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(54) **ELECTRICITY GRID DATA ANALYTICS AS A MODULED SERVICE FOR PRODUCTION, DELIVERY, AND DISTRIBUTION OF POWER AS A DYNAMIC DEMAND RESPONSE WITHIN A RENEWABLE ENERGY-BASED ELECTRICITY GRID INFRASTRUCTURE**

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(63) Continuation of application No. 13/398,735, filed on Feb. 16, 2012, Continuation of application No. 13/398,738, filed on Feb. 16, 2012, which is a continuation of application No. 13/398,744, filed on Feb. 16, 2012.

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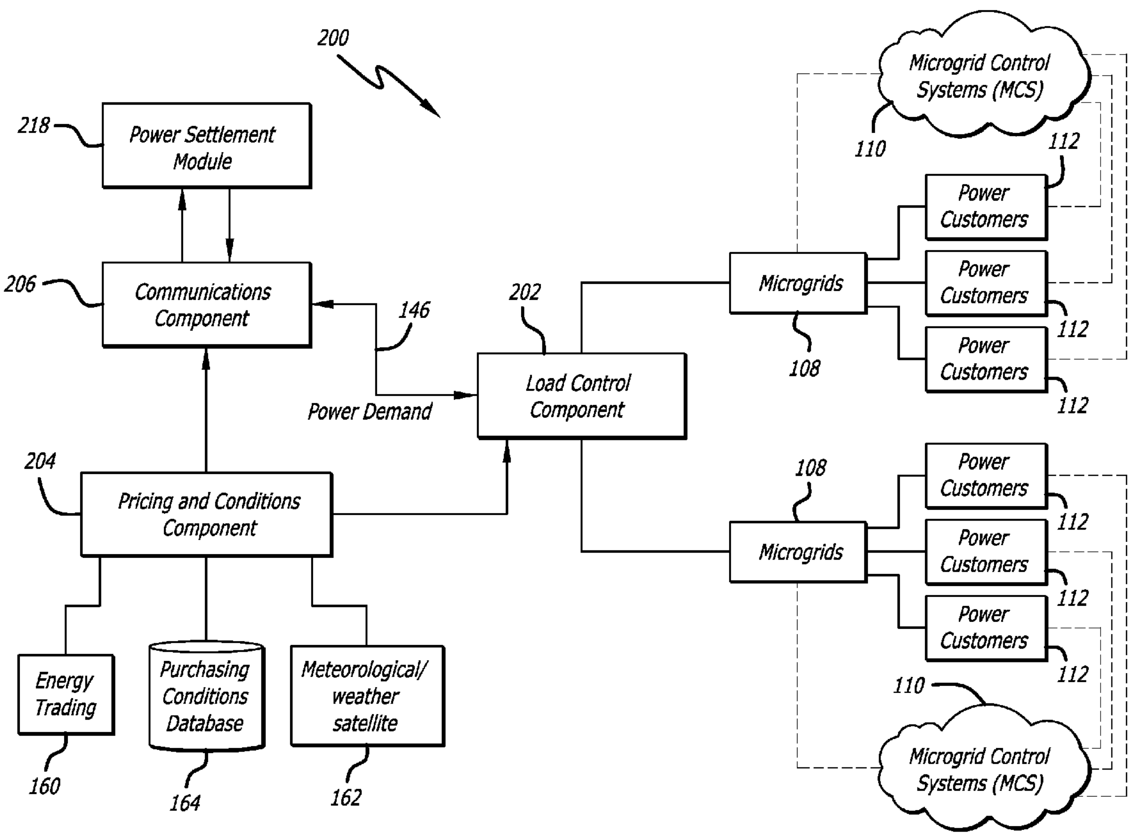
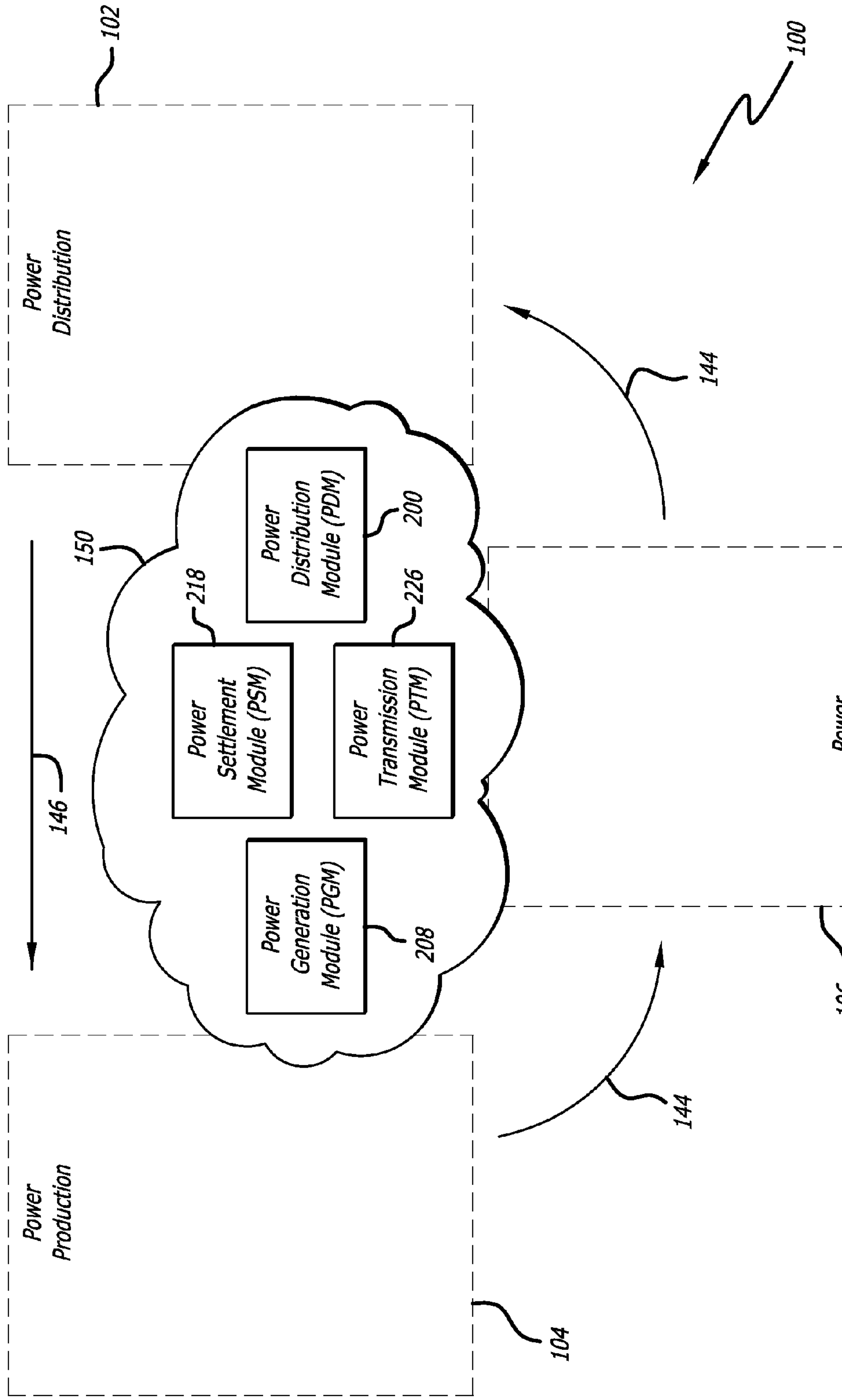
CPC ***G05B 19/02*** (2013.01)
USPC **700/291**; 706/15

(57) **ABSTRACT**

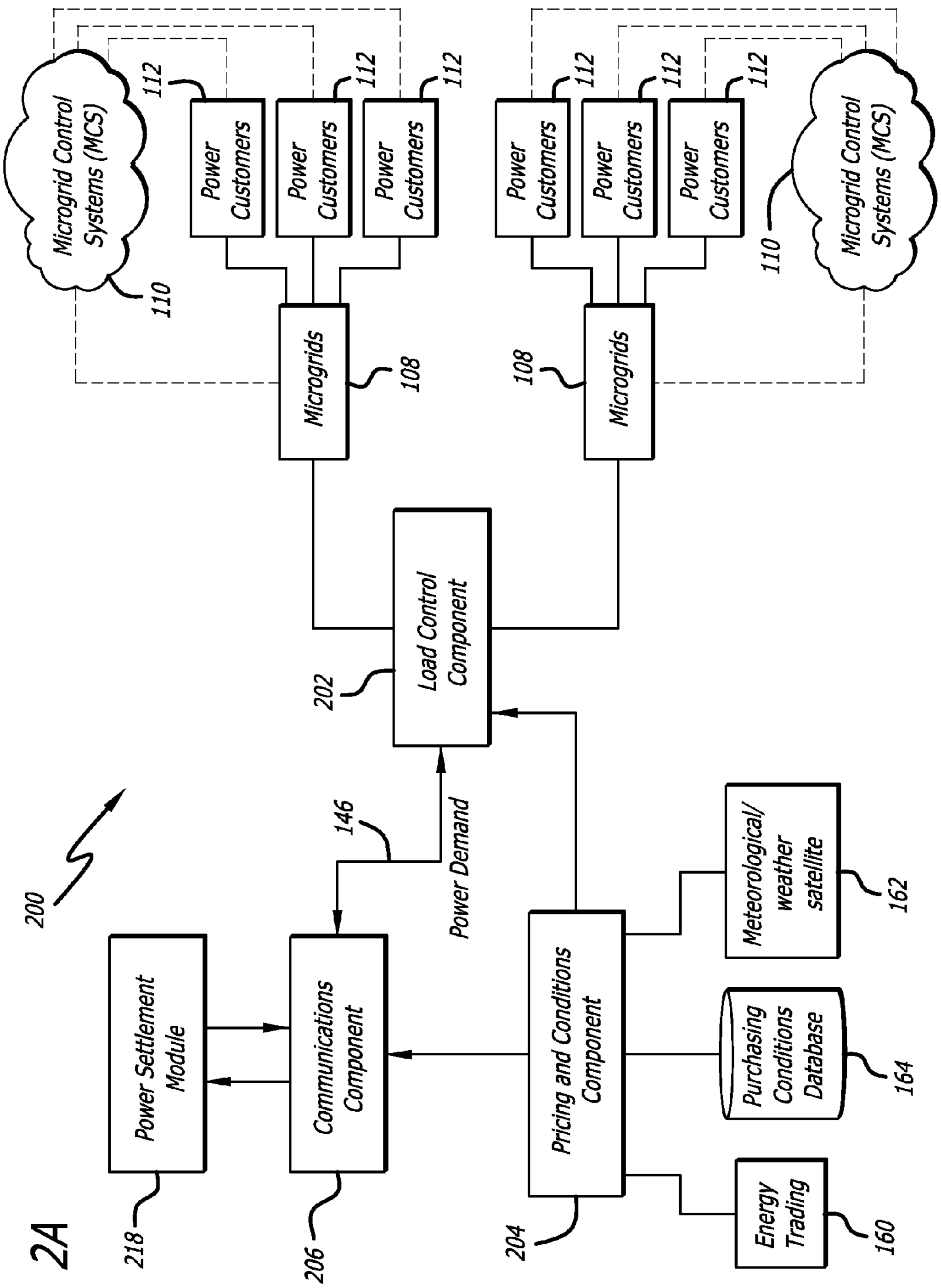
A renewable energy-based electricity grid infrastructure utilizes distributed data analytics to enable modeling and delivery of an appropriate, time-sensitive, dynamic demand response from multiple renewable energy components to an intelligent power distribution network. Data processing resources are identified and aggregated within a distributed computing infrastructure to provide dynamic demand response as a service of a dedicated grid data analytics module. Aggregation of processing resources for grid data analytics also enables the electricity grid infrastructure to virtually, optimally and adaptively make decisions about power production, distribution, and consumption so that a demand response is a moduled service of the electricity grid infrastructure, and enables distributed energy generation from multiple renewable energy resources that is responsive to various types of grid demand situations, such as customer demand, direct current-specific demand, and security issues, and so that power production is substantially balanced with power consumption.





