or more scout applications are each assigned a role and are configured based on the role.

[00117] A method for adaptive management of a power grid of any preceding clause wherein configuring the one or more scout applications includes: generating a new scout application using stored application components based on the formation plan; and testing the new scout application prior to deployment.

[00118] A method for adaptive management of a power grid of any preceding clause further including simulating the formation plan based on updated signals from the network of devices prior to causing the one or more scout applications to be executed by the one or more devices in the network of devices.

[00119] A adaptive power grid management system includes: a context historical archive database; a network adapter, and a processor coupled to the context historical archive database and the network adapter, the processor being configured to execute a artificer module which causes the processor to: receive context data associated with an alert condition from a decision support module, the context data being determined based on signals received from a plurality of devices on a network of devices; form a context meta object by matching the context data with historical context data stored in the context historical archive database; and form a cognitive state machine based on the context meta object for execution by a cognitive state machine operator to affect operations of one or more devices on the network via the network adapter, the cognitive state machine includes a plurality of states each defining at least a task for execution by at least one network device.

[00120] The adaptive power grid management system of any preceding clause wherein the context data include a plurality of vital attributes each associated with a severity degree, and a time stamp.

[00121] The adaptive power grid management system of any preceding clause wherein the context meta object is determined based on a machine learning model trained on historical context data associated with devices on the network of devices.

[00122] The adaptive power grid management system of any preceding clause wherein the context meta object is determined based on a stress force evaluation module that determines possible underlying causes based on a deterministic algorithm.

[00123] The adaptive power grid management system of any preceding clause wherein the context meta object includes a plurality of likely contexts ranked based on probability as determined by a machine learning model.

[00124] The adaptive power grid management system of any preceding clause wherein the processor further forms the cognitive state machine based on determining a plurality of context abstraction panel by on parsing the context meta object into a plurality of context groups and assigning an abstraction problem domain to each context group based on a machine learning algorithm.

[00125] The adaptive power grid management system of any preceding clause wherein each contextual abstraction panel includes one or more of panel positioning, operation classification, functional composition, and a severity index.

[00126] The adaptive power grid management system of any preceding clause wherein the context meta object is further determined based on determining interdependency of one or more abstraction panels based on a machine learning model trained on contextual historical archive database, wherein the context meta object further includes composite abstraction panel data with an associated relevancy index.

[00127] The adaptive power grid management system of any preceding clause wherein the cognitive state machine is determined based on forming a provisional cognitive state machine and validating the provisional cognitive state machine with a simulation engine.

[00128] The adaptive power grid management system of any preceding clause wherein the cognitive state machine defines a number of states, initial states, trigger conditions for each state, a final state with corresponding performance index, and recalibration conditions for one or more states.

[00129] A method for adaptive power grid management includes: receiving, at a processor executing an artificer module, context data associated with an alert condition from a decision support module, the context data being determined based on signals received from a plurality of devices on a network of devices; forming, with the processor, a context meta object by matching the context data with historical context data stored in a context historical archive database; and forming, with the processor, a cognitive state machine based on the context meta object for execution by a cognitive state machine operator to affect operations of one or more

devices on the network via the network adapter, the cognitive state machine includes a plurality of states each defining at least a task for execution by at least one network device.

[00130] The method for adaptive power grid management of any preceding clause wherein the context data include a plurality of vital attributes each associated with a severity degree, and a time stamp.

[00131] The method for adaptive power grid management of any preceding clause wherein the context meta object is determined based on a machine learning model trained on historical context data associated with devices on the network of devices.

[00132] The method for adaptive power grid management of any preceding clause wherein the context meta object is determined based on a stress force evaluation module that determines possible underlying causes based on a deterministic algorithm.

[00133] The method for adaptive power grid management of any preceding clause wherein the context meta object includes a plurality of likely contexts ranked based on probability as determined by a machine learning model.

[00134] The method for adaptive power grid management of any preceding clause wherein forming the cognitive state machine is further based on determining a plurality of context abstraction panel based on parsing the context meta object into a plurality of context groups and assigning an abstraction problem domain to each context group based on a machine learning algorithm.

[00135] The method for adaptive power grid management of any preceding clause wherein each contextual abstraction panel includes one or more of panel positioning, operation classification, functional composition, and a severity index.

[00136] The method for adaptive power grid management of any preceding clause wherein the context meta object is further determined based on determining interdependency of one or more abstraction panels based on a machine learning model trained on contextual historical chive database, wherein the context meta object further includes composite abstraction panel data with an associated relevancy index.

[00137] The method for adaptive power grid management of any preceding clause wherein the cognitive state machine is determined based on forming a provisional cognitive state machine and validating the provisional cognitive state machine with a simulation engine.

[00138] The method for adaptive power grid management of any preceding clause wherein the cognitive state machine defines a number of states, initial states, trigger conditions for each state, and a final state with corresponding performance index.

[00139] Those skilled in the art will recognize that a wide variety of other modifications, alterations, and combinations can also be made with respect to the above-described embodiments without departing from the scope of the invention, and that such modifications, alterations, and combinations are to be viewed as being within the ambit of the inventive concept.

CLAIMS

What is claimed is:

1. An adaptive power grid management system, the system comprises:
a network device database;
a network adapter, and
a processor coupled to the network device database and the network adapter, the processor being configured to:
train, with a machine learning algorithm using historical device signals and historical context information associated with a network of devices, a context model;
receive signals from the network of devices;
determine, based on the context model, context data associate with a current condition of the network of devices;
determine a formation plan based on the context data, the formation plan comprises tasks to be carried out by one or more devices in the network of devices;
configure one or more scout applications based on the formation plan and device information stored in the network device database; and
cause, via the network adapter, the one or more scout applications to be executed by the one or more devices in the network of devices.
2. The system of claim 1, wherein the one or more devices comprises field agent devices associated with one or more of a power plant, a solar farm, a windfarm, a digital substation, a microgrid controller, and an electric vehicle charging station.
3. The system of claim 1, wherein the context data comprises a set of select vital attributes each associated with a severity degree.
4. The system of claim 1, wherein the context data comprises a control area identifier, a timing identifier, and an alert condition identifier.

5. The system of claim 1, wherein the formation plan is determined based on:
matching the context data with context patterns in a context pattern database;
separating the context data into contextual abstraction panels each corresponding to a separate problem domain perspective; and
determining the tasks and the one or more devices associated with each contextual abstraction panel.
6. The system of claim 1, wherein the formation plan is determined based on a state machine comprising a list of steps and trigger conditions determined based on the context data.
7. The system of claim 1, wherein configuring the one or more scout applications comprises selecting a stored scout application matching the formation plan.
8. The system of claim 1, wherein the one or more scout applications are each assigned a role and is configured based on the role.
9. The system of claim 1, wherein configuring the one or more scout applications comprises:
generating a new scout application using stored application components based on the formation plan; and
testing the new scout application prior to deployment.
10. The system of claim 1, wherein the processor is further configured to simulate the formation plan based on updated signals from the network of devices prior to causing the one or more scout applications to be executed by the one or more devices in the network of devices.
11. A method for adaptive management of a power grid, the method comprises:
training, with a machine learning algorithm executing on a processor using historical device signals and historical context information associated with a network of devices, a context

model;

receiving signals from the network of devices;

determine, with the processor and based on the context model, context data associate with a current condition of the network of devices;

determine, with the processor, a formation plan based on the context data, the formation plan comprises tasks to be carried out by one or more devices in the network of devices;

configure, with the processor, one or more scout applications based on the formation plan and device information stored in the network device database; and

cause the one or more scout applications to be executed by the one or more devices in the network of devices.

