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(54) **SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM FOR ENERGY EXTRACTING VESSEL NAVIGATION**

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(52) **U.S. Cl.**
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(58) **Field of Classification Search**
USPC 701/2, 21, 468, 482, 484; 290/53, 54, 290/55
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,335,093 A 6/1982 Salomon
4,546,718 A 10/1985 Schwarz
5,007,285 A * 4/1991 Dahlen et al. 73/170.04
5,027,735 A 7/1991 Labrador
6,508,191 B1 1/2003 Spoljaric

(Continued)

FOREIGN PATENT DOCUMENTS

GB 2286570 A 8/1995
GB 2365385 A 2/2002

(Continued)

OTHER PUBLICATIONS

Office Action for Japanese Appl. No. 2010-534105, dated Oct. 23, 2012, in 9 pages.

(Continued)

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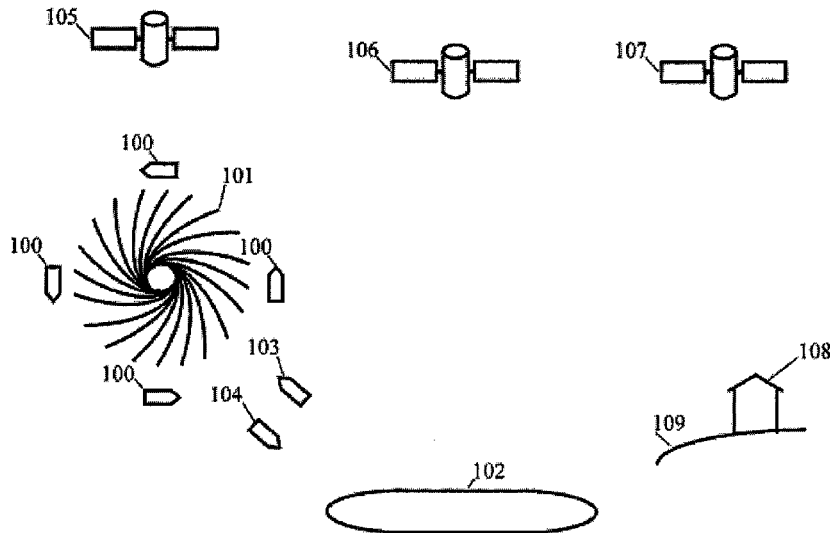
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(57) **ABSTRACT**

A Supervisory Control And Data Acquisition (SCADA) system guides navigation of a vessel enabled to extract energy from wind and/or water currents primarily in offshore marine environments. An exemplary SCADA system embodies server and client software applications running on microprocessor systems at a remote control central service logging and energy distribution facility, and the vessel itself.

20 Claims, 2 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

7,098,846 B2 8/2006 Nielsen et al.
 7,298,056 B2 11/2007 Gizara
 7,453,164 B2 11/2008 Borden et al.
 7,816,802 B2* 10/2010 Green 290/55
 7,948,108 B2* 5/2011 Peralta 290/54
 7,962,251 B2* 6/2011 Gizara et al. 701/2
 8,221,051 B2* 7/2012 Brown 415/3.1
 2003/0080245 A1 5/2003 Greenberg
 2003/0201645 A1* 10/2003 Pacheco 290/54
 2004/0105411 A1 6/2004 Boatwright et al.
 2005/0005093 A1 1/2005 Bartels et al.
 2005/0228553 A1 10/2005 Tryon
 2006/0162642 A1 7/2006 Morse
 2007/0046028 A1 3/2007 Gizara
 2008/0162085 A1 7/2008 Clayton et al.
 2008/0272605 A1 11/2008 Borden et al.
 2009/0073034 A1 3/2009 Lin
 2009/0128402 A1 5/2009 Altenschulte

FOREIGN PATENT DOCUMENTS

GB 2388164 A 11/2003
 JP 2007-057499 3/2007
 WO WO 2005/012079 2/2005

OTHER PUBLICATIONS

Marti, I., et al., "Evaluation of Advanced Wind Power Forecasting Models," Athens, Greece, <http://anemos.cma.fr/download/publications/pub.sub.--2006.sub.--paper.sub.--WP2results.pdf>.
 Kariniotakis, G., et al., "Next Generation Short-Term Forecasting of Wind Power—Overview of the Anemos Project," <http://anemos.cma.fr>.
 Kariniotakis, G., et al., "The Anemos Wind Power Forecasting Platform Technology—Techniques and Experiences," <http://anemos.cma.fr>.
 Monaldo, F., et al., "Ocean Wind Field Mapping from Synthetic Aperture Radar and Its Application to Research and Applied Problems."

