

Electrical Switchboard Monitoring System

Field of the Invention

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This invention relates to an electrical switchboard monitoring system and refers particularly, though not exclusively, to an electrical switchboard monitoring system to predict likely failure of the electrical switchboard.

10 Background to the Invention

15 An electrical switchboard provides electrical power to all mechanical and electrical services in a building such as air-conditioning, lifts, pumps, security system, IT system, and so forth. The building may be an office, commercial building, factory, or a residential building. The failure of the electrical switchboard may be severe because critical facilities will be crippled.

There are three main failures that may occur in an electrical switchboard:

- (1) over-current;
- 20 (2) earth leakage; and
- (3) thermal breakdown.

25 The first and second failures are protected by protective devices such as circuit breakers and fuses. The third failure is usually caused by poor or bad electrical connections. This type of switchboard failure is most dangerous as the occurrence of such a fault usually results in the burning-out of switchgear, circuit breakers or cables, and causes the longest downtime for the electrical network. It may also cause a fire that damages or destroys the building. Being able to predict a thermal breakdown fault is very important.

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Electrical switchboard thermal breakdown failures occur, and are not uncommon, when the bus bar joints are not tightened. This may be due to them be not tightened properly during installation. This can also occur after a long period of operation of the bus bar due to expansion and contraction of the bus bar joints during the day and night, and/or due to the electrical load changing. As the joints 35 loosen, the impedance of the contact increases. As a high current (more than a

few thousand amperes) may pass through the poor joints, the contact area will heat up, and hot spots will occur.

Elements and devices of the electrical switchboard are connected by electrical joints. Bolted electrical busbar joints within the electrical switchboard are subjected to two ageing processes – an ageing process caused by chemical changes in the constriction area, and a second ageing process of a decrease of the joint force caused by creep in the metallic conductor material depending on the temperature. This leads to a situation where the joint resistance will increase with time. This may cause the bolts that tighten the bus bars to expand elongate resulting in a loose joint. This is especially so when the bolt is used to tighten two dissimilar materials or components such as, for example busbars and a cable. They may have different shapes, and different expansion/contraction properties.

Thermal strips or temperature sensors are presently employed to detect a thermal overload. These two methodologies works like a thermometer mounted inside the electrical switchboard. When the temperature inside the switchboard (for the temperature sensor methodology) or the joints of the bus bar (for the thermal strip methodology) rises to a pre-set temperature, the system sounds an alarm to the user to indicate a thermal overload.

These two methods are rigid as they detect the fault and do not predict the fault. They also depend on sensors to detect the fault. This is not an ideal solution as it is not possible to easily determine if the sensors are functioning, or there is no fault. This is because the design of such systems is that "no signal from the sensors means the switchboard is good condition". This may be true. However, a "no signal form the sensor" could mean the sensor is faulty, and not that the switchboard in good condition. There is no way to differentiate between a faulty sensor, and an actual good condition. In addition, there is a relatively high cost in installing temperature sensors.

Thermal scanning is also employed to determine bad joints ("hot spots") within electrical switchboards. This involves using a thermal camera to video-scan the electrical switchboard. The electrical switchboard heat profile is then plotted onto paper.

The cost for each thermal scan is about S\$10,000 to S\$15,000. This is expensive. Also, it is not able to predict bus bar failure as thermal scanning is usually done once a year. In addition, there are chances of human error when performing a manual scan.

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Thermal scanning of a heated joint only tells if there is a hot spot inside the switchboard at the time of scanning. It does not predict if the switchboard would fall due to a thermal breakdown because at the time of measurement, the switchboard may not always be at its peak load.

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Summary of the Invention

According to a preferred aspect of the present invention, there is provided a method for predicting likely failure of an electrical switchboard, the method including the steps:

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- a. during operation, determining an operating resistance of at least one section of a bus bar forming a part of the electrical switchboard;
- b. comparing the operating resistance with a healthy resistance of the at least one section of the bus bar; and
- 20 c. if the operating resistance is greater than the healthy resistance by more than a predetermined amount, generating a fault signal.

According to another preferred aspect of the present invention, there is provided a method for predicting likely failure of an electrical bus bar, the method including the steps:

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- (a) during operation, determining an operating resistance of at least one section of the bus bar;
- (b) comparing the operating resistance with a healthy resistance of the at least one section of the bus bar; and
- 30 (c) if the operating resistance is greater than the healthy resistance by more than a predetermined amount, generating a fault signal.

The operating resistance may be determined by measurement of a current through the at least one section of the bus bar, measurement of a voltage across the at least one section of the bus bar, and calculating the operating resistance from the current and the voltage. The healthy resistance may be determined from

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specifications of material used for the bus bar, and specifications of any circuit breakers in the at least one section of the bus bar.

