

DESCRIPTION

Synchronous generator control, generator system and vessel energy system

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Field of invention

The present invention relates to an arrangement for controlling a synchronous generator, to a generator system comprising the arrangement and to a vessel energy system comprising the generator system.

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Art Background

EP 1 012 943 B1 discloses a system for supplying electromotive consumers with electric energy, wherein a Diesel motor drives an AC generator connected to a rectifier, in order to provide a DC energy stream.

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EP 1 614 621 B1 discloses an electric power supply system for ships having a generator and consumers.

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EP 1 914 162 B1 discloses a DC power distribution system that can be used for marine power and propulsion systems, wherein a Diesel engine drives a generator to supply power to an output converter.

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WO 2010/06077 A2 discloses a power distribution system comprising a plurality of generator systems each comprising an alternating current generator directly connected to a rectifier.

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It has been observed that conventional power distribution systems do not in all situations operate in a safe and reliable manner.

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There may be a need for an arrangement for controlling a synchronous generator, for a generator system and a vessel en-

ergy system, wherein it may be ensured that the system operates in a safe and reliable manner, in particular in case of a fault or malfunction of one or more components of the system or of an external component.

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Summary of the Invention

This need may be met by the subject matter according to the independent claims. Advantageous embodiments of the present
10 invention are described by the dependent claims.

According to an embodiment it is provided an arrangement for controlling a synchronous generator having a stator comprising at least one stator winding and having a rotor with an
15 electromagnet driven by a field current, the rotor being rotatable relative to the stator, the electromagnet being inductively coupled to the stator winding, the arrangement comprising a measurement system adapted to measure at least one quantity, and a controller adapted to cause shutting down the
20 field current, if the quantity satisfies at least one criterion associated with at least one malfunction.

The at least one quantity can includes at least one quantity indicative of a operating condition of a rectifier circuit connected to the output terminal of the stator winding.

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The arrangement does not need to comprise the synchronous generator. The arrangement is however adapted for controlling the synchronous generator.

30 The synchronous generator generates at an output terminal an AC energy stream (voltage and/or current) which has the same frequency as the frequency of the rotor rotating relative to the stator. The synchronous generator may for example be a singly fed electric generator or a doubly fed electric generator. The electric energy is generated upon rotation of the
35 rotor, wherein by induction a voltage is induced in the stator winding due to the rotation (movement) of the electromagnet of the rotor. In particular, the synchronous generator

does not comprise a permanent magnet, but instead an electro-magnet which due to the field current generates a magnetic field, which then induces (at the stator winding) the voltage representing the electric power output stream.

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In particular, the synchronous generator may comprise a stator having three stator windings (formed by wire portions) arranged at different circumferential positions of the stator. The three windings (one per phase) are composed of three
10 separate wires which may be connected in a starlike manner or a triangle-like manner.

The electromagnet of the rotor may comprise a core, in particular a ferromagnetic core, in which a magnetic field is
15 generated upon flow of the field current through a coil of the electromagnet. The field current may in particular be a DC-field current. The rotor may be supported using a bearing.

The measurement system may comprise one or more measurement
20 sensors arranged at one or more positions of the synchronous generator or at one or more positions of further or external components, such as a generator rectifier, a load and so on. The quantity may in particular comprise an electrical quantity. The controller may generate, in particular upon receiving the quantity, a control signal which may be supplied to a
25 further circuitry, which then indirectly shuts down the field current.

Shutting down the field current may shut down or at least reduce a magnetic field generated by the electromagnet, when
30 the field current is flowing through the electromagnet. Thus, shutting down the field current may result in a reduction of the magnetic field and may even lead to a vanishing magnetic field a short time, such as between 0.5 s and 3 s, after
35 shutting down the field current. However, the magnetic field may sustain a while after shutting down the field current due to remanence of the electromagnet. However, the remanence may

only lead to a relatively small magnetic field, which may not induce a significant voltage at the stator winding.

