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(54) **SAILING VESSEL AND METHOD OF OPERATING THE SAILING VESSEL**

(57) Techniques for controlling operation of a sailing vessel, related to harvesting regenerative braking power, are provided. A control system, configured to control operation of a regenerative braking system of the vessel, receives measurements acquired by a wind sensor coupled to the vessel, to determine a current angle of an apparent wind relative to the vessel; determines a current speed of the vessel; determines, based on the current angle of the apparent wind relative to the vessel

and the current speed of the vessel, an amount of regenerative braking power to be applied by a regenerative braking system to an electric propulsion system of the vessel; and automatically controls the regenerative braking system to apply the determined amount of regenerative braking power to the electric propulsion system. The regenerative braking system may be calibrated based on user input.

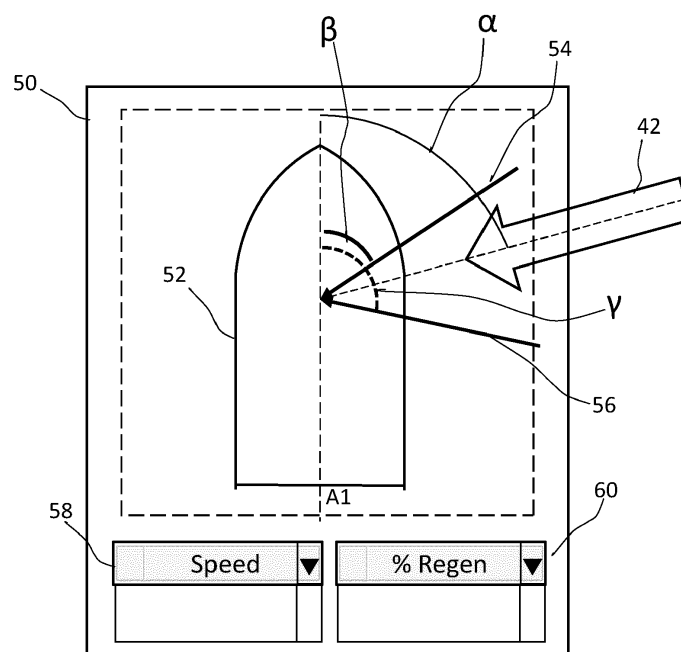


FIG. 4

Description**TECHNICAL FIELD**

[0001] This disclosure relates generally to control systems for marine vessels. In particular aspects, the disclosure relates to a sailing vessel and a method for regeneratively harvesting energy from the sailing vessel. Although the disclosure may be described with respect to a particular sailing vessel type, the disclosure is not restricted to any particular type of boat or ship.

BACKGROUND

[0002] Sailing boats or vessels may have electric motors to maneuver the vessel in certain circumstances. A sailing vessel may use regenerative braking that allows harvesting electrical energy when braking is applied, to feed the generated electrical energy into a charging system of the vessel. The charging system such as a battery stores the electrical energy for reuse.

[0003] A regenerative braking system typically remains active when the vessel is operating. However, because the use of the regenerative braking may worsen a sailing behavior of the vessel, the user or boat operator may turn the regenerative braking system off and then may forget to turn it back on, even in circumstances when regenerative energy could otherwise be harvested.

[0004] Accordingly, there exists a need for improved control of a sailing vessel, in particular, improved control of a regenerative braking system.

SUMMARY

[0005] It is an objective of the present disclosure to promote easy boating, and in particular to simplify use of regenerative braking, in the manner that does not affect maneuvers of a sailing vessel or boat, by automatically controlling the amount of regenerative braking power that is harvested from an electric propulsion system of the vessel during operation of the vessel.

[0006] Regenerative energy harvested during the boat's operation may be stored in an electrical storage system (ESS). The regenerative energy system or regenerative braking system may be calibrated or preset based on user preferences regarding sailing behaviour of the boat, and the regenerative braking system may then be automatically controlled based on the calibration and in dependence on a wind direction relative to the boat and the speed of the boat. When the braking force allowed in different scenarios is controlled automatically, the boat operator's intervention with the regenerative braking will be limited. In this way, a number of times the regenerative function is deactivated or turned off may advantageously be reduced.

[0007] In some examples, the amount of braking force to be applied in various circumstances, depending on a wind direction relative to the sailing boat and a speed of the boat, may be calibrated or adjusted in dependence on user preferences regarding the sailing behaviour of the boat. Thus, in some examples, user input may be received regarding a desired regenerative braking power from the motor, the user input indicating the desired regeneration in dependence on the boat's speed and in dependence on the wind direction relative to the boat or an angle of an apparent wind relative to the boat.

[0008] In an aspect, a method for controlling operation of a sailing vessel is provided. The method comprises receiving measurements acquired by a wind sensor coupled to the vessel, to determine a current angle of an apparent wind relative to the vessel; determining a current speed of the vessel; determining, based on the current angle of the apparent wind relative to the vessel and the current speed of the vessel, an amount of regenerative braking power to be applied by a regenerative braking system to an electric propulsion system of the vessel, the regenerative braking system being configured to selectively convert kinetic energy of the vessel into electrical energy; and automatically controlling the regenerative braking system to apply the determined amount of regenerative braking power to the electric propulsion system.

[0009] The technical benefits may include advantageously maintaining the sailing vessel's dynamics as desirable by a vessel operator. The technical benefits thus also include improved performance, maneuverability, and so-called sailability of the vessel. The efficiency of operating of the vessel may also be improved. As another advantage, the amount of regenerative braking power is automatically adjusted, without the boat operator's intervention, which improves user experience and improves overall performance of the vessel.

[0010] In some examples, the electric propulsion system may comprise two or more electric propulsion systems. In some examples, the electric propulsion system may comprise four or more than four electric propulsion systems. In some examples, automatically controlling the regenerative braking system may comprise applying a first portion of the determined amount of regenerative braking power to one of the electric propulsion systems and applying a second

portion of the determined amount of regenerative braking power to at least one another of the electric propulsion systems.

[0011] The technical benefits may include an improved precision of control of the operation of the vessel.

[0012] In some examples, the method may comprise calibrating the regenerative braking system to be automatically controlled to apply the determined amount of regenerative braking power to the electric propulsion system.

[0013] The technical benefits may include allowing the operation of the vessel to be adjusted based on user preferences regarding the vessel's behavior. Furthermore, the adjustment is performed automatically, which improves accuracy and predictability of control of the vessel.

[0014] In some examples, the calibration may comprise receiving first user input regarding at least one first calibration value of a speed of the vessel set for a first regenerative braking power value of the regenerative braking power, and regarding at least one second calibration value of a speed of the vessel set for a second regenerative braking power value of the regenerative braking power. The calibration may also comprise receiving second user input regarding at least one third calibration value of an angle of the apparent wind relative to the vessel set for a third regenerative braking power value of the regenerative braking power, and regarding at least one fourth calibration value of an angle of the apparent wind relative to the vessel set for a fourth regenerative braking power value of the regenerative braking power.

[0015] The technical benefits may include calibrating the regenerative braking system in accordance with the user preferences, such that the accuracy and predictability of control of the vessel is improved. Also, user experience in operating the vessel is improved. Thus, the regenerative braking system is more likely to remain on or activated during operation of the vessel because the user may not be inclined to turn the regenerative braking system off.

[0016] In some examples, the determining may be performed by combining the current angle of the apparent wind relative to the vessel, the current speed of the vessel, the at least one first calibration value set for the first regenerative braking power value, the at least one second calibration value set for the second regenerative braking power value, the at least one third calibration value set for the third regenerative braking power value, and the at least one fourth calibration value set for the fourth regenerative braking power value.

[0017] In some examples, the calibration may comprise generating one or more interpolated values of a regenerative braking power using the at least one first calibration value set for the first regenerative braking power value, the at least one second calibration value set for the second regenerative braking power value, the at least one third calibration value set for the third regenerative braking power value, and the at least one fourth calibration value set for the fourth regenerative braking power value.

[0018] In some examples, the method may comprise using the one or more interpolated values to generate a 3D-surface model representing dependance of a value of the regenerative braking power on values of the speed of the vessel and the angle of the apparent wind relative to the vessel, wherein the determining may be performed by using the 3D-surface model.

[0019] In some examples, the user input may be received via a display of the sailing vessel and/or via a user device configured to be communicatively coupled to a control system of the sailing vessel.

[0020] In some examples, the regenerative braking system may be operated in one of an on mode, in the off mode, and in an automatic control mode. In some examples, the regenerative braking system may be operated in the off mode or in the automatic control mode. The regenerative braking system may be switched between the modes based on user input and/or in another manner.

[0021] The method may be performed when the regenerative braking system is operated in the automatic control mode.

[0022] In some examples, at least the determining and the controlling may be performed when the regenerative braking system is operated in the automatic control mode.

[0023] In an aspect, a computer program product is provided that comprises program code for performing, when executed by processing circuitry, the method in accordance with any aspects and examples of the present disclosure. The program code may comprise computer-executable instructions which, when executed by the processing circuitry, cause the processing circuitry to perform the method in accordance with any aspects and examples of the present disclosure.

[0024] Advantages and effects of the computer program product are largely analogous to the advantages and effects of the method according to the examples herein. Further, all embodiments of the computer program are applicable to and combinable with all embodiments of the method according to the examples herein, and vice versa.

[0025] In an aspect, a non-transitory computer-readable storage medium is provided that comprising computer-executable instructions which, when executed by the processing circuitry, cause the processing circuitry to perform the method in accordance with any aspects and examples of the present disclosure.

[0026] Advantages and effects of the non-transitory computer-readable storage medium are largely analogous to the advantages and effects of the method according to the examples herein. Further, all embodiments of the computer-readable storage medium are applicable to and combinable with all embodiments of the method according to the examples herein, and vice versa.

[0027] In an aspect, a control system is provided that is configured to control operation of a sailing vessel. The control system comprises processing circuitry that is configured to perform a method in accordance with any aspects and examples of the present disclosure.

[0028] Advantages and effects of the control system are largely analogous to the advantages and effects of the method according to the examples herein. Further, all embodiments of the control system are applicable to and combinable with all embodiments of the method according to the examples herein, and vice versa.

[0029] In an aspect, a sailing vessel is provided that comprises an electric propulsion system configured to generate propulsive force to move the sailing vessel forward, a regenerative braking system, and a control system. The regenerative braking system is configured to selectively convert kinetic energy of the sailing vessel, generated during application of a regenerative braking force onto the electric propulsion system, into electrical energy, for storing the electrical energy in an electrical storage system (ESS). The control system comprises a processing circuitry that is configured to receive measurements acquired by wind sensor coupled to the vessel to determine a current angle of an apparent wind relative to the vessel; determine a current speed of the vessel; determine, based on the current angle of the apparent wind relative to the vessel and the current speed of the vessel, an amount of regenerative braking power to be applied by a regenerative braking system to an electric propulsion system of the vessel; and automatically control the regenerative braking system to apply the determined amount of regenerative braking power to the electric propulsion system.

[0030] Advantages and effects of the sailing vessel are largely analogous to the advantages and effects of the method according to the examples herein. Further, all embodiments of the sailing vessel are applicable to and combinable with all embodiments of the method according to the examples herein, and vice versa.

[0031] In some examples, the processing circuitry may be configured to calibrate the regenerative braking system to be automatically controlled to apply the determined amount of regenerative braking power to the electric propulsion system.

[0032] In some examples, the calibration may comprise receiving first user input regarding at least one first calibration value of a speed of the vessel set for a first regenerative braking power value of the regenerative braking power, and regarding at least one second calibration value of a speed of the vessel set for a second regenerative braking power value of the regenerative braking power. The calibration may also comprise receiving second user input regarding at least one third calibration value of an angle of the apparent wind relative to the vessel set for a third regenerative braking power value of the regenerative braking power, and regarding at least one fourth calibration value of an angle of the apparent wind relative to the vessel set for a fourth regenerative braking power value of the regenerative braking power.

[0033] In some examples, the calibration may comprise generating one or more interpolated values of a regenerative braking power using the at least one first calibration value set for the first regenerative braking power value, the at least one second calibration value set for the second regenerative braking power value, the at least one third calibration value set for the third regenerative braking power value, and the at least one fourth calibration value set for the fourth regenerative braking power value; and using the one or more interpolated values to generate a 3D-surface model representing dependance of a value of the regenerative braking power on values of the speed of the vessel and the angle of the apparent wind relative to the vessel. The determining may be performed by using the 3D-surface model.

[0034] The above aspects, accompanying claims, and/or examples disclosed herein above and later below may be suitably combined with each other as would be apparent to anyone of ordinary skill in the art.

[0035] 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. There are also disclosed herein control systems, units, computer readable media, and computer program products associated with the above discussed technical benefits.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] With reference to the appended drawings, below follows a more detailed description of aspects of the disclosure cited as examples.

FIG. 1 is a diagram illustrating an example of a sailing vessel in which a method in accordance with examples of the present disclosure may be implemented.

