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(54) ENSEMBLE FORECAST STORM DAMAGE RESPONSE SYSTEM FOR CRITICAL INFRASTRUCTURE

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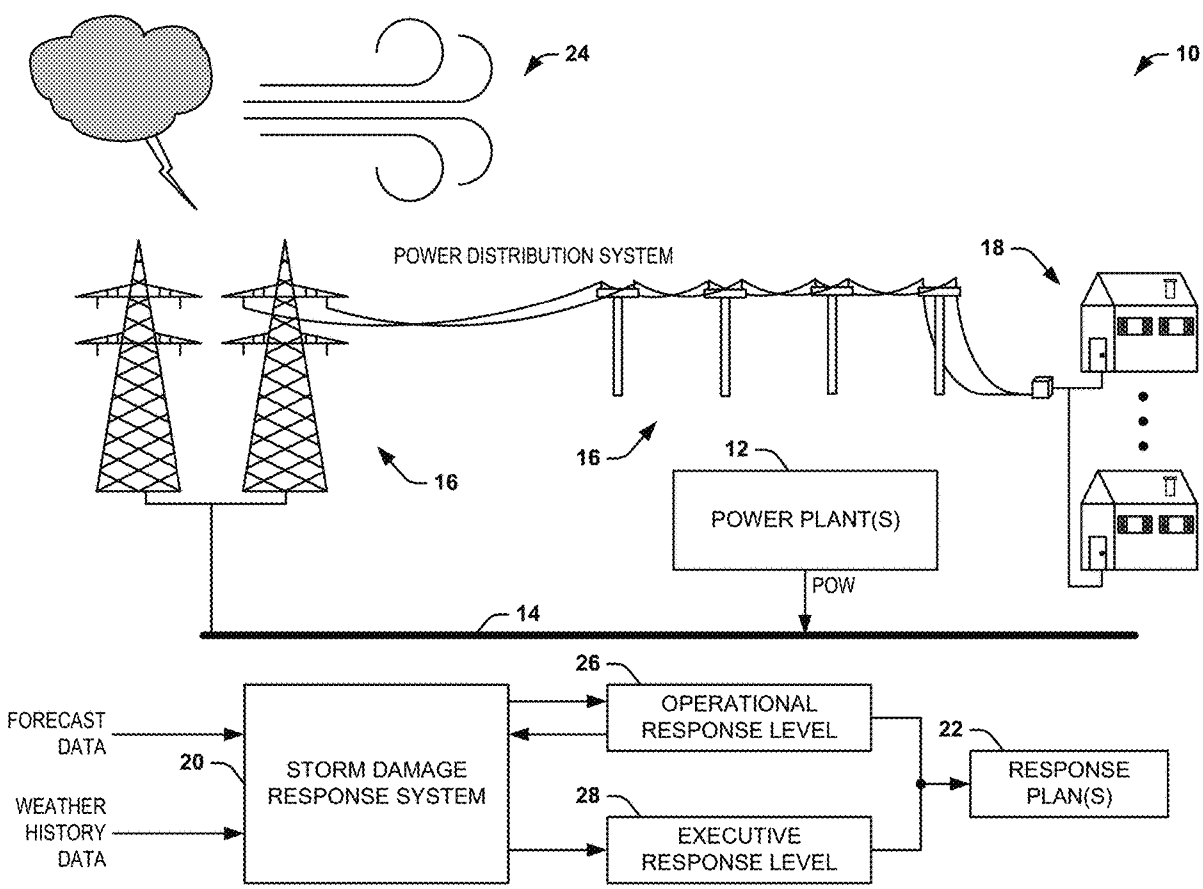
CPC ***G06N 20/20*** (2019.01); ***G06N 7/005*** (2013.01); ***G01W 1/10*** (2013.01); ***G06F 16/25*** (2019.01)

(57) **ABSTRACT**

A storm damage response system includes a storm ensemble database that stores ensemble forecast models associated with potential storm paths of a storm across a geographic area and an inventory database that stores inventory data associated with location and characteristics of power-providing equipment in the geographic area. A storm damage model algorithm generates a storm response plan comprising an operational procedure for repairing or maintaining power transmission and distribution electric systems to mitigate storm damage impact based on generating a probabilistic model for each of the ensemble forecast models based on the inventory data and calculating a statistical impact value associated with the probabilistic model based on an aggregate of iterative probabilistic simulations for the respective ensemble forecast model. The storm response plan can be generated based on the relative statistical impact value of the probabilistic model of each of the ensemble forecast models.



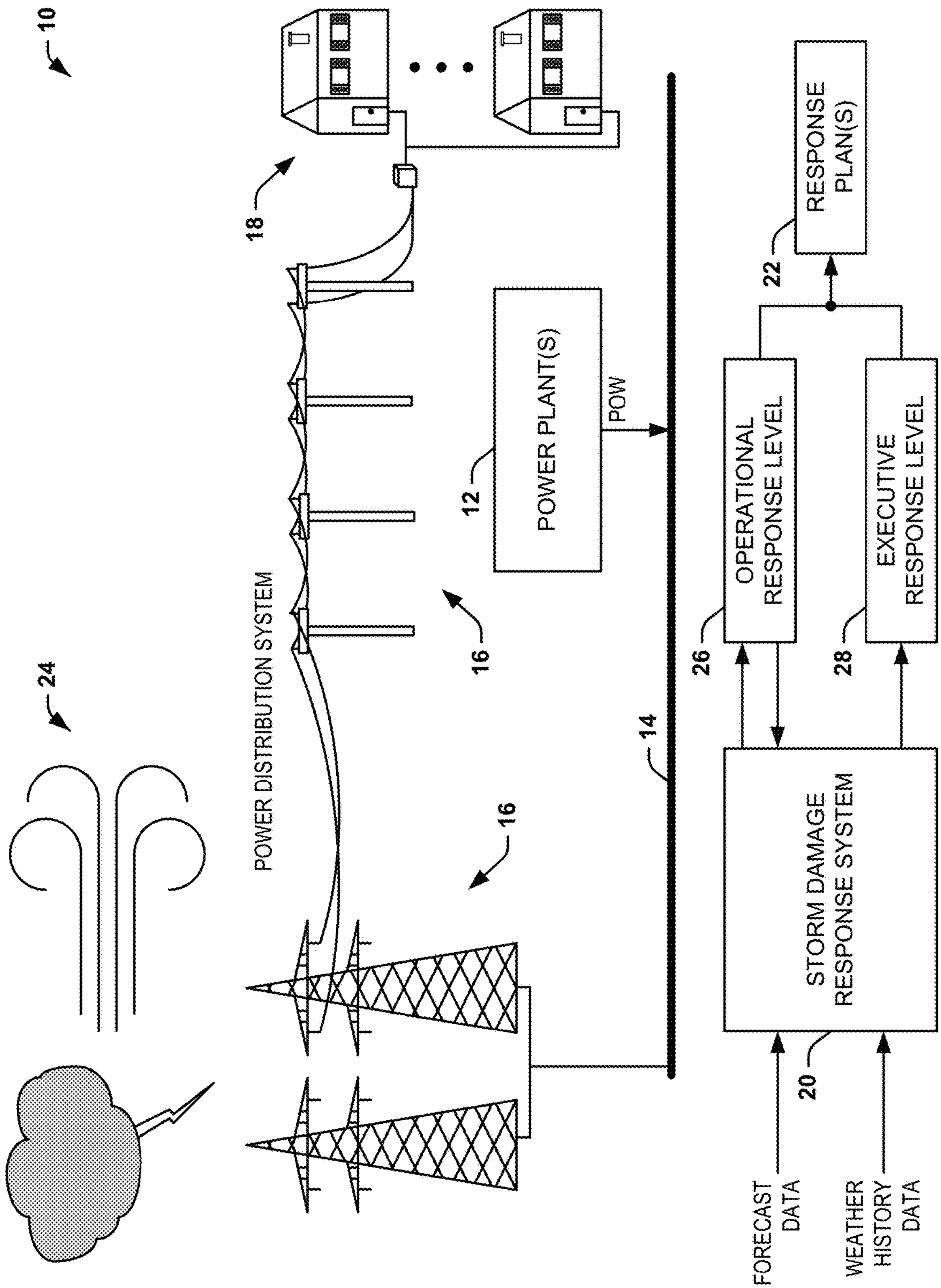

10
24
POWER DISTRIBUTION SYSTEM
16
16
18
12
POWER PLANT(S)
POW
14
20
STORM DAMAGE RESPONSE SYSTEM
26
OPERATIONAL RESPONSE LEVEL
28
EXECUTIVE RESPONSE LEVEL
22
RESPONSE PLAN(S)
FORECAST DATA
WEATHER HISTORY DATA