Thereby, upon shutting down the field current the energy
5 stream output by the synchronous generator at the output terminal or in particular three output terminals may be reduced to a small value, in particular to zero. Thereby, in case of a malfunction (of the arrangement or any external component connected indirectly or directly with the arrangement), in
10 particular output current, may be interrupted or shut off, in order to provide a protection function for protecting the arrangement or any external component connected directly or indirectly with the arrangement. Thereby, a save and reliable operation of the synchronous generator may be ensured.

15 In particular, the synchronous generator may be mechanically connected or coupled to a combustion engine, such as a Diesel generator. In particular, the synchronous generator may provide its output energy stream to a rectifier in order to enable setting up a DC distribution system. Setting up or providing a DC energy distribution system may provide the advantage to run the generator with variable speed, which may result in a reduced fuel consumption and pollution; reduced the costs of the system and decreasing maintenance efforts required on the Diesel engines.
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In particular, when the synchronous generator is connected at its output terminal to a rectifier the protection function is realized by shutting off or stopping the magnetic field supply to the generator magnetization, i.e. the electromagnet of
30 the rotor.

In an embodiment, the quantity is indicative of a temperature of a rectifier circuit connected at the output terminal of
35 the stator winding, wherein the at least one criterion comprises that the temperature is greater than a temperature threshold.

The quantity relating to the rectifier circuit operating condition may additionally or alternatively include a quantity indicative of a DC voltage between DC output terminals of the rectifier circuit. The at least one criterion may comprise
5 that the DC voltage drops below a voltage threshold, which may for example occur upon the occurrence of a fault in a component electrically coupled to the DC output terminals of the rectifier circuit, e.g. a fault on a DC bus or in a component coupled thereto.

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In an embodiment, the at least one quantity may further include a quantity indicative of a operating condition of a magnetization circuit, in particular magnetization circuit current and/or magnetization circuit voltage.

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In a further embodiment, the at least one quantity may further include a stator current and an output current measured for the stator winding to obtain a current difference for providing differential protection for the stator winding.

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In an embodiment, the measurement system is adapted to measure at least one quantity including a quantity relating to the rectifier circuit operating condition, a quantity indicative of a operating condition of the magnetization circuit
25 and stator current and an output current. A comprehensive protection of the generator and of the rectifier circuit coupled thereto may thus be achieved.

Monitoring or measuring the temperature of the rectifier may
30 provide an appropriate indication whether the rectifier is in an acceptable operating condition. In particular, a failure or malfunction may be indicated by a temperature which surpasses the temperature threshold.

35 According to an embodiment of the present invention the quantity is indicative of a stator winding current and/or the quantity is indicative an output current at an AC-output terminal of the stator winding, wherein the at least one crite-

rion comprises that the stator current is above a stator current threshold and/or that the output current is above an output current threshold, wherein the malfunction is a short circuit state of a load or network connected to the output terminal.

The stator winding current may comprise three stator winding current portions, each being associated with a respective one of three stator windings. Further, the output current may be represented by three output current portions each being associated with one of three output terminals corresponding to three output phases. In an intact synchronous generator the stator winding current may be at least approximately equal to the output current. However, if there are some problems with the synchronous generator, in particular with the stator winding or stator windings, the stator winding current may be different from the output current. The stator winding current may be measured at one or more positions at the stator winding and/or the output current may be measured at one or more positions close or at the output terminal.

The stator current threshold may be determined in particular based on electrical properties of components which are connected at the output terminals. Also, the output current threshold may be determined based on electrical properties of one or more components connected to the output terminals. In particular, the current threshold may be determined based on current limits of one or more components connected to the output terminals. Thereby, the components connected to the output terminals may be protected from damage in case of the short circuit state. In particular, the short circuit state may be due to some malfunction or failure in a distribution system, in particular DC energy distribution system, connected at the output terminal of the synchronous generator.

