

DESCRIPTION

TITLE OF INVENTION:

Insulation Deterioration Detection System and Insulation Deterioration
5 Detection Method

TECHNICAL FIELD

[0001] The present disclosure relates to an insulation deterioration detection system and an insulation deterioration detection method, and more particularly, to detection of a partial discharge.

10 BACKGROUND ART

[0002] An electrical device undergoes deterioration in insulating properties of an insulator on a surface of the electrical device or inside the electrical device due to aging. When the insulating properties deteriorate, a partial discharge occurs at a location of deterioration. Further, if the deterioration of insulating properties
15 progresses, an insulation breakdown occurs. The insulation breakdown causes a serious accident such as a ground fault. Thus, in the maintenance and servicing of electrical devices, the operation to detect a partial discharge is performed (see PTLs 1 and 2).

CITATION LIST

20 PATENT LITERATURE

[0003] PTL 1: Japanese Patent Laying-Open No. 2019-211431

PTL 2: Japanese Patent Laying-Open No. 2022-78825

SUMMARY OF INVENTION

TECHNICAL PROBLEM

25 [0004] In this regard, conventional methods measure a wide frequency band, making it difficult to distinguish between electromagnetic waves of partial discharges or spark discharges and noise at some frequencies. Consequently, discharge detection may fail, requiring further improvements in high-precision discharge detection.

[0005] The present disclosure has been made to solve the above problem. An object

of the present disclosure is to provide an insulation deterioration detection system and an insulation deterioration detection method capable of high-precision discharge detection.

SOLUTION TO PROBLEM

5 [0006] An insulation deterioration detection system of the present disclosure includes: an antenna provided in a power receiving and distributing facility for detecting a radio wave; a detection unit connected to the antenna, the detection unit detecting a radio signal through the antenna; and a determination unit that detects a discharge of the power receiving and distributing facility based on the radio signal detected by the
10 detection unit and a relationship with an alternating-current (AC) power supply of the power receiving and distributing facility in detection of the radio signal. The antenna detects a radio signal originating from a partial discharge or a spark discharge in a band of at least 180 MHz to 800 MHz.

[0007] Preferably, the detection unit includes a peak hold circuit that holds a maximum
15 value of the radio signal received by the antenna.

[0008] Preferably, the determination unit detects a discharge of the power receiving and distributing facility based on the radio signal detected by the detection unit and a phase relationship of a three-phase AC power supply of the power receiving and distributing facility in detection of the radio signal.

20 [0009] Preferably, the determination unit detects a discharge of the power receiving and distributing facility when the detection unit detects the radio signal at a rising edge or a falling edge of any phase of the three-phase AC power supply of the power receiving and distributing facility.

[0010] Preferably, the determination unit detects a discharge of the power receiving
25 and distributing facility when the detection unit detects the radio signal in a cycle obtained by multiplying a frequency of the AC power supply of the power receiving and distributing facility by a constant.

[0011] Preferably, the determination unit detects a discharge of the power receiving and distributing facility when the detection unit detects the radio signal two or more

times during one cycle of the AC power supply of the power receiving and distributing facility.

[0012] Preferably, the determination unit detects another discharge of the power receiving and distributing facility when detecting another radio signal at a position 60° or 120° out of phase in the AC power supply relative to a radio signal detected when the detection unit detects the radio signal two or more times during one cycle of the AC power supply of the power receiving and distributing facility.

[0013] Preferably, the radio signal has a specific distribution relative to a phase of the AC power supply.

10 Preferably, the specific distribution is a normal distribution.

[0014] Preferably, the determination unit detects a discharge of the power receiving and distributing facility based on the relationship with the AC power supply of the power receiving and distributing facility when a signal amplitude of the radio signal is greater than or equal to a threshold and when the radio signal is detected.

15 [0015] Preferably, the determination unit detects a spark discharge of the power receiving and distributing facility based on the relationship with the AC power supply of the power receiving and distributing facility when the signal amplitude of the radio signal is greater than or equal to a first threshold and when the radio signal is detected, and the determination unit detects a partial discharge of the power receiving and distributing facility based on the relationship with the AC power supply of the power receiving and distributing facility when the signal amplitude of the radio signal is greater than or equal to a second threshold and less than the first threshold, and when the radio signal is detected.

20 [0016] Preferably, the antenna is placed to face an insulator in the power receiving and distributing facility.

25 Preferably, the antenna is placed to face a bus and a cable that are in proximity to or in contact with an insulator that causes a possible partial discharge in the power receiving and distributing facility.

[0017] Preferably, the insulator is an epoxy resin or a polyester resin.

Preferably, the insulator is porcelain or ceramic.

[0018] Preferably, the power receiving and distributing facility is provided with a plurality of antennas, a plurality of the detection units are further provided respectively in correspondence with the plurality of antennas, and the insulation deterioration
5 detection system further includes a display unit that displays detection results from the plurality of detection units.

[0019] Preferably, the display unit displays a screen showing a distribution comparison between signal intensities of respective radio signals from a plurality of the detection units.

10 [0020] Preferably, the insulation deterioration detection system further includes a position determination unit that determines, based on signal intensities of respective radio signals from a plurality of the detection units, a discharge location in the power receiving and distributing facility.

[0021] Preferably, the position determination unit determines, based on a distribution
15 comparison between signal intensities of respective radio signals from the plurality of detection units, a discharge location in the power receiving and distributing facility, and the display unit displays the discharge location in the power receiving and distributing facility determined by the position determination unit.

[0022] Preferably, the antenna is a monopole antenna including an inverted F-antenna
20 or an inverted L-antenna, and a counterpoise of the monopole antenna and a conductor are brought into conduction, the conductor serving as a reference potential of the power receiving and distributing facility.

[0023] Preferably, the antenna detects a radio wave in a band, of the band of at least
25 180 MHz to 800 MHz, with a largest difference in signal intensity between a radio signal originating from a discharge and a radio signal originating from noise when no discharge has occurred.

[0024] An insulation deterioration detection method of the present disclosure includes: detecting a radio signal via an antenna provided in a power receiving and distributing facility; and detecting a discharge of the power receiving and distributing facility based

on the detected radio signal and a relationship with an AC power supply of the power receiving and distributing facility in detection of the radio signal, wherein the detecting detects a radio wave originating from a partial discharge or a spark discharge in a band of at least 180 MHz to 800 MHz.

5 ADVANTAGEOUS EFFECTS OF INVENTION

[0025] The insulation deterioration detection system and the insulation deterioration detection method of the present disclosure enable detection of weak discharges at the early stage of insulation deterioration by increasing the detection sensitivity of electromagnetic waves originating from discharges and decreasing the detection
10 sensitivity of electromagnetic waves that are not originating from discharges, and also, enable high-precision discharge detection by reducing false detections caused by electromagnetic waves that are not originating from discharges.

BRIEF DESCRIPTION OF DRAWINGS

[0026] Fig. 1 is a diagram illustrating a power reception and transformation facility 1
15 according to Embodiment 1.

Fig. 2 is a diagram illustrating the appearance of a switchboard 10B according to Embodiment 1.

Fig. 3 is a diagram illustrating an insulation deterioration detection system 100 according to Embodiment 1.

20 Fig. 4 shows experimental results illustrating discharges generated in an epoxy resin insulator of a switchboard 10 in terms of frequency characteristics of radio signals received by an antenna 20, according to Embodiment 1.

