

Description

Device and a drive system, in particular for ships, which comprises a device of this type

The invention relates to a device comprising an electric motor/generator unit which can be switched over from a motor mode into a generator mode and vice versa and has a stator and a rotor which has a rotor rotational axis, and a drive shaft which is arranged concentrically with respect to the rotor rotational axis and is connected to the rotor. The invention further relates to a drive system comprising at least one device of this type and to its operation and also to a ship equipped with such a drive system.

Internal combustion engines, especially diesel motors, need large amounts of air for burning the fuel used. The largest possible amount of air or an excess of air during the combustion improves the combustion behavior and thus enhances the performance of the internal combustion engine. The most complete possible combustion is only achieved with a sufficient excess of air. At the same time it is advantageous to supply air with the lowest possible temperature in order, for a given pressure, to make available as great a mass of air as possible. When air is compressed its temperature rises, which means that a lower mass of oxygen reaches the combustion chamber of the internal combustion engine. If an exhaust gas turbocharger, which is operated by the hot exhaust gas stream of the internal combustion engine, is used in the compression process, its heating can additionally have a heating effect via the compression unit for the air and lead to a further heating of the air to be compressed.

In GB 2477548 A a gas turbine machine in which this effect occurs is described as the prior art. Here the exhaust gas stream from a combustion chamber drives a turbocharger or its turbine wheel. The turbine wheel is mounted on one end of a drive shaft. Mounted on the other end of the drive shaft is a compressor wheel of a compressor, which rotates together with the drive shaft and is used for compressing air. The compressed air is fed to the combustion chamber for improved combustion of the fuel used.

GB 2477548 A further describes a gas turbine machine in which the drive shaft for the turbine wheel and, at a distance therefrom, a further drive shaft for the compressor wheel are present and these drive shafts are thus thermally decoupled from one another. The drive shaft driven by the turbine wheel is connected to a generator, while the further drive shaft driving the compressor wheel is connected to an electric motor, which is supplied with energy by the generator.

Since around 3 to 5 times more exhaust gas volume occurs during the combustion of fuel than there has been air supplied for combustion (volume ratio for standard atmospheres) and the exhaust gas is also heated up, the turbine as a rule makes available more energy than is needed just to compress the air.

In accordance with GB 2477548 A this excess of energy is stored in a battery and can be used, when the combustion process starts, to drive the electric motor and to create compressed air without the turbine already operating.

Even with transient processes, such as the rapid connection of load requirements to an internal combustion engine, it is advantageous to make available more compression power. In

accordance with GB 2477548 A the stored energy can be used to further accelerate the compressor wheel independently of the current turbine operation and thus rapidly react to the switch in load.

However the outlay in terms of equipment to provide a decoupled device in accordance with GB 2477548 A is relatively large, as is also the necessary space required and the error quota or failure quota of the device associated therewith.

A device for operating an electrically assisted turbocharger for an internal combustion engine is known from DE 195 18 317 C2, wherein the turbocharger has an exhaust gas turbine and a compressor, which are coupled to one another via a shaft on which a first motor-generator unit is arranged directly, wherein a second motor-generator set acting on the internal combustion engine is present and the stator windings of the first motor-generator set and the second motor-generator set are connected to one another, wherein the first motor-generator set is a multiple-strand, multi-pole asynchronous machine and the second motor-generator set is a separately excited synchronous machine, of which the exciter field is controlled in the stator with respect to its frequency and direction of rotation.

The object of the invention is therefore to provide a device, which reacts rapidly to a change in load, comprising a compressor and a turbine, which overcomes these disadvantages of the prior art. The further object of the invention is to specify a drive system comprising at least one such device, and the use thereof.

For the device the object is achieved by said device comprising:

- A motor-generator unit able to be switched over from motor operation into generator operation and vice versa, having a stator and a rotor which has a rotor axis of rotation and also a drive shaft arranged concentrically to the rotor axis of rotation and connected to the rotor,
- A compressor with a rotatable compressor wheel for compressing air, wherein the compressor wheel is mounted on one side of the rotor on the drive shaft arranged concentrically to the rotor axis, and
- A turbine, which comprises a turbine wheel able to be driven by an exhaust gas stream, which is mounted on the drive shaft arranged concentrically to the rotor axis on a side of the rotor opposite to the compressor wheel,

wherein the compressor and the turbine are arranged decoupled from one another by at least one decoupling arrangement, wherein at least two decoupling arrangements are present, wherein a first decoupling arrangement of the decoupling arrangements is arranged between the compressor and the electric motor/generator unit and a second decoupling arrangement is arranged between the turbine and the electric motor/generator unit.

Electric motor and generator are combined in the inventive device into one electric motor/generator constructional unit which is able to be operated either in generator mode or in motor mode and wherein the switch between the operating modes is possible in a rapid and uncomplicated manner. The electric motor/generator unit in this case forms a mechanical boundary between the turbine and the compressor. Thus these units, although they are directly connected to each other in a space-saving and resource-saving manner by the continuous drive

shaft, with respect to the conduction of heat via the drive shaft however, the electric motor/generator unit acts as a heat insulator between the hot turbine and the compressor that is to be operated at a lower temperature where possible. This enables turbine and compressor to be operated largely thermally decoupled.

