NON-CONTACT VOLTAGE SENSOR FOR INHERENTLY SAFE POINT MACHINE MOTOR PERFORMANCE MONITORING

BACKGROUND

1. Field

[0001] Aspects of the present disclosure generally relate to a non-contact voltage sensor for inherently safe point machine motor performance monitoring.

2. Description of the Related Art

[0002] At present measuring phase offset of a motor requires a voltage sensor to be electrically connected to the motor's control circuits to measure the voltage waveform. This method has serious safety and reliability implications for railway equipment as failure of the monitoring system or sensor may cause railway equipment malfunction and unsafe operation of the whole system. Consequently implementation prerequires safety analysis at significant cost and time making this method unattractive to most railway authorities.

[0003] Therefore, an apparatus is then needed to do a voltage measurement to eliminate any direct electrical connection to the point machine contact circuits.

SUMMARY

[0004] Briefly described, aspects of the present disclosure relate to an inherently safe method for monitoring a point machine's (and other machines) motor performance by measuring phase offset between voltage and current waveforms. The method's novelty is that it uses non-contact capacitive voltage sensors to measure the voltage waveform's shape and zero-crossing without concern for the voltage amplitude. The present

disclosure uses capacitive (non-contact) voltage measurement to eliminate any direct electrical connection to the point machine contact circuits.

[0005] In accordance with one illustrative embodiment of the present disclosure, a monitoring system is provided for monitoring performance of railway equipment in an inherently safe way. The monitoring system comprises a non-contact capacitive voltage sensor for monitoring motor performance of a point machine by measuring a phase offset of a motor of the point machine between voltage and current waveforms. The non-contact capacitive voltage sensor generally works by sensing a small electrostatic charge of a metallic surface that is capacitively coupled to a live circuit and a reference ground such that the non-contact capacitive voltage sensor produces a voltage that is proportional to a sensed voltage without needing to make a direct contact to contact circuits of the motor of the point machine. The non-contact capacitive voltage sensor produces a small voltage signal that is amplified such that this signal can be measured and recorded by the monitoring system.

[0006] In accordance with one illustrative embodiment of the present disclosure, a method of providing a monitoring system for monitoring performance of railway equipment in an inherently safe way is provided. The method comprises providing a non-contact capacitive voltage sensor for monitoring motor performance of a point machine by measuring a phase offset of a motor of the point machine between voltage and current waveforms. The non-contact capacitive voltage sensor generally works by sensing a small electrostatic charge of a metallic surface that is capacitively coupled to a live circuit and a reference ground such that the non-contact capacitive voltage sensor produces a voltage that is proportional to a sensed voltage without needing to make a direct contact to contact circuits of the motor of the point machine. The non-contact capacitive voltage sensor produces a small voltage signal that is amplified such that this signal can be measured and recorded by the monitoring system.

[0007] The above described features and advantages, as well as others, will become more readily apparent to those of ordinary skill in the art by reference to the following detailed description and accompanying drawings. While it would be desirable to provide

one or more of these or other advantageous features, the teachings disclosed herein extend to those embodiments which fall within the scope of the appended claims, regardless of whether they accomplish one or more of the above-mentioned advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, wherein like numbers designate like objects.

[0009] FIG. 1 illustrates a monitoring system for monitoring performance of railway equipment in an inherently safe way in accordance with an embodiment of the present disclosure.

[0010] FIG. 2 illustrates a monitoring system involving two capacitive couplings for AC voltage measurement via a measurement circuit for measuring characteristic of a motor in accordance with an embodiment of the present disclosure.

[0011] FIG. 3 illustrates a cross-section at a section A-A in FIG. 2 for a capacitive coupling of the monitoring system of FIG. 2 where the capacitive coupling comprises a metal foil sleeve around a primary conductor and an air gap or a dielectric material filled between them in accordance with an embodiment of the present disclosure.

[0012] FIG. 4 illustrates a monitoring system involving a single wire arrangement including an inner foil and an outer foil around a primary AC circuit conductor for AC voltage measurement in accordance with an embodiment of the present disclosure.

[0013] FIG. 5 illustrates an end view of the single wire arrangement in FIG. 4 including an insulating gap or a dielectric material between the inner foil and the outer foil in accordance with an embodiment of the present disclosure.

[0014] FIG. 6 illustrates a setup for motor power factor monitoring in accordance with an embodiment of the present disclosure.

[0015] FIG. 7 illustrates a capacitive voltage sensor in accordance with an embodiment of the present disclosure.