* cited by examiner

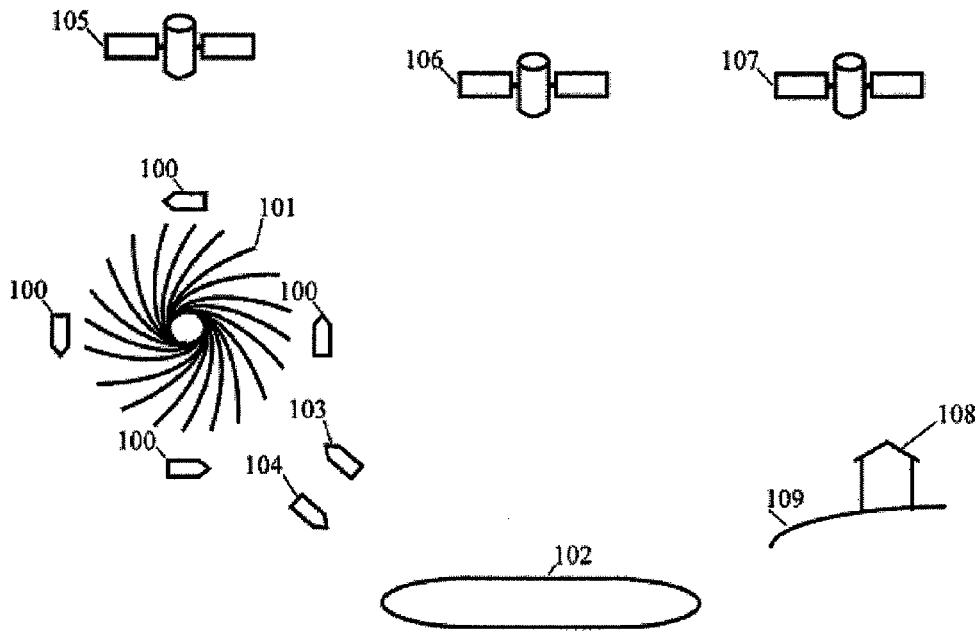


FIG. 1

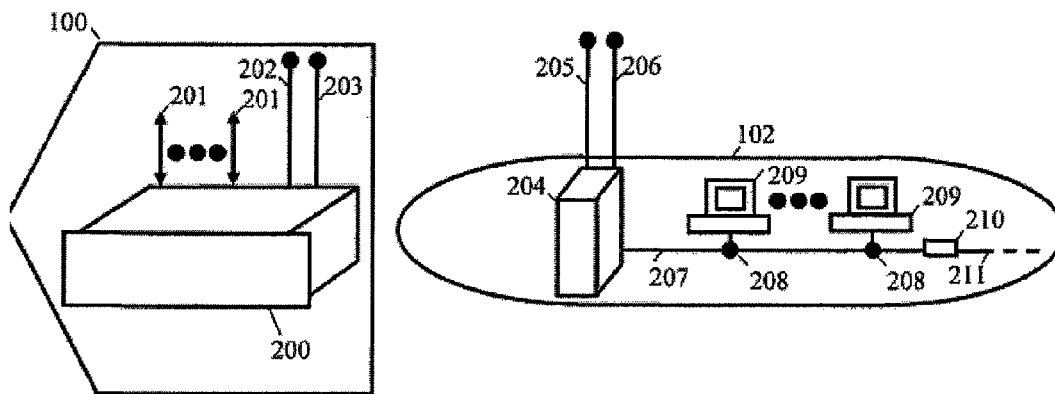


FIG. 2

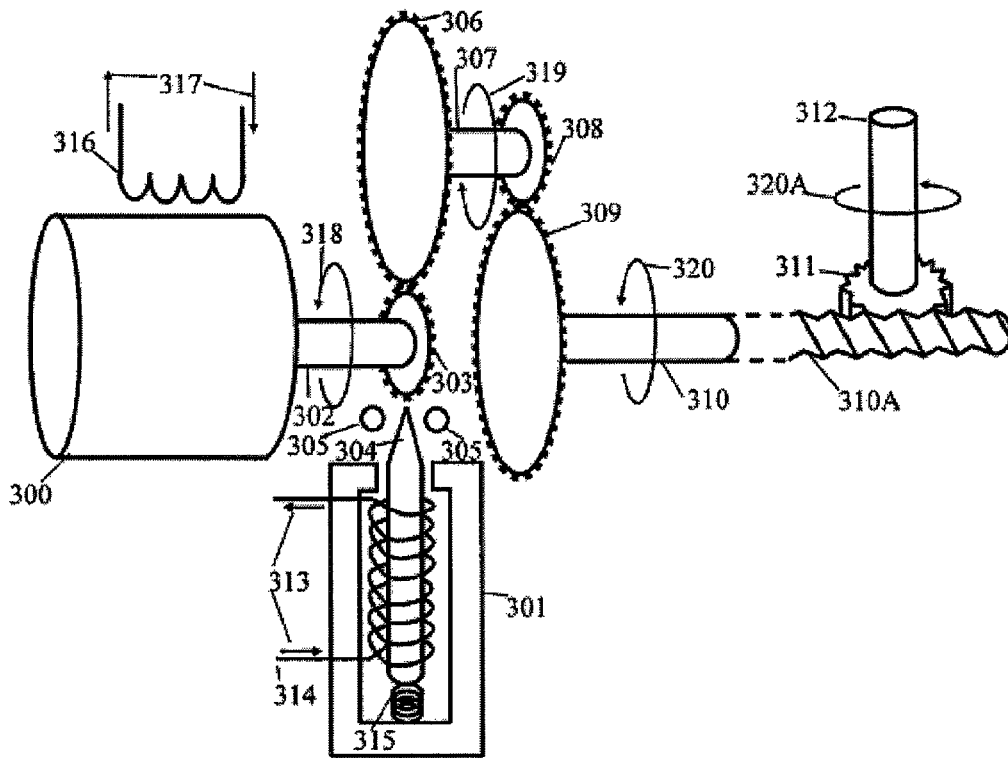


FIG. 3

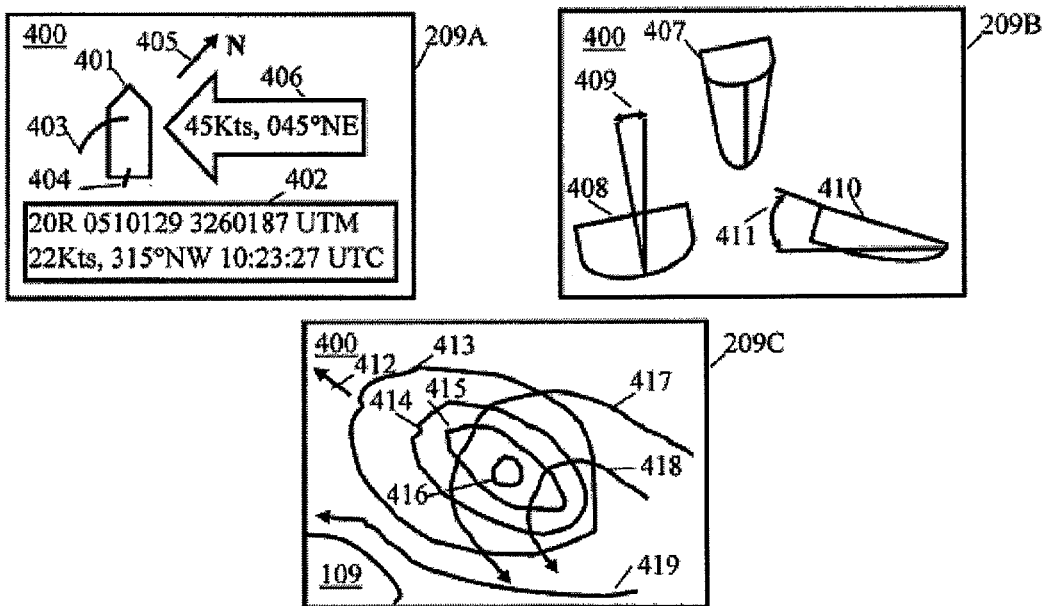


FIG. 4

SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM FOR ENERGY EXTRACTING VESSEL NAVIGATION

The present application is a continuation of U.S. application Ser. No. 13/073,891, filed Mar. 28, 2011, entitled Supervisory Control and Data Acquisition System for Energy Extracting Vessel Navigation, which is a continuation of Ser. No. 12/758,733, filed Apr. 12, 2010, entitled Supervisory Control and Data Acquisition System for Energy Extracting Vessel Navigation, now U.S. Pat. No. 7,962,251, which is a continuation of U.S. application Ser. No. 11/942,576, filed Nov. 19, 2007, entitled Supervisory Control and Data Acquisition System for Energy Extracting Vessel Navigation, now U.S. Pat. No. 7,698,024. The entire contents of the above listed applications are hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is generally in the field of supervisory control and data acquisition systems. More specifically, the present invention is embodied in a remote control system particularly for operation and navigation of a mobile structure that optimally recovers energy from an offshore marine environment.

2. Description of the Related Art

While many systems exist today for recovery of wind energy and water current or wave energy, most systems are stationary, mounted on or anchored to the sea floor. Many other hydrokinetic turbine energy systems exist today that affix to sailing vessels overcoming the limitations of fixed stationary structures. Nonetheless, all wind and hydrokinetic systems have the fundamental limitation of total possible recoverable energy at any given time being directly proportional to the cube of the velocity of the motive fluids. This inherent limitation renders most of these systems economically infeasible when considering the manufacturing and operational costs of the system and the typical ambient wind and water current vectors rarely summing to a magnitude greater than twenty knots. While sailing vessel designs exist such as catamarans, which reputedly can exceed true wind speed, the function of immersing a hydrokinetic turbine as an appendage of such a vessel immediately incurs drag upon the vessel ultimately to reduce the speed of the motive fluid through the turbine to unprofitable energy recovery rates. U.S. Pat. No. 7,298,056 for a Turbine-Integrated Hydrofoil addresses an implementation of a drag-reducing appendage as means to an economically viable solution. The specification of this reference application suggests remote controlled operation but does not expressly depict intentional unmanned operation of such a mobile structure for economic benefit into an environment of such high energy as to otherwise present conditions hazardous to human crews. The aforementioned reference patent application also does not delineate the various parts of the communication system in detail, thus does not enable in full, clear, concise, and exact terms, one skilled in the art to reduce such a remote control system to practice.

Therefore, there exists a need for a novel Supervisory Control And Data Acquisition system that remotely controls the operation and particularly the navigation of a mobile structure that can cost-effectively extract energy in an optimal manner from an environment that inherently presents untenable risk to human life.

SUMMARY OF THE INVENTION

The present invention is directed to a novel Supervisory Control And Data Acquisition (SCADA) remote control sys-