The at least one decoupling arrangement causes a separation of the functional spaces of turbine and compressor. Thermal insulation from turbine to compressor is achieved in particular by this and if necessary also a gas-tight separation between turbine and compressor is provided. Thanks to the second decoupling arrangement, which is arranged between the turbine and the electric motor/generator unit, and the first decoupling arrangement, which is arranged between the compressor and the electric motor/generator unit, overheating of the electric motor/generator unit can be reliably avoided.

The fact that at least two decoupling arrangements are present means that the thermal insulation between turbine and compressor is improved even further. Preferably the decoupling is to be understood in this case as thermal decoupling, wherein a thermal decoupling is especially able to be achieved by means of the decoupling arrangement. For example the respective decoupling arrangement is designed to be cooled with a cooling medium, preferably water or oil, wherein the cooling medium is able to be supplied to and discharged from the respective decoupling arrangement via connections for supply and discharge of media.

In particular the electric motor/generator unit is connected electrically to a converter and the converter is connected

electrically to a transformer. This makes it possible to feed generated electricity into a network, such as preferably a ship's network.

In an especially preferred embodiment of the invention at least one cooling unit is present for cooling the electric motor/generator unit. This thermally separates turbine and compressor in an ideal way and the temperature of the compressed air created is kept as low as possible while exploiting the advantage described at the start.

Preferably the electric motor/generator unit involves a machine based on high-temperature superconductivity, wherein at least one cooling unit is provided for cooling the machine. A machine based on high-temperature superconductivity operates electrically highly efficiently and is usually characterized by an electric motor/generator unit with a very low-mass rotor, which also possesses small spatial dimensions. The use of such a rotor in an inventive device is ideal with respect to the flywheel mass provided by said rotor, since there can be an especially rapid reaction to a change of load.

The object of the invention in relation to a drive system is achieved by the drive system comprising:

- At least one inventive device,
- At least one combustion system for combustion of a stream of fuel and a stream of compressed air while generating a stream of exhaust gas for injection into the turbine(s) of the at least one inventive device and for driving the relevant compressor wheel,
- An air supply device for supplying uncompressed air to the compressor of the at least one inventive device, and

- A feed device for transferring a stream of compressed air formed from the uncompressed air by means of the compressor wheel to the at least one combustion system.

Such a drive system has a compact construction as well as a largely thermal separation between turbine and compressor. It is suitable for use in conjunction with different combustion systems. In particular it can react especially quickly to load connections and disconnections of the combustion system, wherein this refers to reaction times of less than 1 ms. In the event of problems with turbine operation, these can be counteracted by an explicit acceleration of the compressor wheel, so that the probability of a compressor failure is reduced and so that the provision of the combustion system with compressed air being adversely effected is largely excluded.

The combustion system especially involves an internal combustion engine, preferably a diesel engine. In the lower rpm range of the engine air already compressed can be provided and thus the emission behavior can be improved. In this case the combustion system especially forms a part of a main or auxiliary machine.

Especially preferred is a use of the inventive drive system for ships. In particular the drive system is integrated into a ship's drive system already known in accordance with DE 10 2006 020 144 A1.

Thus, in accordance with the invention, a ship including the inventive drive system as well as an electrical ship's network are also provided, wherein the electric motor/generator unit of the at least one inventive device is connected to the

ship's network such that, in generator mode, energy is injected into the ship's network and in motor mode energy is taken from the ship's network.

A method for operating the inventive drive system comprises the following steps:

Creation of a stream of exhaust gas by means of the combustion system, in that a stream of fuel and a stream of compressed air are burnt together with one another;

Operation of the electric motor/generator unit of the at least one device in generator mode while generating electrical energy, wherein the turbine is fed with a stream of exhaust gas and the turbine wheel and thus simultaneously the compressor wheel are driven while forming the stream of compressed air;

Injection of electrical energy generated by means of the electric motor/generator unit into an electrical network, especially a ship's network.

In the event of a spontaneous load requirement on the compressor system for dynamic improvement of the combustion system, there is preferably a switchover from generator mode into motor mode, wherein the electric motor/generator unit is supplied with energy from the electrical network, wherein the drive shaft is accelerated and wherein an increased quantity of compressed air is formed.

The electric motor/generator unit can be switched over from a generator mode to a motor mode and vice versa in a very short time, so that a change in load can be reacted to very rapidly and in a very uncomplicated manner.

Figures 1 to 6 are intended to illustrate by way of example an inventive device, a drive system equipped with said device and the integration of such a drive system into a known ship's drive system. Thus, in the figures:

- FIG. 1 shows a device comprising turbine and compressor,
- FIG. 2 shows operation of the device according to FIG. 1,
- FIG. 3 shows a drive system comprising a device according to FIG. 1,
- FIG. 4 shows a first schematic of a ship's drive system comprising a drive system according to FIG. 3,
- FIG. 5 shows a second schematic of a ship's drive system comprising a drive system according to FIG. 3,
- FIG. 6 shows a third schematic of a ship's drive system comprising a drive system according to FIG. 3,

FIG. 1 shows a device 100 comprising a compressor 400, an electric motor/generator unit 200 and a turbine 500. The electric motor/generator unit 200 comprises a stator 200a and a rotor 200b, which has a rotor axis of rotation 200c, as well as a drive shaft 300 arranged concentric to the rotor axis of rotation 200c and connected to the rotor 200b. The compressor 400 comprises a rotatable compressor wheel 400a for compressing air, wherein the compressor wheel 400a is mounted on one side of the rotor 200b on the drive shaft 300 arranged concentric to the rotor axis of rotation 200c. The turbine 500 comprises a turbine wheel 500a able to be driven by a stream of exhaust gas, which is mounted on a side of the rotor 200b lying opposite the compressor wheel 400a on the drive shaft 300 arranged concentric to the rotor axis of rotation 200c. The compressor 400 and the turbine 500 are arranged here separated from each other and thus also from the electric motor/generator unit 200 by two decoupling arrangements 600a,

600b. To simplify the diagram neither electrical connections of the electric motor/generator unit 200 nor any other media supply lines or discharge lines are shown therein.

