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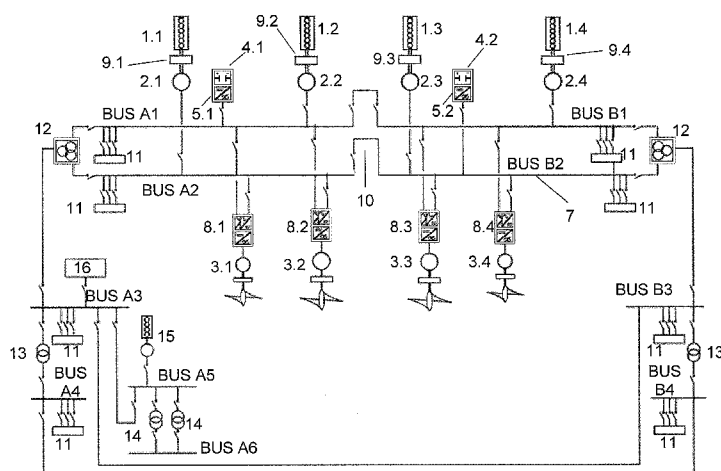


Fig. 1

(57) Abstract: A propulsion system for a vessel is provided, which comprises at least two generator sets, each including an prime mover and a generator, an electric propulsion unit, an energy storage, and a main switchboard by which the at least two generator sets, the electric propulsion unit and the energy storage are connected to each other. Excess electrical power is stored in the energy storage when the generator produces electric power in excess for the instantaneous needs of the vessel, and needed additional energy is taken from the energy storage for the use of the ship electricity network when the electric generator produces electric power instantaneously insufficiently, and the generator of one of the two generator sets is operated as a phase compensator for supplying reactive power to the propulsion system.

Improvement in Ship Propulsion Engine Fuel Efficiency

TECHNICAL FIELD

- 5 The invention relates to an arrangement for achieving an improvement in ship propulsion engine fuel efficiency.

BACKGROUND

- 10 An example for a general propulsion system for a vessel is shown in WO 2009/030807 A2.

- The Market, ship-owners and authorities call for reduced emissions and increased efficiency in ship propulsion systems. One important aspect in
15 this goal is to keep a highest possible (or close to optimum) load on the gensets and avoid fluctuations in this load as much as possible in all operation modes.

- Ship propulsion engines suffer from fluctuating power needs at typically
20 constant rotation speeds, which results in a fuel efficiency drop when the power need is not meeting the optimal power/rpm combination.

- Typically, engine fuel efficiency drops very drastically immediately when the engine running condition deviates from the optimised combination of
25 power and running speed either by fluctuating power need and constant speed or by fluctuating speed and constant power need.

SUMMARY OF INVENTION

- 30 The object of this invention is to improve fuel efficiency by creating improved running conditions for the ship engine.

This object is solved by a propulsion system for a vessel as defined in claim 1, or alternatively by a propulsion system for a vessel as defined in claim 6. Further alternatively, the above object is solved by a method as defined in claim 11 or alternatively by a method as defined in claim 16.

5

In detail, according to a first aspect of the present invention, a propulsion system for a vessel is provided, the propulsion system comprising

at least two generator sets, each including an prime mover and a generator,

10 an electric propulsion unit and
an energy storage,

a main switchboard by which the at least two generator sets, the electric propulsion unit and the energy storage are connected to each other, and

15 a controller for controlling the propulsion system, wherein
the controller is configured to cause storing excess electrical power in the energy storage when the generator produces electric power in excess for the instantaneous needs of the vessel, and taking needed additional energy from the energy storage for the use of the ship
20 electricity network when the electric generator produces electric power instantaneously insufficiently, and

to operate the generator of one of the two generator sets as a phase compensator for supplying reactive power to the propulsion system.

25

According to a second aspect of the present invention, a propulsion system for a vessel is provided, the propulsion system comprising

at least one generator set including an prime mover and a generator,

30 an electric propulsion unit and
an energy storage,

a main switchboard by which the generator set, the electric propulsion unit and the energy storage are connected to each other, and

a controller for controlling the propulsion system, wherein
a transmission is provided between the prime mover and the
generator, and

- the controller is configured to
- 5 adjust the rotational speed of the prime mover of the at least one
generator set based on the electric power consumption and
to operate the transmission such that the speed of the generator is
kept constant.

- 10 According to a third aspect of the present invention, a method for
controlling a propulsion system for a vessel is provided, the propulsion
system comprising at least two generator sets, each including an prime
mover and a generator, an electric propulsion unit, an energy storage,
and a main switchboard by which the at least two generator sets, the
15 electric propulsion unit and the energy storage are connected to each
other, the method comprising

storing excess electrical power in the energy storage when the
generator produces electric power in excess for the instantaneous needs
of the vessel,

- 20 taking needed additional energy from the energy storage for the
use of the ship electricity network when the electric generator produces
electric power instantaneously insufficiently, and

- operating the generator of one of the two generator sets as a
phase compensator for supplying reactive power to the propulsion
25 system.

- According to a fourth aspect of the present invention, a method for
controlling a propulsion system for a vessel is provided, the propulsion
system comprising at least one generator set including an prime mover
30 and a generator, an electric propulsion unit, an energy storage, and a
main switchboard by which the generator set, the electric propulsion unit
and the energy storage are connected to each other, the method
comprising

adjusting the rotational speed of the prime mover of the at least one generator set based on the electric power consumption and

operating a transmission provided between the prime mover and the generator such that the speed of the generator is kept constant.

5

Advantageous developments are set out in the dependent claims.

Thus, invention improves the fuel efficiency of the ship by keeping the engine fuel consumption optimal in relationship to the electricity
10 production of a genset (engine and electric generator) by means of storing excessive energy in an energy storage and releasing it from there when the energy consumption is higher than optimal electricity production capacity of the genset, wherein one electric generator is used as a phase compensator (first embodiment), or by means of adjusting
15 the rotational speed of the engine of the genset following the electric power consumption and at the same time keeping the generator speed constant (second embodiment).