Fig. 5 shows experimental results illustrating discharges generated in a polyester resin insulator of switchboard 10 in terms of frequency characteristics of
25 radio signals received by antenna 20, according to Embodiment 1.

Fig. 6 is a diagram illustrating the timing to receive radio signals and the phase relationship of an AC power supply according to Embodiment 1.

Fig. 7 is a diagram illustrating a phase relationship between a three-phase AC power supply and a radio signal according to Embodiment 1.

Fig. 8 is a diagram illustrating a configuration of a detector 40 according to Embodiment 1.

Fig. 9 is a diagram illustrating signal processing of detector 40 according to Embodiment 1.

5 Fig. 10 is a diagram illustrating data output from a PLC 80 to a PC 60 according to Embodiment 1.

Fig. 11 is a flow diagram illustrating determination processing of a determination unit 62 according to Embodiment 1.

10 Fig. 12 is a diagram illustrating a specific example of the detection time of a signal with a high discharge intensity extracted by determination unit 62 according to Embodiment 1.

Fig. 13 is a diagram illustrating display of a display unit 80 of a power reception and transformation facility 1 according to Embodiment 2.

15 Fig. 14 is a diagram illustrating display of display unit 80 of power reception and transformation facility 1 according to a modification of Embodiment 2.

Fig. 15 is a diagram illustrating another display of display unit 80 of power reception and transformation facility 1 according to the modification of Embodiment 2.

Fig. 16 is a diagram illustrating still another display of display unit 80 of power reception and transformation facility 1 according to the modification of Embodiment 2.

20 Fig. 17 is a diagram illustrating display of display unit 80 of power reception and transformation facility 1 according to a second modification of Embodiment 2.

Fig. 18 is a diagram illustrating another display of display unit 80 of power reception and transformation facility 1 according to the second modification of Embodiment 2.

25 Fig. 19 is a diagram illustrating still another display of display unit 80 of power reception and transformation facility 1 according to the second modification of Embodiment 2.

Fig. 20 is a diagram illustrating an insulation deterioration detection system 110 according to Embodiment 3.

DESCRIPTION OF EMBODIMENTS

[0027] The present embodiments will be described in detail with reference to the drawings. In the drawings, the same or corresponding components are denoted by the same reference characters, and description thereof will not be repeated.

5 [0028] Embodiments of the present invention will be described below with reference to the drawings.

(Embodiment 1)

Fig. 1 is a diagram illustrating a power reception and transformation facility 1 according to Embodiment 1. Referring to Fig. 1, power reception and transformation
10 facility 1 is provided with a plurality of switchboards 10A to 10G (hereinafter collectively referred to as switchboards 10). Various electrical devices are provided in switchboards 10 according to purpose. By way of example, a wiring diagram of power reception and transformation facility 1 is shown, illustrating a case where various electrical devices are provided in correspondence with switchboards 10.
15 [0029] Specifically, shown here is a case where switchboard 10A includes a surge arrester (SAR), a circuit breaker (VCB), a current transformer (CT), and an earthed voltage transformer (EVT). Similarly, various electrical devices are provided for switchboards 10B to 10G.

[0030] Fig. 2 is a diagram illustrating the appearance of switchboard 10B according to
20 Embodiment 1. Fig. 2(A) shows a case where circuit breakers (VCBs) are provided above and below the bus. In this example, an additional circuit breaker (VCB) may be provided for one switchboard. For example, circuit breakers (VCBs) may be placed respectively in the upper stage, the middle stage, and the lower stage.

[0031] This example also illustrates a case where an antenna 20 is installed inside the
25 door of switchboard 10B. Providing antenna 20 inside the door can increase discharge detection sensitivity compared to when antenna 20 is provided outside the door of switchboard 10B. Further, while this example shows a case where a detector 40 is provided outside switchboard 10B, detector 40 may be provided inside switchboard 10B. Additionally, antenna 20 may be an inverted F-type antenna or an

inverted L-type antenna. By way of example, this example shows that antenna 20 is provided inside switchboard 10B, and the antenna is connected to the detector via a coaxial cable through a gap in the switchboard, a penetration hole, or a dedicated coaxial connector. It is desirable to measure the smallest possible discharge for maintenance and servicing, and thus, antenna 20 is desirably placed inside the switchboard. However, if radio waves arising from discharges leak out of the switchboard, or if the space for installing antenna 20 cannot be provided inside the power reception and transformation facility, antenna 20 may be placed outside the switchboard.

[0032] Fig. 2(B) is a view as viewed from the side direction of switchboard 10B. Antenna 20 is provided to face the insulator within switchboard 10B. By way of example, antenna 20 is provided to face a conductor support insulator 150 provided for the bus. Conductor support insulator 150 may be an epoxy resin, a polyester resin, porcelain, or ceramic. Further, an epoxy resin or a polyester resin is also used for an insulator such as a CT/PT case or a VCB case. Porcelain or ceramic may be used for a bushing for a transformer or a static capacitor. The epoxy resin, polyester resin, porcelain, or ceramic may generate a partial discharge due to surface contamination.

[0033] A signal originating from a discharge occurring in the insulator within the switchboard propagates to the bus through the conductor connected to the insulator.

Thus, antenna 20 can be placed to face not only the insulator, deterioration of which is anticipated, but also the conductor, that is, the bus and the cable, in proximity to or in contact with the insulator, enabling efficient detection of a radio wave associated with a discharge. This arrangement enables efficient detection of a radio wave associated with a discharge occurring between the equipment connected to the insulator inside the switchboard and antenna 20. Further, using a monopole antenna, such as an inverted F-type antenna or an inverted L-type antenna, for antenna 20 is a desirable embodiment because antenna 20 can have reduced dimensions and can be placed inside the device. Such an antenna has a counterpoise, that is, a ground for the antenna (a conductor serving as a reference potential). However, the counterpoise needs to have a smaller

size such that the antenna has a small size enough to be provided inside the device, which may deteriorate the reception performance of the antenna. Thus, connecting the counterpoise to the conductor of the device directly or via a lead wire is desirable because this increases the size of the counterpoise, stabilizing the reference potential relative to the antenna element of the monopole antenna, which may improve the reception sensitivity of the antenna. Further, connecting the counterpoise to the conductor of the device prevents the counterpoise from becoming electrically charged in the environment with an intense electric field and an intense ferromagnetic field.

[0034] Fig. 3 is a diagram illustrating insulation deterioration detection system 100 according to Embodiment 1.

Referring to Fig. 3, insulation deterioration detection system 100 is provided in correspondence with each of the plurality of switchboards 10A to 10G of power reception and transformation facility 1 and includes an antenna 20 for detecting radio waves, a detector 40 connected to antenna 20 via a coaxial cable 30, a programmable logic controller (PLC) 80, a personal computer (PC) 60, and a display unit 80. This example shows a case where insulation deterioration detection system 100 is provided in switchboards 10A and 10B by way of example. Insulation deterioration detection system 100 may also be provided in correspondence with one switchboard. Detector 40 detects radio signals received by antenna 20. PLC 80, which is connected to an AC power supply correlated with power reception and transformation facility 1, acquires information on the phase relationship of the AC power supply in detection of the radio signal detected by detector 40 and outputs the acquired information to PC 60. PC 60 detects a discharge of power reception and transformation facility 1 based on the information from PLC 80. Specifically, PC 60 includes a determination unit 62 and a screen generation unit 64.