FIG. 2 shows operation of the device according to FIG. 1. The same reference characters identify the same elements in this figure. The turbine 500 is fed by a hot exhaust gas stream 510, which drives the turbine wheel 500a not shown here in detail (cf. FIG. 1) and thus also drives the drive shaft 300. The compressor wheel 400a also starts to move at the same time as the drive shaft 300 (cf. FIG. 1) and a stream of compressed air 410' is created from the uncompressed air 410 supplied to the compressor 400. As a result of the rotation of the drive shaft 300 the rotor 200b is also rotated and a voltage U is induced in the stator 200a, which can be tapped off via terminals 200d.

The electric motor/generator unit 200 or its housing is supplied with coolant 130a and cooled via a cooling unit 130 further provided here. The heated coolant 130b is discharged from the electric motor/generator unit 200 and the heat taken up is removed again, via a heat exchanger not shown here in detail for example. The coolant 130a cooled down again is supplied once again in a circulation process to the electric motor/generator unit 200 to cool said unit.

FIG. 3 shows a drive system 110 comprising a device 100 in accordance with Figures 1 and 2. The same reference characters identify the same elements in this figure. The drive system 110 has a main machine 2, which comprises a combustion system 800. The combustion system 800, especially a diesel engine, is supplied with a stream of fuel 900, especially diesel fuel, and a stream of compressed air 410', which the compressor 400

provides and which is supplied to the combustion system 800 via a feed device 412 merely shown schematically. In the combustion system 800 the fuel and the oxygen from the compressed air are burned, wherein a hot stream of exhaust gas 510 is formed. The hot stream of exhaust gas 510 drives the turbine wheel 500a of the turbine 500 and escapes from the turbine 500 as an exhaust gas stream 510' with reduced energy content compared to the hot exhaust gas stream 510. Uncompressed air 410 is supplied to the compressor via an air supply device 411 merely shown schematically in the figure.

FIG. 4 shows a usage example for an inventive drive system in the form of a greatly schematicized first ship's drive system 1 with waste heat recovery, e.g. for a large container ship. On the basis of a ship's drive system disclosed in DE 10 2006 020 144 A1 a drive system 100 according to FIG. 3 is integrated. The same reference characters as in Figures 1 to 3 identify the same elements in this figure.

The drive system of the first ship's drive system 1 has a main machine 2 embodied as a slow-running two-stroke diesel engine, which is connected via a propeller shaft 3 to a ship's propeller 4 for driving the ship.

An electrical ship's network 5 serves to supply electrical devices and systems on board the ship with energy. A distinction should be made here between critical consumers 6, which, if switched off, lead to a blackout on board the ship, and non-critical consumers 7 (e.g. hotel load) which do not lead to a blackout. For reasons of clarity only one critical consumer 6 and one non-critical consumer 7 are shown in FIG. 4 in each case. In practice a greater number of these types of

consumers 6, 7 would be supplied with power from the ship's network 5 in each case.

A number of generators 8 are provided for supplying energy to the ship's network 5, which are each driven by an auxiliary machine 9 running faster than the main machine 2. The auxiliary machines 9 usually involve fast-running four-stroke diesel engines with an output of up to 5 MW for example. Usually a generator 8 and a diesel engine 9 are combined in each case into a diesel generator set 10.

The turbine 500 of a device 100 is supplied with the hot exhaust gas stream 510, which flows here out of the combustion system of the main machine 2 not shown in detail. The compressed air stream 410' then subsequently provided by the compressor 400 is supplied to the combustion system of the main machine 2 and burned there together with the fuel stream 900 to form the hot exhaust gas 510.

The electric motor/generator unit 200 is connected electrically via a converter 51' and a transformer 35' to the ship's network 5. The converter 51' is embodied as an direct current intermediate circuit converter and consists of a motor-side power converter 13' and a network-side power converter 14'.

During the switchover from motor to generator mode the intermediate circuit capacitor 52' feeds electrical energy into the ship's network 5 such that the voltage and the frequency of the ship's network 5 do not fall below predetermined threshold values in each case. The time for the switchover from motor mode into generator mode and the dimensioning of the intermediate circuit capacitor 52' with

respect to the energy able to be fed in during the time of switching over into the ship's network 5 are tailored to one another for this purpose.

The exciter current I_E' for the electric motor/generator unit 200 is likewise obtained from the ship's network 5 and is controlled and regulated via a static exciter 15'. The electric motor/generator unit 200 is controlled and regulated via the converter 51' and the static exciter 15' by the control and regulation system 16', which is preferably designed in digital technology. The power converter 13', the further power converter 14' and the static exciter 15' are likewise able to be controlled and regulated independently of one another here by the control and regulation system 16'.

For improved clarity the cooling unit 130 for the electric motor/generator unit 200 is not shown here.