The first embodiment includes the use of an energy storage into which
20 the excess electric energy is charged and from which the charged electric energy is released according to the need of a ship power network in a manner which lowers the engine load fluctuation and improves thereby the fuel efficiency of the engine.

25 The second embodiment of the invention includes the use of a mechanical or electrical transmission between the engine and generator or propulsion shaft in order to enable the engine to run at lower than nominal speed when the energy need of the ship propulsion system or ship electrical network is lower than the nominal power of the engine and thereby allow
30 the engine to run in higher fuel efficiency rate and at the same time keep the generator speed constant to produce the electricity in the nominal ship network frequency.

SHORT DESCRIPTION OF THE DRAWINGS

In the following, embodiments of the invention are described by referring to the attached drawings, in which:

5

Fig. 1 shows an overview over a propulsion system for a vessel according to a first embodiment of the present invention,

Fig. 2 shows a modified propulsion unit of the propulsion system
10 according to the first embodiment of the present invention, and

Fig. 3 shows a controller according to the first embodiment,

Fig. 4 shows a modified example for a propulsion system according to the
15 second embodiment of the present invention

DETAILED DESCRIPTION OF THE EMBODIMENTS OF INVENTION

First Embodiment

20

In the following, a general overview over the first embodiment is given.

In particular, according to the first embodiment, an energy-storage assisted engine fuel efficiency improvement method and system is
25 provided as follows:

The engine fuel efficiency improvement method and system include the periodical or irregular balancing of ship network electrical power by

- storing excess electrical power in an energy storage such as a
30 supercapacitor or a secondary battery when the generator produces electric power in excess for the instantaneous needs of the ship,

- taking needed additional energy from the energy storage for the use of the ship electricity network when the electric generator produces electric power instantaneously insufficiently, and
- operating the generator of one of the two generator sets as a phase compensator for supplying reactive power to the propulsion system.

A general example for a propulsion system according to the first embodiment of the present invention is in the following:

- 10 The propulsion system for a vessel according to this example for the present embodiment comprises at least two generator sets, each including an prime mover and a generator, an electric propulsion unit and an energy storage, a main switchboard by which the at least two generator sets, the electric propulsion unit and the energy storage are
- 15 connected to each other, and a controller for controlling the propulsion system. The controller carries out the functions as described above.

- In the following, some examples are described by referring to Fig. 1, which shows a propulsion system for a vessel according to the first
- 20 embodiment. This system comprises generator sets comprising of internal combustion engines 1.1 to 1.4 (as examples for a prime mover) and generators 9.1 to 9.4. In each of the generators sets, the internal combustion engine is connected with the generator by a clutch 9.1 to 9.4. The generators are connected with a main switchboard 7 which consists
- 25 of busses A1, A2, B1 and B2. In this example, the main switchboard may operate with 690 V and 60 Hz. The busses A1 and A2 on the one hand and the busses B1 and B2 on the other hand may be connected or disconnected via a bus link 10. Furthermore, batteries 4.1 and 4.2 are connected via inverters 5.1 and 5.2 with the main switchboard 7. In
- 30 addition, propulsion units 3.1 to 3.4 (comprising an electric motor and a propeller connected thereto via a transmission or a clutch) are connected to the main switchboard 7 via inverters 8.1 to 8.4. In this example, the propulsion units 3.2 and 3.3 are main propulsion thrusters operating with

up to 2300 kW, whereas the propulsion units 3.1 and 3.4 operate with up to 1100 kW. It is noted that all connections of the above elements are realized via switches, as shown in the drawing.

5 Fig. 1 shows some additional elements provided in such a system, for example further busses, shore connections and the like. For example, transformers 12 (1600 kVA) are provided for the busses A1 and A2, and for the busses B1 and B2, via which further busses A3, A4, B3 and B4 operating on different voltages are connected. The busses A3 and B3
10 may operate on 450 V, whereas the busses A4 and B4 operate on 230 V. The busses A3 and A4 and the busses B3 and B4 are be connected via transformers 13 (99kVA). With the busses, several feeders 11 may be connected. Moreover, in this example a shore connection 16 is provided at the bus A3. A further bus A5 (operating on 440 V) is connected to bus
15 A3. To this bus, a generator set 15 comprising an engine and a generator is connected, this generator being an emergency generator (Em Gen), and a further bus A6 (operating on 230 V) is connected to the bus A5 via two transformers 14 (operating with 50 kVA each). Moreover, the busses A3 and B3, and also the busses A4 and B4 are connectable.

20

Example 1 - Battery assisted no-break system to be used in DP (Dynamic Positioning) vessels (Fig. 1)

A multi engine DP vessel is operated in DP (Dynamic Position) mode by
25 one engine running in parallel with a de-clutched generator and one or more energy-storage/active-rectifier assemblies. The active rectifier includes a AC-DC/DC-AC converter receiving electric energy from the power network in network voltage and frequency and providing it back from the energy storage to power the power network in the network
30 voltage and frequency. During shutdown of the engine, the energy storage provides necessary power to the consumers while the de-clutched generator controls the voltage, the kVAr dynamic and provides the necessary short circuit current.

Example 2 - Island Mode, active rectifier and rotating synchronous generator (Fig. 2)

5 Setup:

Engine has nominal fuel efficiency of about 50%, propeller is attached to it through a mechanical gearbox or directly on the shaft. When engine rpm and load stay steady, the fuel efficiency stays at a very high level.

10 Problem:

A ship going through waves generates almost sinusoidal load variation to the propulsion system which alters around the nominal load in calm sea. The engine fuel efficiency lowers very drastically when the load alters from the nominal load, which increases the actual fuel need from the
15 nominal significantly.

Solution:

When the engine load caused by the propeller is lowered under the nominal steady load level, the engine is additionally loaded by charging of
20 a fast chargeable energy storage such as a supercapacitor (designated with "ACTIVE POWER" in Fig. 2) by a generator coupled with the engine shaft. When the engine load from the propulsion reaches the level above the nominal load, the engine is supported by releasing the power from the energy storage resulting that the load of the engine remains steady
25 and the fuel efficiency as well.