FIG. 2 is a diagram illustrating an example of a part of the sailing vessel of FIG. 1.

FIG. 3 is a diagram illustrating a view of the sailing vessel of FIG. 1, showing a direction in which the speed of the vessel is measured and a direction of the current wind and a current angle of the apparent wind relative to the vessel.

FIG. 4 is a diagram illustrating an example of a user interface configured to receive user input as part of calibration of the vessel and regenerative braking system in accordance with examples of the present disclosure.

FIG. 5 illustrates a visual representation of an example of a three-dimensional model that may be used to determine an amount of regenerative braking power to be applied in an automatic control mode of the vessel and regenerative braking system, in accordance with examples of the present disclosure.

FIGs. 6, 7, and 8 are diagrams illustrating examples of a user interface configured to receive user input as part of calibration of the vessel and regenerative braking system, in accordance with examples of the present disclosure.

FIG. 9 is a flowchart illustrating an example of a method for controlling operation of a sailing vessel in accordance with examples of the present disclosure.

FIG. 10 is a schematic diagram of a computer system for implementing examples in accordance with the present disclosure.

DETAILED DESCRIPTION

[0037] 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.

[0038] The present disclosure relates to control of a regenerative braking system that generates electric power while charging an electric storage system (ESS) e.g. a battery of the sailing vessel, and to a method of operating the vessel such that the regenerative braking system may be automatically controlled.

[0039] In sailing vessels or sailboats, a regenerative braking system typically remains active or on when the sailboat or vessel is operating. At the same time, when regenerative braking is used, it may alter intended sailing properties of the vessel, which may negatively affect overall experience of a user or sailor operating the sailboat. For example, regenerative braking, if applied when the sailboat is moving upwind i.e. against the wind, may cause the boat to feel sluggish to the operator. Thus, the use of a regenerative braking function, implemented by the regenerative braking system, may worsen the sailing behavior of the boat which worsens the sailing experience of the user or operator, since the user typically expects smoother sailboat behavior. This may be particularly relevant when the boat is used to sail around islands or in any other marine area where a sailing direction may change frequently. As a result, the user may find the regenerative braking undesirable and may turn the regenerative braking system off in its entirety. Often, the user forgets to turn the regenerative braking system back on, and the system remains off even though the regenerative energy could otherwise be harvested for later reuse.

[0040] In aspects herein, an automatic control of the regenerative braking system is provided that allows automatically controlling how much energy or power is sent to the ESS during regenerative braking.

[0041] Aspects of the present disclosure relate to controlling operation of the sailing vessel such that the vessel may operate in an automatic control mode of the regenerative braking system, in which mode an amount of applied regenerative braking power is automatically controlled and adjusted, in dependence on a wind direction relative to the vessel and a speed of the vessel. The present disclosure thus provides for an automatic adjustment of an amount of power or energy that is captured via regenerative braking and fed into an electric storage system (ESS) of the boat. A propeller of the sailing boat is driven by an electric motor, and the motor is configured to control resistance of the propeller through water. Kinetic energy recovered from the propeller braking may be selectively converted into electric form and stored in the ESS such as e.g. a battery, capacitor bank, or another device configured to store the electrical energy or power for reuse by the electric motor.

[0042] The techniques described herein, which allow automatically adjusting a percentage of energy that is directed to the ESS via the regenerative braking, may advantageously allow maintaining the sailing vessel's dynamics as desirable by a vessel operator. The technical benefits include improving performance, maneuverability, and so-called sailability of the vessel. The amount of regenerative braking power is automatically adjusted, without the boat operator's intervention, in dependence on an angle of the apparent wind relative to the sailing vessel, and speed of the vessel, such as the speed over ground and/or through the water. The regenerative braking system may be pre-calibrated based on user input indicating user's preferences regarding the vessel's behaviour in connection with regenerative braking. The braking force allowed in different scenarios may be limited. In the automatic control mode, the regenerative braking system may remain active whereas the applied amount of the regenerative braking power is adjusted as the vessel is operated in water. Thus, the present approach may advantageously allow decreasing a number of times the regenerative braking system is manually turned off due to e.g. sailing performance loss.

[0043] FIG. 1 illustrates an example of a sailing vessel or boat 10 in which a method in accordance with examples of the present disclosure may be implemented. The vessel 10 may be any sailing watercraft or sailboat that may be used for any type of sailing - recreational sailing, commercial sailing, long-distance cruising, elite racing, and/or any other type of sailing. The vessel 10 comprises a hull or body 12, an electric propulsion system 14, an ESS 16 such as e.g. one or more batteries, a control system 18, and a regenerative energy or regenerative braking system 20. The electric propulsion system 14 comprises an electric motor 15 configured to provide propulsion power to a thrust mechanism e.g. a propeller 17. Operation of the electric motor 15 may be controlled by a motor controller 13. The regenerative braking system 20 may be controlled, in accordance with the techniques described herein, by controlling the motor controller 13, e.g., by controlling the current to flow in reverse through the motor controller 13, in contrast to an operation without regenerative braking.

[0044] In FIG. 1, the electric propulsion system 14 is shown as a center propulsion system that is mounted substantially along a centerline or central longitudinal axis A1 of the body 12 of the vessel 10. The vessel 10 may additionally or alternatively comprise one or more propulsion systems on a starboard side and one or more propulsion systems on a port side. In some examples, the vessel may comprise two propulsion systems. In some examples, the vessel may comprise four propulsion systems. In some examples, the vessel may comprise more than four propulsion systems. Furthermore, in some implementations, there may be more than one, e.g. two or more, electric motors coupled to the same propeller. In

some examples, multiple electric motors may be connected to the same axle to gain a higher power output. Such implementations are also possible in hybrid systems.

[0045] In some examples, the vessel 10 may comprise the propulsion system on the starboard side and the propulsion system on the port side, without the centerline propulsion system. Thus, in some implementations, the vessel 10 may comprise two or more motors. Each of the propulsion systems may be configured similarly to the propulsion system 14 shown in FIG. 1.

[0046] Thus, in some examples, the electric propulsion system may comprise two or more electric propulsion systems. In some examples, automatically controlling the regenerative braking system may comprise applying a first portion of the determined amount of regenerative braking power to one of the electric propulsion systems and applying a second portion of the determined amount of regenerative braking power to at least one another of the electric propulsion systems.

[0047] The vessel 10 may also comprise a dashboard or instrument panel or display 30 shown in FIG. 1. The display 30 may be a built-in component of the vessel 10 or a separate component.

[0048] The regenerative energy or regenerative braking system 20, shown very schematically in FIG. 1, is configured to selectively convert kinetic energy of the propeller 17 into electrical energy that is stored in the ESS 16, for reuse by the motor 15 or other electrical systems in the vessel. For example, the energy stored in the ESS 16 may be used for one or more of a radar, a heater, an oven, and an air conditioner, and/or by other one or more electrical systems of the vessel.

[0049] The regenerative braking system may be part of a control device such as e.g. an electronic control unit (ECU), a helm control unit (HCU), or a command control module (CCM), which may be provided on the vessel 10 and/or outboard the motor 15. In some examples, the regenerative braking system 20 may be part of the control system 18. In some examples, the regenerative braking system 20 may be part of electric power steering system (EPS). Regardless of its specific location and configuration, the regenerative braking system 20 may be controlled to direct, during the vessel operation, a certain amount of power to the ESS 16. The techniques in accordance with the present disclosure allow operating the regenerative braking system 20 in an automatic control mode and in one or more of an on mode and an off mode. In the automatic control mode, the amount of power directed to the ESS 16 is controlled automatically. Also, the automatic control mode may involve application of so-called negative regenerative braking power, as predetermined based on user-selected preferences, to provide a certain amount of power from the ESS 16 to the electric propulsion system 14.

[0050] The vessel 10 may comprise various sensors configured to sense operational data associated with the vessel 10. In particular, as shown in FIG. 1, the vessel 10 comprises a speed sensor or sensing device 22 configured to output data indicative of the speed of the vessel 10. The speed sensor may be configured to perform speed over ground and/or speed through water measurements. The speed sensor 22 configured to perform the ground speed measurement may use information extracted from a navigation system of the vessel 10, e.g., global Positioning System (GPS) or other speed sensing device or system of the vessel 10. The speed sensor configured to acquire the speed through water measurements may use one or more onboard sensors such as e.g. doppler-based sensors, electromagnetic sensors, or other types of sensors. The vessel may comprise various one or more sensors used to determine a speed of the vessel 10. For example, one or more accelerometers may be used, and the speed of the vessel 10 may be estimated using images acquired by one or more onboard cameras, data acquired using one or more light detection and ranging (LiDAR) sensors, and/or data acquired using other types of technologies. Furthermore, the speed of the vessel 10 may be estimated based on rotation of the propeller 17 and the torque applied to the propeller 17.

[0051] The vessel 10 also comprises at least one wind sensor 24 configured to measure wind speed and/or direction. As shown in FIG. 1, the vessel 10 may comprise at least one other sensor 23 which may be one or more of any of various types of sensing and/or measuring devices. Non-limiting examples of such sensing and/or measuring devices comprise one or more out of an altitude sensor, a heading sensor, a wind strength sensor, an acceleration sensor or accelerometer, a gyroscope, a gyroscope/accelerometer, a velocity sensor, a compass, a global positioning satellite system (GPS), an inertial measurements unit (IMU), a time of day sensor, a calendar, and/or any other sensors configured to measure a state of the vessel 10 and/or surrounding environment.

[0052] In examples herein, sensor measurements acquired by the wind sensor 24 may be used to determine an angle of an apparent wind relative to the vessel 10, the angle may, as a non-limiting example, be relative to the bow or front of the vessel. The apparent angle of the wind may be determined using measurements acquired from other sensing and/or measuring devices, in addition to the at least one wind sensor 24, e.g. any of the at least one other sensor 23. The wind sensor 24, e.g., in co-operation with a speed sensor and or heading sensor, may be used to calculate an apparent angle of the wind relative to north, or any other static direction. The other static direction, as non-limiting examples, may be the south, the east, the west, 10 degrees, or other degrees.

[0053] Because the wind sensor may determine a current apparent wind angle relative to the vessel with a certain delay, to compensate for this delay, another sensor, e.g. a heading sensor, may be used to estimate a direction from which the wind is coming during turning of the vessel. In this way, the angle of the wind is determined in a timely manner which allows controlling the vessel 10 in accordance with the techniques described herein. The heading sensor may be e.g. a magnetic compass, a GPS compass, a gyroscope, or another suitable type or types of sensor. In some examples, the heading

sensor may be used to acquire apparent wind angle measurements relative to the north. In some examples, a lowpass filter may be applied to the apparent wind angle measurements relative to the north to generate a low pass filtered angle. A difference between the low pass filtered angle and the heading may then be obtained to determine with improved accuracy a wind angle relative the vessel. In another non-limiting example, the lowpass filter may be applied to the north and south components of the apparent wind vector in the case that the wind sensor 24 also can measure the wind strength, from which a lowpass filtered apparent wind angle can be calculated. A difference between the low pass filtered angle and the heading may then be obtained to determine with improved accuracy a wind angle relative the vessel.

[0054] As yet another non-limiting example, the wind angle as measured by the wind sensor 24 may be used together with the heading rate of the vessel, or the change of the heading. In this case, the wind angle may be calculated as a weighted average between the sum of an apparent wind angle previously calculated and the heading rate multiplied by a time delta since the previous apparent wind angle calculation, and the measured apparent wind, to determine the apparent wind angle during turning of the vessel.

[0055] It should be noted that the speed sensor 22, the wind sensor 24, and the at least one other sensor 23 may be disposed in any suitable positions on the vessel 10. For example, the wind sensor 24 may be positioned on a mast (not shown). The control system 18, also shown in FIG. 2, may comprise processing circuitry 26 e.g. one or more processors, and a storage medium 28. The storage medium 28 may comprise one or more memory devices configured to store tangible computer-executable instructions that may be executed by the processing circuitry 26 to perform methods in accordance with examples of the present disclosure. An example computer system 1000 that can be used to realize the different functions discussed herein will be discussed below in connection to FIG. 10. The control system 18 may communicate with one or more sensor systems or devices for obtaining information about the surrounding environment of the vessel 10.

[0056] The storage medium 28 may comprise a user profile module 25 that may store, for one or more users or operators of the vessel, respective one or more user regenerative braking profiles. The user regenerative braking profile may include a representation of user preferences regarding the vessel's regenerative braking function implemented by the regenerative braking system. The representation of the user preferences, generated and stored in any suitable format, may be generated based on user input received from the user as part of calibration of the regenerative braking function. For a user of the vessel, a corresponding user regenerative braking profile may be stored such that the vessel may be instructed to operate in accordance with the preferences set in the user regenerative braking profile when the user operates the vessel. For example, a suitable user regenerative braking profile may be selected via, e.g., the dashboard 30 of the vessel, a user's device such as a smartphone, or another device, to cause the regenerative braking system of the vessel to operate in accordance with the calibration of the system as reflected in the user regenerative braking profile. The user regenerative braking profile stored for a user may be updated responsive to the user updating user preferences, e.g., receiving one or more other calibration values from the user. For example, the user may provide input regarding the vessel's calibration, operate the vessel in the water, to then recalibrate the vessel if desired.