12. The method of claim 11, wherein the one or more devices comprises field agent devices associated with one or more of a power plant, a solar farm, a windfarm, a digital substation, a microgrid controller, and an electric vehicle charging station.

13. The method of claim 11, wherein the context data comprises a set of select vital attributes each associated with a severity degree.

14. The method of claim 11, wherein the context data comprises a control area identifier, a timing identifier, and an alert condition identifier.

15. The method of claim 11, wherein the formation plan is determined based on:
matching the context data with context patterns in a context pattern database;
separating the context data into contextual abstraction panels each corresponding to a separate problem domain perspective; and
determining the tasks and the one or more devices associated with each contextual abstraction panel.

16. The method of claim 11, wherein the formation plan is determined based on a state machine comprising a list of steps and trigger conditions determined based on the context

data.

17. The method of claim 11, wherein configuring the one or more scout applications comprises selecting a stored scout application matching the formation plan.

18. The method of claim 11, wherein the one or more scout applications are each assigned a role and are configured based on the role.

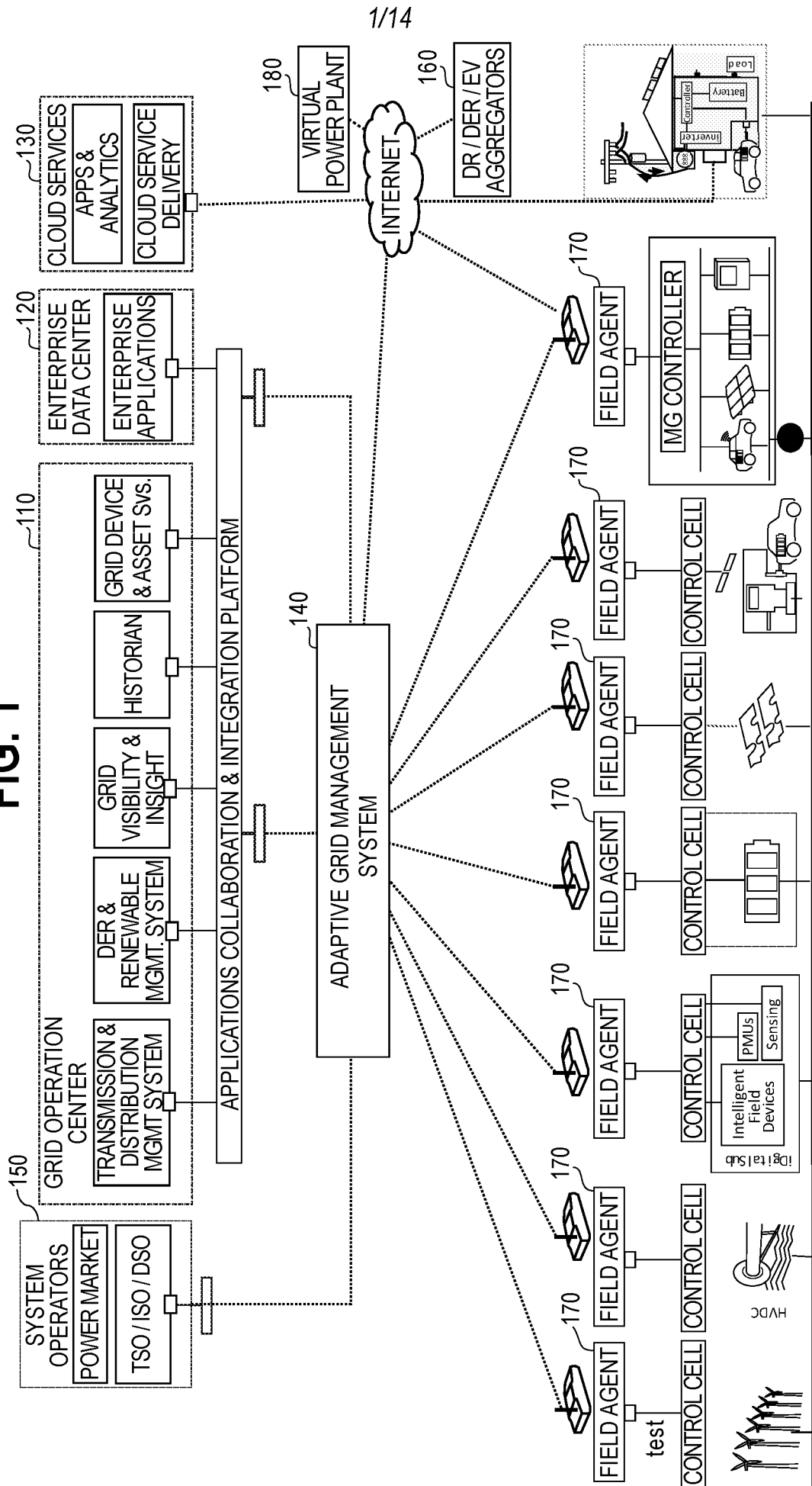
19. The method of claim 11, wherein configuring the one or more scout applications comprises:

generating a new scout application using stored application components based on the formation plan; and

testing the new scout application prior to deployment.

20. The method of claim 11, further comprising simulating the formation plan based on updated signals from the network of devices prior to causing the one or more scout applications to be executed by the one or more devices in the network of devices.

