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(54) MARINE PROPULSION SYSTEM

(57) The present disclosure relates to a marine propulsion system for a marine vessel, comprising an engine, a propeller unit having one or more propellers, a transmission arranged between the engine and the propeller unit, a clutch arrangement arranged in connection with the transmission, the clutch arrangement is configured to transfer power between the engine and the propeller unit, and an input unit, the input unit is configured to receive an input signal indicative of a propeller speed and to issue a propeller speed reference based on the input signal, wherein the propulsion system further comprises a control unit being operatively connected with the propeller unit, the clutch arrangement and the input unit, the control unit is configured to control the propulsion system based on propeller speed references during varying operations and/or speeds of the marine propulsion system.

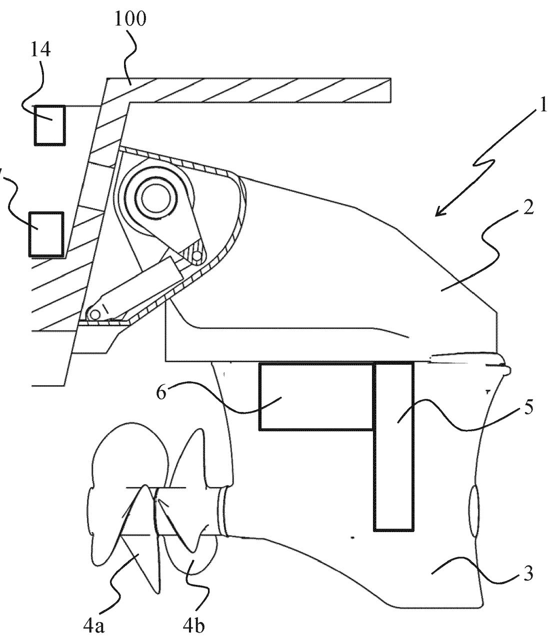

FIG. 1

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Description

TECHNICAL FIELD

[0001] The disclosure relates generally to a propulsion system. In particular aspects, the disclosure relates to a marine propulsion system for a marine vessel. The disclosure can be applied to marine vessels, such as water crafts, motorboats, work boats, sport vessels, boats, ships, among other vessel types. Although the disclosure may be described with respect to a particular marine vessel, the disclosure is not restricted to any particular marine vessel.

BACKGROUND

[0002] Marine propulsion systems for a marine vessel often have an engine providing torque to one or more propellers driving the marine vessel with different speeds. In addition some kind of transmission and a clutch are arranged for transferring power between the engine and the propellers. The main design criteria of the clutch are to be able to transfer maximum driveline torque without slippage of the clutch.

[0003] However, most of the time driving the marine vessel it is not in full speed which may have the consequence that during lower speed the transferred torque is only a fraction of maximum clutch capability. This may the consequence that the control of the transfer of torque at lower speeds is performing poorly

SUMMARY

[0004] According to a first aspect of the disclosure, a marine propulsion system for a marine vessel, comprising

an engine,
a propeller unit having one or more propellers,
a transmission arranged between the engine and the propeller unit,
a clutch arrangement arranged in connection with the transmission, the clutch arrangement is configured to transfer power between the engine and the propeller unit, and
an input unit, the input unit is configured to receive an input signal indicative of a propeller speed and to issue a propeller speed reference based on the input signal,
wherein the propulsion system further comprises a control unit being operatively connected with the propeller unit, the clutch arrangement and the input unit, the control unit is configured to control the propulsion system based on propeller speed references during varying operations and/or speeds of the marine propulsion system. The first aspect of the disclosure may seek to provide improved control from low speed to full speed of the marine vessel and thereby to improve slip control performance. A technical benefit may include that a higher degree of control of the propulsion system is obtained independently of variation of the speed of the marine vessel. The robustness of the clutch slip control has been increased and at the same time slip-stick behavior of the clutch near full clutch engagement has been minimized.

[0005] Optionally in some examples, including in at least one preferred example, the control unit further comprises a propeller speed controller, the propeller speed controller is configured to control the propeller speed on basis of the propeller speed references. A technical benefit may include that the propeller speed may be controlled so that the intended propeller speed is obtained.

[0006] Optionally in some examples, including in at least one preferred example, the clutch arrangement comprises a clutch plate and a clutch piston, the clutch piston being activated by at least one hydraulic area so as to provide an actuation pressure on the clutch plate. A technical benefit may include that it is ensured that the intended power between the engine and the propeller unit may be provided.

[0007] Optionally in some examples, including in at least one preferred example, the clutch arrangement has a predetermined actuation pressure, the predetermined actuation pressure is a reference pressure. A technical benefit may include that it is ensured that the intended power between the engine and the propeller unit may be provided.

[0008] Optionally in some examples, including in at least one preferred example, the clutch arrangement comprises one or more pressure sensor(s), the pressure sensor being configured to detect and/or measure an actuation pressure of the clutch arrangement. A technical benefit may include that the actuation pressure may continuously be detected and/or measured.

[0009] Optionally in some examples, including in at least one preferred example, the control unit comprises an actuation pressure controller, the actuation controller is configured to control the actuation pressure on basis of the reference pressure and/or the measured actuation pressure. A technical benefit may include that it is ensured that the intended power between the engine and the propeller unit may be provided.

[0010] Optionally in some examples, including in at least one preferred example, the clutch piston is configured to be actuated by a first hydraulic area and/or a second hydraulic area. A technical benefit may include incorporating a first hydraulic area and a second hydraulic area which are configured to pressurize the clutch piston individually or together whereby the compressive forces on the clutch plate may be reduced which again increases resolution in the control pressure.

[0011] Optionally in some examples, including in at least one preferred example, the first hydraulic area is pressurized by an electrically controlled proportional pressure valve and the second hydraulic area is pressurized by an electrically controlled on/off valve. A technical benefit may include Furthermore, by incorporating an electrically controlled proportional pressure valve for controlling the pressure in the first hydraulic area and an electrically controlled on/off valve for controlling the pressure in the second hydraulic area a higher level of redundancy is obtained. In case of failure to of the electrically controlled proportional valve, the electrically controlled on/off valves can provide gear engagement independently of the status of the proportional valve. Furthermore, a higher level of reliability resulting in possible fuel savings is obtained. The electrical control of the on/off valve makes it possible to engage transmission or gear based on a degree of clutch slippage. Hence, the speed difference over the clutch arrangement may be used to decide if the electrically controlled on/off valve shall be opened or closed.

[0012] Optionally in some examples, including in at least one preferred example, the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve is/are controlled by a predetermined current, the predetermined current is a current reference. A technical benefit may include that a reference point is provided which may be used as a control parameter.

[0013] Optionally in some examples, including in at least one preferred example, the control unit comprises a current controller, the current controller is configured to closed-loop current control the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve on basis of the current reference. A technical benefit may include that it is ensured that the intended power between the engine and the propeller unit may be provided.

[0014] Optionally in some examples, including in at least one preferred example, the system further comprises an engine controller, the engine controller is configured to control an engine speed on basis of the propeller speed references. A technical benefit may include the engine speed may be controlled so that the intended propeller speed is obtained.

[0015] Optionally in some examples, including in at least one preferred example, the engine controller is configured to increase engine speed near full clutch engagement so that the clutch engagement is kept below where slip-stick behavior of the clutch disc may occur. A technical benefit may include that the risk for a slip-stick behavior of the clutch disc may be minimized.

[0016] Optionally in some examples, including in at least one preferred example, the control unit and the engine controller are operatively connected. A technical benefit may include that both the control unit and the engine controller is cooperating in providing the intended power between the engine and the propeller unit.

[0017] According to a second aspect of the disclosure, a marine vessel comprising a marine propulsion system of any of the preceding claims. The second aspect of the disclosure may seek to provide improved control from low speed to full speed of the marine vessel and thereby to improve slip control performance.

[0018] According to a third aspect of the disclosure, a method of controlling a marine propulsion system as describe above, comprising

providing a control unit being operatively connected with the propeller unit, the transmission and the clutch arrangement,
receiving an input from the input unit,
issuing a propeller speed reference based on the input,
controlling the propulsion system on basis on the propeller speed references during varying operations and/or speeds of the marine propulsion system. The third aspect of the disclosure may seek to provide improved control from low speed to full speed of the marine vessel and thereby to improve slip control performance.

[0019] The disclosed aspects, examples (including any preferred examples), and/or accompanying claims may be suitably combined with each other as would be apparent to anyone of ordinary skill in the art. Additional features and advantages are disclosed in the following description, claims, and drawings, and in part will be readily apparent therefrom to those skilled in the art or recognized by practicing the disclosure as described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Examples are described in more detail below with reference to the appended drawings.

FIG. 1 is an exemplary of a marine propulsion system according to an example.
FIG. 2 is an exemplary of a marine propulsion system according to another example.
FIG. 3 is an exemplary of a clutch arrangement according to an example.
FIG. 4 is an overview of a control unit according to an example.
FIG. 5 is an example of a relationship between propeller speed and control signal.
FIG. 6 is an example of different operations of a low speed situation of the propulsion system.
FIG. 7 is an example of a marine vessel.
FIG. 8 is a schematic flowchart of an example of a method for controlling a propulsion system.
FIGS. 9-11 are schematic flow charts of the methods of controlling the different components of the propulsion system via the sub-controllers of the control unit.