[0035] Determination unit 62 detects a discharge of power reception and transformation facility 1 based on the radio signal detected by detector 40 and the relationship with the AC power supply of power reception and transformation facility 1 in detection of the radio signal. Specifically, determination unit 62 detects a discharge

of power reception and transformation facility 1 based on the radio signal detected by detector 40 and the phase relationship of the three-phase AC power supply of power reception and transformation facility 1 in detection of the radio signal. Determination unit 62 detects a discharge of power reception and transformation facility 1 when a radio signal is detected by detector 40 at a rising edge and a falling edge of any phase of the three-phase AC power supply of power reception and transformation facility 1. Screen generation unit 64 generates a screen to be displayed on display unit 80, based on a detection result from determination unit 62.

[0036] PC 60 includes at least one or more central processing units (CPUs) and a memory. PC 60 implements various functions by the CPU executing a program stored in the memory. Specifically, PC 60 implements the functions of determination unit 62 and screen generation unit 64. This example describes a configuration in which PLC 80 and PC 60 are provided separately, but they may be implemented as one device. Alternatively, PLC 80 and PC 60, together with detector 40, may be integrated into one device. Further, the functions of PLC 80 and PC 60 may be implemented using an external server via a network. While this example describes a configuration in which antenna 20 and detector 40 are connected using coaxial cable 30, they may be connected wirelessly instead of by wire.

[0037] Fig. 4 shows experimental results illustrating discharges occurring in the epoxy resin insulator of switchboard 10 in terms of frequency characteristics of radio signals received by antenna 20, according to Embodiment 1. Referring to Fig. 4(A), this example shows the relationship between the signal intensity and the frequency characteristics of the radio signal when a partial discharge has occurred in the epoxy resin insulator. Examples of the insulator in switchboard 10 include conductor support insulators, CT/PT cases, and VCB cases, and herein, the frequency characteristics in the use of the epoxy resin are shown. Further, noise refers to dark noise when no discharge has occurred. Examples of the noise include radio waves from devices within the apparatus, exogenous noise entering as radio waves through gaps in the apparatus, and radio waves, generated by currents propagating via cables

pulled into and from outside the apparatus, radiating within the apparatus. Shown here as an example is a case where, when a partial discharge has occurred, a higher signal intensity of the radio signal than that of dark noise is obtained in the frequency band of 180 MHz to 800 MHz. For example, a partial discharge can be determined when a radio signal exceeding a predetermined threshold V_{th1} (-30 dBm) is detected in this frequency band. The threshold can be freely determined based on the environment, frequency, or an antenna used. However, reducing a difference from the dark noise increases false detections, while increasing the difference tends to increase discharges not to be detected even though they have occurred. Thus, in Fig. 4(A), the threshold is set to -30 dBm, approximately 10 dBm greater than the maximum value of dark noise. Particularly in Fig. 4(A), the difference between the radio wave components of dark noise and the radio wave components caused by partial discharge is significant in the frequency band of 200 MHz to 400 MHz. Thus, a partial discharge may be determined using the frequency band, of the frequency band of 180 MHz to 800 MHz, where the difference in intensity between the radio wave components of dark noise and the radio wave components of partial discharge is greater than or equal to a predetermined value. Consequently, the possibility of false detection can be reduced.

[0038] Fig. 4(B) shows a relationship between the signal intensity and frequency characteristics of the radio signal when a spark discharge has occurred in the epoxy resin insulator of switchboard 10. Herein, the frequency characteristics when an epoxy resin is used as the insulator for switchboard 10 are shown. Shown here as an example is a case where, when a spark discharge has occurred, a higher signal intensity of a radio signal than that of the noise is obtained in the frequency band of 180 MHz to 800 MHz. For example, a spark discharge can be determined when a radio signal exceeding a predetermined threshold V_{th2} (-20 dBm) is detected in this frequency band.

[0039] This threshold is merely an example and can be appropriately changed according to the type or condition of the material of the insulator. Further, based on a

difference in intensity, the threshold may be used to determine a partial discharge or a spark discharge.

[0040] Fig. 5 shows experimental results illustrating discharges that have occurred in the polyester resin insulator of switchboard 10 in terms of frequency characteristics of radio signals received by antenna 20, according to Embodiment 1. Referring to Fig. 5(A), this example shows the relationship between the signal intensity and the frequency characteristics of the radio signal when a partial discharge has occurred in the polyester resin insulator. By way of example, shown here is a case where, when a partial discharge has occurred, a higher signal intensity of the radio signal than that of dark noise can be obtained in the frequency band of 180 MHz to 800 MHz. For example, a partial discharge can be determined when a radio signal exceeding predetermined threshold V_{th1} (-30 dBm) is detected in this frequency band. The threshold can be freely determined based on the environment, frequency, or an antenna used. However, reducing a difference from the dark noise increases false detections, whereas increasing the difference tends to increase discharges not to be detected even though they have occurred. Thus, in Fig. 5(A), the threshold is set to -30 dBm, approximately 10 dBm greater than the signal intensity of dark noise.

[0041] Fig. 5(B) shows a relationship between the signal intensity and the frequency characteristics of the radio signal when a spark discharge has occurred in the polyester resin insulator of switchboard 10. Shown here as an example is a case where, when a spark discharge has occurred, a higher signal intensity of a radio signal than that of the noise is obtained in the frequency band of 180 MHz to 800 MHz. For example, a spark discharge can be determined when a radio signal exceeding predetermined threshold V_{th2} (-20 dBm) is detected in this frequency band.

[0042] This threshold is merely an example and can be appropriately changed according to the type or condition of the material of the insulator. Further, based on a difference in intensity, the threshold may be used to determine a partial discharge or a spark discharge.

[0043] In contrast, depending on the environment or condition of switchboard 10, the

noise conditions may also change, and accordingly, a radio signal with a momentarily high signal intensity may be detected.

[0044] Thus, in this example, to avoid such situations, a discharge that has occurred in power reception and transformation facility 1 is detected based on the phase

5 relationship of the AC power supply of power reception and transformation facility 1 in detection of the radio signal.

[0045] Fig. 6 is a diagram illustrating the timing to receive radio signals and the phase relationship of the AC power supply according to Embodiment 1. Referring to Fig. 6, this example shows that a radio signal with a high signal intensity is received at

10 positions 60° and 240° out of phase relative to the R phase among the R, S, and T phases of the three-phase AC power supply. Specifically, the experimental results show that a discharge is detected at 60° , that is, at the rising edge of the T phase, and 240° , that is, at the falling edge with a phase lag of 180° from the falling edge, relative to the R phase of the three-phase AC power supply.

15 [0046] Fig. 7 is a diagram illustrating the phase relationship between a three-phase AC power supply and a radio signal according to Embodiment 1. Fig. 7 shows a case where the horizontal axis represents time, and the vertical axis represents amplitude dBm. The waveforms of the AC power supply in the R, S, and T phases of the three-phase AC power supply and the discharge timing according to Embodiment 1 will be

20 described. As shown in Fig. 7, the R phase, the S phase, and the T phase are illustrated, which are 120° out of phase each other. This example shows a case where a discharge has occurred near zero-crossing at the falling edge and the rising edge of the T phase relative to the R phase.

