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Tews

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(54) **DETECTION OF LIGHTNING AND RELATED CONTROL STRATEGIES IN ELECTRIC POWER SYSTEMS**

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G01R 31/58	(2020.01)
H02H 1/00	(2006.01)
H02H 7/26	(2006.01)

(52) **U.S. Cl.**

CPC ***G01R 29/0842*** (2013.01); ***G01R 29/085*** (2013.01); *G01R 31/08* (2013.01); *G01R 31/086* (2013.01); *G01R 31/58* (2020.01); *H02H 1/0007* (2013.01); *H02H 7/26* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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(57) **ABSTRACT**

The present disclosure pertains to systems and methods for detecting lightning and using such information to implement appropriate control strategies in an electric power system. In one embodiment, a system may include a data acquisition subsystem configured to receive a plurality of representations of electrical conditions associated with at least a portion of the electric power system. The system may also include a traveling wave subsystem to identify an initial traveling wave in the electric power system and generated by lightning and identify at least one subsequent traveling wave in the electric power system and generated by lightning. A lightning analysis subsystem may perform an analysis of the initial traveling wave and the at least one subsequent traveling wave to determine a characteristic of the ionosphere based on the analysis and a lightning location. An adaptive control subsystem may adjust a control strategy based on the lightning location.

19 Claims, 5 Drawing Sheets

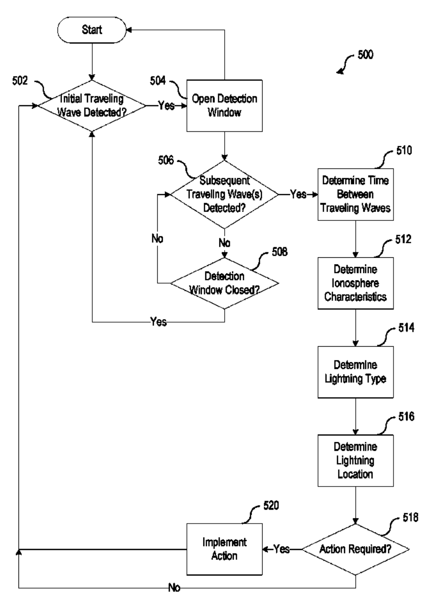

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Figure 1A

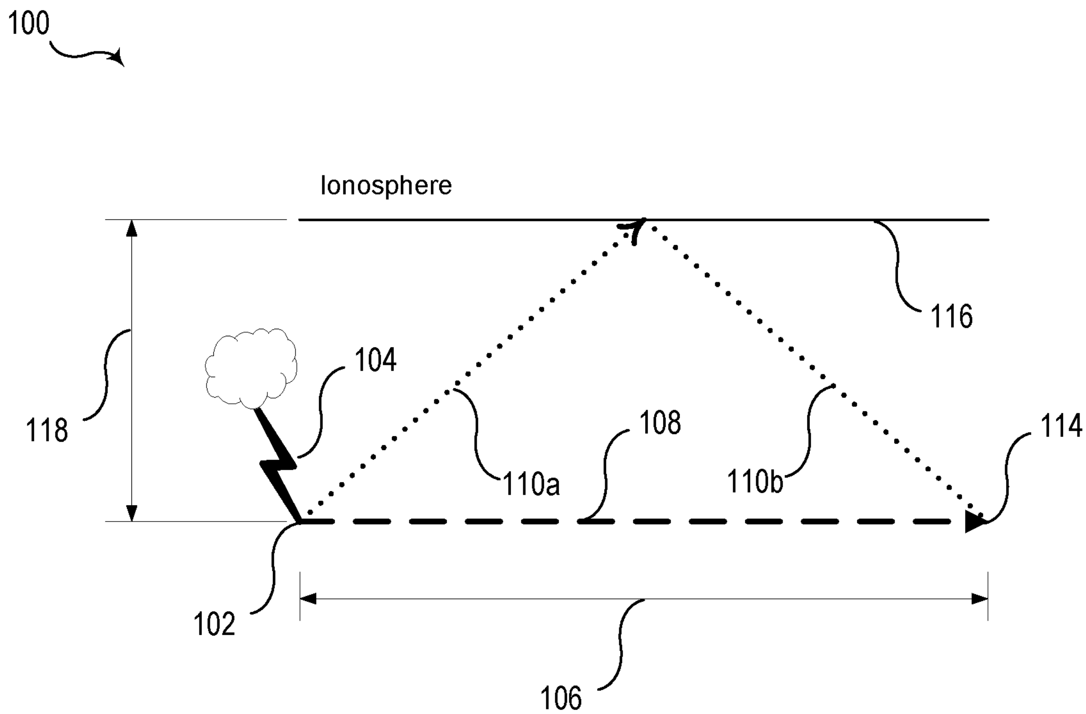


Figure 1B

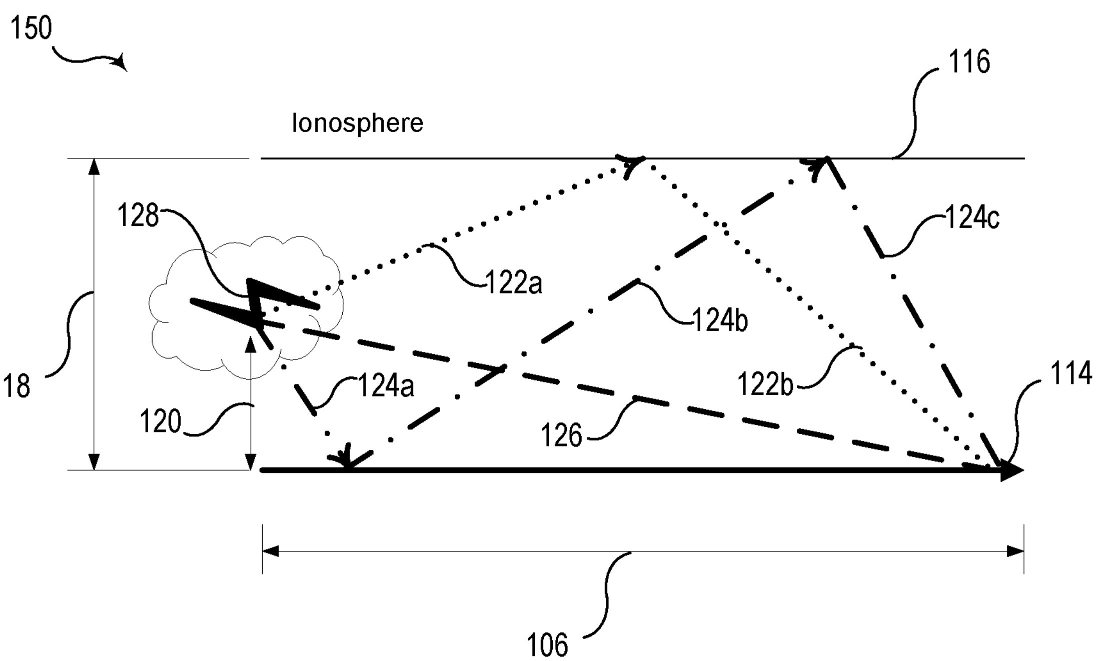


Figure 2A

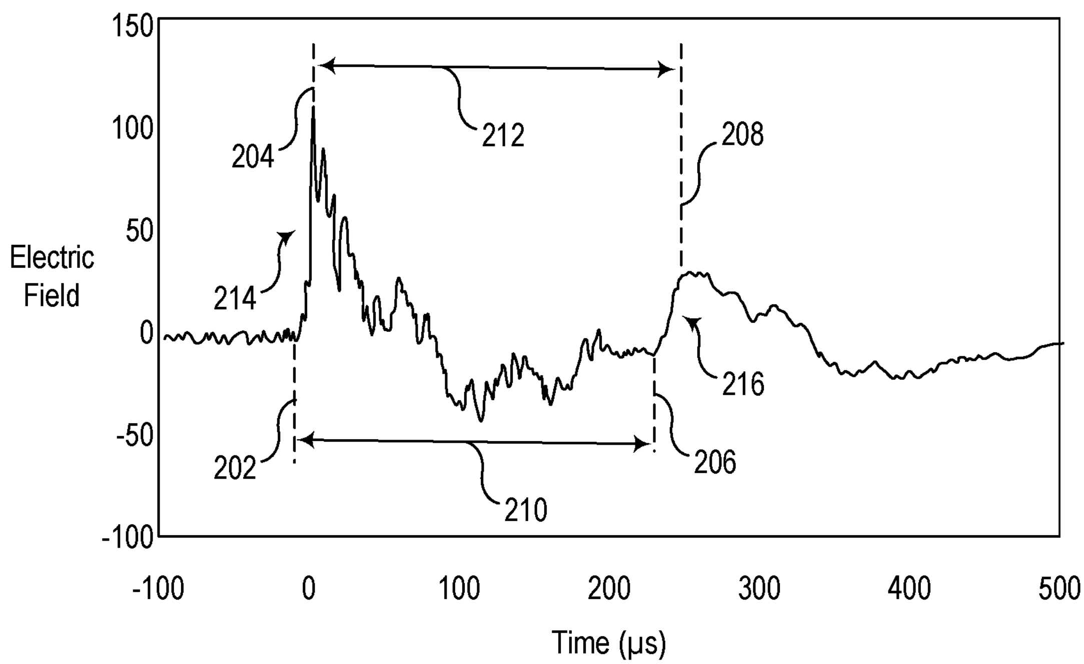


Figure 2B

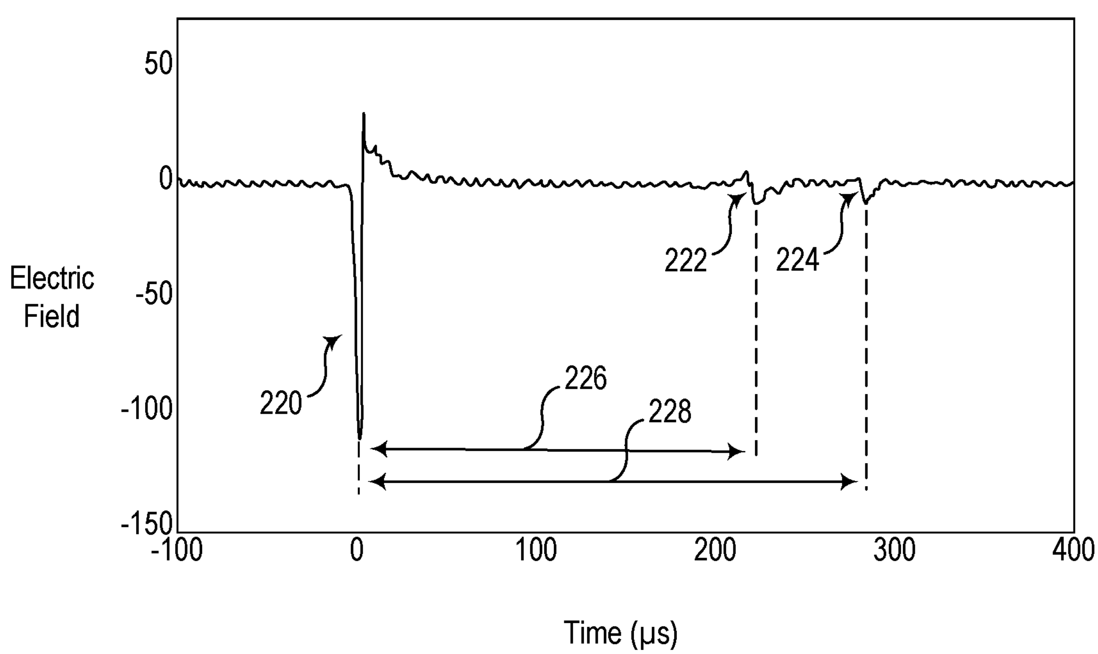


Figure 3

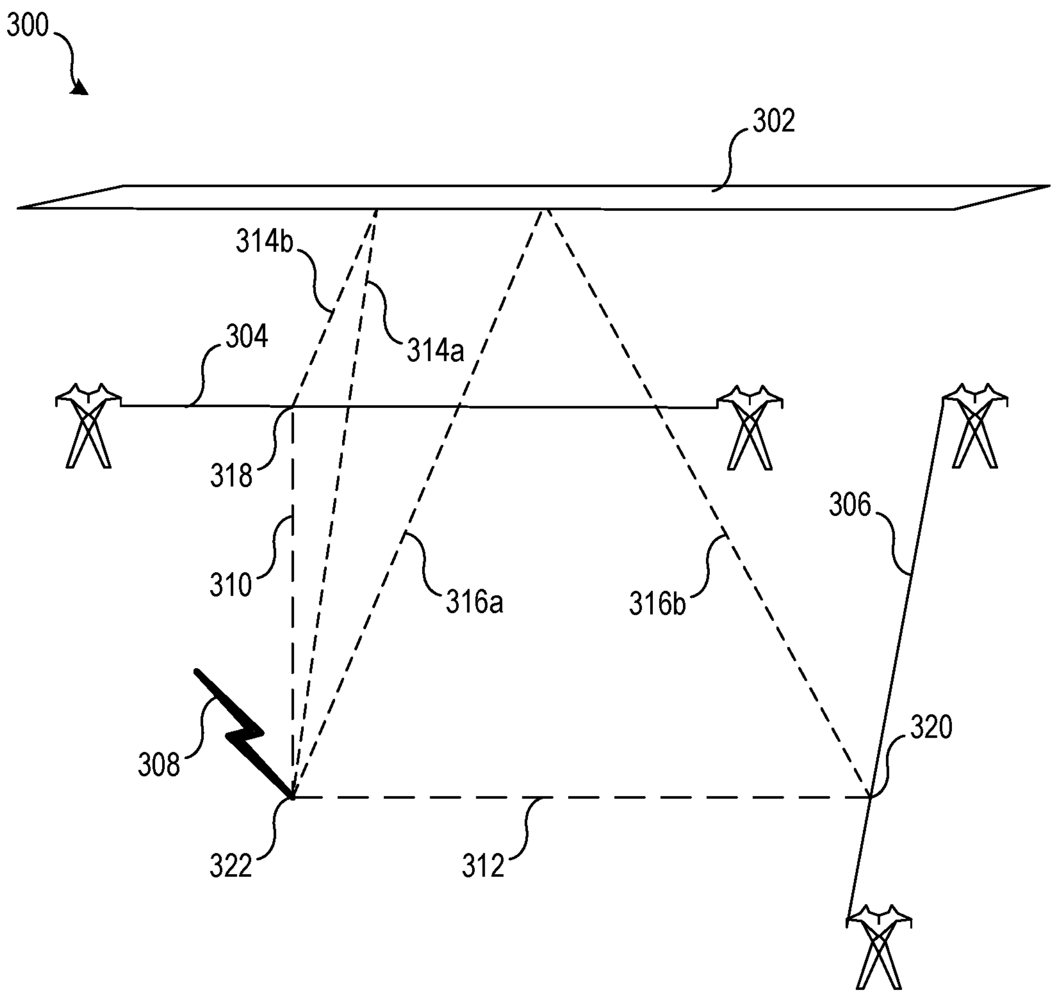
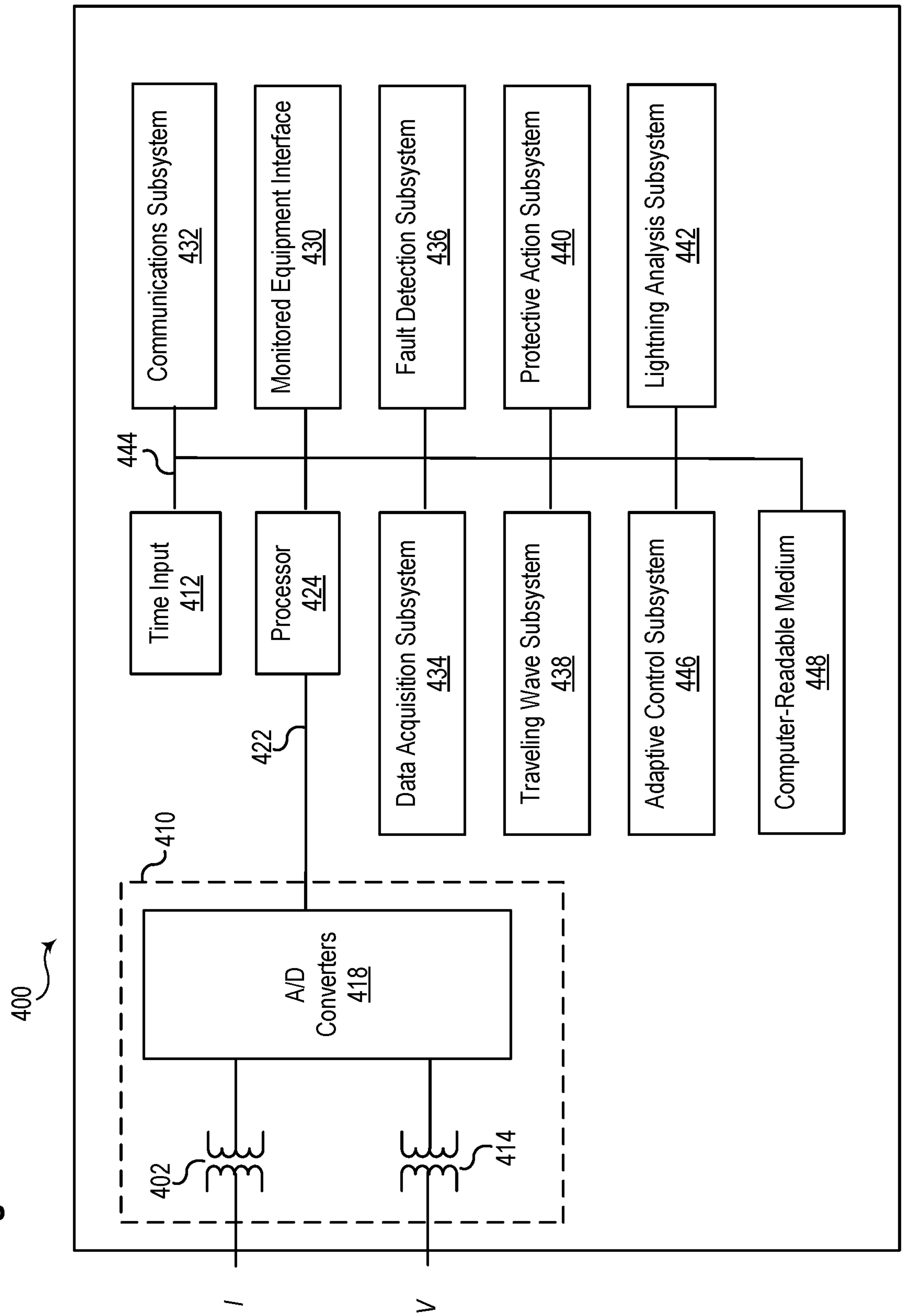