FIG. 1



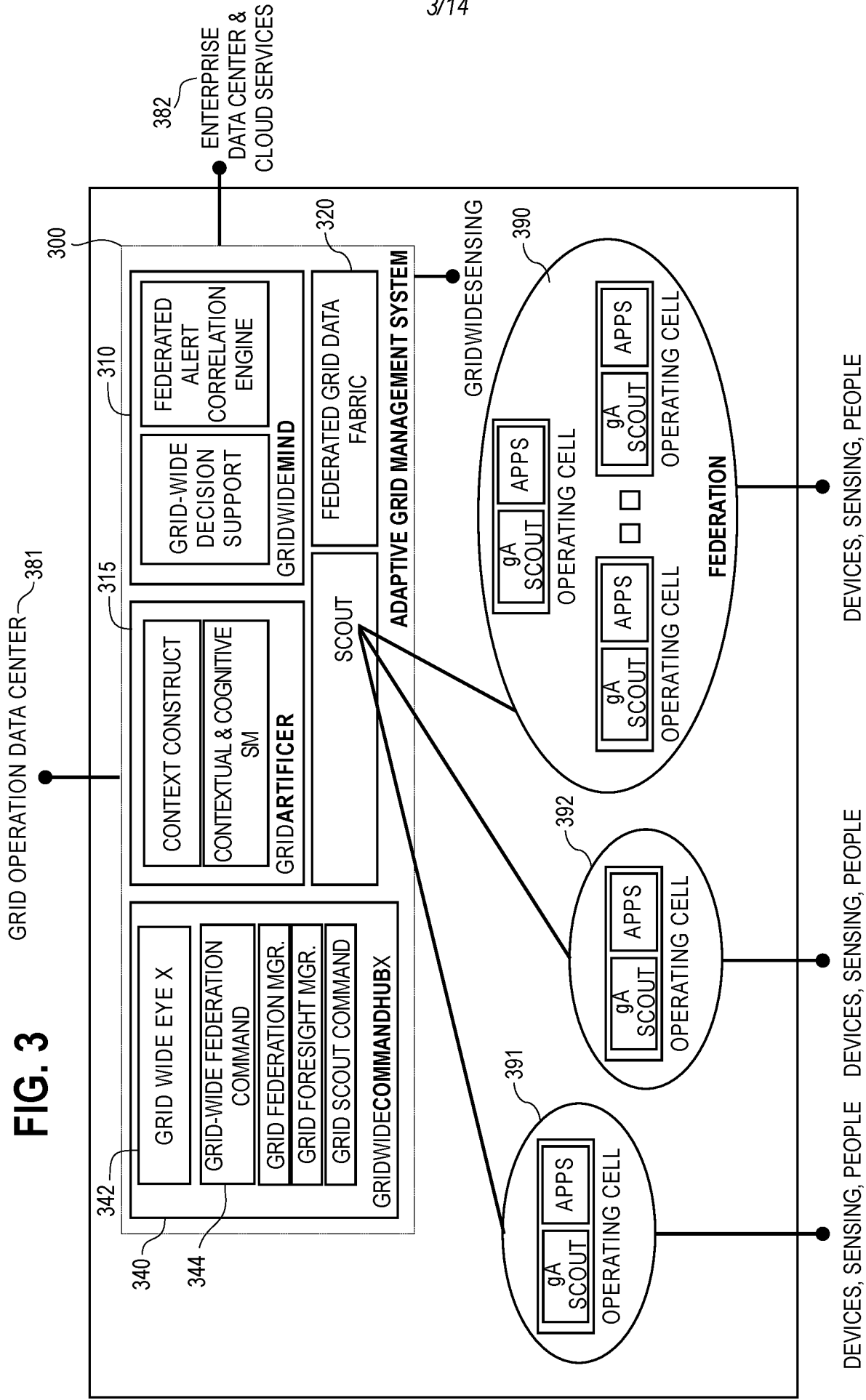