[0047] In this example, the occurrence of a discharge is determined based on whether a

25 radio signal with a high signal intensity is detected again at a position 180° out of phase after the initial detection of a radio signal with a high signal intensity. When a radio signal with a high signal intensity has been detected twice at a timing 180° out of phase which is correlated with the waveform of the AC power supply, a discharge is determined. In this example, a discharge is detected in the T phase, and a discharge

can be detected similarly in the R phase and the S phase.

[0048] Thus, assuming that the AC power supply is 60 Hz, a discharge occurs twice, that is, one at the rising edge from zero-crossing and the other at the falling edge from zero-crossing, occur within one cycle. Consequently, the discharge detection signal exhibits a frequency characteristic of 120 Hz that is twice a frequency of 60 Hz of the AC power supply. Utilizing this characteristic, a discharge is determined when the frequency characteristic of the discharge detection signal is twice that of the AC power supply. Further, to reduce false detections, a discharge may be determined when a discharge detection signal having a frequency twice that of the AC power supply has been repeatedly detected.

[0049] Further, the amplitude originating from a discharge may fluctuate as the position of discharge shifts due to the characteristics of discharge, or the discharge location may differ between the rising edge and the falling edge from zero-crossing. Thus, a radio signal appearing with a cycle twice that of the AC power supply and having a different amplitude may be determined as a radio signal originating from a discharge, or a radio signal exhibiting fluctuations in amplitude or waveform in repeated measurements may be determined as a radio signal originating from a discharge.

[0050] Combining one or more of these characteristics can prevent false detections. This is because antennas may mistakenly detect radio signals from, for example, ship radio, airport radio, TV broadcasting, or mobile phones as dark noise. However, these signals are unrelated to the cycle of the AC power supply, and accordingly, do not occur in a cycle (e.g., 120 Hz) obtained by multiplying 60 Hz or the like by a constant. Even if a signal with a cycle of 120 Hz is mistakenly detected, repeated measurements can eliminate random factors.

[0051] Further, radio signals generated from electronic devices inside the apparatus are highly likely to generate a radio signal in synchronization with the AC power supply, leading to a potential false detection. However, typical electronic devices, which operate in a cycle of 60 Hz, rarely operate in a cycle of 120 Hz, and can reduce false

detections by measurement in a cycle twice its original cycle. Further, even if electronic devices generating radio signals in a cycle of 120 Hz are provided inside the apparatus, since the electronic devices typically operate repeatedly in a stable state, the generated radio signals exhibit few changes in amplitude or frequency.

5 [0052] In contrast, radio signals originating from a discharge are highly likely to exhibit a different amplitude or a different waveform for each of the repeated measurements. Thus, a radio signal from an electronic device and a radio signal originating from a discharge can be distinguished from each other based on whether the relevant signal is a stable radio signal or a radio signal having large fluctuation
10 components. Further, radio signals from typical electronic devices are generated intermittently, whereas radio signals originating from discharges are intermittent electromagnetic waves occurring at a frequency of approximately once every few minutes, or longer, at a lower frequency of once every few days. Thus, to distinguish between radio signals from electronic devices and radio signals originating from
15 discharges, information regarding the frequency at which radio signals are detected may also be used.

[0053] Further, as shown in Fig. 6, when a radio signal originating from a discharge is detected two or more times and the measurement results are plotted as points with the horizontal axis representing phase and the vertical axis representing radio wave
20 intensity, the radio signals may be determined to be originating from a partial discharge if the distribution of the measurement results exhibits a specific distribution. For example, the specific distribution refers to a probability distribution including a normal distribution (Gaussian distribution). Further, to obtain an accurate distribution, measurement results from ten or more measurements may be used or the number of
25 measurements at the occurrence of a discharge may be increased.

[0054] The above has described a case where the AC current is detected by placing a sensor in the AC power supply in order to obtain the cycle of the AC power supply and the cycle of the discharge, and a radio signal originating from a discharge is detected by placing an antenna near the discharge source, thereby determining a discharge through

combination of two signals.

[0055] In this regard, to synchronize a rising timing and a fall timing from zero-crossing of the AC power supply with the discharge timing, two signals may be synchronized with each other by measuring the electrical length from the sensor
5 attached to the AC power supply to the detector and the electrical length from the discharge source to the detector via the antenna and correcting the electrical lengths in post-processing. Correction of the electrical lengths may be performed while taking into account a difference in, for example, the position at which the antenna is attached or a cable length for each measurement target.

10 [0056] Further, while Fig. 7 shows discharges at zero-crossing, the discharge does not necessarily need to be synchronized with the phase of the AC power supply. A discharge may be determined when a received signal of 120 Hz from the antenna is obtained. Since the frequency of the AC power supply operating the device is known, determining radio signals, occurring at the cycle twice the cycle of the AC power
15 supply, as radio signals originating from discharges eliminates the need for the sensor of the AC power sensor and the detector, and also eliminates the need for correction of an electrical length. Consequently, detecting radio signals with a cycle twice the cycle of the AC power supply requires only attaching an antenna to the device. This enables detection of discharges with fewer false detections, irrespective of the device to
20 be measured.

[0057] Further, when discharges occur simultaneously at two or more locations, such as when discharges occur at the same timing not only in the T phase but also in the R phase, the discharge detection signal exhibits frequency characteristics of 240 Hz and 360 Hz, which are obtained by multiplying 120 Hz by a constant. Thus, detecting
25 these signals allows for application to a plurality of discharge sources. With the horizontal axis representing a phase, a signal of 120 Hz is 180° out of phase, and a signal of 240 Hz appears at a position 60° or 120° out of phase relative to this signal. Further, at 360 Hz, a signal appears at a position 60° and 120° out of phase relative to the signal of 120 Hz.

[0058] However, it can be considered that a radio wave has occurred in a cycle obtained by multiplying 120 Hz by a constant in discharges near adjacent T phase, R phase, and S phase. However, for discharges from insulators at different positions, a difference in propagation distance due to the distance between the discharge source and the antenna does not strictly lead to a cycle obtained by multiplying 120Hz by a constant. Thus, the number of discharge sources can be determined based on a difference in amplitude or frequency because it is determined that there are two discharge sources when there are two signals with a cycle of 120 Hz, or the amplitude or frequency of the discharge varies depending on the degree of deterioration of an insulator.

[0059] Further, the amplitude of a discharge at the rising edge from zero-crossing and the amplitude or frequency of a discharge at the falling edge from zero-crossing are not necessarily the same. In particular, radio signals originating from partial discharges are weak and subject to the measurement limits of a measuring instrument, and accordingly, for example, discharges occurring at the falling edge from zero-crossing can only be detected. Thus, a signal detected in the same cycle as the frequency of the AC power supply, for example, 60 Hz may be detected as a partial discharge. In this case, a radio signal originating from a discharge may be determined in combination with information specific to a discharge, which is not possessed by the surrounding electronic devices that are noise sources or exogenous noise. Examples of the information include the following: the number of detections is increased for improved reliability because reliability may be low compared to detection at a double frequency, for example, 120 Hz; the amplitude may vary by several percent to several tens of percent in amplitude per measurement; and there is a change of about 0.01% to 1% in peak frequency (a maximum value in the set frequency band).

[0060] Although description has been given assuming that amplitude and frequency are different from each other, they may be regarded as frequency characteristics if the amplitude can be acquired in a plurality of frequencies.