In more detail, Fig. 2 shows an example for a propulsion unit according to this example of the first embodiment. As shown, the propulsion unit differs from the propulsion unit 3.2 in Fig. 1 in that not only an electric
30 motor 22 (which is in this case a generator/motor unit) is coupled to the propeller (main propulsion thruster), but also an engine 21, and the engine and the motor may be coupled with the propeller 24 via a two-speed clutch 23. In this way, the generator/motor can support the

engine, but, in addition, due to the generator function of the generator/motor, also electric power can be generated in case only small propulsion power is needed. The remaining elements shown in Fig. 2 are similar to those shown in Fig. 1.

5

The generator can be coupled to the propulsion system by a gearbox or it can be of the type shaft generator/motor located on the propeller shaft or on the engine connected to the crankshaft.

10 The generator can also be used to produce continuously current for the ship power network. In this case the power output of the generator is altered so that it results again for even the load to the propulsion engine of the ship.

15 An Island Mode (i.e., in which the vessel produces its own propulsion power without a shore connection) can be realised by:

- variable frequency generator (maybe shaft or gear mounted)
- Active rectifier - DC link and inverter
- generator-clutch-engine assembly

20 - main switchboard

- power management functionality

The electric consumers are supplied from the main switchboard, wherein active power is supplied from the active rectifier while reactive power,
25 kVAr dynamics and short circuit current are supplied from the de-clutched generator. Main switchboard is operating constant voltage and constant frequency.

In the following, the measures according to the first embodiment are
30 described in some more detail mainly by referring to Figs. 1 and 3.

The system according to the first embodiment comprises the following components: an inverter system supplying the vessel main grid (i.e., the

main switchboard), a battery system, rotating phase compensator and a fuelled generating set for permanent power supply system.

1. Inverter system supplying the vessel main grid

5

This inverter system is designed for supplying needed power to the grid consumers, and is designed for parallel operation with diesel or dual fuel generation sets and/or a rotating phase compensation system (de-clutched generator set).

10

The inverter system is supplied from a battery source including a rectifier for battery charging. An example for the inverter system is the AC-DC/DC-AC converter 5.1 or 5.2 shown in Fig. 1.

15 2. Battery system

The battery system is designed for the defined operational modes, both with respect to power(kW) and capacity (kWh). The battery is connected to the DC link of the system. The battery power and capacity must be
20 designed according to required propulsion needs and other consumption needs for the time it takes to reconnect one of the stand-by generator sets after a failure of the generator set in operation.

An example for the battery system is shown in Fig. 1 as the battery 4.1
25 or 4.2. Alternatively, instead (or in addition to) the battery, a supercapacitor may be applied.

3. Rotating phase compensation

30 A rotating phase compensation system (generator) is designed to fulfill the need for reactive power in the system (kVAr) voltage stability, dynamic need for kVAr during transient conditions (DOL (direct on line) starts, other load appliances, transformer inrushes) and main short-

circuit current contribution. The generator may be declutched from the main engine during this operation.

In Fig. 1, each of the four generator sets shown on top of the drawing,
5 connected to the buses A1 to B2 (main switchboard), may be used as the rotating phase compensation system. Between the engine 1.1, 1.2, 1.3, 1.4 and the corresponding generator 2.1, 2.2, 2.3, 2.4 of each genset a clutch 9.1, 9.2, 9.3, 9.4 is provided. Thus, one (or more) of the genset may be operated as the rotating phase compensation system (rotation
10 phase compensator) by opening the clutch (declutching) between the engine and the generator of the corresponding generator set. For example, when in Fig. 1 the generator 2.1 is applied as the rotating phase compensator, the clutch 9.1 between the engine 1.1 and the generator 2.1 would be opened, so that the generator 2.1 is de-clutched
15 from the engine 1.1.

However, alternatively, the clutch between the generator and the engine may be omitted and the generator may be operated with a switched off engine.

20

4. Fuelled Generating Set for permanent power supply

As a minimum, one generator set must be in operation to supply the needed power over time and to keep the batteries charged. At a failure of
25 this genset, the battery will supply the needed power in parallel with the rotating phase compensator until the standby genset has connected.

For example, in the arrangement of Fig. 1, the generator set consisting of the engine 1.3 and the generator 2.3 may be used for supplying the
30 needed power. The generator set, which supplies power, may also be referred to as power supplying generator set.

In the following, main functionality and modes of operation according to the first embodiment are described. The control functions may be carried out by a controller 20 as shown in Fig. 3. The controller receives various detection signals from various sensors (not shown) (e.g., engine speeds, motor speeds, voltage and current measurements etc.) and supplies control signals to the different units and switches in the propulsion system such as the generator sets, inverters etc. The controller itself may be a computer including CPU, ROM, RAM and the like. Moreover, the controller may consist of different units, e.g., power management may be performed by one unit, and control of the propulsion units may be performed by another unit.

First, low power operations are described (DP low, Harbour mode, low steaming, standby)

15

As mentioned above, a minimum of one system as described above needs to be in operation:

- One set of fuelled genset
- One set of rotating phase compensator (declutched genset for reactive power needs)
- One set of Battery supplied inverter system of suitable power.

20

For example, in the system of Fig. 1, the generator set consisting of the engine 1.1 and the generator 2.1 may be used as the rotation phase compensator (i.e., the generator 2.1 is declutched from the engine 1.1), and the generator set consisting of the engine 1.3 and the generator 2.3 is used for power supply, wherein the inverter 5.1 and the battery 4.1 are in operation.

25

Thus, normal operation during a low power demand is as follows:

30

- One genset supplies required power to all consumers (closed bus tie). That is, in this example the buslink 10 (consisting of suitable switches) is closed, so that the main switchboard (consisting of 690V/60

Hz busses A1, A2, B1 and B2 is fully connected, thereby achieving a closed bus tie.

· One inverter system connected to the other side of the bus tie is in operation. That is, in the example for Fig. 1, when the generator 2.1 is used as the rotation phase compensator, the inverter system 5.2 is in operation, whereas the inverter system 5.1 is out of operation.