tem for a mobile structure that recovers naturally occurring energy from severe weather patterns. The present specification embodies an offshore energy recovery system wherein an algorithm optimizes efficiency in the system by accounting for data from weather observations, and from sensors on the mobile structure, while relating these data points to performance models for the mobile structure itself. The present specification exemplifies the use of the algorithm in navigating a sailing vessel optimized to reduce drag while responding to wind and water velocity vectors by adjusting points of sail, rudder rotation, openness of turbine gates, and ballast draft, through control outputs from the microprocessor system on-board the sailing vessel. The SCADA system includes computer servers that gather data through diverse means such as Global Position Satellite (GPS) systems, weather satellite systems of the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and United States Air Force Defense Meteorological Satellite Program (DMSP) communicated through various geographic and weather data resources including but not limited to the Geographic Information System (GIS) of NOAA's National Weather Service (NWS) along with all other weather information sources available from its National Hurricane Center (NHC) and Tropical Prediction Center (TPC). The SCADA computer servers run Human Machine Interface (HMI) secure software applications which communicate to microprocessor systems running client software with a Graphical User Interface (GUI) to allow remote humans to optionally interact and choose mission critical navigation plans.

In addition, the present invention is not limited to implementation of the exemplary referenced Turbine-Integrated Hydrofoil system of U.S. Pat. No. 7,298,056. The present invention applies to remote control of any system that exploits energy from weather patterns that avail formidable amounts of naturally occurring energy. Any mobile structure that extracts energy from electrical storms, windstorms, offshore tropical storms or hurricanes, or any aerodynamic or hydrokinetic electromechanical mobile system for renewable energy recovery under remote control especially benefits from the present invention. Otherwise whereby without the present invention that enables a mobile system to automatically track environmental conditions hazardous to humans anywhere in the universe, such risks of danger renders manned operation undesirable and thus the cost benefits and ease of implementation of such energy exploitation systems unrealizable.

Finally, because the system embodied within the present invention comprises an algorithm that optimizes energy extraction using yield functions derived from weather and geospatial data and vessel performance models, the same system using just the path cost algorithm without weighing energy extraction yield factors into the cost of travel, may guide navigation of vessels for logistics-only purposes past such weather patterns.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a top-level view of all components in an exemplary system in accordance with one embodiment of the present invention.

FIG. 2 illustrates a block diagram of the control, communications, and computer systems running server and client software applications in an exemplary system.

FIG. 3 illustrates electromechanical circuits for actuating control of various mechanisms affecting position and velocity of the mobile structure in an exemplary system.

FIG. 4 illustrates a representation of the graphical user interface on a client computer system in one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention pertains to a remote control system and algorithm for supervisory control and data acquisition enabling navigation and automatic operation of a mobile energy recovery system. The following description contains specific information pertaining to various embodiments and implementations of the invention. One skilled in the art will recognize that one may practice the present invention in a manner different from that specifically depicted in the present specification. Furthermore, the present specification need not represent some of the specific details of the present invention in order to not obscure the invention. A person of ordinary skill in the art would have knowledge of such specific details not described in the present specification. Obviously, others may omit or only partially implement some features of the present invention and remain well within the scope and spirit of the present invention.