[0061] Fig. 8 is a diagram illustrating a configuration of detector 40 according to

Embodiment 1. Referring to Fig. 8, detector 40 includes a bandpass filter 41, an amplification and absolute-valuing circuit 42, a peak hold circuit 43, an A/D conversion circuit 44, a zero-valuing disable circuit 45, a D/A conversion circuit 46, and a reset signal generator 47.

5 [0062] Detector 40 receives input of a signal SA, which is a discharge waveform (input), via antenna 20 connected to coaxial cable 30.

[0063] Bandpass filter 41 is a circuit that passes the input signal SA in a predetermined frequency band and removes signals in the other bands. In this example, bandpass filter 41 passes signals in the predetermined frequency band of 180 MHz to 800 MHz
10 and removes the signals in the other bands. This enables receipt of only radio signals arising from discharges.

[0064] Amplification and absolute-valuing circuit 42 amplifies a signal and absolute-values a signal, adjusting a waveform to facilitate detection of characteristics of a radio signal. The adjusted signal SB is input to peak hold circuit 43.

15 [0065] Reset signal generator 47 generates a reset signal in a predetermined cycle. In this example, reset signal generator 47 generates a reset signal every 30 μ s. Specifically, reset signal generator 47 outputs a reset signal of 1 μ s as a reset period after 29 μ s.

[0066] Peak hold circuit 43 holds the peak value of the adjusted signal SB, which is an
20 analog signal, after resetting in response to the reset signal.

[0067] A/D conversion circuit 44 converts the analog signal from peak hold circuit 43 into a digital signal and outputs the digital signal to zero-valuing disable circuit 45.

[0068] Zero-valuing disable circuit 45 holds the maximum data output from A/D conversion circuit 44 according to the reset signal for a predetermined period.

25 Specifically, the predetermined period is 30 μ s.

[0069] D/A conversion circuit 46 outputs a signal SE, which is an analog signal converted from the digital signal from zero-valuing disable circuit 45, to the external PLC 80.

[0070] Fig. 9 is a diagram illustrating signal processing of detector 40 according to

Embodiment 1. Referring to Fig. 9, at a time T0, a radio signal of discharge waveform is input to detector 40 via antenna 20. Amplification and absolute-valuing circuit 42 adjusts the waveform of the radio signal of discharge waveform. Peak hold circuit 43 holds a peak value of this radio signal. A/D conversion circuit 44 converts the radio signal into a digital value and outputs the digital value to zero-valuing disable circuit 45. Zero-valuing disable circuit 45 holds the peak value held by peak hold circuit 43 via A/D conversion circuit 44 according to input of a reset signal for a predetermined period. D/A conversion circuit 46 outputs the peak value held by peak hold circuit 43 as an analog signal.

[0071] Similarly, the same signal processing is performed at times T1, T2, T3,

Zero-valuing disable circuit 45 is capable of holding the peak value held by peak hold circuit 43 via A/D conversion circuit 44 for a predetermined period (30 μ s). Thus, for example, if only peak hold circuit 43 is provided in detector 40, there is a possibility that the discharge waveform may be missed when data is output to PLC 80 during the period in which data is reset by the reset signal. However, since the peak value is held for a predetermined period and output regardless of the reset period, data can be reliably output to the PLC, and a discharge can be detected.

[0072] Fig. 10 is a diagram illustrating data output from PLC 80 to PC 60 according to Embodiment 1. Referring to Fig. 10, PLC 80 receives data (discharge intensity data) from detector 40 according to a predetermined cycle and outputs the data to PC 60 in association with phase information (time) of the AC power supply at the time of receipt.

[0073] This example shows a case where the data from detector 40 is received in a time-series manner and is associated with phase information (time). Specifically, PLC 80 receives data from detector 40 every 30 μ s, which is a predetermined cycle. For example, the case where the R phase of the AC power supply serves as a reference is shown. By way of example, shown here is a case where, when the voltage of the AC power supply in the R phase is zero at time 0, a signal indicating the discharge intensity is received from detector 40 every 30 μ s.

[0074] For example, shown here is a case where time (ms) is associated with discharge intensity as data numbers "1" to "8". The phase of the AC power supply can be calculated based on this time.

[0075] Subsequently, PLC 80 similarly associates the discharge intensity detected by detector 40 with phase information (time) and outputs the result to PC 60.

[0076] Fig. 11 is a flowchart illustrating determination processing by determination unit 62 according to Embodiment 1. Referring to Fig. 11, determination unit 62 acquires data (step S2). For example, in the format as shown in Fig. 10, determination unit 62 acquires, from PLC 80, data on the phase information (time) of the AC power supply associated with the discharge intensity detected by detector 40. Subsequently, for the acquired data, determination unit 62 extracts a detection time of a signal with a discharge intensity greater than or equal to a threshold (step S4). For example, as described with reference to Fig. 4 by way of example, determination unit 62 determines whether there is a signal with a discharge intensity greater than or equal to threshold Vth1 and extracts the phase information (time) of a signal with a high discharge intensity.

[0077] Fig. 12 is a diagram illustrating a specific example of the detection time of the signal with a high discharge intensity extracted by determination unit 62 according to Embodiment 1. Fig. 12 shows a case where a discharge has occurred in the T phase of the AC power supply by way of example. Specifically, shown here is a case where a signal with a discharge intensity greater than or equal to a threshold has been detected at a position of 60° (time "0.002777"), a position of 240° (time "0.011111"), a position of 420° (time "0.019444"), a position of 600° (time "0.027777"), ... relative to 0° of R phase of the AC power supply.

[0078] Referring again to Fig. 11, determination unit 62 determines whether there is a signal with a discharge intensity greater than or equal to the threshold at the position 180° out of phase (step S8). For example, for the AC power supply of 60 Hz, the position 180° out of phase occurs after a lapse of 0.008333 s. The time at which the first signal with a discharge intensity greater than or equal to the threshold was detected

can be compared with the time at which the next signal with a discharge intensity greater than or equal to the threshold was detected, thereby determining whether the relevant position is a position 180° out of phase (time "0.008333").

5 [0079] When determining in step S8 that there is no signal with a discharge intensity greater than or equal to the threshold at the position 180° out of phase (NO in step S8), determination unit 62 determines that no discharge has occurred and terminates the processing (END).

10 [0080] In contrast, when determining in step S8 that there is a signal with a discharge intensity greater than or equal to the threshold at the position 180° out of phase (YES in step S8), determination unit 62 detects a discharge (step S10), and then, terminates the processing (END).

15 [0081] This example describes the case where whether there is a signal with a discharge intensity greater than or equal to the threshold at a position 180° out of phase is determined in step S8. However, the phase shift of 180° is not strictly required, and a discharge may be detected if there is a signal with a discharge intensity greater than or equal to the threshold near the relevant position.

20 [0082] Further, the flow in Fig. 11 describes the case where a discharge is detected when a signal with a discharge intensity greater than or equal to the threshold has appeared once at a position 180° out of phase. However, detection of a discharge may be determined when such a signal has appeared multiple times consecutively. This enables high-precision discharge detection.

[0083] Determination unit 62 can also detect a discharge according to a method different from the above flow.

25 [0084] Specifically, determination unit 62 can detect a discharge based on the data on the extracted detection time in a predetermined period as shown in Fig. 12.

[0085] Determination unit 62 may analyze the frequency characteristics as data characteristics of the detection times in Fig. 12 and determine detection of a discharge when the frequency is 120 Hz. In other words, determination unit 62 detects a discharge of the power reception and transformation facility when a radio signal with a

discharge intensity greater than or equal to a threshold is detected in a cycle obtained by multiplying the frequency (e.g., 60 Hz) of the AC power supply by a constant.