· The highest possible load (constant load) is applied on the connected genset, and thereby the best efficiency is achieved.

· Constant load on genset is provided by using the inverter system for peak shaving and thereby improving efficiency.

· The batteries will be charged when required (Peakshaving). Thus the genset may be loaded to a higher power than in traditional power generation system, before the standby generator is connected.

· The declutched genset is operating as the rotation phase compensator, as described above. The power factor seen by the active genset (i.e., the genset by which power is generated) may be adjusted to 1.0. That is, the declutched genset (e.g., the generator 2.1) is operated such that, by considering the total load on the main switchboard (busses A1 to B2) for the active genset (e.g., engine 1.2 and generator 2.2) the power factor is 1.0, thus increasing the generator (2.2) efficiency. The power factor 1.0 is achieved by adjustment of the supply of the reactive power to the network from the de-clutched generator.

· Required redundancy in fault situations on the power generating segment is obtained by the battery assisted inverter and phase compensator still running on a different segment. For example, when a genset on bus B2 (e.g., engine 1.3 and generator 2.3) in Fig. 1) generates power and a failure occurs in this segment (i.e., in bus B2), a

genset on bus A1 (e.g., generator 2.1 in Fig. 1) could still provide the phase compensation, also battery (4.1) and inverter (5.1) to be in operation when the bus link 10 (bus tie) is opened.

5 · The battery will have required energy to support necessary load until the standby genset is connected.

10 · In combination with the switchboard segment protection, a 75 % redundancy can be obtained e.g. in the LLC (Low Loss Concept – a diesel electric propulsion system by Wartsila) system – meaning all propellers in operation and 75% remaining power after a busbar or genset failure. That is, in the example of Fig. 3.1., four segments are provided, namely, busses A1, A2, B1 and B2. When a failure occurs in bus B2 (e.g., due to a failure in genset consisting of the engine 1.3 and the generator 2.3), this
15 bus B2 will be isolated, and by means of the switches, the propulsion units consisting of the electric motors 3.3 and 3.4 and speed controls 8.3 and 8.4, are still be connected to another segment, e.g., bus B1.

In the following, normal operation with high power demand is described.

20

· Several gensets supply required power to all consumers (closed or open bus tie). For example, in the system of Fig. 1, the gensets consisting of the engines 1.2, 1.3 and 1.4 and the generators 2.2, 2.3 and 2.4 may be in operation.

25

· One or more inverter systems are connected to the other side of the bus tie in operation. That is, in the example of Fig. 4, both inverters 5.1 and 5.2 may be in operation.

30 · The highest possible load (Constant load) is set on connected genset(s), and thereby the best efficiency is achieved.

- Constant load on genset by using the Inverter system for peak shaving and thereby improving efficiency.

- The batteries will be charged when required (Peakshaving). Thus
5 the genset may be loaded to a higher power than in traditional power generation system, before the standby generator is connected.

- The declutched genset is operating as a phase compensator. The power factor seen by the engine driven generator may be adjusted to
10 1.0, as described above.

- Required Redundancy in fault situations on the power generating segment is obtained by the battery assisted inverter and phase compensator still running on the same or different segment.
15

- The battery will have required energy to support necessary load until the standby genset is connected.

- In combination with the switchboard segment protection, a 75 %
20 redundancy can be obtained in the LLC system – meaning all propellers in operation and 75% remaining power after a busbar or genset failure.

In the following, failure modes are described, wherein a bus bar failure on starboard or port side is considered.

25

If a bus bar failure occurs, the affected segment will be isolated and leave the remaining healthy system in operation.

If the failure is on the side where the engine driven genset is operating,
30 the Inverter system will supply required power to the system after disconnection of the faulty segment. The controller (the PMS (power management system) will limit the propulsion power to the available battery capacity until the standby genset has connected.

The standby genset may be the declutched generator set which will be in operation a few seconds after the failure since the generator is already synchronized.

5

Hence, according to the first embodiment, a reliable and fuel-efficient power supply for a propulsion system for a vessel is achieved.

10 Second Embodiment

In the following, a second embodiment of the present invention is described by referring to Fig. 4. A main difference to the first embodiment is that between the generator and the prime mover in some or more gensets, a transmission is provided.

15

Thus, according to a general example for the second embodiment, a propulsion system for a vessel comprises at least one generator set including an prime mover and a generator, an electric propulsion unit an energy storage, a main switchboard by which the generator set, the electric propulsion unit and the energy storage are connected to each other, and a controller for controlling the propulsion system. Moreover, between the prime mover and the generator, a transmission is provided. The controller adjusts the rotational speed of the prime mover of the at least one generator set based on the electric power consumption and operates the transmission such that the speed of the generator is kept constant.

20

25

That is, for example, when a constant AC frequency of 60 Hz is to be maintained, the generator has to be driven by corresponding constant speed. Depending on the load, this could mean for the prime mover to operate at an inefficient operation point. Hence, the transmission can be operated such that the prime mover is operated at a high-efficient

30

operation point, and the generator can still be driven with the necessary constant speed.

5 In the following, the measures according to the second embodiment are described in more detail by referring to the example shown in Fig. 4. The functions according to the second embodiment may be carried out by a controller similar as the controller 20 shown in Fig. 3.

10 In this example, a 2 Speed Gearbox is used, i.e., a transmission providing two different transmission ratios (Fig. 4).

Fig. 4 shows a propulsion system for a vessel similar to that as shown in Fig. 1, wherein in some of the gensets, the clutch shown in Fig. 1 is replaced by a two-speed gear. In more detail, between the engine 1.1 and the generator 2.1, now a two-speed gear 6.1 is provided, and
15 between the engine 1.4 and the generator 2.4, now a two-speed gear 6.4 is provided. The two-speed gear may also include a clutch. In this specific example, the clutches 9.2 and 9.3 are provided between the engines 1.2 and 1.3 and the corresponding generators 2.2 and 2.3, similar as shown
20 in Fig. 1.

