



(51) International Patent Classification:

E21B 3/00 (2006.01) B60L 3/04 (2006.01)
G01R 31/56 (2020.01) G01R 27/18 (2006.01)
G01R 31/52 (2020.01)

(21) International Application Number:

PCT/SE2019/051026

(22) International Filing Date:

18 October 2019 (18.10.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1830298-4 19 October 2018 (19.10.2018) SE

(71) Applicant: EPIROC ROCK DRILLS AKTIEBOLAG

[SE/SE]; 701 91 Örebro (SE).

(72) Inventors: TIERNEY, Mark; Lindängen, 732 91 Arboga (SE). TIERNEY, Thomas; Norra Lunger 143, 732 91 Arboga (SE). SVENSSON, Filip; Björka 611, 705 97 Glan-shammar (SE). ROTH, Patrik; Vintrosavägen 3, 719 94 Vintrosa (SE). JOHANSSON, Lars; Norra Gottsätter 497, 705 91 Örebro (SE). ANDERSSON, Emil; Berga 1038, 716 93 Fjugesta (SE). HELLBERG, Arne; Rudbecksgatan 35, 702 11 Örebro (SE).

(74) Agent: ZACCO SWEDEN AB; P.O. Box 5581, Val-hallavägen 117N, 114 85 Stockholm (SE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,

(54) Title: MINING MACHINE WITH ELECTRICAL INSULATION STATUS MONITORING

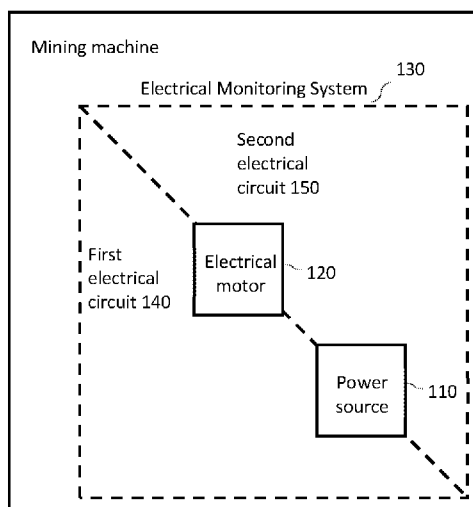


Figure 1

(57) Abstract: The present invention relates to a mining machine configured for electrical insulation status monitoring, a corresponding method performed in the mining machine and a computer program product. The mining machine comprises at least one power source(110), at least one electrical motor (120, 250) configured to power one or more mining operations of the mining machine; and an electrical monitoring system (130, 210) for monitoring an electrical insulation status of a first or a second electrical circuit (140, 150). The electrical monitoring system (130) comprises at least a first electrical insulation monitor (270) configured to monitor the electrical insulation status of the mining machine during one or more mining operations when connected to the first electrical circuit (140) and at least a second electrical insulation monitor (280) configured to monitor the electrical insulation status of the mining machine when connected to the second electrical circuit (150). The mining machine further comprises one or more contactors (290) comprised in the first and second electrical circuit and wherein the electrical monitoring system is configured to open the one or more contactors in the first electrical circuit when closing the one or more contactors in the second electrical circuit.

MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

Mining machine with electrical insulation status monitoring

TECHNICAL FIELD

The present invention relates to a mining machine configured for electrical insulation status monitoring, a
5 corresponding method performed in the mining machine and a computer program product.

BACKGROUND OF THE INVENTION

There is ongoing work in adapting mining machines to operate using electricity and more specifically for,
at least in part, operate in a battery-powered mode. The electrically operated mining machine may be
connected to an external power source, e.g., a power grid, for supply of power to charge one or more
10 batteries comprised in the mining machine or for direct powering of the mining machine when operating
in a stationary mode, e.g., during a stationary mining operation. In addition to a grid connection, the
external power source could also be a diesel power generator or a power bank comprising batteries or
other type of energy storage devices.

Individual mining machines are configured to operate according to recurring mining cycles, i.e., cycles of
15 mining operations defined for the specific machines. Thus, a mining machine, i.e., work machine, is often
used in a repeated work cycle. Mining operations involve a wide variety of mining machines, such as face
drill rigs, production drill rigs, rock bolting rigs, cable bolting rigs, concrete spraying machines, loaders,
haulers and dumpers. The listed mining machines require considerable power during operation and the
mining machines usually have high power demands during predictable phases of a mining cycle. The term
20 "work cycle" may reflect a route of the work machine and mining operation performed by the working
machine according to a repetitive and at least partially predetermined pattern. During the performance of
the work cycle, the work machine uses different power supplies. The day-to-day operations of mining
typically involve many mining operations, performed by a variety of mining machines during such work
cycles. The operations comprise cycles of drilling, blasting, ventilating, as well as loading, transporting and
25 dumping material that has been cut during the work cycles of mining operations, i.e., mining cycles. These
work cycles place demands on power that are unique to mining, where charging of a battery may be on-
going at the same time as a grid connection provides powering to a stationary high power operation.

Thus, an electrical mining machine could be powered by either a mains or grid connection, or by a
rechargeable battery system; each power source associated with a high voltage. If a machine has an
30 electrical insulation fault, a hazard situation (electrical flashover) may arise, primarily for a service

technician. The technician or operator would benefit from receiving information relating to an electrical insulation fault, e.g., before the off grid mining machine is connected to a power supply. The technician would also benefit from knowing the electrical insulation status of the disconnected battery system as well as the disconnected mains power supply, and the electrical insulation status when the machine is connected to a power supply. If an insulation monitor is malfunctioning it is also desirable to have a redundant system of insulation monitors.