According to an embodiment of the present invention the controller is adapted to integrate a square of the stator winding current and/or of the output current over a certain time

range to obtain an integration value, wherein the at least one criterion comprises that the integration value is greater than an integration threshold, wherein the malfunction is an overload state of a load connected to the output terminal.

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In particular, the integration threshold may be based on electrical properties, in particular electrical limits, of one or more components connected to the output terminals. Thereby, overloading of a load connected (indirectly or di-

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rectly) at the output terminal may be avoided.

According to an embodiment of the present invention the controller is adapted to determine a difference between the stator winding current and the output current to obtain a cur-

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rent difference, wherein the at least one criterion comprises that the current difference is greater than a current difference threshold, wherein the malfunction comprises a malfunction of the generator.

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The difference of the stator winding current and the output current may be zero or at least approximately zero for an intact stator winding, but may deviate from zero for a stator winding which is not operating in a correct manner. Thereby, a malfunction or failure of the generator may be detected by determining the difference and the synchronous generator may be shut off, in particular regarding its power output, in order to protect other components or the synchronous generator itself from damage. Alternatively, a current unbalance detection for detecting different currents for different phases

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could be implemented.

According to an embodiment of the present invention the quantity is indicative of a temperature of a rectifier circuit, in particular a diode, connected at the output terminal of the stator winding, wherein the at least one criterion comprises that the temperature is greater than a temperature threshold or a change of the temperature is greater than a temperature change threshold.

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When a rectifier circuit, in particular comprising two diodes connected in series per phase of the output terminals (wherein each phase is connected between the two diodes connected
5 in series) the synchronous generator may provide electric energy to a DC energy distribution system. In particular, the rectifier may block a reverse current such that it may be enough to shut down the field current, in order to stop the generator output current.

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In particular, the stator current threshold and/or the output current threshold and/or the integration threshold and/or an output voltage upper threshold and/or an output voltage power threshold and/or a temperature may be based on electrical
15 properties of the diode, in particular electrical limit values of the diode.

Monitoring or measuring the temperature of the rectifier may provide an appropriate indication whether the rectifier is in
20 an acceptable operating condition. In particular, a failure or malfunction may be indicated by a temperature which surpasses the temperature threshold.

According to an embodiment of the present invention the quantity is indicative of an output voltage at an AC-output terminal of the stator winding, wherein the at least one criterion comprises that the output voltage is greater than an
25 output voltage upper threshold, wherein the malfunction is an overvoltage condition at the output terminal.

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The overvoltage may also impair or damage one or more components connected at the output terminals and by shutting down the output of the synchronous generator these components may be protected.

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According to an embodiment of the present invention the quantity is indicative of an output voltage at an AC-output terminal of the stator winding, wherein the at least one criterion

rion comprises that the output voltage is smaller than an output voltage lower threshold, wherein the malfunction is an undervoltage condition at the output terminal.

- 5 An undervoltage may impair the functionality of an energy distribution system connected directly or indirectly with the output terminals of the synchronous generator. By detecting the undervoltage impairment of the DC energy distribution system may be avoided or at least reduced.

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According to an embodiment of the present invention the quantity is indicative of a output frequency of an output voltage or output current at the AC-output terminal of the stator winding, wherein the at least one criterion comprises that
15 the output frequency deviates more than a frequency deviation threshold from a target frequency, wherein the malfunction is an erroneous frequency at the output terminal.

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The frequency of the voltage and/or current at the output terminal of the synchronous generator may correspond or may be equal (at least approximately) to the frequency of rotation of the rotor rotating relative to the stator. However, if the rotation frequency is too low or too high the driving combustion engine, such as a Diesel engine, may not operate
25 in an optimal working condition. In case of a deviation of the frequency from the target frequency is detected, the combustion engine mechanically driving the synchronous generator may be controlled in order to reestablish the target frequency.