[0086] Further, determination unit 62 may determine that a discharge of power reception and transformation facility 1 has been detected when a radio signal with a discharge intensity greater than or equal to a threshold has been detected at the rising edge and the falling edge of any phase of the three-phase AC power supply of power reception and transformation facility 1.

[0087] Further, determination unit 62 may determine that a radio signal is originating from a partial discharge when the distribution of measurement results, which are obtained by detection of a radio signal originating from a discharge two or more times and plotting measurement results as points with the horizontal axis representing phase and the vertical axis representing radio wave intensity, has a specific distribution, as described with reference to Fig. 6.

[0088] Further, determination unit 62 can also detect in which phase a discharge has occurred among the R, S, and T phases, as described with reference to Fig. 7. When detecting another radio signal with a signal intensity greater than or equal to a threshold at a position 60° or 120° out of phase in the AC power supply relative to a radio signal detected when a radio signal with a signal intensity greater than or equal to the threshold has been detected two or more times in one cycle of the AC power supply, determination unit 62 detects the other radio signal as another discharge of the power reception and transformation facility.

[0089] This example has described the case where whether a signal has a discharge intensity greater than or equal to threshold V_{th1} is determined by way of example. However, for example, whether a spark discharge has occurred can be detected by determining whether a signal has a discharge intensity greater than or equal to threshold V_{th2} .

[0090] (Embodiment 2)

Embodiment 2 will describe a case where information about a position at which a discharge has occurred is displayed to the user.

[0091] Specifically, screen generation unit 64 of PC 60 displays the level of a discharge intensity of power reception and transformation facility 1 on display unit 80 based on the signal intensity of the radio signal from detector 40.

[0092] Fig. 13 is a diagram illustrating display of display unit 80 of power reception and transformation facility 1 according to Embodiment 2. Referring to Fig. 13(A), this example shows a case where antennas 20A to 20G are provided in correspondence with switchboards 10A to 10G, respectively.

[0093] Detector 40 is connected to each of antennas 20A to 20G and detects a radio signal received by each of antennas 20A to 20G. PLC 80 is connected with a plurality of antennas and is connected with an AC power supply correlated with power reception and transformation facility 1. PLC 80 acquires information on the phase relationship of the AC power supply in detection of the radio signal detected by detector 40, and outputs the information to PC 60. PC 60 detects a discharge of power reception and transformation facility 1 based on information from PLC 82 according to the method described above in Embodiment 1.

[0094] Referring to Fig. 13(B), when determination unit 62 detects a discharge, screen generation unit 64 displays, on display unit 80, a graph corresponding to the signal intensities of the radio signals detected by the plurality of antennas 20A to 20G.

[0095] By way of example, screen generation unit 64 displays, on display unit 80, a graph showing a high discharge intensity in correspondence with the position corresponding to antenna 20D, which has the highest discharge intensity among the plurality of antennas 20A to 20G.

[0096] The user can determine the position corresponding to antenna 20 at the position with the highest discharge intensity as a discharge location, based on the distribution comparison between signal intensities displayed on display unit 80.

[0097] This method allows the user not only to detect the occurrence of a discharge but also to check the position of the discharge location.

[0098] Fig. 14 is a diagram illustrating display of display unit 80 of power reception and transformation facility 1 according to a modification of Embodiment 2. Referring

to Fig. 14(A), this example shows a case where a plurality of antennas 20P to 20R, located at different positions, are provided in one switchboard 10.

[0099] Detector 40 is connected with each of antennas 20P to 20R and detects a radio signal received by each of antennas 20P to 20R. PLC 80 is connected with an AC power supply correlated with power reception and transformation facility 1. PLC 80 acquires information on the phase relationship between this power supply and the AC power supply in detection of the radio signal detected by detector 40, and outputs the information to PC 60. PC 60 detects a discharge of power reception and transformation facility 1 based on the information from PLC 82 according to the method described above in Embodiment 1.

[0100] Referring to Fig. 14(B), when determination unit 62 detects a discharge, screen generation unit 64 displays, on display unit 80, a graph corresponding to the signal intensities of the radio signals detected by the plurality of antennas 20P to 20R.

[0101] By way of example, screen generation unit 64 displays, on display unit 80, a graph showing a high discharge intensity in correspondence with the position corresponding to antenna 20P, which has the highest discharge intensity among the plurality of antennas 20P to 20R.

[0102] The user can determine the position corresponding to antenna 20 at the position with the highest discharge intensity as the discharge location, based on the distribution comparison between signal intensities displayed on display unit 80. In this example, the user can determine the position corresponding to antenna 20P, which has the highest discharge intensity among the plurality of antennas 20P to 20R, as the discharge location.

[0103] Fig. 15 is a diagram illustrating another display of display unit 80 of power reception and transformation facility 1 according to the modification of Embodiment 2. Referring to Fig. 15(A), this example shows a case where the plurality of antennas 20P to 20R, located at different positions, are provided in one switchboard 10.

[0104] Detector 40 is connected with each of antennas 20P to 20R and detects a radio signal received by each of antennas 20P to 20R. PLC 80 is connected with an AC

power supply correlated with power reception and transformation facility 1. PLC 80 acquires information on the phase relationship between this power supply and the AC power supply in detection of the radio signal detected by detector 40, and outputs the information to PC 60. PC 60 detects a discharge of power reception and transformation facility 1 based on information from PLC 82 according to the method described above in Embodiment 1.

[0105] Referring to Fig. 15(B), when determination unit 62 detects a discharge, screen generation unit 64 displays, on display unit 80, a graph corresponding to the signal intensities of the radio signals detected by the plurality of antennas 20P to 20R.

[0106] By way of example, screen generation unit 64 displays, on display unit 80, a graph showing a high discharge intensity in correspondence with the position corresponding to antenna 20Q, which has the highest discharge intensity among the plurality of antennas 20P to 20R.

[0107] The user can determine the position corresponding to antenna 20 at the position with the highest discharge intensity as the discharge location, based on the distribution comparison between signal intensities displayed on display unit 80. In this example, the user can determine the position corresponding to antenna 20Q, which has the highest discharge intensity among the plurality of antennas 20P to 20R, as the discharge location.

[0108] Fig. 16 is a diagram illustrating still another display of display unit 80 of power reception and transformation facility 1 according to the modification of Embodiment 2. Referring to Fig. 16(A), this example shows a case where the plurality of antennas 20P to 20R, located at different positions, are provided in one switchboard 10.

[0109] Detector 40 is connected with each of antennas 20P to 20R and detects the radio signal received by each of antennas 20P to 20R. PLC 80 is connected with an AC power supply correlated with power reception and transformation facility 1. PLC 80 acquires information on the phase relationship between this power supply and the AC power supply in detection of the radio signal detected by detector 40, and outputs this information to PC 60. PC 60 detects a discharge of power reception and

transformation facility 1 based on information from PLC 82 according to the method described above in Embodiment 1.

[0110] Referring to Fig. 16(B), when determination unit 62 detects a discharge, screen generation unit 64 displays, on display unit 80, a graph corresponding to the signal intensities of the radio signals detected by the plurality of antennas 20P to 20R.