102
Power Distribution
100
144
150
Power Distribution Module (PDM)
200
218
226
Power Settlement Module (PSM)
Power Transmission Module (PTM)
Power Transmission
146
Power Generation Module (PGM)
208
106
144
Power Production
104

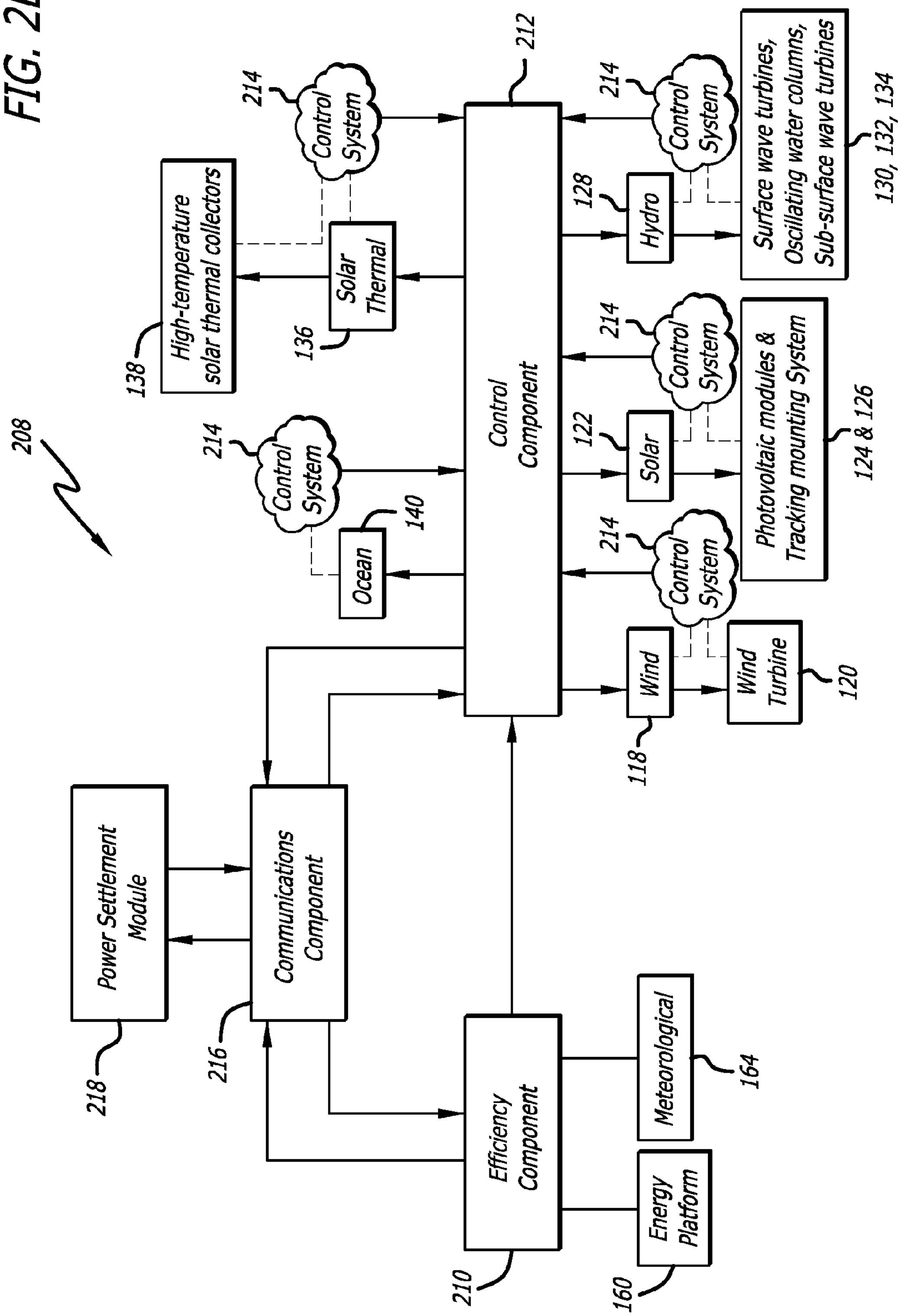
FIG. 1



200
Microgrid Control Systems (MCS)
110
112
Power Customers
Microgrids
108
Load Control Component
202
146
Power Demand
Communications Component
206
Power Settlement Module
218
Pricing and Conditions Component
204
Meteorological/ weather satellite
162
Purchasing Conditions Database
164
Energy Trading
160

FIG. 2A

FIG. 2B


208
Power Settlement Module
218
Communications Component
216
Efficiency Component
210
Meteorological
164
Energy Platform
160
Control Component
212
Control System
214
Ocean
140
Solar Thermal
136
High-temperature solar thermal collectors
138
Wind
118
Wind Turbine
120
Solar
122
Photovoltaic modules & Tracking mounting System
124 & 126
Hydro
128
Surface wave turbines, Oscillating water columns, Sub-surface wave turbines
130, 132, 134

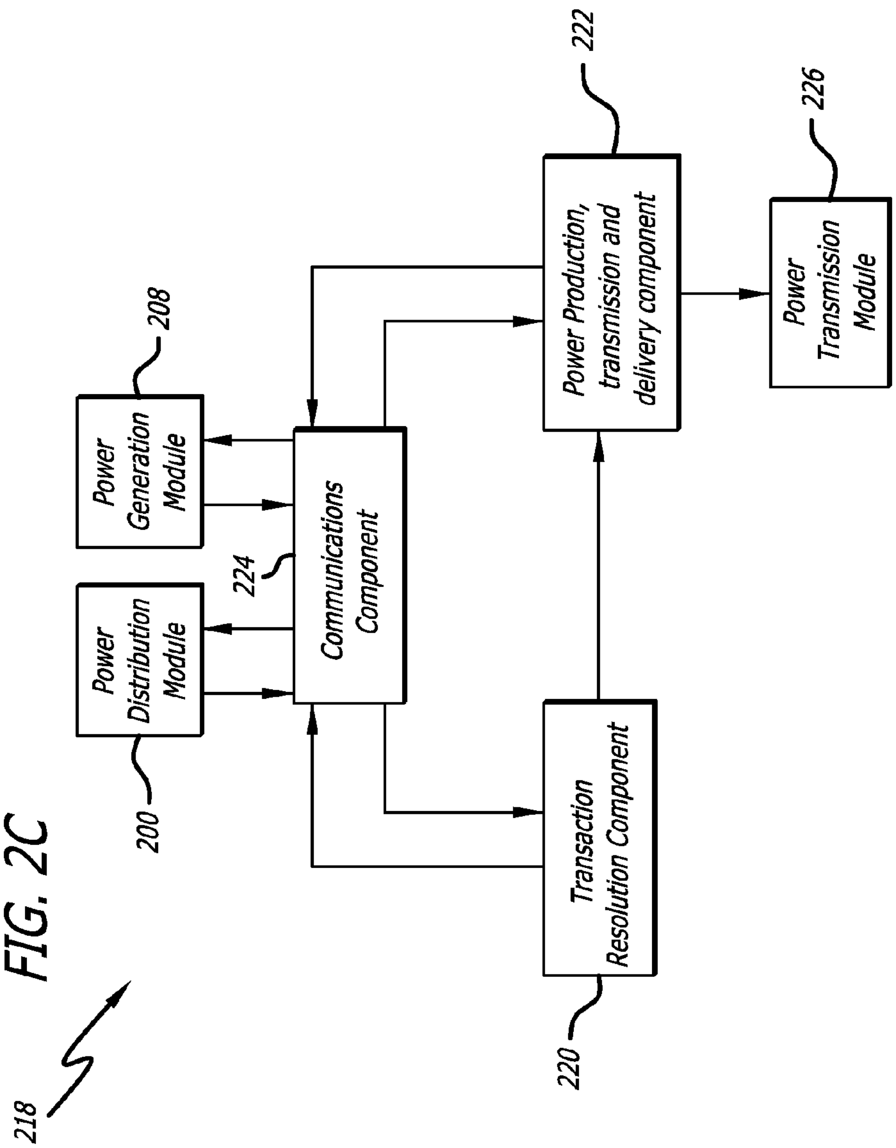

218
200
Power Distribution Module
208
Power Generation Module
224
Communications Component
222
Power Production, transmission and delivery component
226
Power Transmission Module
220
Transaction Resolution Component