[0057] In some examples, the storage medium 28 may comprise a sails type/sailing style module 27 that may store settings for the vessel 10, regarding operation of the vessel's regenerative braking function, for certain one or more types of sails and/or sailing style(s) that may be used to operate the vessel 10. Thus, different settings may be stored for a high regen sailing style, racing style, up-wind sailing, spinnaker sails, and/or other types of sails and/or the sailing styles.

[0058] In some examples, the information stored in the sails type/sailing style module 27 may be stored in the user profile module 25 such that, for a certain user, different user's preferences regarding the vessel's regenerative braking function may be stored for respective different types of sails and/or sailing styles.

[0059] The control system 18 may be arranged to receive a signal from at least one input device 32 shown in FIG. 2. The control system 18 may also be arranged to control at least in part the regenerative braking function of the vessel 10, in response to receiving, as part of calibration of the regenerate braking function, user input via the input device 32 such as e.g. a display.

[0060] The input device 32 may be e.g. a manual input device operable from a position on-board the vessel 10. The input device may be realized as a menu choice in an existing navigation system interface on the vessel. For instance, the vessel 10 may comprise a display located in connection to a steering system or helm of the vessel for displaying, e.g., sea charts, radar images, light detection and ranging (LiDAR) images, thermal camera images, and the like. This display, which may be part of the dashboard 30, may comprise or may be a touch-sensitive display.

[0061] The input device 32 may also be a portable device 34 arranged to be wirelessly connected to the control system 18. In some examples, the portable device 34 may be a user device such as e.g. a smartphone, tablet device, or other device configured to connect to the control system 18 via a wireless link 35, such as e.g. a Wi-Fi link in the family of wireless network protocols based on the IEEE 802.11 family of standards, a Bluetooth wireless link, the Internet, satellite, or any using any other wireless communications technology. In some examples, the portable device 34 may be positioned remotely relative to the vessel 10. The control system 18 may be configured to receive data from more than one input device, including one or more onboard input devices and/or one or more remote input devices.

[0062] In some examples, the portable device 34 may be realized as a relatively simple remote control device which transmits a radio signal to a radio receiver or transceiver arranged on the vessel.

[0063] In examples herein, the control system 18 is arranged and configured to receive measurements from a sensor e.g. wind sensor 24 to determine a current angle of an apparent wind relative to the vessel 10. The control system 18 is also arranged and configured to determine a current speed of the vessel using measurements obtained e.g. by a speed sensor such as the speed sensor 22. **FIG. 3** illustrates a view of the sailing vessel 10 showing the central longitudinal axis A1 of the vessel 10, and showing by an arrow 40 a direction in which the speed of the vessel 10 is measured, by an arrow 42 a direction of the current wind, and a current angle α of the apparent wind. The automatic control of an amount of regenerative braking, once activated, is performed based on the current speed of the boat and the current angle of the apparent wind.

[0064] In FIG. 3, the current angle α of the apparent wind is shown at a starboard side of the vessel i.e. from the right as shown in FIG. 3. It should be appreciated that the current angle of the apparent wind may be as experienced from a port side of the vessel i.e. from the left as shown in FIG. 3. Throughout this disclosure, hereinbelow, the angle of the apparent wind will be shown from the starboard side of the vessel for illustration purposes, but it should be appreciated that the same description applies to the angle of the apparent wind relative to the vessel from the port side.

[0065] In some examples, the vessel 10 may be configured to operate in one of three modes related to the regenerative braking function of the regenerative braking system - an on mode in which the regenerative braking function is on e.g. the regenerative braking system is turned on or activated, an off mode in which the regenerative braking function is off or deactivated e.g. the regenerative braking system is turned off or deactivated, and an automatic control mode in which the regenerative braking function is turned on or activated and is controlled automatically, based on the current vessel's speed and the angle of the apparent wind relative to the vessel. In some examples, the vessel 10 may be configured to operate in one of the off mode and the automatic control mode.

[0066] The regenerative braking system may be switched to operate in one of the operating modes, for example, based on an instruction from the user. For example, the display 30 or other component of the vessel 10 may include control elements configured to receive user input regarding selection of the operating modes of the regenerative braking system. The vessel 10 may be switched to operate in one of the modes based on user input received e.g. via one or more of the input device 32, the input device 34, or any other input device.

[0067] In the automatic control mode, in some circumstances, the amount of the regenerative braking power harvested for storage in the ESS may be zero or close to zero, even though the regenerative braking function remains active. For example, when the vessel is sailed upwind, the amount of the regenerative braking power may be reduced. In the automatic control mode, the regenerative braking function may be controlled to apply regenerative braking gradually, such that the vessel can be maneuvered in the manner as desired or acceptable by the user.

[0068] In examples in accordance with the present disclosure, the regenerative braking function implemented e.g. by the regenerative braking system of the vessel 10 may be calibrated prior to its use. The calibration of the regenerative braking function, as performed by the regenerative braking system 20, may be performed based on user input which may be received via one or more of the input device 32, input device 34, display 30, or another input device or system. In some examples, the calibration comprises receiving first user input regarding at least one first calibration value of a speed of the vessel set for a first regenerative braking power value of the regenerative braking power, and regarding at least one second calibration value of a speed of the vessel set for a second regenerative braking power value of the regenerative braking power. The calibration may also comprise receiving second user input regarding at least one third calibration value of an angle of the apparent wind relative to the vessel set for a third regenerative braking power value of the regenerative braking power, and regarding at least one fourth calibration value of an angle of the apparent wind relative to the vessel set for a fourth regenerative braking power value of the regenerative braking power.

[0069] As used herein, the value of the regenerative braking power, which may be expressed as a percentage of the regenerative braking power or an amount of the regenerative braking power, may refer to a part of the kinetic energy or power of the vessel that is converted into electrical energy or power that is fed to a storage such as the ESS. The part of the regenerative braking power is applied to the electric propulsion system, e.g. by the electric motor to the propeller or another rotating element, to selectively convert kinetic energy of the vessel to electrical energy or power and store this energy or power in the ESS of the vessel.

[0070] The value of the regenerative braking power, expressed as a percentage of the regenerative braking power or an amount of the regenerative braking power, may refer to a part of a maximum possible regenerative braking power or a thrust, RPM, or moment which produces a maximum power output that can be applied to the electric propulsion system, e.g. by the electric motor to the propeller or another rotating element, to selectively convert kinetic energy of the vessel to electrical energy or power and store this energy or power in the ESS of the vessel. The maximum power output may be obtained using a Maximum Power Point Tracking (MPPT).

[0071] As an example, if the regenerative braking is turned off and the vessel is going at a certain speed, e.g., 4 knots, once the regenerative braking is turned on up to 100%, the vessel may decelerate to the speed where the force from the wind will be equal to the drag from the regenerative braking and the drag from the vessel. Thus, the speed may be decreased by for example a knot. When the vessel has reached a speed where these forces are at equilibrium, no further slowing down will occur, given that the wind's strength does not change.

[0072] The first and third regenerative braking power values of the regenerative braking power may be e.g. 0% regenerative braking power, and the second and fourth values of the regenerative braking power may be e.g. 100% regenerative braking power. Thus, the user may specify at which vessel speed and at which angle of the apparent wind relative to the vessel the desired regenerative power comprises a minimum value of 0% and a maximum value of 100%, respectively. Thus, the user input comprising calibration values may be received at least for two endpoint values of the regenerative braking power such as, e.g., 0% and 100%. Others endpoints may be used, e.g. in some examples, there may be a minimum negative percent of the regenerative power. For missing or non-specified values of the vessel speed and the angle of the apparent wind relative to the vessel, the desired regenerative power may be interpolated.

[0073] In some examples, the minimum value of the regenerative braking power may be lower than 0%, i.e. calibration values may be received for the vessel speed and the angle of the apparent wind relative to the vessel at which, instead of harvesting electric power for storage in the ESS, some set amount of power will be directed to the electric propulsion system of the vessel. Negative values of the regenerative braking power may thus be used for boosting the electric propulsion system e.g. at lower vessel speeds.

[0074] In some examples, the third regenerative braking power value of the regenerative braking power may be the same as the first value of the regenerative braking power. The fourth regenerative braking power value of the regenerative braking power may be the same as the second regenerative braking power value of the regenerative braking power. In some examples, the third value and the fourth value may be different from the first and second value e.g. percentages, respectively.

[0075] Furthermore, in some examples, user input may be received with respect to more than two values of the calibration speed of the vessel and more than two values of the calibration angle of the apparent wind relative to the vessel. For example, user input may be received indicating three or more values of regenerative braking power for respective speed of the vessel and the angle of the apparent wind relative to the boat.

[0076] In some examples, a certain number of values may be specified for the regenerative braking power at certain two or more speeds of the vessel, and a certain different number of values may be specified for the regenerative braking power at certain two or more angles of the apparent wind relative to the vessel.

[0077] Thus, in examples herein, the user input may indicate user preferences regarding behavior of the vessel in water. Thus, the behavior and maneuverability of the sailing vessel e.g. as it travels against the wind as well as in other circumstances, may be adjusted according to user preferences regarding the amount or percentage of the regenerative braking power applied to or by the electric propulsion system. As mentioned above, application of regenerative braking, particularly when a sailboat is traveling upwind, may cause the boat's behavior to feel sluggish to the boat operator, in which case the operator may turn the regenerative braking function off. The techniques in accordance with the present disclosure allow adjusting the amount of applied regenerative braking power such that, for example, as the boat is traveling upwind, the amount of the applied regenerative braking power may be automatically reduced to thereby avoid the boat sailing undesirably slow for the user. In this way, the user may not be inclined to turn the regenerative braking system off and the system may remain on, which is generally desirable.

[0078] FIG. 4 illustrates an example of a user interface 50 that may be displayed for receiving user input as part of calibration of the vessel 10 and regenerative braking system 20 in accordance with examples of the present disclosure. The user interface 50 may present various features that allow receiving user input indicating selection of calibration values of the speed of the vessel and calibration values of the angle of the apparent wind relative to the vessel.

[0079] The user interface 50 may include a representation 52 of a sailing vessel, which may be of any suitable type of representation. The representation 52 may allow the user to set the wind angles and respective amounts or percentages of the regenerative braking power in an intuitive manner. The user interface 50 may be presented by the control system 18 or by another system communicatively coupled with the control system 18. The user interface 50 may be presented, e.g., on the dashboard 30 of the vessel or on a display of a user device communicatively coupled to the control system 18.

[0080] The user interface may represent an angle β of the apparent wind relative to the vessel, marked with a bold solid line, at which a certain amount or percentage e.g. 0% of regenerative braking power, also referred to as regen, is applied. The user interface may also represent an angle γ of the apparent wind relative to the vessel, marked with a dotted line, at which a certain amount or percentage e.g. 100% of regenerative braking power is applied. The current angle α of the apparent wind relative to the boat and the current wind direction 42 may also be indicated, similar to the example of FIG. 3.

[0081] The user interface 50 may be arranged and configured to display interactive visual elements that may be used to indicate user selection regarding the calibration. For example, features such as e.g. lines 54 and 56, used to indicate the angles β and γ with respect to the central longitudinal axis A1 of the vessel, may be movable via the user input. The angles β and γ represent respective wind angles of attack of the vessel, wherein an angle of attack from the wind is defined as an angle between a course of the vessel and an apparent wind direction.

[0082] The user interface 50 may receive user input indicating positioning or repositioning of the lines 54 and 56 to thereby allow user selection of the angle β of the apparent wind relative to the vessel and of the angle γ of the apparent wind relative to the vessel, respectively. The user interface 50 may be presented in the manner that enables the user to initiate a display of multiple lines similar to the lines 54 and 56, and/or to initiate a display of any other features or elements for

selecting calibration values of the angle the apparent wind relative to the vessel, set for corresponding amounts of regenerative braking power.

[0083] The angles may be selected in other ways, e.g. using other suitable elements of the user interface that are configured to receive user input. For example, the user interface 50 may display features that allow receiving numerical values indicating the angles β and γ of the apparent wind relative to the vessel, for certain respective amounts of regenerative braking power. Any suitable number of values of the angle of the apparent wind relative to the vessel may be received from the user as part of the calibration of the regenerative braking system.

[0084] In some examples, the representation 52 rendered on the user interface 50 may be interactive such that, for selected e.g. based on user input values of the vessel speed and the angle of the apparent wind, the representation 52 may visually demonstrate to the user how the selected calibration values would affect the behaviour of the vessel.