DETAILED DESCRIPTION

[0021] The detailed description set forth below provides information and examples of the disclosed technology with sufficient detail to enable those skilled in the art to practice the disclosure.

[0022] Marine propulsion systems for a marine vessel with an engine providing torque to one or more propellers driving the marine vessel with different speeds, also have a transmission and a clutch for transferring power between the engine and the propellers. The main design criteria of the clutch are to be able to transfer maximum driveline torque without slippage of the clutch. Unintended slippage is a faulty condition in which there is not enough friction in the clutch whereby the clutch may fail to adequately engage or disengage the transmission. The consequence may be that propulsion system in these circumstances not are transferring the intended torque to drive the marine vessel.

[0023] However, most of the time driving the marine vessel it is not in full speed which may have the consequence that during lower speed the transferred torque is only a fraction of maximum clutch capability. This may the consequence that the control of the transfer of torque at lower speeds is performing poorly.

[0024] By incorporating an input unit configured to receive an input signal indicative of a propeller speed and to issue a propeller speed reference based on the input signal, and providing a control unit being operatively connected with the propeller unit, the clutch arrangement and the input unit, and controlling the propulsion system on basis of propeller speed references during varying operations and/or speeds of the marine propulsion system a higher robustness of the clutch slip control has been achieved, especially during low speed operations. Stable performance of the slip control is necessary, to be able to provide propeller speeds below idle speed of the engine. In this case continuous operation with clutch slippage is required. In addition, it is possible to minimize the slip-stick behavior of the clutch arrangement near full clutch engagement.

[0025] **FIG. 1** is an exemplary marine propulsion system **1** according to an example. The marine propulsion system **1** is configured to be comprised on a marine vessel **100.** The marine propulsion system **1** comprises an engine **2.** In the example of **FIG. 1,** the engine **2** may be an internal combustion engine. The combustion engine may be any type of internal combustion engine driven by e.g. diesel, gasoline, natural gas, hydrogen or any other combustible fuel. The marine propulsion system may also comprise a parallel hybrid driveline, so that one engine **2** and one or more electric motor(s) are sharing the load. In addition, the engine **2** may be provided outside the marine vessel **100** as an outboard engine **2.** In another example, the engine may be arranged on the marine vessel **100** as an inboard engine. Furthermore, the propulsion system **1** may comprise one engine or a plurality of engines.

[0026] The propulsion system **1** also comprises a propeller unit **3** comprising one or more propellers **4a, 4b.** In the example the propeller unit **3** has a first propeller **4a** and a second propeller **4b.** In other examples, the propeller unit may comprise one propeller or a plurality of propellers. If two or more propellers are arranged they may be arranged as counter-rotating propellers, for instance. The propulsion system **1** also comprises a transmission **5** arranged between the engine **2** and the propeller unit **3** to ensure that the intended rotation is provided to the propeller unit **3.** The transmission **5** may comprises one or more gear(s). In addition, a hydraulic clutch arrangement **6** is arranged. The clutch arrangement **6** is configured to control a power transfer between the engine **2** and the propeller unit **3.**

[0027] The propulsion system **1** also comprises an input unit **14,** the input unit **14** is configured to receive an input signal indicative of a propeller speed and to issue a propeller speed reference based on the input signal. The input signal may be activated by an operator or captain and/or is an automatically generated input signal from another unit. The input unit **14** may be a throttle lever, joystick, steering wheel or other devices for maneuvering the marine vessel **100.** In the present example the input unit **14** is arranged on the marine vessel **100.** The propeller speed reference is based on the received input signal indicating the intended propeller speed in a given circumstance and/or operation under nominal load conditions of the marine vessel **100.**

[0028] The propulsion system **1** further comprises a control unit 7 being operatively connected with the propeller unit **3,** the clutch arrangement **6** and the input unit **14,** the control unit **7** is configured to control the propulsion system **1** based on propeller speed references during varying operations and/or speeds of the marine propulsion system **1.** Hence, a higher robustness of the control of the propulsion system has been achieved under different speed conditions of the marine vessel **100.** In the example, the control unit **7** is arranged in the relation to the marine vessel, however, in other examples it may be arranged at the engine, the clutch arrangement or the propeller unit or in relation to other components of the propulsion system **1.**

[0029] In **FIG. 2,** an exemplary of a marine propulsion system **1** according to an example is shown. The propulsion system **1** has the engine **2,** the propeller unit **3** with one or more propellers. Furthermore, the transmission **5** is arranged between the engine **2** and the propeller unit **3** to ensure that the intended rotation is provided to the propeller unit **3.** The clutch arrangement **7** may comprise a clutch plate **8** and a clutch piston **9,** the clutch piston **9** being activated by at least one hydraulic area **24** so as to provide an actuation pressure on the clutch plate **8.** The at least one hydraulic area **24** may be pressurized by at least an electrically controlled valve **25.**

[0030] **FIG. 3** shows an example of the clutch arrangement **6.** The clutch arrangement **6** comprises the clutch plate **8.** In the example one clutch plate **8** is arranged. In other examples two or more clutch plates may be arranged in the clutch arrangement **6.** The clutch plate **8** is activated by the clutch piston **9.** According to the example, the clutch piston **9** is configured to be actuated by a first hydraulic area **10** and/or a second hydraulic area **11.** The first hydraulic area **10** is pressurized by the electrically controlled proportional pressure valve **12** and the second hydraulic area **11** is pressurized by the electrically controlled on/off valve **13,** and the control unit **7** is operatively connected with the electrically controlled proportional pressure valve **12** and the electrically controlled on/off valve **13.** In the example, a pump **15** is delivering a hydraulic fluid to the first hydraulic area **10** via the electrically controlled proportional pressure valve **12,** and the second hydraulic area **11** via the electrically controlled on/off valve **13,** respectively. A hydraulic tank **16** is arranged in fluid communication with the pump **15.** In addition, the input unit **14** is operatively connected with the control unit **7.**

[0031] The electrically controlled valve **25,** the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13** is/are controlled by a predetermined current, the predetermined current is a current reference.

[0032] Furthermore, a pressure sensor **17** is configured to measure an actuation pressure of the clutch arrangement **6.** In the example, the pressure sensor **17** is arranged in connection with the clutch piston **9.** In other examples, the pressure sensor **17** may be arranged in connection with other components of the clutch arrangement **6** for measuring and/or detecting the actuation pressure of the clutch arrangement. Also, a plurality of pressure sensors may be arranged for measuring and/or detecting the actuation pressure at different positions and at different components of the clutch arrangement **6.** The clutch arrangement **6** has a predetermined actuation pressure, the predetermined actuation pressure is a pressure reference.

[0033] Moreover, a shunt resistor **18** may be arranged in connection with the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13,** the shunt resistor **18** is configured to measure a control current with a mA accuracy. In the example shown in **FIG. 3** both the electrically controlled proportional pressure valve **12** and the electrically controlled on/off valve **13** have a shunt resistor **18.** The shunt resistor **18** is configured to communicate measured control current to the control unit **7.**

[0034] In **FIG. 4,** an overview of a control unit **7** according to an example is shown. In the example, the control unit **7** comprises different sub-controllers which may control different components of the propulsion system 1 independently or in common.

[0035] The control unit **7** may comprise a propeller speed controller **21,** the propeller speed controller **21** is configured to control the propeller speed on basis of the propeller speed references **200.** The propeller speed references **200** are received and issued from the input unit **14.** The actual propeller speed is detected at point **210** and is compared with the propeller speed references **200** in the propeller speed controller **21.** If a difference between the propeller speed reference **200** and the detected propeller speed at **210** is observed the propeller speed controller **21** will control the propeller speed accordingly so that the actual propeller speed at **210** will correspond to the propeller speed reference **200.** This may be provided with a closed-loop control. The propeller speed controller **21** comprises a feed-forward speed part **30.** Based on speed reference magnitude, the feed-forward speed part **30** roughly calculate the pressure needed to reach intended rpm, under nominal load conditions. The feed-back speed part of the propeller speed controller is intended to compensate for differences from nominal load conditions, due to current, fouling or dents on propeller(s), varying friction in transmission, etc.

[0036] The control unit **7** may also comprise an actuation pressure controller **20,** the actuation pressure controller **20** is configured to control the actuation pressure on basis of the pressure reference **201** and/or the measured actuation pressure. The one or more pressure sensors **17** are operatively connected with the actuation pressure controller **20.** The pressure sensor(s) **17** is/are configured to measure forward and/or reverse actuation pressure at point **211,** the measured actuation pressure **211** is used as feedback to the actuation pressure controller **20.** The actuation pressure controller **20** is configured to control the actuation pressure of the clutch arrangement **6** by a closed-loop control. The actual actuation pressure is detected at point **211** and is compared with the pressure reference **201** in the actuation propeller controller **20.** If a difference between the pressure reference **201** and the measured actuation pressure **211** is observed the actuation pressure controller **20** will control the actuation pressure accordingly so that the actual actuation pressure at **211** will correspond to the pressure reference **201.** The actuation pressure controller **20** comprises a feed-forward pressure part **31.** Based on pressure reference magnitude, the feed-forward pressure part **31** may calculate the current that shall be applied to one of the electrically controlled valves, such as for instance the proportional pressure valve, to obtain the intended pressure. These calculations may be based on stated current to pressure characteristics of the valves. The feed-back part of the actuation pressure controller is intended to compensate for differences from nominal valve characteristics due to variations in oil temperature, valve hysteresis, etc.