FIG. 1

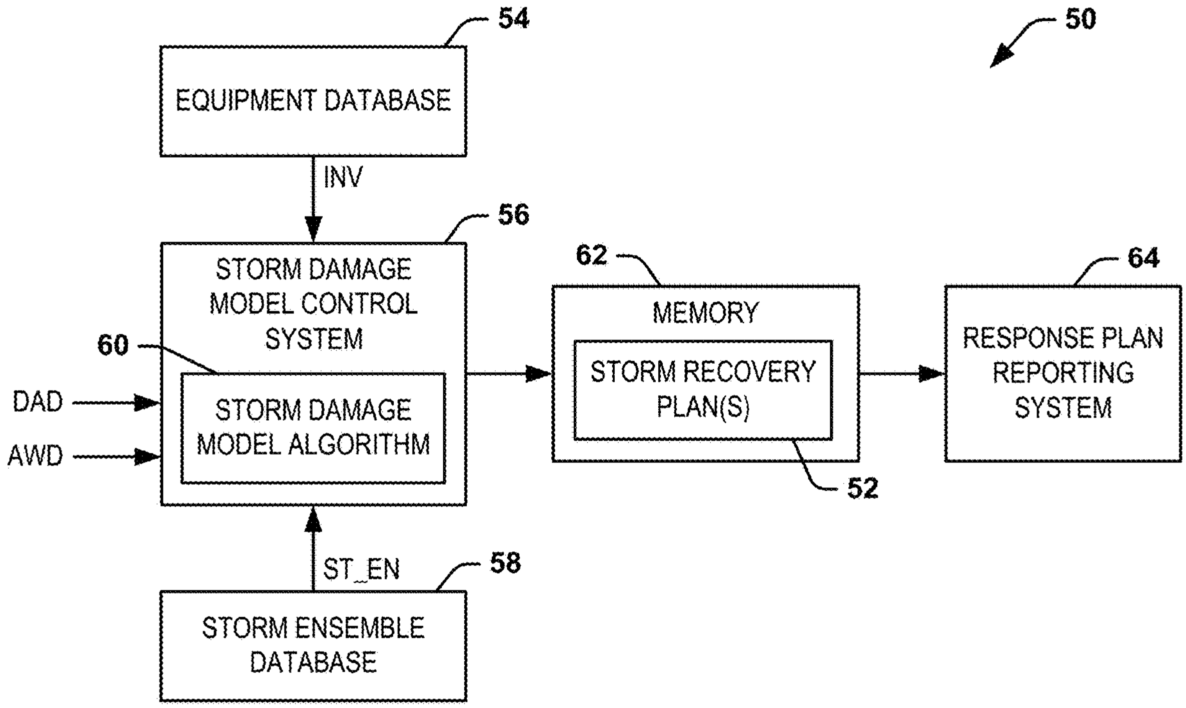

50
54
EQUIPMENT DATABASE
INV
56
STORM DAMAGE
MODEL CONTROL
SYSTEM
60
STORM DAMAGE
MODEL ALGORITHM
DAD
AWD
62
MEMORY
STORM RECOVERY
PLAN(S)
52
64
RESPONSE PLAN
REPORTING
SYSTEM
ST_EN
58
STORM ENSEMBLE
DATABASE