FIG. 2C

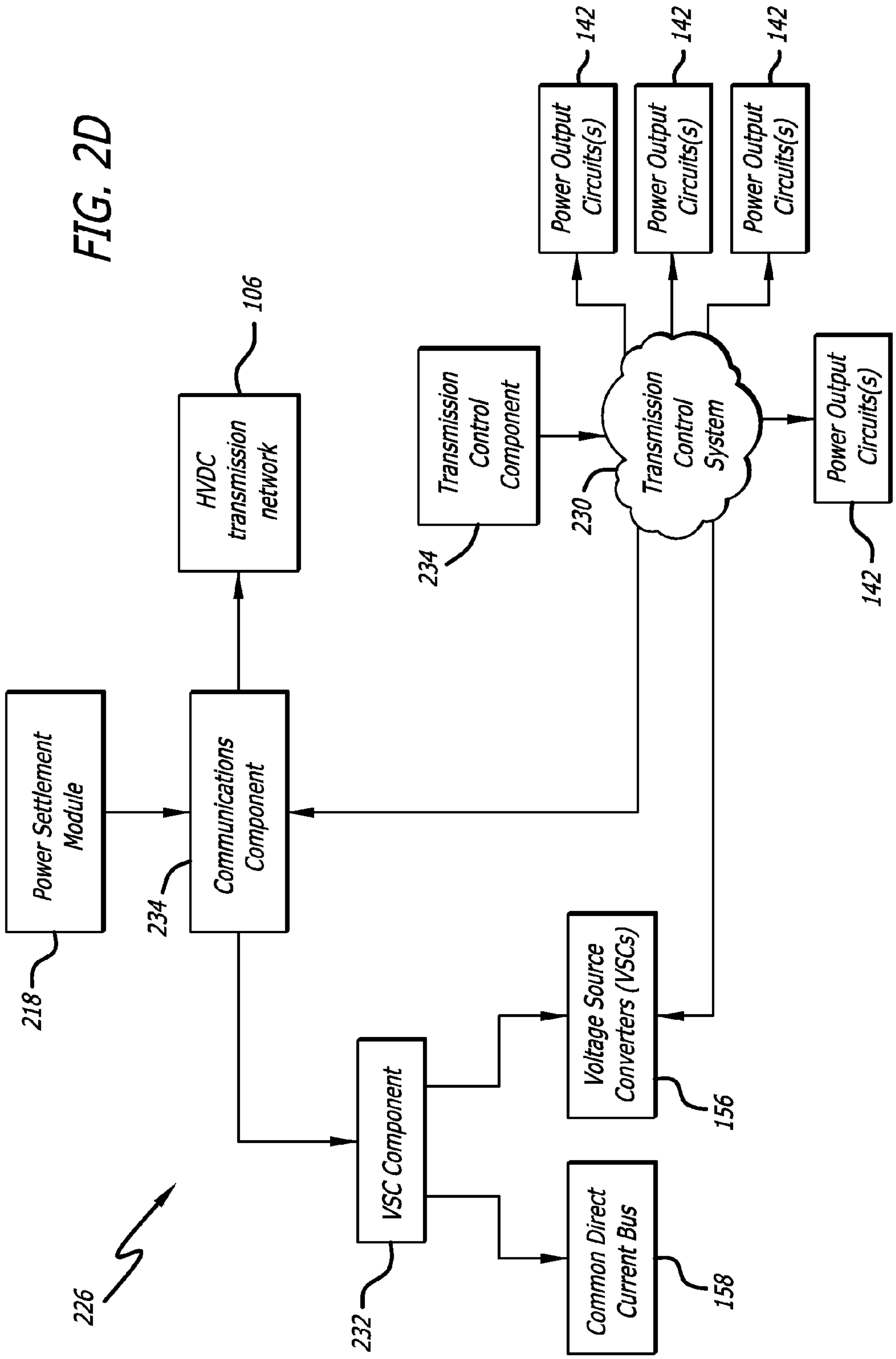

Power Settlement Module
218
Communications Component
234
HVDC transmission network
106
Transmission Control Component
234
Transmission Control System
230
Power Output Circuits(s)
142
Power Output Circuits(s)
142
Power Output Circuits(s)
142
Power Output Circuits(s)
142
Voltage Source Converters (VSCs)
156
VSC Component
232
Common Direct Current Bus
158
226

FIG. 2D

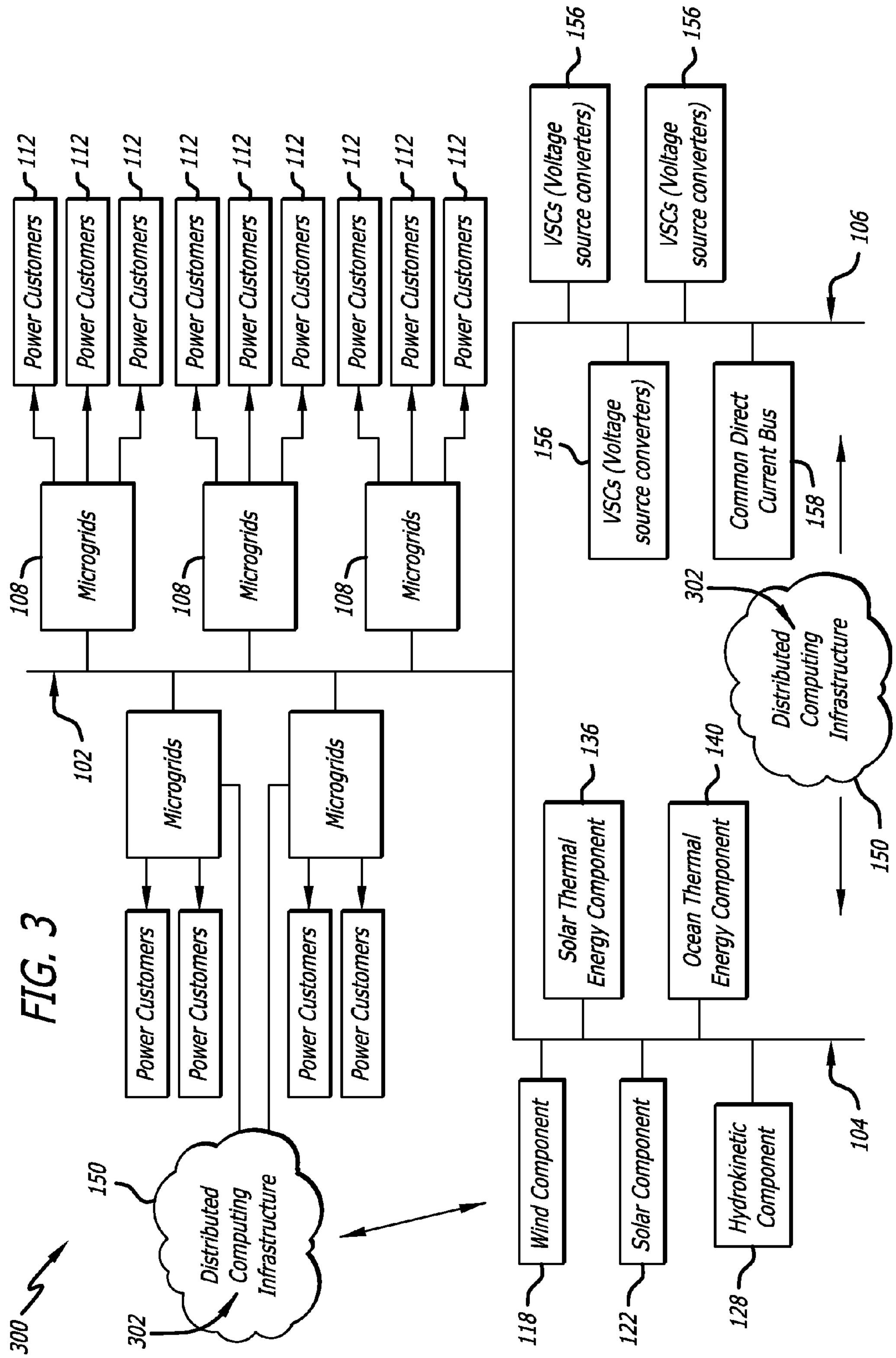

300
102
104
106
108
112
118
122
128
136
140
150
156
158
302
Power Customers
Microgrids
VSCs (Voltage source converters)
Common Direct Current Bus
Distributed Computing Infrastructure
Solar Thermal Energy Component
Ocean Thermal Energy Component
Wind Component
Solar Component
Hydrokinetic Component