[0037] The control unit 7 may also comprise a current controller **19,** the current controller **19** is configured to closed-loop current control the electrically controlled valve **25,** the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13** on basis of the current reference **202.** The shunt resistors **18** may be arranged in connection with the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13,** the shunt resistor

18 is configured to measure a control current at point **212** with a mA accuracy. The current controller **19** is configured to closed-loop current control the electrically controlled valve **25,** the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13** on basis of the measured control current **212** and/or the current reference **202.** The actual control current is detected at point **212** and is compared with the current reference **202** in the current controller **19.** If a difference between the current reference **202** and the measured control current **212** is observed the current controller **19** will control the current accordingly so that the actual current at **212** will correspond to the current reference **202.** As mentioned previously, the current controller compensates for temperature variations in valve coils, and implements dithering to minimize hysteresis caused by stiction of a valve body.

[0038] The current controller **19** may have a control frequency of more than 500Hz, preferably more than 1kHz, more preferably more than 2kHz.

[0039] Moreover, the current controller **19** may be configured to implement dithering of current 200Hz/±10mA to minimize hysteresis of electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve.

[0040] The propulsion system **1** may further comprise an engine controller **40,** the engine controller **40** is configured to control an engine speed on basis of propeller speed references 200. The engine controller **40** is configured to increase engine speed near full clutch engagement so that the clutch engagement is kept below where slip-stick behavior of the clutch disc may occur. Furthermore, the engine controller **40** may be configured to reset engine speed to idle speed when the clutch is set for full engagement. The engine controller is a feed forward controller.

[0041] In addition, the engine controller **40** may be operatively connected with the input unit **14.** Also, the control unit **7** and the engine controller **40** may be operatively connected.

[0042] The current controller **19,** the actuation pressure controller **20,** the propeller speed controller **21** and/or the engine controller **40** may be operatively connected.

[0043] In **FIG. 5,** an example of a relationship between propeller speed (Y-axis) and control signal (X-axis) for a propulsion system according to the disclosure. The first curve **300** shows the increase and the second curve **301** shows the decrease. Near **100**% propeller speed is where the slip-stick (area **310**) of the clutch arrangement occur. In this area **310** the control unit has a high control frequency for avoiding or at least minimizing the risk for slip-stick.

[0044] In **FIG. 6,** an example of different operations of a low speed situation of the propulsion system **1. FIG. 6** show a low speed throttle request in relation to engine speed (rpm) and propeller speed (rpm). An increase of 100 rpm of idle speed results in clutch engagement of 85.7% maximum.

[0045] In **FIG. 7,** a marine vessel **100** is shown. The marine vessel **100** comprises the propulsion system **1** as described above. In the example shown in **FIG. 7,** the propeller unit **3** is configured to pull the marine vessel **100.** In another example the propeller unit may be configured to push the marine vessel. The engine **2** is an internal combustion engine arranged onboard the marine vessel **100.** The input unit **14** is in the example arranged at the operator's position on the marine vessel **100.**

[0046] **FIG. 8** shows a schematic flow chart of the method of controlling a marine propulsion system **1** as described above.

[0047] In step **500,** a control unit is being provided and is operatively connected with the propeller unit, the transmission and the clutch arrangement. In step **501,** an input signal is received from the input unit. In step **502,** a propeller speed reference is issued based on the input signal in step **501.** In step **503,** the propulsion system is controlled on basis on the propeller speed references during varying operations and/or speeds of the marine propulsion system.

[0048] **FIGS. 9-11** show schematic flow charts of the methods of controlling the different components of the propulsion system via the sub-controllers of the control unit **7.**

[0049] In **FIG. 9,** the schematic flow chart of the propeller speed controller is shown. In step **600,** the propeller speed reference is provided. In step **601,** the actual propeller speed is detected or measured. In step **602,** the actual propeller speed is compared with the propeller speed reference. If the actual propeller speed is substantial equal to the propeller speed reference it is continued to step **603.** If the actual propeller speed is different from the propeller speed reference it is continued to step **604** wherein the propeller speed is either increased or decreased in view of the propeller speed reference. Based on speed reference magnitude, the feed-forward speed part roughly calculate pressure needed to reach intended rpm, under nominal load conditions. The feed-forward speed part in step **600** feeds the calculated pressure to step **700.** The feed-back part is intended to compensate for differences from nominal load conditions, due to current, fouling or dents on propeller(s), varying friction of transmission, etc.

[0050] In **FIG. 10,** the schematic flow chart of the actuation pressure controller is shown. In step **700,** the actuation pressure reference is provided, for instance as described above. In step **701** the actual actuation pressure is detected or measured. In step **702,** the actual actuation pressure is compared with the actuation pressure reference. If the actual actuation pressure is substantial equal to the actuation pressure reference it is continued to step **703.** If the actual actuation pressure is different from the actuation pressure reference it is continued to step **704** wherein the actuation pressure is either increased or decreased in view of the actuation pressure reference. Based on pressure reference magnitude, the feed-forward pressure part calculate the current that shall be applied to the pressure valves to get the intended pressure. Calculation is based on stated current to pressure characteristics of valve. The feed-forward pressure part in step **700** feeds the calculated pressure to step **800.** The feed-back part is intended to compensate for differences from nominal valve characteristics due to variations in oil temperature, valve hysteresis, etc.

[0051] In **FIG. 11,** the schematic flow chart of the current controller is shown. In step **800,** the current reference is provided. In step **801,** the actual current is detected or measured. In step **802,** the actual current is compared with the current reference. If the actual current is substantial equal to the current reference it is continued to step **803.** If the actual current is different from the current reference it is continued to step **804** wherein the current is either increased or decreased in view of the current reference. As mentioned previously, the current controller compensates for temperature variations in valve coils, and implements dithering to minimize hysteresis caused by stiction of a valve body.

[0052] Certain aspects and variants of the disclosure are set forth in the following examples numbered consecutive below.

[0053] Example 1: A marine propulsion system (**1**) for a marine vessel, comprising

- an engine (**2**),
- a propeller unit (**3**) having one or more propellers (**4a, 4b**),
- a transmission (**5**) arranged between the engine and the propeller unit,
- a clutch arrangement (**6**) arranged in connection with the transmission, the clutch arrangement is configured to transfer power between the engine and the propeller unit, and
- an input unit (**14**), the input unit is configured to receive an input signal indicative of a propeller speed and to issue a propeller speed reference (**200**) based on the input signal, wherein the propulsion system (**1**) further comprises a control unit (**7**) being operatively connected with the propeller unit, the clutch arrangement and the input unit, the control unit is configured to control the propulsion system based on propeller speed references (**200**) during varying operations and/or speeds of the marine propulsion system.

[0054] Example 2: The marine propulsion system (**1**) of example 1, wherein the control unit (**7**) further comprises a propeller speed controller (**21**), the propeller speed controller is configured to control the propeller speed on basis of the propeller speed references (**200**).

[0055] Example 3: The marine propulsion system (**1**) of any of the preceding examples, wherein the clutch arrangement (**6**) comprises a clutch plate (**8**) and a clutch piston (**9**), the clutch piston (**9**) being activated by at least one hydraulic area so as to provide an actuation pressure on the clutch plate.

[0056] Example 4: The marine propulsion system (**1**) of example 3, wherein the clutch arrangement (**6**) has a predetermined actuation pressure, the predetermined actuation pressure is a pressure reference.

[0057] Example 5: The marine propulsion system (**1**) of any of the preceding examples, wherein the clutch arrangement (**6**) comprises one or more pressure sensor(s) (**17**), the pressure sensor being configured to detect and/or measure an actuation pressure of the clutch arrangement.

[0058] Example 6: The marine propulsion system (**1**) of example 5, wherein the control unit (**7**) comprises an actuation pressure controller (**20**), the actuation controller is configured to control the actuation pressure on basis of the reference pressure and/or the measured actuation pressure.

[0059] Example 7: The marine propulsion system (**1**) of example 5 and/or 6, wherein the one or more pressure sensors (**17**) are operatively connected with the actuation pressure controller (**20**).

[0060] Example 8: The marine propulsion system (**1**) of any of the examples 5 to 7, wherein the pressure sensor(s) (**17**) is/are configured to measure forward and/or reverse actuation pressure, the measured actuation pressure is used as feedback to the actuation pressure controller.

[0061] Example 9: The marine propulsion system (**1**) of any of the examples 6 to 8, wherein the actuation pressure controller (**20**) is configured to control the actuation pressure of the clutch arrangement by a closed-loop control.

[0062] Example 10: The marine propulsion system (**1**) of any of the examples 3 to 9, wherein the at least one hydraulic area (**24**) is pressurized by at least an electrically controlled valve (**25**).

[0063] Example 11: The marine propulsion system of any of the examples 3 to 10, wherein the clutch piston (**9**) is configured to be actuated by a first hydraulic area (**10**) and/or a second hydraulic area (**11**).

[0064] Example 12: The marine propulsion system (**1**) of example 11, wherein the first hydraulic area (**10**) is pressurized by an electrically controlled proportional pressure valve (**12**) and the second hydraulic area (**11**) is pressurized by an electrically controlled on/off valve (**13**).