Figure 4


400
Communications Subsystem 432
Monitored Equipment Interface 430
Fault Detection Subsystem 436
Protective Action Subsystem 440
Lightning Analysis Subsystem 442
444
Time Input 412
Processor 424
Data Acquisition Subsystem 434
Traveling Wave Subsystem 438
Adaptive Control Subsystem 446
Computer-Readable Medium 448
422
410
A/D Converters 418
402
414
I
V

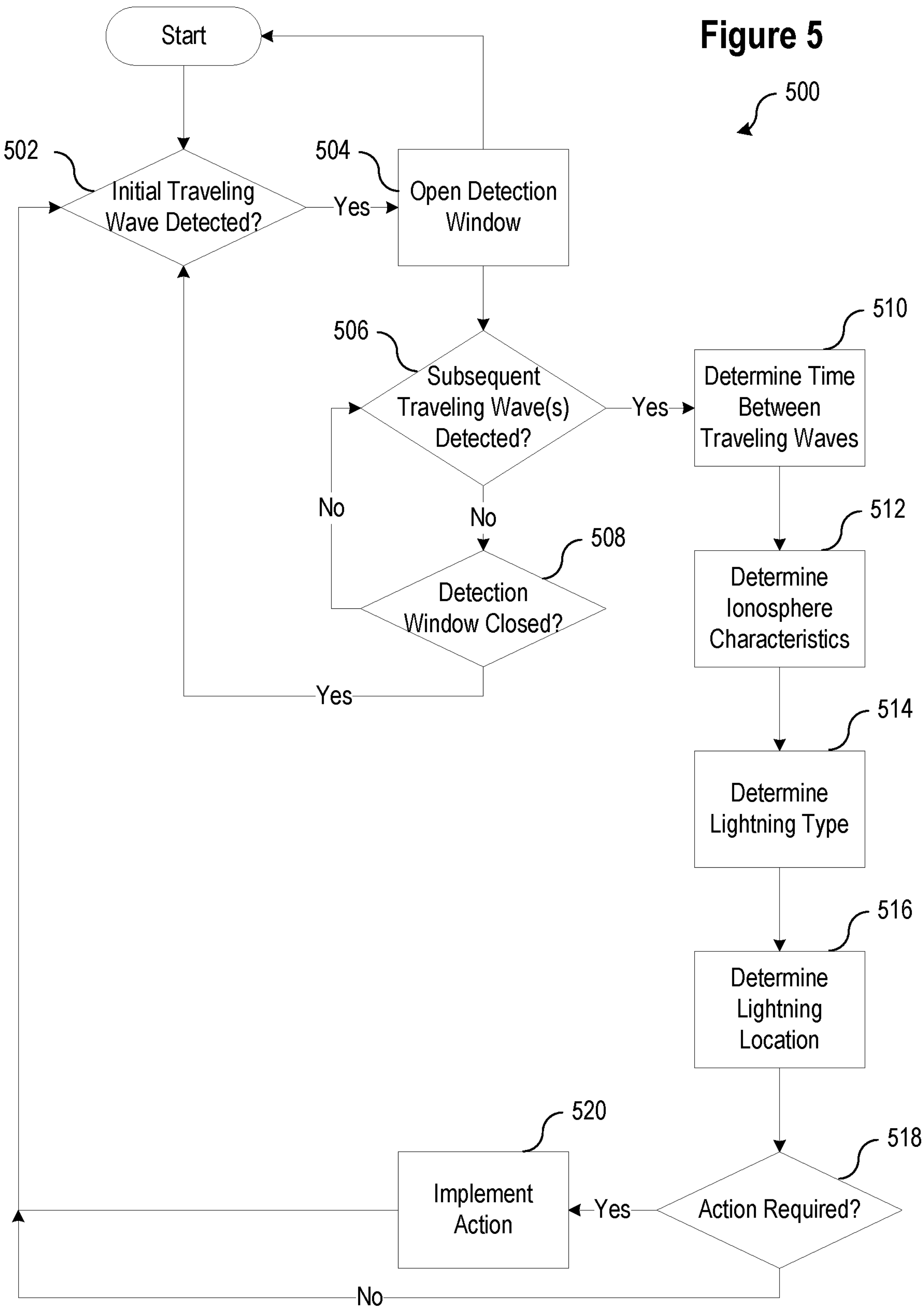

Start
502
Initial Traveling Wave Detected?
Yes
504
Open Detection Window
506
Subsequent Traveling Wave(s) Detected?
Yes
No
No
508
Detection Window Closed?
Yes
510
Determine Time Between Traveling Waves
512
Determine Ionosphere Characteristics
514
Determine Lightning Type
516
Determine Lightning Location
518
Action Required?
Yes
520
Implement Action
No
500

Figure 5

DETECTION OF LIGHTNING AND RELATED CONTROL STRATEGIES IN ELECTRIC POWER SYSTEMS

TECHNICAL FIELD

The present disclosure pertains to systems and methods for detecting lightning and using such information to implement appropriate control strategies in an electric power system.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting and non-exhaustive embodiments of the disclosure are described, including various embodiments of the disclosure, with reference to the figures, in which:

FIG. **1**A illustrates a conceptual representation of a cloud-to-ground-lightning strike along with a ground wave and skywave that may be detected by an electric power system consistent with embodiments of the present disclosure.

FIG. **1**B illustrates a conceptual representation of a compact intracloud discharge (CID) along with two skywaves that may be detected by an electric power system consistent with embodiments of the present disclosure.

FIG. **2**A illustrates a plot over time of an electric field measured at a receiver and generated from a CG lightning strike consistent with embodiments of the present disclosure.

FIG. **2**B illustrates a plot over time of an electric field measured at a receiver and generated from CID lightning consistent with embodiments of the present disclosure.