FIG. 2

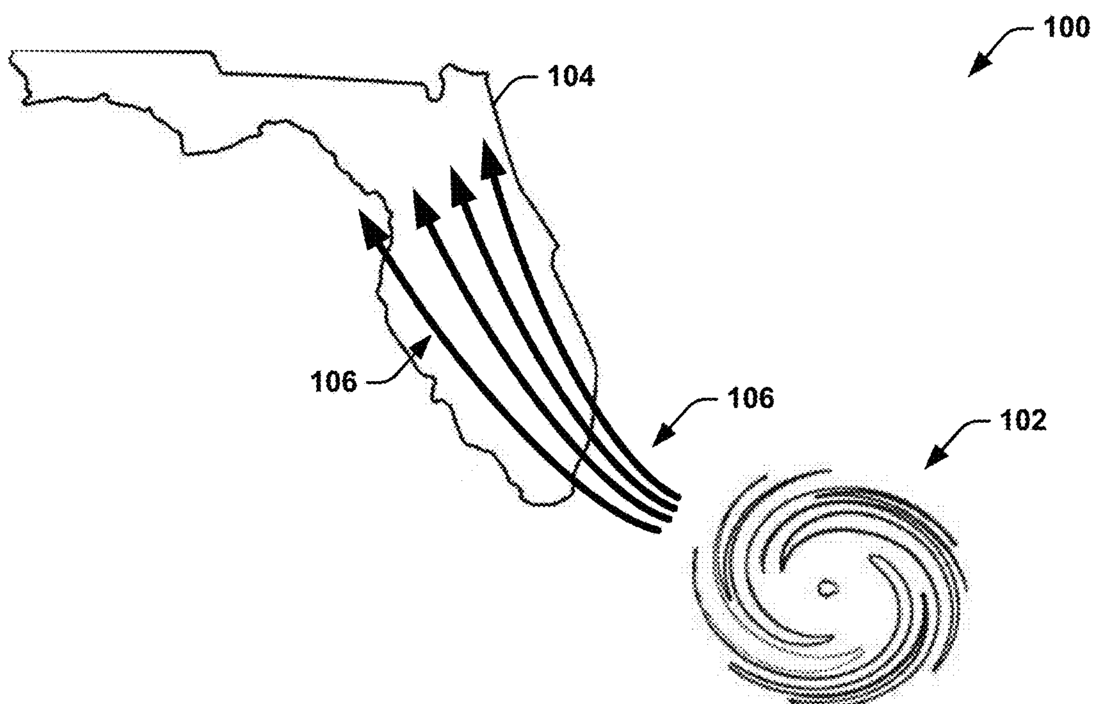

100
104
106
106
102

FIG. 3

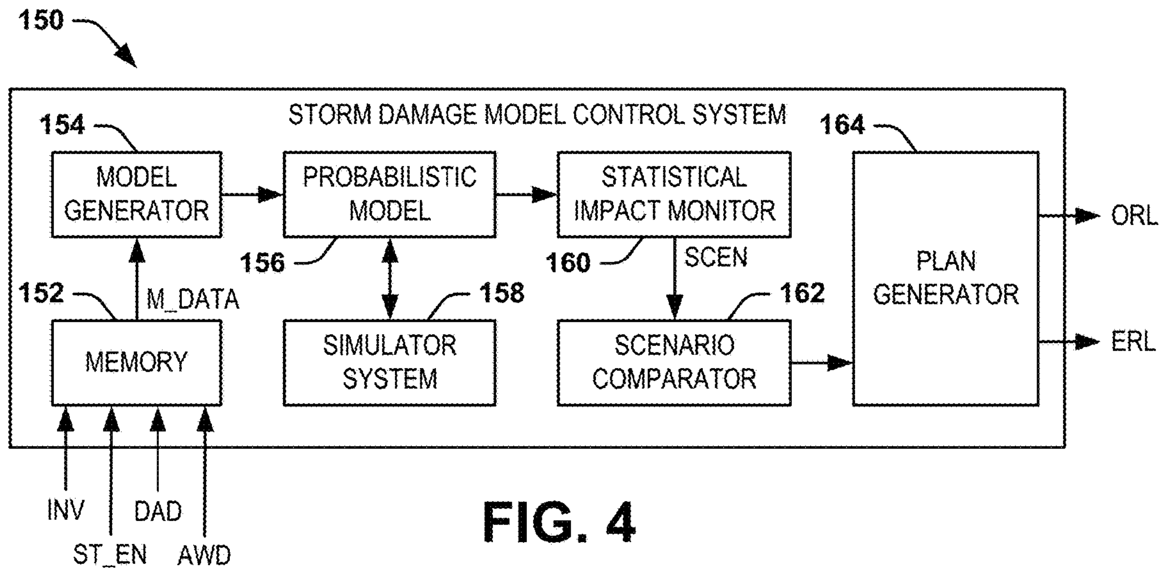


FIG. 4

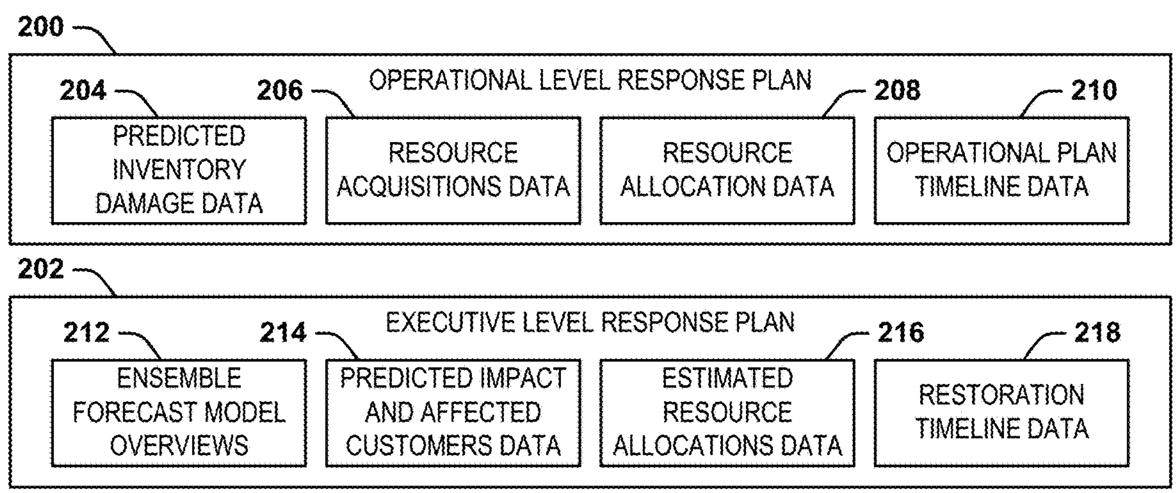


FIG. 5

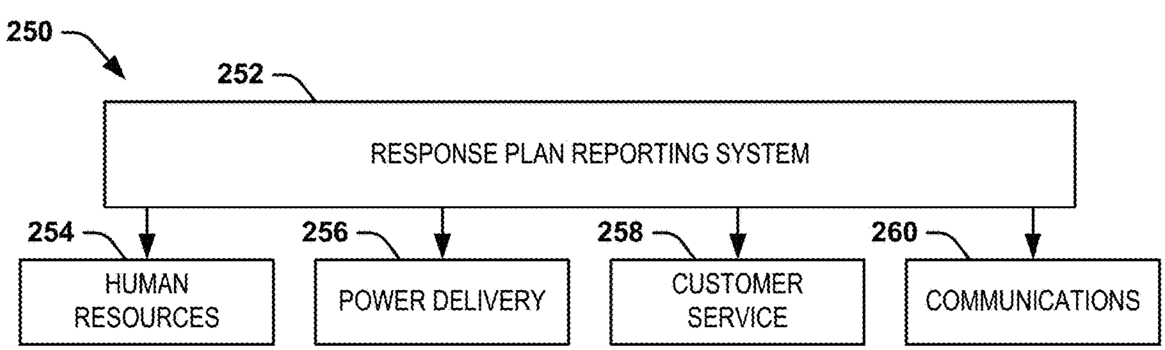


FIG. 6

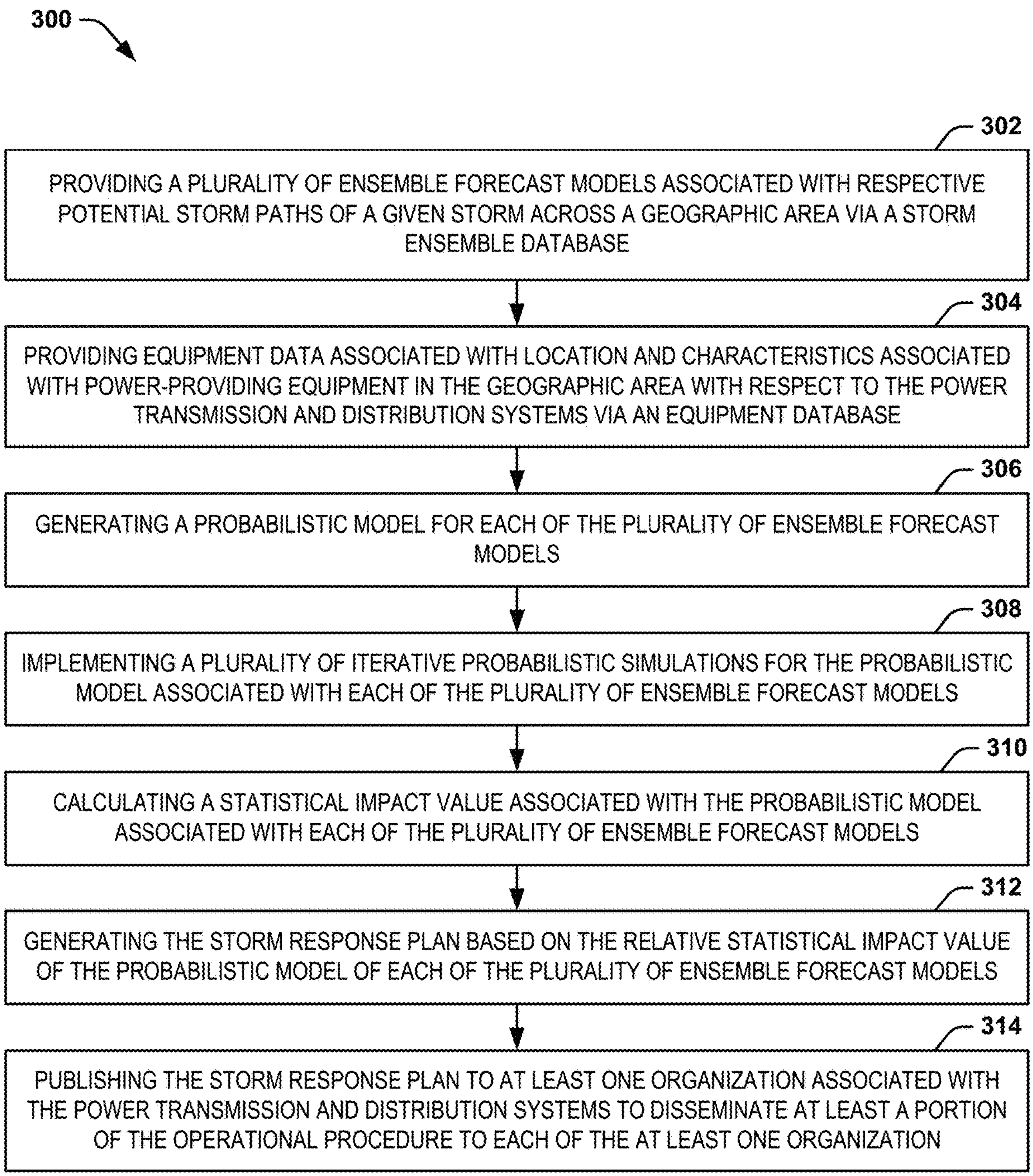

300
302
PROVIDING A PLURALITY OF ENSEMBLE FORECAST MODELS ASSOCIATED WITH RESPECTIVE POTENTIAL STORM PATHS OF A GIVEN STORM ACROSS A GEOGRAPHIC AREA VIA A STORM ENSEMBLE DATABASE
304
PROVIDING EQUIPMENT DATA ASSOCIATED WITH LOCATION AND CHARACTERISTICS ASSOCIATED WITH POWER-PROVIDING EQUIPMENT IN THE GEOGRAPHIC AREA WITH RESPECT TO THE POWER TRANSMISSION AND DISTRIBUTION SYSTEMS VIA AN EQUIPMENT DATABASE
306
GENERATING A PROBABILISTIC MODEL FOR EACH OF THE PLURALITY OF ENSEMBLE FORECAST MODELS
308
IMPLEMENTING A PLURALITY OF ITERATIVE PROBABILISTIC SIMULATIONS FOR THE PROBABILISTIC MODEL ASSOCIATED WITH EACH OF THE PLURALITY OF ENSEMBLE FORECAST MODELS
310
CALCULATING A STATISTICAL IMPACT VALUE ASSOCIATED WITH THE PROBABILISTIC MODEL ASSOCIATED WITH EACH OF THE PLURALITY OF ENSEMBLE FORECAST MODELS
312
GENERATING THE STORM RESPONSE PLAN BASED ON THE RELATIVE STATISTICAL IMPACT VALUE OF THE PROBABILISTIC MODEL OF EACH OF THE PLURALITY OF ENSEMBLE FORECAST MODELS
314
PUBLISHING THE STORM RESPONSE PLAN TO AT LEAST ONE ORGANIZATION ASSOCIATED WITH THE POWER TRANSMISSION AND DISTRIBUTION SYSTEMS TO DISSEMINATE AT LEAST A PORTION OF THE OPERATIONAL PROCEDURE TO EACH OF THE AT LEAST ONE ORGANIZATION

FIG. 7

ENSEMBLE FORECAST STORM DAMAGE RESPONSE SYSTEM FOR CRITICAL INFRASTRUCTURE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part (CIP) U.S. application Ser. No. 15/948,489, which was filed on 9 Apr. 2018, and entitled "Ensemble Forecast Storm Damage Response System for Critical Infrastructure", the entirety of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] This disclosure relates generally to transmission and distribution electric systems, and more specifically to an ensemble forecast storm damage response system for critical infrastructure.

BACKGROUND

[0003] Catastrophic storms such as hurricanes and tropical storms have wreaked significant devastation on peoples' homes and the supporting infrastructure. Most such storms are forecasted, but typically only a few days before the storm makes landfall. While the storm is forecasted, the ability to accurately predict the path that the storm will travel over the course of more than a few hours can be illusive. Additionally, the power of the storm may be such that significant damage is inevitable to homes, commerce buildings, and other critical infrastructure such as the electric power grid and its power-providing equipment (e.g., power stations, utility transformers, utility poles and power lines) even with modern building and construction techniques. As a result, it is very difficult to prepare for the evacuation and inevitable damage prior to the storm making landfall. Additionally, the unpredictable nature of a catastrophic storm renders it also very difficult to prepare for and conduct recovery efforts to restore the infrastructure to allow people to return to their homes.

SUMMARY

[0004] One example includes a storm damage response system. The storm damage response system includes a storm ensemble database that stores ensemble forecast models associated with potential storm paths of a storm across a geographic area and an inventory database that stores inventory data associated with location and characteristics of power-providing equipment in the geographic area. A storm damage model algorithm generates a storm response plan comprising an operational procedure for repairing or maintaining power transmission and distribution electric systems to mitigate storm damage impact based on generating a probabilistic model for each of the ensemble forecast models based on the inventory data and calculating a statistical impact value associated with the probabilistic model based on an aggregate of iterative probabilistic simulations for the respective ensemble forecast model. The storm response plan can be generated based on the relative statistical impact value of the probabilistic model of each of the ensemble forecast models.

[0005] Another example includes a method for generating a storm response plan comprising an operational procedure for repairing or maintaining the transmission and distribution electric systems to mitigate storm damage impact. The method includes providing a plurality of ensemble forecast models associated with respective potential storm paths of a given storm across a geographic area via a storm ensemble database and providing inventory data associated with location and characteristics associated with power-providing equipment and characteristics of a consumer population in the geographic area with respect to the transmission and distribution electric systems via an inventory database. The method also includes providing actual windspeed data corresponding to measured actual windspeed from a past storm and providing damage assessment data corresponding to actual damage to the power-providing equipment resulting from the past storm at the measured actual windspeed. The method also includes generating a probabilistic model for each of the plurality of ensemble forecast models. The probabilistic model includes probabilistic data associated with operational failure of the power-providing equipment, as defined by the inventory data, based on a portion of the geographic area that is associated with the potential storm path of the respective one of the plurality of ensemble forecast models, and based on the actual windspeed data and the damage assessment data. The method also includes implementing a plurality of iterative probabilistic simulations for the probabilistic model associated with each of the plurality of ensemble forecast models and calculating a statistical impact value associated with the probabilistic model associated with each of the plurality of ensemble forecast models. The method further includes generating the storm response plan based on the relative statistical impact value of the probabilistic model of each of the plurality of ensemble forecast models and publishing the storm response plan to at least one organization associated with the transmission and distribution electric systems to disseminate at least a portion of the operational procedure to each of the at least one organization.