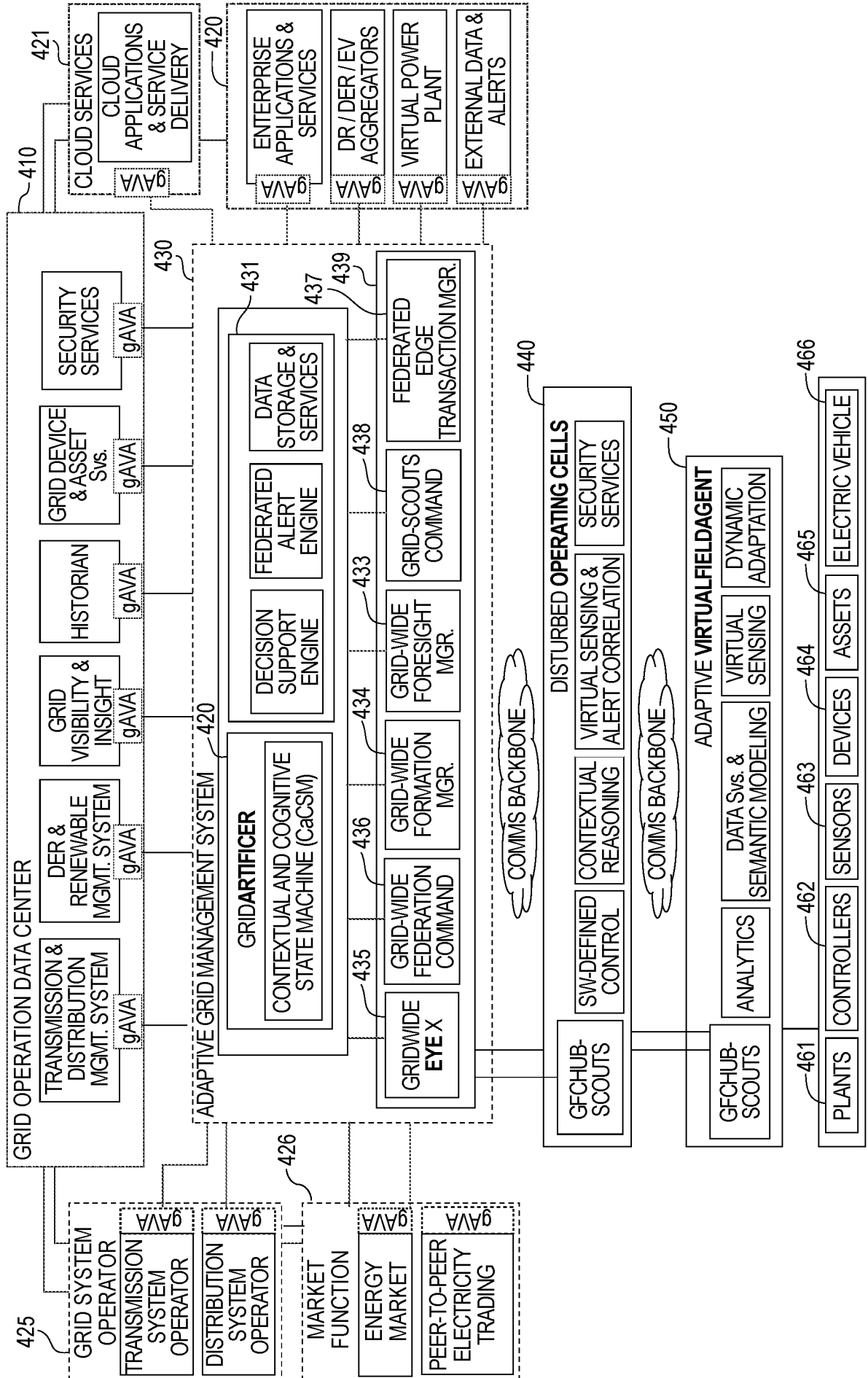
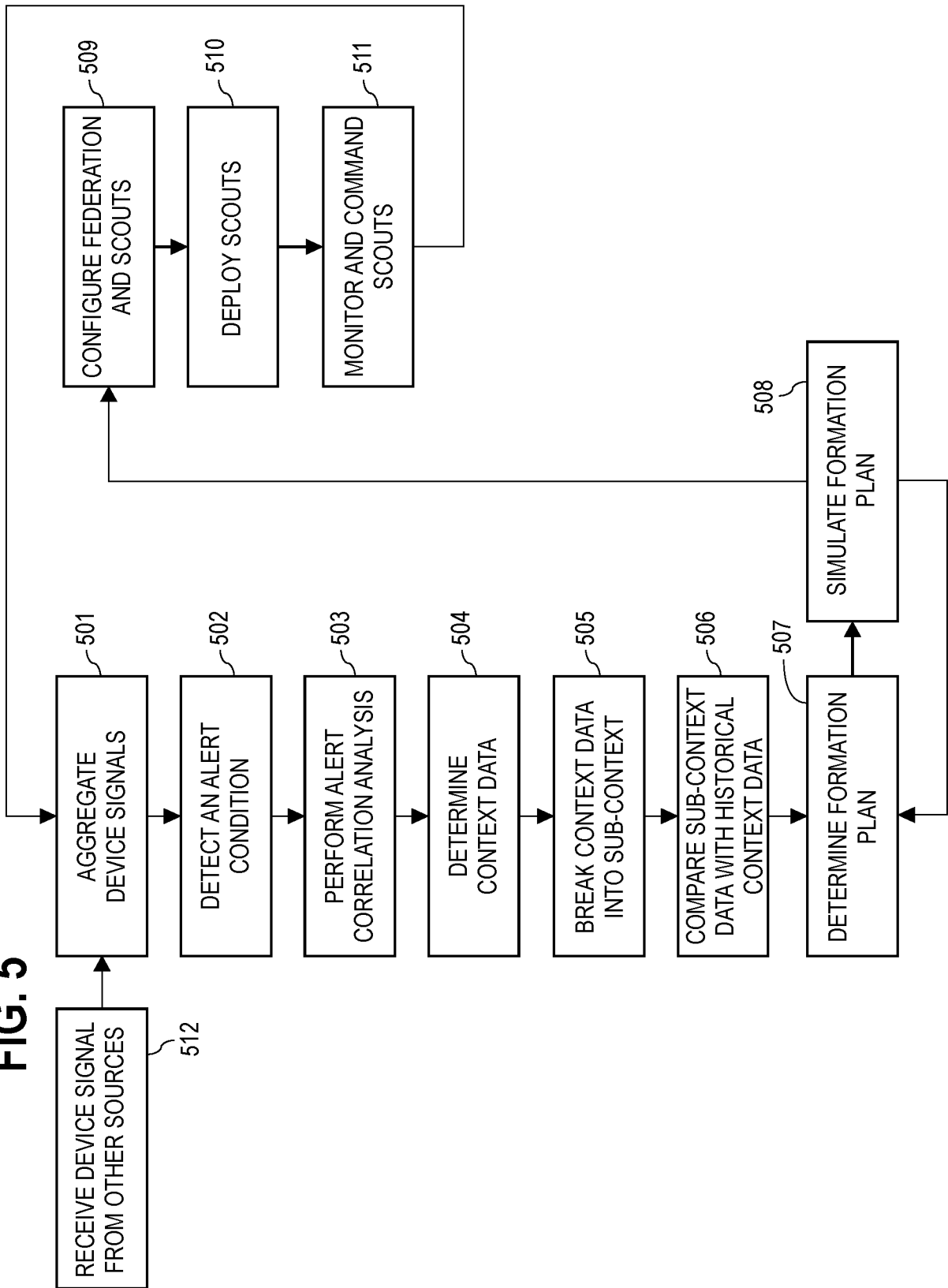