The second embodiment is related to the following problem:

Genset fuel efficiency is at its peak when the load and rpm are both at
25 design output and speed. The generator rpm is set to be producing a constant frequency for the network, for example 60Hz (can be anything else selected for the network). The generator has to rotate at constant speed. When the power requirement of the genset is lower the engine fuel amount has to be lowered which results in the combustion process to
30 be transferred from the optimised state, which means lower fuel efficiency for producing a certain kWh.

A possible solution could be as follows:

Speed of the engine can be altered to match the amount of shaft power (kW) needed, which results also in better fuel efficiency at lower rpm. In conventional gensets this results also in a lower frequency of the produced AC (alternating current), which has to be compensated by converting the frequency of the current in a converter unit, which again lowers the fuel efficiency.

Hence, according to the present embodiment, the following solution is applied:

The genset includes a gearbox (e.g., two-speed gear 6.1 and 6.4 shown in Fig. 4) between the engine (e.g., a pressure or spark ignited medium speed engine) and the generator. The gearbox has at least two selectable transmission ratios: a first transmission ratio for the nominal electric power output and at least one second transmission ratio for the at least one second electric power output allowing the generator rpm to stay at the nominal speed producing the nominal frequency AC when the engine rpm is lowered to a speed at which the fuel efficiency is higher than at the combination of the first transmission ratio and a lowered power output.

Hence, according to the second embodiment, a fuel-efficient power supply for a propulsion system for a vessel is achieved.

The embodiments described above are only examples, and various modifications can be applied.

For example, the above-described embodiments may be combined. That is, the transmissions according to the second embodiment may be applied to the gensets according to the first embodiment, i.e., the clutch between the engine and the generator in some or all of the gensets may

be modified such that declutching and providing two (or more) transmission ratios is possible.

As a further example, in the arrangement shown in Fig. 4, no clutches
5 may be arranged between the engine 1.2 and the generator 2.2, and between the engine 1.3 and the generator 2.3, and the two-speed transmissions 6.1 and 6.4 may be maintained. In addition, one or more of the AC-DC/DC-AC converters 5.1 and 5.2 and energy storages 4.1 and 4.2 shown in Fig. 1 may be added to the arrangement shown in Fig. 4.

10

Furthermore, the specific arrangements of the propulsion system for a vessel as shown in Figs. 1, 2 and 4 are only examples, and arbitrary modifications are possible. For example, the main switchboard (e.g., the busses A1 to B2) is illustrated as an AC main switchboard. However, also
15 a DC main switchboard (DC busses) is possible, wherein the inverters would have to be correspondingly modified.

Moreover, in the above embodiments, a power of 60 Hz is used. However, it may be possible to apply variable engine speeds (similar as
20 in the second embodiment) according to a load demand, and to accept frequency of the power generated by the generators based on the variable engine speed within defined limits. That is, a power distribution system (i.e., the main switchboard and connected elements) may be designed such that it can accept the produced frequency (when the
25 generator is driven with a variable engine speed) within defined limits. For example, a frequency range from 47 Hz to 63 Hz may be acceptable.

LIST OF ABBREVIATIONS

30

DOL - Direct on line
DP - Dynamic positioning
LLC - Low Loss Concept

- PCS - Phase compensating system
- PMS - Power Management System
- PTI - Power Take In
- PTO - Power Take Out
- 5 SLD - Single Line Diagram

REFERENCE LIST

- 10 In the drawings, the following reference numbers are used:
 - 1 (1.1 to 1.4) Engine (e.g., diesel, gas, dual fuel engine or gas turbine)
 - 2 (2.1 to 2.4) Generator
 - 3 (3.1 to 3.4) Electric Motor
 - 4 (4.1 to 4.2) Energy storage (e.g., supercapacitor or secondary battery)
- 15 5 (5.1 to 5.2) AC-DC/DC-AC converter
 - 6 (6.1, 6.4) Gear box with clutch
 - 7 Main switchboard
 - 8 (8.1 to 8.4) Propeller rotational speed control
 - 9 (9.1 to 9.4) clutch
- 20 10 buslink
 - 11 feeders
 - 12, 13, 14 transformers
 - 15 generator set
 - 20 controller
- 25 21 engine
 - 22 motor/generator
 - 23 two-speed clutch
 - 24 propeller

CLAIMS

1. A propulsion system for a vessel comprising
at least two generator sets, each including an prime mover and a
5 generator,
an electric propulsion unit and
an energy storage,
a main switchboard by which the at least two generator sets, the
electric propulsion unit and the energy storage are connected to each
10 other, and
a controller for controlling the propulsion system, wherein
the controller is configured to cause storing excess electrical power
in the energy storage when the generator produces electric power in
excess for the instantaneous needs of the vessel, and taking needed
15 additional energy from the energy storage for the use of the ship
electricity network when the electric generator produces electric power
instantaneously insufficiently, and
to operate the generator of one of the two generator sets as a
phase compensator for supplying reactive power to the propulsion
20 system.
2. The system according to claim 1, wherein
the generator operated as a phase compensator is connected to
the prime mover via a clutch, and
25 the controller is configured to de-clutch the generator from the
prime mover when the generator is operated as the phase compensator.
3. The system according to claim 1 or 2, wherein
the main switchboard comprises switchboard segments connected
30 via switches for isolating a switchboard segment in case of a failure in
this segment.
4. The system according to claim 3, wherein

the electric propulsion unit is connectable to at least two switchboard segments via switches.

5. The system according to any one of the claims 2 to 4, wherein the
5 controller is configured,

when a failure occurs in the power supplying generator set, to re-clutch the generator operated as the phase compensator with its prime mover and to operate this generator set as a new power supplying generator set.

10

6. A propulsion system for a vessel comprising
at least one generator set including an prime mover and a generator,

an electric propulsion unit and

15 an energy storage,

a main switchboard by which the generator set, the electric propulsion unit and the energy storage are connected to each other, and
a controller for controlling the propulsion system, wherein

a transmission is provided between the prime mover and the
20 generator, and

the controller is configured to

adjust the rotational speed of the prime mover of the at least one generator set based on the electric power consumption and

to operate the transmission such that the speed of the generator is
25 kept constant.