[0006] Another example includes a storm damage response system. The system includes a storm ensemble database configured to store a plurality of ensemble forecast models associated with respective potential storm paths of a given storm across a geographic area and an inventory database configured to store inventory data associated with location and characteristics associated with power-providing equipment and characteristics of a consumer population in the geographic area with respect to the transmission and distribution electric systems. The inventory data can include vegetation data comprising geographic locations and characteristics of each of a plurality of greenery regions in the geographic area. The characteristics of each of the greenery regions can include a relationship of the respective one of the greenery regions with location and characteristics associated with power-providing equipment in the geographic area. The system further includes a storm damage model control system configured to implement a storm damage model algorithm to generate a storm response plan comprising an operational procedure for repairing or maintaining the transmission and distribution electric systems to mitigate storm damage impact. The storm damage model algorithm can be configured to generate a probabilistic model for each of the plurality of ensemble forecast models based on a predetermined percentage of failure of each of the at least a portion of the power-providing equipment with respect to the given storm, and to calculate a statistical impact value associated with the probabilistic model based on an aggregate of a plurality of iterative probabilistic simulations for the probabilistic model associated with the respective one of the plurality of ensemble forecast models. The storm damage model control system can be configured to generate the storm response plan based on the relative statistical impact value of the probabilistic model of each of the plurality of ensemble forecast models. The storm response plan can include an operational level response plan comprising geographic-based resource allocation and inventory repair action plans and an executive level response plan comprising a total resource cost and a timeline for providing recovery for affected customer outages resulting from the storm damage impact with respect to the transmission and distribution electric systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** illustrates an example of a utility power system.

[0008] FIG. **2** illustrates an example of a storm damage response system.

[0009] FIG. **3** illustrates an example diagram of ensemble forecast models of a storm.

[0010] FIG. **4** illustrates an example of a storm damage model control system.

[0011] FIG. **5** illustrates an example of storm response plan reports.

[0012] FIG. **6** illustrates an example diagram of storm response plan reporting.

[0013] FIG. **7** illustrates an example of a method for generating a storm response plan.

DETAILED DESCRIPTION

[0014] This disclosure relates generally to the transmission and distribution electric system, and more specifically to an ensemble forecast storm damage response system for critical infrastructure. After detection of the formation of a storm, such as a hurricane, one or more weather forecasting services can provide information regarding ensemble forecast models that can each correspond to a potential path of the storm across a geographic area, as well as characteristics of the storm (e.g., wind speed and/or precipitation). The ensemble forecast models can be saved in a database, and can be frequently updated via the weather forecasting service(s). Additionally, an inventory database can store inventory data associated with power-providing equipment associated with one or more transmission and distribution electric systems. As an example, the power-providing equipment can include power stations, utility transformers, utility poles, power lines, and any of a variety of other equipment for generating and distributing power to consumers in the geographic area that can be potentially affected by the storm. As an example, the inventory data can also include maintenance data associated with the power-providing equipment from which percentage probabilities of failure can be assigned over a range of characteristics of a given storm.

[0015] A storm damage model control system can be configured to generate a storm response plan based on the ensemble forecast model and based on the inventory data. As an example, for each of the ensemble forecast models, the storm damage model control system can implement a storm damage model algorithm that can generate a probabilistic model for each of the ensemble forecast models based on a predetermined percentage of failure of the power-providing equipment with respect to the given storm based on the inventory data. The storm damage model algorithm can also implement iterative probabilistic simulations for the probabilistic model to calculate a statistical impact value associated with the probabilistic model (e.g., based on an aggregate of the iterative probabilistic simulations for the probabilistic model). The storm damage model control system can thus evaluate the statistical impact value associated with each of the ensemble forecast models to generate the storm response plan, such as accounting for timeline, cost, and/or efficiency.

[0016] A storm damage response system can be implemented in any of a variety of utility power systems, such as demonstrated in the example of FIG. **1**. FIG. **1** illustrates an example of a utility power system **10**. The utility power system **10** includes a power generator system **12** that is configured to provide generator power, demonstrated in the example of FIG. **1** as POW, to a power transmission system **14**, which can correspond to a power bus or point-of-interconnect (POI) that provides power via power-providing equipment **16** (e.g., transformers and power lines) to consumers, demonstrated generally at **18**. In the example of FIG. **1**, the power generator system **12** can be arranged as any of a variety of power generator systems, such as fossil-fuel power, wind power, solar power, or battery power.

[0017] In addition, the utility power system **10** includes a storm damage response system **20** that is configured to generate one or more storm damage response plans **22** that correspond to an operational procedure for repairing or maintaining the power generator systems to mitigate damage impact resulting from a storm **24**. In the example of FIG. **1**, the storm damage response system **20** can receive forecast data or weather history data, such as from a weather forecasting service, that can correspond to ensemble forecast models of an incoming storm (e.g., the storm **24**) or to characteristics of a historical storm or a simulated storm. The storm damage response system **20** can thus generate the storm damage response plan(s) **22** that can correspond to subsequently repairing the damage of the incoming storm **24** or can correspond to maintaining the power generator system **12**, the power transmission system **14**, and/or the power-providing equipment **16** in a preventative manner.

[0018] Additionally, the storm damage response system **20** can be configured to generate the storm damage response plan(s) **22** at an operational response level **26** and an executive response level **28**. For example, the operational response level plan **26** can correspond to multiple storm damage response plans that correspond to the respective ensemble model forecasts of the storm **24**, and can include geographic-based resource allocation and inventory repair action plans. As another example, the executive response level plan **28** can correspond to an aggregate of the operational response level plans **26**, and can include a total estimated resources and an estimated timeline for providing recovery for affected customer outages resulting from the storm damage impact with respect to the transmission and distribution electric systems.

[0019] FIG. **2** illustrates an example of a storm damage response system **50**. The storm damage response system **50** can correspond to the storm damage response system **20** in the example of FIG. **1**, and can thus generate one or more storm damage response plans **52** that correspond to an operational procedure for repairing or maintaining transmission and distribution electric systems to mitigate damage impact resulting from a storm.

[0020] The storm damage response system **50** includes an inventory database **54** that is configured to store inventory data associated with power-providing equipment associated with one or more transmission and distribution electric systems. As an example, the power-providing equipment can include power stations, and can also include utility transformers and/or power lines (e.g., the power transmission system **14**, and/or the power-providing equipment **16**), and any of a variety of other equipment for generating and distributing power to consumers in the geographic area that can be potentially affected by the storm. The inventory database **54** can also include a variety of characteristics associated with the power-providing equipment, such as including maintenance data associated with the power-providing equipment. The maintenance data can correspond to information as to when a given set of power-providing equipment was last repaired or maintained, a current state of repair, and/or a proximity or relationship with other features of the geographic area (e.g., proximity to trees, mobile homes, water features, or other features that may be more susceptible or relevant to storm damage). As yet another example, the inventory data can also store information regarding the effects of prior storms, such as to account for already damaged portions of the power-providing equipment or associated geographic features, such that the changes to the power-providing equipment or associated geographic features can affect the anticipated damage of the storm.

[0021] For example, the maintenance data can include a variety of information regarding vegetation in the geographic area. A region of interest with the vegetation in the geographic area is referred to hereinafter as "greenery region", and the information regarding the respective greenery region(s) is described hereinafter as "vegetation data". The vegetation data can include geographic locations and characteristics of each of the greenery regions. The vegetation data can also include data regarding the relationship between roadside trees and powerlines, such that the maintenance data can include times of last trimming of trees that are proximal to roadside powerlines or other power-providing equipment. The characteristics can include information such as the geographic borders of the greenery regions, the average height and/or density of trees in the greenery regions, and/or other characteristics of the greenery regions (e.g., water basins or characteristics of structures in the respective greenery regions). As an example, the vegetation data can be gathered from a variety of sources, such as periodic overhead imaging of the canopy of the greenery region(s) (e.g., via aircraft, such as drones, and/or satellite imagery) and/or from park services or regional government data sources, such as to monitor dynamic conditions of the greenery regions (e.g., tree growth). The vegetation data can also include information regarding vulnerability or potential for damage from storms, such as based on the height and/or density information and/or adjusted for varying wind speeds. In the example of FIG. **2**, the updates to the vegetation data (e.g., including the overhead imaging and/or other sources of data) are demonstrated as a signal VEG that is provided to the inventory database **54**.

[0022] The vegetation data can be associated and/or correlated with the maintenance data of the power-providing equipment. For example, the vegetation and/or maintenance data can include associated location data of the greenery regions with respect to locations of the power-providing equipment, such as including distance and direction. Therefore, the vegetation data and/or the maintenance data can be indicative of potential damage to the power-providing equipment in the event of a storm. For example, based on the factors of density and/or height of the vegetation defined in the vegetation data, the maintenance data and vegetation data can collectively assess a potential for damage to power-providing equipment based on the proximity of the power-providing equipment to the borders of the greenery regions. Furthermore, the assessments for potential damage can be adjusted based on windspeed and direction, such that the different assessments (e.g., probabilities, as described in greater detail below) for potential damage can be assigned for each of several ranges of windspeed for each of different vector directions of the wind through the greenery regions or through the geographic area.

[0023] As an example, as described in greater detail herein, the power-providing equipment can be assigned probabilistic data that is associated with percentage probabilities of failure over a range of characteristics of a hypothetical storm (e.g., wind speed and/or direction, precipitation levels, or other characteristics of the storm). For example, the percentage probabilities of failure of the power-providing equipment can be assigned in a predetermined manner based on the maintenance data, and can thus change over the range of the characteristics of the hypothetical storm. For example, the probabilistic data can be assigned as a single probability or a range of probabilities for each of a set of tiers of storm conditions (e.g., range of wind speeds and/or precipitation). Therefore, the inventory data in the inventory database **54** can include the probabilistic data as an appended tag to the power-providing equipment described in the inventory data. The probabilistic data can thus incorporate substantially all aspects of the inventory data and the maintenance data (e.g., including the vegetation data) with respect to providing an indication of failure percentage for each relevant component of the power-providing equipment over the set of tiers of storm conditions. In the example of FIG. **2**, the inventory database **54** is demonstrated as providing the inventory data, demonstrated as "INV", to a storm damage model control system **56**.