5 The predetermined amount may be at least one of: minor fault, major fault and critical fault. The fault signal may be at least one of: minor fault signal, major fault signal and critical fault signal.

Also, at the electrical switchboard there may be generated at least one of: display and alarm.

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Preferably, the fault signal is sent by a transmission module. The transmission module may send the fault signal to a monitoring system by a transmission being one of: radio frequency transmission, SMS, email, text message, alarm signal and status signal. The transmission may be over at least one of: direct transmission,
15 the atmosphere, a local area network, a wide area network, the Internet.

The predetermined amount may be a multiplication factor in the range of two to four for minor faults, in the range five to nine for major faults, and more than ten for critical faults.

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In another aspect, the present invention provides apparatus for predicting likely failure of an electrical switchboard having a bus bar, the apparatus including:

- a. sensors for sensing a voltage across at least one section of the bus bar and a current through the at least one section of the bus bar;
- 25 b. transducers for receiving output signals from the sensors and generating a signal to a processor;
- c. the processor being for receiving the signal and from the signal calculating an operating resistance of the bus bar from the voltage and the current, comparing the operating resistance with a healthy resistance and, if the
30 operating resistance exceeds the healthy resistance by more than a predetermined amount, generating a fault signal; and
- d. a transmission module for sending the fault signal.

In yet another aspect, the present invention provides apparatus for predicting likely
35 failure of a bus bar, the apparatus including:

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- (a) sensors for sensing a voltage across at least one section of the bus bar and a current through the at least one section of the bus bar;
 - (b) transducers for receiving output signals from the sensors and generating a signal to a processor;
 - (c) the processor being for receiving the signal and from the signal calculating an operating resistance of the bus bar from the voltage and the current, comparing the operating resistance with a healthy resistance and, if the operating resistance exceeds the healthy resistance by more than a predetermined amount, generating a fault signal; and a transmission module for sending the fault signal.
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The healthy resistance is determined from specifications of material used for the bus bar and specifications of any circuit breakers in the at least one section of the bus bar.

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The predetermined amount may be at least one selected from the group consisting of: minor fault, major fault and critical fault. The fault signal may be at least one of: minor fault signal, major fault signal and critical fault signal.

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At the electrical switchboard there may be generated at least one of: display and alarm.

The transmission module may send the fault signal to a monitoring system by a transmission being: radio frequency transmission, SMS, email, text message, alarm signal and status signal.

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The predetermined amount may be a multiplication factor in the range of two to four for minor faults, in the range five to nine for major faults, and more than ten for critical faults.

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In a further aspect, the present invention provides an electrical switchboard including the apparatus as described above.

35 In a final aspect, the present invention provides a computer usable medium comprising a computer program code configured to cause a processor to execute

one or more functions to enable the processor perform the method described above.

Brief Description of the Drawings

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In order that the invention may be fully understood and readily put into practical effect, there shall now be described by way of non-limitative example only preferred embodiments of the present invention, the description being with reference to the accompanying illustrative drawings in which:

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Figure 1 is an illustration of an electrical switchboard according to a preferred form of the present invention;

Figure 2 is a schematic illustration of the system architecture;

Figure 3 is a flow chart for the operational flow of the system of Figures 1 and 2;

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and

Figure 4 is a flow chart showing an alternative operation to that of Figure 3.

Description of Preferred Embodiments

20 To refer to Figures 1 and 2, there is shown the apparatus for measuring contact resistance of joints for dynamic readings to be taken on-line. Such readings can be analysed for predictions to be made to determine if the joints are deteriorating. This enables action to be scheduled in advance to prevent failure due to thermal breakdown.

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In Figure 1 there is shown an electrical switchboard 10 that includes a bus bar 12. There is also an air circuit breaker 14 to protect the bus bar 12 from current overload.

30 The system has voltage and current transducers 20 with sensors 16 connected to bus bar 12 at or adjacent each end thereof. Sensors 16 are operatively connected to transducers 20. The transducers 20 output to a processor 22 that outputs to a transmission module 24. Processor 22 also output to a local display and/or alarm 30. Processor 22 may include memory 60, preferably a non-volatile memory.

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Figure 2 shows the electrical switchboard 10, transducers 20, processor 22, and transmission module 24. Transmission module 24 transmits to a central monitoring

system 28 over a transmission network 26. Transmission network 26 may be a direct link to the monitoring system 28, the atmosphere, a local area network, a wide area network, or the Internet. Transmission may be by radio frequency transmission, SMS, email, text message, alarm signal, status signal, and so forth.

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The process is shown in Figure 3. Once the system is installed and started (30), the transducers 20 are used to measure the current through bus bar 12 (32) and the voltage across bus bar 12 (34).