Thus, there is a need to configure the mining machines for safe power insulation monitoring.

SUMMARY OF THE INVENTION

It is an object of the present disclosure to solve or mitigate, alleviate, or eliminate at least some of the above-identified deficiencies in the art and to provide a solution for improved charge management.

According to a first aspect, the object is achieved by a mining machine comprising at least one power source and at least one electrical motor configured to power one or more mining operations of the mining machine. The mining machine also comprises an electrical monitoring system for monitoring an electrical insulation status of a first or a second electrical circuit. The electrical monitoring system comprises at least a first electrical insulation monitor configured to monitor the electrical insulation status of the mining machine during one or more mining operations when connected to the first electrical circuit and at least a second electrical insulation monitor configured to monitor the electrical insulation status of the mining machine when connected to the second electrical circuit. The electrical monitoring system also comprises one or more contactors comprised in the first and second electrical circuit and wherein the electrical monitoring system is configured to open the one or more contactors in the first electrical circuit when closing the one or more contactors in the second electrical circuit.

In some embodiments, the power source may comprise one or more batteries controlled from a battery management system, BMS, and the first electrical insulation monitor may be comprised in the BMS.

In some embodiments, the first electrical insulation monitor may be configured for real-time monitoring and reporting of a current resistance value of the first electrical circuit. The first electrical insulation monitor may report the value to a processing circuitry of the electrical monitoring system.

In some embodiments, the second electrical insulation monitor may be configured for real-time monitoring and reporting of a current resistance value of the second electrical circuit to a processing circuitry of the electrical monitoring system.

In some embodiments, the first electrical circuit may be an electrical main circuit and the second electrical circuit may be an electrical sub-circuit electrically isolated from the main circuit with at least one contactor. The mining machine may comprise an electrical insulation main monitor monitoring the electrical insulation status on the main circuit when the contactors are open. It may also comprise an at least one
5 electrical insulation sub monitor monitoring the electrical insulation status on the sub-circuit when the contactors are open. Wherein the electrical insulation main monitor may monitor the electrical insulation status on the main circuit and the one or more sub circuits if the one or more contactors may be closed and whereby the one or more insulation sub monitors may be inactivated.

In yet some embodiments the monitoring may be started directly on the machine, from a connected
10 Remote Control System (RCS) or in an application running in e.g. a mobile phone or any other template.

According to a second aspect, the object is achieved by a method for monitoring a insulation status of a mining machine that comprises at least one power source, at least one electrical motor configured to power one or more mining operations of the mining machine; and an electrical monitoring system for monitoring an electrical insulation status of a first or a second electrical circuit. The method comprises
15 monitoring the insulation status during one or more mining operations when connected to the second electrical circuit and open one or more contactors in the first electrical circuit when closing the one or more contactors in the second electrical circuit.

According to a third aspect of the disclosure, the object is achieved by a computer program comprising computer program code which, when executed cause execution of the method according to the second
20 aspect.

Embodiments provide the advantage of a secure and user-friendly operation with improved security on the basis that the electrical insulation monitor system will be monitoring the circuit both when the machine is connected to the battery and/or the main supply and when it is disconnected. Embodiments allow accurate, continuous, real-time determination of the electrical insulation status. Embodiments
25 provide for electrical insulation monitoring both during grid or battery connection, as well as when disconnected from a power supply.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 schematically illustrates a mining machine comprising a first and a second electrical circuit;

Figure 2 schematically illustrates an electrical monitoring system comprised in a mining machine;

Figure 3 schematically illustrates an electrical monitoring system comprised in a mining machine;

Figure 4 is a flowchart illustrating exemplary method steps for monitoring an insulation status on a mining machine;

Figure 5 is a flowchart illustrating exemplary method steps for monitoring an insulation status on a mining machine.

DETAILED DESCRIPTION OF THE INVENTION

Aspects of the present disclosure will be described more fully hereinafter with reference to the accompanying drawings. The apparatus and method disclosed herein can, however, be realized in many different forms and should not be construed as being limited to the aspects set forth herein. Like numbers in the drawings refer to like elements throughout.

The terminology used herein is for the purpose of describing particular aspects of the disclosure only, and is not intended to limit the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

In some implementations and according to some aspects of the disclosure, the functions or steps noted in the blocks can occur out of the order noted in the operational illustrations. For example, two blocks shown in succession can in fact be executed substantially concurrently or the blocks can sometimes be executed in the reverse order, depending upon the functionality/acts involved. Also, the functions or steps noted in the blocks can according to some aspects of the disclosure be executed continuously in a loop.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps, or components, but does not preclude the presence or addition of one or more other features, integers, steps, components, or groups thereof. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

In cooperation with attached drawings, the technical contents and detailed description of the present invention are described thereafter according to a preferable embodiment, being not used to limit its executing scope. Any equivalent variation and modification made according to appended claims is all covered by the claims claimed by the present invention.

Reference will now be made to the drawing figures to describe the present invention in detail.

Figure 1 schematically illustrates a mining machine. As previously explained, an electrically operated mining machine may be connected to an external power source, e.g., a power grid, for supply of power to charge one or more batteries comprised in the mining machine or for direct powering of the mining machine when operating in a stationary mode, e.g., during a stationary mining operation. In addition to a grid connection, the external power source could also be a diesel power generator or a power bank comprising batteries or other type of energy storage devices.

Individual mining machines are configured to operate according to recurring mining cycles, i.e., cycles of mining operations defined for the specific machines. Thus, a mining machine, i.e., work machine, is often used in a repeated work cycle. Mining operations involve a wide variety of mining machines, such as face drill rigs, production drill rigs, rock bolting rigs, cable bolting rigs, concrete spraying machines, loaders, haulers and dumpers. The listed mining machines require considerable power during operation and the mining machines usually have high power demands during predictable phases of a mining cycle.