[0024] The storm damage response system **50** also includes a storm ensemble database **58**. The storm ensemble database **58** is configured to store ensemble forecast models associated with respective potential storm paths of a given storm across the geographic area. For example, the storm ensemble database **58** can be provided the ensemble forecast models from one or more weather forecasting services, and can be updated by the weather forecasting service(s) based on observed changes to the storm. As an example, the ensemble forecast models can include information regarding potential paths of the storm across the geographic area, as well as characteristics of the storm (e.g., wind speed and/or precipitation). In the example of FIG. **2**, the storm ensemble database **58** is demonstrated as providing the ensemble forecast models, demonstrated as "ST_EN", to the storm damage model control system **56**.

[0025] FIG. **3** illustrates an example diagram **100** of ensemble forecast models of a storm **102**. In the example of FIG. **3**, the storm is demonstrated as a hurricane that is located off the coast of the state of Florida, demonstrated diagrammatically at **104**. As an example, in response to detection of the formation of the storm **102**, such as before achieving classification as a hurricane, the associated weather forecasting service(s) can provide one or more ensemble forecast models to the storm damage response system **50**. In the example of FIG. **3**, the ensemble forecast models are demonstrated as arrows **106** that demonstrate potential paths of the storm **102** across the geographic area of Florida **104**.

[0026] As an example, the weather forecasting service(s) can provide a set of initial ensemble forecast models **106**, and can periodically update the ensemble forecast models **106** based on perceived changes to the storm. The ensemble forecast models **106** can include not only the potential paths of the storm **102**, but can also include data associated with the storm **102**, such as wind speed, speed of the storm (e.g., along the storm path), precipitation, and/or a variety of other characteristics of the storm **102**. Additionally, the data regarding the characteristics of the storm **102** can differ from one ensemble forecast model to the other, such as based on known effects of geographic features of the geographic region (e.g., mountains) on the storm **102**. As described herein, the storm damage response system **50** can generate the storm response plan(s) based on the set of ensemble forecast models of the storm **102**.

[0027] As another example, the ensemble forecast models **106** can correspond to historical storms that have already occurred. As an example, the historical storm data can be implemented to simulate the effects of a storm in generating the storm damage response plan(s) **52** and/or can be implemented to estimate the probabilities of failure of the power-providing equipment described by the inventory data in the inventory database **54**. As yet another example, the ensemble forecast models **106** can correspond to simulated storms that can be implemented to simulate the effects of a storm in generating the storm damage response plan(s) **52**. As an example, the simulated storms represented by the ensemble forecast models **106** can be implemented to generate the storm damage response plan(s) to determine an operational maintenance plan for determining which portions of the power-providing equipment might be most vulnerable to damage from a potential storm. The storm damage response plan(s) can thus correspond to a preventative maintenance action plan for making cost-effective repairs to the power-providing equipment that can potentially mitigate more costly repairs that would be required after significant damage caused by a real storm.

[0028] Referring back to the example of FIG. **2**, the storm damage model control system **56** is configured to implement a storm damage model algorithm **60** to generate the storm damage response plan(s) **52** based on the inventory data INV and the ensemble forecast models ST_EN. In addition, the storm damage model control system **56** is configured to receive damage assessment data DAD and actual windspeed data AWD associated with a prior storm, as described in greater detail herein. As an example, the effects of a recently occurred storm can be evaluated and documented to provide the damage assessment data DAD. The damage assessment data DAD can therefore correspond to specific identified and documented damage to the power-providing equipment after occurrence of a storm having known characteristics. The actual windspeed data AWD can correspond to measured windspeeds of the recently occurred storm, such as at each of plural locations across the geographic area (e.g., and across different times during the storm). As described in greater detail herein, the damage assessment data DAD and the actual windspeed data AWD can be implemented to refine the storm damage model algorithm **60** for future storms, such as based on a machine learning process.

[0029] In the example of FIG. **2**, the storm damage response plan(s) **52** are stored in a memory **62**. The memory **62** is accessible by a response plan reporting system **64** that is configured to publish the storm damage response plan(s) **52** to a predetermined set of organizations associated with the power system(s) to disseminate at least a portion of the operational procedure to each of the organizations, as described in greater detail herein. As a result, each of the respective organizations can act upon respective portions of the storm damage response plan(s) **52** to contribute to the operational procedure for mitigating the effects of the storm damage and/or to restore the power system(s) and associated power-providing equipment back to normal operating conditions.

[0030] FIG. **4** illustrates an example of a storm damage model control system **150**. The storm damage model control system **150** can correspond to the storm damage model control system **56** in the example of FIG. **2**. Therefore, reference is to be made to the example of FIGS. **2** and **3** in the following description of the example of FIG. **4**.

[0031] The storm damage model control system **150** includes a memory **152** that is configured to store the received inventory data INV and the ensemble forecast models ST_EN, such as provided from the inventory database **54** and the storm ensemble database **58**, respectively. Additionally, in the example of FIG. **4**, the memory **152** is configured to receive the damage assessment data DAD and the actual windspeed data AWD associated with a prior storm. The storm damage model control system **150** also includes a model generator **154** that is configured to generate a probabilistic model, demonstrated at **156**, associated with the storm (e.g., incoming actual storm, historical storm, or simulated storm). As an example, the probabilistic model **156** can be stored in a memory, such as the memory **152**. In the example of FIG. **4**, the model generator **154** accesses model data M_DATA from the memory **152** to generate the probabilistic model **156**. As an example, the model data M_DATA can include a single one of the ensemble forecast models ST_EN associated with a single potential path of the storm (e.g., one of the ensemble forecast models **106**), and can also include a set of the inventory data INV that includes the equipment (power system(s) and/or power-providing equipment) that is predicted to be affected by the storm with respect to the respective ensemble forecast model. Therefore, the probabilistic model **156** can correspond to one probabilistic model of a plurality of probabilistic models, each of the plurality of probabilistic models corresponding to a respective one of the ensemble forecast models ST_EN and being associated with a respective set of the inventory data.

[0032] As an example, the probabilistic model **156** can be refined by the model generator **154** based on the damage assessment data DAD and the actual windspeed data AWD. For example, the initial probabilistic model **156** can be based on the set of inventory data INV for each of the ensemble forecast models ST_EN. The probabilistic model **156** can be stored, for example, in the memory **152**. In response to an actual storm event, and thus subsequent to the application of the probabilistic model **156**, the damage assessment data DAD and the actual windspeed data AWD can be obtained with respect to the actual storm event.

[0033] For example, the damage assessment data DAD can be obtained from a variety of sources, such as from overhead imaging of the geographic area (e.g., via aircraft, such as drones, and/or satellite imagery), storm response repair crew personnel, consumer response (e.g., based on reported outages or regional damage reports), or a combination thereof. The actual windspeed data AWD can be obtained from recorded windspeeds during the actual storm for each different portion of the geographic. The actual windspeed data AWD can thus differ from the forecasted windspeeds associated with the ensemble forecast models ST_EN. As a result, the combination of the damage assessment data DAD and the actual windspeed data AWD can provide for an accurate indication of the damage sustained to the specific relevant components of the power-providing equipment at actual recorded windspeeds for a given state of the inventory data INV. Furthermore, the damage assessment data DAD and the actual windspeed data AWD can be updated in response to additional actual storms to provide more data and/or more accurate data as to the effect of given windspeeds of storms on the power-providing equipment.

[0034] The damage assessment data DAD and the actual windspeed data AWD can thus be implemented by the model generator **154** to generate a more accurate probabilistic model **156** for subsequent storms. In generating the probabilistic model **156**, the model generator **154** can access the damage assessment data DAD and the actual windspeed data AWD, such as for similar characteristics of an imminent storm, to refine the probabilistic model **156** that is generated based on the inventory data INV for each ensemble forecast model ST_EN. For example, the refinement of the probabilistic model **156** based on the inventory data INV for each ensemble forecast model ST_EN can be implemented in any of a variety of ways, such as based on a machine learning algorithm. Based on the feedback provided by the damage assessment data DAD and the actual windspeed data AWD of actual damage to the power-providing equipment based on specific known windspeeds, the model generator **154** can provide for a more accurate probabilistic model **156** for future storms.

[0035] While the example of FIG. **4** demonstrates that the damage assessment data DAD and the actual windspeed data AWD are provided to the memory **152**, the information provided by the damage assessment data DAD and the actual windspeed data AWD can be implemented in other or additional ways, as described herein. For example, the damage assessment data DAD and the actual windspeed data AWD can alternatively or additionally be provided to the inventory database **54** in the example of FIG. **2**, such that the damage assessment data DAD and the actual windspeed data AWD can be implemented to refine the probabilistic data for each of the relevant power-providing equipment in the inventory database **54**. As a result, the model generator **154** can generate the probabilistic model **156** based on the inventory data INV as updated by damage assessment data DAD and the actual windspeed data AWD. Accordingly, the model generator **154** can generate the probabilistic model **156** for future storms based on the damage assessment data DAD and the actual windspeed data AWD associated with past storms in a feedback manner in a variety of different ways.

[0036] Upon generating the probabilistic model **156**, the storm damage model control system **150** can implement a plurality of iterative probabilistic simulations on the probabilistic model **156**. In the example of FIG. **4**, the storm damage model control system **150** includes a simulator system **158** which can be configured as a software module that is configured to run the plurality of iterative probabilistic simulations on the probabilistic model **156**. As an example, the simulator system **158** can implement a predetermined number of simulations, such as Monte Carlo simulations, to provide a set of potentially different outcomes with respect to failures of the power-providing equipment described by the set of inventory data of the probabilistic model **156**.

[0037] For example, as described previously, the inventory data can be assigned probabilistic data that is associated with percentage probabilities of failure over a range of characteristics of a hypothetical storm (e.g., wind speed and/or direction, precipitation levels, or other characteristics of the storm). As also described previously, the given ensemble forecast model that is associated with the probabilistic model **156** has defined characteristics (e.g., wind speed, precipitation amount, and affected land area of the geographic region) of the given storm. Therefore, the model generator **154** can delineate the set of inventory data that is associated with the given storm of the ensemble forecast model, and can assign percentage probabilities of failure of the specific characteristics of the given storm of the ensemble forecast model to the set of inventory of the probabilistic model **156**. As a result, each of the plurality of iterative probabilistic simulations on the probabilistic model **156** can result in a different outcome based on the different potential failures of the power-providing equipment described by the set of inventory data in response to the characteristics of the storm. Accordingly, by implementing the plurality of iterative probabilistic simulations on the probabilistic model **156** (e.g., ten or more simulations), the simulator system **158** can accommodate different potential scenarios of resulting damage from the storm associated with the respective ensemble forecast model.