[0016] FIG. 8 illustrates a method of providing a monitoring system for monitoring performance of railway equipment in an inherently safe way in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0017] Various technologies that pertain to systems and methods that provide a monitoring system for monitoring performance of railway equipment. A non-contact voltage sensor is provided for inherently safe point machine motor performance monitoring. A voltage measurement is done to eliminate any direct electrical connection to the point machine's contact circuits. The drawings discussed below, and the various embodiments used to describe the principles of the present disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of the present disclosure may be implemented in any suitably arranged apparatus. It is to be understood that functionality that is described as being carried out by certain system elements may be performed by multiple elements. Similarly, for instance, an element may be configured to perform functionality that is described as being carried out by multiple elements. The numerous innovative teachings of the present application will be described with reference to exemplary non-limiting embodiments.

[0018] To facilitate an understanding of embodiments, principles, and features of the present disclosure, they are explained hereinafter with reference to implementation in illustrative embodiments. In particular, they are described in the context of a monitoring system for monitoring performance of railway equipment. Embodiments of the present

disclosure, however, are not limited to use in the described devices or methods.

[0019] The components and materials described hereinafter as making up the various embodiments are intended to be illustrative and not restrictive. Many suitable components and materials that would perform the same or a similar function as the materials described herein are intended to be embraced within the scope of embodiments of the present disclosure.

[0020] These and other embodiments of the system are provided for providing a monitoring system for monitoring performance of railway equipment according to the present disclosure are described below with reference to FIG. 1 herein. The drawing is not necessarily drawn to scale.

[0021] Consistent with an embodiment of the present disclosure, FIG. 1 represents a monitoring system 105 for monitoring performance of railway equipment in an inherently safe way in accordance with an embodiment of the present disclosure. The monitoring system 105 comprises a non-contact capacitive voltage sensor 107 for monitoring motor performance of a point machine 110 by measuring a phase offset 112 (e.g., a phase offset of one-quarter cycle (90 degrees or $\pi/2$ radians)) of a motor 115 of the point machine 110 between voltage and current waveforms 120. A phase offset is the difference in time or space between two waveforms. It's also known as "phase difference". Phase is simply a rotation on the complex plane, and a phase offset is a static rotation. For example, a phase offset of 90 degrees offsets the phase trace by +90 degrees, such that a phase value of 0 degrees will be shown on the trace as +90 degrees.

[0022] A point machine (also known as a point motor, switch machine or switch motor) is a device for operating railway turnouts especially at a distance. Modern point machines have an electric motor and gears to convert the rotational motion of the motor into the linear motion required to switch the points. The gear assembly also provides required transmission ratio so that it can generate necessary force to move switch blades. The point machine (in this case an electric motor) and associated mechanism may be used to operate a switch. The point machine performs following functions: moving switch blades,

locking the blades and detection and proving the position of blades.

[0023] The non-contact capacitive voltage sensor 107 generally works by sensing a small electrostatic charge 122 of a metallic surface 125 that is capacitively coupled to a live circuit 130 and a reference ground 132 such that the non-contact capacitive voltage sensor 107 produces a voltage 135 that is proportional to a sensed voltage 137 without needing to make a direct contact to contact circuits 140 of the motor 115 of the point machine 110. The non-contact capacitive voltage sensor 107 produces a small voltage signal 145 that is amplified such that this signal can be measured and recorded by the monitoring system 105.

[0024] The non-contact capacitive voltage sensor 107 measures a voltage waveform's shape and zero-crossing without concern of a voltage amplitude. The non-contact capacitive voltage sensor 107 is not electrically connected to control circuits 150 of the motor 115 of the point machine 110 to measure the voltage waveform.

[0025] The non-contact capacitive voltage sensor 107 uses a capacitive (non-contact) voltage measurement to eliminate any direct electrical connection to the contact circuits 140 of the motor 115 of the point machine 110. The capacitive (non-contact) voltage measurement does not reduce safety or reliability of a monitored railway equipment or system because the non-contact capacitive voltage sensor 107 is electrically isolated from the monitored railway equipment.

[0026] Any failure of the monitoring system 105 or the non-contact capacitive voltage sensor 107 remains isolated from the monitored railway equipment and a failure of the monitored railway equipment remains isolated from the monitoring system 105 or the non-contact capacitive voltage sensor 107. Such a monitoring method can be applied to existing point machine installations without disturbing and potentially cause it failure to existing point machine control circuits. Since a voltage amplitude is not important, a voltage measurement can be performed at an equipment power supply (not shown) instead of at the point machine 110.

[0027] The non-contact capacitive voltage sensor 107 does not need to be located inside the point machine 110 thereby minimising installation cost and risk. The non-contact capacitive voltage sensor 107 uses a non-contact voltage measurement.