FIG. **3** illustrates a conceptual planar diagram of a system to determine a location of a lightning strike consistent with embodiments of the present disclosure.

FIG. **4** illustrates a functional block diagram of a system to detect lightning by identifying and analyzing traveling waves and to implement adaptive control strategies consistent with embodiments of the present disclosure.

FIG. **5** illustrates a flow chart of a method to detect lightning by identifying and analyzing traveling waves and to implement adaptive control strategies consistent with embodiments of the present disclosure.

DETAILED DESCRIPTION

Electrical power systems are required to operate in a variety of conditions and while exposed to potential damage from weather and other elements. The weather can have a significant impact on the operation of electric power systems and the techniques used to control such systems.

In various embodiments consistent with the present disclosure, systems may detect lightning and adjust control strategies in response to lightning. Lightning may couple to conductors in electric power systems and create traveling waves that may be detected by high-speed monitoring systems associated with such electrical conductors. Traveling waves are transient signals that propagate at nearly the speed of light, and as such, high-speed monitoring is necessary to detect and analyze traveling waves. In some embodiments, high-speed detection systems may generate one million samples per second or more of electrical parameters (e.g., voltage).

Information related to lightning may be used to adjust the control strategies used in connection with the electric power system. Various embodiments consistent with the present disclosure may provide a variety of types of information (e.g., the type of lightning, the location of the lightning, the

rate of lightning, etc.) that may be used to adjust control strategies used in an electric power system. For example, during lightning storms, certain control strategies (e.g., automatic reclosure following trips) may be retrained to reduce the risk of fire. Further, such information may be used to change relay settings or group settings, change wide-area remedial action scheme (RAS) behavior, and inform system operators of potential issues.

If a power system operator (or RAS) has real-time knowledge of a likelihood of specific assets having a decreased reliability due to lightning, they can take proactive measures. Such measures may include bringing online redundant capacity/lines, postponing outages, coordinating with neighboring utilities, and the like. A lightning strike may trigger a protective relay (removing equipment from service due to over-voltage conditions), or cause damage to power system equipment, which would then be mitigated by a protective relay. In either scenario, the removal of service of a power system device, can cause weakness in overall stability of a power system. Using time and location information of an evolving lightning storm, the operator of a power system may respond appropriately.

In addition to using information related to lightning for control of an electric power system, such information may also provide valuable information about weather conditions and the ionosphere. Information about lightning is typically obtained using specialized sensors. Such sensors are both expensive and limited in area, where electric power systems are widely distributed and systems and methods consistent with the present disclosure may be retrofitted into an existing electrical power system. As such, information may be gathered from large areas using existing infrastructure. Such information may be useful for weather and atmospheric prediction, modeling, and research.

The embodiments of the disclosure will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout. It will be readily understood that the components of the disclosed embodiments, as generally described and illustrated in the figures herein, could be arranged and designed in a wide variety of different configurations. Thus, the following detailed description of the embodiments of the systems and methods of the disclosure is not intended to limit the scope of the disclosure, as claimed, but is merely representative of possible embodiments of the disclosure. In addition, the steps of a method do not necessarily need to be executed in any specific order, or even sequentially, nor need the steps be executed only once unless otherwise specified.

In some cases, well-known features, structures, or operations are not shown or described in detail. Furthermore, the described features, structures, or operations may be combined in any suitable manner in one or more embodiments. It will also be readily understood that the components of the embodiments as generally described and illustrated in the figures herein could be arranged and designed in a wide variety of different configurations.

Several aspects of the embodiments described may be implemented as software modules or components. As used herein, a software module or component may include any type of computer instruction or computer-executable code located within a memory device and/or transmitted as electronic signals over a system bus or wired or wireless network. A software module or component may, for instance, comprise one or more physical or logical blocks of computer instructions, which may be organized as a routine, program, object, component, data structure, etc. that performs one or more tasks or implements particular abstract data types.

In certain embodiments, a particular software module or component may comprise disparate instructions stored in different locations of a memory device, which together implement the described functionality of the module. Indeed, a module or component may comprise a single instruction or many instructions, and may be distributed over several different code segments, among different programs, and across several memory devices. Some embodiments may be practiced in a distributed computing environment where tasks are performed by a remote processing device linked through a communications network. In a distributed computing environment, software modules or components may be located in local and/or remote memory storage devices. In addition, data being tied or rendered together in a database record may be resident in the same memory device, or across several memory devices, and may be linked together in fields of a record in a database across a network.

Embodiments may be provided as a computer program product including a non-transitory computer and/or machine-readable medium having stored thereon instructions that may be used to program a computer (or another electronic device) to perform processes described herein. For example, a non-transitory computer-readable medium may store instructions that, when executed by a processor of a computer system, cause the processor to perform certain methods disclosed herein. The non-transitory computer-readable medium may include, but is not limited to, hard drives, floppy diskettes, optical disks, CD-ROMs, DVD-ROMs, ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, solid-state memory devices, or other types of machine-readable media suitable for storing electronic and/or processor-executable instructions.

FIG. **1**A illustrates a conceptual representation **100** of a cloud-to-ground ("CG") lightning strike **104** along with a groundwave **108** and skywave **110***a*, **110***b* that may be detected by an electric power system consistent with embodiments of the present disclosure. CG lightning **104** strikes the ground at point **102** at time t_0 and launches a groundwave **108**. The groundwave **108** propagates a distance **106** before being detected by a receiver **114** located at a distance, r, from the point **102** at which the CG lightning strike **104** occurred.

The CG lightning strike **104** also launches a skywave **110***a* that reflects **110***b* off of the ionosphere **116** before being detected by receiver **114**. The additional distance traveled by the skywave **110** in comparison to the groundwave **108** results in a temporal delay, t_1, between when the groundwave **108** and the skywave **110**. The height **118** of the ionosphere **116**, H_p, may be determined using the temporal delay, t_1, the distance, r, and the speed of light, c, as shown in Eq. 1.

$$H_p = \frac{\sqrt{(ct_1)^2 + 2 \cdot ct_1 r}}{2} \qquad \text{Eq. 1}$$

Various embodiments may use different techniques to determine the height **118** of the ionosphere **116**, H_p, and the distance, r. In some embodiments, multiple measurement locations may be used, and the height **118** of the ionosphere **116**, H_p, may be considered a constant across the measurements. As such, one variable may be eliminated and a values for both the height **118** of the ionosphere **116**, H_p, and the distance, r, may be determined. Further, in some embodiments, multiple lightning strikes may be analyzed over a span of time. The height **118** of the ionosphere **116**, H_p, may be considered a constant across measurements relatively close in time. This strategy again allows for one variable to be eliminated and for values of both the height **118** of the ionosphere **116**, H_p, and the distance, r, to be determine. In yet other embodiments, a system of equations may be determined and solved using multiple lighting strikes, spectral attenuation may be used to estimate a distance the distance, r, and/or vector direction finding may be used.