The following drawings and their accompanying detailed description apply as merely exemplary and not restrictive embodiments of the invention. To maintain brevity, the present specification has not exhaustively described all other embodiments of the invention that use the principles of the present invention and has not exhaustively illustrated all other embodiments in the present drawings.

FIG. 1 illustrates a top-level diagram of all components of an exemplary practical embodiment of the present invention. Block 100 represents an offshore mobile energy recovery structure in the process of energy extraction in an exemplary embodiment of the present invention. Exemplary embodiments of mobile structure 100 include sailing or propelled vessels or barges or any mobile buoyant energy recovery system known by one of ordinary skill in the art. A non-exhaustive list of mobile structures 100 for energy recovery includes: the Turbine-Integrated Hydrofoil of U.S. Pat. No. 7,298,056; any wave energy conversion system with propulsion means allowing relocation; one or plural wind turbines on floating platforms with propulsion means allowing relocation; or one or plural lightening rods on floating platforms with propulsion means allowing relocation for extracting energy from electrical storms; or any mobile system that extracts energy from pneumatic and/or hydrokinetic sources with aerodynamic and/or hydrodynamic drive means. The aforementioned list of mobile structures 100 represents purely exemplary embodiments by no means restrictive of mobile structure 100 embodiments within the scope and spirit of the present invention. FIG. 1 further depicts mobile structure 100 in the process of energy extraction circumnavigating what appears to be a vortical weather pattern 101. As one may infer from the counterclockwise vortex streamlines, the weather pattern 101 manifests in the northern hemisphere as implied by the Coriolis effect. Note that this representation of a weather pattern 101 is strictly exemplary and that a weather pattern 101 consistent with a description of a cyclone in the southern hemisphere; a typhoon in south east Asia; a williwaw non-vortical gap flow or barrier jet wind storm offshore from the Alaskan coast or similar weather pattern elsewhere; any tropical storm; or any hurricane, remains well within the scope of a weather pattern 101 for the purposes of the present invention. The exemplary embodiment further comprises a central service facility 102 for the purpose of service logging, maintenance, and bulk energy storage for later distribution,

and especially where the remote control of the mobile structure 100 occurs. One may note that energy storage comprises compressed hydrogen, metal hydride storage, or charged batteries or capacitors, as long as the mobile structure 104 and the central service facility 102 employ energy storage systems with compatible upload interfaces. The graphical representation of the central service facility 102 in FIG. 1 evokes the notion of a large vessel such as a tanker ship, but a port facility equally qualifies as a central service facility 102 within the scope of the present invention. The depiction of mobile structure 103 en route to the weather pattern 101 and mobile structure 104 returning to the central service facility 102 emphasizes that complete round-trip operation of one or plural mobile structures 100, 103, 104, whether engaged in energy recovery as in mobile structure 100 or returning a payload as in mobile structure 104, essentially comprises tasks performed by the remote control system of the present invention.

Essential to the operation of the complete SCADA system is the communication of data from various sources. FIG. 1 further illustrates three types of satellites, Global Position Satellites (GPS) 106, weather satellites 105, and telecommunications satellites 107, comprising the SCADA remote control system in this exemplary embodiment. In practically all embodiments, the SCADA system tracks the position and velocity of the mobile structure 100 through a GPS 106 system. The central service facility 102, if itself indeed mobile, likely also tracks its own location using a GPS 106 system. This specification will further expound upon the use of the GPS 106 system as a SCADA control algorithm input in subsequent paragraphs describing FIG. 4. This specification will hereinafter use the generic term weather satellite 105 when referring to any of the weather tracking satellites availing weather data to various government and private entities. A non-exhaustive list of weather satellites 105 able to serve this function includes: the NASA QuikSCAT; the NOAA Synthetic Aperture Radar (SAR) satellites including Radarsat-1, and Envisat satellites; any of the satellites serving the NOAA Satellite Services Division (SSD) National Environmental Satellite Data and Information Service (NESDIS) including Meteosat-7, Eumetsat, MTSAT-IR, Global Earth Observation Systems, GOES-EAST (GOES-12), GOES-WEST (GOES-11), GOES-9, GOES-10, GOES-13, or POES satellites. The aforementioned list of weather satellites 105 represents purely exemplary embodiments by no means restrictive of weather satellites 105 embodiments within the scope and spirit of the present invention. Telecommunications satellites 107 represent how data communicates between the central service facility 102 and one or plural of many possible entities including those accessible through the Internet from where all weather data in this exemplary embodiment disseminates, such as from the National Weather Service 108 Geographic Information System (GIS) computer servers. Besides weather satellite 105 data, the NWS 108 GIS and many other such entities including those accessible through the Internet disseminate weather data from other sources such as: oceanic weather buoys; coastal meteorology stations, Coastal Marine Automated Network Stations (C-MAN); NOAA Aircraft Operations Center; NOAA National Hurricane Center (NHC) Aircraft Reconnaissance "Hurricane Hunters"; United States Air Force 53rd Weather Reconnaissance Squadron; USAF GPS Dropwindsondes; and RIDGE radar. The aforementioned non-exhaustive list of alternate sources of weather information disseminated from the NWS 108 or similar weather data disseminating entities including those accessible through the Internet represents exemplary but not restrictive sources of weather data alternate to weather satel-

lite **105** sources. The physical location of dissemination of data such as within an NWS **108** GIS computer server or similar weather data disseminating entities including those accessible through the Internet appears terrestrial-based; in other words, the hardware resides on physical object **109**, such as a landmass or seamount. Obviously, if the central service facility **102** existed at a port on shore, a more cost-effective and potentially higher bandwidth data communications link such as fiber optic cable thus supplants the telecommunications satellites **107** in communication with the NWS **108** GIS or other similar weather data disseminating computer servers. Telecommunications satellites **107** perform another function in an exemplary system such as communicating between the central service facility **102** and the mobile structure **100**. However, the preferred embodiment employs a more cost-effective wireless communications system communicating between the mobile structure **100** and the central service facility **102** upon which this present specification will subsequently expound.