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- According to an embodiment of the present invention it is provided a generator system comprising an arrangement according to one of the preceding embodiments, the synchronous generator having the stator comprising the at least one stator
35 winding and having the rotor with the electromagnet driven by the field current, the rotor being rotatable relative to the stator, the electromagnet being inductively coupled to the stator winding; and a system for providing the field current,

wherein the controller is adapted to cause shutting down the field current by supplying a control signal to system for providing the field current.

5 The system for providing the field current may be configured in different ways. In particular, the field current may be provided to the electromagnet by direct electrical contact between an energy source and a coil of the electromagnet or
10 may be provided to the electromagnet of the rotor by inductive coupling, thereby avoiding mechanical contacts between rotating parts and static parts. The controller may be communicatively connected to the system for providing the field current in an optical, electric manner or using radio frequency communication.

15 The system for providing the field current may be supplied with electric energy also from the output terminal of the synchronous generator. Thereby, a separate energy supply may be suspended with. The generator system may in particular
20 provide electric energy for a DC energy distribution system.

Since the generator system comprises the arrangement for controlling the synchronous generator components of the synchronous generator and components connected to the output terminals of the synchronous generator may be protected from damage as is explained above.

According to an embodiment of the present invention the system for providing the field current comprises a slip ring mechanically coupled to the rotor and electrically coupled to
30 the electromagnet and a brush contacting the slip ring, wherein shutting down the field current comprises interrupting current flow supplied to the brush.

35 The brush or the brushes may electrically contact the slip ring. Thereby, a mechanical connection between the brush and the slip ring may be established. Thus, when the brush electrically contacts the slip ring a current provided to the

brush may flow through the slip ring and through the electromagnet of the rotor, whereupon a magnetic field is generated which then in turn induces an electric voltage at the stator windings of the stator.

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According to an embodiment of the present invention the system for providing the field current comprises (instead of the slip ring and the brush) a rotating coil mechanically coupled to the rotor; a rotatable rectifier mechanically coupled to
10 the rotor and electrically coupled to the rotating coil and providing the field current to the electromagnet of the rotor; a stator electromagnet inductively coupled to the rotating coil; and a stator electromagnet supply system for supplying an exciting voltage to the stator electromagnet,
15 wherein shutting down the field current comprises interrupting the exciting voltage to the stator electromagnet.

Upon rotation of the rotating coil (connected to the rotor) the stator electromagnet induces a voltage in the rotating
20 coil thereby establishing an AC-signal which is rectified using the rotatable rectifier and is then supplied as a DC-field current to the electromagnet of the rotor.

The stator electromagnet is driven by a stator electromagnet
25 supply system. Interrupting the exciting voltage to the stator electromagnet may cause shutting down the field current, since the stator electromagnet will not generate any magnetic field, when the exciting voltage is interrupted. Thereby, the output current of the synchronous generator may be shut down
30 in a simple and reliable manner without requiring a particular switch at an output terminal of the generator.

According to an embodiment of the present invention the stator electromagnet supply system comprises at least one con-
35 trollable switch, in particular isolated gate bipolar transistor (IGBT), driven by a gate driver circuit, wherein shutting down the field current comprises supplying a shut-down signal to the gate driver. The stator electromagnet supply

system may in particular comprise four controllable switches, wherein two pairs of series connected controllable switches are connected between two DC-bars and wherein the exciting voltage to the stator electromagnet is tapped at a connection
5 between the two controllable switches in each pair.

The shut-down signal may cause the controllable switches to adapt a non-conducting state. Thereby, the generator output current may be easily switched off.

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According to an embodiment of the present invention the generator system further comprises an emergency stop switch between the at least one controllable switch and the stator electromagnet. The emergency stop switch may also be controlled by the controller of the arrangement for controlling
15 the synchronous generator.

According to an embodiment of the present invention the generator system further comprises a generator rectifier connected to the AC-output terminal, in particular three AC-output terminals, the rectifier comprising in particular a diode and a temperature sensor for measuring the temperature of the diode, wherein in particular the rectifier is the only load connected to the output terminal of the generator.