[0038] The storm damage model control system **150** also includes a statistical impact monitor **160** that is configured to assign a statistical impact value to each of the scenarios corresponding to the respective iterative simulations of the probabilistic model **156** provided by the simulator system **158**. The statistical impact value can include one or more quantitative values or metrics that are associated with the predicted storm damage and/or potential efforts associated with recovery from the predicted storm damage. As an example, the statistical impact monitor **160** can determine a repair or maintenance cost associated with a given scenario based on the power-providing equipment that failed in a given one of the iterative probabilistic simulations. The cost can include costs associated with allocation of resources (e.g., personnel, equipment, logistical resources, or any other resources) and/or costs associated with prolonged power outage (e.g., associated with long-term macro-economic societal effects). As another example, the statistical impact monitor **160** can determine a repair or maintenance timeline associated with repairing the power-providing equipment to restore the power to consumers and businesses in the geographic region. As yet another example, the statistical impact monitor **160** can also determine an amount of resources outside of the scope of the power-providing equipment that may be necessary to recover from the storm, such as medical personnel, rescue personnel, or other recovery personnel that may be necessary to recover from the storm effects (e.g., such as necessitating government or neighboring provincial intervention). Because these determinations can be substantially inclusive of all aspects of recovery and can be highly interrelated, the statistical impact monitor **160** can substantially simplify each scenario to a quantitative value that is representative of the potential impact of the storm.

[0039] The storm damage model control system **150** also includes a scenario comparator **162** and a plan generator **164**. In the example of FIG. **4**, the statistical impact monitor **160** provides each of the scenarios, demonstrated as "SCEN", corresponding to each of the respective iterative probabilistic simulations of the probabilistic model **156** to the scenario comparator **162**. In response, the scenario comparator **162** can select a given one of the scenarios SCEN based on a predetermined set of criteria to provide to the plan generator **164**. As a result, the plan generator **164** can generate an operational level storm damage response plan, demonstrated as "ORL" that corresponds to the operational procedure for responding to the impact of the storm for the respective scenario. As an example, the predetermined set of criteria can correspond to selecting the respective scenario of the set of scenarios based on a "worst case" corresponding to the most severe potential impact, such as by selecting the scenario having the highest statistical impact value. As another example, the predetermined set of criteria can correspond to or include other criteria, such as based on a tiered or weighted importance, that can include cost, time, resources, or other factors. As yet another example, the scenario comparator **162** can be configured to select action plans from multiple scenarios, such as based on failures or likelihoods of failure from selective different scenarios to create an aggregate scenario.

[0040] Accordingly, the plan generator **164** can generate the operational level storm damage response plan ORL based on the scenario or aggregate scenario selected by the scenario comparator **162**, with the operational level storm damage response plan ORL corresponding to the operational procedure and action plan for recovering from the potential impact of the storm for the selected scenario associated with the respective one of the ensemble forecast models. As an example, the operational level storm damage response plan ORL can correspond to a single operational response level plan, such as the operational response level plan **26** in the example of FIG. **1**. For example, the operational level storm damage response plan ORL can include geographic-based resource allocation and inventory repair action plans based on the set of inventory data for the respective ensemble forecast model. However, the operational level storm damage response plan ORL corresponds to only a single one of the ensemble forecast models, and thus only a single potential path of the storm. Because the path of an incoming storm may be difficult to predict, the storm damage model control system **150** can thus generate a operational level storm damage response plan ORL (e.g., an operational level response plan) for each of the ensemble forecast models in an iterative manner. Therefore, the storm damage model control system **150** can generate a probabilistic model **156**, implement the iterative probabilistic simulations for the probabilistic model **156**, assign a statistical impact value for each of the respective scenarios of the iterative probabilistic simulations, and generate a respective operational level storm damage response plan ORL for each of the ensemble forecast models.

[0041] Based on the aggregation of operational level storm damage response plans ORL that are generated by the plan generator **164**, the plan generator **164** can also generate an executive level storm damage response plan, demonstrated as "ERL". As an example, the executive level storm damage response plan ERL can be generated based on all of the operational level storm damage response plans ORL, such as to account for any possible storm path of the incoming storm based on the potential impact of each of the respective ensemble forecast models. As an example, the executive level storm damage response plan ERL can include a total estimated resources required and an estimated timeline for providing recovery for affected customer outages resulting from the storm damage impact with respect to the power generator systems and power-providing equipment based on an aggregate impact of the ensemble forecast models (e.g., an aggregation of the operational level storm damage response plans ORL).

[0042] For example, similar to as described previously for the scenario comparator **162**, the plan generator **164** can select a given one of the operational level storm damage response plans ORL based on a predetermined set of criteria to provide the executive level storm damage response plan ERL. As an example, the predetermined set of criteria can correspond to selecting the respective operational level storm damage response plans ORL corresponding to "worst case" scenario of the set of ensemble forecast models. As another example, the executive level storm damage response plan ERL can be generated based on an aggregation of each of the operational level storm damage response plans ORL.

[0043] For example, the plan generator **164** can base the executive level storm damage response plan ERL on percentage probabilities associated with each of the ensemble forecast models (e.g., as provided by the weather forecasting service). Therefore, the percentage probabilities associated with each of the ensemble forecast models can correspond to weights for purposes of determining a predictive impact of each of the operational level storm damage response plans ORL, and thus a predicted impact of the storm based on the respective percentages of likelihood of the ensemble forecast models. As yet another example, the executive level damage response plan ERL can include an overview of each of the ensemble forecast models and/or the respective corresponding operational level storm damage response plans ORL, such that the executive level damage response plan ERL can allow for a change in the selected operational level damage response plan ORL or can be used to select the operational level damage response plan ORL. Accordingly, the executive level storm damage response plan ERL can be generated based on the generated operational level storm damage response plans ORL.

[0044] FIG. **5** illustrates an example of storm response plan reports. Particularly, the storm response plan reports are demonstrated in the example of FIG. **5** as an operational level damage response plan **200** and an executive level damage response plan **202**. The operational level damage response plan **200** and the executive level damage response plan **202** can correspond to the operational level damage response plan ORL and the executive level damage response plan ERL in the example of FIG. **4**. Therefore, reference is to be made to the examples of FIGS. **1-4** in the following description of the example of FIG. **5**.

[0045] The operational level damage response plan **200** includes predicted inventory damage data **204**, resource acquisition data **206**, resource allocation data **208**, and operational plan timeline data **210**. The predicted inventory damage data **204** can correspond to a predicted set of the affected power-providing equipment inventory that is likely or predicted to be damaged or destroyed by the storm. For example, the predicted inventory damage data **204** can correspond to the set of inventory that was demonstrated to have failed based on the iterative probabilistic simulations on the probabilistic model **156**. Therefore, the predicted inventory damage data **204** can form the basis for repairs that are associated with the operational plan for post-storm restoration.

[0046] The resource acquisitions data **206** can correspond to the resources that are needed to fulfill the operational plan for post-storm restoration. As an example, the resource acquisitions data **206** can include power-providing equipment that is necessary to be acquired to fulfill the operational plan, and can include both "spare" power-providing equipment and power-providing equipment that needs to be ascertained (e.g., from vendors, from other provincial or corporate inventory stores, from government aid organizations (e.g., Edison Electric Institute (EEI), the Federal Emergency Management Agency (FEMA)), or other sources). The resource acquisitions data **206** can also include human resources and associated equipment, such as technicians, vehicles and other transportation to provide the technicians, and supporting equipment (e.g., tools for the technicians, food and fresh water for the technicians and/or for displaced people, etc.). The resource acquisitions data **206** can thus define the necessary resources to restore the power generator systems and associated power-providing equipment after the storm damage based on the predicted inventory damage data **204** over the operational plan.

[0047] The resource allocation data **208** can correspond to an allocation of the resources that are needed to fulfill the operational plan for post-storm restoration. As an example, the resource allocation data **208** can include an allocation of the power-providing equipment to specific portions and areas of the geographic region, such as to specific power generator systems and/or to specific geographic areas in the geographic region where damage to the power-providing equipment is located. The resource allocation data **208** can also include locations to lodge technicians and associated equipment, as defined by the resource acquisitions data **206**, during the storm. As a result, the technicians and associated equipment can begin to implement the operational plan substantially immediately after the storm has passed through the geographic area or has dissipated entirely. The resource allocation data **208** can thus define the manner in which the resources are allocated across the geographic region to restore the power generator systems and associated power-providing equipment after the storm damage based on the resource acquisitions data **206** over the operational plan.

[0048] The operational plan timeline data **210** can correspond to an ordered timeline of the operational plan for restoring the power generator systems and associated power-providing equipment after the storm damage. As an example, the operational plan timeline data **210** can include a detailed and ordered timeline as to the repairs to be performed via the allocated resources defined by the resource allocation data **208**. For example, certain portions of the power generator systems and the associated power-providing equipment may need to be repaired before other portions of the power generator systems and the associated power-providing equipment to provide efficient and effective restoration after the impact of the storm. As an example, the resource allocation data **208** and the operational plan timeline data **210** can be interrelated as to providing a timeline for the allocation of the resources to the different portions of the geographic region affected by the storm. Therefore, the operational plan timeline data **210** provides the logistical details for restoration of the power generator systems and the associated power-providing equipment in response to the storm damage.