FIG. 2 illustrates an exemplary system wherein the mobile structure **100** further comprises a control and communications microprocessor system **200** along with the central service facility **102** further comprising a microprocessor system running secure server **204** software applications and workstations **209** running secure client software applications communicating with the server **204** via a Local Area Network (LAN) **207**. In some embodiments, all the secure server and client software applications running within the central service facility **102** may execute on a single large computing system, but given today's state of the art computing technology, a multi-processor server-client LAN **207** topology offers the greatest advantage in terms of flexible architecture, cost-effective computing power, reliability, scalability, and durability. In some embodiments, the control and communications microprocessor system **200** located within the mobile structure **100** comprises a type of microprocessor computing system **200** known as a Programmable Logic Controller (PLC). Traditionally evolving from industrial process control applications, a PLC **200** comprises ruggedized hardware robust to physical environments demanding resistance to mechanical shock and vibration, temperature extremes, and specifically, customization for control and communication purposes fitting SCADA system applications. Regardless of whether the microprocessor system **200** comprises custom hardware or an off-the-shelf product from a renowned PLC vendor, the microprocessor system **200** needs to execute certain functions as depicted in FIG. 2 in practically all embodiments. The microprocessor system **200** will require input, output, and input/output (I/O) functions **201** for communicating with sensors and control circuits. A wide variety of sensor and control circuits communicating with the microprocessor system **200** through I/O **201** necessary for inputting and outputting variables to the preferred SCADA control algorithm exist within most practical embodiments of the mobile structure **100**. A non-exhaustive list of sensor and control circuits **201** includes: accelerometers and gyroscopes for analysis of vessel **100** stability also known as attitude, or heeling and listing, along with heading, or to borrow aviation terms, pitch, roll and yaw, respectively, and rendering virtual contours of immediate local oceanic surface and possibly advanced features such as dead reckoning; ballast draft readings and adjustments; a wind vane and anemometer or if combined into a single unit an aerovane for analysis of apparent wind vectors' direction and magnitude respectively; fuel gauges for both propulsion motor fuel reserves and output fuel from energy recovery functions and thus mobile structure **100** weight and energy efficiency; electrolyzer electrode tempera-

ture gauges; energy extracting electric generator armature voltage readings and field current adjustments; energy extracting turbine gate opening readings and adjustments affecting mobile structure **100** drag; a compass for mobile structure **100** direction; a GPS receiver **202** for tracking position, velocity, and using way points to compare wind sensor data comprising local apparent wind vectors, minus mobile structure **100** velocity to determine local true wind vector, then comparing that empirical data to data from weather satellites **105** and other sources measuring and/or estimating true wind velocity; rudder rotation readings and adjustments; propeller rotational speed readings and adjustments; sail trim and/or boom rotation readings and adjustments; radar and/or sonar systems for physical object detection, identification, and avoidance; and one or plural video camera data streams allowing actual views of the surrounding environment of the mobile structure **100**, and physical object visual pattern matching. The aforementioned list of microprocessor I/O functions **201** represents purely exemplary embodiments by no means restrictive of I/O function **201** embodiments within the scope and spirit of the present invention. In terms of SCADA software data structure development, any or all of the aforementioned I/O functions **201** constitute one or plural SCADA object tag definitions, for various software layers to communicate from the mobile structure **100** microprocessor system **200**; to the central service facility **102** servers **204**; to the central service facility **102** workstations **209**. Weather satellite **105** data or alternate sources of weather information disseminated from the NWS **108** or similar weather data disseminating entities including those accessible through the Internet will also constitute SCADA object tag definitions. This specification will further expound upon the use of the SCADA object tags within the preferred SCADA control algorithm in subsequent paragraphs describing FIG. 4.

The remaining functions associated with the microprocessor system **200** in FIG. 2 include the antenna **202** representing the receiver for the GPS system. The other antenna **203** represents the means by which the microprocessor system **200** of the mobile structure **100** receives and transmits over a wireless physical medium to the central service facility **102** server **204**. As previously mentioned, one system of communication **203** embodies satellite **107** telecommunications. In the preferred embodiments, as long as the mobile structure **100** remains within line-of-sight with the central service facility **102**, as one presumes on the open sea, a point-to-point Code Division Multiple Access (CDMA) system permitting high bandwidth data including video camera data streams provides the communications function in the preferred embodiment. Another wireless physical medium in the form of point-to-point Ultra High Frequency (UHF) radio exists. While of lower bandwidth, UHF offers wider range and does not require line-of-sight as does CDMA, and thus an embodiment of the present invention may incorporate UHF as a redundant back-up in case of loss-of-signal for the CDMA. For SCADA systems without video data streams, UHF may actually serve the primary communication channel function. These wireless telecommunications systems represent exemplary embodiments without restriction to other possible wireless telecommunications systems embodied within the scope and spirit of the present invention.

The central service facility **102** houses the server **204** for the primary purpose of aggregating weather data from anyone or plural weather data disseminating entities including those accessible through the internet such as the NWS **108**. Some embodiments achieve robust data reliability through implementing redundant or multiple servers **204**. The telecommunications system represented in FIG. 2 includes the link **205**

to the mobile structure **100** and the link **206** to the NWS **108** or similar weather data disseminating entities including the Internet itself. On the central service facility **102**, link **205** and link **206** complete the channel with the mobile structure **100** and weather data disseminating entities including those accessible through the internet such as the NWS **108**, respectively, using physical mediums and protocols as previously discussed. The LAN **207** in exemplary embodiments conforms to such network standards as IEEE 802.3, 802.3u, 802.11a, b, or g or any standard suiting the needs of the server-client software applications in the present invention, and the Network Interface Cards (NIC's) **208**, hardware generally integrated into the workstations **209**, likewise conform to the aforementioned exemplary network standards. All embodiments very likely operate under the most common protocol implemented today, Transmission Control Protocol/Internet Protocol (TCP/IP) for passing of packets of data associated with SCADA object tags between the server **204**, the workstations **209**, and the PLC **200**. In an embodiment wherein the central service facility **102** resides on land **109**, the LAN **207** accesses a Wide Area Network (WAN) **211** for weather satellite **105** data or alternate sources of weather information disseminated from the NWS **108** or similar weather data disseminating entities including those accessible through the Internet through a router **210** instead of through a telecommunications satellite **107** as in an offshore central service facility **102**. Either the server **204** or the router **210** may execute firewall security software during network communications. Other forms of secure communication between the server **204**, the workstations **209**, and the PLC **200** may include Internet Protocol Security (IPSec) with packet encryption and decryption occurring during transmission and reception within TCP/IP for all the aforementioned computer systems. These network standards and protocols examples represent several of many possible network standards and protocols configurations within the scope of the present invention and one must view these network standards and protocols configurations as exemplary, not restrictive.