In various embodiments of the present disclosure, an electric power system may act as the receiver **114**. CG lightning strike **104** induces a transient signal in transmission and/or distribution lines of the electric power system that may be detected using a high-speed (e.g., one million samples per second) monitoring system. One specific embodiment comprises the SEL-T400L Time-Domain Line Production relay available from Schweitzer Engineering Laboratories of Pullman, Washington, which samples electric parameters at a rate of one million samples per second. Groundwave **108** and skywave **110** create a high-speed transient signal that may each be detected and used in Eq. 1 to calculate the height **118** of the ionosphere **116**.

Detection of lightning in proximity to an electric power system may be used to adjust control strategies. For example, various responses of the system may be made more sensitive to potential lightning strikes or made more robust. Further, strategies could be implemented to mitigate against the potential for fire caused by equipment in the electric power system (e.g., blocking recloser algorithms).

FIG. **1**B illustrates a conceptual representation of a compact intracloud discharge (CID) **128** along with skywaves **122**, **124**, and **126** that may be detected by an electric power system consistent with embodiments of the present disclosure. The CID **128** occurs at t_0 and at a distance **106** from receiver **114**. Skywave **126** follows a direct path from CID **128**, and thus arrives at receiver **114** at t_1 before skywaves **122** and **124**, both of which must reflect before arriving at receiver **114**. Skywave **122***a* travels from CID **128** and reflects off ionosphere **116**. Skywave **122***b* travels from the point of reflection off the ionosphere **116** before reaching receiver **114** at t_2. Skywave **124***a* travels from CID **128** and reflects off of the ground. The reflection, skywave **124***b*, reflects again off the ionosphere **116**, creating skywave **124***c*, which is detected by receiver **114** at t_3.

As described below, the times of arrival of each skywave (i.e., t_1, t_2, and t_3) may be analyzed to determine the height **120** of CID **128**, the height **118** of the ionosphere **116**, and the distance **106** between the CID **128** and the receiver **114**. Further, detection of three skywaves (as opposed to detection of a groundwave and a skywave) differentiates CID lightning from CG lightning. All of this information may be used by an electric power system to adjust a control strategy.

FIG. **2**A illustrates a plot over time of an electric field measured at a receiver and generated from a CG lightning strike consistent with embodiments of the present disclosure. The CG lightning strike creates a first traveling wave **214** corresponding to a groundwave and a second traveling wave corresponding to a skywave **216**. The time between the arrival of the first traveling wave **214** and the second traveling wave **216** may be used with Eq. 1 to determine the height of the ionosphere. Other parameters, such as a distance between the CG lightning strike and a receiver may also be determined.

The time between the arrival of the first traveling wave **214** and the second traveling wave **216** may be determined using various schemes. For example, one scheme may detect a time delay **210** between the start of the ramp (i.e., points **202** and **206**) of each traveling wave **214**, **216**. Another scheme may detect a time delay **212** between a peak value **204** of the first traveling wave **214** and a peak value **208** of the second traveling wave **216**.

FIG. **2**B illustrates a plot over time of an electric field measured at a receiver and generated from CID lightning consistent with embodiments of the present disclosure. A first traveling wave **220** may be generated by a skywave that follows a direct path from the CID to a receiver. A second traveling wave **222** may be generated by a skywave that reflects off the ionosphere before being detected by the receiver. A third traveling wave **224** may be generated by a skywave that first reflects off the ground, then reflects off the ionosphere before being detected by the receiver. Using information about the time **226** between the first skywave **220** and the second skywave **222**, along with the time **228** between the first skywave **220** and the third skywave **224**, a system may estimate both the height of the CID lightning and the ionosphere.

In connection with both FIG. **2**A and FIG. **2**B, a skywave detection subsystem and/or a groundwave detection subsystem may detect an initial traveling wave and subsequent traveling waves. In various embodiments, detection of an initial traveling wave may open a detection window for identification of a subsequent traveling wave. The length of the window may be determined by the length of the transmission line associated with the first traveling wave. If a subsequent traveling wave is not detected within the window, the window may close. Closure of the window without detection of a subsequent traveling wave may be an indication that the initial traveling wave was caused by a phenomena other than lightning.

FIG. **3** illustrates a conceptual planar diagram of a system **300** to determine a location **322** of a lightning strike **308** consistent with embodiments of the present disclosure. System **300** includes two transmission lines **304** and **306**. Lightning strike **308** strikes at location **322** and generates ground waves **310** and **312**, which propagate toward transmission lines **304** and **306**, respectively. Lightning strike **308** also launches skywaves **314** and **316**. Skywaves **314***a* and **316***a* travel from lightning strike **308** toward ionosphere **302**. Reflections of skywaves **314***b* and **316***b* reflect off of ionosphere **302** and back toward transmission lines **304** and **306**, respectively.

Ground waves **310** and **312** and skywaves **314** and **316** may be detected by high-speed monitoring systems associated with transmission lines **304** and **306**. Using the techniques described above, system **300** may identify locations **318** and **320** along transmission lines **304** and **306**, respectively, at which the lightning strike **308** occurred. The peaks of waves **314** and **316** correspond to the shortest path to transmission lines **304** and **306**. Using the locations **318** and **320**, system **300** may determine the location **322** of the lightning strike **308**.

FIG. **4** illustrates a functional block diagram of a system **400** to detect lightning by identifying and analyzing traveling waves and to implement adaptive control strategies consistent with embodiments of the present disclosure. System **400** may be implemented using hardware, software, firmware, and/or any combination thereof. In some embodiments, system **400** may be embodied as an IED, while in other embodiments, certain components or functions described herein may be associated with other devices or performed by other devices. The specifically illustrated configuration is merely representative of one embodiment consistent with the present disclosure.