[0049] The executive level damage response plan **202** includes ensemble forecast model overviews **212**, predicted impact and affected customers data **214**, estimated resource allocations data **216**, and restoration timeline data **218**. The ensemble forecast model overviews **212** can correspond to each of the ensemble forecast models, such that the ensemble forecast model overviews **212** can allow a user to selectively view each of the ensemble forecast models and any associated data. For example, the ensemble forecast model overviews **212** can graphically demonstrate each of the ensemble forecast models, and can include data associated with each of the ensemble forecast models. As another example, the ensemble forecast model overviews **212** can allow a user to selectively view each operational level damage response plan ORL (e.g., a given operational level damage response plan **200**) associated with each of the ensemble forecast models. For example, the selected operational level damage response plan **200** can be implemented to populate the data associated with the executive level damage response plan **202**, such as to allow selection of a given one of the operational level damage response plans **200** that is to be implemented to restore the power generator systems and/or associated power-providing equipment.

[0050] The predicted impact and affected customers data **214** can provide data associated with the predicted damage of the storm. The predicted inventory damage data **204** can correspond to a predicted set of the affected power-providing equipment inventory that is likely or predicted to be damaged or destroyed by the storm. For example, the predicted impact and affected customers data **214** can correspond to an overview of the set of inventory that was demonstrated to have failed based on the iterative probabilistic simulations on the probabilistic model **156**. Additionally, the predicted impact and affected customers data **214** can indicate the power customers that are predicted to be affected or most affected by the impact of the storm, such as can form the basis for selection of the operational level damage response plan **200**. Therefore, the predicted impact and affected customers data **214** can form the basis for repairs that are associated with the operational plan for post-storm restoration.

[0051] The estimated resource allocations data **216** can correspond to an amount and allocation of the resources that are needed to fulfill the operational plan for post-storm restoration. As an example, the estimated resource allocations data **216** can include power-providing equipment that is necessary to fulfill the operational plan, such as based on a comparison of what is needed for the operational plan and what is "on hand". The estimated resource allocations data **216** can also include human resources and associated equipment, such as technicians, vehicles and other transportation to provide the technicians, and supporting equipment (e.g., tools for the technicians, food and fresh water for the technicians and/or for displaced people, etc.). The estimated resource allocations data **216** can thus define the necessary resources to restore the power generator systems and associated power-providing equipment after the storm damage, and can be determinative as to whether external help/mutual assistance (e.g., EEI or from a government emergency relief organization (e.g., FEMA)) is necessary to be contacted to fulfill the operational plan.

[0052] The restoration timeline data **218** can correspond to a timeline of the operational plan for restoring the power generator systems and associated power-providing equipment after the storm damage. As an example, the restoration timeline data **218** can include an estimate of a total time for restoration of the power generator systems and/or the power-providing equipment. For example, the restoration timeline data **218** can be used to provide estimates of restoring power to affected geographic areas and the customers that are likely to be affected by power outages caused by the storm. The restoration timeline data **218** can be used for selection of a given one of the operational level damage response plans **200** (e.g., satisfying a timing criterion), and can also be used to inform agencies and customers as to expected power restoration. Therefore, the restoration timeline data **218** provides the predicted timing of restoration of the power generator systems and the associated power-providing equipment in response to the storm damage.

[0053] FIG. **6** illustrates an example diagram **250** of storm response plan reporting. The diagram **250** demonstrates a response plan reporting system **252** and a plurality of organizations to which the storm damage response plan(s) are disseminated. As an example, the response plan reporting system **252** can correspond to the response plan reporting system **64** in the example of FIG. **2**. Therefore, reference is to be made to the examples of FIGS. **2-5** in the following description of the example of FIG. **6**.

[0054] The response plan reporting system **252** can provide the storm damage response plan(s) (e.g., the storm damage response plan(s) **52** in the example of FIG. **2**, or at least one of the operational level damage response plan **200** and the executive level damage response plan **202** of the example of FIG. **5**) to each of the separate organizations. In the example of FIG. **6**, the organizations include human resources **254**, power delivery **256**, customer service **258**, and communications **260**.

[0055] As an example, human resources **254** can implement the storm damage response plan(s) to provide information to employees of the power generator system(s). For example, human resources **254** can provide an indication to employees when to evacuate prior to the incoming storm, such as based on the operational plan timeline (e.g., the operational plan timeline data **210**). Human resources **254** can also indicate details to logistics personnel to obtain necessary inventory, and to technicians to provide them with preparation for their efforts to provide restoration after the storm, such as defined in the resource acquisitions data **206** and/or resource allocation data **208**. Power delivery **256** can implement the storm damage response plan(s) to provide control of the power generator systems and/or power-providing equipment before and/or after the storm. As an example, power delivery **256** can implement the storm damage response plan(s) to identify protocols with respect to the power generator system(s) and the power-providing equipment to safely disable the respective equipment, and/or to provide an indication at the power generation sources as to when to safely re-enable the power generator system(s).

[0056] Customer service **258** can implement the storm damage response plan(s) to communicate the status of the operational plan. For example, customer service **258** can communicate the predicted timeline of the operational plan to potentially affected customers, and can communicate updates to the affected customers during the execution of the operational plan. Additionally, customer service **258** can provide other information to affected customers, such as safety information and/or evacuation information. Communications **260** can implement the storm damage response plan(s) to provide emergency crews to portions of the geographic region that are predicted to be affected, and thus are predicted to require emergency services. Communications **260** can include dispatching and emergency services, and can refer to any of a variety of other organizations within the power generator system(s) organization or outside of the power generator system(s) organization that may require information about the operational plan to restore the damage from the storm.

[0057] The disclosure herein thus describes storm damage response system to effectively and efficiently provide power recovery efforts in response to a coming storm, or for a simulated storm to provide preventative maintenance. The storm damage response system described herein, for example, allows for the capability to predetermine the resources that are necessary to fulfill the operational plan for restoring the power generator system(s) (and by extension, the power-providing equipment) after the storm damage. Based on the manner in which the storm damage response plan(s) are generated, the storm damage response plan(s) can be implemented to provide justification for requesting additional resources from external mutual assistance partners (e.g., EEI). Additionally, the storm damage response plan(s) can facilitate pre-staging resources, including technicians and equipment resources, to allow for a faster response and more effective logistical planning for after the storm has passed based on the estimated workload provided by the storm damage response plan(s). Accordingly, by providing the storm damage response plan(s) at both an operational level (based on the iterative probabilistic simulations) and the executive level, the storm damage response system can account for a multitude of different scenarios to estimate the effects and the respective restoration steps at all levels of the power generator system organization.

[0058] In view of the foregoing structural and functional features described above, methods in accordance with various aspects of the present disclosure will be better appreciated with reference to FIG. **7**. While, for purposes of simplicity of explanation, the method of FIG. **7** is shown and described as executing serially, it is to be understood and appreciated that the present disclosure is not limited by the illustrated orders, as some aspects could, in accordance with the present disclosure, occur in different orders and/or concurrently with other aspects from that shown and described herein. Moreover, not all illustrated features may be required to implement method in accordance with an aspect of the present disclosure.

[0059] FIG. **7** illustrates a method **300** for generating a storm response plan (e.g., the storm response plan(s) **22**) comprising an operational procedure for repairing or maintaining power generator systems (e.g., the power generator system **12**) to mitigate storm damage impact. At **302**, a plurality of ensemble forecast models (e.g., the ensemble forecast models **106**) associated with respective potential storm paths of a given storm (e.g., the storm **24**) across a geographic area are provided via a storm ensemble database (e.g., the storm ensemble database **58**). At **304**, providing inventory data (e.g., the inventory data INV) associated with location and characteristics associated with power-providing equipment in the geographic area with respect to the power generator systems via an inventory database (e.g., the inventory database **54**). At **306**, a probabilistic model (e.g., the probabilistic model **156**) is generated for each of the plurality of ensemble forecast models. The probabilistic model includes probabilistic data associated with operational failure of the power-providing equipment, as defined by the inventory data, based on a portion of the geographic area that is associated with the potential storm path of the respective one of the plurality of ensemble forecast models. At **308**, a plurality of iterative probabilistic simulations are implemented for the probabilistic model associated with each of the plurality of ensemble forecast models (e.g., via the simulator system **158**). At **310**, a statistical impact value associated with the probabilistic model associated with each of the plurality of ensemble forecast models is calculated (e.g., via the statistical impact monitor **160**). At **312**, the storm response plan is generated based on the relative statistical impact value of the probabilistic model of each of the plurality of ensemble forecast models (e.g., via the plan generator **164**). At **314**, the storm response plan is published to at least one organization (e.g., the organizations **254**, **256**, **258**, and **260**) associated with the power generator systems to disseminate at least a portion of the operational procedure to each of the at least one organization.

[0060] What have been described above are examples of the disclosure. It is, of course, not possible to describe every conceivable combination of components or method for purposes of describing the disclosure, but one of ordinary skill in the art will recognize that many further combinations and permutations of the disclosure are possible. Accordingly, the disclosure is intended to embrace all such alterations, modifications, and variations that fall within the scope of this application, including the appended claims. Additionally, where the disclosure or claims recite "a," "an," "a first," or "another" element, or the equivalent thereof, it should be interpreted to include one or more than one such element, neither requiring nor excluding two or more such elements. As used herein, the term "includes" means includes but not limited to, and the term "including" means including but not limited to. The term "based on" means based at least in part on.

What is claimed is:

1. A storm damage response system comprising:

a storm ensemble database configured to store a plurality of ensemble forecast models associated with respective potential storm paths of a given storm across a geographic area, as provided from and updated by a weather forecasting service;

an inventory database configured to store inventory data associated with location and characteristics associated with power-providing equipment in the geographic area with respect to power generator systems; and

a storm damage model control system configured to implement a storm damage model algorithm to generate a predictive storm response plan comprising an operational procedure for repairing or maintaining the power generator systems to mitigate storm damage impact, the storm damage model algorithm being configured to generate a probabilistic model for each of the plurality of ensemble forecast models based on the inventory data and to calculate a statistical impact value associated with the probabilistic model based on an aggregate of a plurality of iterative probabilistic simulations for the probabilistic model associated with the respective one of the plurality of ensemble forecast models, the storm damage model control system being configured to generate the predictive storm response plan based on the relative statistical impact value of the probabilistic model of each of the plurality of ensemble forecast models.