FIG. 3 illustrates the control-actuating electromechanical circuits in an embodiment of the mobile structure **100**. Exemplary controls on the mobile structure **100**, **103**, **104** include rudder rotation, propeller rotation in propelled embodiments, and sail trim or boom rotation in sailing embodiments. Actuation of all mechanical members begins with motor **300** activation by driving a current **317** through the motor's **300** winding **316**. As shown in FIG. 3, the rotor **302** of the motor **300** affixed to a small gear **303** couples to a larger gear **306** affixed to an intermediate gear shaft **307** affixed to another small gear **308** coupled to another larger gear **309** affixed to the final drive shaft **310** in a direct drive system or to a worm **310A** in a worm drive system. A system comprising such gear ratios as depicted in FIG. 3 serves the purpose of reducing torque on the motor **300** that generally exhibits a high rotational velocity, low torque characteristic in lightweight, economical motor **300** embodiments. For actuating a propeller, the preferred embodiment obviously installs a motor **300** capable of greater torque and variable speed. In the worm drive embodiment, the worm **310A** and worm gear **311** interface further reduces the torque on the rotor **302** compared to that on the final drive shaft **312**. An embodiment comprising a worm drive also affords the advantage of the braking effect such that the direction of transmission always goes from the rotor **302** to the shaft **312** and not vice versa given an appropriate coefficient of friction between the worm **310A** and the worm gear **311**. Other embodiments rely upon the detent torque of a stepper motor **300** for braking. In other embodiments, such as servo motors **300** or variable reluctance motors

300 may not afford adequate detent torque and thus a solenoid **301** inserts a spring-activated **315** plunger tip **304** between the teeth of the first small gear **303** to lock-in detent and sustain torque against stops **305** when the solenoid **301** coil **314** has no current **313** flowing. Such an embodiment proceeds in actuating a control mechanism first by driving current **313** in the direction shown per the right hand rule causing the solenoid **301** coil **314** to unlock the gear **303**, then driving current **317** in the motor winding **316**, to initiate rotation **318** translated through rotation **319** to rotation **320** or **320A** to rotate a rudder or rotate a sail boom. Once actuation completes, the solenoid **301** coil **314** no longer conducts current, returning the solenoid **301** plunger tip **304** to the locked position. All such control algorithm steps thus have their own unique SCADA object tag definitions. As PLC's **200** have traditionally evolved from industrial process applications including SCADA systems control software, portability of Computer Numeric Controlled (CNC) G-code for servo-motors **300**, and servo mechanisms such as mechanical lead screw, or ball screw systems analogous to worm drive systems enable preferred embodiments of control actuators in the present invention. One must note that partial implementations or minor deviations known by one of ordinary skill in the art of any of the exemplary embodiments of the aforementioned control actuator electromechanical circuits do not represent a departure from the scope or spirit of the present invention.

FIG. 4 illustrates the visual representations that appear on the Graphical User Interface (GUI) **400** of one or plural client workstations **209** at the central service facility **102**, and illustrates how a human can affect the behavior of exemplary SCADA algorithms. The foregoing exemplary SCADA algorithms run on one or plural server **204** processing systems including a GIS that performs all the data collection, processing, storage, analyses and navigation vector determinations accessible through the GUI **400** on one or plural client workstations **209**. Three different workstations **209A**, **B**, or **C** displaying information pertaining to one or plural mobile structures **100**, or one workstation displaying three different GUIs **400** at different times, at one time displaying the GUI **400** of workstation **209A**, at another time the GUI **400** of workstation **209B**, and at another time the GUI **400** of workstation **209C** operate at the central service facility **102**. Using typical computer pointing and data entry hardware, a human operating the workstation **209** may interact with the GUI **400** to invoke any of the GUIs **400** on any of the workstations **209A**, **B**, or **C** as shown in FIG. 4. The GUI **400** of workstation **209A** displays position, heading, velocity, and points of sail for the mobile structure **100** in the process of energy extraction in a sailing vessel embodiment. Vessel icon **401** graphically shows direction of the mobile structure **100** relative to true north given by the compass icon **405**. GPS field **402** numerically provides vessel instantaneous location, velocity, and heading. Sail icon **403** and rudder icon **404** along with surface true wind data **406** begotten from various aforementioned weather data. Sources **108**, or empirically derived from GPS **202** and aerovane sensor **201** data as previously described permits observation and control of the points of sail of the mobile structure **100** in a sailing vessel embodiment. Obviously, in a propelled embodiment, a propeller icon serves analogous functions as the sail icon **403**.