[0085] As shown in FIG. 4, the user interface 50 may present features that can receive user input indicating selection of calibration values of the speed of the vessel as well as respective values of the amount or percentage of the regenerative braking power or regen. For example, a drop-down menu or another feature 58 may be used to receive an indication of selection of a speed of the vessel, and a drop-down menu or another feature 60 may be used to receive an indication of selection of a percentage of regen corresponding to the speed of the vessel. The values that may be received via the menus 58 and 60 may be preselected e.g. there may be a set of values for the speed of the vessel and corresponding percent of regen that may be selected via user input. In some implementations, the calibration values may be received as free text. The user interface 50 may present one or more of any type of features configured to receive user input indicating selection of the calibration values of the speed of the vessel and corresponding values of the amount or percentage of the regenerative braking power or regen. As one example, user input may be received indicating that at the speed of 4 knots the regen is 0% and at the speed of 6 knots the regen is 100%.

[0086] In some examples, the user interface 50 may present visual and/or other types of features that allow selection of calibration values in dependence on a type of the sails used for the vessel 10 and/or a sailing style used to operate the vessel. The user interface 50 may be configured to received user input regarding these features, so that different sailing styles and/or types of sails can be selected and different operation parameters can be selected for the vessel based on the sailing styles and/or types of sails.

[0087] In use, the calibrated regenerative braking function implemented by the regenerative braking system performs interpolation to automatically select an amount or percentage of the regenerative braking power based on actual or current values of the speed of the vessel and the angle of the apparent wind relative to the vessel. Any type of linear or non-linear interpolation may be used.

[0088] In some examples, a dependance of an amount or percentage of the regenerative braking power on a speed of the vessel and an angle of the wind relative to the vessel may be expressed as a three-dimensional model or surface having a three-dimensional profile and referred to as a 3D-surface model. FIG. 5 illustrates a visual representation of an example of a three-dimensional model or surface 500 that can be described as a function that takes a wind angle or the angle of the apparent wind relative to the boat or vessel and a speed of the vessel as input, and returns an amount or percentage of regenerative braking power shown as % regen in FIG. 5. The speed is shown in knots, the angle of the apparent wind relative to the vessel is shown in degrees, and the percentage of regenerative braking power is shown for ranges 0-20%, 20-40%, 40-60%, 60-80%, and 80-100%, with the ranges additionally shown on the right of the chart. The speed of the vessel may be expressed in other values. Also, the regenerative braking power may be expressed in other ways, as the representation shown in FIG. 5 is an example only.

[0089] The 3D-surface model 500 as shown in FIG. 5 may be stored in the storage medium 28 of the control system 18 and/or in another storage device. The model 500 may be stored in any suitable format, and the representation as in FIG. 5 is shown for illustrative purposes only. The 3D-surface model 500 may be stored as part of a user regenerative braking profile e.g. in the user profile module 25 as shown in FIGs. 1 and 2. Additionally or alternatively, the 3D-surface model 500 may be stored in the sails type/sailing style module 27 also shown in FIGs. 1 and 2.

[0090] In use, when the vessel is operated on the water, given a current speed of the vessel and the current angle of the apparent wind, the 3D-surface model 500 can be used to determine an amount of regenerative braking power to be applied by the regenerative system to the electric propulsion system of the vessel.

[0091] In some examples, a plurality of values of the vessel speed and the angle of the apparent wind relative to the vessel may be used to calibrate a regenerative braking function.

[0092] FIG. 6 illustrates an example of a user interface 50a, such as a user interface similar to the user interface 50 shown in FIG. 3, through which user input may be received comprising multiple values of the vessel speed and the angle of the apparent wind relative to the vessel, to calibrate a regenerative braking function. The user input may be described as first user input regarding a speed of the vessel and second user input regarding an angle of the apparent wind relative to the vessel. The first user input may comprise at least one first calibration value of a speed of the vessel set for a first regenerative braking power value of the regenerative braking power, and at least one second calibration value of a speed of the vessel set for a second regenerative braking power value of the regenerative braking power. The second user input may comprise at least one third calibration value of an angle of the apparent wind relative to the vessel set for a third

regenerative braking power value of the regenerative braking power, and at least one fourth calibration value of an angle of the apparent wind relative to the vessel set for a fourth regenerative braking power value of the regenerative braking power. The terms "first", "second", "third", and "fourth" are used for description purposes only and not to indicate any specific order.

[0093] As shown in FIG. 6, the first user input may comprise three vessel speed values, shown by way of example only as 4 knots, 4.5 knots, and 6 knots, received for 0%, 40%, and 100% of regenerative braking power, respectively. There may be one or more other speed values between the values of 4 knots and 4.5 knots, set for corresponding percent of the regenerative braking power. Any number, theoretically infinite, of vessel speed values and corresponding values of the amount or percent of the regenerative braking power may be received, as shown by three-dot symbols.

[0094] As also shown in FIG. 6, the second user input may be received with regard to a representation of the vessel 52a, comprising in this example four values for the angle of the apparent wind relative to the vessel, for example, 65 degrees, 80 degrees, 105 degrees, and 130 degrees, corresponding to 0%, 30%, 40%, and 100% of regenerative braking power, respectively. Any suitable number, theoretically infinite, of the angle of the apparent wind may be received, for example, with respect to a representation of a half-circle 55, to generate a user regenerative braking power profile.

[0095] Various interactive visual elements may be displayed in association with the representation of the vessel 52a, to enable the user to input desired values for the angle of the apparent wind relative to the vessel, for corresponding values of the regenerative braking power. The values of the regenerative braking power may be a set of selectable values, or the user may be enabled to enter desired values within an allowable range e.g. from 0% to 100%, or from a certain negative value to 100%.

[0096] FIG. 7 illustrates another example of a user interface 50a, comprising the representation 52a of the vessel, which is configured to receive user input comprising calibration values. In this example, it is shown that the regenerative braking power values do not need to be all increasing or decreasing consecutively. Thus, as shown in FIG. 7, four values for the angle of the apparent wind relative to the vessel may be received, e.g., 65 degrees, 80 degrees, 105 degrees, and 130 degrees, corresponding to 0%, 60%, 45%, and 100% of regenerative braking power, wherein the values of the regenerative braking power are not successively or consecutively increasing. The dependency between the angle of the apparent wind relative to the vessel and the regenerative braking power may follow a certain profile that meets user preferences regarding the boat's behavior.

[0097] FIG. 8 illustrates yet another example of a user interface 50a, comprising the representation of the vessel 52a, wherein the representation 52a is configured to receive user input comprising calibration values. In the example of FIG. 8, it is shown that calibration values of regenerative braking power, received from the user, may have negative values, i.e. values lower than 0%. Negative values of the regenerative braking power may be used to set that, in some circumstances, the power from the ESS may be directed to the electric motor to drive the vessel. The electric propulsion system 14 may thus receive an additional boost in certain vessel operating conditions as predetermined by the user. In some cases, at certain low speeds, the regenerative braking power may be set to negative values. For example, as shown in FIG. 8, at the vessel speed of 2 knots, a value of the regenerative braking power may be set to -20%, indicating that a percent-based boost may be given by the motor or the ESS to the electric propulsion system. As further shown by way of example only in FIG. 8, at the vessel speed of 3 knots, a value of the regenerative braking power may be set to 0%; and at the vessel speed of 5 knots, a value of the regenerative braking power may be set to 100%. Any suitable number of the calibration values may be selected. It should be appreciated that, as in other examples in this disclosure, these values are shown as examples only.

[0098] It should be noted that, even though FIGs. 6-8 illustrate that calibration values for the angle of the apparent wind relative to the vessel may be received with respect to the starboard side of the vessel, the user interface may include elements or features configured to receive calibration values for the angle of the apparent wind relative to the vessel with respect to the port side of the vessel. In some examples, the calibration values may be received with respect to both the starboard and port sides of the vessel. In some examples, the calibration values may be received without specific indication of the starboard side or the port side.

[0099] FIG. 9 illustrates an example of a process or method 900 for controlling operation of a sailing vessel e.g. vessel 10, in accordance with examples of the present disclosure. The vessel comprises electric propulsion system 14 configured to generate propulsive force to move the sailing vessel forward, and a regenerative braking system 20 configured to selectively convert kinetic energy of the sailing vessel, generated during application of a regenerative braking force onto the electric propulsion system, into electrical energy, for storing the electrical energy in electrical storage system (ESS) 16. The method 900 may be performed by a controller device or system such as e.g. control system 18 which may be installed on the vessel 10 or may be positioned remotely relative to the vessel 10. The processing circuitry 26 of the control system 18 may execute tangible computer-executable instruction stored a storage device, e.g. storage medium 28, to perform the method 900, in accordance with examples of the present disclosure.

[0100] The method 900 is performed, at least in part, when the regenerative braking system is operated in an automatic control mode. As discussed above, in some examples, the vessel and the regenerative braking system may be operated in the on mode in which the regenerative braking system is turned on and is not automatically controlled, in the off mode, or in

the automatic control mode. In some examples, the vessel and the regenerative braking system may be operated in the off mode or in the automatic control mode. In the automatic control mode, the amount of the applied regenerative braking power is adjusted automatically, based on the current vessel speed and the current the angle of the apparent wind relative to the vessel.

[0101] The regenerative braking system may be calibrated for operating in the automatic control mode, so that the automatic control is advantageously performed in accordance with user preferences regarding vessel's maneuverability and performance.

[0102] At **block S1**, the method 900 comprises calibrating a regenerative braking system of the vessel to be automatically controlled to apply a determined amount of regenerative braking power to the electric propulsion system.

The calibration may comprise receiving first user input regarding at least one first calibration value of a speed of the vessel set for a first regenerative braking power value of the regenerative braking power, and regarding at least one second calibration value of a speed of the vessel set for a second regenerative braking power value of the regenerative braking power. The calibration may also comprise receiving second user input regarding at least one third calibration value of an angle of the apparent wind relative to the vessel set for a third regenerative braking power value of the regenerative braking power, and regarding at least one fourth calibration value of an angle of the apparent wind relative to the vessel set for a fourth regenerative braking power value of the regenerative braking power.

[0103] In some examples, four limits or endpoints may be set, based on received user input, for desired regenerative braking power from the motor. In some examples, more than two calibration values are obtained for the vessel speed and the angle of the apparent wind relative to the vessel. The regeneration may be scaled depending on how fast the vessel is moving, and the regeneration may be further scaled by the angle of the apparent wind relative to the vessel. Thus, the user may be enabled to set up a boat speed where 100% regen will be activated and a boat speed where 0% regen will be activated, and missing values will be interpolated. The user may also be enabled to set an angle of the apparent wind angle where 100% regen will be used and an angle of the apparent wind where 0% regen will be used. Interpolated values for the regenerative braking power generated from the calibration values for the vessel speed may be combined in a suitable manner with interpolated values for the regenerative braking power generated from the calibration values for the angle of the apparent wind relative to the vessel. For example, the interpolated values may be multiplied, weighted and summed, averaged, or otherwise combined for controlling, in use, the regeneration power based on actual or current vessel speed and wind angle.

[0104] The calibration values may be received in advance, e.g., before the user operates the vessel. Also, the user may calibrate or recalibrate the regenerative braking function of the vessel during operation of the vessel.

[0105] The user input may be received via a display of the sailing vessel, e.g., display of input device 32 shown in FIG. 2 and/or via any other input device such as e.g. one or more knobs, buttons, joysticks, switches, pads or any other input devices. Additionally or alternatively, the user input may be received via a user device, e.g., portable device 34 shown in FIG. 2, configured to be communicatively coupled to the control system of the sailing vessel. The user input may be received via one or more of any suitable devices. The user input may be received to calibrate the regenerative braking system one or more times, e.g. multiple times. The user input may be stored, in some cases along with interpolated values, in a user regenerative braking profile e.g. in user profile module 25 configured to store user regenerative braking profiles for one or more users. The user regenerative braking profile may also store information identifying the user, as well as any other information related to operation of the vessel and that may be set based on user input. The user regenerative braking profile may be stored in the format such that it is accessible to the user upon receiving user credentials comprising any suitable identification information. The user regenerative braking profile may be stored as part of a user profile comprising various other information related to user preferences regarding operation of the vessel and other functions.

[0106] In some examples, the method 900 may be implemented, at least in part, as an application or an app. The user may be enabled to access the app, e.g., via the user's portable device 34 or other computer device, to set or modify user preferences, view a status of the vessel, view related parameters e.g. the current speed, the angle of the apparent wind, and other parameters.

[0107] Two or more calibration values for the speed of the vessel and two or more calibration values for the angle of the apparent wind relative to the vessel, or briefly the angle of the apparent wind, may be set for respective the same or different regenerative braking power values. For example, in some examples, the calibration values of the vessel speed and the angle of the apparent wind may be set for two endpoints such as a minimum regenerative braking power of 0% and a maximum regenerative braking power of 100%. The calibration values of the vessel speed and the angle of the apparent wind may be set for any suitable number of regenerative braking power values.