FIG. 3

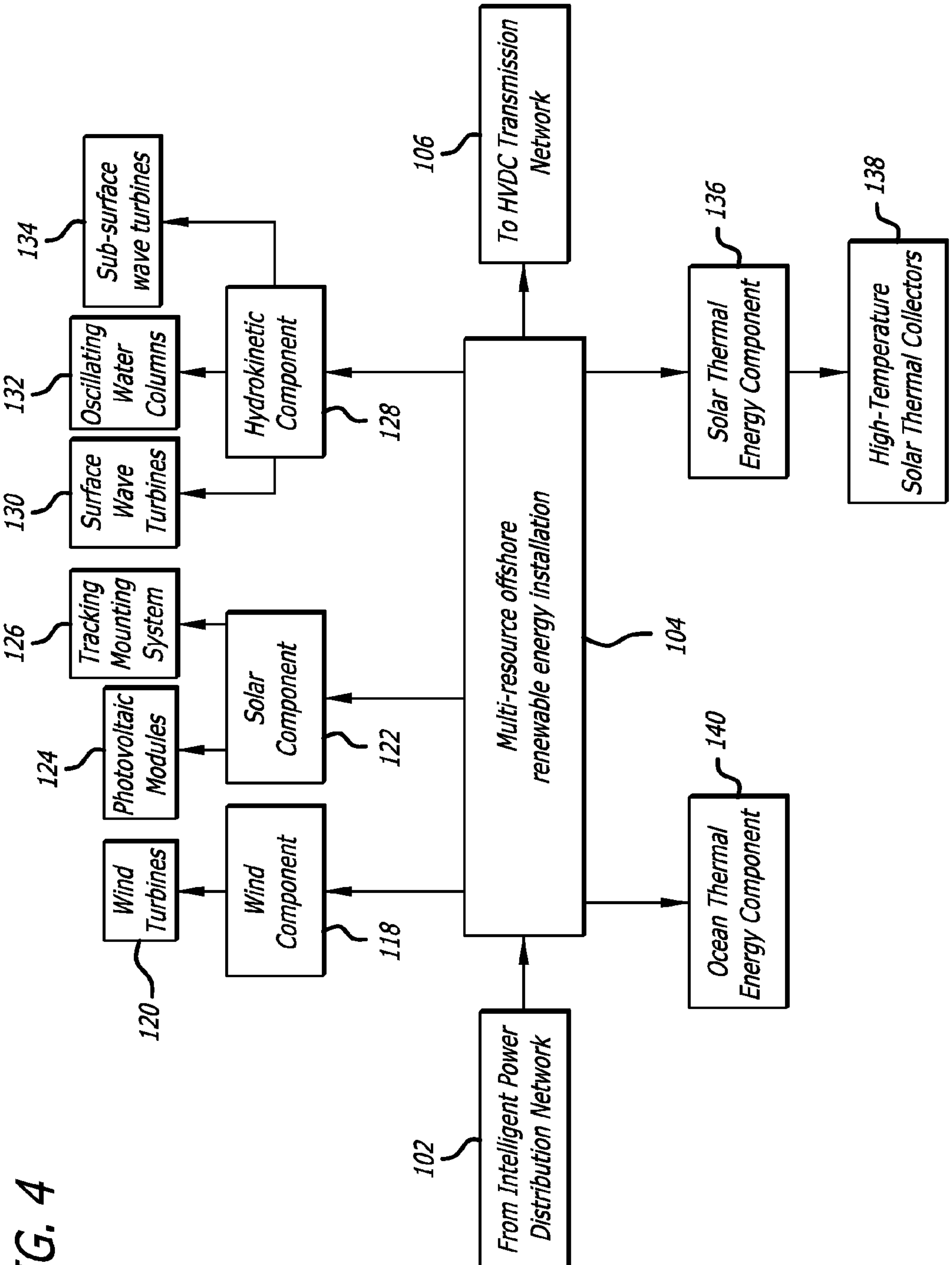

From Intelligent Power Distribution Network
102
Multi-resource offshore renewable energy installation
104
To HVDC Transmission Network
106
Wind Component
118
Wind Turbines
120
Solar Component
122
Photovoltaic Modules
124
Tracking Mounting System
126
Hydrokinetic Component
128
Surface Wave Turbines
130
Oscillating Water Columns
132
Sub-surface wave turbines
134
Solar Thermal Energy Component
136
High-Temperature Solar Thermal Collectors
138
Ocean Thermal Energy Component
140

FIG. 4

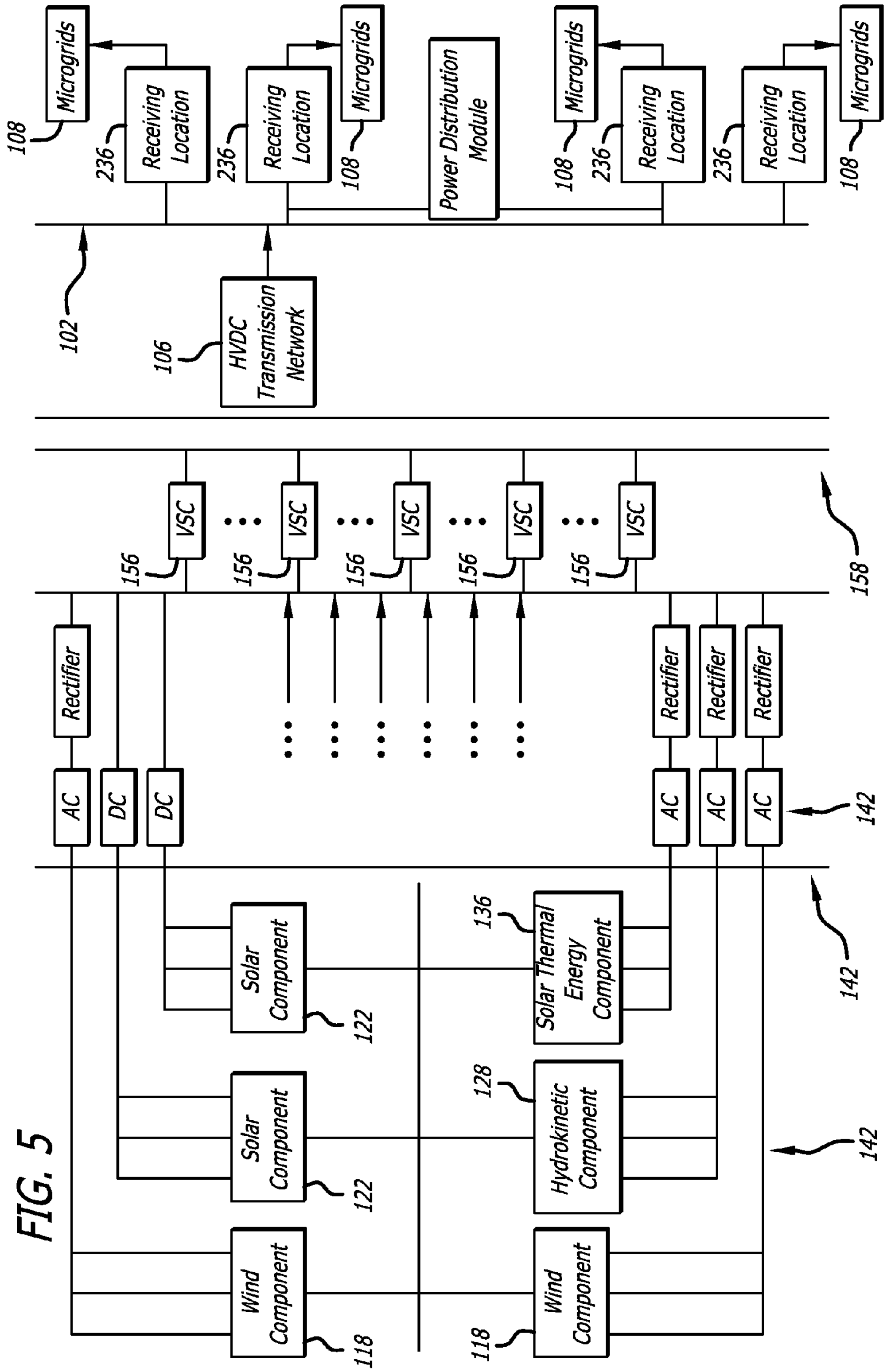

Microgrids
Receiving Location
Power Distribution Module
HVDC Transmission Network
VSC
Rectifier
AC
DC
Solar Component
Solar Thermal Energy Component
Hydrokinetic Component
Wind Component
108
236
102
106
156
158
142
136
128
122
118