[0065] Example 13: The marine propulsion system (**1**) of any of the examples 10 to 12, wherein the electrically controlled valve (**25**), the electrically controlled proportional pressure valve (**12**) and/or the electrically controlled on/off valve (**13**) is/are controlled by a predetermined current, the predetermined current is a current reference.

[0066] Example 14: The marine propulsion system (**1**) of example 13, wherein the control unit (**7**) comprises a current controller (**19**), the current controller is configured to closed-loop current control the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve on basis of the current reference.

[0067] Example 15: The marine propulsion system (**1**) of example 14, wherein the current controller (**19**) has a control frequency of more than 500Hz, preferably more than 1kHz, more preferably more than 2kHz.

[0068] Example 16: The marine propulsion system (**1**) of example 14 and/or 15, wherein the current controller (**19**) is configured to implement dithering of current 200Hz/±10mA to minimize hysteresis of electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve.

[0069] Example 17: The marine propulsion system (**1**) of any of the examples 10 to 16, wherein a shunt resistor (**18**) is arranged in connection with the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve, the shunt resistor (**18**) is configured to measure a control current with a mA accuracy.

[0070] Example 18: The marine propulsion system (**1**) of example 17, wherein the current controller (**19**) is configured to closed-loop current control the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve on basis of the measured control current and/or the current reference.

[0071] Example 19: The marine propulsion system (**1**) of any of the preceding examples, further comprising an engine controller (**40**), the engine controller is configured to control an engine speed on basis of an input of the operator.

[0072] Example 20: The marine propulsion system (**1**) of example 19, wherein the engine controller (**40**) is configured to increase engine speed near full clutch engagement so that the clutch engagement is kept below where slip-stick behavior of the clutch disc may occur.

[0073] Example 21: The marine propulsion system (**1**) of example 19 and/or 20, wherein the engine controller (**40**) is configured to reset engine speed to idle speed when the clutch is set for full engagement.

[0074] Example 22: The marine propulsion system (**1**) of any of the examples 19 to 21, wherein the engine controller (**40**) is a feed forward controller.

[0075] Example 23: The marine propulsion system (**1**) of any of the examples 19 to 22, wherein the engine controller (**40**) is operatively connected with the input unit (**14**).

[0076] Example 24: The marine propulsion system (**1**) of any of the examples 19 to 23, wherein the control unit (**7**) and the engine controller (**40**) are operatively connected.

[0077] Example 25: The marine propulsion system (**1**) of any of the examples 2 to 24, wherein the current controller (**19**), the actuation pressure controller (**20**), the propeller speed controller (**21**) and/or the engine controller (**40**) are operatively connected.

[0078] Example 26: The marine propulsion system (**1**) of any of the preceding examples, wherein the input signal is activated by an operator or captain and/or is an automatically generated input signal.

[0079] Example 27: The marine propulsion system (**1**) of any of the preceding examples, wherein the clutch arrangement (**6**) comprises a forward clutch unit and a reverse clutch unit.

[0080] Example 28: The marine propulsion system (**1**) of any of the preceding examples, wherein the propeller unit (**3**) is configured to pull the marine vessel (**100**) and/or is configured to push the marine vessel (**100**).

[0081] Example 29: The marine propulsion system (**1**) of any of the preceding examples, wherein the clutch arrangement (**6**) comprises a plurality of clutch plates (**8**).

[0082] Example 30: The marine propulsion system (**1**) of any of the preceding examples, further comprises an additional engine or engines.

[0083] Example 31: A marine vessel (**100**) comprising a marine propulsion system (**1**) of any of the preceding examples.

[0084] Example 32: A method of controlling a marine propulsion system (**1**) of any of the examples 1 to 30, comprising

providing a control unit (**7**) being operatively connected with the propeller unit (**3**), the transmission (**5**) and the clutch arrangement (**6**),
receiving an input signal from the input unit (**14**),
issuing a propeller speed reference (**200**) based on the input signal,
controlling the propulsion system (**1**) on basis on the propeller speed references (**200**) during varying operations and/or speeds of the marine propulsion system.

[0085] Example 33: The method of example 32, further comprising

providing a propeller speed controller (**21**),
controlling the propeller speed on basis of the propeller speed references (**200**).

[0086] Example 34: The method of example 32 and/or 33, further comprising setting and/or calculating a predetermined actuation pressure, the predetermined actuation pressure is a pressure reference.

[0087] Example 35: The method of any of the examples 32 to 34, further comprising measuring an actuation pressure of the clutch arrangement.

[0088] Example 36: The method of example 35, further comprising

providing an actuation pressure controller (**20**),
controlling the actuation pressure on basis of the reference pressure and/or the measured actuation pressure.

[0089] Example 37: The method of example 36, further comprising measuring forward and/or reverse actuation pressure,

applying the measured actuation pressure as feedback to the actuation pressure controller (**20**).

[0090] Example 38: The method of any of the examples 36 and/or 37, further comprising controlling the actuation pressure of the clutch arrangement by a closed-loop control.

[0091] Example 39: The method of any of the examples 32 to 38, further comprising pressurizing a hydraulic area by at least an electrically controlled valve, an electrically controlled proportional pressure valve and/or an electrically controlled on/off valve.

[0092] Example 40: The method of example 39, further comprising

determining and/or calculating a predetermined current, the predetermined current is a current reference,

providing a current controller (**19**),

controlling by a closed-loop current control the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve on basis of the current reference.

[0093] Example 41: The method of example 40, further comprising controlling with a control frequency of more than 500Hz, preferably more than 1kHz, more preferably more than 2kHz.

[0094] Example 42: The method of example 39 and/or 40, further comprising implementing dithering of current 200Hz/±10mA to minimize hysteresis of the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve.

[0095] Example 43: The method of any of the examples 39 to 42, further comprising providing a shunt resistor (**18**) in connection with the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve,

measuring a control current with a mA accuracy by the shunt resistor.

[0096] Example 44: The method of example 43, further comprising controlling by a closed-loop current control the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve on basis of the measured control current and/or the current reference.

[0097] Example 45: The method of any of the examples 32 to 44, further comprising providing an engine controller (**40**),

controlling an engine speed on basis of an input of the operator.

[0098] Example 46: The method of example 45, further comprising increasing engine speed near full clutch engagement so that the clutch engagement is kept below where slip-stick behavior of the clutch disc may occur.

[0099] Example 47: The method of example 45 and/or 46, further comprising resetting engine speed to idle speed when the clutch is set for full engagement.

[0100] The terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including" when used herein specify the presence of stated features, integers, actions, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, actions, steps, operations, elements, components, and/or groups thereof.

[0101] It will be understood that, although the terms first, second, etc., may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element without departing from the scope of the present disclosure.

[0102] Relative terms such as "below" or "above" or "upper" or "lower" or "horizontal" or "vertical" may be used herein to describe a relationship of one element to another element as illustrated in the Figures. It will be understood that these terms and those discussed above are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element, or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present.

[0103] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0104] It is to be understood that the present disclosure is not limited to the aspects described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the present disclosure and appended claims. In the drawings and specification, there have been disclosed aspects for purposes of illustration only and not for purposes of limitation, the scope of the disclosure being set forth in the following claims.

Claims

1. A marine propulsion system (**1**) for a marine vessel (**100**), comprising

- an engine (**2**),
- a propeller unit (**3**) having one or more propellers (**4a, 4b**),
- a transmission (**5**) arranged between the engine and the propeller unit,
- a clutch arrangement (**6**) arranged in connection with the transmission, the clutch arrangement is configured to transfer power between the engine and the propeller unit, and
- an input unit (**14**), the input unit is configured to receive an input signal indicative of a propeller speed and to issue a propeller speed reference (**200**) based on the input signal,

wherein the propulsion system further comprises a control unit (**7**) being operatively connected with the propeller unit, the clutch arrangement and the input unit, the control unit is configured to control the propulsion system based on propeller speed references (**200**) during varying operations and/or speeds of the marine propulsion system.

2. The marine propulsion system (**1**) of claim 1, wherein the control unit (**7**) further comprises a propeller speed controller (**21**), the propeller speed controller is configured to control the propeller speed on basis of the propeller speed references (**200**).

3. The marine propulsion system (**1**) of any of the preceding claims, wherein the clutch arrangement (**6**) comprises a clutch plate (**8**) and a clutch piston (**9**), the clutch piston being activated by at least one hydraulic area so as to provide an actuation pressure on the clutch plate.

4. The marine propulsion system (**1**) of claim 3, wherein the clutch arrangement (**6**) has a predetermined actuation pressure, the predetermined actuation pressure is a pressure reference (**201**).

5. The marine propulsion system (**1**) of any of the preceding claims, wherein the clutch arrangement (**6**) comprises one or more pressure sensor(s) (**17**), the pressure sensor being configured to detect and/or measure an actuation pressure (**211**) of the clutch arrangement.

6. The marine propulsion system (**1**) of claim 5, wherein the control unit (**7**) comprises an actuation pressure controller (**20**), the actuation pressure controller (**20**) is configured to control the actuation pressure on basis of the pressure reference (**201**) and/or the measured actuation pressure (**211**).

7. The marine propulsion system (**1**) of any of the claims 3 to 6, wherein the clutch piston (**9**) is configured to be actuated by a first hydraulic area (**10**) and/or a second hydraulic area (**11**).