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The generator rectifier may comprise six diodes, wherein three pairs of diodes are arranged in parallel and wherein between the two diodes of each pair one output terminal of the stator winding is connected. Thereby, the generator system may setup or establish a DC energy distribution system. The generator rectifier advantageously blocks reverse current.
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According to an embodiment of the present invention the generator may comprises separate winding sets and have a respective rectifier connected to each of the separate winding sets.
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Further in particular, the generator rectifier may comprise an isolation switch downstream of the diodes. Because of the diodes no current can flow back from the DC-output terminal of the generator to the synchronous generator.

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According to an embodiment of the present invention it is provided an energy system , in particular vessel energy system or free standing (autarkical) electrical system, drilling system, or industry grid, comprising a combustion engine for providing mechanical energy; a generator system according to one of the embodiments described above and arranged for converting the mechanical energy to electrical energy; and a DC-distribution system coupled to the a DC-output terminal of the generator rectifier for distributing the electrical energy, in particular to at least one propulsion motor.

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The combustion engine may in particular comprise a Diesel engine. The generator system comprises the generator rectifier and thus converts the mechanical energy provided by the combustion engine into a DC energy stream. The DC-distribution system may provide the electrical energy in the form of a DC-energy stream to one or more variable speed drives for driving one or more propulsion motors. The vessel may for example be a ship, a platform, in particular an oil platform.

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The aspects defined above and further aspects of the present invention are apparent from the examples of embodiment to be described hereinafter and are explained with reference to the examples of embodiment. The invention will be described in more detail hereinafter with reference to examples of embodiment but to which the invention is not limited.

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Brief Description of the Drawings

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The following particular embodiments of the present invention are described with reference to the accompanying drawings.

The invention is not limited to the illustrated or explained or described embodiments.

- Fig. 1 schematically illustrates a vessel energy system according to an embodiment of the present invention, wherein the vessel energy system comprises a generator system according to an embodiment of the present invention;
- Fig. 2 schematically illustrates the generator system according to an embodiment of the present invention, which is comprised in the vessel energy system illustrated in Fig. 1; and
- Fig. 3 illustrates a graph explaining a functionality of an arrangement for controlling a synchronous generator according to an embodiment of the present invention.
- Fig. 1** schematically illustrates a vessel energy system 100 according to an embodiment of the present invention including a generator system 101 according to an embodiment of the present invention which comprises an arrangement 103 for controlling a synchronous generator 105 according to an embodiment of the present invention.

The vessel energy system 100 comprises a Diesel engine 107 which is mechanically connected to the generator system 101, in particular to the synchronous generator 105 comprised in the generator system 101. The generator system 101 further comprises a generator cubicle 109 which is connected at an output terminal 111 of the generator 105 providing AC-energy stream 119 in order to generate at an output terminal 113 of the generator cubicle a DC energy stream 121 from the AC-energy stream 119 provided at the AC-output terminal 111 of the generator 105. In particular, although not illustrated, the generator 105 comprises three output terminals 111 providing three phases shifted by 120° relative to each other.

The generator cubicle 109 comprises an arrangement 103 for controlling the synchronous generator 105, a rectifier circuit (also referred to as generator rectifier) 115 and an isolation switch 117. The generator rectifier 115 generates from the AC energy stream 119 provided by the generator 105 a DC energy stream 121 which is provided to a DC energy distribution system 123.

10 The DC energy distribution system 123 may provide electric energy to one or more propulsion motors for example on a vessel, a ship or a platform at the sea.

Fig. 2 schematically illustrates the generator system 101 illustrated in Fig. 1 in some more detail.

The generator system 101 comprises the generator 105, the rectifier circuit 115, a system 125 for providing a field current 127 and an arrangement or controller 103 for controlling the synchronous generator 105.