[0108] Thus, in some examples, more than two calibration values for each of the vessel speed and the angle of the apparent wind relative to the vessel may be received, as shown in the examples of FIGs. 4, 6, 7, and 8. Furthermore, as shown in FIG. 8, in some cases, calibration values may be received for negative values of the regenerative braking power i.e. below 0%, indicating that a boost to the electric propulsion system may be automatically performed based on the user settings.

[0109] The control system may receive user input, referred to herein as the first user input, regarding at least two

calibration values of the speed of the vessel set for respective regenerative braking power values. For example, FIG. 6 shows calibration values of the speed of the vessel such as 4 knots, 4.5 knots, and 6 knots, set for values of 0%, 10%, and 100% of regenerative braking power, respectively. FIGs. 4, 6, 7, and 8 also illustrate that the control system may receive user input, referred to herein as the second user input, regarding at least two calibration values of the angle of the apparent wind relative to the vessel set for respective regenerative braking power values. The control system 18 may interpolate values for the regenerative braking power that should be applied for various vessel speed and angle of the apparent wind values.

[0110] In some examples, the calibration of the regenerative braking system may comprise generating one or more interpolated values of the regenerative braking power using the at least one first calibration value set for the first regenerative braking power value, the at least one second calibration value set for the second regenerative braking power value, the at least one third calibration value set for the third regenerative braking power value, and the at least one fourth calibration value set for the fourth regenerative braking power value.

[0111] The control system 18 e.g. the processing circuitry 26 may use various interpolation techniques that involve using the calibration values received for corresponding regenerative braking power values to estimate unknown values of the regenerative braking power for other values of the vessel speed and angle of the apparent wind relative to the vessel. Any type of linear or non-linear interpolation may be used. Non-limiting examples of interpolation techniques include linear interpolation, nearest-neighbor approach, piecewise constant interpolation, polynomial interpolation, spline interpolation, and mimetic interpolation. In some examples, linear interpolation is used.

[0112] In some examples, the method 900 comprises using the one or more interpolated values, along with the calibration values, to generate a 3D-surface model representing dependence of a value of the regenerative braking power on values of the speed of the vessel and the angle of the apparent wind relative to the vessel. An example of a visual representation 500 of the 3D-surface model is shown in FIG. 5.

[0113] The one or more interpolated values may be generated by combining the calibration values with actual, measured values of the speed of the vessel and the angle of the apparent wind, as discussed below.

[0114] The processing at block S1, comprising calibrating a regenerative braking system of the vessel to be automatically controlled in dependence on the current speed of the vessel and the current angle of the apparent wind, may be performed in advance i.e. before the vessel is operated in water. Also, in some cases, the calibration may be performed during operation of the vessel.

[0115] At block S2, the control system 18 receives measurements from a wind sensor coupled to the vessel to determine the current angle of the apparent wind relative to the vessel. For example, wind sensor 24 shown in FIG. 1 may be used. Measurements acquired by other sensors, e.g., the sensor 23, may additionally be used to determine the current angle of the apparent wind relative to the vessel.

[0116] At block S3, the control system 18 measures or determines the current speed of the vessel. The current speed of the vessel may be determined from measurements acquired by a suitable speed sensing device e.g. speed sensor 22 shown in FIG. 1. The speed sensing device may be configured to perform measurements of the speed of the vessel over the ground and/or measurements of the speed of the vessel through the water. The speed sensing device may use the GPS and/or another technology to determine the current speed of the vessel over the ground. The speed sensing device, which may be configured to measure the speed of the vessel through the water may comprise one or more Doppler-based sensors, electromagnetic sensors, and/or other type of sensors.

[0117] It should be noted that the measurements of the angle of the apparent wind relative to the vessel and the measurements of the vessel's speed may be determined simultaneously or in any suitable order.

[0118] At block S4, the control system 18 determines, based on the angle of the apparent wind relative to the vessel and the current speed of the vessel, an amount of regenerative braking power to be applied by the regenerative braking system to the electric propulsion system of the vessel. In some examples, the determining may be performed by combining the current angle of the apparent wind relative to the vessel, the current speed of the vessel, the at least one first calibration value set for the first regenerative braking power value, the at least one second calibration value set for the second regenerative braking power value, the at least one third calibration value set for the third regenerative braking power value, and the at least one fourth calibration value set for the fourth regenerative braking power value.

[0119] The combining may be performed in any suitable manner. In some examples, a first amount of regenerative braking power may be calculated using the current speed of the vessel, the at least one first calibration value of a speed of the vessel set for the first regenerative braking power value of the regenerative braking power, and the at least one second calibration value of a speed of the vessel set for a second regenerative braking power value of the regenerative braking power. A second amount of regenerative braking power may be calculated using the current angle of the apparent wind relative to the vessel, the at least one third calibration value of an angle of the apparent wind relative to the vessel set for the third regenerative braking power value of the regenerative braking power, and the at least one fourth calibration value of an angle of the apparent wind relative to the vessel set for the fourth regenerative braking power value of the regenerative braking power. The calculated first and second amounts or values of the regenerative braking power may be combined in a suitable manner. Non-limiting examples of combining the calculated first and second amounts comprises multiplying the

values, taking a mean value of the first and second amounts, and taking a minimum value of the first and second amounts.

[0120] In some examples, the calculated first and second amounts or values of the regenerative braking power may be weighted and summed. In some examples, the weights may be certain default settings and/or they may be automatically selected. In some examples, the weights may be set based on user input which may be received via a user interface e.g. user interface 50, 50a or any other suitable user interface. The weights may be set in any other ways, including using a combination of ways.

[0121] As an example, a regenerative braking function of the vessel may have been calibrated by setting a vessel speed of 2 knots for 0% regen and 8 knots for 100% regen, and setting an apparent wind angle (relative to the vessel) of 30 degrees for 0% and 90 degrees for 100%. If the vessel is traveling at a current speed of 4 knots with the angle of the apparent wind is determined to be 60 degrees, when linear interpolation is used, a first amount of regenerative braking power may be calculated as follows based on the vessel speed:

$$(4-2) / (8-2) * (0\%-100\%) \approx 33\% \quad (1)$$

[0122] A second amount of regenerative braking power may be calculated as follows based on the angle of the apparent wind relative to the vessel:

$$(60-30) / (90-30) * (0-100\%) = 50\% \quad (2)$$

[0123] And the amount of regenerative braking power may be calculated as follows, by multiplying the first amount calculated in (1) and the second amount calculated in (2):

$$0.33 * 0.5 = 16.5\% \quad (3)$$

[0124] Thus, the first amount of regenerative braking power may be scaled using the second amount of regenerative braking power. The first and second amounts or values of regenerative braking power may be combined in any other suitable manner. For example, the first and second amounts or values of regenerative braking power may be weighted and summed, or averaged. In some examples, a smallest value of the first and second amounts of regenerative braking power may be applied to the electric propulsion system. In some examples, a highest value of the first and second amounts of regenerative braking power may be applied to the electric propulsion system.

[0125] In some examples, determining the amount of regenerative braking power to be applied by the regenerative braking system to the electric propulsion system of the vessel may be performed by using the 3D-surface model. Thus, given the current speed and the current wind angle, the 3D-surface model can be used to look up a desired regenerative braking function. For example, the 3D model as shown in FIG. 5 may be used, where the height of the surface represents a desired current amount of the regenerative braking power, mapped to the vessel speed and the wind angle.

[0126] In some examples, the control system 18 may automatically detect a type of sails used for the vessel 10, and the amount of regenerative braking power to be applied by the regenerative braking system may be adjusted based on the type of the sails.

[0127] At **block S5**, the control system 18 automatically controls the regenerative braking system to apply the determined amount of regenerative braking power to the electric propulsion system. Thus, the control system 18 automatically controls the regenerative braking power based on the current speed of the vessel and the current angle of the apparent wind relative to the vessel. The braking force applied to the electric propulsion system by the electric motor, as controlled by the regenerative braking system, thus varies depending on the vessel speed and the wind angle.

[0128] In some examples, the determined amount of regenerative braking power, e.g., as a percentage of the regenerative braking power or another type of value, may be provided to a controller such as e.g. the motor controller 13 that converts the percentage or another value to one or more control parameters that can be used to control the motor and the propeller. The parameters may comprise rotations per minute (RPM) of the propeller, RPM of the motor, a torque, current setpoint for the motor, and/or one or more other parameters.

[0129] In some examples, a regulator may be used that assists the propeller in attaining an amount of the regenerative braking power that is close to the determined amount of regenerative braking power. In some examples, a Maximum Power Point Tracking (MPPT) technique may be employed to keep the load on the propeller at the right level for the efficient transfer of power from the propeller to the ESS.

[0130] In some examples, the RPM of the propeller and/or the RPM of the motor are controlled to achieve the determined amount of regenerative braking power.

[0131] In some examples, the determined amount of regenerative braking power is applied in a similar manner to one or more propulsion systems of the vessel 10. For example, a driveline in the vessel 10, which transfers power from the electric motor to the propeller, may be controlled in dependence on the determined amount of regenerative braking power.

[0132] In some examples, the electric propulsion system may comprise two or more electric propulsion systems. In some examples, automatically controlling the regenerative braking system may comprise applying a first portion of the determined amount of regenerative braking power to one of the electric propulsion systems and applying a second portion of the determined amount of regenerative braking power to at least one another of the electric propulsion systems.

[0133] In some examples, e.g. in implementations in which the vessel 10 comprises a propulsion system on the starboard side and a propulsion system on the port side, the determined amount of regenerative braking power may be different between the propulsion systems. For example, the regenerative braking power may be scaled between the port propulsion system and the starboard propulsion system, by using the apparent wind angle. As one example, if the determined amount of regenerative braking power is 50% and the current wind is from the port side, the determined amount of regenerative braking power may be split e.g. 45% to the motor of the port side propulsion system and 55% to the motor of the starboard side propulsion system. The regenerative braking power may be divided in any other suitable manner between two or more propulsion systems that may be included in the vessel 10. In some examples, the method 900 is performed when the regenerative braking system is operated in the automatic control mode. For example, the control system may receive user input instructing the regenerative braking system to be operated in the automatic control mode. In some examples, at least the determining, as performed at block S4, and the automatic controlling, as performed at block S5, are performed when the regenerative braking system is operated in the automatic control mode.

[0134] The process 900 may be performed repeatedly as the vessel is operated in water and the regenerative braking system is operated in the automatic control mode. Thus, as new measurements of the speed and the angle of the apparent wind are acquired as the vessel is sailed through the water, the amount of regenerative braking power to be applied to the electric propulsion system of the vessel may be recalculated based on the acquired measurements and based on previously received calibration values. The method 900 may be performed until the control system receives user input to deactivate the automatic control mode of the regenerative braking system or until the vessel docks.

[0135] The techniques in accordance with the present disclosure advantageously allow regeneratively harvesting energy from the sailing vessel while keeping the change in the vessel's dynamics at a minimum. Thus, the vessel may be controlled to operate in the manner that does not prompt the user to turn the regenerative braking system off. Rather, the regenerative braking system may remain active or on, and the amount of regenerative power is varied automatically.

[0136] It should be appreciated that, even though the present disclosure describes controlling the regenerative braking power, in addition or alternatively, a propeller speed or a torque applied to a propeller shaft may be controlled in a similar manner, based on the vessel speed and the angle of the apparent wind relative to the vessel.

[0137] FIG. 10 is a schematic diagram of a computer system 1000 for implementing examples disclosed herein. A control system e.g. control system 18 may be implemented as the computer system 1000. The computer system 1000 is adapted to execute instructions from a computer-readable medium to perform these and/or any of the functions or processing described herein. The computer system 1000 may be connected (e.g., networked) to other machines in a LAN, an intranet, an extranet, or the Internet. While only a single device is illustrated, the computer system 1000 may include any collection of devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. Accordingly, any reference in the disclosure and/or claims to a computer system, computing system, computer device, computing device, control system, control unit, electronic control unit (ECU), processor device, processing circuitry, etc., includes reference to one or more such devices to individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. For example, control system may include a single control unit or a plurality of control units connected or otherwise communicatively coupled to each other, such that any performed function may be distributed between the control units as desired. Further, such devices may communicate with each other or other devices by various system architectures, such as directly or via a Controller Area Network (CAN) bus, etc.

[0138] The computer system 1000 may comprise at least one computing device or electronic device capable of including firmware, hardware, and/or executing software instructions to implement the functionality described herein. The computer system 1000 may include processing circuitry 1002 (e.g., processing circuitry including one or more processor devices or control units), a memory 1004, and a system bus 1006. The computer system 1000 may include at least one computing device having the processing circuitry 1002. The system bus 1006 provides an interface for system components including, but not limited to, the memory 1004 and the processing circuitry 1002. The processing circuitry 1002 may include any number of hardware components for conducting data or signal processing or for executing computer code stored in memory 1004. The processing circuitry 1002 may, for example, include a general-purpose processor, an application specific processor, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a circuit containing processing components, a group of distributed processing components, a group of distributed computers configured for processing, or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. The

processing circuitry **1002** may further include computer executable code that controls operation of the programmable device.