FIG. 4



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FIG. 5

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FIG. 6

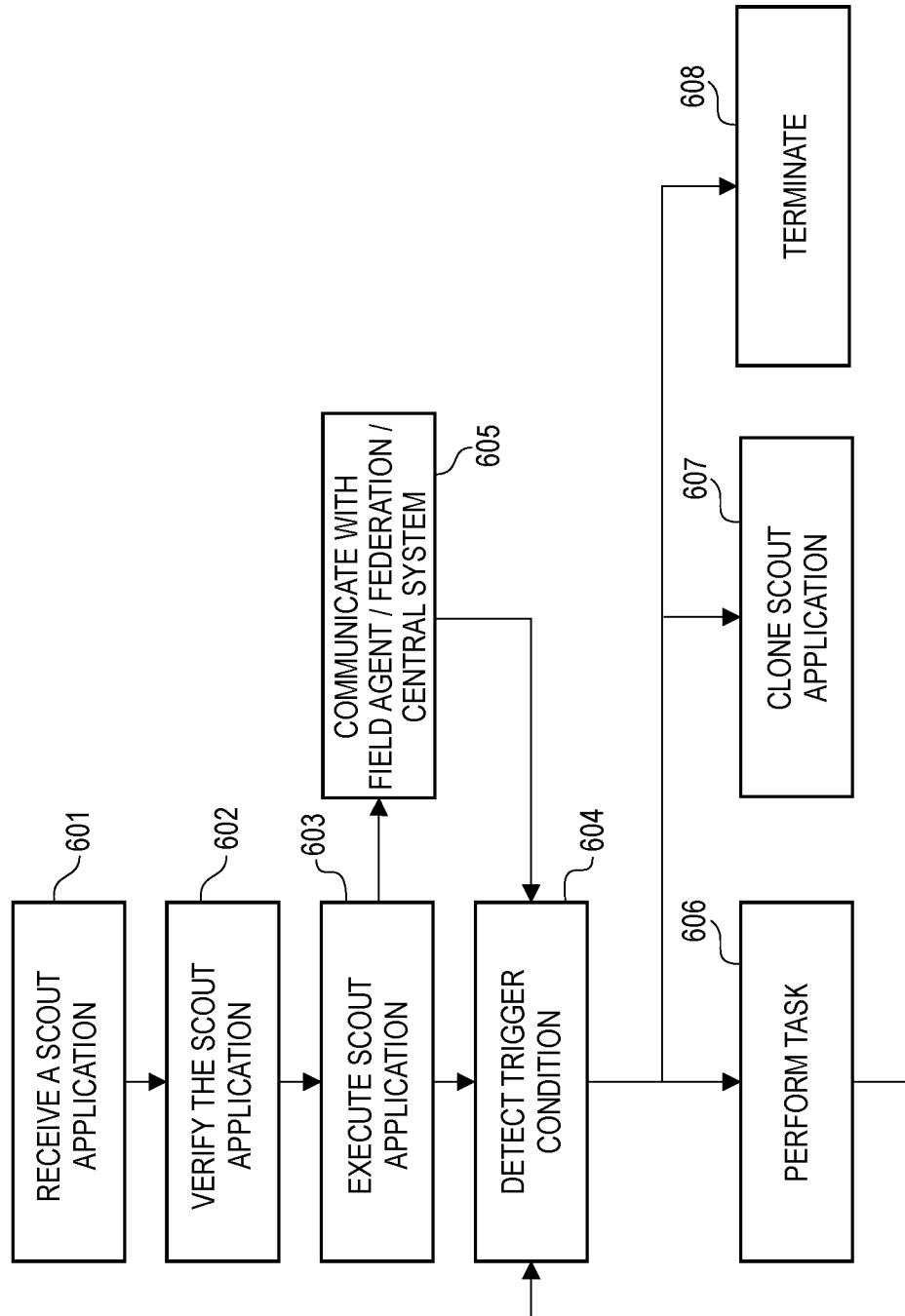
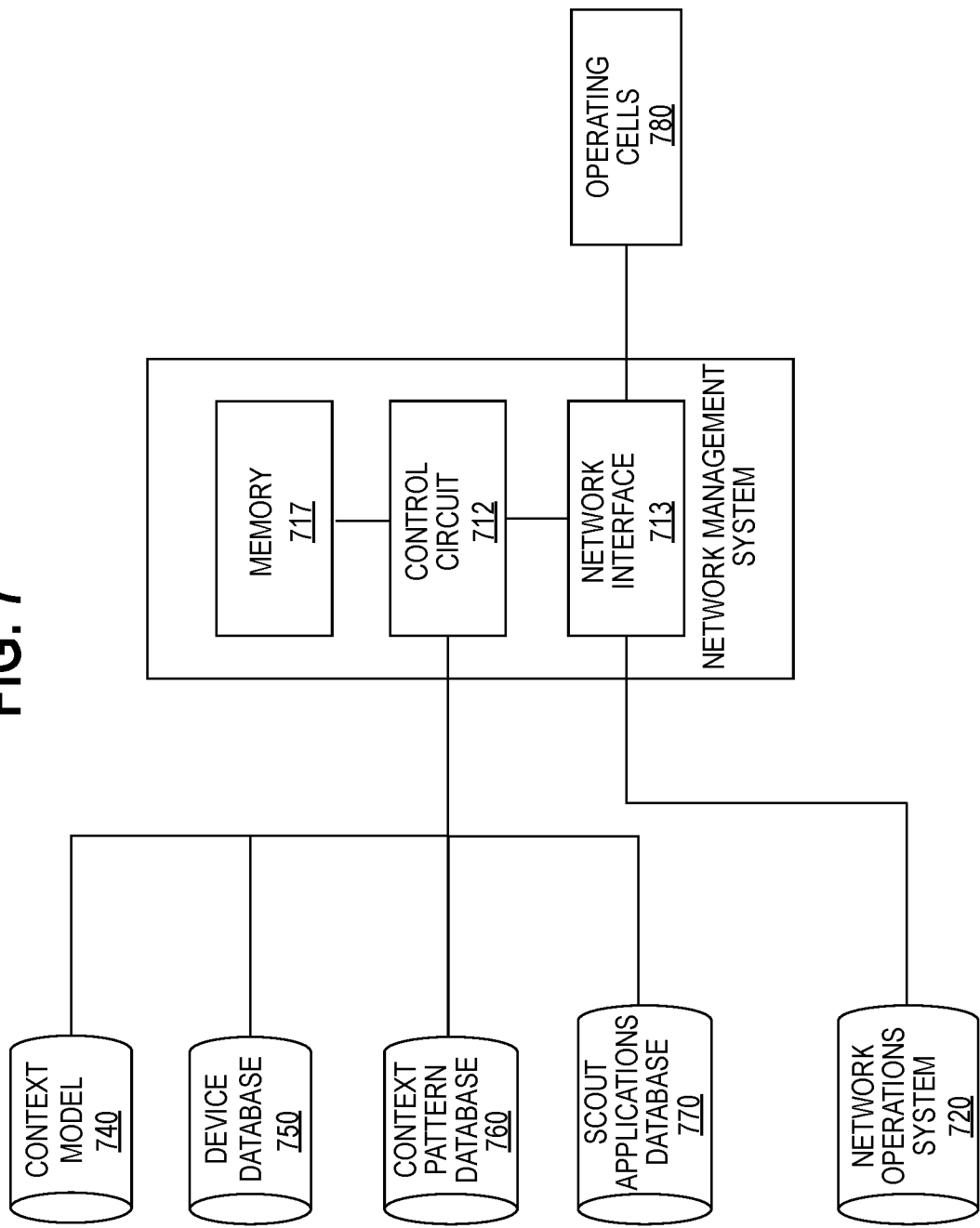