FIG. 5

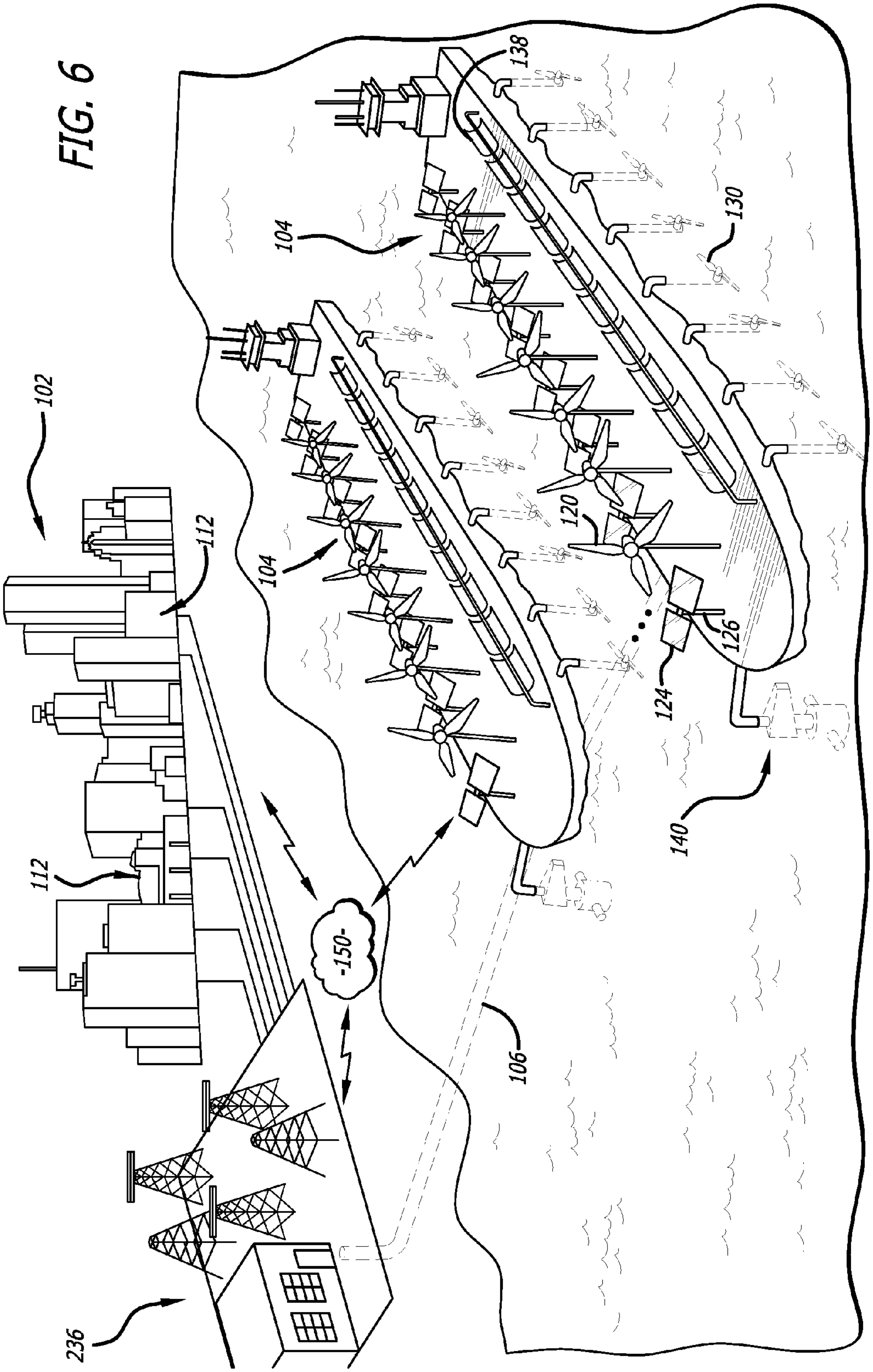


FIG. 6

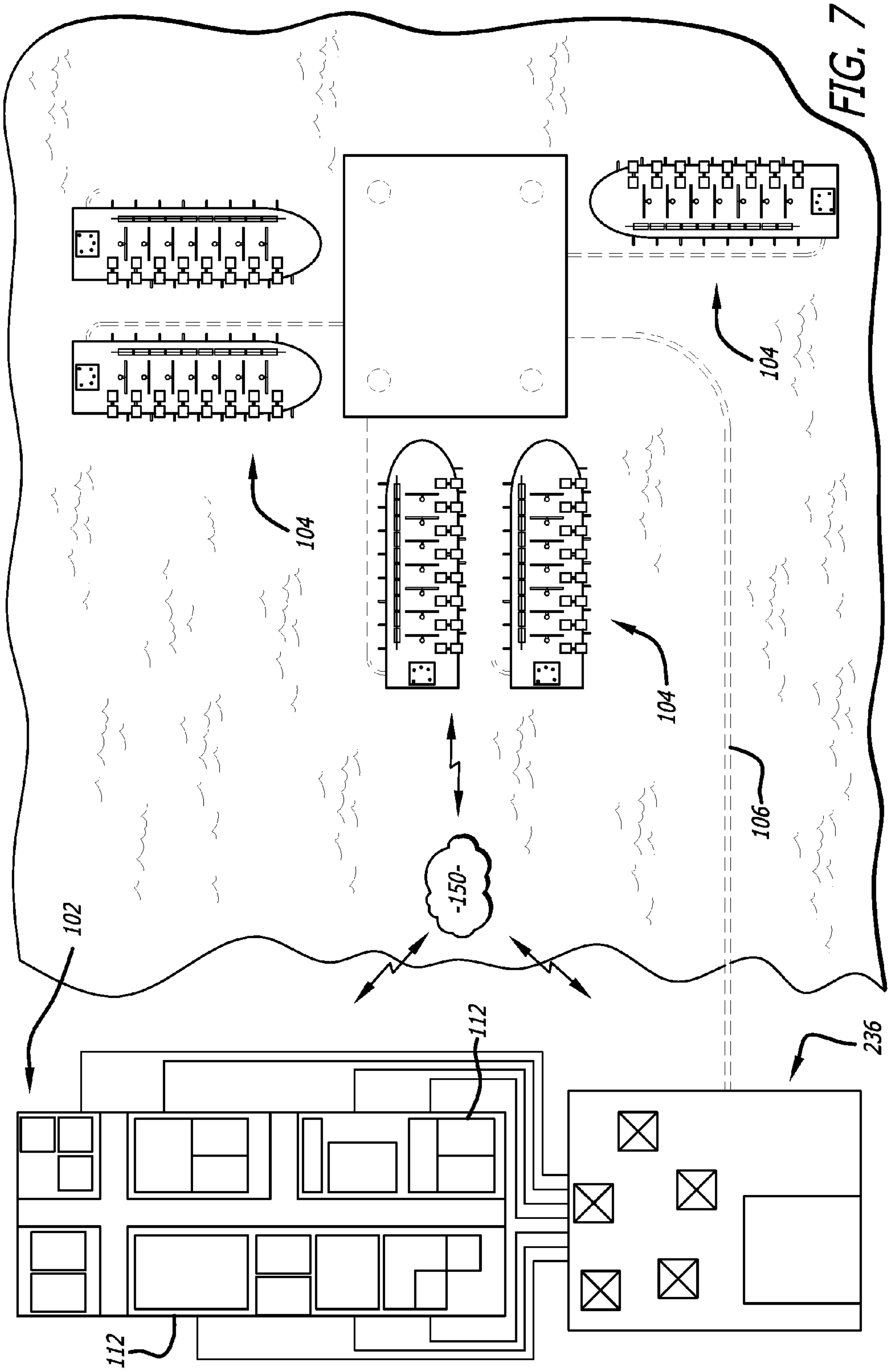


FIG. 7

ELECTRICITY GRID DATA ANALYTICS AS A MODULED SERVICE FOR PRODUCTION, DELIVERY, AND DISTRIBUTION OF POWER AS A DYNAMIC DEMAND RESPONSE WITHIN A RENEWABLE ENERGY-BASED ELECTRICITY GRID INFRASTRUCTURE

CROSS REFERENCE TO RELATED PATENT APPLICATIONS

[0001] To the fullest extent provided by law, the present non-provisional patent application is a continuation of, and claims priority to and the full benefit of the following U.S. non-provisional utility patent applications: Ser. No. 13/398,735, filed Feb. 16, 2012; Ser. No. 13/398,738, filed Feb. 16, 2012; and Ser. No. 13/398,744, filed Feb. 16, 2012.

STATEMENT REGARDING FEDERALLY-SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

FIELD OF THE INVENTION

[0003] The present invention relates to renewable energy resources. Specifically, the present invention relates to systems, methods, and apparatuses for supplying the power needs of an intelligent electricity grid from an entirely-renewable energy resource platform.

BACKGROUND OF THE INVENTION

[0004] As the interest in power generated from renewable energy resources rapidly increases, increasing attention is being focused systems and methods in which such power is produced, transmitted, delivered, and consumed. Despite technological advances in developing renewable energy resources and in electricity grids, current energy infrastructure suffers from many limitations that need rapid improvement as demand for such power increases, and grid security importance and regulatory requirements for use of "green" resources become more prominent.

[0005] Power derived from renewable energy such as solar, wind, wave, and solar thermal resources are becoming increasingly relied upon, but each includes several limitations that impede them from becoming widespread, low-cost, efficient, and continually viable sources of electricity. Each is inherently unreliable, owing to factors such as changes in the time of day and variations in weather conditions that mean that maximized performance of components for each resource is very difficult to manage. Combining any of these together proves even more difficult to manage the inherent inefficiencies involved in operating devices and components to meet energy demand.

[0006] Power derived from renewable energy sources is generated both on land and at sea. Offshore energy installations present many complicated challenges. The majority of all offshore energy installations are primarily devoted to carbon-based, non-renewable resources, but each of solar power, wind power, wave, and solar thermal-based power can be and are generated from offshore installations. However, implementing offshore installations are extremely challenging, time-consuming, expensive, and environmentally sensitive. Many issues must addressed by the energy provider wishing to use an offshore base for generating power of any kind. Just a few examples of issues that present significant challenges include storage of power, its transmission to the onshore power grid, providing power to the offshore installation itself, maintenance, distance from the electricity grid, and exposure to weather elements. Additionally, building a large-scale multi-resource platform or installation is very expensive and often has a large environmental impact footprint, making such an installation a questionable investment. All of these issues can reduce the attractiveness of constructing and operating such an installation.

[0007] Storage issues are a particularly challenging problem attendant to transferring power generated offshore to the onshore electricity grid. The electricity grid itself contains limited inherent facility for storing electrical energy. Power must be generated constantly to meet uncertain demand, which often results in over-generation (and hence wasted energy) and sometimes results in under-generation (and hence power failures). Additionally, there is limited facility for storing electrical energy at the point of generation, particularly in the case of offshore installations where available space must be maximized and cost and environmental issues are major considerations.

[0008] Nonetheless, requirements for buying power generated from "clean" or "green" renewable resources are rapidly increasing. Enhanced ecological and environmental awareness, and a desire to reduce energy dependency on carbon-based fossil fuels and to decrease availability and price concerns resulting from exposure to geopolitical concerns, has lead many governments to implement regulations that either dictate or impose limits on the amount of power produced and consumed that is generated from carbon-based or otherwise non-renewable energy sources. Because of this, there is a strong and continually developing need for efficient and cost-effective power generated from renewable energy resources.

[0009] Furthermore, despite these challenges and many others in the existing technology concerning power from renewable resources, there exists a strong need for improved systems and methods of producing, transmitting, distributing and delivering energy so that the needs of power customers can be satisfied from renewable energy sources. There is also a strong and increasing need for clean, reliable, efficient sources of power that are not dependent on geopolitical issues and which maximize the availability of renewable resources to deliver power in real-time as needed and instructed by "smart" electricity grids. There is further a need for an energy management network capable of integrating data from multiple sources that influence the amount of such power available to be generated and required for delivery to customers of electricity grids. Additionally, there exists a strong need in the art for a platform that is capable of efficiently-provided power from multiple renewable energy resources that minimize many of the challenges facing energy providers, as well as for electricity grid infrastructure that is capable of meeting electricity demand substantially from renewable energy resources, maintaining grid infrastructure integrity against increasing public security concerns, and maximizing operational efficiency and capacity to reduce the costs associated with the many inherent inefficiencies with renewable energy resources.

[0010] It is accordingly one object of the present invention to provide a renewable energy resource management system and method of managing power distribution from a renewable resource provider to an intelligent power distribution network, that addresses many of the problems and challenges facing the buyers and sellers of power derived from renewable energy resources such as wind, solar, wave, and solar thermal energy, and with generating, transmitting and distributing power to meet the capacity of a developing, sophisticated, and intelligent electricity grid infrastructure. It is a further object of the present invention to provide a multi-resource renewable energy installation and method of operation that addresses problems and challenges with generating power from renewable energy resources in an efficient and cost-effective manner to meet the substantially increasing demand, need, and requirement for power from such resources. It is yet another object of the present invention to provide an improved electricity grid infrastructure, and methods of operating and automating the same, that address the problems and challenges associated with meeting electricity demand substantially from renewable energy resources, maintaining grid infrastructure security, and maximizing operational efficiency and capacity to meet real-time power demands of grid customers.

[0011] It will be apparent to those of skill in the art that one would be not be motivated to combine existing art, and one would not consider it reasonable to try to combine existing art, to arrive at the teachings of the present invention. There are many reasons why existing technology teaches against the disclosures of the present invention. For example, there are inherent market biases favoring the use of existing, non-renewable energy resources. Existing energy production infrastructure strongly favors the use of non-renewable energy resources, and the costs of generating power from renewable energy resources are far higher, despite the availability of and ease with which wind, solar, wave, and solar thermal energy can be obtained. Additionally, energy commodity prices and weather conditions fluctuate widely, making it very difficult and often prohibitively expensive to efficiently generate, transmit, and distribute power derived from renewable energy resources. These fluctuations, and the inherent inefficiencies resulting from them in utilizing renewable resources, make it difficult for providers to justify investing in the infrastructure needed to develop, transmit, and distribute power from renewable energy resources. This includes investing in and building offshore installations, whether dedicated to a single renewable resource or hosting multiple components that generate power from several different renewable resources in the same location. It will therefore be readily apparent based on all of the above that it would not be obvious to combine any of the teachings of the prior art to arrive at the specific technological advances discussed herein.

BRIEF SUMMARY OF THE INVENTION

[0012] The present invention discloses, in one aspect thereof, an energy management system that presents an operational infrastructure for managing the generation, transmission, delivery, and distribution of power to "smart" electricity topologies derived from multiple renewable energy resources. The infrastructure is fully network-connected in a distributed computing environment, and enables utilities and providers to respond to peak demand loads more effectively and efficiently, balance power production with power consumption, and supply power consumers entirely from multiple renewable resources.