[0139] The system bus **1006** may be any of several types of bus structures that may further interconnect to a memory bus (with or without a memory controller), a peripheral bus, and/or a local bus using any of a variety of bus architectures. The memory **1004** may be one or more devices for storing data and/or computer code for completing or facilitating methods described herein. The memory **1004** may include database components, object code components, script components, or other types of information structure for supporting the various activities herein. Any distributed or local memory device may be utilized with the systems and methods of this description. The memory **1004** may be communicably connected to the processing circuitry **1002** (e.g., via a circuit or any other wired, wireless, or network connection) and may include computer code for executing one or more processes described herein. The memory **1004** may include non-volatile memory **1008** (e.g., read-only memory (ROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), etc.), and volatile memory **1010** (e.g., random-access memory (RAM)), or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a computer or other machine with processing circuitry **1002**. A basic input/output system (BIOS) **1012** may be stored in the non-volatile memory **1008** and can include the basic routines that help to transfer information between elements within the computer system **1000**.

[0140] The computer system **1000** may further include or be coupled to a non-transitory computer-readable storage medium such as the storage device **1014**, which may comprise, for example, an internal or external hard disk drive (HDD) (e.g., enhanced integrated drive electronics (EIDE) or serial advanced technology attachment (SATA)), HDD (e.g., EIDE or SATA) for storage, flash memory, or the like. The storage device **1014** and other drives associated with computer-readable media and computer-usable media may provide non-volatile storage of data, data structures, computer-executable instructions, and the like.

[0141] Computer-code which is hard or soft coded may be provided in the form of one or more modules. The module(s) can be implemented as software and/or hard-coded in circuitry to implement the functionality described herein in whole or in part. The modules may be stored in the storage device **1014** and/or in the volatile memory **1010**, which may include an operating system **1016** and/or one or more program modules **1018**. All or a portion of the examples disclosed herein may be implemented as a computer program **1020** stored on a transitory or non-transitory computer-usable or computer-readable storage medium (e.g., single medium or multiple media), such as the storage device **1014**, which includes complex programming instructions (e.g., complex computer-readable program code) to cause the processing circuitry **1002** to carry out actions described herein. Thus, the computer-readable program code of the computer program **1020** can comprise software instructions for implementing the functionality of the examples described herein when executed by the processing circuitry **1002**. In some examples, the storage device **1014** may be a computer program product (e.g., readable storage medium) storing the computer program **1020** thereon, where at least a portion of a computer program **1020** may be loadable (e.g., into a processor) for implementing the functionality of the examples described herein when executed by the processing circuitry **1002**. The processing circuitry **1002** may serve as a controller or control system for the computer system **1000** that is to implement the functionality described herein.

[0142] The computer system **1000** may include an input device interface **1022** configured to receive input and selections to be communicated to the computer system **1000** when executing instructions, such as from a keyboard, mouse, touch-sensitive surface, etc. Such input devices may be connected to the processing circuitry **1002** through the input device interface **1022** coupled to the system bus **1006** but can be connected through other interfaces, such as a parallel port, an Institute of Electrical and Electronic Engineers (IEEE) 1394 serial port, a Universal Serial Bus (USB) port, an IR interface, and the like. The computer system **1000** may include an output device interface **1024** configured to forward output, such as to a display, a video display unit (e.g., a liquid crystal display (LCD) or a cathode ray tube (CRT)). The computer system **1000** may include a communications interface **1026** suitable for communicating with a network as appropriate or desired.

[0143] The operational actions described in any of the exemplary aspects herein are described to provide examples and discussion. The actions may be performed by hardware components, may be embodied in machine-executable instructions to cause a processor to perform the actions, or may be performed by a combination of hardware and software. Although a specific order of method actions may be shown or described, the order of the actions may differ. In addition, two or more actions may be performed concurrently or with partial concurrence.

[0144] 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, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0145] 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.

[0146] 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.

[0147] 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.

[0148] 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 inventive concepts being set forth in the following claims.

Claims

1. A method for controlling operation of a sailing vessel, the method comprising:

receiving (S2) measurements acquired by a wind sensor coupled to the vessel, to determine a current angle of an apparent wind relative to the vessel;
determining (S3) a current speed of the vessel;
determining (S4), based on the current angle of the apparent wind relative to the vessel and the current speed of the vessel, an amount of regenerative braking power to be applied by a regenerative braking system to an electric propulsion system of the vessel, the regenerative braking system being configured to selectively convert kinetic energy of the vessel into electrical energy; and
automatically controlling (S5) the regenerative braking system to apply the determined amount of regenerative braking power to the electric propulsion system.

2. The method of claim 1, comprising calibrating (S1) the regenerative braking system to be automatically controlled to apply the determined amount of regenerative braking power to the electric propulsion system.

3. The method of claim 2, wherein the calibrating (S1) comprises:

receiving first user input regarding at least one first calibration value of a speed of the vessel set for a first regenerative braking power value of the regenerative braking power, and regarding at least one second calibration value of a speed of the vessel set for a second regenerative braking power value of the regenerative braking power; and
receiving second user input regarding at least one third calibration value of an angle of the apparent wind relative to the vessel set for a third regenerative braking power value of the regenerative braking power, and regarding at least one fourth calibration value of an angle of the apparent wind relative to the vessel set for a fourth regenerative braking power value of the regenerative braking power.

4. The method of claim 3, wherein the determining (S4) is performed by combining the current angle of the apparent wind relative to the vessel, the current speed of the vessel, the at least one first calibration value set for the first regenerative braking power value, the at least one second calibration value set for the second regenerative braking power value, the at least one third calibration value set for the third regenerative braking power value, and the at least one fourth calibration value set for the fourth regenerative braking power value.

5. The method of claim 3, wherein the calibrating (S1) comprises:
generating one or more interpolated values of a regenerative braking power using the at least one first calibration value set for the first regenerative braking power value, the at least one second calibration value set for the second

regenerative braking power value, the at least one third calibration value set for the third regenerative braking power value, and the at least one fourth calibration value set for the fourth regenerative braking power value.

6. The method of claim 5, comprising using the one or more interpolated values to generate a 3D-surface model representing dependance of a value of the regenerative braking power on values of the speed of the vessel and the angle of the apparent wind relative to the vessel, wherein the determining (S4) is performed by using the 3D-surface model.

7. The method of any one of claims 2 to 6, wherein the user input is received via a display of the sailing vessel and/or via a user device configured to be communicatively coupled to a control system of the sailing vessel.

8. The method of any one of claims 1 to 7, wherein at least the determining (S4) and the controlling (S5) are performed when the regenerative braking system is operated in an automatic control mode.

9. A computer program product comprising program code for performing, when executed by processing circuitry, the method of any one of claims 1 to 8.

10. A non-transitory computer-readable storage medium comprising computer-executable instructions which, when executed by processing circuitry, cause the processing circuitry to perform the method of any one of claims 1 to 8.

11. A control system (18) configured to control operation of a sailing vessel, the control system (18) comprising processing circuitry (26) that is configured to perform a method in accordance with any one of claims 1 to 8.

12. A sailing vessel (10) comprising:

an electric propulsion system (14) configured to generate propulsive force to move the sailing vessel (10) forward; a regenerative braking system (20) configured to selectively convert kinetic energy of the sailing vessel, generated during application of a regenerative braking force onto the electric propulsion system, into electrical energy, for storing the electrical energy in an electrical storage system (ESS); and a control system (18) comprising a processing circuitry (26) that is configured to:

receive measurements acquired by wind sensor coupled to the vessel to, determine a current angle of an apparent wind relative to the vessel; determine a current speed of the vessel; determine, based on the current angle of the apparent wind relative to the vessel and the current speed of the vessel, an amount of regenerative braking power to be applied by a regenerative braking system to an electric propulsion system of the vessel; and automatically control the regenerative braking system to apply the determined amount of regenerative braking power to the electric propulsion system.

13. The sailing vessel of claim 12, wherein the processing circuitry is configured to calibrate the regenerative braking system to be automatically controlled to apply the determined amount of regenerative braking power to the electric propulsion system.

14. The sailing vessel of claim 13, wherein the calibration comprises:

receiving first user input regarding at least one first calibration value of a speed of the vessel set for a first regenerative braking power value of the regenerative braking power, and regarding at least one second calibration value of a speed of the vessel set for a second regenerative braking power value of the regenerative braking power; and receiving second user input regarding at least one third calibration value of an angle of the apparent wind relative to the vessel set for a third regenerative braking power value of the regenerative braking power, and regarding at least one fourth calibration value of an angle of the apparent wind relative to the vessel set for a fourth regenerative braking power value of the regenerative braking power.

15. The sailing vessel of claim 14, wherein the calibration comprises:

generating one or more interpolated values of a regenerative braking power using the at least one first calibration

value set for the first regenerative braking power value, the at least one second calibration value set for the second regenerative braking power value, the at least one third calibration value set for the third regenerative braking power value, and the at least one fourth calibration value set for the fourth regenerative braking power value; and using the one or more interpolated values to generate a 3D-surface model representing dependance of a value of the regenerative braking power on values of the speed of the vessel and the angle of the apparent wind relative to the vessel,
wherein the determining (S4) is performed by using the 3D-surface model.

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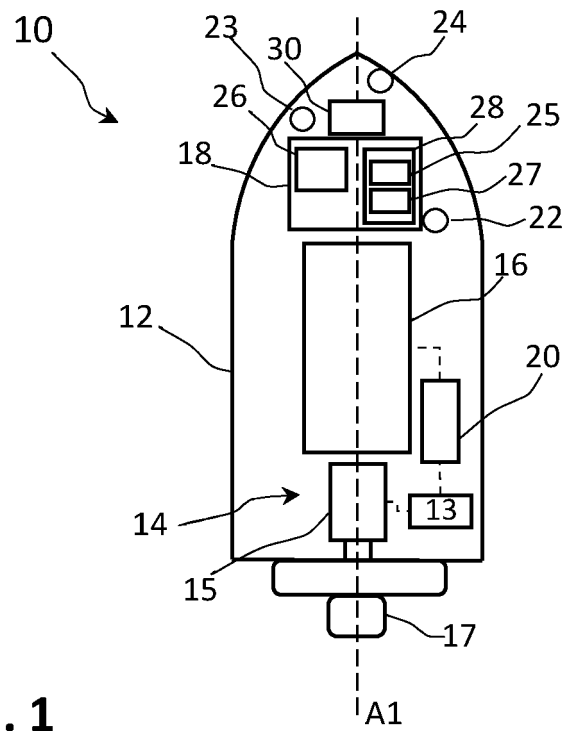