FIG. 7



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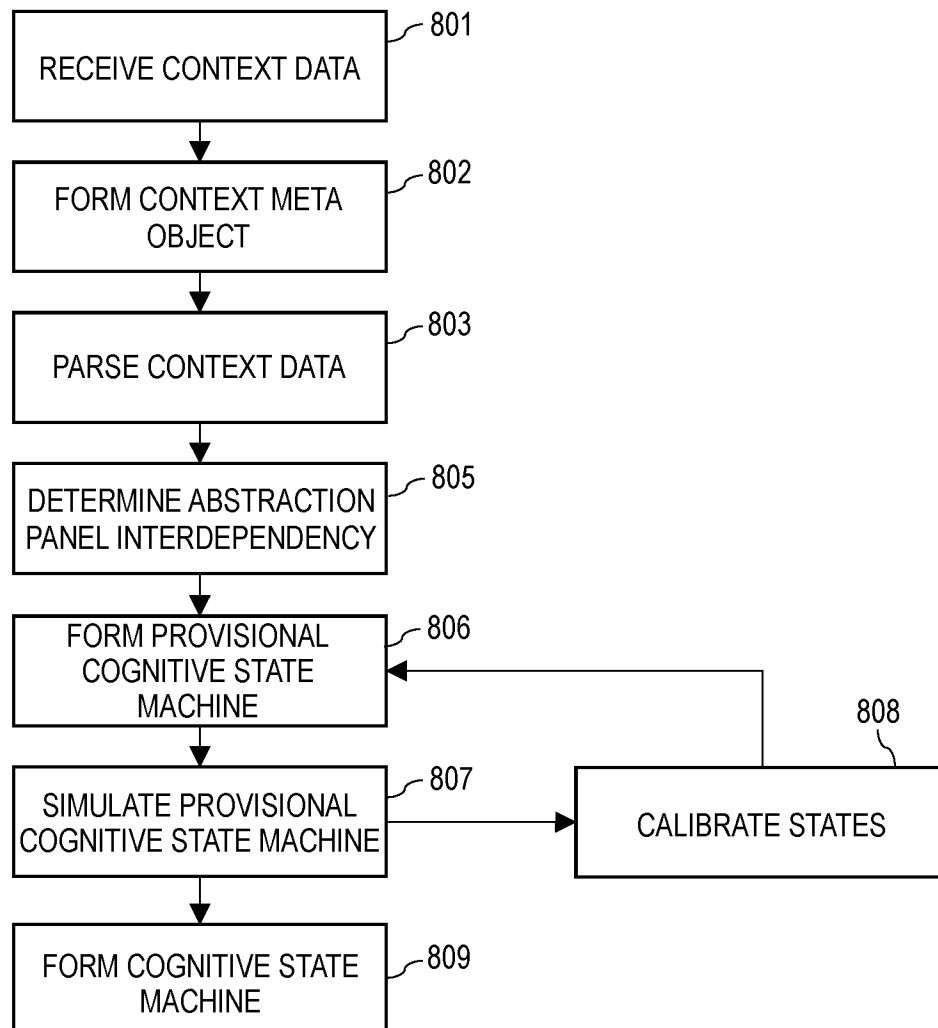
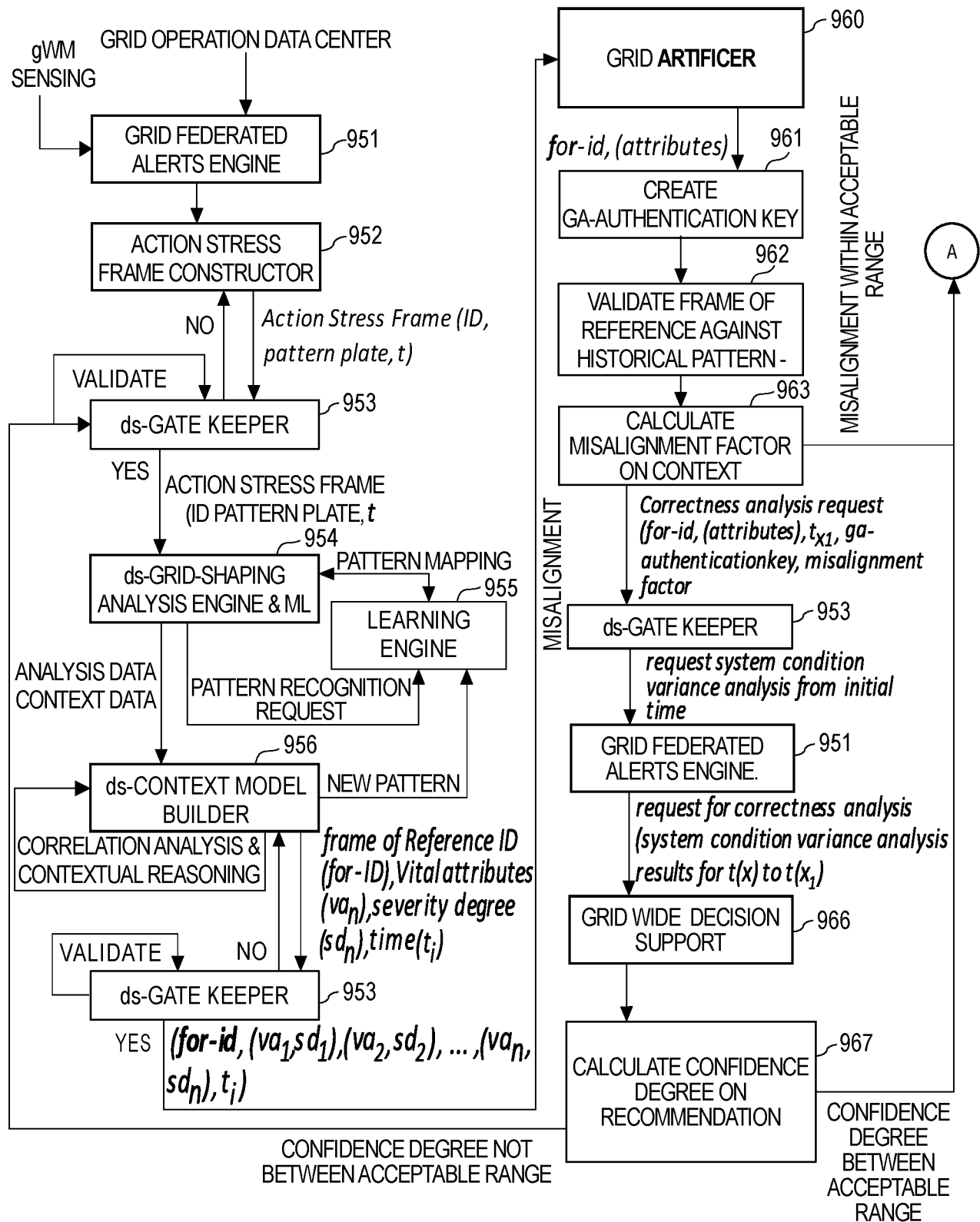
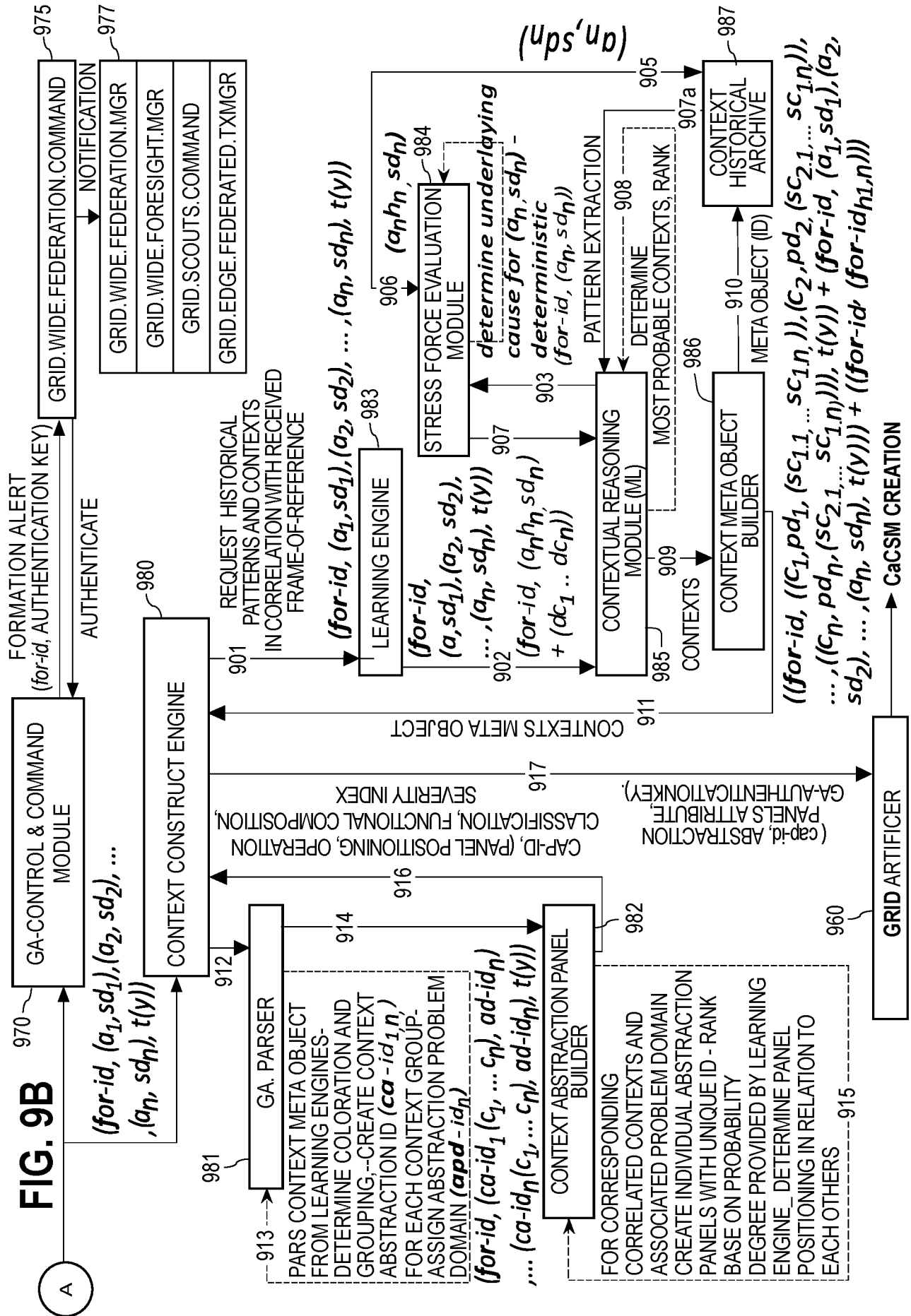
FIG. 8