[0013] In another aspect of the present invention, a multi-resource renewable energy installation provides the ability to efficiently produce power from multiple renewable energy resources in a single location. The multi-resource renewable energy installation is a fully network-connected, distributed platform for producing power from multiple renewable energy resources and maintaining an efficient operational capacity of each such resource to transmit and deliver real-time power demands of customers that balances power production to consumption to minimize both supply and demand-side power storage requirements.

[0014] In a further aspect, the present invention discloses an innovative electricity grid infrastructure that enables robust and dynamic multi-directional communications and automated decision-making systems to provide electricity grid operators with multiple capabilities to efficiently generate, transmit, deliver and distribute power. The electricity grid infrastructure enables both supply and demand-side improvements in responding to peak demand loads, balancing and maintaining power production with power consumption to minimize grid storage requirements, re-configuring assets for power production and re-routing power for consumption as needed, and supplying power demand entirely from multiple renewable energy resources.

[0015] Together, the aspects of the present invention provide significant improvements and advances in systems and methods in which power is produced, transmitted, delivered and distributed. The present invention therefore incorporates and integrates concepts in producing power from renewable, non carbon-based energy resources, transmitting and distributing power to increasingly interconnected and intelligent electricity grids, and delivering power to end consumers, as discussed herein.

[0016] In one embodiment of the present invention, a renewable energy resource management system comprises a distributed computing infrastructure configured to integrate a plurality of modules over one or more interconnected computing networks to efficiently manage a delivery of power generated by a multi-resource offshore renewable energy installation having a plurality of renewable energy resource components and capable of generating power from multiple renewable energy resources to an intelligent power distribution network composed of a plurality of microgrids each capable of being separately decoupled from the intelligent power distribution network for distribution of power thereto, the plurality of modules at least including a power generation module, a power distribution module, a power settlement module, and a power settlement module. The power distribution module having a load control component configured to forecast a power requirement of the intelligent power distribution network over a specific period of time, based on a continuing assessment of a power demand of each power user of each microgrid in the plurality of microgrids that is communicated to the load control component and to manage a power delivery to each microgrid in the plurality of microgrids responsive to the power demand, and having a renewable energy resource pricing and conditions component to continually assess a renewable resource commodity price for each renewable energy resource of the multiple renewable energy resources over the specific period of time to forecast a variable purchase price range at which each renewable energy resource is to be purchased and to assess a renewable energy resource purchasing condition required of the intelligent power distribution network as determined by one or more of a regulatory requirement and a contractual requirement, and having a communications component configured to communicate to the power settlement module at least the power requirement of the intelligent power distribution network, the variable purchase price range at which each renewable energy resource is to be purchased, and the renewable energy resource purchasing condition.

[0017] The power generation module having a renewable resource efficiency component configured to continually assess the renewable resource commodity price for each renewable energy resource of the multiple renewable energy resources over the specific period of time to forecast a variable selling price range at which each renewable energy resource is to be sold and to generate a meteorological conditions forecast for each renewable energy resource of the multiple renewable energy resources for the specific period of time, and having a renewable resource control component configured to continually assess an operative availability and forecast an available power capacity of each renewable energy resource component at the multi-resource offshore renewable energy installation, relative to at least the variable selling price range at which each renewable energy resource is to be sold and the meteorological conditions forecast for each renewable energy resource, to meet the power requirement for the specific period of time, and a communications component configured to communicate to the power settlement module the available power capacity of each renewable energy resource component, for the specific period of time, the variable selling price range at which each renewable energy resource is to be sold, and the meteorological conditions forecast, and the power settlement module having a transaction resolution component configured to resolve a final price at which each renewable energy resource will be purchased by the intelligent power distribution network from the multi-resource offshore renewable energy installation for the specific period of time and a production, transmission, and delivery component configure to arrange a power transfer from the multi-resource offshore renewable energy installation over a high-voltage direct current transmission system for distribution by the load control component to each microgrid in the intelligent power distribution network by communicating, through a communications component, instructions to the power generation module to produce power and to the power transmission module to transmit power. the power transmission module having one or components configured to initiate the power transfer responsive to instructions from the power settlement module, operate a plurality of voltage source converters coupled to power output circuits of each renewable energy resource component that provide a substantially constant voltage level for connection to a common direct current bus in the high voltage direct current transmission system, and monitor the power output circuits and voltage source converters to ensure that the power requirement is being satisfied. The offshore multi-resource renewable energy installation including a wind component comprising at least one wind turbine, a photovoltaic component comprising at least one photovoltaic module, a hydrokinetic component comprising at least one of a surface wave turbine, an oscillating column, and an undersea wave turbine, and a solar thermal energy component comprising at least one high-temperature solar thermal collector, each of the wind component, the photovoltaic component, the hydrokinetic component, and the solar thermal energy component having a separate renewable energy resource component control system coupled thereto to independently and variably operate each of the at least one wind turbine, the at least one photovoltaic module, the at least one of a surface wave turbine, an oscillating column, and an undersea wave turbine, and the at least one high-temperature solar thermal collector responsive to instructions from the power generation module to generate a specific amount of power balanced with the power requirement of the intelligent power distribution network for the specific period of time, that maximizes an efficient operational capacity of each renewable energy resource component generating the power requirement, and minimizes both a power storage requirement at the multi-resource offshore renewable energy installation and a power storage requirement at a receiving location of the intelligent power distribution network.

[0018] In another embodiment of the present invention, a renewable energy resource management system comprises an intelligent power distribution network segregated into one or more microgrids each separately coupled to the intelligent power distribution network so that each is capable of being decoupled to provide power separately thereto as needed, and each configured to distribute power to a segment of customers of the intelligent power distribution network in response to a power requirement of each segment of customers for a specific period of time determined and communicated by a microgrid control system managing each microgrid. The embodiment also includes a load management module capable of communicating with the intelligent power distribution network and an offshore multi-resource renewable energy installation in a distributed computing infrastructure in which a transfer of power from the offshore renewable resource installation to the intelligent power distribution network that satisfies only the power requirement as needed by each microgrid and maximizes an efficient utilization of each renewable energy resource component in a plurality of renewable resource components available at the offshore multi-resource renewable energy installation is settled, so that a storage requirement of power generated at the offshore renewable energy resource installation and a storage requirement of power delivered to a receiving location prior to transmission to the intelligent power distribution network is maintained at a minimum amount, the efficient utilization of each renewable resource component determined, for the specific amount of time, by a meteorological condition forecasted for each resource at the offshore multi-resource renewable energy installation as determined by communicating with a first external network, a commodity purchase price forecasted for each resource as determined by communicating with a second external network, and a resource availability forecasted for each resource as determined by communication with a component control system managing each renewable energy resource component. The plurality of renewable resource components available at the offshore multi-resource renewable energy installation include a wind component, a photovoltaic component, a hydrokinetic component, and a solar thermal collection component, each renewable resource component operable to generate power from one or more output circuits coupled to a plurality of voltage source converters and a common direct current bus over which a combined power output that includes a rectified alternating power output portion and a direct current power output is provided for transmission to the intelligent power distribution network over a sub-sea high voltage direct current transmission link.

[0019] In another embodiment, the present invention discloses a method of managing power distribution from a renewable energy resource provider to an intelligent power distribution network. The method comprises communicating with an intelligent power distribution network to determine, over a specific period of time, a power requirement of customers represented by a plurality of microgrids each separately coupled to the intelligent power distribution network and each continuously communicating a power demand for the customers represented, and to determine a purchase price range at which the power requirement will be purchased, the price range calculated from a first commodity pricing forecast of each renewable energy resource at a multi-resource offshore renewable energy installation site, and to determine contractual and regulatory requirements of each microgrid relative to the purchase of power produced from one or more of the renewable energy resources. The method also comprises communicating with components representing each renewable energy resource at the offshore multi-resource renewable energy installation to determine, for the specific period of time, an efficient use of the components representing each renewable energy resource including a wind component, a photovoltaic component, a hydrokinetic component, and a solar thermal collection component, based upon a forecast of meteorological conditions relative to each renewable energy resource at the multi-resource offshore renewable energy installation site, a selling price range at which the power produced will be sold, the selling price range calculated from a second commodity pricing forecast of each renewable energy resource at the offshore multi-resource renewable energy installation site, and availability of power produced from one or more of the renewable energy resources based upon operating conditions at the offshore multi-resource renewable energy installation. The method also includes settling a transfer of the power requirement to the intelligent power distribution network from the multi-resource offshore renewable energy installation and instructing the multi-resource offshore renewable energy installation to produce a specific amount of power from each of the wind component, a photovoltaic component, a hydrokinetic component, and a solar thermal collection component, each component having one or more power output circuits coupled to a plurality of voltage source converters and a common direct current bus over which a combined power output that includes a rectified alternating current power output portion and a direct current power output is provided for transmission of the power requirement to the intelligent power distribution network over a high-voltage direct current transmission system.

[0020] Other embodiments, features and advantages of the present invention will become apparent from the following description of the embodiments, taken together with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0021] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the invention and together with the description, serve to explain the principles of the invention.

[0022] FIG. **1** is a system diagram of a renewable resource energy management system according to one embodiment of the present invention;

[0023] FIG. **2**A is a conceptual diagram of components in a power distribution module in a renewable resource energy management system;

[0024] FIG. **2**B is a conceptual diagram of components in a power generation module in a renewable resource energy management system;

[0025] FIG. **2**C is a conceptual diagram of components in a power settlement module in a renewable resource energy management system;

[0026] FIG. **2**D is a conceptual diagram of components in a power transmission module in a renewable resource energy management system;

[0027] FIG. **3** is a system diagram of an electricity grid infrastructure according to another embodiment of the present invention;

[0028] FIG. **4** is a system diagram of a multi-resource offshore renewable energy installation according to another embodiment of the present invention;

[0029] FIG. **5** is a diagram of power output circuits from a multi-resource offshore renewable energy installation connected to a power transmission system according to the present invention;

[0030] FIG. **6** is a perspective plan view of a multi-resource offshore renewable energy installation and electricity grid infrastructure according to one embodiment of the present invention; and

[0031] FIG. **7** is a top plan view of a multi-resource offshore renewable energy installation and electricity grid infrastructure according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0032] In the following description of the present invention reference is made to the accompanying figures which form a part thereof, and in which is shown, by way of illustration, exemplary embodiments illustrating the principles of the present invention and how it is practiced. Other embodiments will be utilized to practice the present invention and structural and functional changes will be made thereto without departing from the scope of the present invention.

[0033] The present invention discloses an energy management system and method for power transmission to an intelligent electricity grid from a multi-resource renewable energy platform, an offshore multi-resource renewable energy installation and method of maximizing its operational capacity, and a renewable energy-based electricity grid infrastructure and method of its operation and automation. Each of these embodiments achieves one or more of the objectives of the present invention.