The generator 105 has a stator 129 comprising at least one stator winding 131, wherein in the particular case three stator windings 131 are illustrated providing three output terminals 133 of the generator 105 for three electrical phases. The stator windings 131 are established by respective wires 135. The generator 105 has a rotor 137 with an electromagnet 139 which is driven by the field current 127. Thereby, the rotor 137 is rotatable relative to the stator 129.

30 The system 125 for providing the field current 127 comprises a rotating coil 141 which is mechanically coupled to the rotor 137, a rotatable rectifier 143 which is mechanically coupled to the rotor 137 and electrically coupled to the rotating coil 141 and providing the field current 127 to the electromagnet 139 of the rotor 137. Further, the system 125 for providing the field current 127 comprises a stator electromagnet 145 which is inductively coupled to the rotating coil

141. Further, the system 125 for providing the field current 127 comprises a stator electromagnet supply system 147 for supplying an exciting voltage from an output terminal 149 thereof to the stator electromagnet 145. Thereby, the stator
5 electromagnetic supply system 147 is supplied with electric energy via input terminals 151 which are connected via a transformer 153 to the three output terminals 133 of the generator 105.

10 The stator electromagnet supply system 147 comprises four isolated gate bipolar transistors 155 which are driven by a gate drive circuit 157 which receives control signals via signal lines 159 from the arrangement or controller 103 for controlling the synchronous generator 105.

15 The generator system 101 further comprises an emergency stop switch 161 between the output terminals 149 of the stator electromagnet supply system 147 and the stator electromagnet 145 for shutting off a supply voltage.

20 The generator rectifier circuit 115 comprises six diodes 163 which are arranged as three pairs of series connected diodes between two DC output terminals 180 of the generator system 101. The three phase output terminals 133 of the synchronous
25 generator 105 are connected between two diodes 163 of each pair of diodes of the generator rectifier circuit 115.

The generator system 101 is configured and arranged to protect the diodes 163 from damage in particular in case of a
30 short circuit event caused by some defective load connected to the to the DC output terminals 180, for example.

Therefore, the arrangement 103 acquires using by a not illustrated measurement system at least one quantity, such as a
35 stator current 167, an output current 165 and/or an output voltage 168 relating to the output of the generator 105. Further, the arrangement 103 may receive a temperature signal 169 (from temperature sensor 170) indicating the temperature

of one or more of the diodes 163 of the generator rectifier circuit 115. Further, the arrangement 103 receives the measurement values 171 indicating the DC voltage between the DC output terminals 180. Further, the arrangement 103 receives
5 one or more control signals from other controllers, such as the signals 173. Further, the arrangement 103 may be controlled by a human interface 175.

In particular, the arrangement 103 (which may also be referred to as generator control module, profinet communication interface, household control 30 Hz to 120 Hz voltage, current and frequency measurements) is adapted to shut down the field current 127 in case of a malfunction of the generator or of any component connected directly or indirectly at the output
15 terminals 133 of the generator 105.

Therefore, the controller 103 or the arrangement including the controller 103 and the measurement system for providing the current measurement signal, is adapted to cause shutting
20 down the field current 127, if at least one of the quantities received satisfies at least one criterion associated with at least one malfunction.

In particular, **Fig. 3** illustrates a graph explaining one protection function of the controller 103 comprised in the generator system 101 illustrated in Fig. 2. On an abscissa 301 the time in seconds is indicated, while on an ordinate 302 the diode current 177 flowing through the diode 163 of the generator rectifier circuit 115 is indicated in Ampere.
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The curve 303 indicates the diode current limit of the diodes 163. The curve 305 illustrates the actual diode current 177 flowing through the diode 163 after a short circuit on the DC bus 180 and after the controller 103 has caused shutting down the field current 127 30 ms after the short circuit appeared.
35 Before the short circuit appeared, the generator 105 was running at a frequency of 62.5 Hz and nominal conditions. As can be seen from Figure 3 the actual current (curve 305) lies

well below the current limit (curve 303) such that the diodes 163 of the generator rectifier 115 are protected from damage.