System **400** includes a communications subsystem **432** to communicate with devices and/or IEDs. In certain embodiments, communications subsystem **432** may facilitate direct communication with other IEDs or communicate with systems over a communications network. Measurements relating to electrical conditions and other information used by system **400** may be transmitted via communications subsystem **432**. Further, measurements and information created by system **400** may be transmitted via communications subsystem **432** to other components.

A monitored equipment interface **430** may receive status information from, and issue control instructions to, a piece of monitored equipment (e.g., a generator, transformer, circuit breaker, or the like). Monitored equipment interface **430** may implement control actions upon the detection of an over-excitation condition. Such instructions may include changing an excitation of a generator or a transformer or disconnecting a generator or a transformer.

Processor **424** processes communications received via communications subsystem **432**, monitored equipment interface **430**, and the other subsystems and components in system **400**. Processor **424** may operate using any number of processing rates and architectures. Processor **424** may perform various algorithms and calculations described herein. Processor **424** may be embodied as a general-purpose integrated circuit, an application-specific integrated circuit, a field-programmable gate array, and/or any other suitable programmable logic device. Processor **424** may communicate with other elements in system **400** by way of bus **444**.

Computer-readable medium **448** may comprise any of a variety of non-transitory computer-readable storage media. Computer-readable medium **448** may comprise executable instructions to perform processes described herein. Computer-readable medium **448** may comprise non-transitory machine-readable media such as, but is not limited to, hard drives, removable media, optical disks, CD-ROMs, DVD-ROMs, ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, solid-state memory devices, or other types of media/machine-readable media suitable for storing electronic instructions. Such electronic instructions may be executed on processor **424**.

A sensor subsystem **410** may receive current measurements (I) and/or voltage measurements (V). The sensor subsystem **410** may comprise A/D converters **418** that sample and/or digitize filtered waveforms to form corresponding digitized current and voltage signals provided to a data bus **422**. A high-fidelity current transformer **402** and/or a high-fidelity voltage transformer **414** may include separate signals from each phase of a three-phase electric power system. A/D converters **418** may be connected to processor **424** by way of data bus **422**, through which digitized representations of current and voltage signals may be transmitted to processor **424**.

Although the illustrated embodiment encompasses sensor component **410**, in other embodiments, representations of electrical conditions may be received through a variety of types of data acquisition interfaces. For example, digitized representations may be received via communications subsystem **432**. In another example, monitored equipment interface **430** may be configured to receive high-speed representations of electrical conditions from another device. A variety of types of data acquisition systems may be used consistent with the present disclosure.

System **400** may further comprise a time input **412**, which may be used to receive a time signal (e.g., a common time reference) allowing system **400** to apply a time-stamp to the acquired samples. In various embodiments, the common time reference may comprise a time signal derived from a GNSS. In certain embodiments, a common time reference may be received via communications subsystem **432**, and accordingly, a separate time input **412** may not be required for time-stamping and/or synchronization operations. One such embodiment may employ the IEEE 1588 protocol.

Data acquisition subsystem **434** may collect data samples such as the current and voltage measurements. The data samples may be associated with a timestamp and made available for retrieval and/or transmission to a remote IED via communications subsystem **432**. Data acquisition subsystem **434** may operate in conjunction with fault detection subsystem **436**. Data acquisition subsystem **434** may control the recording of data used by the fault detection subsystem **436**. According to one embodiment, data acquisition subsystem **434** may selectively store and retrieve data and may make the data available for further processing. Such processing may include processing by fault detection subsystem **436**, which may be configured to determine the occurrence of a fault within an electric power distribution system.

Traveling wave subsystem **438** may operate in conjunction with data acquisition subsystem **434** to measure and record traveling waves in real-time since they are transient signals that dissipate rapidly in an electric power delivery system. Traveling waves may also be analyzed in conjunction with fault detection subsystem **436** to identify the occurrence of a fault and the location of the source of traveling waves. Traveling wave subsystem **438** may further determine whether a traveling wave was generated by lightning or other events in the electric power system, such as faults. Faults may launch traveling waves that may be analyzed by fault detection subsystem **436** and used to determine the location of a fault and other information (e.g., the type of fault).

A protective action subsystem **440** may implement a protective action based on the identification of a fault by fault detection subsystem **436**. In various embodiments, a protective action may include tripping a breaker, selectively isolating a portion of the electric power system, etc. Protective action subsystem **440** may coordinate protective actions with other devices in communication with system **400**.

A lightning analysis subsystem **442** may operate in conjunction with traveling wave subsystem **438** to identify and analyze groundwaves and skywaves caused by lightning. Among other things, lightning analysis subsystem **442** may determine times between groundwaves and skywaves and may use such information to calculate the height of the ionosphere and the height of CID lightning. Based on the analysis of the times between groundwaves and skywaves, lightning analysis subsystem **442** may identify a location of a lightning strike. In one specific embodiment, a location may be determined using the principles described in connection with FIG. **3**.

An adaptive control subsystem **446** may adapt a control strategy implemented by system **400** based on detection of lightning. For example, various responses of the system **400** may be made more sensitive to potential lightning strikes or made more robust. Further, strategies could be implemented to mitigate against the potential for fire caused by equipment in the electric power system (e.g., blocking recloser algorithms).

FIG. **5** illustrates a flow chart of a method **500** to detect lightning by identifying and analyzing traveling waves and to implement adaptive control strategies consistent with embodiments of the present disclosure. At **502**, a system implementing method **500** may determine whether an initial traveling wave has been detected. An initial traveling wave may represent a ground wave (e.g., groundwave **214** illustrated in FIG. **2**A) or a skywave (e.g., skywave **220** illustrated in FIG. **2**B). An initial wave may be detected by a groundwave and skywave analysis subsystem, such as lightning analysis subsystem **442** illustrated in FIG. **4**). Method **500** may remain at **502** until an initial traveling wave is detected.