FIG. 1

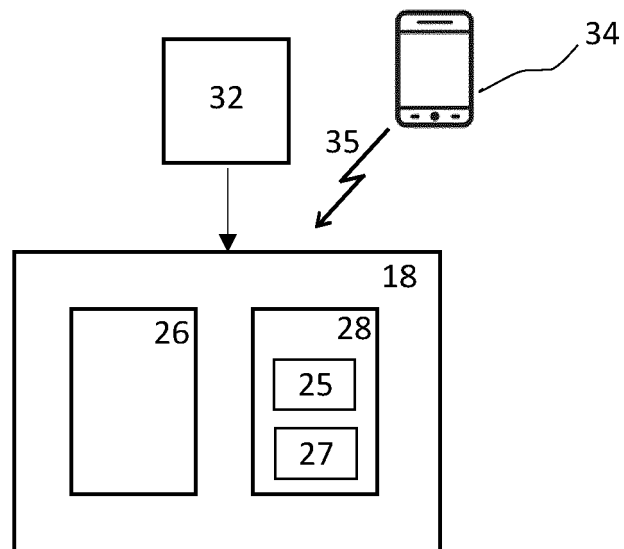


FIG. 2

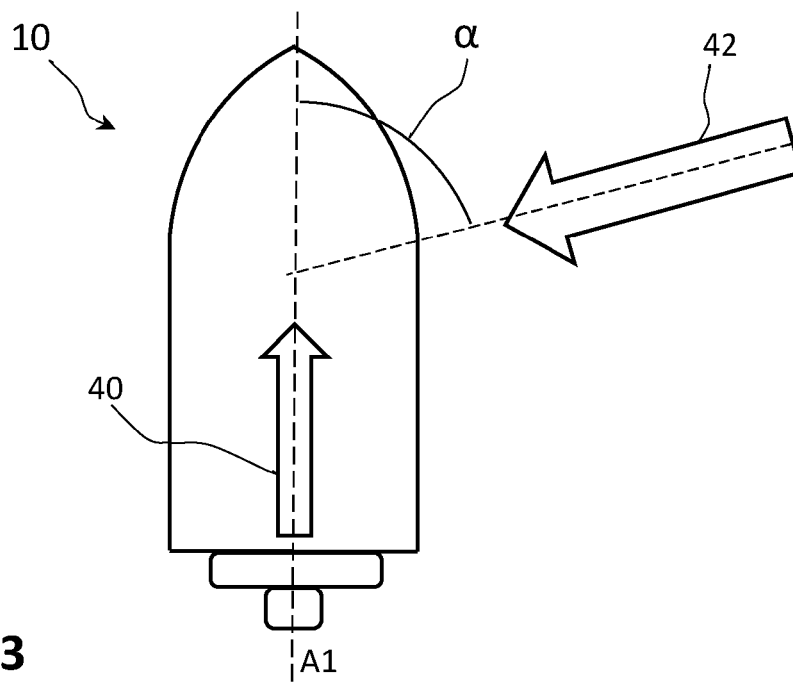


FIG. 3

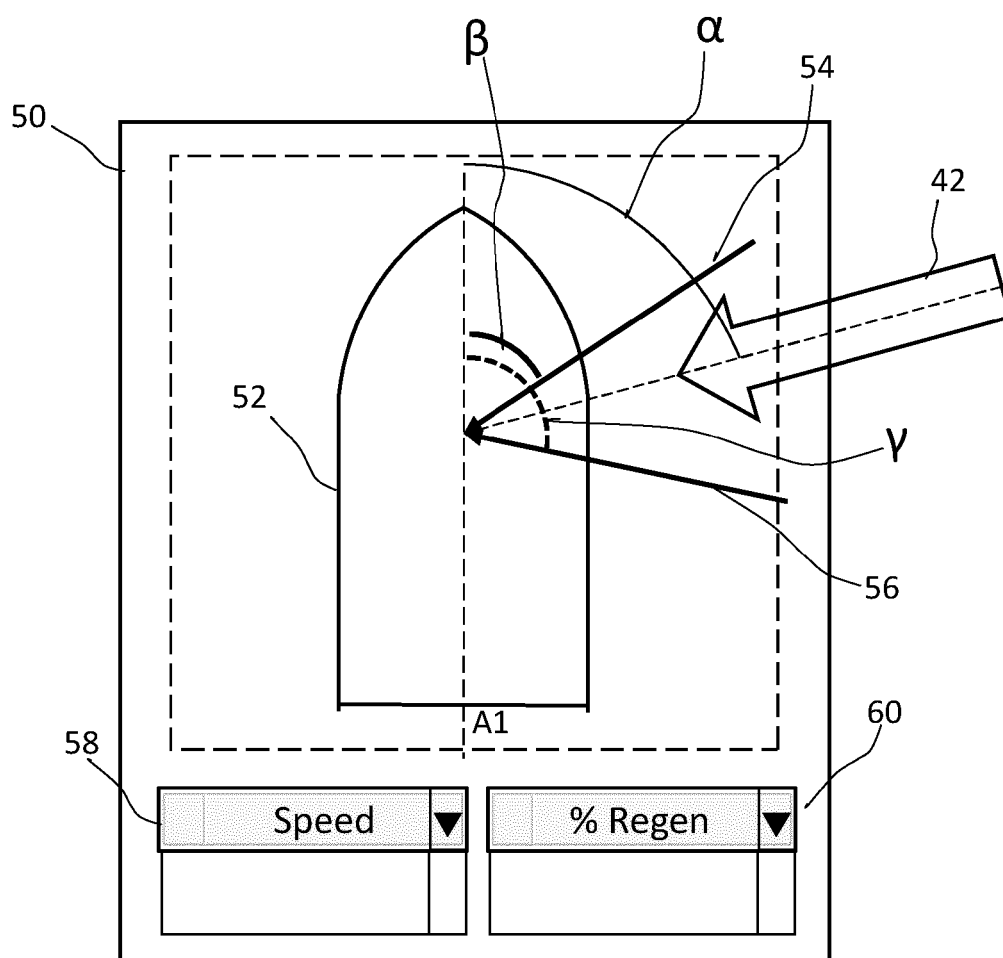


FIG. 4

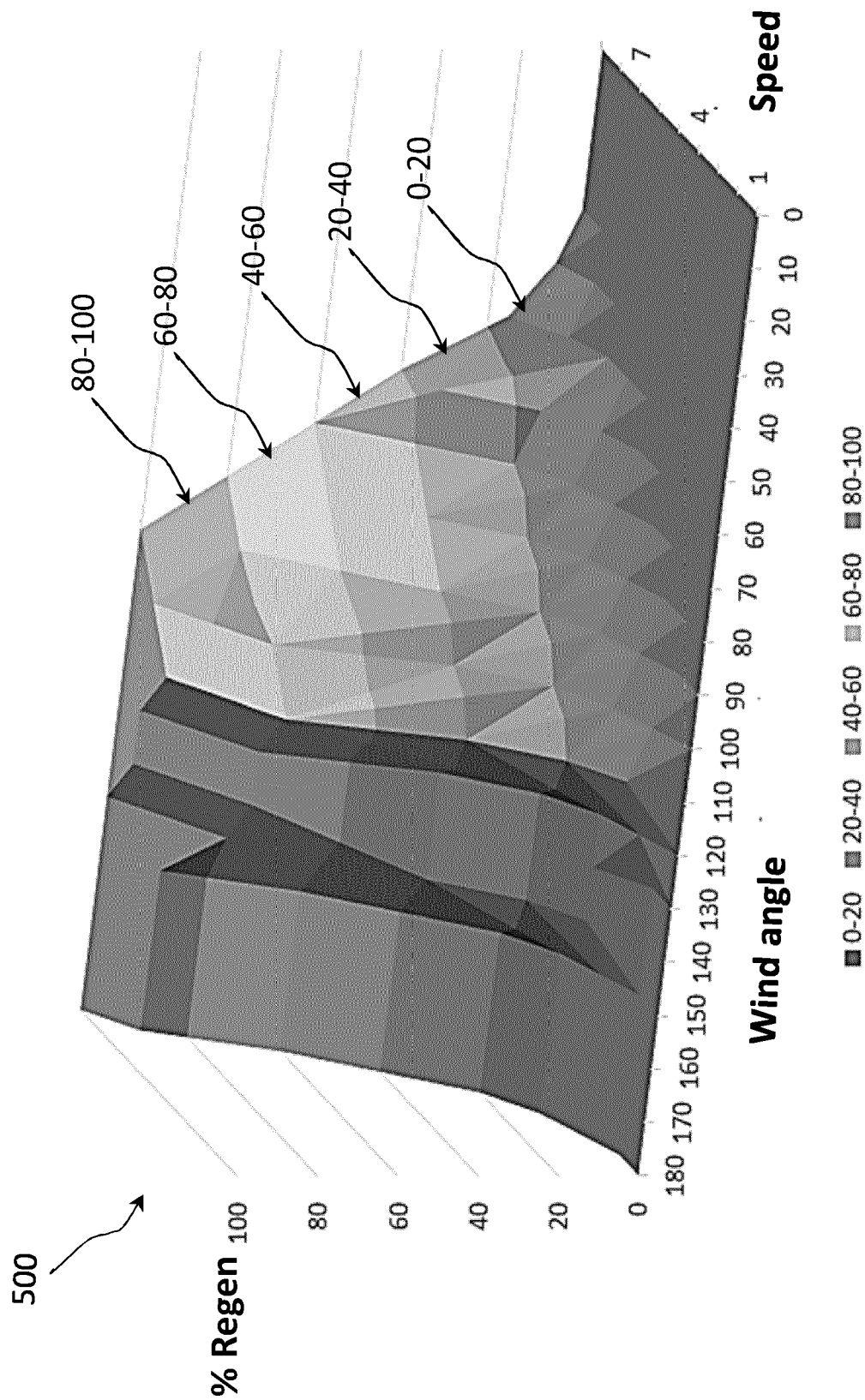


FIG. 5

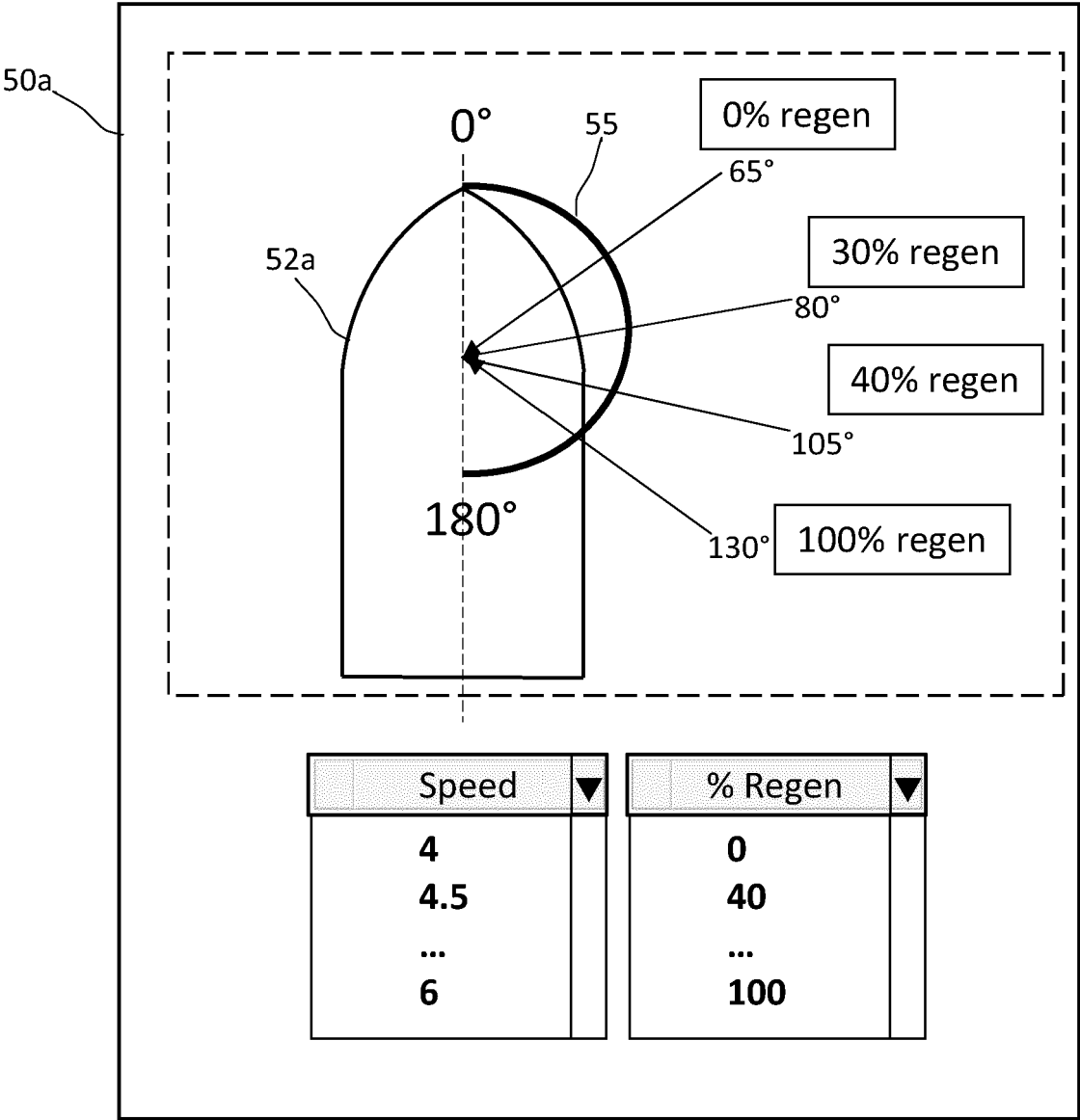


FIG. 6

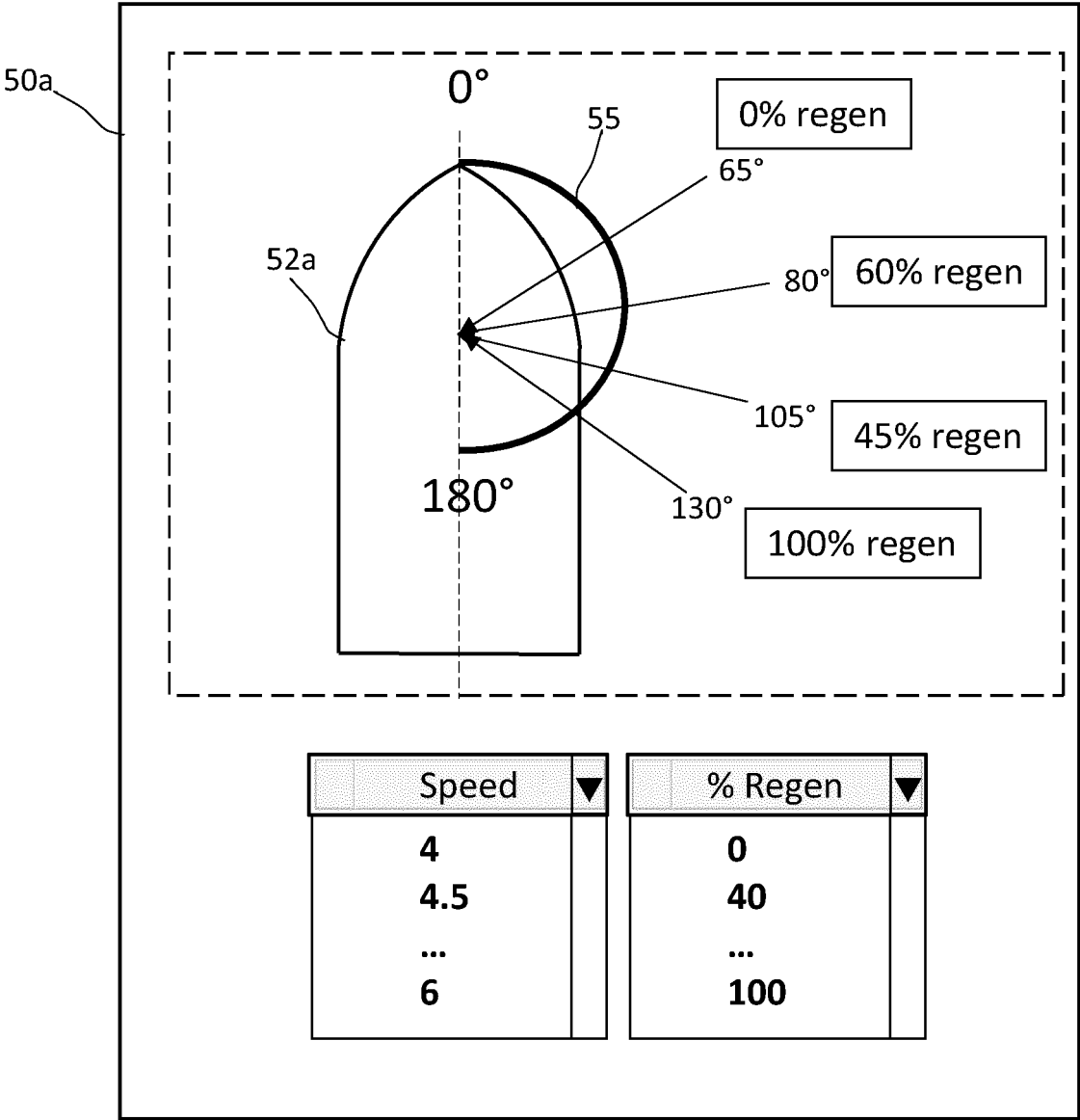


FIG. 7

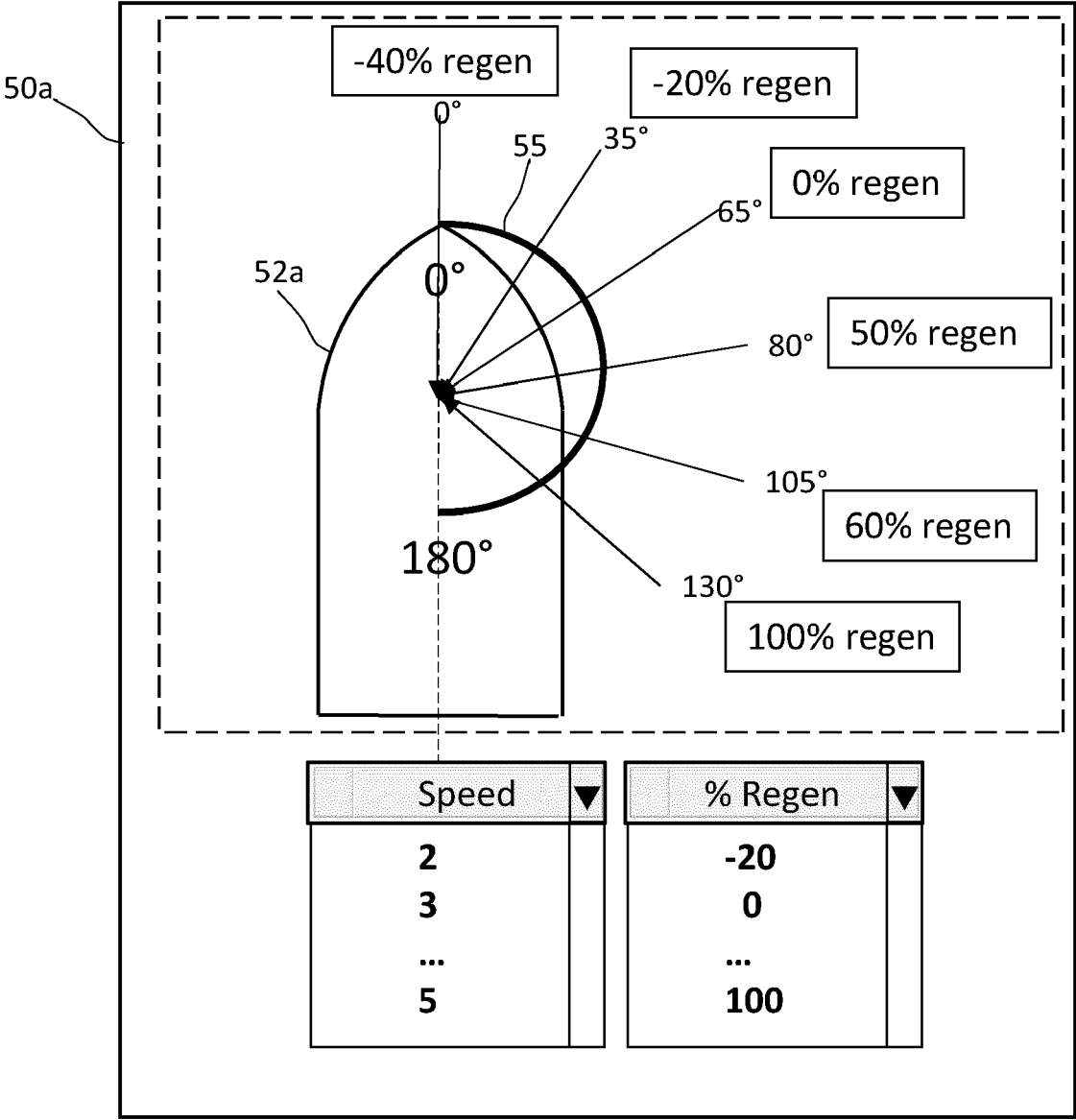


FIG. 8

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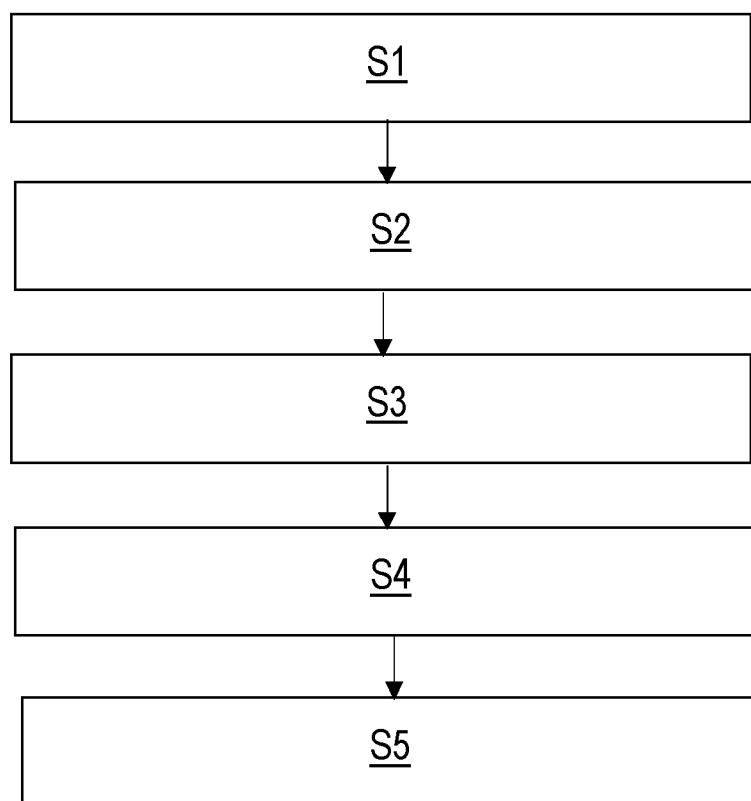


FIG. 9

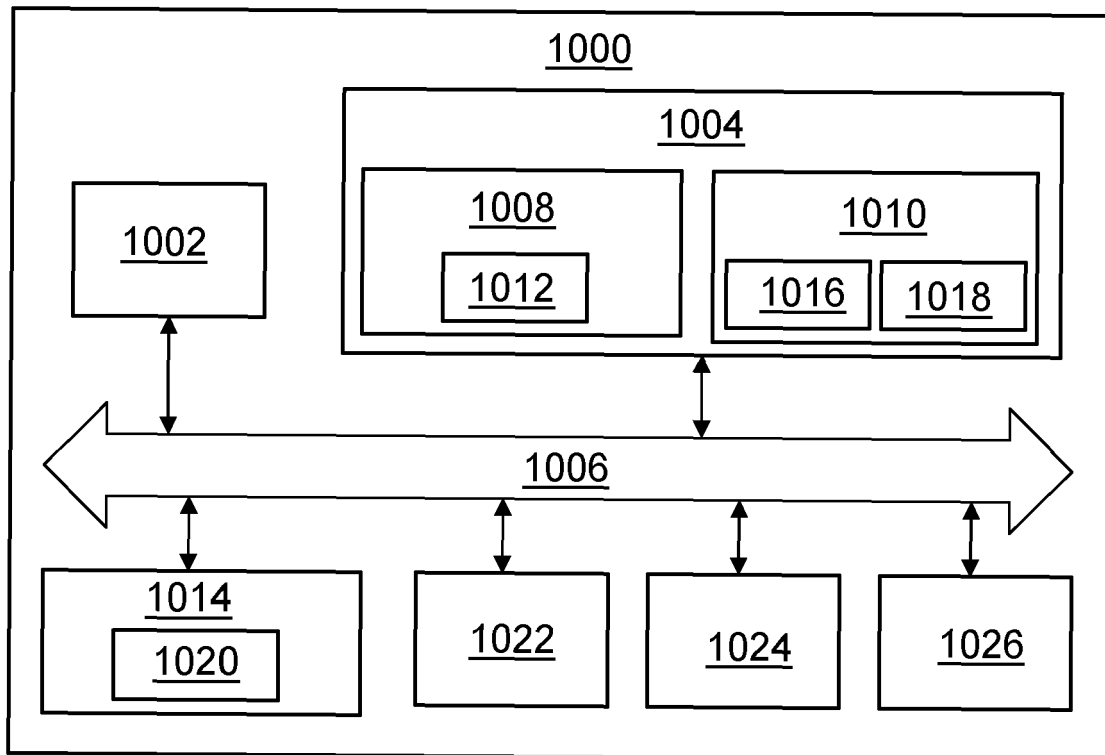


FIG. 10



EUROPEAN SEARCH REPORT

Application Number

EP 24 18 9043

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	US 7 482 767 B2 (SOLOMON TECHNOLOGIES INC [US]) 27 January 2009 (2009-01-27) * column 12, line 17 - column 18, line 15; claims; figures *	1-15	INV. B63H19/04 B63H21/17 B63H21/21 B63H23/24
A	US 2020/239118 A1 (RAJ ANIL [US]) 30 July 2020 (2020-07-30) * claim 1; figures *	1-15	
A	WO 2021/099335 A1 (SHIP MOTION GROUP B V [NL]) 27 May 2021 (2021-05-27) * paragraphs [0045] - [0048]; figures *	1	
A	WO 2024/100275 A1 (SEADRIVE AS [NO]) 16 May 2024 (2024-05-16) * claim 1 *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			B63H
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		24 January 2025	Knoflachner, Nikolaus
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention 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			

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 24 18 9043

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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24-01-2025

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 7482767 B2	27-01-2009	AU 2005210624 A1	18-08-2005
		CA 2554690 A1	18-08-2005
		US 2006175996 A1	10-08-2006
		WO 2005075234 A2	18-08-2005

US 2020239118 A1	30-07-2020	US 2020239118 A1	30-07-2020
		US 2022242539 A1	04-08-2022

WO 2021099335 A1	27-05-2021	EP 4061701 A1	28-09-2022
		NL 2024257 B1	29-07-2021
		WO 2021099335 A1	27-05-2021

WO 2024100275 A1	16-05-2024	NO 20221209 A1	13-05-2024
		WO 2024100275 A1	16-05-2024

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