In addition a waste heat recovery system 20 converts residual heat of the main machine 2, which is provided via the lower-energy exhaust gas stream 510' escaping from the turbine 500, into electrical energy for the ship's network 5. To this end heat from the lower-energy exhaust gas stream 510' is transferred via a heat exchanger 21 to a steam circuit not shown in any greater detail, into which a steam turbine 22 is connected, which is coupled to a turbo generator 23. The electrical energy generated by the turbo generator 23 is fed into the ship's network 5.

A software-controlled power management system 30 insures demand-driven provision of the electrical energy for the various consumers 6, 7 and, depending on requirement and available power, connects individual consumers 6, 7, diesel

generator sets 10, the turbo generator 23 or the electric motor/generator unit 200 to the ship's network 5 or disconnects them from the network via switches 31, 32, 32', 33, 33'. To this end the power management system 30 is connected via control lines 34, 34' or other connections to the switches 31, 32, 32', 33', the diesel generator sets 10, the control and regulation system 16' and also to a control and regulation system of the waste heat recovery system 20 not shown in any greater detail. Furthermore a communication connection 17 is present between a control and regulation system of the main machine 2 not shown in any greater detail and the control and regulation system 16', to notify a rapid change in load, for example if the propeller 4 lifts up out of the water, as quickly and as efficiently as possible to the control and regulation system 16'.

The primary objective in operation of the ship's drive system 1 is to feed into the ship's network 5 the entire available energy from the device 100 and from the waste heat recovery system 20. As soon as the electric motor/generator unit 200 and/or the turbo generator 23 feeds energy into the ship's network, the load on the diesel generator sets 10 is relieved by the power management system 30 and, where possible, the sets are even turned off. Through these measures the fuel and operating costs as well as the emissions of the diesel generator sets 10 can be greatly reduced.

Advantageously the electric motor/generator unit 200 is torque-regulated both in motor mode and in generator mode and is thus regulated in proportion to the electrical power consumed or delivered.

With high load requirements on the main machine the electric motor/generator unit 200 is operated in motor mode and electrical energy is fed in from the ship's network 5, in order to further accelerate the drive shaft 300 (cf. FIG. 1) and thereby rapidly provide the large quantity of compressed air needed over the short term as quickly as possible.

FIG. 5 shows a further usage example for an inventive drive system in the form of a greatly schematicized second ship's drive system 1' with waste heat recovery, e.g. for a large container ship. On the basis of a ship's drive system disclosed in DE 10 2006 020 144 A1, a drive system 100 according to FIG. 3 is integrated. The same reference characters as in Figures 1 to 4 identify the same elements.

The drive system of the ship's drive system 1' has a main machine 2 embodied as a slow-running two-stroke diesel engine, which is connected via a propeller shaft 3 to a ship's propeller 4 for driving the ship.

Here once again an electrical ship's network 5 serves to supply electrical devices and systems on board the ship with energy. A distinction should be made here between critical consumers 6, which, if switched off, lead to a blackout on board the ship, and non-critical consumers 7 (e.g. hotel load) which do not lead to a blackout. For reasons of clarity only one critical consumer 6 and one non-critical consumer 7 are shown in FIG. 5 in each case. In practice a greater number of these types of consumers 6, 7 would be supplied with power from the ship's network 5 in each case.

A number of generators 8 are provided for supplying energy to the ship's network 5, which is each driven by an auxiliary

machine 9 running faster than the main machine 2. The auxiliary machines 9 usually involve fast-running four-stroke diesel engines with an output of up to 5 MW for example. Usually a generator 8 and a diesel engine 9 are combined in each case into a diesel generator set 10.

A shaft generator/motor 11 is coupled mechanically to the propeller shaft 3 and is connected electrically via a converter 51 and a transformer 35 to the ship's network 5. The converter 51 is embodied as a direct current intermediate circuit converter and consists of a motor-side power converter 13 and a network-side power converter 14.

During the switchover from motor to generator mode the intermediate circuit capacitor 52 feeds electrical energy into the ship's network 5 such that the voltage and the frequency of the ship's network 5 do not fall below predetermined threshold values in each case. The time for the switchover from motor mode into generator mode and the dimensioning of the intermediate circuit capacitor 52 with respect to the energy able to be fed in during the time of switching over into the ship's network 5 are tailored to one another for this purpose.

The shaft generator/motor 11 is embodied as a slow-running synchronous machine and preferably acts directly, without intermediate gearing, on the propeller shaft 3. The shaft generator/motor 11 can however also be coupled to the propeller shaft 3 via gearing or can be coupled to the crankshaft of the main machine 2 and this can be at the end which lies away from the propeller shaft 3.

The exciter current I_E for the shaft generator/motor 11 is likewise obtained from the ship's network 5 and is controlled and regulated via a static exciter 15.

By controlling and regulating the flow of electrical energy through the converter 51 and the exciter current I_E , the shaft generator/motor 11 can be operated either as a motor or as a generator. In motor mode electrical energy from the ship's network 5 is then converted into mechanical energy for driving the ship's propeller 4. Power reserves in the ship's network 5 can thus be used to increase the drive power of the ship, through which either the speed of the ship increases or, with the speed of the ship remaining the same, the load on the main machine 2 can be relieved. In generator mode mechanical energy of the propeller shaft 3 is converted into electrical energy for the ship's network 5. This enables power reserves of the main machine 2 to be used for generating energy for the ship's network 5. Preferably for this purpose the rated power of the shaft generator/motor 11 amounts to at least 5% of the rated power of the main machine 2.