Upon detection of an initial traveling wave, a detection window may open at **504**. The length of the detection window may be determined by the length of the transmission line associated with the initial traveling wave. At **506**, a system implementing method **500** may determine whether one or more subsequent traveling waves are detected. The subsequent traveling waves may be ground waves or skywaves. At **508**, a system implementing method **500** may determine whether the detection window has closed. Closure of the detection window without detection of a subsequent traveling wave may be an indication that the initial traveling wave was caused by a phenomena other than lightning.

If a subsequent traveling wave is detected at **506**, a time between the traveling waves may be determined at **510**. Where multiple subsequent traveling waves are detected, the time between the initial traveling wave and each subsequent traveling wave may be determined, as illustrated in FIG. **2**B and described above.

At **512**, **514**, and **516**, various types of information may be determined. At **512**, the ionosphere characteristics may be determined using the time between traveling waves determined at **510**. The ionosphere characteristics may include the height of the ionosphere at different locations. At **514**, the type of lightning type may be determined. In various embodiments, CG and CID lightning may be identified. In one embodiment, a lightning analysis subsystem, such as lightning analysis subsystem **442** in FIG. **4**, may determine the ionosphere characteristics and the type of lightning. At **516**, the location of the lightning may be determined. In one embodiment, a location subsystem, may be used to determine the location of the lightning.

At **518**, a system a system implementing method **500** may determine whether action is required. Various types of action may be implemented at **520**. In one embodiment, the action may include adapting a control strategy. For example, various responses of the system may be made more sensitive to potential lightning strikes or made more robust. An adaptive control subsystem, such as adaptive control subsystem **446** in FIG. **4** may be used to modify a control strategy. Still further, a protective action subsystem, such as protective action subsystem **440** in FIG. **4**, may implement protective actions based on lightning detection.

While specific embodiments and applications of the disclosure have been illustrated and described, it is to be understood that the disclosure is not limited to the precise configurations and components disclosed herein. Accordingly, many changes may be made to the details of the above-described embodiments without departing from the underlying principles of this disclosure. The scope of the present invention should, therefore, be determined only by the following claims.

What is claimed is:

1. A system to detect lightning and to control at least a portion of an electric power system, the system comprising:

a data acquisition subsystem configured to receive a plurality of representations of electrical conditions associated with at least a portion of the electric power system;

a traveling wave subsystem to:

identify an initial traveling wave generated by lightning and traveling in an electrical conductor configured to provide electric power as part of the electric power;

open a detection window upon detection of the initial traveling wave;

monitor for at least one subsequent traveling wave during the detection window; and

identify the at least one subsequent traveling wave generated by lightning and traveling in the electrical conductor configured to provide electric power as part of the electric power;

a lightning analysis subsystem to perform an analysis of the initial traveling wave and the at least one subsequent traveling wave and to determine:

an ionosphere characteristic based on the analysis; and

a lightning location; and

an adaptive control subsystem to adjust a control strategy based on the lightning location and during the detection window;

wherein, the adjusting of the control strategy comprises blocking an automatic reclosure algorithm following a trip, and the adjusting of the control strategy is retrained to reduce the risk of fire.

2. The system of claim **1**, wherein the lightning analysis subsystem is further configured to determine a type of lightning based on the analysis of the initial traveling wave and the at least one subsequent traveling wave.

3. The system of claim **2**, wherein the type of lightning comprises one of cloud-to-ground (CG) lightning and compact intracloud discharge (CID) lightning.

4. The system of claim **3**, wherein the lightning analysis subsystem is further configured to determine a height of CID lightning.

5. The system of claim **1**, wherein the data acquisition subsystem is configured to receive about one million representations of electrical conditions per second.

6. The system of claim **1**, wherein the ionosphere characteristic comprises a height.

7. The system of claim **1**, wherein the lightning analysis subsystem is configured to determine the lightning location based on information gathered from at least two transmission lines in the electric power system.

8. The system of claim **1**, wherein the traveling wave subsystem is further configured to detect a plurality of traveling waves generated by a fault, and further comprises a protective action subsystem to implement a protective action in response to the fault.

9. The system of claim **1**, wherein the energized electrical conductor comprises a transmission line.

10. The system of claim **1**, wherein the energized electrical conductor comprises a distribution line.

11. A method of detecting lightning and controlling at least a portion of an electric power system, the method comprising:

receiving, using a data acquisition subsystem, a plurality of representations of electrical conditions associated with at least a portion of the electric power system;

identifying, using a traveling wave subsystem, an initial traveling wave generated by lightning and traveling in an electrical conductor configured to provide electric power as part of the electric power system;

opening, using the traveling wave subsystem, a detection window upon detection of the initial traveling wave;

monitoring, using the traveling wave subsystem, for at least one subsequent traveling wave during the detection window;

identifying, using the traveling wave subsystem, the at least one subsequent traveling wave generated by lightning and traveling in the electrical conductor configured to provide electric power as part of the electric power;

performing, using a lightning analysis subsystem, an analysis of the initial traveling wave and the at least one subsequent traveling wave to determine:

an ionosphere characteristic based on the analysis; and

a lightning location; and

adjusting, using an adaptive control subsystem, a control strategy based on the lightning location and during the detection window;

wherein, adjusting the control strategy comprises blocking an automatic reclosure algorithm following a trip to reduce the risk of fire.

12. The method of claim **11**, further comprising determining, using the lightning analysis subsystem, a type of lightning based on the analysis of the initial traveling wave and the at least one subsequent traveling wave.

13. The method of claim **12**, wherein the type of lightning comprises one of cloud-to-ground (CG) lightning and compact intracloud discharge (CID) lightning.

14. The method of claim **13**, further comprising determining, using the lightning analysis subsystem, a height of CID lightning.

15. The method of claim **11**, wherein the plurality of representations received by the data acquisition subsystem comprise about one million representations of electrical conditions per second.

16. The method of claim **11**, wherein the ionosphere characteristic comprises a height.

17. The method of claim **11**, further comprising opening, using the traveling wave subsystem, a detection window upon detection of the initial traveling wave and monitoring for the at least one subsequent traveling wave during the detection window.

18. The method of claim **11**, further comprising gathering, using the lightning analysis subsystem, information from at least two transmission lines in the electric power system to determine the lightning location.

19. The method of claim **11**, further comprising: detecting, using the traveling wave subsystem, a plurality of traveling waves generated by a fault; and implementing, using a protective action subsystem, a protective action in response to the fault.

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