[0111] By way of example, screen generation unit 64 displays, on display unit 80, a graph showing a high discharge intensity in correspondence with the position corresponding to antenna 20R, which has the highest discharge intensity among the plurality of antennas 20P to 20R.

[0112] The user can determine the position corresponding to antenna 20 at the position with the highest discharge intensity as the discharge location, based on the distribution comparison between signal intensities displayed on display unit 80. In this example, the user can determine the position corresponding to antenna 20R, which has the highest discharge intensity among the plurality of antennas 20P to 20R, as the discharge location.

[0113] By providing a plurality of antennas in one switchboard 10, this method allows the user not only to detect a discharge that has occurred within this switchboard 10 but also to determine the position of the discharge location.

[0114] Fig. 17 is a diagram illustrating display of display unit 80 of power reception and transformation facility 1 according to a second modification of Embodiment 2.

Referring to Fig. 17(A), this example shows a case where a plurality of antennas 20P, 20R, located at different positions, are provided in one switchboard 10.

[0115] The configuration of Fig. 17 is different from the configuration of Fig. 14 in that antenna 20Q is removed and only antennas 20P, 20R are provided.

[0116] Referring to Fig. 17(B), when determination unit 62 detects a discharge, screen generation unit 64 displays, on display unit 80, a graph corresponding to the signal intensities of the radio signals detected by the plurality of antennas 20P, 20R.

[0117] By way of example, screen generation unit 64 displays, on display unit 80, a graph showing a high discharge intensity in correspondence with the position

corresponding to the antenna with the highest discharge intensity among antenna 20P, 20R.

[0118] The user can determine the position corresponding to antenna 20 at the position with the highest discharge intensity as the discharge location, based on the distribution comparison between signal intensities displayed on display unit 80. In this example, the user can determine the position corresponding to antenna 20P with the highest discharge intensity among the plurality of antennas 20P, 20R, as the discharge location.

[0119] Fig. 18 is a diagram illustrating another display of display unit 80 of power reception and transformation facility 1 according to the second modification of

Embodiment 2. Referring to Fig. 18(A), this example shows a case where the plurality of antennas 20P, 20R are provided at different positions in one switchboard 10.

[0120] Referring to Fig. 18(B), when determination unit 62 detects a discharge, screen generation unit 64 displays, on display unit 80, a graph corresponding to the signal intensities of the radio signals detected by the plurality of antennas 20P, 20R.

[0121] By way of example, screen generation unit 64 displays, on display unit 80, a graph showing a high discharge intensity in correspondence with the position of the antenna with the highest discharge intensity among the plurality of antennas 20P, 20R.

[0122] Based on the distribution comparison between signal intensities displayed on display unit 80, the user can determine the position corresponding to antenna 20 at the position with the highest discharge intensity, as the discharge location. This example shows a case where the discharge intensities of antennas 20P, 20R are at the same level.

[0123] In this case, the user can determine the position corresponding to between antennas 20P, 20R as the discharge location.

[0124] Fig. 19 is a diagram illustrating still another display of display unit 80 of power reception and transformation facility 1 according to the second modification of Embodiment 2. Referring to Fig. 19(A), this example shows a case where the plurality of antennas 20P, 20R are provided at different positions in one switchboard 10.

[0125] Referring to Fig. 19(B), when determination unit 62 detects a discharge, screen generation unit 64 displays, on display unit 80, a graph corresponding to the signal intensities of the radio signals detected by the plurality of antennas 20P, 20R.

[0126] By way of example, screen generation unit 64 displays, on display unit 80, a graph showing a high discharge intensity in correspondence with the position corresponding to the antenna with the highest discharge intensity among the plurality of antennas 20P, 20R.

[0127] The user can determine the position corresponding to antenna 20 at the position with the highest discharge intensity as the discharge location, based on the distribution comparison between signal intensities displayed on display unit 80. In this example, the user can determine the position corresponding to antenna 20R, which has the highest discharge intensity among the plurality of antennas 20P, 20R, as the discharge location.

[0128] For example, considering radio waves in a far-field, since discharge intensity is inversely proportional to distance, the discharge intensity can be converted to a distance ratio according to the reception intensities of antennas 20P, 20R, and accordingly, a discharge source can be found from this information. Further, depending on the frequency of a measurement object and the dimensions of a switchboard, the radio waves may be in the near field (the radio waves can be in near field with generally one wavelength or less, and one wavelength is 1 m at 300 MHz). In this case, the discharge intensity is inversely proportional to the square or cube of the distance, and thus, it is desirable to convert the discharge intensity to a distance ratio while also considering the characteristics of electromagnetic waves in the near field.

[0129] By comparing the discharge intensities detected by a plurality of antennas, this method can determine the position of the discharge location even when the number of antennas is reduced.

[0130] This example has described the case where the position of a discharge location is determined with a reduced number of antennas for one switchboard 10. However, this method is similarly applicable to, for example, a configuration as shown in Fig. 13.

Specifically, this example describes the case where antennas 20B, 20D, 20F are removed in a configuration as shown in Fig. 13. When determination unit 62 detects a discharge, screen generation unit 64 displays a graph showing a high discharge intensity in correspondence with the position corresponding to antenna 20 at the position with the highest discharge intensity among the radio signals detected by a plurality of antennas 20A, 20C, 20E, 20G.

[0131] The user can determine the position corresponding to antenna 20 at the position with the highest discharge intensity as the discharge location, based on the distribution comparison between signal intensities displayed on display unit 80.

[0132] This method enables not only detecting the occurrence of a discharge but also determining the position of a discharge location while reducing the number of antennas.

[0133] (Embodiment 3)

Embodiment 3 will describe the method of determining a position at which a discharge has occurred.

[0134] Fig. 20 is a diagram illustrating an insulation deterioration detection system 110 according to Embodiment 3.

[0135] Referring to Fig. 20, insulation deterioration detection system 110 is different from insulation deterioration detection system 100 described with reference to Fig. 3 in that PC 60 is replaced with a PC 61. PC 61 is different from PC 60 in that it further includes a position determination unit 66.

[0136] Position determination unit 66 determines a discharge location, based on the distribution comparison between signal intensities described in Embodiment 2 and displays the discharge location on display unit 80. Specifically, position determination unit 66 determines the position corresponding to antenna 20D at the position with the highest discharge intensity, based on the distribution comparison between signal intensities described with reference to Fig. 13, as the discharge location, and then displays the information about this determined location on display unit 80. This allows the user to easily grasp the position of the discharge location. This is similarly applicable to the other examples of Figs. 14 to 19.

[0137] (Other Embodiments)

In any other embodiment, detection of a discharge may be determined by machine learning as determination processing by determination unit 62.

5 [0138] Specifically, data with discharge intensity associated with phase information at the time of occurrence of a discharge is used as learning data to generate a learned model for inferring a discharge from an insulator.

[0139] Determination unit 62 detects a discharge from an insulator based on data with discharge intensity associated with phase information, using the generated learned model.