The shaft generator/motor 11 is controlled and regulated via the converter 51 and a static exciter 15 by a common control and regulation system 16, preferably designed in digital technology. The power converter 13, the power converter 14 and the static exciter 15 are able to be controlled and regulated independently of one another here by the control and regulation system 16.

For this the control and regulation system 16, using measurement devices not described in any greater detail, detects the rotational speed of the shaft generator/motor, the

motor voltage, motor frequency, intermediate circuit current, network voltage and network frequency.

The turbine 500 of a device 100 is supplied with the hot exhaust gas stream 510, which flows out of the combustion system of the main machine 2 not described here in any greater detail. The compressed air stream 410' subsequently provided to the compressor 400 is fed to the combustion system of the main machine 2 and is burned there together with the fuel stream 900 to form the hot exhaust gas.

The electric motor/generator unit 200 is connected electrically via a further converter 51' and a further transformer 35' to the ship's network 5. The exciter current I_E' for the electric motor/generator unit 200 is likewise obtained from the ship's network 5 and is controlled and regulated via a further static converter 15'.

The electric motor/generator unit 200 is controlled and regulated via the further converter 51' and the further static exciter 15' by a further control and regulation system 16'. The further converter 51' is embodied like the converter 51 and comprises further power converters 13', 14'. The further power converter 13', the further power converter 14' and the further static converter 15' are likewise able to be controlled and regulated independently of one another by the control and regulation system 16'.

Furthermore a communication connection 17 is present between a control and regulation system of the main machine 2 not shown in any greater detail and the control and regulation system 16', to notify a rapid change in load, if the propeller 4 lifts up out of the water for example, as quickly and as

efficiently as possible to the control and regulation system 16'.

A further communication line 17' connects the two control and regulation systems 16, 16', in order to make possible a direct and efficient mutual intervention here.

The cooling unit 130 for the electric motor/generator unit 200 has also not been shown here for reasons of improved clarity.

In addition a waste heat recovery system 20 converts residual heat of the main machine 2, which is provided via the lower-energy exhaust gas stream 510' escaping from the turbine 500, into electrical energy for the ship's network 5. To this end heat from the lower-energy exhaust gas stream 510' is transferred via a heat exchanger 21 to a steam circuit 22 not shown in any greater detail, into which a steam turbine is connected, which is coupled to a turbo generator 23. The electrical energy generated by the turbo generator 23 is fed into the ship's network 5.

A software-controlled power management system 30 insures demand-driven provision of the electrical energy for the various consumers 6, 7 and, depending on requirement and available power, connects individual consumers 6, 7, diesel generator sets 10, the turbo generator 23, the shaft generator 11 or the electric motor/generator unit 200 to the ship's network 5 or disconnects them from the network via switches 31, 32, 32', 33, 33'. To this end the power management system 30 is connected via control lines 34, 34' or other connections to the switches 31, 32, 32', 33, 33', the diesel generator sets 10, the control and regulation system 16' and also to a

control and regulation system of the waste heat recovery system 20 not shown in any greater detail.

The primary objective in operation of the ship's drive system 1 is to feed into the ship's network 5 the entire available energy from the device 100 and from the waste heat recovery system 20. As soon as the electric motor/generator unit 200 and/or the turbo generator 23 feeds energy into the ship's network, the load on the diesel generator sets 10 is relieved by the power management system 30 and, where possible, the sets are even turned off. Through these measures the fuel and operating costs as well as the emissions of the diesel generator sets 10 can be greatly reduced.

If the electric motor/generator unit 200 and/or the waste heat recovery system 20 even generates more energy than is needed for the electrical ship's consumers 6, 7, then the shaft generator/motor unit 11 is operated in motor mode with this excess energy and thus an additional drive force is imparted to the propeller shaft 3. In this operating mode only the electric motor/generator unit 200 and/or the waste heat recovery system 20 feeds electrical energy into the ship's network; the diesel generator sets 10 on the other hand are switched off.

An unplanned outage of the energy generation by the electric motor/generator unit 200 and/or the waste heat recovery system 20, e.g. in the event of a fault, would thus however lead to a collapse of the voltage and the frequency of the ship's network 5 with the consequence of a safety shutdown of the critical and non-critical consumers 6, 7, and thus to a blackout of the ship, since it takes a few seconds for the

diesel generator sets 10 to be started and to be available for supplying energy to the ship's network 5.

In order to avoid this, the shaft generator/motor 11 is switched over from motor mode into generator mode within less than 1 second after fault signaling. During the switchover time the energy demand of the ship's network 5 is fed from the energy stored in the intermediate circuit capacitor 52, 52'. This briefly takes over the energy supply for the critical consumers 6 and feeds energy into the ship's network 5 for this purpose, and does so such that voltage and frequency of the ship's network 5 do not fall below a threshold value predetermined in each case. The threshold values are selected here so that a safety shutdown of the critical ship's consumers 6, which could lead to a blackout of the ship, is avoided. The switchover time and the energy delivery capability of the intermediate circuit capacitors 52, 52' during the switchover time are tailored to one another for this purpose.

A short switchover time is able to be achieved on the one hand by the electric motor/generator unit 200 and/or the waste heat recovery system 20 signaling the fault to the control and regulation system 16, 16' via a direct line connection 36, i.e. by bypassing the power management system 30. Delays in the signal transmission by the software of the power management system 30 can be avoided by this.