Pointing and data entry hardware on the workstation **209A** allows a human operator to point and select the aforementioned icons and data fields to alter visual representations and alter instantaneous control of the mobile structure **100**. For instance, if a human operator points and selects vessel icon **401**, sail icon **403**, or rudder icon **404**, the operator may view a alphanumeric field indicating points of sail using nautical

terms such as “Beam Reach” to describe that point of sail shown on the display of workstation 209A. At this point, the GUI 400 can numerically give displacement angles of the boom and the rudder with an option to the human operator to manually change these values, override auto-navigation, and actuate rotation of the boom or rudder on the mobile structure 100 as previously described. Herein the GUI 400, the preferred SCADA algorithm invokes performance models for the mobile structure 100 to estimate or forecast energy efficiency thereof, using a Velocity Prediction Program (VPP) performing Computational Fluid Dynamics (CFD) calculations on the sailing vessel along with its energy extracting appendage. The GUI 400 at this point also suggests for instance, a “Broad Reach” point of sail given prevailing wind and optimal least-cost or highest yield path analysis inputs. Selecting the vessel icon 401 also permits the human operator to monitor, adjust, and receive performance predictions based on turbine gate openness and fuel tank fullness affecting the overall drag on the mobile structure 100, given the VPP performing CFD calculations on the modeled energy extracting turbine appendage. Note for a preferred SCADA algorithm of the present invention, the sailing vessel VPP will output data tabulating generated power, instead of velocity for typical prior art VPP’s, for the given true wind speed, turbine gate openness, fuel tank fullness, and heading, along with the accompanying points of sail and control settings. Obviously, an exemplary SCADA algorithm performs an analogous propeller performance VPP and least-cost path analysis for a propelled mobile structure 103,104 during these GUI 400 operations. Selecting the GPS field 402 allows the human operator to change viewing options such as converting units of parameters such as position, changing the Universal Transverse Mercator (UTM) kilometer units to miles or to degrees, minutes, seconds of longitude and latitude; velocity, knots to kilometers per hour or miles per hour; or time, from Coordinated Universal Time (UTC) to local time. Selecting the GPS field 402 for a propelled embodiment of mobile structure 103, 104 allows for manually changing propeller rotational speed. Selecting the compass icon 405 or the true wind data 406 allows the viewing orientation angle of the vessel icon 401 to move relative to the compass icon 405 or true wind data 406, respectively.

The GUI 400 of workstation 209B in FIG. 4 illustrates a virtual reality representation 407, along with the attitude of the vessel, listing and heel angle, or to borrow aviation terms, roll and pitch, respectively, for the mobile structure 100 in the process of energy extraction. The virtual reality rendering 407 indicates a downward or plunging heel angle or pitch, and a port listing or roll. Had the vessel assumed an upward or breaching heel angle, the rendering 407 would display the deck instead of the hull as indicated in the rendering 407. If the mobile structure 100 sensors include a video camera data stream, actual oceanic surface in the vicinity the vessel will display in this GUI 400 frame. The view parallel 408 to the direction of travel further displays the port listing coordinated with the rendering 407, along with the angle of listing 409. A starboard listing or roll would result in an angle 409 in the opposite direction. The view perpendicular 410 to the direction of travel further displays the plunging or downward heel or pitch, coordinated with the rendering 407 and displaying the heel angle 411. Likewise, a breaching or upward pitch would result in the heel angle 411 displayed in opposite direction. Selecting the virtual reality 407 icon allows for changing the camera angle. Selecting the listing angle 409 icon or the heel angle 411 icon allows the human operator to manually set the threshold for a broach warning and associated control.

The GUI 400 of workstation 209C in FIG. 4 illustrates a weather map with path analysis lines 417, 418, 419 for the mobile structure 100 operating in the weather pattern 101. Browsing the GUI 400 of workstation 209C initiates a least-cost and highest yield path analysis whereby a weather semi-variogram accounting for spatial structure including physical object 109, such as a landmass or seamount, global trends and anisotropy, air temperature, water temperature, wind direction, wind speed, and wave data forms a basis for mapping predictive costs, or yields in the case of energy extraction. From the predictive map, the preferred SCADA algorithm assigns weights that average over suggested routes 417, 418, 419 based on path length in a weighted cost or yield raster. In the GUI 400 of workstation 209C, each concentric closed surface 413, 414, 415 represents areas of increasing wind and surge current energy inward to the eye 416 for a given weather pattern 101. While a global trend may indicate a greater degree of symmetry and counterclockwise, in this example northern hemispheric, vortex trend as in the FIG. 1 representation of the weather pattern 101, anisotropy caused by physical object 109, such as a landmass or seamount and other stochastic modeled factors such as air temperature, water temperature, wind direction, wind speed, and wave data result in a probabilistic field that the semivariogram 413, 414, 415 represents. From this probability field, weather prediction analysis can predict a path 412 for the storm that further affects the least-cost or highest yield analysis. Note that in the GUI 400 of workstation 209C, the concentric closed surfaces 413, 414, 415 can selectively represent semivariogram values or else predictive energy regions, also known as a cost raster for non-energy extracting vessel logistics or a yield raster when referring to energy extraction. The preferred embodiment also includes an advanced detection of physical object 109, such as a landmass or seamount, identification and avoidance system that remotely utilizes the integrated sensors including but not limited to on-board radar and sonar systems to perform sweeping remotely sensed anomalies returns. A preferred SCADA algorithm then compares the signatures of these electromagnetic energy returns against known libraries of predefined physical object 109, such as a landmass or seamount, based on size, shape, rate of movement and other characteristics to identify possible type of physical object 109, such as a landmass or seamount, feature detected. Optionally, an exemplary algorithm further correlates the signatures against a video camera data stream for further classification and confirmation of the physical object 109, such as a landmass or seamount. A preferred SCADA algorithm then invariably correlates the identified physical object 109, such as a landmass or seamount, spatially against the vessel’s 100, 102, 103, 104 current location, path and velocity in order to assess the need for altering the vessel’s 100, 102, 103, 104 course to initiate avoidance and altered path routing and associated cost accounting. A preferred SCADA algorithm then indexes the identified physical object 109, such as a landmass or seamount, in the algorithmic path controls to include avoidance or least cost path towards the physical object 109, such as a landmass or seamount, depending on predetermined logic and/or human operator interaction. A preferred SCADA algorithm of the present invention thereby further accounts for VPP modeling of the mobile structure 100 when assigning weights that average over a path 417, 418, 419 based on direction and length in a weighted anisotropic energy yield raster. Depending on the cost or yield goal, the highest yield algorithm may select a path 417 or 418, yielding the highest energy in the shortest time with least risk to structural harm to the mobile structure 100, while the least-cost algorithm yields the shortest logistical trajectory

with least risk to structural harm to an offshore embodiment of the central service facility **102**, a non-energy extracting vessel. Selecting the path lines **417**, **418**, **419** allows the human operator to optionally choose mission critical navigation parameters such as cost and yield weights and cost or yield goals.