In particular, the controller 103 may acquire measurement values relating to the stator, such as it may acquire three phase current measurement, three phase voltage measurement, three phase mutual point current measurement and output frequency measurement.

Further, the controller 103 may acquire values which are related to the rectifier circuit 115, such as DC measurement values, diode bridge temperatures, such as the signals 169 and 171.

Further, the controller 103 may acquire measurement values relating to the magnetization circuit 145, 147, in particular external magnetization circuit current, external magnetization circuit voltage, such as signals 177.

The generator system 101 is adapted to protect from short circuit, overvoltage, undervoltage, unbalanced load protection, differential current protection, overexcitation, underexcitation and inverse time over current (overload condition). Further, the generator system 101 is adapted for monitoring frequency, overspeed, temperature and fault history.

It should be noted that the term "comprising" does not exclude other elements or steps and "a" or "an" does not exclude a plurality. Also elements described in association

with different embodiments may be combined. It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

CLAIMS

1. Arrangement (102) for controlling a synchronous generator (105) having a stator (129) comprising at least one stator winding (131) and having a rotor (137) with an electromagnet (139) driven by a field current (127), the rotor (137) being rotatable relative to the stator (129), the electromagnet (139) being inductively coupled to the stator winding (131), the arrangement (102) comprising:
- 10 a measurement system adapted to measure at least one quantity (167, 165, 168, 169, 171);
- a controller (103) adapted to cause shutting down the field current (127), if the quantity satisfies at least one criterion associated with at least one malfunction,
- 15 wherein the at least one quantity (167, 165, 168, 169, 171) includes at least one quantity (169, 171) indicative of a operating condition of a rectifier circuit (115) connected to the output terminal (133) of the stator winding (131).
- 20 2. Arrangement according to claim 1, wherein the quantity is indicative of a temperature (169) of the rectifier circuit (115) connected at the output terminal (133) of the stator winding (131),
- wherein the at least one criterion comprises that the
- 25 temperature is greater than a temperature threshold,
- or wherein the quantity is indicative of a DC voltage (171) between DC output terminals (180) of the rectifier circuit (115).
- 30 3. Arrangement according to claim 1 or 2, wherein the at least one quantity (167, 165, 168, 169, 171) further includes a quantity indicative of a operating condition of a magnetization circuit (145, 147), in particular magnetization circuit current and/or magnetization circuit voltage.
- 35 4. Arrangement according to one of the preceding claims, wherein the at least one quantity (167, 165, 168, 169, 171) further includes a stator current (167) and an output current

(165) measured for the stator winding (131) to obtain a current difference for providing differential protection for the stator winding (131).

5 5. Arrangement according to any of the preceding claims, wherein the quantity is indicative of a stator winding current (167) and/or wherein the quantity is indicative an output current (165) at an AC-output terminal (133) of the stator winding (131),
10 wherein the at least one criterion comprises that the stator current is above a stator current threshold and/or that the output current (177) is above an output current threshold (303), wherein the malfunction is a short circuit state of a load
15 connected to the output terminal.

6. Arrangement according to claim 4 or 5, wherein the controller is adapted to integrate a square of the stator winding current and/or of the output current (177) over a certain
20 time range to obtain an integration value, wherein the at least one criterion comprises that the integration value is greater than an integration threshold, wherein the malfunction is an overload state of a load connected to the output terminal.

25 7. Arrangement according to one of claims 4-6, wherein the controller is adapted to determine
a difference between the stator winding current (167) and the output current (165) to obtain a current difference,
30 wherein the at least one criterion comprises that the current difference is greater than a current difference threshold, wherein the malfunction comprises a malfunction of the generator and/or

a difference or differences between current flow of different phases of the stator winding current and/or the output
35 current to obtain a phase associated current difference, wherein the at least one criterion comprises that the phase

associated current difference is greater than an phase associated current difference threshold,
wherein the malfunction comprises a malfunction of the generator.