To this end the control and regulation system 16 has a signal input, which is connected via the line connection 36, i.e. by "hard" wiring, directly to a signal generator of the electric motor/generator unit 200 and the waste heat recovery system 20 for fault triggering. In the exemplary embodiment the signal

generator is a floating auxiliary contact of the switch 32, 32' not described in greater detail, which is opened in the event of a fault in order to disconnect the electric motor/generator unit 200 and/or the turbo generator 23 from the ship's network 5.

Furthermore this type of short switchover time is able to be achieved by the activation of the power converters 13, 13', 14, 14' and the static exciter 15, 15' taking place during the switchover from motor mode to generator mode, without pulse switch-offs, i.e. solely by changing the switch-on points and thus switch-on durations of the power converter valves. When thyristors are used as power converter valves usually only the switch-on times are controlled here via the so-called control angle α . When GTOs, IGBTs or IGCTs are used both the switch-on times and also the switch-off times can be controlled.

This type of activation of the power converter valves without pulse switch-off is possible by virtue of the control and regulation system 16 regulating the shaft generator/motor 11 via the converter 51 and the power converter 15 or the electric motor/generator unit 200 via the converter 51' and the power converter 15' in motor mode and generator mode with the same type of regulation. Pulse switch-offs during the transition from motor mode to generator mode and the delays associated therewith, as would be necessary with different types of regulation for motor and generator mode, can be avoided thereby.

Advantageously the shaft generator/motor 11 and also the electric motor/generator unit 200 are operated both in motor mode and in generator mode under torque control and thereby

proportional to the electrical power consumed or delivered, since the rotational speed changes relatively slowly.

With high load requirements on the main machine the electric motor/generator unit 200 is operated in motor mode and electrical energy is fed from the ship's network 5 in order to further accelerate the drive shaft 300 (cf. FIG 1) and through this to provide the short-term requirement for the quantity of compressed air needed as quickly as possible.

FIG. 6 shows a further usage example for an inventive drive system in the form of a greatly schematicized third ship's drive system 1'' with waste heat recovery, e.g. for a large container ship. On the basis of a ship's drive system disclosed in DE 10 2006 020 144 A1 a drive system 100 according to FIG. 3 is integrated. The same reference characters as in Figures 1 to 5 identify the same elements in this figure.

The drive system of the ship's drive system 1'' has a main machine 2 embodied as a slow-running two-stroke diesel engine, which is connected via a propeller shaft 3 to a ship's propeller 4 for driving the ship.

An electrical ship's network 5 serves to supply electrical devices and systems on board the ship with energy. A distinction should be made here between critical consumers 6, which, if switched off, lead to a blackout on board the ship, and non-critical consumers 7 (e.g. hotel load) which do not lead to a blackout. For reasons of clarity only one critical consumer 6 and one non-critical consumer 7 is shown in FIG. 4 in each case. In practice a greater number of these types of

consumers 6, 7 would be supplied with power from the ship's network 5 in each case.

A number of generators 8 are provided for supplying energy to the ship's network 5, which are each driven by an auxiliary machine 9 running faster than the main machine 2. The auxiliary machines 9 usually involve fast-running four-stroke diesel engines with an output of up to 5 MW for example. Usually a generator 8 and a diesel engine 9 are combined in each case into a diesel generator set 10.

A shaft generator/motor 11 is coupled mechanically to the propeller shaft 3 and is connected electrically via a converter 51 and a transformer 35 to the ship's network 5. The converter 51 is embodied as a direct current intermediate circuit converter and consists of a motor-side power converter 13 and a network-side power converter 14.

During the switchover from motor to generator mode the intermediate circuit capacitor 52 feeds electrical energy into the ship's network 5 such that the voltage and the frequency of the ship's network 5 do not fall below predetermined threshold values in each case. The time for the switchover from motor mode into generator mode and the dimensioning of the intermediate circuit capacitor 52 with respect to the energy able to be fed in during the time of switching over into the ship's network 5 are tailored to one another for this purpose.

The shaft generator/motor 11 is embodied as a slow-running synchronous machine and preferably acts directly, without intermediate gearing, on the propeller shaft 3. The shaft generator/motor 11 can however also be coupled to the

propeller shaft 3 via gearing or can be coupled to the crankshaft of the main machine 2 and this can be at the end which lies away from the propeller shaft 3.

The exciter current I_E for the shaft generator/motor 11 is likewise obtained from the ship's network 5 and is controlled and regulated via a static exciter 15.

By controlling and regulating the flow of electrical energy through the converter 51 and the exciter current I_E , the shaft generator/motor 11 can be operated either as a motor or as a generator. In motor mode electrical energy from the ship's network 5 is then converted into mechanical energy for driving the ship's propeller 4. Power reserves in the ship's network 5 can thus be used to enhance the drive power of the ship, through which either the speed of the ship increases or, with the speed of the ship remaining the same, the load on the main machine 2 can be relieved. In generator mode mechanical energy of the propeller shaft 3 is converted into electrical energy for the ship's network 5. This enables power reserves of the main machine 2 to be used for generating energy for the ship's network. Preferably for this purpose the rated power of the shaft generator/motor 11 amounts to at least 5% of the rated power of the main machine 2.

The shaft generator/motor 11 is controlled and regulated via the converter 51 and a static exciter 15 by a common control and regulation system 16, preferably designed in digital technology. The power converter 13, the power converter 14 and the static exciter 15 are able to be controlled and regulated independently of one another here by the control and regulation system 16.

For this the control and regulation system 16, using measurement devices not described in any greater detail, detects the rotational speed of the shaft generator/motor, the motor voltage, motor frequency, intermediate circuit current, network voltage and network frequency.