Turning back to Figure 1, a schematic illustration is provided of a mining machine according to the present disclosure. In its most general form, the mining machine comprises at least one power source 110 and at least one electrical motor 120 configured to power one or more mining operations of the mining machine. The mining machine also comprises an electrical monitoring system 130 for monitoring an electrical insulation status of a first or second electrical circuit 140, 150. The electrical monitoring system 130 comprises at least a first electrical insulation monitor, configured to monitor the electrical insulation status of the mining machine during one or more mining operations when connected to the first electrical circuit 140. The electrical monitoring system 130 comprises also at least a second electrical insulation monitor 270 configured to monitor the electrical insulation status of the mining machine when connected to the second electrical circuit 150. The electrical monitoring system 130 also comprises one or more contactors, e.g., circuit breakers or relays, comprised in the first and second electrical circuit 140, 150 and wherein the electrical monitoring system 130 is configured to open the one or more contactors in the first electrical circuit 140 when closing the one or more contactors in the second electrical circuit 150.

Thus, the mining machine comprises an electrical monitoring system capable of monitoring electrical insulation between electrically operated parts of the machine and the machine chassis. The purpose of the system is to detect and generate alarms if the insulation quality of the electrical installation on the machine falls below a certain threshold.

The insulation resistance on new installations and electrical equipment is usually very good. Over time, operation causes an inevitable reduction in insulation resistance. The causes could be static overvoltage,

bends and vibrations, temperature and moisture, aggressive atmosphere as well as improper installations. If insulation resistance is insufficient, the protection against direct or indirect contact cannot be ensured leading to that the lives of individuals are put at risk. Short-circuits and earth fault currents can cause fires and explosions as well as interruption in production.

5 The electrical monitoring system may be activated from the mining machine, from a connected Remote Control System (RCS) or in an application running in e.g. a mobile phone or any other template. When the test is completed the test button stops flashing and remains on while the insulation value is presented on an electrical insulation panel meters. As illustrated in Figure 4, electrical insulation panel meters could be arranged on the machine, in the connected RCS or in the application. The machine can be connected to
10 different energy sources; extra low voltage (e.g. 24V battery or similar), low voltage battery (e.g. 512V battery) or low voltage AC supply (e.g. 400V supply). Monitoring may be initiated before the mining machine is powered up, during operation or during charging.

So called contactors may be selected from their applicability to be used in higher voltage applications or higher current applications, e.g., applications in a four hundred to a thousand Volt range or up to 1500
15 Ampere when applying lower voltages. In the context of the present disclosure, a contactor may be a relay, a circuit breaker, a coupling device or a switch, all with the aim of breaking the circuit.

Reference is made to figure 2, which shows an embodiment of the mining machine comprising the electrical monitoring system 210 for monitoring the electrical insulation status of the first or the second electrical circuit 140, 150. The mining machine comprises first and second power sources 220, 230 in the
20 form of one or more batteries 220 and an inverter 240 receiving power from a grid connection, a diesel generator or a power bank 230. The first electrical circuit 140 is formed by at least one electrical motor 250, at least one inverter 260, the first insulation monitor 270 and the one or more batteries 220, when the contactors 290 of the first electrical circuit 140 are closed, and the contactors 290 of the second electrical circuit 150 are open. The second electrical circuit 150 is formed by the at least one power source
25 230, the inverter 240 and the second electrical insulation monitor 280 when the contactors 290 of the second electrical circuit 150 are closed, and the contactors 290 of the first electrical circuit 140 are open. A third electrical circuit 294 is formed when all contactors 290 are open, hence the mining machine is completely powered off. A third insulation monitor 292 will measure on the third electrical circuit 294 comprising the at least one electrical motor 250 and the inverter 260.

30 The first electrical circuit 140 may comprise the one or more batteries 220, hence the mining machine is power supplied by the battery and the contactors 290 in the first electrical circuit 140 is closed. The at

least one electrical motor 250 is powering one or more mining operations of the mining machine. The first electrical insulation monitor 270 is configured to monitor the electrical insulation status in the first electrical circuit 140. The first electrical insulation monitor 270 is also configured for real-time monitoring and reporting of a current, real-time monitoring the current resistance value of the first electrical circuit 140 and reporting the electrical insulation status repeatedly to a control system. The real-time monitoring and reporting is e.g every second. The first electrical insulation monitor 270 may be an integrated part of a Battery Management System (BMS)-system.

The contactors 290 of the first electrical circuit 140 may be opened and the contactors 290 comprised in the second electrical circuit 150 may be closed, hence the mining machine may be connected to an external power source 230 e.g. an electrical network, the electrical grid, a diesel generator or a power bank, which may comprise worn-out old battery packs. The second electrical insulation monitor 280 is configured to monitor the electrical insulation status in the second electrical circuit 150 and is configured to monitoring the current resistance value of the second electrical circuit 150 and reporting to the control system, when an isolation value is below a threshold or when the signal disappears.