7. The system according to claim 6, wherein

the transmission provides at least two transmission ratios and the controller is configured to adjust the rotational speed of the prime mover
30 and to select the transmission ratio of the transmission such that the prime mover operates in a high efficiency mode and the generator is driven with a constant speed.

8. The system according to any one of the claims 1 to 7, wherein
the controller is configured to provide variable engine speed
according to load demand and
to accept a frequency of the power generated by the generators
5 based on the variable engine speed within defined limits.
9. The system according to any one of the claims 1 to 8, wherein the
energy storage comprises a battery and/or a supercapacitor.
- 10 10. The system according to any one of the claims 1 to 9, wherein the
prime mover is an internal combustion engine.
11. A method for controlling a propulsion system for a vessel, the
propulsion system comprising at least two generator sets, each including
15 an prime mover and a generator, an electric propulsion unit, an energy
storage, and a main switchboard by which the at least two generator
sets, the electric propulsion unit and the energy storage are connected to
each other, the method comprising
storing excess electrical power in the energy storage when the
20 generator produces electric power in excess for the instantaneous needs
of the vessel,
taking needed additional energy from the energy storage for the
use of the ship electricity network when the electric generator produces
electric power instantaneously insufficiently, and
25 operating the generator of one of the two generator sets as a
phase compensator for supplying reactive power to the propulsion
system.
12. The method according to claim 11, wherein
30 the generator operated as a phase compensator is connected to
the prime mover via a clutch, the method further comprising
de-clutching the generator from the prime mover when the
generator is operated as the phase compensator.

13. The method according to claim 11 or 12, wherein
the main switchboard comprises switchboard segments connected
via switches, the method further comprising
- 5 isolating a switchboard segment in case of a failure in a segment
by operating the switches correspondingly.
14. The method according to claim 13, wherein
the electric propulsion unit is connectable to at least two
- 10 switchboard segments via switches.
15. The system according to any one of the claims 12 to 14, further
comprising,
when a failure occurs in the power supplying generator set, re-
- 15 clutching the generator operated as the phase compensator with its
prime mover and operating this generator set as a new power supplying
generator set.
16. A method for controlling a propulsion system for a vessel, the
- 20 propulsion system comprising at least one generator set including an
prime mover and a generator, an electric propulsion unit, an energy
storage, and a main switchboard by which the generator set, the electric
propulsion unit and the energy storage are connected to each other, the
method comprising
- 25 adjusting the rotational speed of the prime mover of the at least
one generator set based on the electric power consumption and
operating a transmission provided between the prime mover and
the generator such that the speed of the generator is kept constant.
- 30 17. The method according to claim 16, wherein
the transmission provides at least two transmission ratios and the
method further comprises

adjusting the rotational speed of the prime mover and selecting the transmission ratio of the transmission such that the prime mover operates in a high efficiency mode and the generator is driven with a constant speed.

5

18. The method according to any one of the claims 11 to 17, further comprising

providing variable engine speeds according to a load demand and

accepting a frequency of the power generated by the generators

10 based on the variable engine speed within defined limits.

19. The method according to any one of the claims 11 to 18, wherein the energy storage comprises a battery and/or a supercapacitor.

15 20. The method according to any one of the claims 11 to 19, wherein the prime mover is an internal combustion engine.