The turbine 500 of a device 100 is supplied with the hot exhaust gas stream 510, which flows here out of the combustion system of the main machine 2 not shown in detail. The compressed air stream 410' then subsequently provided by the compressor 400 is supplied to the combustion system of the main machine 2 and burned there together with the fuel stream 900 to form the hot exhaust gas.

The electric motor/generator unit 200 is connected electrically to the ship's network 5 via a further converter 51' and a further transformer 35'. The exciter current I_E' for the electric motor/generator unit 200 is likewise obtained from the ship's network 5 and is controlled and regulated via a further static exciter 15'. The electric motor/generator unit 200 is likewise controlled and regulated via the further converter 51' and the further static exciter 15' by the control and regulation system 16. The further converter 51' is embodied like the converter 51 and comprises further power converter 13', power converter 14'. The further power converter 13', the further power converter 14' and the further static exciter 15' are likewise able to be controlled and regulated independently of one another here by the control and regulation system 16.

For improved clarity the cooling unit 130 for the electric motor/generator unit 200 is not shown here.

In addition a waste heat recovery system 20 converts residual heat of the main machine 2, which is provided via the lower-energy exhaust gas stream 510' escaping from the turbine 500, into electrical energy for the ship's network 5. To this end heat from the lower-energy exhaust gas stream 510' is transferred via a heat exchanger 21 to a steam circuit not shown in any greater detail, into which a steam turbine 22 is connected, which is coupled to a turbo generator 23. The electrical energy generated by the turbo generator 23 is fed into the ship's network 5.

A software-controlled power management system 30 insures demand-driven provision of the electrical energy for the various consumers 6, 7 and, depending on requirement and available power, connects individual consumers 6, 7, diesel generator sets 10, the turbo generator 23, the shaft generator/motor 11 or the electric motor/generator unit 200 to the ship's network 5 or disconnects them from the network via switches 31, 32, 32', 33, 33'. To this end the power management system 30 is connected via control lines 34 or other connections to the switches 31, 32, 32', 33, 33', the diesel generator sets 10, the control and regulation system 16 and also to a control and regulation system of the waste heat recovery system 20 not shown in any greater detail.

The primary objective in operation of the ship's drive system 1 is to feed into the ship's network 5 the entire available energy from the device 100 and from the waste heat recovery system 20. As soon as the electric motor/generator unit 200 and/or the turbo generator 23 feeds energy into the ship's network, the load on the diesel generator sets 10 is relieved by the power management system 30 and, where possible, the sets are even turned off. Through these measures the fuel and

operating costs as well as the emissions of the diesel generator sets 10 can be greatly reduced.

If the electric motor/generator unit 200 and/or the waste heat recovery system 20 generates even more energy than is needed for the electrical ship's consumers 6, 7, then the shaft generator/motor unit 11 is operated in motor mode with this excess energy and thus an additional drive force is given to the propeller shaft 3. In this operating mode only the electric motor/generator unit 200 and/or the waste heat recovery system 20 feeds electrical energy into the ship's network; the diesel generator sets 10 on the other hand are switched off.

An unplanned outage of the energy generation by the electric motor/generator unit 200 and/or the waste heat recovery system 20, e.g. in the event of a fault, would thus however lead to a collapse of the voltage and the frequency of the ship's network 5 with the consequence of a safety shutdown of the critical and non-critical consumers 6, 7, and thus to a blackout of the ship, since it takes a few seconds for the diesel generators 10 to be started and to be available for supplying energy to the ship's network 5.

In order to avoid this, the shaft generator/motor 11 is switched over from motor mode into generator mode within less than 1 second after fault signaling. During the switchover time the energy demand of the ship's network 5 is fed from the energy stored in the intermediate circuit capacitor 52, 52'. This briefly takes over the energy supply for the critical consumers 6 and feeds energy into the ship's network 5 for this purpose, and does so such that voltage and frequency of the ship's network 5 do not fall below a threshold value

predetermined in each case. The threshold values are selected here so that a safety shutdown of the critical ship's consumers 6, which could lead to a blackout of the ship, is avoided. The switchover time and the energy delivery capability of the intermediate circuit capacitors 52, 52' during the switchover time are tailored to one another for this purpose.

A short switchover time is able to be achieved on the one hand by the electric motor/generator unit 200 and/or the waste heat recovery system 20 signaling the fault to the control and regulation system 16 via a direct line connection 36, i.e. by bypassing the power management system 30. Delays in the signal transmission by the software of the power management system 30 can be avoided by this.

To this end the control and regulation system 16 has a signal input, which is connected via the line connection 36, i.e. by "hard" wiring, directly to a signal generator of the electric motor/generator unit 200 and the waste heat recovery system 20 for fault triggering. In the exemplary embodiment the signal generator is a floating auxiliary contact of the switch 32, 32' not described in greater detail, which is opened in the event of a fault in order to disconnect the electric motor/generator unit 200 and/or the turbo generator 23 from the ship's network 5.

Furthermore this type of short switchover time is able to be achieved by the activation of the power converters 13, 13', 14, 14' and the static exciter 15, 15' taking place during the switchover from motor mode to generator mode, without pulse switch-offs, i.e. solely by changing the switch-on points and thus switch-on durations of the power converter valves. When

thyristors are used as power converter valves usually only the switch-on times are controlled here via the so-called control angle α . When GTOs, IGBTs or IGCTs are used both the switch-on times and also the switch-off times can be controlled.