Individual mining machines are configured to operate according to recurring mining cycles, i.e., cycles of mining operations defined for the specific machine. Thus, a mining machine, i.e., work machine, is often used in a repeated work cycle. Mining operations involve a wide variety of mining machines, such as face drill rigs, production drill rigs, rock bolting rigs, cable bolting rigs, concrete spraying machines, loaders, haulers and dumpers. The listed mining machines require considerable power during operation and the mining machines usually have high power demand during predictable phases of a mining cycle. The term "work cycle" comprises a route of the work machine and a power on and a power off of the mining machine. The work cycle is repeated during the working hours. During the performance of the work cycle, the mining machine uses different power supplies. The day-to-day operations of mining typically involve many mining operations, performed during such work cycle. The operations comprise cycles of drilling, blasting, ventilating, as well as loading, transporting and dumping material that has been cut during the cycles of mining operations, i.e., mining cycles. These mining cycles place demands on power that are unique to mining, where charging of a battery may be on-going at the same time as a grid connection provides powering to a stationary high power operation.

As shown in figure 3 the entire electrical power circuit 304 of the mining machine is divided in sections, an electrical main circuit 307, defined as the third electrical circuit 294 above, and one or more electrical sub circuits 305, 306. The main circuit 307 represents the machine disconnected from power supply. Sub circuit

305 represents a battery supply. Sub circuit 306 represents a main supply, where the machine being connected to the grid 312. The electrical circuits 305, 306, 307 may be electrically isolated from the main circuit 307. When sub circuit 305 and the main circuit 307 are electrically connected by closing contactor 308 and when opening contactor 313 the first electrical circuit is formed. When sub circuit 306 and the main circuit 307 are electrically connected by closing contactor 313 and when opening contactor 308 the second electrical circuit is formed.

The electrically sub circuit 305 is a low voltage battery circuit. It is electrically isolated from the rest of the machine with a contactor 308. To ensure that a possible deterioration in electrical insulation can be detected before a battery 319 is connected to the machine, a separate electrical insulation sub monitor 309 is used for this sub circuit 305. This separate electrical insulation sub monitor 309 will only monitor the electrical insulation status of the electrical sub circuit 305 and present the result on its electrical insulation sub panel meter. This separate insulation sub monitor 309 is only active when the contactor 308 is open. When the battery contactor 308 is closed the battery insulation sub monitor 309, and its sub panel meter, is deactivated and the function of detecting possible insulation faults in this sub circuit is taken over by an insulation main monitor 310.

The electrically sub circuit 306 is a low voltage AC supply circuit. This sub circuit 306 is the lower voltage side of a transformer 311. The low voltage supply, the grid 312, is transferred from the supply voltage level (e.g. >400V) down to the low voltage AC supply level (e.g. 400V). The electrically sub circuit 306 is electrically isolated from the rest of the machine until the contactor 313 is closed. To ensure that a possible deterioration in electrical insulation can be detected before the electrically sub circuit 306 is connected to the machine, a separate insulation sub monitor 314 is used for this sub circuit 306. This insulation sub monitor 314 shows the result of the measuring on its electrical insulation sub panel meter. This insulation sub monitor 314 and its sub panel meter, is active only when the contactor 313 is open. Once this contactor 313 closes, the function of detecting possible insulation faults on the sub circuit 306 is taken over by the insulation main monitor 310.

The electrical main circuit 307 is a DC link circuit. There is a separate electrical insulation main monitor 310 installed on the main circuit 307. To this electrical main circuit 307 different units can be connected, i.e., the at least one electrical motor, such as a traction motor 315, an auxiliary motor 316 or a diesel generator 317. The motors are connected to the circuit via an inverter 318a, 318b, 318c (AC/DC). The electrical insulation main monitor 310 will detect any insulation faults on the main circuit 307 cabling, one or more inverters 318a, 318b, 318c and their associated units 315, 316, 317. The electrical main circuit 307 is

electrically isolated from the electrical sub-circuits 305, 306 with contactors 308, 313. A contactor is a switch used for switching an electrical power circuit. Contactors differ from generic relays in that they are particularly suitable for higher voltage applications or higher current applications, e.g., applications in a four hundred to a thousand Volt range or up to 1500 Ampere when applying lower voltages. The plurality of contactors enables different electrical connections between the battery system and electrically powered systems of the mining machine, as well as the grid connection. Specifically, one or more first contactors 308 are configured to control a first connection between the electrical circuit 305 of the rechargeable battery 319 and the electrical main circuit 307, the machine circuit. One or more second contactors 313 are configured to control a second connection between the electrical grid circuit 306 and the electrical main circuit 307. When the electrical main circuit 307 is electrically disconnected from the electrical sub-circuits 305, 306, the contactors 308, 313 are open, the electrical insulation main monitor unit 310 will only monitor the electrical insulation status of the electrical main circuit 307 and present the result on the electrical insulation main panel meter.

The insulation main monitor 310 is also used to monitor insulation resistance on the sub circuit 305 and/or on the sub circuit 306 once these systems have been connected via their contactors 308, 313. The insulation main monitor 310 thereby monitors the electrical insulation status on the main circuit 307 cabling, the sub circuit 305 cabling and/or on the sub circuit 306 cabling and all the connected equipment, hence on the entire electrical power circuit 4. The insulation main monitor 310 shows the result of its measuring on the electrical insulation main panel meter.

During the pre-connected test (the contactors 308, 313 are open) the insulation of each sub circuit 305, 306, 307 is checked by using each of the systems separate insulation monitors 309, 310, 314. An alarm signal may be generated in order to indicate an insulation fault, on the machine, in the connected RCS or in the application.

When the battery 319 is connected to supply energy to the main circuit 307 or when the battery receives charging from the main circuit 307, the insulation main monitor 310 will be activated. The contactor 308 is then closed connecting the main circuit 307 with the sub circuit 305, thereby the insulation main monitor 310 will be activated and in real-time measure the insulation on both these sections together. The battery 319 can receive charging from either the diesel generator 317, off-grid, or from the electrical grid 312. If charged via the electrical grid 312, the battery 319 could be charged via a transformer 311 or without a transformer 311. When the battery 319 receives charging from the electrical grid 312 both the contactors

308 and 313 are closed and the insulation main monitor 310, is in this situation monitoring the entire electrical installation, hence, the circuits 305, 306, 307 and all the connected electrical equipment.