For all the aforementioned GUI **400** icons and data fields, a SCADA object tag definition exists for accessing the aforementioned data structures and evoking the aforementioned control. Object tags allow for structured programming techniques facilitating manageability and sustainability of a substantially large code base traversing multiple software application layer interfaces from the workstations **209**, to the server **204** and from the server **204** to the PLC's **200**, and from the server **204** to the one or plural of many possible entities including those accessible through the Internet from where all weather data in this exemplary embodiment disseminates, such as from the National Weather Service **108**. Functional differences within the GUI **400** for workstations **209A,B**, or **C** clearly do not present a substantial departure from the scope and spirit of the present invention.

From the preceding description of the present invention, this specification manifests various techniques for use in implementing the concepts of the present invention without departing from its scope. Furthermore, while this specification describes the present invention with specific reference to certain embodiments, a person of ordinary skill in the art would recognize that one could make changes in form and detail without departing from the scope and the spirit of the invention. This specification presented embodiments in all respects as illustrative and not restrictive. All parties must understand that this specification does not limited the present invention to the previously described particular embodiments, but asserts the present invention's capability of many rearrangements, modifications, omissions, and substitutions without departing from its scope.

Thus, a supervisory control and data acquisition system for energy extracting vessel navigation has been described.

What is claimed is:

1. A supervisory control and data acquisition system for an offshore energy recovery system comprising:

one or more mobile buoyant energy recovery systems; said one or more mobile buoyant energy recovery systems including sensors configured to track position of, velocity of, and amount of energy recovered by said one or more mobile buoyant energy recovery systems;

a remote control, said remote control further including a microprocessor system configured to govern navigation of said one or more mobile buoyant energy recovery systems during energy recovery,

wherein said remote control is further configured to provide control of one or more mechanisms that govern navigation of said one or more mobile buoyant energy recovery systems during energy recovery.

2. The supervisory control and data acquisition system of claim **1** wherein said remote control further comprises a prediction of energy recovery of said one or more mobile buoyant energy recovery systems, said prediction including access to a primary geographic information system data and a predictive performance model for velocity.

3. The supervisory control and data acquisition system of claim **2** wherein said microprocessor system is further configured to access transmitted sensor or Global Position Satellite data from said one or more mobile buoyant energy recovery systems, and weather and environmental data from secondary geographic information systems from one or more

sources to govern said navigation of said one or more mobile buoyant energy recovery systems during energy recovery.

4. The supervisory control and data acquisition system of claim **3** wherein said microprocessor system further runs software systems performing an algorithm to optimize said energy recovery based on said predictive performance models for velocity to predict energy recovery, said sensors of said mobile buoyant energy recovery system, and said weather information.

5. The supervisory control and data acquisition system of claim **1** wherein said microprocessor system is further configured to run a client software, said client software including a graphical user interface, said graphical user interface in communication with said remote control.

6. The supervisory control and data acquisition system of claim **5** wherein said client software further runs human machine interface software to display data from an optimization algorithm upon said graphical user interface.

7. The supervisory control and data acquisition system of claim **6** wherein said microprocessor system is further configured to access data or communicate through Transmission Control Protocol and Internet Protocol.

8. The supervisory control and data acquisition system of claim **1** wherein said control of one or more mechanisms that govern navigation of said one or more mobile buoyant energy recovery systems during energy recovery comprises control of one or more motors located at said one or more mobile buoyant energy recovery systems that rotate a rudder of said mobile buoyant energy recovery system.

9. The supervisory control and data acquisition system of claim **1** further comprising one or more motors located at said one or more mobile buoyant energy recovery systems coupled to propellers which drive said mobile buoyant energy recovery system wherein said control of one or more mechanisms that govern navigation of said one or more mobile buoyant energy recovery systems during energy recovery comprises control of said one or more motors.

10. The supervisory control and data acquisition system of claim **1** wherein said control of one or more mechanisms that govern navigation of said one or more mobile buoyant energy recovery systems during energy recovery comprises control of one or more motors located at said one or more mobile buoyant energy recovery systems that rotate a boom about a mast of a sailing vessel.

11. The supervisory control and data acquisition system of claim **3** wherein said microprocessor system access to data from said one or more mobile buoyant energy recovery systems sensors occurs over one or more wireless radio frequency signal channels.

12. The supervisory control and data acquisition system of claim **11** wherein said wireless radio frequency signal channel is point-to-point Ultra High Frequency Radio.

13. The supervisory control and data acquisition system of claim **11** wherein said wireless radio frequency signal channel is Code Division Multiple Access Radio.

14. The supervisory control and data acquisition system of claim **11** wherein said wireless radio frequency signal channel is satellite communications.

15. The supervisory control and data acquisition system of claim **1** wherein said microprocessor system further comprises an algorithm to analyze yield of energy for said one or more mobile buoyant energy recovery systems on a predicted path based on weather and environmental data and predictive performance models for velocity to predict energy recovery of said mobile buoyant energy recovery system.

16. The supervisory control and data acquisition system of claim 15 wherein said sensors further comprise radar or sonar;

wherein said algorithm to analyze yield of energy for said one or more mobile buoyant energy recovery systems accesses data from said radar or sonar for physical object detection, identification, and avoidance;

wherein said algorithm to analyze yield of energy for said one or more mobile buoyant energy recovery systems analyzes yield of energy for a path for said avoidance.

17. The supervisory control and data acquisition system of claim 16 wherein said mobile buoyant energy recovery system sensors further comprise one or more video camera data streams;

wherein said algorithm accesses said video camera data streams to further classify or confirm said physical object detection, identification, and avoidance.

18. The supervisory control and data acquisition system of claim 1 wherein a client software accesses said microprocessor system through a secure remote client control connection software application.

19. The supervisory control and data acquisition system of claim 5 wherein said graphical user interface comprises one or more virtual reality representations of various view angles.

20. The supervisory control and data acquisition system of claim 19 wherein said mobile buoyant energy recovery system sensors further comprise one or more video camera data streams to enhance said virtual reality representations of various view angles.

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