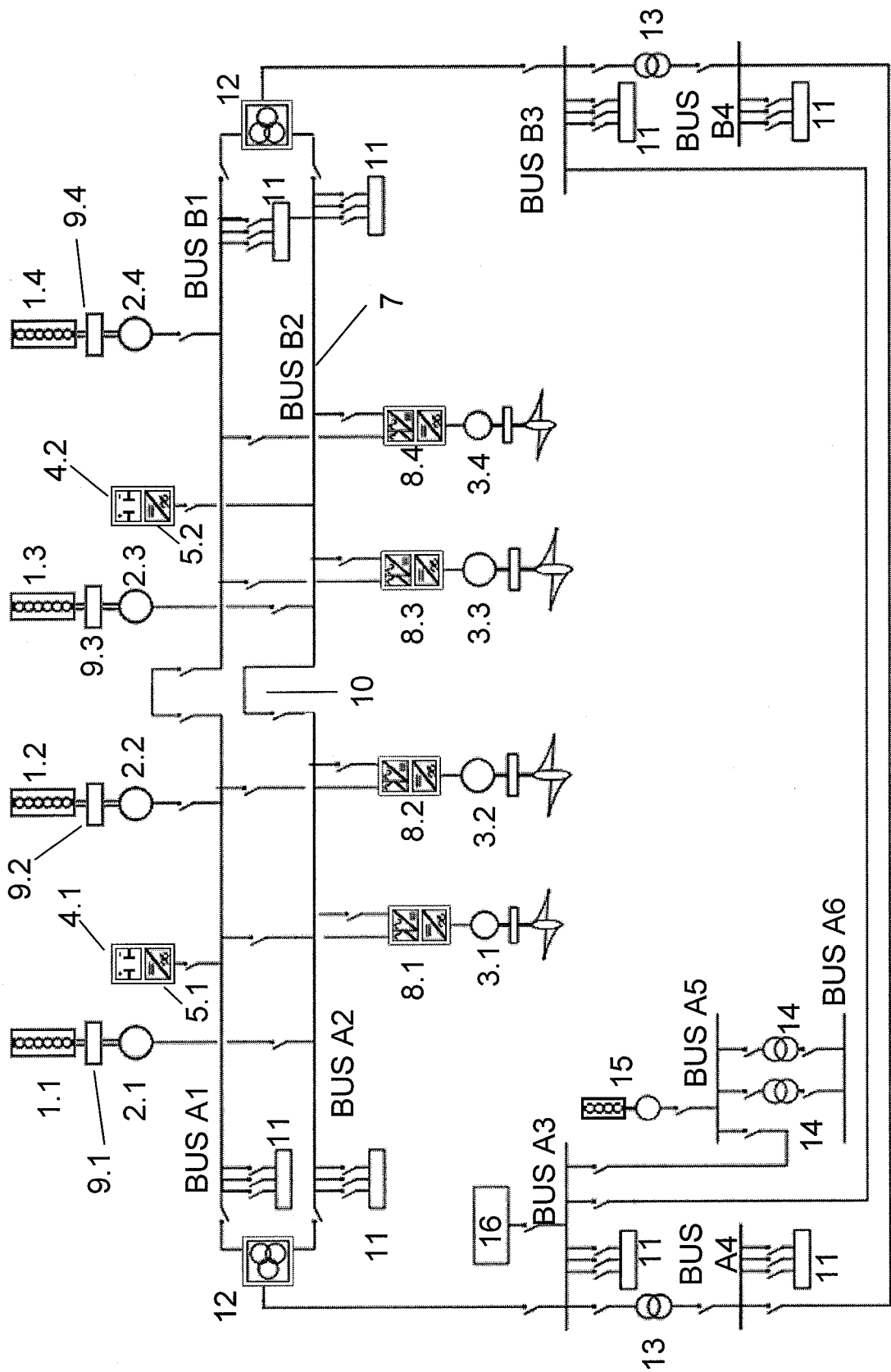


Fig. 1

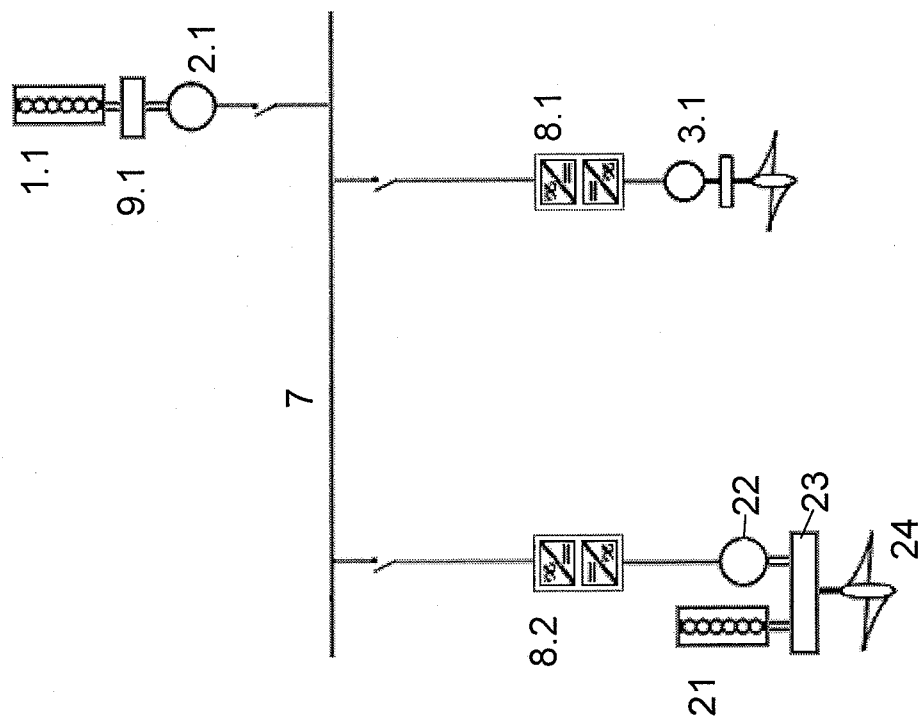


Fig. 2

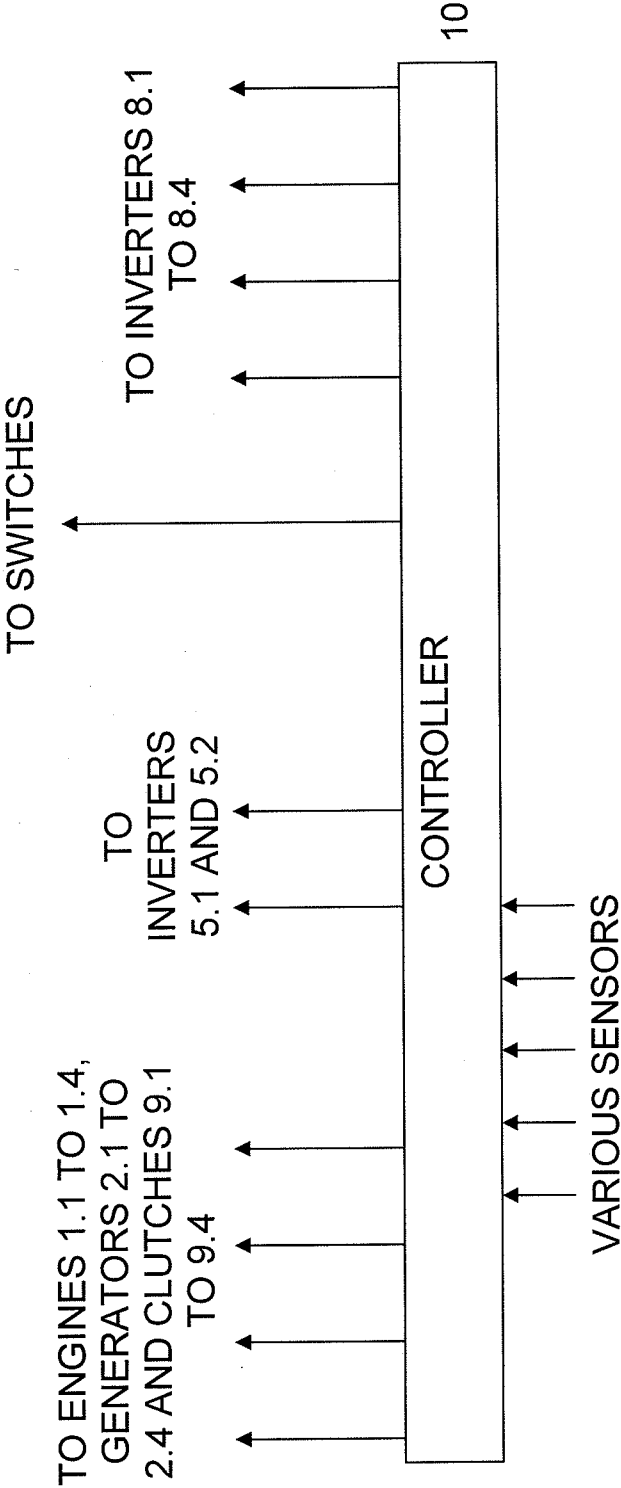


Fig. 3

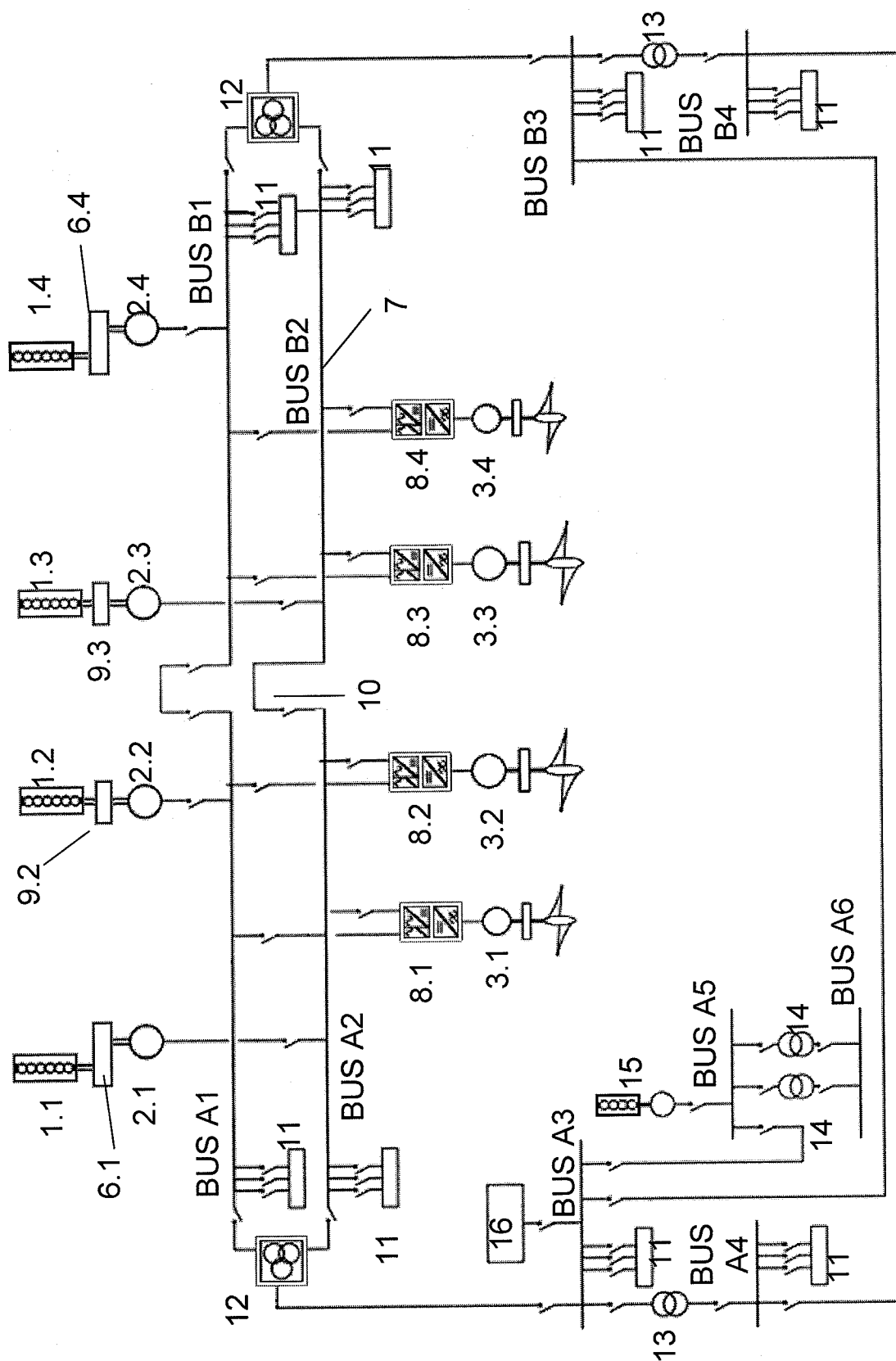


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2012/061994

A. CLASSIFICATION OF SUBJECT MATTER

INV. B63H21/17 B63H23/24 B63J3/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B63H B63J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RU 2 110 441 C1 (AROVA; G MORSKAJA AKADEMIJA IM ADM S) 10 May 1998 (1998-05-10)	1,2,5, 8-12,15, 18-20
Y	column 4, line 40 - line 65; figures	3,4,13, 14
Y	----- WO 2009/030807 A2 (WAERTSILAE FINLAND OY [FI]; LEVANDER OSKAR [FI]; SIPILAE TUOMAS [FI];) 12 March 2009 (2009-03-12) cited in the application	3,4,6,7, 13,14, 16,17
A	figures	1,11
Y	----- JP 61 102148 A (KANZAKI KOKYUKOKI MFG CO LTD) 20 May 1986 (1986-05-20) abstract	6,7,16, 17
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

5 November 2012

Date of mailing of the international search report

13/11/2012

Name and mailing address of the ISA/

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Goeman, Frits

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2012/061994

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RU 2 110 440 C1 (G MORSKAJA AKADEMIJA IM ADM S; AROVA) 10 May 1998 (1998-05-10) figures -----	1,2,5, 8-12,15, 18-20
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A	WO 2007/124968 A1 (SIEMENS AG [DE]; FROEHLICH HANS-JOACHIM [DE]; TIGGES KAY [DE]) 8 November 2007 (2007-11-08) the whole document -----	1,11
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A	EP 0 058 037 A2 (VICKERS SHIPBUILDING & ENG [GB]) 18 August 1982 (1982-08-18) abstract -----	6,16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2012/061994

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-5, 8-15, 18-20

to operate one of the generators as a phase compensator

2. claims: 6, 7, 16, 17

to operate the transmission such that the speed of the generator is constant

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2012/061994

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