When the mining machine is powered on, supplied by either the low voltage battery sub circuit 305 or low voltage AC supply sub circuit 306, the insulation main monitor 310 operates on the voltage (e.g. 600-800V) of the circuit it is contacted with. When the mining machine is powered off it is using an extra low voltage level background current (e.g.24V or similar).

Different levels of resistance indicate if the insulation is reduced or not.

- E.g. $1\text{M}\Omega$ - $>10\text{M}\Omega$ indicates acceptable insulation level. No further action required
- E.g. $100\text{k}\Omega$ - $1\text{M}\Omega$ indicates a warning level. The machine can be operated but requires attention. A service technician should be contacted as soon as possible.
- E.g. $<100\text{k}\Omega$ indicates a fault level. A service technician should be contacted as soon as possible and the machine could be used, but only to be moved to a convenient place for service.
- Error. If one of the meters 3a, 3b, 3c indicates error during the pre-connected check, there is an internal fault with that particular electrical insulation circuit 305, 306, 307 or its connected electrical equipment. A service technician should be contacted as soon as possible. If an error is indicated on the meter 3a and 3c during normal operation, the error can be ignored, since the electrical insulation monitor 309, 314 and its meter 3a, 3c of the particular sub circuit is inactivated. The DC link meter 310 is the active meter in this machine state.

Figure 4 is a flowchart illustrating exemplary method steps for insulation monitoring of a mining machine.

In its most general form, the method comprises monitoring an insulation status of a mining machine comprising at least one power source, at least one electrical motor configured to power one or more mining operations of the mining machine and an electrical monitoring system 130 for monitoring an electrical insulation status of a first or a second electrical circuit. Monitoring S40 the electrical insulation status on the mining machine during one or more mining operations when connected to the first electrical circuit, when closing S42 one or more contactors in the first electrical circuit when opening S42 one or more contactors in the second electrical circuit. Monitoring S41 the electrical insulation status of the mining machine when connected to the second electrical circuit, when opening S42 the one or more contactors in the first electrical circuit and when closing S42 the one or more contactors in the second electrical circuit.

The monitoring S43 can also be activated, when the mining machine is completely powered off, on the third electrical circuit.

Figure 5 is a flowchart illustrating exemplary method steps for insulation monitoring of a mining machine. In its most general form, the method comprises monitoring S50 the insulation status on the electrical main circuit and a plurality of electrical sub circuits, the circuits being electrically isolated from each other, by contactors. Presenting S51 the electrical insulation status of the respective electrical circuits on a respective panel meter. Connecting S52 the machine to power supply, hence, connect the electrical main circuit with one or more sub circuits and monitor the electrical insulation status on the connected main and sub circuits. Presenting S53 the electrical insulation status on an electrical insulation main panel meter, wherein the electrical insulation status is based on the connected electrical circuits' insulation status. The configuration could be either circuit 7, circuit 7 and 5, circuit 7 and 6, or circuit 7 and 5 and 6.

CLAIMS

1. A mining machine comprising at least one power source (110), at least one electrical motor (120) configured to power one or more mining operations of the mining machine; and an electrical
5 monitoring system (130, 210) for monitoring an electrical insulation status of a first or a second electrical circuit (140, 150), wherein the electrical monitoring system (130) comprises:
 - at least a first electrical insulation monitor configured to monitor the electrical insulation status of the mining machine during one or more mining operations when connected to the first electrical circuit (140)
 - 10 - at least a second electrical insulation monitor configured to monitor the electrical insulation status of the mining machine when connected to the second electrical circuit (150); and
 - one or more contactors comprised in the first and second electrical circuit (140, 150) and wherein the electrical monitoring system (130) is configured to open the one or more contactors in the first electrical circuit (140) when closing the one or more contactors in the second electrical circuit
15 (150).
2. The mining machine according to claim 1 wherein the at least one power source (110) comprises one or more batteries controlled from a battery management system, BMS, and the first electrical insulation monitor is comprised in the BMS.
- 20 3. The mining machine according to claim 1 or 2 wherein the first electrical insulation monitor is configured for real-time monitoring and reporting of a current resistance value of the first electrical circuit (140) to a processing circuitry of the electrical monitoring system (130).
- 25 4. The mining machine according to any of the preceding claims, wherein the second electrical insulation monitor is configured for real-time monitoring and reporting of a current resistance value of the second electrical circuit (150) to a processing circuitry of the electrical monitoring system (130).
5. The mining machine according to claim 4, wherein the second electrical insulation monitor (280) is
30 configured to report only when the monitored value is below a threshold.
6. The mining machine of claim 4, wherein the power source is an inverter receiving power from a grid connection, a diesel generator or a power bank.

7. The mining machine according to any of the preceding claims, wherein the first or second insulation monitor (270, 280) is configured to be connected to the first or second electrical circuit (140, 150), when the other first or second insulation monitor (270, 280) is malfunctioning.

5

8. The mining machine according to claim 1, wherein the first electrical circuit (140) is an electrical main circuit (307) and the second electrical circuit (150) is an electrical sub-circuit (305, 306) electrically isolated from the main circuit (307) with at least one contactor (308, 313), the electrical monitoring system comprising:

- 10 - an electrical insulation main monitor (310) monitoring the electrical insulation status on the main circuit (307) when the contactors (308, 313) are open,
- an at least one electrical insulation sub monitor (309, 314) monitoring the electrical insulation status on the sub-circuit (305, 306) when the contactors (308, 313) are open, and
- 15 - the electrical insulation main monitor (310) monitoring the electrical insulation status on the main circuit (307) and the one or more sub circuits (305, 306) if the one or more contactors (308, 313) are closed and whereby the one or more insulation sub monitors (309, 314) are inactivated.