- 10 This may done by using voltage and current sensors 16 across the bus bar 12 and using these results to determine the resistance of the bus bar. The voltage and current sensors 16 may be together, as shown, or may be separate. The measurement, and monitoring, may be across the entire bus bar (as shown) or simultaneously across each section of the bus bar. This may be for all or certain
- 15 required sections of the bus bar. Monitoring may be continuous, or may be at periodic intervals. The periodic intervals may be a matter of seconds, minutes or hours. By monitoring across sections it is possible to accurately locate the problem and thus take corrective action more quickly. This may include the circuit breakers in the section as bad circuit breaker contacts can also cause a thermal breakdown
- 20 due false tripping resulting from an increase in the operating temperature.

By measuring the voltage and current across the bus bar and/or each bus bar section, it is possible to calculate (36) the measured resistance R_m (real time value) of the bus bar as:

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Resistance – Voltage/Current (ohm)

- From the specification for the material used for bus bar 12 as well as circuit breaker 14 specifications (including contact resistance), the theoretical resistance (healthy
- 30 resistance) of the bus bar, R_n during normal operation can be determined (40). It may also be determined by direct measurement after installation but prior to full use. The R_n is stored in processor 20, preferably in non-volatile memory 60.

- By comparing (38) the value of R_m and R_n , it is possible to determine whether the
- 35 bus bar is normal. If resistance R_m is greater than R_n , the bus bar joints are breaking down and the bus bar requires maintenance.

To enable earlier detection of the electrical bus bar breakdown process, faults can be classified according to a number of categories. There may be any suitable number of categories such as, two, three, four or five. For example, the faults may be classified as being minor (56), major (46) or critical (42). A minor fault happens
5 when the R_m is, for example, in the range two to four times the value of R_h . A major fault occurs when R_m is, for example, five to nine times the value of R_h . A critical fault occurs when R_m is, for example, more than ten times the value of R_h . Maintenance priority can then be managed so that equipment that requires immediate attention (for major and critical alarms) can be given priority over those
10 that require more routine maintenance (for minor alarms).

The processor 22 compares R_h with R_m . If the R_m is such that a critical fault is occurring (42), a critical fault signal is generated (44) and sent by transmission module 24. If the comparison indicates it is not a critical fault a check is made to
15 determine if it is a major fault (46). If it is a major fault, a major fault signal is generated (48) by processor 22 and sent by transmission module 24. If not a major fault, a final check is made to determine if it is a minor fault (50). If a minor fault, a minor fault signal is generated (52) by processor 22 and sent by transmission module 24. If not a minor fault, the system reverts back to the start.
20 At each signal generation step 44, 48 and 52, a local display at electrical switchboard 10 is initiated and/or an alarm generated or sounded (58). The signal may be sent to a central monitoring centre where it is received and displayed so the operating centre personnel may be aware of the problem, the nature of the problem (major, minor, critical), the location of the problem (which electrical switchboard) and where on the bus bar the problem is located.
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The transmission is preferably they are of: radio frequency transmission, direct link to the monitoring centre, a local area network, wide area network or the Internet; and may be by SMS, email, text message, alarm signal, status signal.
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As shown in Figure 4, the order of steps 42, 46 and 50 may be reversed, if desired. After step 38 there may be added a preliminary test (62) to determine if a fault condition exists. If yes, process steps 42 to 52 are followed. If not, it passes directly back to the start 30.
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The present invention also extends to a computer usable medium comprising a computer program code that is configured to cause the processor 22 to execute one or more functions as described above.

- 5 Whilst there has been described in the foregoing description preferred embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design, construction or operation may be made without departing from the present invention.

The claims

1. A method for predicting likely failure of an electrical switchboard, the method including the steps:
 - 5 (a) during operation, determining an operating resistance of at least one section of a bus bar forming a part of the electrical switchboard;
 - (b) comparing the operating resistance with a healthy resistance of the at least one section of the bus bar; and
 - 10 (c) if the operating resistance is greater than the healthy resistance by more than a predetermined amount, generating a fault signal.
2. A method for predicting likely failure of an electrical bus bar, the method including the steps:
 - 15 (a) during operation, determining an operating resistance of at least one section of the bus bar;
 - (b) comparing the operating resistance with a healthy resistance of the at least one section of the bus bar; and
 - 20 (c) if the operating resistance is greater than the healthy resistance by more than a predetermined amount, generating a fault signal.
3. A method as claimed in claim 1 or claim 2, wherein the operating resistance is determined by measurement of a current through the at least one section of the bus bar, measurement of a voltage across the at least one section of the bus bar, and calculating the operating resistance from the current and the voltage.
4. A method as claimed in any one of claims 1 to 3, wherein the healthy resistance is determined from specifications of material used for the bus bar and specifications of any circuit breakers in the at least one section of the bus bar.
5. A method as claimed in any one of claims 1 to 4, wherein the predetermined amount is at least one selected from a plurality of categories of fault.