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8. Arrangement according to one of the preceding claims,
wherein the quantity is indicative of a temperature (169) of
a diode (163) of the rectifier circuit (115),
wherein the at least one criterion comprises that a change of
10 the temperature is greater than a temperature change threshold.

9. Arrangement according to one of the preceding claims,
wherein the quantity is indicative of an output voltage (168)
15 at an AC-output terminal of the stator winding (131),
wherein the at least one criterion comprises that the output
voltage is greater than an output voltage upper threshold,
wherein the malfunction is an overvoltage condition at the
output terminal.

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10. Arrangement according to one of the preceding claims,
wherein the quantity is indicative of an output voltage (168)
at an AC-output terminal (133) of the stator winding (131),
wherein the at least one criterion comprises that the output
25 voltage is smaller than an output voltage lower threshold,
wherein the malfunction is an undervoltage condition at the
output terminal.

11. Arrangement according to one of the preceding claims,
30 wherein the quantity is indicative of an output frequency
(168) of an output voltage or output current at an AC-output
terminal of the stator winding,
wherein the at least one criterion comprises that the output
frequency deviates more than a frequency deviation threshold
35 from a target frequency.
wherein the malfunction is an erroneous frequency at the output terminal.

12. Generator system (101), comprising:

an arrangement (102) according to one of the preceding claims;

the synchronous generator (105) having the stator (129) comprising the at least one stator winding (131) and having the rotor (137) with the electromagnet (139) driven by the field current (127), the rotor being rotatable relative to the stator, the electromagnet (139) being inductively coupled to the stator winding (131); and

10 a system (125) for providing the field current (127), wherein the controller (103) is adapted to cause shutting down the field current (127) by supplying a control signal (159) to system (125) for providing the field current.

15 13. Generator system according to claim 12, wherein the system (125) for providing the field current comprises a slip ring mechanically coupled to the rotor and electrically coupled to the electromagnet and a brush contacting the slip ring, wherein shutting down the field current comprises interrupting current flow supplied to the brush.

14. Generator system according to claim 12, wherein the system (125) for providing the field current (127) comprises:

25 a rotating coil (141) mechanically coupled to the rotor (137);

a rotatable rectifier (143) mechanically coupled to the rotor (137) and electrically coupled to the rotating coil (141) and providing the field current (127) to the electromagnet (139) of the rotor (137);

30 a stator electromagnet (145) inductively coupled to the rotating coil (141);

a stator electromagnet supply system (147) for supplying an exciting voltage to the stator electromagnet (145), wherein shutting down the field current (127) comprises interrupting the exciting voltage to the stator electromagnet.

15. Generator system according to claim 14, wherein the stator electromagnet supply system (147) comprises at least one

controllable switch (155), in particular isolated gate bipolar transistor, driven by a gate driver circuit (157), wherein shutting down the field current (127) comprises supplying a shut-down signal (159) to the gate driver (157).

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16. Generator system according to claim 15, further comprising an emergency stop switch (161) between the at least one controllable switch (155) and the stator electromagnet (145).

10 17. Generator system according to one of claims 12 to 16, further comprising:

a generator rectifier (115) connected to the AC-output terminal (133), in particular three AC-output terminals, the rectifier comprising in particular a diode (163) and a tem-
15 perature sensor (170) for measuring the temperature (169) of the diode (163),

wherein in particular the rectifier is the only load connected to the output terminal (133) of the generator (105).

20 18. Energy system, in particular vessel energy system (100), comprising:

a generator system (101) according to one of claims 12 to 17 arranged for converting mechanical energy provided by a combustion engine (107) to electrical energy;

25 a DC-distribution system (123) coupled to the a DC-output terminal (180) of the rectifier circuit (115) for distributing the electrical energy, in particular to at least one propulsion motor.