10 [0140] The learning algorithm in generation of a learned model may be any known algorithm such as supervised learning, unsupervised learning, or reinforcement learning. For example, in one example, k-means (clustering), which is unsupervised learning, may be employed to detect a discharge based on whether data points belong to a cluster. In addition to non-hierarchical clustering using k-means, any other known
15 clustering-enabled algorithm may be used. For example, hierarchical clustering such as the nearest neighbor method may be employed. Further, in supervised learning, by setting the horizontal axis as phase and the vertical axis as discharge intensity, data can be processed similarly to time-series data. Thus, methods such as recurrent neural network (RNN), which is one of the neural networks capable of input of time-series
20 data, gradient boosting, which is one of the decision trees, or autoregressive integrated moving average (ARIMA) model based on statistical approach can be used. Further, these outputs can be used for anomaly detection in which these outputs are classified into two values, that is, normality without discharge and anomaly with discharge, class classification in which these outputs are classified into three values, that is, normality
25 without discharge, partial discharge, and spark discharge, or regression prediction in which discharge states several days to several years in advance are predicted. Further, discharges are highly dependent on temperature and humidity environments, and thus, learning the trend that changes over time or with the environment by reinforcement learning is desirable because it can reduce false detections.

[0141] It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. It is intended that the scope of the present invention is defined by claims, not only by the above description, and encompasses all modifications and variations equivalent in meaning and scope to the claims.

5 REFERENCE SIGNS LIST

[0142] 1 power reception and transformation facility; 10 switchboard; 20 antenna; 30 coaxial cable; 40 detector; 41 bandpass filter; 42 amplification and absolute-valuing circuit; 43 peak hold circuit; 44 A/D conversion circuit; 46 D/A conversion circuit; 45 zero-valuing disable circuit; 47 reset signal generator; 60, 10 61 PC; 62 determination unit; 64 screen generation unit; 66 position determination unit; 100, 110 insulation deterioration detection system.

CLAIMS

[Claim 1] An insulation deterioration detection system comprising:
an antenna provided in a power receiving and distributing facility for detecting
5 a radio wave;
a detection unit connected to the antenna, the detection unit detecting a radio
signal through the antenna; and
a determination unit that detects a discharge of the power receiving and
distributing facility based on the radio signal detected by the detection unit and a
10 relationship with an alternating-current (AC) power supply of the power receiving and
distributing facility in detection of the radio signal,
wherein the antenna detects a radio signal originating from a partial discharge
or a spark discharge in a band of at least 180 MHz to 800 MHz.

15 [Claim 2] The insulation deterioration detection system according to claim 1,
wherein the detection unit includes a peak hold circuit that holds a maximum value of
the radio signal received by the antenna.

[Claim 3] The insulation deterioration detection system according to claim 1,
20 wherein the determination unit detects a discharge of the power receiving and
distributing facility based on the radio signal detected by the detection unit and a phase
relationship of a three-phase AC power supply of the power receiving and distributing
facility in detection of the radio signal.

25 [Claim 4] The insulation deterioration detection system according to claim 3,
wherein the determination unit detects a discharge of the power receiving and
distributing facility when the detection unit detects the radio signal at a rising edge or a
falling edge of any phase of the three-phase AC power supply of the power receiving
and distributing facility.

[Claim 5] The insulation deterioration detection system according to claim 1,
wherein the determination unit detects a discharge of the power receiving and
distributing facility when the detection unit detects the radio signal in a cycle obtained
5 by multiplying a frequency of the AC power supply of the power receiving and
distributing facility by a constant.

[Claim 6] The insulation deterioration detection system according to claim 5,
wherein the determination unit detects a discharge of the power receiving and
10 distributing facility when the detection unit detects the radio signal two or more times
during one cycle of the AC power supply of the power receiving and distributing
facility.

[Claim 7] The insulation deterioration detection system according to claim 6,
15 wherein the determination unit detects another discharge of the power receiving and
distributing facility when detecting another radio signal at a position 60° or 120° out of
phase in the AC power supply relative to a radio signal detected when the detection unit
detects the radio signal two or more times during one cycle of the AC power supply of
the power receiving and distributing facility.

20 [Claim 8] The insulation deterioration detection system according to claim 1,
wherein the radio signal has a specific distribution relative to a phase of the AC power
supply.

25 [Claim 9] The insulation deterioration detection system according to claim 8,
wherein the specific distribution is a normal distribution.

[Claim 10] The insulation deterioration detection system according to claim 1,
wherein the determination unit detects a discharge of the power receiving and

distributing facility based on the relationship with the AC power supply of the power receiving and distributing facility when a signal amplitude of the radio signal is greater than or equal to a threshold and when the radio signal is detected.

5 [Claim 11] The insulation deterioration detection system according to claim 10, wherein

 the determination unit detects a spark discharge of the power receiving and distributing facility based on the relationship with the AC power supply of the power receiving and distributing facility when the signal amplitude of the radio signal is
10 greater than or equal to a first threshold and when the radio signal is detected, and

 the determination unit detects a partial discharge of the power receiving and distributing facility based on the relationship with the AC power supply of the power receiving and distributing facility when the signal amplitude of the radio signal is greater than or equal to a second threshold and less than the first threshold, and when
15 the radio signal is detected.

 [Claim 12] The insulation deterioration detection system according to claim 1, wherein the antenna is placed to face an insulator in the power receiving and distributing facility.

20

 [Claim 13] The insulation deterioration detection system according to claim 12, wherein the antenna is placed to face a bus and a cable that are in proximity to or in contact with an insulator that causes a possible partial discharge in the power receiving and distributing facility.

25

 [Claim 14] The insulation deterioration detection system according to claim 12, wherein the insulator is an epoxy resin or a polyester resin.

 [Claim 15] The insulation deterioration detection system according to claim

12, wherein the insulator is porcelain or ceramic.

[Claim 16] The insulation deterioration detection system according to claim 1,
wherein

5 the power receiving and distributing facility is provided with a plurality of
antennas,

a plurality of the detection units are further provided respectively in
correspondence with the plurality of antennas, and

10 the insulation deterioration detection system further comprises a display unit
that displays detection results from a plurality of the detection units.

[Claim 17] The insulation deterioration detection system according to claim
14, wherein the display unit displays a screen showing a distribution comparison
between signal intensities of respective radio signals from a plurality of the detection
15 units.

[Claim 18] The insulation deterioration detection system according to claim
14, further comprising a position determination unit that determines, based on signal
intensities of respective radio signals from a plurality of the detection units, a discharge
20 location in the power receiving and distributing facility.

[Claim 19] The insulation deterioration detection system according to claim
16, wherein

25 the position determination unit determines, based on a distribution comparison
between signal intensities of respective radio signals from the plurality of detection
units, a discharge location in the power receiving and distributing facility, and

the display unit displays the discharge location in the power receiving and
distributing facility determined by the position determination unit.

[Claim 20] The insulation deterioration detection system according to claim 1,
wherein

the antenna is a monopole antenna including an inverted F-antenna or an
inverted L-antenna, and

5 a counterpoise of the monopole antenna and a conductor are brought into
conduction, the conductor serving as a reference potential of the power receiving and
distributing facility.

[Claim 21] The insulation deterioration detection system according to claim 1,
10 wherein the antenna detects a radio wave in a band, of the band of at least 180 MHz to
800 MHz, with a largest difference in signal intensity between a radio signal
originating from a discharge and a radio signal originating from noise when no
discharge has occurred.

15 [Claim 22] An insulation deterioration detection method comprising:
detecting a radio signal via an antenna provided in a power receiving and
distributing facility; and

detecting a discharge of the power receiving and distributing facility based on
the detected radio signal and a relationship with an AC power supply of the power
20 receiving and distributing facility in detection of the radio signal,

wherein the detecting detects a radio signal originating from a partial discharge
or a spark discharge in a band of at least 180 MHz to 800 MHz.