6. A method as claimed in claim 5, wherein the plurality of fault is at least one selected from the group consisting of: minor fault, major fault and critical fault.
- 5 7. A method as claimed in any one of claims 1 to 6, wherein the fault signal is at least one selected from the group consisting of: minor fault signal, major fault signal and critical fault signal.
- 10 8. A method as claimed in any one of claims 1 to 7, wherein at the electrical switchboard is generated at least one selected from the group consisting of: display and alarm.
- 15 9. A method as claimed in any one of claims 1 to 8, wherein the fault signal is sent by a transmission module.
- 20 10. A method as claimed in claim 9, wherein the transmission module sends the fault signal to a monitoring system by a transmission selected from the group consisting of: radio frequency transmission, SMS, email, text message, alarm signal and status signal.
- 25 11. A method as claimed in claim 10, wherein the transmission is over at least one selected from the group consisting of: direct transmission, the atmosphere, a local area network, a wide area network, the Internet.
- 30 12. A method as claimed in any one of claims 4 to 6, wherein the predetermined amount is a multiplication factor in the range of two to four for minor faults, in the range five to nine for major faults, and more than ten for critical faults.
- 35 13. A method as claimed in any one of claims 3 to 12, wherein there are a plurality of sections of the bus bar, the measurement of voltage and current taking place for each of the plurality of sections.
14. A method as claimed in claim 13, where the measurement of voltage and current at each of the sections takes place simultaneously.

15. A method as claimed in any one of claims 3 to 14, wherein the measurement of voltage and current is periodic.
16. Apparatus for predicting likely failure of an electrical switchboard having a bus bar, the apparatus including:
- (a) sensors for sensing a voltage across at least one section of the bus bar and a current through the at least one section of the bus bar;
 - (b) transducers for receiving output signals from the sensors and generating a signal to a processor;
 - (c) the processor being for receiving the signal and from the signal calculating an operating resistance of the bus bar from the voltage and the current, comparing the operating resistance with a healthy resistance and, if the operating resistance exceeds the healthy resistance by more than a predetermined amount, generating a fault signal; and a transmission module for sending the fault signal.
17. Apparatus for predicting likely failure of a bus bar, the apparatus including:
- (a) sensors for sensing a voltage across at least one section of the bus bar and a current through the at least one section of the bus bar;
 - (b) transducers for receiving output signals from the sensors and generating a signal to a processor;
 - (c) the processor being for receiving the signal and from the signal calculating an operating resistance of the bus bar from the voltage and the current, comparing the operating resistance with a healthy resistance and, if the operating resistance exceeds the healthy resistance by more than a predetermined amount, generating a fault signal; and a transmission module for sending the fault signal.
18. Apparatus as claimed in claim 16 or claim 17, wherein the healthy resistance is determined from specifications of material used for the bus bar and specifications of any circuit breakers in the at least one section of the bus bar.

19. Apparatus as claimed in any one of claims 16 to 18, wherein the predetermined amount is at least one selected from a plurality of categories of fault.
- 5 20. Apparatus as claimed in claim 19, wherein the category of fault is at least one selected from the group consisting of: minor fault, major fault and critical fault.
- 10 21. Apparatus as claimed in any one of claims 16 to 20, wherein the fault signal is at least one selected from the group consisting of: minor fault signal, major fault signal and critical fault signal.
- 15 22. Apparatus as claimed in any one of claims 16 to 21, wherein at the electrical switchboard is generated at least one selected from the group consisting of: display and alarm.
- 20 23. Apparatus as claimed in any one of claims 16 to 22, wherein the transmission module sends the fault signal to a monitoring system by a transmission selected from the group consisting of: radio frequency transmission, SMS, email, text message, alarm signal and status signal.
- 25 24. Apparatus as claimed in claim 23, wherein the transmission is over at least one selected from the group consisting of: direct transmission, the atmosphere, a local area network, a wide area network, the Internet.
- 25 25. Apparatus as claimed in claim 21, wherein the predetermined amount is a multiplication factor in the range of two to four for minor faults, in the range five to nine for major faults, and more than ten for critical faults.
- 30 26. An electrical switchboard including the apparatus as claimed in any one of claims 16 to 25.
- 35 27. Computer usable medium comprising a computer program code configured to cause a processor to execute one or more functions to enable the processor perform the method of any one of claims 1 to 15.