FIG. 9A



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FIG. 10A

FIG. 10A CONTINUED

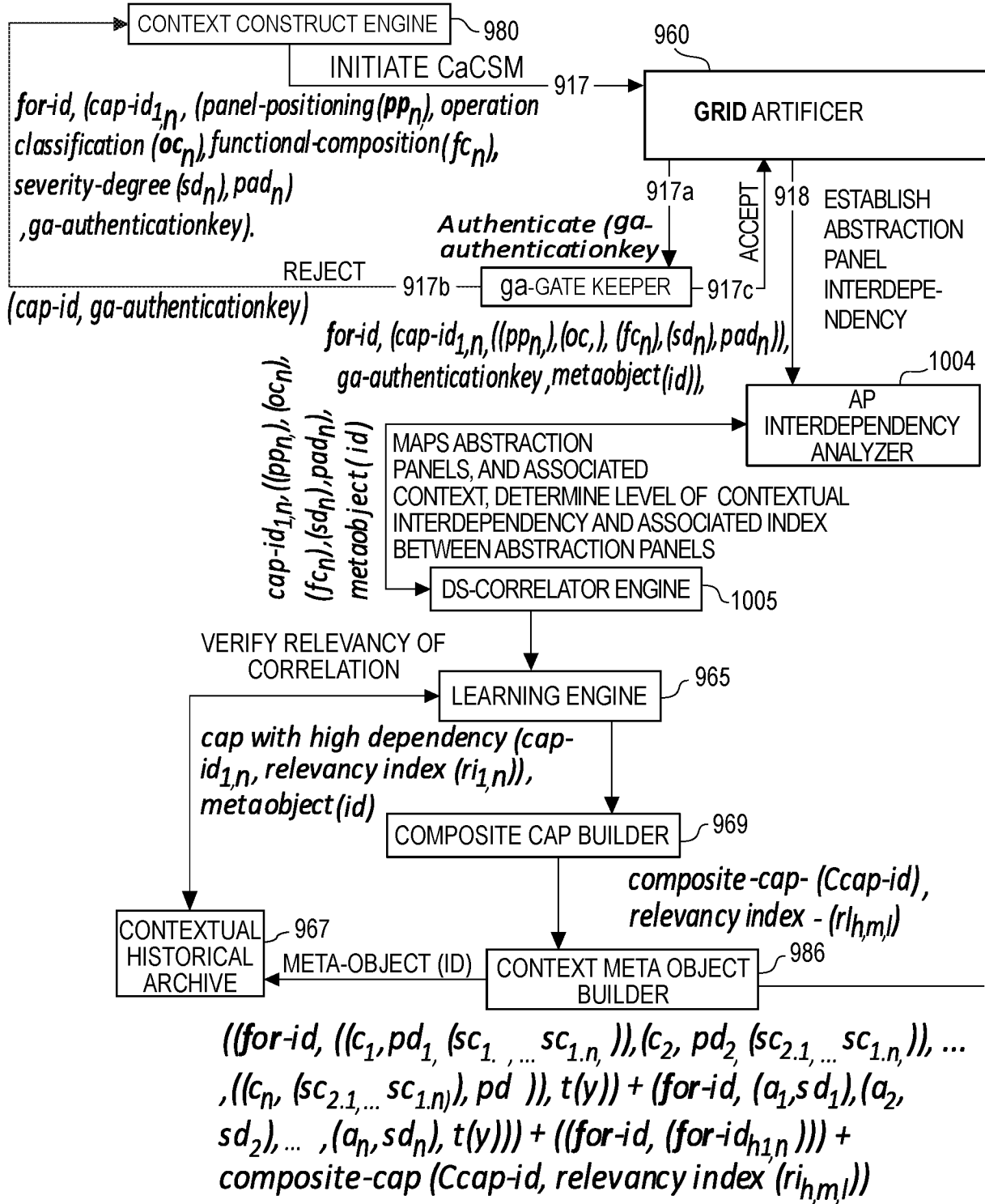


FIG. 10A
CONTINUED

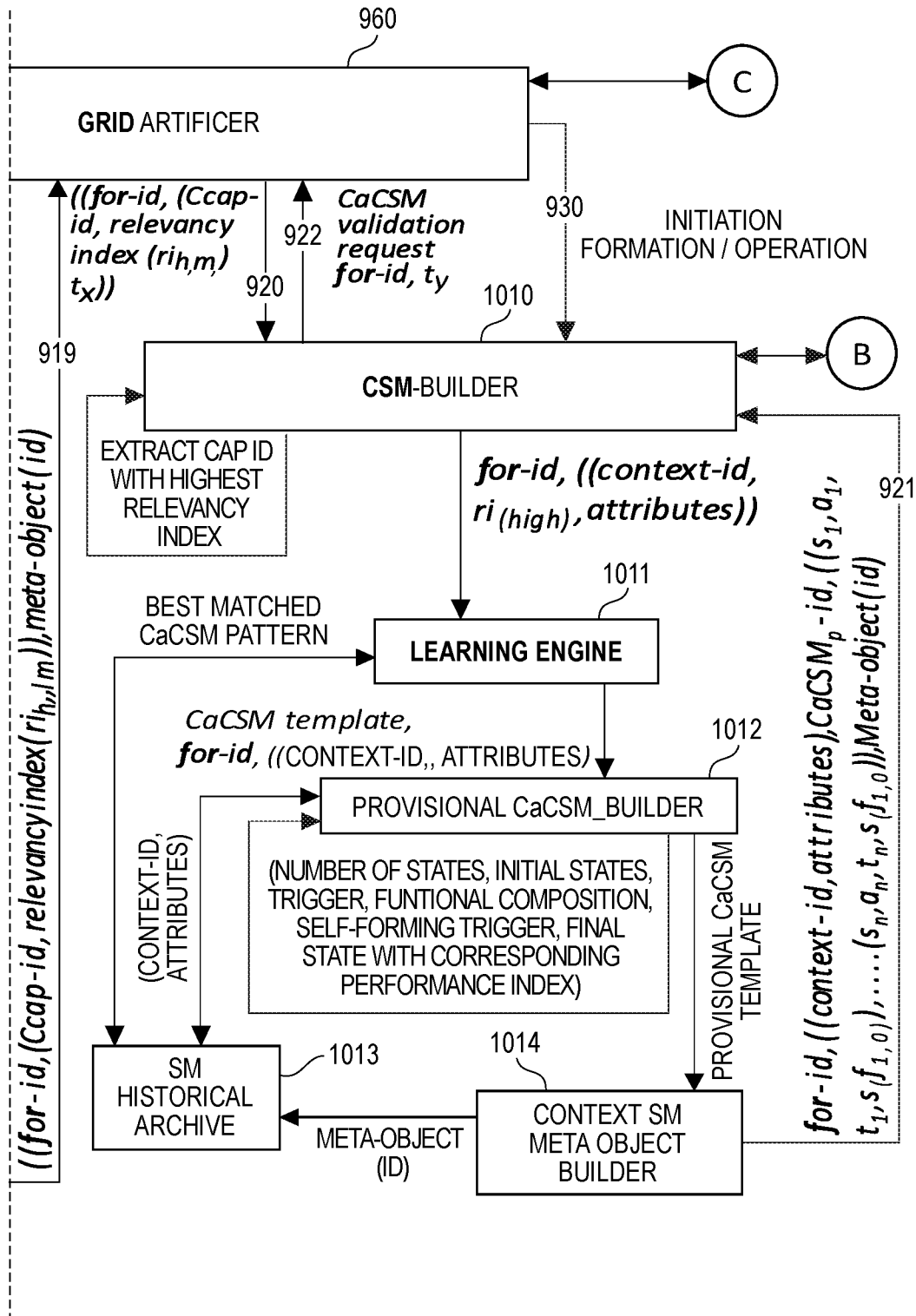
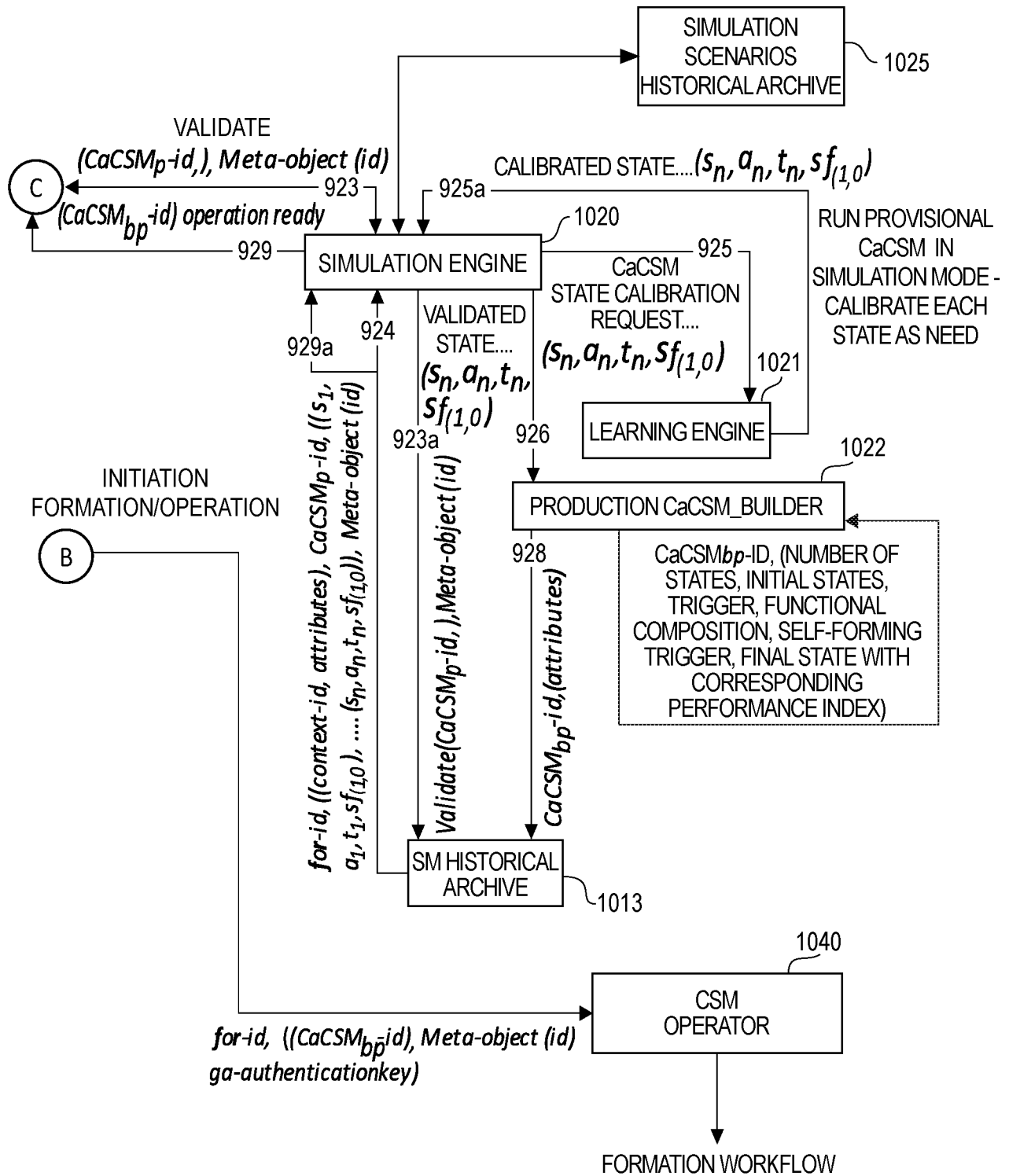
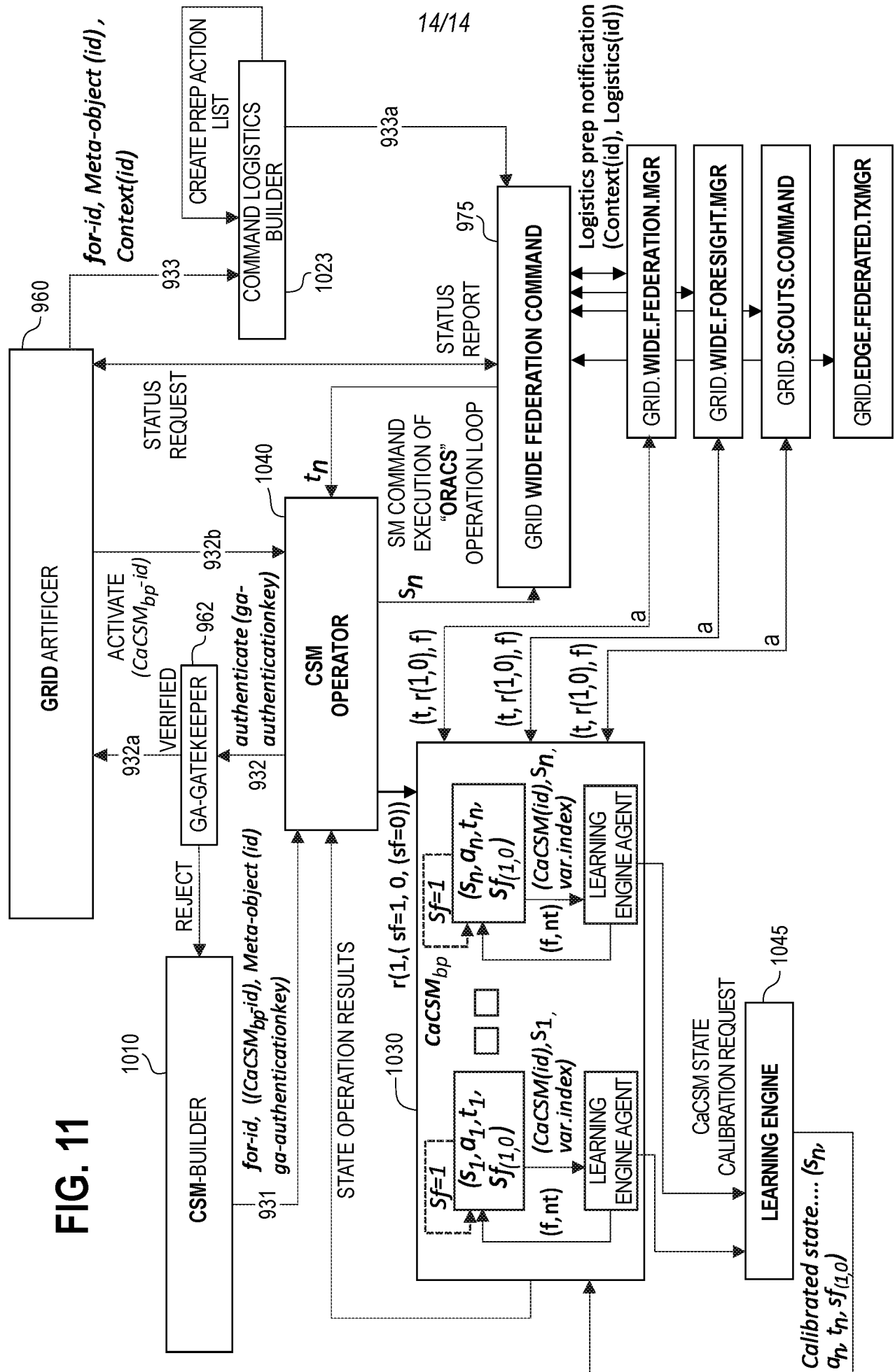


FIG. 10B





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PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 21335-155917		FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. PCT/US22/46851	International filing date (<i>day/month/year</i>) 17 October 2022 (17.10.2022)	(Earliest) Priority Date (<i>day/month/year</i>) 15 October 2021 (15.10.2021)	
Applicant GENERAL ELECTRIC COMPANY			

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 1

☐ as suggested by the applicant.

☒ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US22/46851

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. G06N 20/00; G06N 3/08 (2023.01)

ADD. G05B 13/02; G06F 8/36; G06F 8/71; G06F 11/28; G06F 16/242; G06F 30/20; H02J 3/18 (2023.01)

CPC - INV. G06N 20/00; G06N 3/08

ADD. G05B 13/0265; G06F 8/36; G06F 8/71; G06F 11/30; G06F 16/242; G06F 30/20; G06F 2111/10; H02J 3/1885

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)

See Search History document

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

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2018/0262525 A1 (GENERAL ELECTRIC COMPANY) 13 September 2018; See paragraphs [0021-0022], [0026-0032], [0052], [0054]	1-20
A	US 2021/0210959 A1 (GENERAL ELECTRIC COMPANY) 08 July 2021; See entire document for additional information	1-20
A	US 5,649,190 A (SHARIF-ASKARY, J. ET AL.) 15 July 1997; see entire document for additional information	1-20

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

22 February 2023 (22.02.2023)

Date of mailing of the international search report

MAR 28 2023

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

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