This type of activation of the power converter valves without pulse switch-off is possible by virtue of the control and regulation system 16 regulating the shaft generator/motor 11 via the converter 51 and the power converter 15 or the electric motor/generator unit 200 via the converter 51' and the power converter 15' in motor mode and generator mode with the same type of regulation. Pulse switch-offs during the transition from motor mode to generator mode and the delays associated therewith, as would be necessary with different types of regulation for motor and generator mode, can be avoided thereby.

Advantageously the shaft generator/motor 11 and also the electric motor/generator unit 200 are operated both in motor mode and in generator mode under torque control and thereby proportional to the electrical power consumed or delivered, since the rotational speed changes relatively slowly.

With high load requirements on the main machines the electric motor/generator unit 200 is operated in motor mode and electrical energy is fed from the ship's network in order to further accelerate the drive shaft 300 (cf. FIG 1) and through this to provide the short-term requirement for the quantity of compressed air needed as quickly as possible.

In such cases a device 100 could not only, as is shown in Figures 4 to 6, recycle the exhaust gas stream of the main machine 2. The exhaust gas streams of the auxiliary machines 9

- individually or combined - can also be supplied to a further device 100, in order to provide electrical energy, which can be fed into the ship's network 5, in generator mode of the respective electric motor/generator unit, or in motor mode to be able to react to a change in load at the auxiliary machines 9 and to provide within a short time the quantity of compressed air needed by an auxiliary machine 9.

Furthermore, instead of the intermediate circuit capacitors 52, 52', a DC link circuit can also be used, as shown in a form of embodiment in accordance with DE 10 2006 020 144 A1.

Claims

1. A device (100) comprising

- A motor-generator unit (200) able to be switched over from motor operation into generator operation and vice versa, having a stator (200a) and a rotor (200b) which has a rotor axis of rotation (200c) and also a drive shaft (300) arranged concentrically to the rotor axis of rotation (200c) and connected to the rotor (200b),
- A compressor (400) with a rotatable compressor wheel (400a) for compressing air (410), wherein the compressor wheel (400a) is mounted on one side of the rotor (200b) on the drive shaft (300) arranged concentrically to the rotor axis (200c), and
- A turbine (500), which comprises a turbine wheel (500a) able to be driven by an exhaust gas stream (510), which is mounted on the drive shaft (300) arranged concentrically to the rotor axis (200c) on a side of the rotor (200b) opposite to the compressor wheel (400a),

wherein the compressor (400) and the turbine (500) are arranged decoupled from one another by at least one decoupling arrangement (600a, 600b),

wherein at least two decoupling arrangements (600a, 600b) are present, wherein a first decoupling arrangement (600a) of the decoupling arrangements (600a, 600b) is arranged between the compressor (400) and the electric motor/generator unit (200) and a second decoupling arrangement (600b) is arranged between the turbine (500) and the electric motor/generator unit (200).

2. The device as claimed in claim 1,

wherein the electric motor/generator unit (200) is connected electrically to a converter (51') and wherein the converter (51') is connected electrically to a transformer (35').

3. The device as claimed in claim 1 or claim 2, wherein at least one cooling unit (130) is present for cooling the electric motor/generator unit (200).

4. The device as claimed in claim 3, wherein the electric motor/generator unit (200) involves a machine based on high-temperature superconductivity and the at least one cooling unit (130) is provided for cooling the machine.

5. A drive system (110) especially for ships, having

- At least one device (100) as claimed in one of claims 1 to 4,
- At least one combustion system (800) for burning a stream of fuel (900) and a stream of compressed air (410') while creating a stream of exhaust gas (510) for feeding into the turbine(s) 500 of the at least one device (100) and for driving the respective compressor wheel (500a),
- An air supply device (411) for supplying uncompressed air (410) to the compressor (400) of the at least one device (100), and
- A feed device (412) for transferring a stream of compressed air (410') formed by the compressor wheel (400a) from the uncompressed air (410) to at least one combustion system (800),

6. The drive system as claimed in claim 5, wherein the combustion system (800) involves an internal combustion engine.

7. The drive system as claimed in claim 5 or claim 6,

wherein the combustion system (800) forms a part of a main machine or auxiliary machine (2, 9).

8. A ship comprising a drive system (110) as claimed in one of claims 5 to 7 and also an electrical ship's network (5), wherein the electric motor/generator unit (200) of the at least one device (100) is connected to the ship's network (5) such that, in generator mode, energy is fed into the ship's network (5) and in motor mode energy is taken from the ship's network (5).

9. A method for operating a drive system (110) as claimed in one of claims 5 to 7, comprising the following steps:
Creating a stream of exhaust gas (510) by means of the combustion system (800), by a stream of fuel (900) and a stream of compressed air (410') being burned together with one another;
Operating the electric motor/generator unit (200) of the at least one device (100) in generator mode while generating electrical energy, wherein the turbine (500) is fed with a stream of exhaust gas (510) and the turbine wheel (500a), and thus at the same time the compressor wheel (400a), are driven while forming the stream of compressed air (410');
Feeding electrical energy created by means of the electric motor/generator unit (200) into an electrical network, especially into a ship's network (5).

10. The method as claimed in claim 9, wherein, in the event of a spontaneous load demand on the combustion system (800), there is a switchover from generator mode into motor mode, wherein the electric motor/generator unit (200) is supplied with electrical energy, wherein the

drive shaft (300) is accelerated, and wherein an increased quantity of compressed air (410') is formed.