[0028] Referring to FIG. 2, it illustrates a monitoring system 205 involving two capacitive couplings 207(1-2) for AC voltage measurement 210 via a measurement circuit 212 for measuring characteristic of a load, e.g., a motor 215 in accordance with an embodiment of the present disclosure. The monitoring system 205 includes a primary AC power supply 217 and a switch 220 in series.

[0029] Turning now to FIG. 3, it illustrates a cross-section at a section A-A in FIG. 2 for a capacitive coupling 207(1) of the monitoring system 205 of FIG. 2 where the capacitive coupling 207(1) comprises a metal foil sleeve 306 around a primary conductor 309 and an air gap or a dielectric material 313 filled between them in accordance with an embodiment of the present disclosure.

[0030] FIG. 4 illustrates a monitoring system 405 involving a single wire arrangement 407 including an inner foil 410(1) and an outer foil 410(2) around a primary AC circuit conductor 415 for AC voltage measurement 420 in accordance with an embodiment of the present disclosure.

[0031] As seen in FIG. 5, it illustrates an end view of the single wire arrangement 407 as shown in FIG. 4 including an insulating gap or a dielectric material 504 between the inner foil 410(1) and the outer foil 410(2) in accordance with an embodiment of the present disclosure.

[0032] FIG. 6 illustrates a setup for motor power factor monitoring in accordance with an embodiment of the present disclosure. Voltage transducers (VTs) 607(1-2) provide a phase angle w.r.t. to a motor current (current will lag voltage) of a 3PH motor (point machine) 609. Note that the VTs 607(1-2) may not provide an absolute voltage amplitude (and hence RMS) but this does not matter for phase angle measurement. Also, the VTs 607(1-2) does provide the relative amplitude of voltage at different motor loads allowing

us to calculate the voltage drop at different loads as a ratio to the open circuit voltage, and thus accurately calculate motor power. Current transducers (CTs) 617(1-2) along with the voltage transducers (VTs) 607(1-2) are coupled to a programmable logic controller (PLC) 621 for power factor monitoring.

[0033] FIG. 7 illustrates a capacitive voltage sensor 703 in accordance with an embodiment of the present disclosure. A wire insulator 707 is applied to a portion of a copper wire conductor 711 and the wire insulator 707 is covered with a foil 714. An adhesive tape 719 is attached to the foil 714 while a sensor wire 723 is coupled to the adhesive tape 719.

[0034] As shown in FIG. 8, it illustrates a method 800 of providing the monitoring system 105 for monitoring performance of railway equipment in an inherently safe way in accordance with an embodiment of the present disclosure. Reference is made to the elements and features described in FIGs. 1-7. It should be appreciated that some steps are not required to be performed in any particular order, and that some steps are optional.

[0035] The method 800 comprises a step 805 of providing the non-contact capacitive voltage sensor 107 for monitoring motor performance of the point machine 110 by measuring a phase offset of the motor 115 of the point machine 110 between voltage and current waveforms. The non-contact capacitive voltage sensor 107 generally works by sensing a small electrostatic charge of a metallic surface that is capacitively coupled to a live circuit and a reference ground such that the non-contact capacitive voltage sensor 107 produces a voltage that is proportional to a sensed voltage without needing to make a direct contact to contact circuits of the motor of the point machine. The non-contact capacitive voltage sensor 107 produces a small voltage signal that is amplified such that this signal can be measured and recorded by the monitoring system 105.

[0036] This method 800 does not have serious safety and reliability implications for railway equipment as failure of the monitoring system or sensor may not cause railway equipment malfunction and unsafe operation of the whole system. Safety analysis at significant cost and time may not be needed making this method 800 attractive to most

railway authorities.

[0037] Unlike existing solutions the method 800 of capacitive voltage measurement does not reduce the safety or reliability of the monitored railway equipment or system because the voltage sensor is electrically isolated from the railway equipment. Any failure of the monitoring system 105 or sensor 107 remains isolated from the railway equipment and failure of the railway equipment remains isolated from the monitoring system. In addition the method can be applied to existing point machine installations without disturbing and potentially cause it failure to the existing point machine control circuits. Also since voltage amplitude is not important, the voltage measurement can be performed at the equipment power supply instead of at the point machine so the sensor does not need to be located in the point machine thereby minmising installation cost and risk.

[0038] An inherently safe method is provided for monitoring point machine (and other machines) motor performance by measuring phase offset between voltage and current waveforms. The method 800's novelty is that it uses non-contact capacitive voltage sensors to measure the voltage waveform's shape and zero-crossing without concern for the voltage amplitude.