2. The system of claim **1**, wherein the inventory data comprises vegetation data, the vegetation data comprising geographic locations and characteristics of each of a plurality of greenery regions in the geographic area, the characteristics of each of the greenery regions comprising a relationship of the respective one of the greenery regions with location and characteristics associated with power-providing equipment in the geographic area.

3. The system of claim **2**, wherein the inventory data comprises maintenance data, the maintenance data comprising information corresponding to at least one of when the power-providing equipment was last repaired or maintained, a current state of repair, a proximity or relationship with features of the geographic area, and times of last trimming of trees that are proximal to the power-providing equipment.

4. The system of claim **1**, wherein the storm damage model control system is configured to receive actual windspeed data corresponding to measured actual windspeed from a past storm and damage assessment data corresponding to actual damage to the power-providing equipment resulting from the past storm at the measured actual windspeed, wherein the storm damage model algorithm is configured to generate the probabilistic model for each of the plurality of ensemble forecast models based on the inventory data, the actual windspeed data, and the damage assessment data.

5. The system of claim **1**, wherein the storm damage model control system comprises a model generator configured to generate the probabilistic model associated with each of the plurality of ensemble forecast models, the probabilistic model comprising probabilistic data associated with operational failure of the power-providing equipment, as defined by the inventory data, based on a portion of the geographic area that is associated with the potential storm path of the respective one of the plurality of ensemble forecast models, wherein the storm damage model control system is further configured to assign a predetermined percentage of failure of each of at least a portion of the power-providing equipment over a range of storm characteristics based on maintenance data of the power-providing equipment associated with the inventory data, wherein the maintenance data comprises information corresponding to at least one of when the power-providing equipment was last repaired or maintained, a current state of repair, and a proximity or relationship with features of the geographic area, wherein the probabilistic data is generated based on the predetermined percentage of failure of each of the at least a portion of the power-providing equipment with respect to the given storm.

6. The system of claim **5**, wherein the storm damage model control system further comprises a simulator system configured to implement the plurality of iterative probabilistic simulations on the probabilistic model associated with each of the plurality of ensemble forecast models to generate the statistical impact value for the respective probabilistic model based on the plurality of iterative probabilistic simulations, the statistical impact value being indicative of a cost-based resource allocation estimate based on the probabilistic data associated with the operational failure of the power-providing equipment relative to at least one of time, cost, resource availability, and storm severity constraints.

7. The system of claim **6**, wherein the storm damage model control system further comprises:

a scenario comparator configured to select the probabilistic model associated with a respective one of the plurality of ensemble forecast models based on the statistical impact value; and

a plan generator configured to generate the predictive storm response plan based on the inventory data associated with the selected probabilistic model, the predictive storm response plan comprises:

an operational level response plan associated with the selected probabilistic model, the operational response level plan comprising geographic-based resource allocation and inventory repair action plans based on the inventory data and the respective one of the plurality of ensemble forecast models; and

an executive level response plan comprising a total estimated resources and an estimated timeline for providing recovery for affected customer outages resulting from the storm damage impact with respect to the power generator systems based on an aggregate impact scenario associated with the plurality of ensemble forecast models.

8. The system of claim **1**, wherein the statistical impact value is indicative of a cost-based resource allocation estimate based on the probabilistic data associated with the operational failure of the power-providing equipment relative to time, cost, resource availability, and storm severity constraints, wherein the system further comprises a scenario comparator configured to select the probabilistic model associated with a respective one of the plurality of ensemble forecast models based on the statistical impact value associated with each of the plurality of ensemble forecast models to generate the predictive storm response plan.

9. The system of claim **8**, wherein the scenario comparator is configured to select the probabilistic model based on a predetermined set of criteria, wherein the predetermined set of criteria comprises a weighted importance associated with at least one of the time, the cost, and the resource availability associated with the statistical impact value.

10. A method for generating a storm response plan comprising an operational procedure for repairing or maintaining power generator systems to mitigate storm damage impact, the method comprising:

providing a plurality of ensemble forecast models associated with respective potential storm paths of a given storm across a geographic area via a storm ensemble database;

providing inventory data associated with location and characteristics associated with power-providing equipment in the geographic area with respect to the power generator systems via an inventory database;

providing actual windspeed data corresponding to measured actual windspeed from a past storm;

providing damage assessment data corresponding to actual damage to the power-providing equipment resulting from the past storm at the measured actual windspeed;

generating a probabilistic model for each of the plurality of ensemble forecast models, the probabilistic model comprising probabilistic data associated with operational failure of the power-providing equipment, as defined by the inventory data, based on a portion of the geographic area that is associated with the potential storm path of the respective one of the plurality of ensemble forecast models and based on the actual windspeed data and the damage assessment data;

implementing a plurality of iterative probabilistic simulations for the probabilistic model associated with each of the plurality of ensemble forecast models;

calculating a statistical impact value associated with the probabilistic model associated with each of the plurality of ensemble forecast models;

generating the storm response plan based on the relative statistical impact value of the probabilistic model of each of the plurality of ensemble forecast models; and

publishing the storm response plan to at least one organization associated with the power generator systems to disseminate at least a portion of the operational procedure to each of the at least one organization.

11. The method of claim **10**, wherein generating the storm recover plan comprises:

generating an operational level response plan comprising geographic-based resource allocation and inventory repair action plans; and

generating an executive level response plan comprising a total resource cost and a timeline for providing recovery for affected customer outages resulting from the storm damage impact with respect to the power generator systems.

12. The method of claim **10**, wherein providing the inventory data comprises providing vegetation data, the vegetation data comprising geographic locations and characteristics of each of a plurality of greenery regions in the geographic area, the characteristics of each of the greenery regions comprising a relationship of the respective one of the greenery regions with location and characteristics associated with power-providing equipment in the geographic area.

13. The method of claim **10**, wherein calculating the statistical impact value comprises calculating the statistical impact value to be indicative of a cost-based resource allocation estimate based on the probabilistic data associated with the operational failure of the power-providing equipment relative to at least one of time, cost, resource availability, and storm severity constraints.

14. The method of claim **10**, further comprising assigning a predetermined percentage of failure of each of at least a portion of the power-providing equipment over a range of storm characteristics based on maintenance data of the power-providing equipment associated with the inventory data, wherein the maintenance data comprises information corresponding to at least one of when the power-providing equipment was last repaired or maintained, a current state of repair, and a proximity or relationship with features of the geographic area, wherein generating the probabilistic model comprises generating the probabilistic data based on the predetermined percentage of failure of each of the at least a portion of the power-providing equipment with respect to the given storm.

15. A storm damage response system comprising:

a storm ensemble database configured to store a plurality of ensemble forecast models associated with respective potential storm paths of a given storm across a geographic area;

an inventory database configured to store inventory data associated with location and characteristics associated with power-providing equipment in the geographic area with respect to power generator systems, the inventory data comprising vegetation data, the vegetation data comprising geographic locations and characteristics of each of a plurality of greenery regions in the geographic area, the characteristics of each of the greenery regions comprising a relationship of the respective one of the greenery regions with location and characteristics associated with power-providing equipment in the geographic area;

a storm damage model control system configured to implement a storm damage model algorithm to generate a storm response plan comprising an operational procedure for repairing or maintaining the power generator systems to mitigate storm damage impact, the storm damage model algorithm being configured to generate a probabilistic model for each of the plurality of ensemble forecast models based on a predetermined percentage of failure of each of the at least a portion of the power-providing equipment with respect to the given storm, and to calculate a statistical impact value associated with the probabilistic model based on an aggregate of a plurality of iterative probabilistic simulations for the probabilistic model associated with the respective one of the plurality of ensemble forecast models, the storm damage model control system being configured to generate the storm response plan based on the relative statistical impact value of the probabilistic model of each of the plurality of ensemble forecast models, the storm response plan comprising an operational level response plan comprising geographic-based resource allocation and inventory repair action plans and an executive level response plan comprising a total resource cost and a timeline for providing recovery for affected customer outages resulting from the storm damage impact with respect to the power generator systems.

16. The system of claim **15**, further comprising a response plan reporting system configured to publish the storm response plan to a plurality of organizations associated with the power generator systems to disseminate at least a portion of the operational procedure to each of the plurality of organizations.

17. The system of claim **15**, wherein the storm ensemble database is configured to store the plurality of ensemble forecast models as at least one of simulated and historical storms associated with the geographic area to provide the storm response plan as a prophylactic maintenance plan for the power generator systems.

18. The system of claim **15**, wherein the storm damage model control system comprises a model generator configured to generate the probabilistic model associated with each of the plurality of ensemble forecast models, the probabilistic model comprising probabilistic data associated with operational failure of the power-providing equipment, as defined by the inventory data, based on a portion of the geographic area that is associated with the potential storm path of the respective one of the plurality of ensemble forecast models.

19. The system of claim **18**, wherein the storm damage model control system further comprises a simulator system configured to implement the plurality of iterative probabilistic simulations on the probabilistic model associated with each of the plurality of ensemble forecast models to generate the statistical impact value for the respective probabilistic model based on the plurality of iterative probabilistic simulations, the statistical impact value being indicative of a cost-based resource allocation estimate based on the probabilistic data associated with the operational failure of the power-providing equipment relative to at least one of time, cost, resource availability, and storm severity constraints.

20. The system of claim **15**, wherein the storm damage model control system is configured to receive actual windspeed data corresponding to measured actual windspeed from a past storm and damage assessment data corresponding to actual damage to the power-providing equipment resulting from the past storm at the measured actual windspeed, wherein the storm damage model algorithm is configured to generate the probabilistic model for each of the plurality of ensemble forecast models based on the inventory data, the actual windspeed data, and the damage assessment data.

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