8. The marine propulsion system (**1**) of claim 7, wherein the first hydraulic area (**10**) is pressurized by an electrically controlled proportional pressure valve (**12**) and the second hydraulic area (**11**) is pressurized by an electrically controlled on/off valve (**13**).

9. The marine propulsion system (**1**) of any of the claims 7 to 8, wherein an electrically controlled valve (**25**), the electrically controlled proportional pressure valve (**12**) and/or the electrically controlled on/off valve (**13**) is/are controlled by a predetermined current, the predetermined current is a current reference (**202**).

10. The marine propulsion system (**1**) of claim 9, wherein the control unit (**7**) comprises a current controller (**19**), the current controller is configured to closed-loop current control the electrically controlled valve (**25**), the electrically controlled proportional pressure valve (**12**) and/or the electrically controlled on/off valve (**13**) on basis of the current reference (**202**).

11. The marine propulsion system (**1**) of any of the preceding claims, further comprising an engine controller (**40**), the engine controller is configured to control an engine speed on basis of the propeller speed reference (**200**).

12. The marine propulsion system (**1**) of claim 11, wherein the engine controller (**40**) is configured to increase engine speed near full clutch engagement so that the clutch engagement is kept below where slip-stick behavior of the clutch disc may occur.

13. The marine propulsion system (**1**) of any of the claims 11 to 12, wherein the control unit (**7**) and the engine controller (**40**) are operatively connected.

14. A marine vessel (**100**) comprising a marine propulsion system (**1**) of any of the preceding claims.

15. A method of controlling a marine propulsion system (**1**) of any of the claims 1 to 13, comprising

providing a control unit (7) being operatively connected with the propeller unit, the transmission and the clutch arrangement,
receiving an input signal from the input unit (**14**),
issuing a propeller speed reference (**200**) based

on the input signal,
controlling the propulsion system (**1**) on basis on the propeller speed references (**200**) during varying operations and/or speeds of the marine propulsion system (**1**).

Amended claims in accordance with Rule 137(2) EPC.

1. A marine propulsion system (**1**) for a marine vessel (**100**), comprising

- an engine (**2**),
- a propeller unit (**3**) having one or more propellers (**4a, 4b**),
- a transmission (**5**) arranged between the engine and the propeller unit,
- a clutch arrangement (**6**) arranged in connection with the transmission, the clutch arrangement is configured to transfer power between the engine and the propeller unit, and
- an input unit (**14**), the input unit is configured to receive an input signal indicative of a propeller speed and to issue a propeller speed reference (**200**) based on the input signal, wherein the propulsion system further comprises a control unit (7) being operatively connected with the propeller unit, the clutch arrangement and the input unit, the control unit is configured to control the propulsion system based on propeller speed references (**200**) during varying operations and/or speeds of the marine propulsion system,

wherein the clutch arrangement (**6**) comprises a clutch plate (**8**) and a clutch piston (**9**), the clutch piston being activated by at least one hydraulic area so as to provide an actuation pressure on the clutch plate, the clutch arrangement (**6**) has a predetermined actuation pressure, the predetermined actuation pressure is a pressure reference (**201**),
wherein the clutch arrangement (**6**) comprises one or more pressure sensor(s) (**17**), the pressure sensor being configured to detect and/or measure an actuation pressure (**211**) of the clutch arrangement, the control unit (**7**) comprises an actuation pressure controller (**20**), the actuation pressure controller (**20**) is configured to control the actuation pressure on basis of the pressure reference (**201**) and/or the measured actuation pressure (**211**).

2. The marine propulsion system (**1**) of claim 1, wherein the control unit (**7**) further comprises a propeller speed controller (**21**), the propeller speed controller is configured to control the propeller speed on basis of the propeller speed references (**200**).

3. The marine propulsion system (1) of any preceding claims, wherein the one or more pressure sensors (17) are operatively connected with the actuation pressure controller (20).

4. The marine propulsion system (1) of any of the claims 1 to 3, wherein the pressure sensor(s) (17) is/are configured to measure forward and/or reverse actuation pressure, the measured actuation pressure is used as feedback to the actuation pressure controller.

5. The marine propulsion system (1) of any of the claims 3 to 4, wherein the actuation pressure controller (20) is configured to control the actuation pressure of the clutch arrangement by a closed-loop control.

6. The marine propulsion system (**1**) of any of the preceding claims, wherein the clutch piston (**9**) is configured to be actuated by a first hydraulic area (**10**) and/or a second hydraulic area (**11**).

7. The marine propulsion system (1) of claim 6, wherein the first hydraulic area (**10**) is pressurized by an electrically controlled proportional pressure valve (**12**) and the second hydraulic area (**11**) is pressurized by an electrically controlled on/off valve (**13**).

8. The marine propulsion system (**1**) of any of the claims 6 to 7, wherein an electrically controlled valve (**25**), the electrically controlled proportional pressure valve (**12**) and/or the electrically controlled on/off valve (**13**) is/are controlled by a predetermined current, the predetermined current is a current reference (**202**).

9. The marine propulsion system (**1**) of claim 8, wherein the control unit (**7**) comprises a current controller (**19**), the current controller is configured to closed-loop current control the electrically controlled valve (**25**), the electrically controlled proportional pressure valve (**12**) and/or the electrically controlled on/off valve (**13**) on basis of the current reference (**202**).

10. The marine propulsion system (1) of any of the claims 7 to 9, wherein a shunt resistor (18) is arranged in connection with the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve, the shunt resistor (18) is configured to measure a control current with a mA accuracy.

11. The marine propulsion system (**1**) of any of the preceding claims, further comprising an engine controller (**40**), the engine controller is configured to control an engine speed on basis of the propeller speed reference (**200**).

12. The marine propulsion system (**1**) of claim 11, wherein the engine controller (**40**) is configured to increase engine speed near full clutch engagement so that the clutch engagement is kept below where slip-stick behavior of the clutch disc may occur.

13. The marine propulsion system (**1**) of any of the claims 11 to 12, wherein the control unit (**7**) and the engine controller (**40**) are operatively connected.

14. A marine vessel (**100**) comprising a marine propulsion system (**1**) of any of the preceding claims.

15. A method of controlling a marine propulsion system (**1**) of any of the claims 1 to 13, comprising

providing a control unit (**7**) being operatively connected with the propeller unit, the transmission and the clutch arrangement,
receiving an input signal from the input unit (**14**),
issuing a propeller speed reference (**200**) based on the input signal,
controlling the propulsion system (**1**) on basis on the propeller speed references (**200**) during varying operations and/or speeds of the marine propulsion system (**1**).