20

9. The mining machine according to claim 1, wherein an alarm is generated if the electrical insulation result is below a threshold.

10. The mining machine according to claim 1, wherein the monitoring can be started directly on the machine, from a connected Remote Control System (RCS) or in an application running in e.g. a mobile phone or any other template.

25

11. A method for monitoring an insulation status of a mining machine comprising at least one power source (110), at least one electrical motor (120) configured to power one or more mining operations of the mining machine; and an electrical monitoring system (130) for monitoring an electrical insulation status of a first or a second electrical circuit (140, 150), the method comprising:

- 30 - monitoring (S40) the electrical insulation status on the of the mining machine during one or more mining operations when connected to the first electrical circuit (140);
- monitoring (S41) the electrical insulation status of the mining machine when connected to the second electrical circuit (150); and

- opening (S42) one or more contactors (290) in the first electrical circuit (140) when closing the one or more contactors (290) in the second electrical circuit (150).

12. The method according to claim 11 wherein monitoring connected to the first electrical circuit (140) comprise real-time monitoring of the current resistance value of the first electrical circuit (140) and real-time reporting of the electrical insulation status to a control system.

13. The method according to claim 11 wherein monitoring connected to the second electrical circuit (150) comprise real-time monitoring of the current resistance value of the second electrical circuit (150) and reporting to the control system, when an isolation value is below a threshold or when the signal disappears.

14. The method according to claim 11 wherein the first electrical circuit (140) is an electrical main circuit (307) and the second electrical circuit (150) is an electrical sub-circuit (305, 306) electrically isolated from the main circuit (307) with at least one contactor (308, 313), the method comprising:

- monitoring the electrical insulation status on the sub circuit (305, 306) when the contactors (308, 313) are open; and
- connecting the electrical main circuit (307) with one or more electrical sub circuits (305, 306) and monitoring the electrical insulation status on the connected circuits.

15. The method according to claim 11, comprise generating an alarm if the electrical insulation result is below a threshold.

16. The method according to claim 11, wherein the monitoring can be started directly on the machine, from a connected Remote Control System (RCS) or in an application running in e.g. a mobile phone or any other template.

17. A computer program comprising computer program code which, when executed cause execution of the method according to any of claims 11 to 16.