[0039] While a monitoring system based on a non-contact capacitive voltage sensor is described here a range of one or more other non-contact systems are also contemplated by the present disclosure. For example, other non-contact systems may be implemented based on one or more features presented above without deviating from the spirit of the present disclosure.

[0040] The techniques described herein can be particularly useful for a point machine. While particular embodiments are described in terms of a point machine, the techniques described herein are not limited to such a point machine but can also be used with other machines.

[0041] While embodiments of the present disclosure have been disclosed in exemplary forms, it will be apparent to those skilled in the art that many modifications,

additions, and deletions can be made therein without departing from the spirit and scope of the disclosure and its equivalents, as set forth in the following claims.

[0042] Embodiments and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments that are illustrated in the accompanying drawings and detailed in the following description. Descriptions of well-known starting materials, processing techniques, components and equipment are omitted so as not to unnecessarily obscure embodiments in detail. It should be understood, however, that the detailed description and the specific examples, while indicating preferred embodiments, are given by way of illustration only and not by way of limitation. Various substitutions, modifications, additions and/or rearrangements within the spirit and/or scope of the underlying inventive concept will become apparent to those skilled in the art from this disclosure.

[0043] As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such process, article, or apparatus.

[0044] Additionally, any examples or illustrations given herein are not to be regarded in any way as restrictions on, limits to, or express definitions of, any term or terms with which they are utilized. Instead, these examples or illustrations are to be regarded as being described with respect to one particular embodiment and as illustrative only. Those of ordinary skill in the art will appreciate that any term or terms with which these examples or illustrations are utilized will encompass other embodiments which may or may not be given therewith or elsewhere in the specification and all such embodiments are intended to be included within the scope of that term or terms.

[0045] In the foregoing specification, the disclosure has been described with reference to specific embodiments. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the

disclosure. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of disclosure.

[0046] Although the disclosure has been described with respect to specific embodiments thereof, these embodiments are merely illustrative, and not restrictive of the disclosure. The description herein of illustrated embodiments of the disclosure is not intended to be exhaustive or to limit the disclosure to the precise forms disclosed herein (and in particular, the inclusion of any particular embodiment, feature or function is not intended to limit the scope of the disclosure to such embodiment, feature or function). Rather, the description is intended to describe illustrative embodiments, features and functions in order to provide a person of ordinary skill in the art context to understand the disclosure without limiting the disclosure to any particularly described embodiment, feature or function. While specific embodiments of, and examples for, the disclosure are described herein for illustrative purposes only, various equivalent modifications are possible within the spirit and scope of the disclosure, as those skilled in the relevant art will recognize and appreciate. As indicated, these modifications may be made to the disclosure in light of the foregoing description of illustrated embodiments of the disclosure and are to be included within the spirit and scope of the disclosure. Thus, while the disclosure has been described herein with reference to particular embodiments thereof, a latitude of modification, various changes and substitutions are intended in the foregoing disclosures, and it will be appreciated that in some instances some features of embodiments of the disclosure will be employed without a corresponding use of other features without departing from the scope and spirit of the disclosure as set forth. Therefore, many modifications may be made to adapt a particular situation or material to the essential scope and spirit of the disclosure.

[0047] Respective appearances of the phrases "in one embodiment," "in an embodiment," or "in a specific embodiment" or similar terminology in various places throughout this specification are not necessarily referring to the same embodiment. Furthermore, the particular features, structures, or characteristics of any particular embodiment may be combined in any suitable manner with one or more

other embodiments. It is to be understood that other variations and modifications of the embodiments described and illustrated herein are possible in light of the teachings herein and are to be considered as part of the spirit and scope of the disclosure.

[0048] In the description herein, numerous specific details are provided, such as examples of components and/or methods, to provide a thorough understanding of embodiments of the disclosure. One skilled in the relevant art will recognize, however, that an embodiment may be able to be practiced without one or more of the specific details, or with other apparatus, systems, assemblies, methods, components, materials, parts, and/or the like. In other instances, well-known structures, components, systems, materials, or operations are not specifically shown or described in detail to avoid obscuring aspects of embodiments of the disclosure. While the disclosure may be illustrated by using a particular embodiment, this is not and does not limit the disclosure to any particular embodiment and a person of ordinary skill in the art will recognize that additional embodiments are readily understandable and are a part of this disclosure.

[0049] It will also be appreciated that one or more of the elements depicted in the drawings/figures can also be implemented in a more separated or integrated manner, or even removed or rendered as inoperable in certain cases, as is useful in accordance with a particular application.