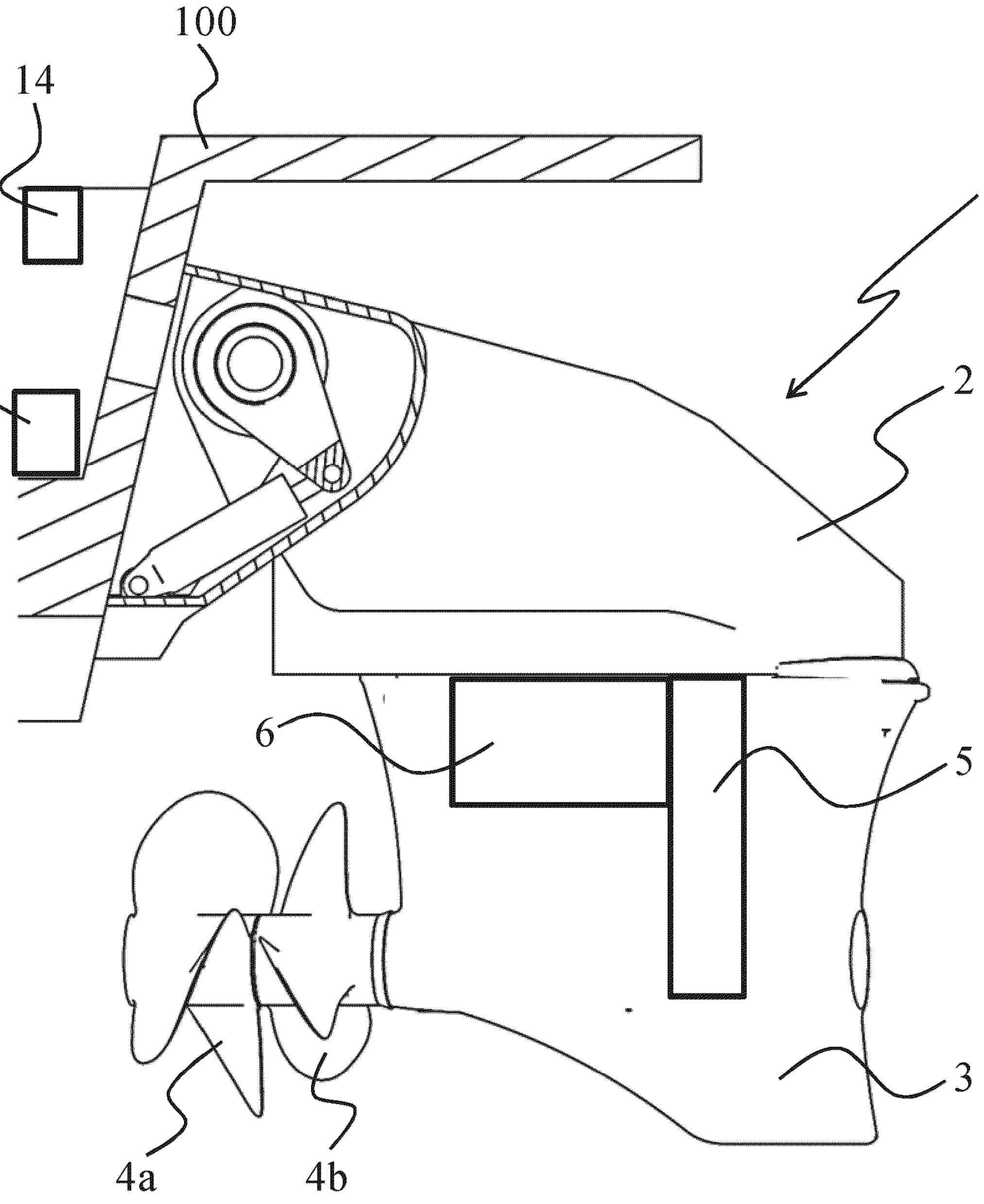

FIG. 1

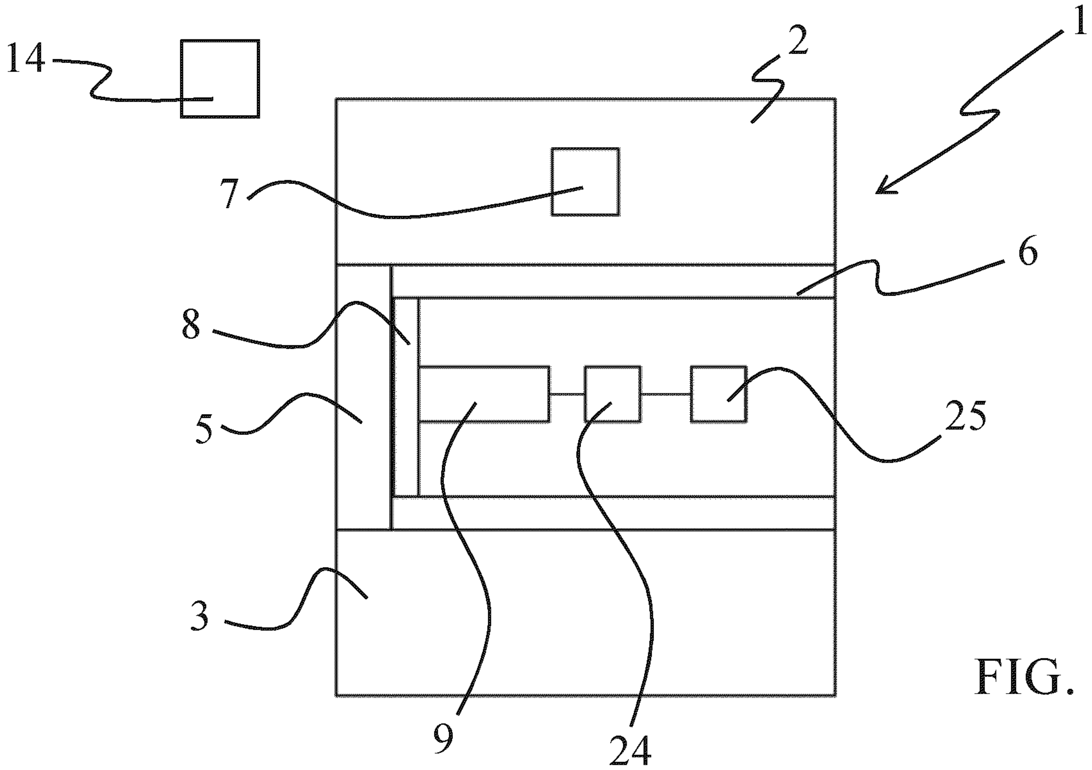

FIG. 2

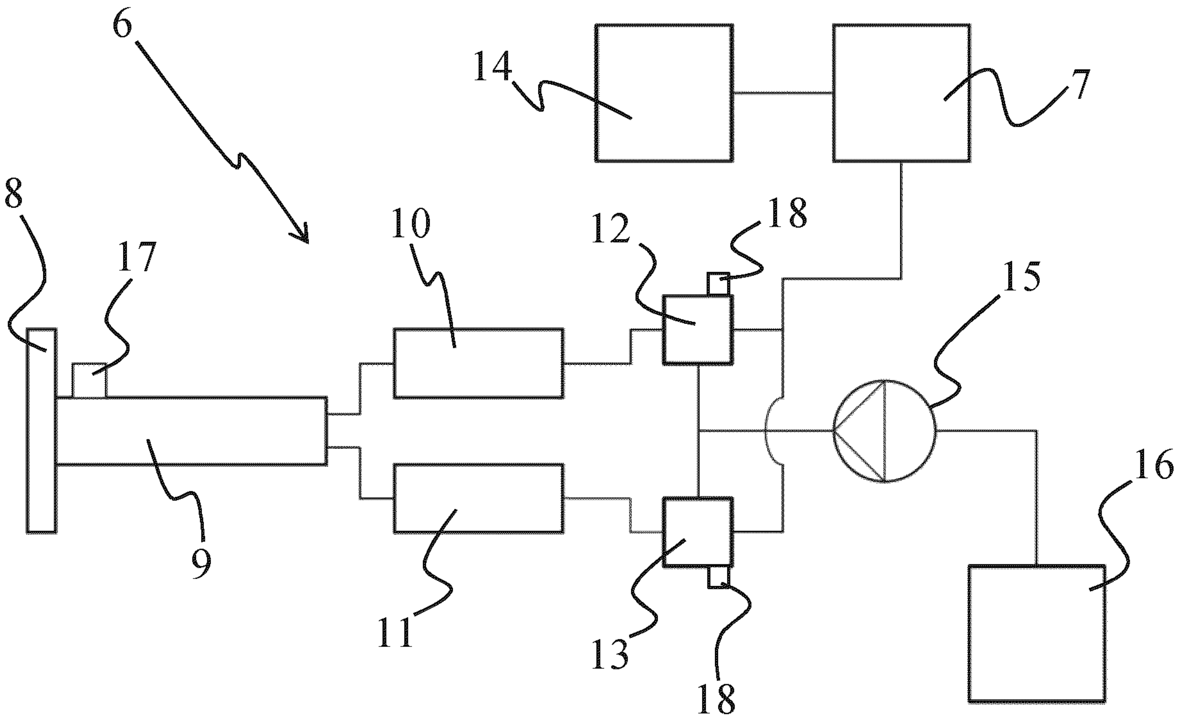

FIG. 3

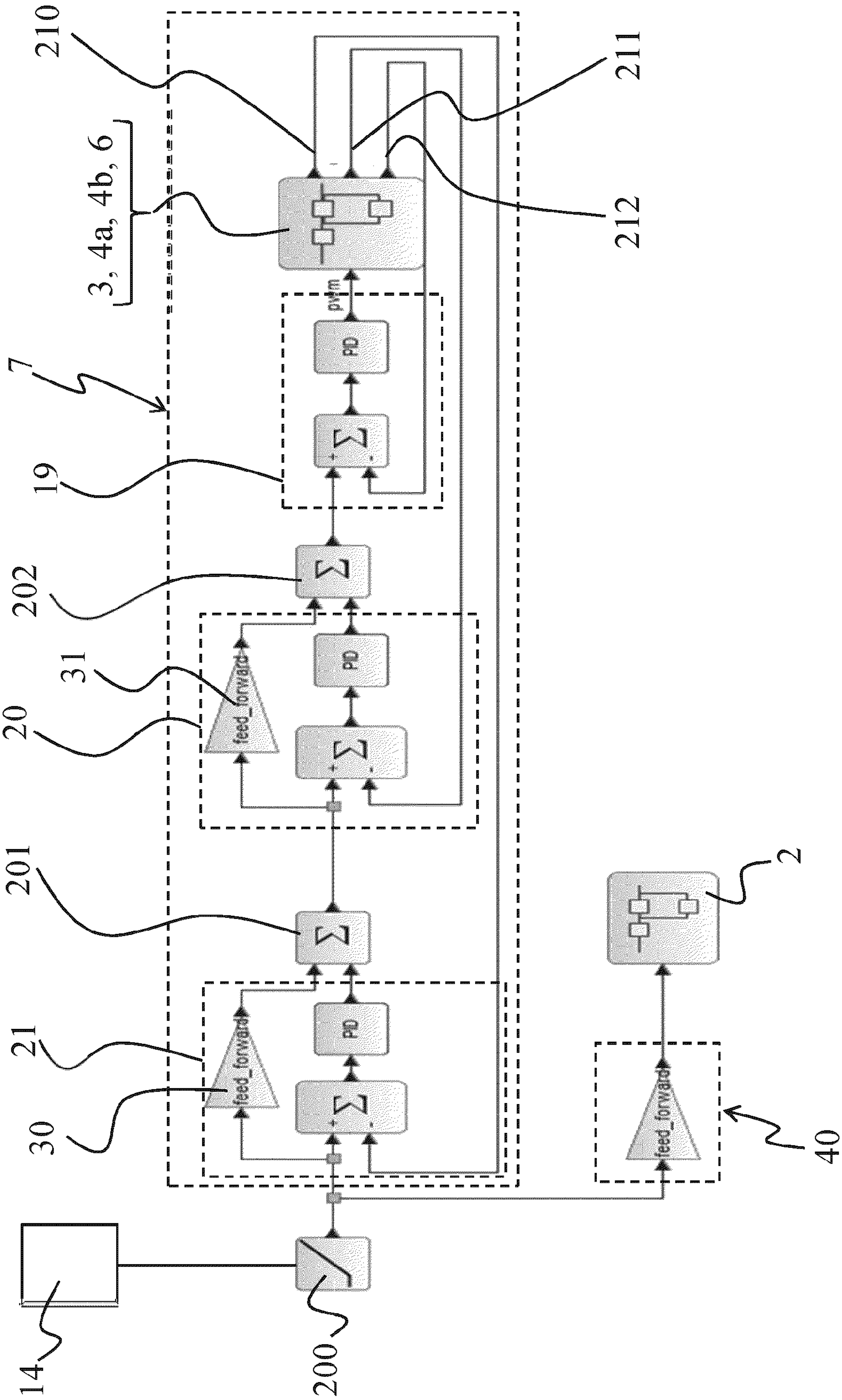
210
211
212
3, 4a, 4b, 6
7
19
pwm
PID
202
31
20
feed_forward
201
21
30
2
40
14
200