[0034] These include, but are not limited to, reducing costs of producing power from renewable energy resources; maximizing efficient operational capacity of multiple sources of power from renewable energy in the same location; adapting power production to power consumption to balance power loads and minimize or eliminate the need for large-scale, expensive power storage components; reducing dependency on non-renewable energy resources by introducing large-scale power production to meet power demands entirely from renewable resources; addressing and enhancing a growing need for power grid infrastructure security, stability, and reliability; providing power for future direct current-specific electricity grids and different sources of power to different power consumers as needed; enhancing electricity grid infrastructure automation, optimization, risk and outage management, self-checking and self-healing; and integrating distributed grid and cloud computing into the broader infrastructure for producing, transmitting, distributing, and delivery power.

[0035] The present invention also provides a framework within which a consistent flow of power can be delivered as needed while minimizing the impact of fluctuations that results in peaks and valleys. The present invention also allows power from renewable energy resources to be bought and sold at the low cost and high profit by aggregating multiple variables to make sure power-producing assets operate efficiently. Within this framework, available power-producing assets do not need to all be operated at the same time or at the same speed, and power is produced from substantially the most efficient available assets.

[0036] FIG. **1** is a system diagram of a renewable resource energy management system **100** according to one embodiment of the present invention. The renewable energy resource management system **100** is configured to, in one aspect, arrange a power transaction between a buyer and a seller of power. The "buyer" is an intelligent power distribution network **102**, which may comprise a portion of one or more electricity grids, each of which is composed of a plurality of microgrids **108**. Each microgrid **108** serves a plurality of power customers **112** who are at least communicatively coupled thereto. The "seller" is one or more multi-resource offshore renewable energy installations **104** at least comprising several renewable energy resource components **116** capable of generating power from multiple sources of renewable energy **114**. Many multi-resource offshore renewable energy installations **104** may be coupled together and included with the scope of the present invention, so that for example ultra-large offshore energy "farms" can be connected together to meet the power needs of the intelligent power distribution network **102** or electricity grid infrastructure **300**.

[0037] Each renewable energy resource component **116** comprises of a plurality of apparatuses and systems which perform the work necessary to produce power. Each of these renewable energy resource components **116**, and each apparatus and system therein, are separately controllable and are independently and variably operable to provide a power requirement **144** as determined and instructed by the intelligent power distribution network **102**.

[0038] The renewable resource energy management system **100** provides a "network of networks" approach to electricity grid architecture with distributed master control capabilities and a wide-area communications infrastructure that integrates electricity grid automation and optimization concepts with balancing power production to power consumption and maximizing efficiency of power production from renewable energy resources. The renewable resource energy management system **100** is hosted within a distributed computing infrastructure **150** which includes one or more multiple interconnected computing networks **152**. System of modules and control systems within the present invention that manage and process data flow, communicate, and provide the necessary input and output signals to perform the various functions discussed herein are resident within this distributed computing infrastructure **150**, which may be thought as incorporating cloud and/or grid computing principles to provide the operating environment for the present invention.

[0039] The renewable resource energy management system **100** includes a modular load management system having plurality of modules each responsible for one or more functional aspects of the present invention. These include a power distribution module **200** responsible for managing the intelligent power distribution network **102** through a plurality of components, such as a load control component **202**, a renewable energy resource pricing and conditions component **204**, and a communications component **206**. A power generation module **208** is responsible for managing the multi-resource offshore renewable energy installation **104**, and also includes a plurality of components, such as a renewable resource efficiency component **210**, a renewable resource control component **212**, and a communications component **216**. A power settlement module **218** is responsible for managing actions and communications between the intelligent power distribution network **102**, the multi-resource offshore renewable energy installation **104**, and a transmission system **106**, one such action being to arrange a transfer of power from the multi-resource offshore renewable energy installation **104** to the intelligent power distribution network **102**. The power settlement module **218** includes a transaction resolution component **220**, a power production, transmission and delivery component **222**, and a communications component **224**. The plurality of modules further includes a power transmission module **226**, responsible for managing the transfer of the power requirement **144** to the intelligent power distribution network **102**. The power transmission module **226** also includes several components, such as a voltage source converter component **220**, a transmission control component **228**, and a communications component **234**.

[0040] At least because of the distributed nature of its master control capabilities, the renewable energy resource management system **100** is capable of modular scalability so that many other modules performing various functions may be added and integrated to "plug in" through the distributed computing infrastructure **150**. Examples of modules that could be supported by the scalability of the present invention include, but are not limited to, data storage modules capable of accumulating large amounts of data inherent in such systems, and billing modules providing applications such as calculation of the complex charges and credits associated with time-sensitive purchases and sales of power from renewable energy. It is therefore contemplated that any number of modules, performing functions of any type, from high-level system to specifically-designed tasks, may be integrated into the renewable energy resource management system **100**.

[0041] Communications components **206**, **216**, **224**, and **234** are configured to communicate data within the renewable resource energy management system **100** and the distributed computing infrastructure **150** using high-capacity wireless broadband networks that enable high-speed multi-directional Internet protocol communications. Wireless broadband networks may be of any technical type, such as for example standards-based technologies like WiMAX, within which various computing networks are capable of operating, such as field area networks and SCADA systems. Frequency spectrums for wireless broadband communications may be licensed or unlicensed in the present invention. In one embodiment, the privately-hosted and shared distributed computing infrastructure **150** may utilize one or more licensed, private spectrums as one means of enhancing communications security in the present invention.

[0042] The intelligent power distribution network **102** includes the plurality of microgrids **108**, each of which are responsible for one or more activities, including communicating with power customers **112** coupled thereto. Each microgrid **108** has at least one controller and a microgrid control system **110**, which models data flow between each microgrid **108** and each of its power customers **112**, with each device, meter, or other apparatus or system coupled to each power customer **112** capable of predicting and/or determining customer **112** power usage and needs. Examples of such devices include "smart" power meters which have resident controllers capable of analyzing and communicating each customer's patterns to microgrids **108** and/or microgrid control systems **110**.

[0043] FIG. 2A is a conceptual diagram of components in a power distribution module **200** according to the present invention. The power distribution module **200** is a series of processes performed across one or more processors within the renewable resource energy management system **100** and is responsible for various distribution-side functions. The load control component **202** of the power distribution module **200** is configured to perform multiple functions within the distributed computing infrastructure **150**. One such function is to forecast a power requirement **144** of the intelligent power distribution network **102** over any specific or given period of time. This is performed at least in part by continually assessing power demand **146** of all microgrids **108** forming the intelligent power distribution network **102**, through communications with each device, apparatus, or controller coupled to each power customer **112**, and components of each microgrid **108**. The load control component **202** may perform this continual assessment in a number of ways, such as by requesting data from controllers configured to determine multiple data sets from each apparatus, device or customer **112**. This may also be performed by requesting data from each microgrid **108** via its microgrid control system **110**.

[0044] The load control component **202**, and each microgrid **108** and microgrid control system **110**, are capable of bi-directional communications with each device, apparatus, or customer **112** to perform "push" capabilities to send instructions thereto to perform one or more tasks. This may be the case where the load control component **202** and microgrid **108** wish to add or remove devices, apparatuses, or customers **112**. This may also be the case where the load control component **202** and microgrid **108** have a need to suspend operation of a particular device, apparatus or customer **112** for a specific reason. One example of this is a customer **112** who is a semiconductor manufacturing plant requiring a specific level of power—where the load control component **202** and/or microgrid **108** sense a voltage spike is about to occur with that customer **112**, power delivery can be re-routed so that the voltage spike is avoided and systems coupled to the semiconductor plant are not damaged. It is therefore contemplated that the load control component **202** and/or each microgrid **108** and microgrid control system **110** are fully capable of pushing signals to devices, apparatuses, and customers to perform specific tasks within the power distribution module **200**.

[0045] The power demand **146** is comprised of multiple variables which form an overall picture of the power needs of each customer **112** over a specific period of time. The multiple variables are influenced by the type of power customer **112** and any particular power needs it may have, its history of power usage, and issues like contractual or regulatory requirements, where applicable, that impose certain limitations on what kind of power can be consumed, and when. Power need may therefore be derived from an aggregation of data reflecting different usage components, such as alternating current, direct current, or both, a usage type, such as for example a semiconductor manufacturing or a plant or a high-security public infrastructure building, and any fluctuation tolerance over the specific period of time at issue which may influence load variances, such as where the number and type of devices requiring power changes over the specific period of time. It is to be understood that many variables exist and many different examples may be used to explain that power needs may be derived from complex modeling of various systems.

[0046] The load control component **202** is also configured to manage a delivery of the power requirement **144** to each microgrid **108** in response to the continuing assessment of power demand **146** of each microgrid. This is performed in conjunction with communications with critical distribution-side delivery infrastructure such as receiving locations, transformers, sub-stations, and the like that serve as power intake points from the transmission system **106**.

[0047] Based on the power need of each customer **112**, the load control component aggregates the power demand **146** of each microgrid to arrive at the forecasted power requirement **144** that will eventually be distributed for delivery across the entire intelligent power distribution network **102** over the specific period of time. The power requirement **144** will be both communicated to the power settlement module **218** to arrange the transfer of power from the multi-resource offshore renewable energy installation **104**, and to orchestrate, together with each microgrid **108**, distribution of the power network across the intelligent power distribution network **102**.

[0048] The power requirement **144** is the result of mathematical modeling of several factors, including multiple variables that comprise the power need of each customer **112**, and other factors affecting the broader intelligent power distribution network **102**, such as higher-level electricity grid and microgrid topology that influence usage type (alternating or direct current), usage transmission distance to account for losses, and any fluctuation tolerance, as well as other variables as noted herein, such as regulatory and contractual requirements for using energy derived from particular sources determined by another component of the power distribution module **200**. In this way, the modeling used to arrive at the power requirement **144** permits scalability of the present invention by incorporating input data from the both the microgrid **108** level and the power customer **112** level, allowing seamless integration of lower-level customers **112**, additional microgrids **108**, and multiple large-scale electricity grids serving large geographic areas as needed.

[0049] The load control component **202** is therefore responsible for responding to peak demand loads through communications with each microgrid **108** and/or each microgrid control system **110**, as well as managing and monitoring load distribution across the entire intelligent power distribution network **102**. This load control framework enables many other critical grid infrastructure functions attendant to load distribution, such as faster service restoration in the event of outages or security issues, automatic re-routing of power as needed, and generally ensuring a resilient, flexible grid infrastructure.