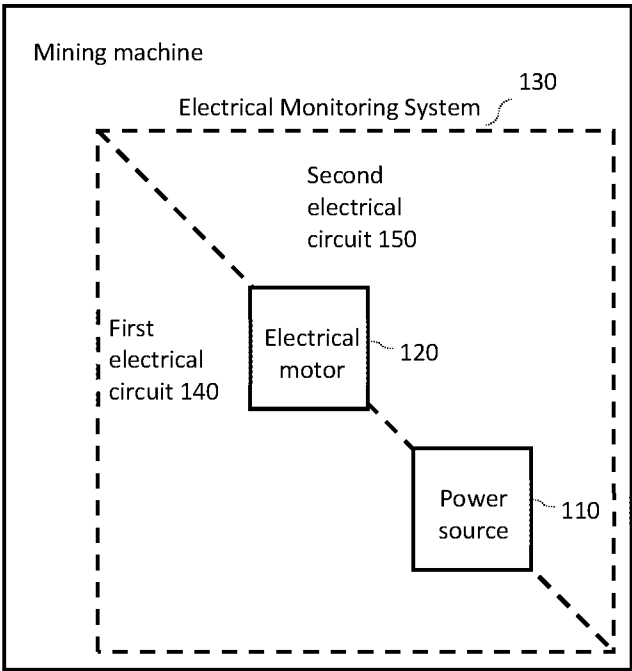


Figure 1

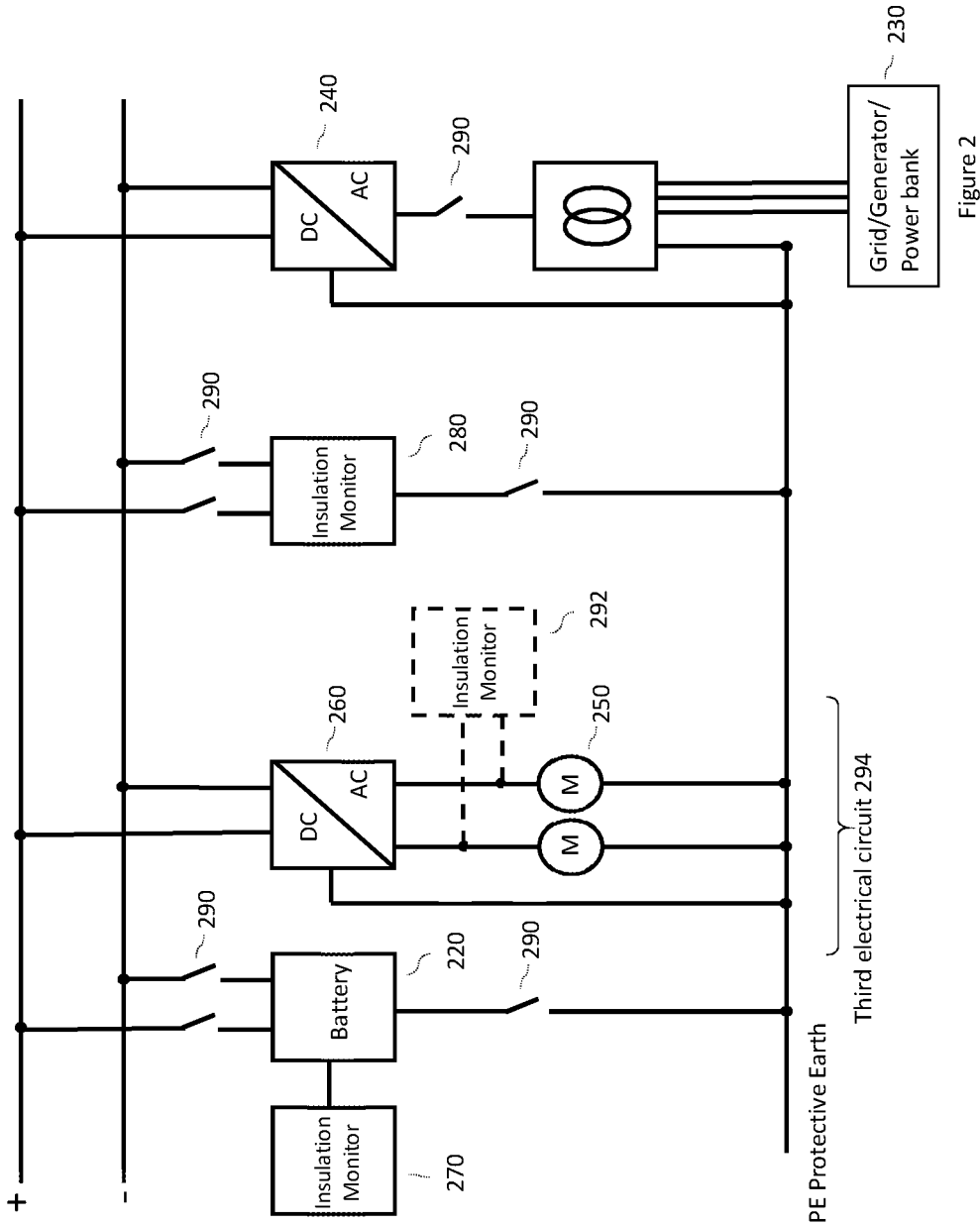


Figure 2

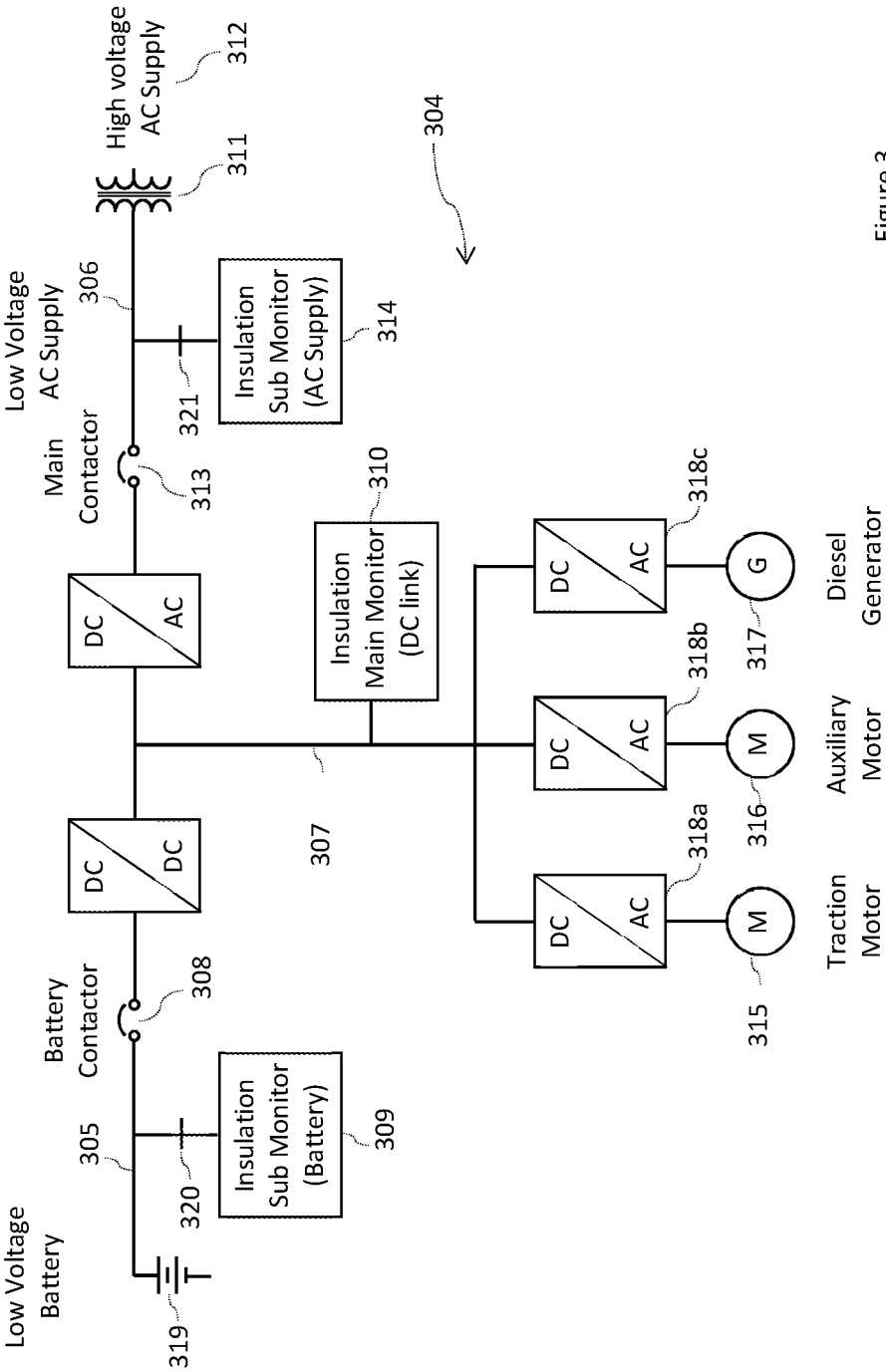


Figure 3

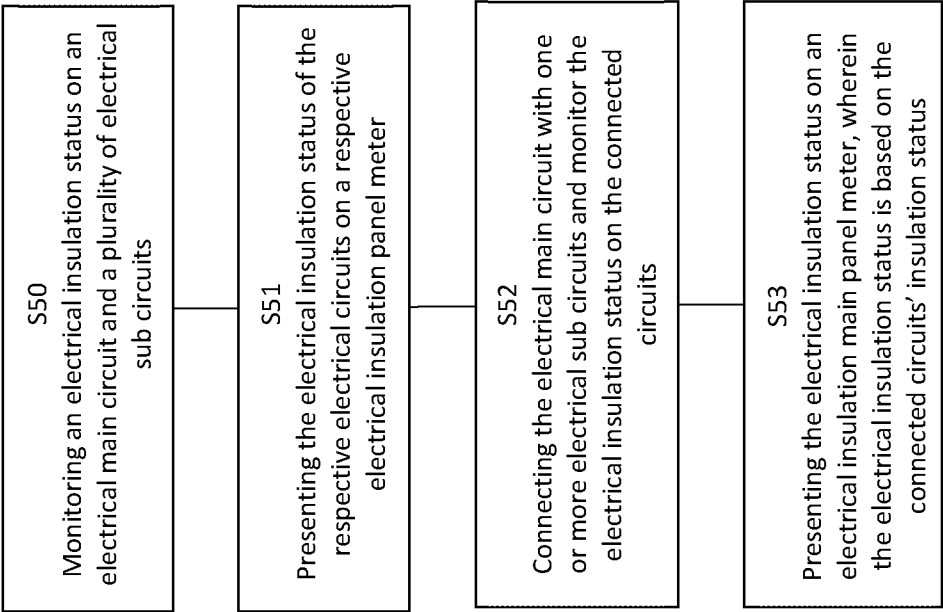


Figure 5

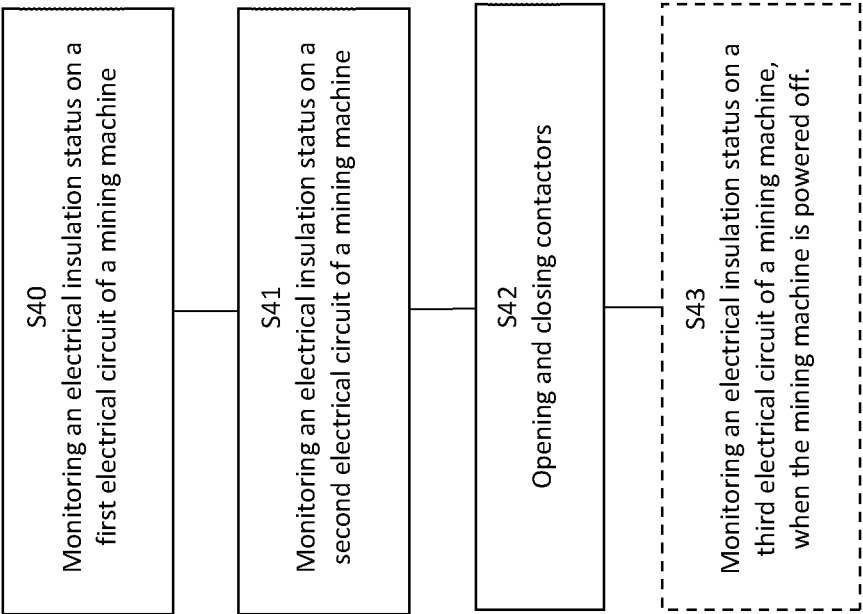


Figure 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2019/051026

A. CLASSIFICATION OF SUBJECT MATTER INV. E21B3/00 G01R31/56 G01R31/52 B60L3/04 ADD. G01R27/18		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) E21C G01R B60L H02H		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/219656 A1 (LINDSEY ROBERT W [US]) 3 September 2009 (2009-09-03) paragraph [0016] - paragraph [0047]; figures 1-3 -----	1-17
X	US 5 155 441 A (ZELM RICHARD J [US]) 13 October 1992 (1992-10-13) column 1, line 18 - line 22 column 5, line 32 - column 16, line 21; claim 1; figures 1-14 -----	1,11,17
A	US 2015/192632 A1 (CROSMAN III ALEXANDER C [US] ET AL) 9 July 2015 (2015-07-09) abstract -----	1-17
A	US 2018/045767 A1 (DAIGLE JEFFREY LOUIS [US] ET AL) 15 February 2018 (2018-02-15) abstract -----	1-17
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 6 February 2020		Date of mailing of the international search report 21/02/2020
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Hijazi, Ali

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SE2019/051026

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009219656	A1	03-09-2009	NONE
US 5155441	A	13-10-1992	NONE
US 2015192632	A1	09-07-2015	US 2015192632 A1 09-07-2015
		WO 2015105642 A1	16-07-2015
US 2018045767	A1	15-02-2018	US 2018045767 A1 15-02-2018
		US 2019049507 A1	14-02-2019