FIG. 4

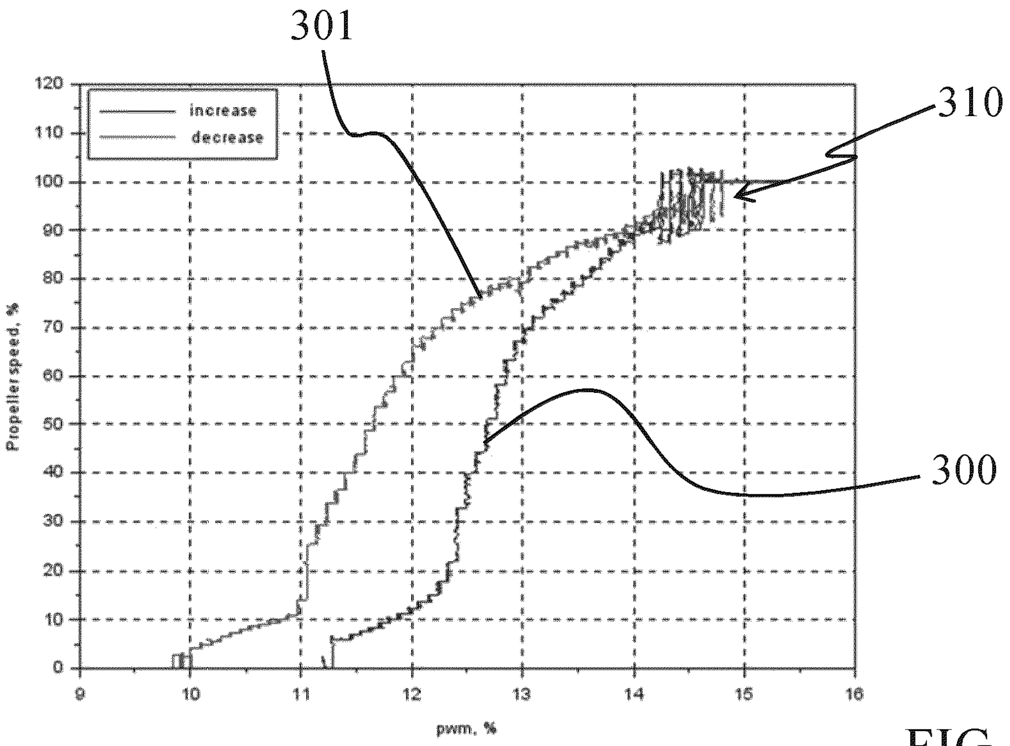
301
310
300
increase
decrease
Propeller speed, %
pwm, %
120
110
100
90
80
70
60
50
40
30
20
10
0
9
10
11
12
13
14
15
16

FIG. 5

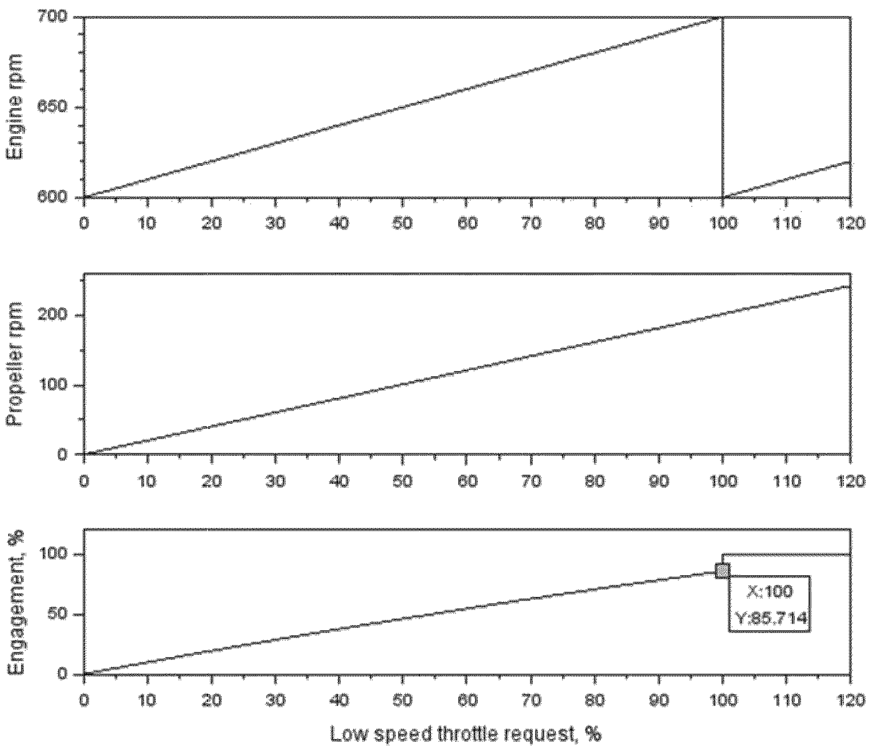
Engine rpm
700
650
600
Propeller rpm
200
100
0
Engagement, %
100
50
0
X:100
Y:85.714
0
10
20
30
40
50
60
70
80
90
100
110
120
Low speed throttle request, %