[0050] Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any component(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or component.

CLAIMS:

1. A monitoring system for monitoring performance of railway equipment in an inherently safe way, the monitoring system comprising:

a non-contact capacitive voltage sensor for monitoring motor performance of a point machine by measuring a phase offset of a motor of the point machine between voltage and current waveforms,

wherein the non-contact capacitive voltage sensor generally works by sensing a small electrostatic charge of a metallic surface that is capacitively coupled to a live circuit and a reference ground such that the non-contact capacitive voltage sensor produces a voltage that is proportional to a sensed voltage without needing to make a direct contact to contact circuits of the motor of the point machine, and

wherein the non-contact capacitive voltage sensor produces a small voltage signal that is amplified such that this signal can be measured and recorded by the monitoring system.

2. The monitoring system of claim 1, wherein the non-contact capacitive voltage sensor measures a voltage waveform's shape and zero-crossing without concern of a voltage amplitude.

3. The monitoring system of claim 2, wherein the non-contact capacitive voltage sensor is not electrically connected to control circuits of the motor of the point machine to measure the voltage waveform.

4. The monitoring system of claim 3, wherein the non-contact capacitive voltage sensor uses a capacitive (non-contact) voltage measurement to eliminate any direct electrical connection to the contact circuits of the motor of the point machine.

5. The monitoring system of claim 4, wherein the capacitive (non-contact) voltage measurement does not reduce safety or reliability of a monitored railway equipment or system because the non-contact capacitive voltage sensor is electrically isolated from the monitored railway equipment.

6. The monitoring system of claim 5, wherein any failure of the monitoring system or the non-contact capacitive voltage sensor remains isolated from the monitored railway equipment and a failure of the monitored railway equipment remains isolated from the monitoring system or the non-contact capacitive voltage sensor.

7. The monitoring system of claim 1, wherein such a monitoring method can be applied to existing point machine installations without disturbing and potentially cause it failure to existing point machine control circuits.

8. The monitoring system of claim 1, wherein since a voltage amplitude is not important, a voltage measurement can be performed at an equipment power supply instead of at the point machine.

9. The monitoring system of claim 1, wherein the non-contact capacitive voltage sensor does not need to be located inside the point machine thereby minimising installation cost and risk.

10. The monitoring system of claim 1, wherein the non-contact capacitive voltage sensor uses a non-contact voltage measurement.

11. A method of providing a monitoring system for monitoring performance of railway equipment in an inherently safe way, the method comprising:

providing a non-contact capacitive voltage sensor for monitoring motor performance of a point machine by measuring a phase offset of a motor of the point machine between voltage and current waveforms,

wherein the non-contact capacitive voltage sensor generally works by sensing a small electrostatic charge of a metallic surface that is capacitively coupled to a live circuit and a reference ground such that the non-contact capacitive voltage sensor produces a voltage that is proportional to a sensed voltage without needing to make a direct contact to contact circuits of the motor of the point machine, and

wherein the non-contact capacitive voltage sensor produces a small voltage signal that is amplified such that this signal can be measured and recorded by the monitoring system.

12. The method of claim 11, wherein the non-contact capacitive voltage sensor measures a voltage waveform's shape and zero-crossing without concern of a voltage amplitude.

13. The method of claim 12, wherein the non-contact capacitive voltage sensor is not electrically connected to control circuits of the motor of the point machine to measure the voltage waveform.

14. The method of claim 13, wherein the non-contact capacitive voltage sensor uses a capacitive (non-contact) voltage measurement to eliminate any direct electrical connection to the contact circuits of the motor of the point machine.

15. The method of claim 14, wherein the capacitive (non-contact) voltage measurement does not reduce safety or reliability of a monitored railway equipment or system because the non-contact capacitive voltage sensor is electrically isolated from the monitored railway equipment.

16. The method of claim 15, wherein any failure of the monitoring system or the non-contact capacitive voltage sensor remains isolated from the monitored railway equipment and a failure of the monitored railway equipment remains isolated from the monitoring system or the non-contact capacitive voltage sensor.

17. The method of claim 11, wherein such a monitoring method can be applied to existing point machine installations without disturbing and potentially cause it failure to existing point machine control circuits.

18. The method of claim 11, wherein since a voltage amplitude is not important, a voltage measurement can be performed at an equipment power supply instead of at the point machine.

19. The method of claim 11, wherein the non-contact capacitive voltage sensor does not need to be located inside the point machine thereby minimising installation cost and risk.

20. The method of claim 11, wherein the non-contact capacitive voltage sensor uses a non-contact voltage measurement.