FIG. 6

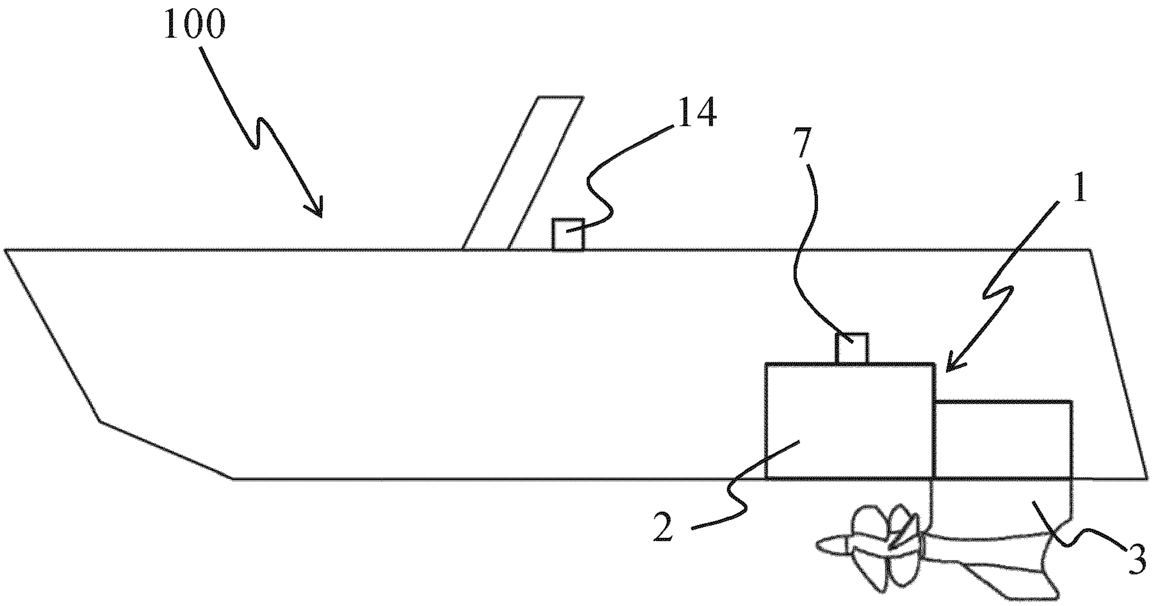

FIG. 7

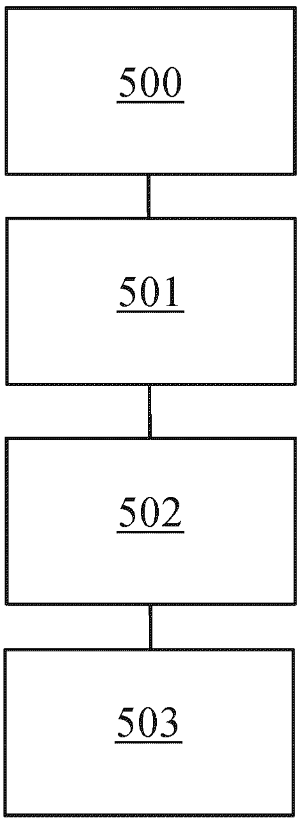

FIG. 8

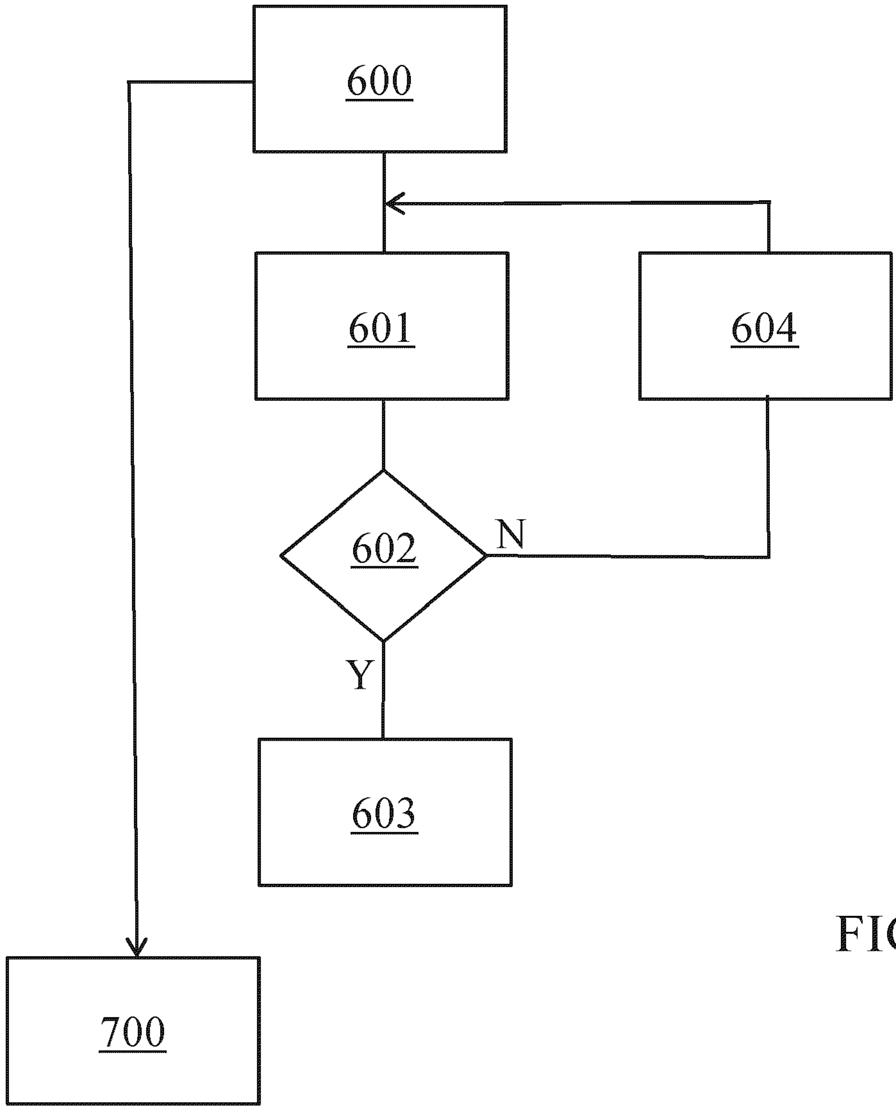

FIG. 9

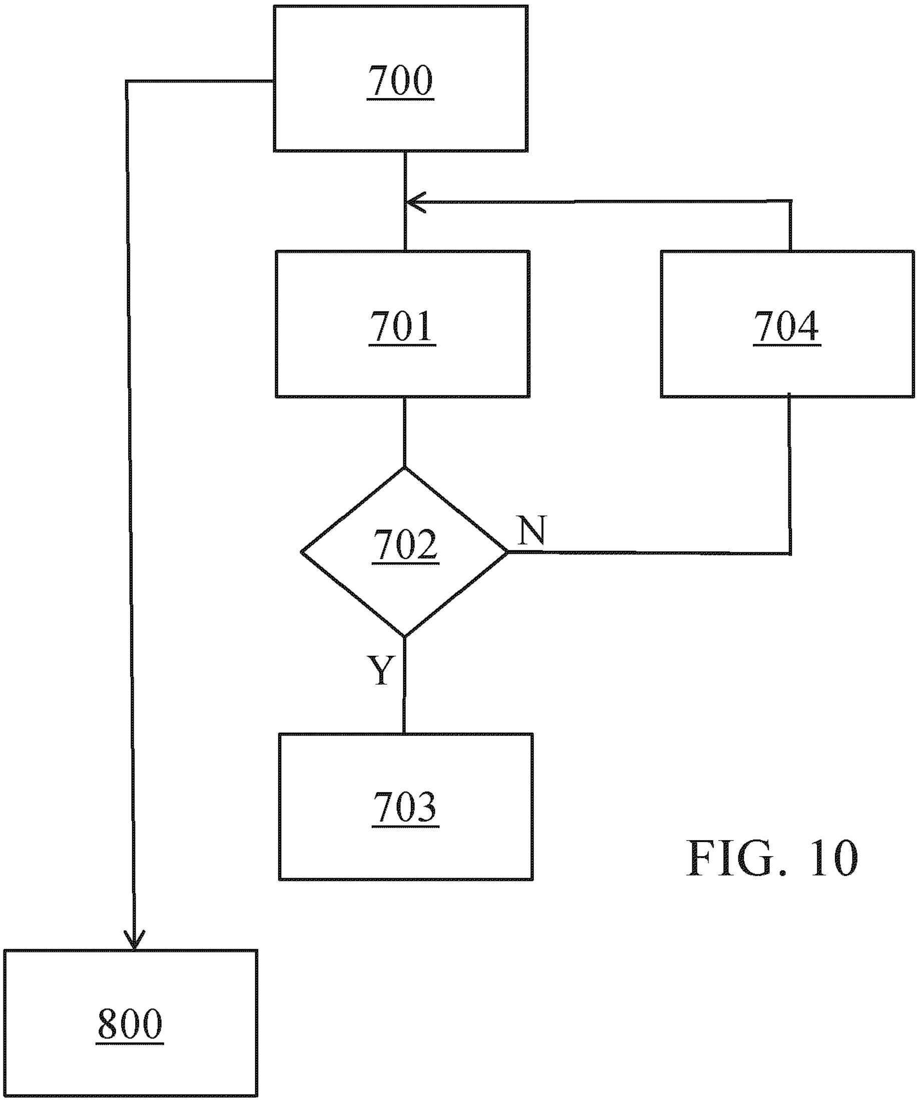

FIG. 10

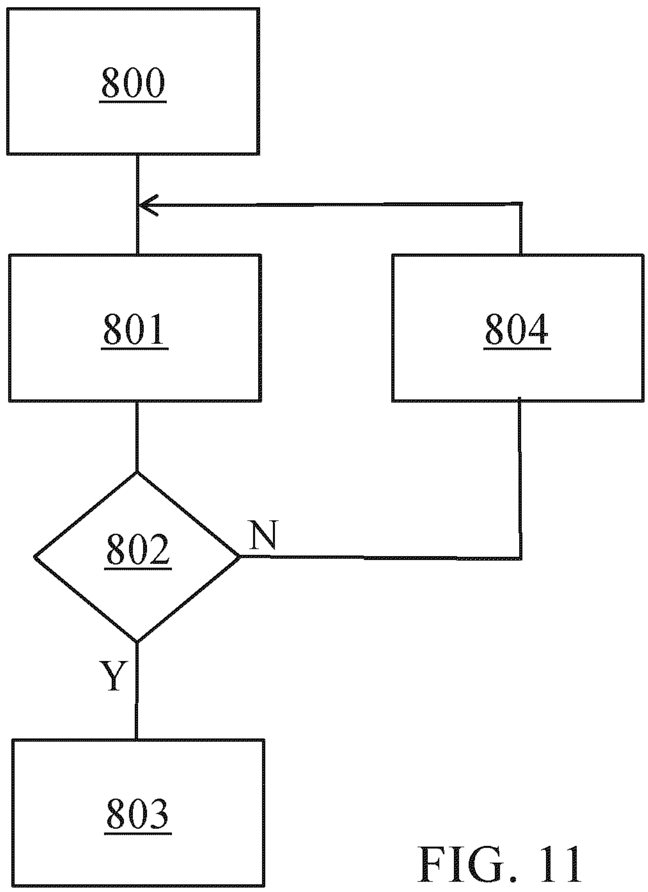

FIG. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 5493

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	US 2010/121505 A1 (YAMAZAKI TAKAYOSHI [JP] ET AL) 13 May 2010 (2010-05-13) * figures 1-14 * -----	1-7, 11-15 8-10	INV. B63B79/10 B63B79/40 B63H23/30
			TECHNICAL FIELDS SEARCHED (IPC)
			B63B B63H

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	5 April 2024	Freire Gomez, Jon

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

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05-04-2024

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		CN 101228065 A	23-07-2008
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		US 2010121505 A1	13-05-2010
		WO 2007010767 A1	25-01-2007

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