[0050] The power distribution module **200** also includes a renewable energy resource pricing and conditions component **204**, which is responsible for a different function of the power distribution module **200**—determining a commodity price range at which power from each renewable energy resource **114** is to be purchased. In addition to generating the forecasted power requirement **144**, the power distribution module **200** also provides the power settlement module **218** with this commodity price range.

[0051] Energy from renewable resources is a commodity often traded between buyers and sellers on commodities markets and exchanges, and commodity prices for each of the renewable energy resources **114** from which power is produced at the multi-resource offshore renewable energy installation **104** vary widely over time for a variety of reasons, such as for example weather conditions. Therefore, in order to facilitate a cost-effective purchase price for the power requirement **144** to service the intelligent power distribution network **102**, the renewable energy resource pricing and conditions component **204** performs an assessment of commodity price data for each renewable resource **114** available for providing the power requirement **144** and forecasts a commodity purchase price range at which each renewable energy resource **114** will be purchased.

[0052] Additionally, power customers **112**, and the intelligent power distribution network **102** itself, may have certain purchasing conditions related to contractual and regulatory requirements obligating them to purchase energy from particular renewable energy resources at particular times and in particular quantities, such as for example commodity price signals, or other conditions such as tariffs. These purchasing conditions may impose additional constraints on the amount and purchase price of each renewable energy resource **114**. Purchasing conditions data may be available from a variety of sources—such as from an external database maintaining such requirements, or any other internal or external source. Regardless, the renewable energy resource pricing and conditions component **160** is responsible for accumulating this information and incorporating it into models for purchases of power relative to each renewable energy resource **114**.

[0053] The renewable energy resource pricing and conditions component **204** performs one or more processes to model the commodity price data for each renewable energy resource **114** and account for any purchasing conditions, and arrives at the forecasted commodity purchase price range at which reach renewable resource will be purchased for the specific period of time. The renewable energy resource pricing and conditions component **204** may also take into account meteorological conditions in the area where the multi-resource offshore renewable resource installation **120** is located in arriving at this forecast. The forecasted commodity purchase price range is then communicated, via the communications component **206**, to the power settlement module **218**.

[0054] In order to access at least commodity price data and meteorological data, the renewable energy resource pricing and conditions component **204** communicates with one or more external computing networks **154** that are outside the distributed computing infrastructure **150**. In the case of commodity prices for each renewable energy resource **114**, the renewable energy resource pricing and conditions component **204** may access one or more energy commodity trading platforms **160** to determine the purchase price range for each renewable energy resource **114** for the specific period of time. The owner or operator of one or more electricity grids and/or microgrids **108** coupled to the intelligent power distribution network **102** may also buy, sell, or trade, financial instruments allowing the power distribution module **200** to hedge, or control, exposure to price fluctuations in the commodity price data for each renewable energy resource **114**. Similarly the renewable energy resource pricing and conditions component **204** may access one or more meteorological weather platform or site **162**, and one or more purchasing conditions database **164**. Regardless, the power distribution module **200** is to be understood to include the capability to communicate with one or more external computing networks **154** to accomplish forecasts of commodity price data, meteorological conditions, and where applicable, include purchasing conditions from contractual and regulatory requirements of each microgrid **108** and/or power customer **112** in those forecasts.

[0055] The communications component **206** is at least responsible for communicating data to the power settlement module **218**, within the power distribution module **200**, and with the one or more external computing networks **154**. The data to be communicated to the power settlement module **218** includes the power requirement **144**, the commodity purchase price range at which the power requirement **144** will be purchased for each renewable energy resource **114** available at the multi-resource offshore renewable energy installation **104**, and any purchasing condition relative to the purchase of power from renewable energy resources **114**. The communications component **160** includes one or more processes and circuit elements configured to aggregate various data inputs and transmit the resulting aggregated data incorporating the power requirement **144**, the commodity purchase price range, and any purchasing condition within the distributed computing infrastructure **150**. The communications component **206** therefore incorporates logic elements to ensure incoming data from the load control component **202** and the renewable energy resource pricing and conditions component **204** is in a form that can be utilized by the power settlement module **218** to settle a transfer of the power requirement **144** in accordance with the present invention.

[0056] FIG. **2**B is a conceptual diagram of components in a power generation module **208** according to the present invention. The power generation module **208** is a series of processes performed across one or more processors within the renewable resource energy management system **100** and is responsible for various production-side functions governing operations in the multi-resource offshore renewable energy installation **104**. The power generation module **208** includes a renewable resource efficiency component **210**, a renewable resource control component **212**, and a communications component **216**.

[0057] The renewable resource efficiency component **210** is configured to perform multiple tasks. One such task is to continually assess commodity prices for each renewable energy resource **114**, and forecast a commodity selling price range for each renewable energy resource **114**. Further, the renewable resource efficiency component **210** continually assesses, and forecasts, meteorological conditions at the location of the multi-resource offshore renewable energy installation **104** to help determine the ability of each renewable resource component **116** to operate over the specific period of time. This meteorological conditions forecast is also incorporated into the commodity price selling range. Both the commodity price selling range and the meteorological conditions forecasts are determined relative to the specific period of time, which is communicated from the power settlement module **218** via the communications component **216**.

[0058] As with the power distribution module **200**, in order to access commodity price data and meteorological conditions data, the renewable energy resource efficiency component **210** must communicate with one or more external computing networks **154** that are outside the framework of the distributed computing infrastructure **150**. The communications component **224** facilitate the use of the one or more external computing networks **154** that allow the renewable resource efficiency component **210** to access the one or more energy commodity trading platforms **160**, the one or more meteorological weather platform or site **162**, and the one or more purchasing conditions database **164** to accomplish forecasts of commodity price data and meteorological conditions. It is also possible that the operator of the multi-resource offshore renewable energy installation **104** may buy, sell, or trade, financial instruments allowing the power generation module **208** to hedge, or control, exposure to price fluctuations in the commodity price data for each renewable energy resource **114** over the specific period of time.

[0059] The renewable energy resource control component **212** is configured to continually assess an operational availability and power capacity **148** of each renewable energy resource component **116** at the multi-resource offshore renewable energy installation **104**. This is performed through renewable energy resource control systems **214** each at least controlling one of the renewable energy resource components **116**. It is further contemplated that each apparatus within each renewable energy resource component **116** may also have a dedicated control sub-system controlling the specific apparatus and responsive to output data from the renewable resource control system **214**.

[0060] Each apparatus in each renewable energy resource component **116** has a controller coupled thereto capable at least of operating the apparatus to produce power, and to provide input data to either or both of the control sub-system for the apparatus and the renewable resource control system **214** responsible for the respective renewable energy resource component **116**. The renewable energy resource control system **214** receives input data from each controller of each apparatus and/or each control sub-system to model the overall operational availability and power capacity **148** of each renewable energy resource component **116**.

[0061] The renewable energy resource control component **212** uses output signals from each renewable energy resource control system **214** to forecast a power production capacity **148** of each renewable energy resource component **116** over the specific period of time. The specific period of time is communicated from the power settlement module **218** via the communications component **216**. This power production capacity **148** forecast is a function of at least the operational availability of each renewable energy resource component **116** as indicated in output signals of the renewable energy resource control systems **214**, and may also modulate those signals with the forecasted meteorological conditions and commodity pricing data relative to each renewable energy resource **114** at the multi-resource offshore renewable energy installation **120** that are communicated from the renewable resource efficiency component **210**. Therefore the power production capacity **148** reflects the operational availability and a predicted level of operational efficiency of each renewable energy resource component over the specific period of time.

[0062] The renewable energy resource control component **212** also receives incoming instructions from the power settlement module **218** following resolution of a transaction, to produce power responsive to the power requirement **144** and the commodity prices of a transaction settled therein. Either of the power settlement module **218** or the renewable energy resource control component **212** may further determine the specific proportions or amount of power from each renewable energy resource component to be produced for the specific period of time. The renewable energy resource control component **212** therefore is capable of determining an operational efficiency level of power production capacity for each renewable energy resource component **116** in response to instructions from the power settlement module **118** and reflective of multiple variables, such as the forecasted meteorological conditions and commodity price data, as well as the power requirement **144** over the specific period of time. Regardless, the renewable energy resource control systems **214** then begin operating each apparatus as determined by either the power generation module **208** or the power settlement module **218**. Power will therefore be produced from an efficient combination of renewable energy resources that satisfies the power requirement **144** and balances power production with the power to be consumed by the intelligent power distribution network for the specific period of time.

[0063] The communications component **216** is at least responsible for communicating data to the power settlement module **218**, within the power generation module **208**, and with the one or more external computing networks **154**. The data to be communicated to the power settlement module **218** at least includes the power generating capacity **148** of component **116**, the commodity selling price range at which the power requirement **144** will be sold for each renewable energy resource **114** available at the multi-resource offshore renewable energy installation **104**, and the meteorological conditions forecast. The meteorological conditions forecast may be included regardless of whether it is represented within the forecasted power capacity **148** of each renewable energy resource component **116**.

[0064] The communications component **216** is comprised of one or more processes and circuit elements configured to aggregate and transmit the data to be communicated to the power settlement module **218**, which incorporates the level of operation, the commodity selling price range, and the meteorological conditions forecast, within the distributed computing infrastructure **150**. The communications component **216** therefore also includes logic elements to ensure incoming data from the renewable resource efficiency component **210** and the renewable resource control component **212** is in a form that can be utilized by the power settlement module **218** to settle a transfer of the power requirement **144** in accordance with the present invention. The communications component **216** is also responsible for communicating information from the power settlement module **218** to the renewable resource control component **212** for further input data to the renewable energy resource control systems **214**.

[0065] It should be noted that the operator of the multi-resource offshore renewable energy installation **104** may also have renewable energy selling conditions relative to providing power from certain renewable energy resources **114**. It is therefore contemplated that the renewable resource efficiency component **210** will be responsible for assessing this information, and the communications component **216** will be responsible for integrating it into data communicated to the power settlement module **218**.

[0066] FIG. 2C is a conceptual diagram of components in a power settlement module **218** according to the present invention. A power settlement module **218** is another series of processes performed across one or more processors within the renewable resource energy management system **100** and is responsible for various global functions, such as settling the sale and purchase of power generated from each renewable energy resource **114** and arranging a transfer of power from the multi-resource offshore renewable energy installation **104** to the intelligent power distribution network **102** via the transmission system **106**. The power settlement module **218** includes a transaction resolution component **220**, a power production, transmission and delivery component **222**, and a communications component **224**. Within these components, the power settlement module **218** communicates data to all of the power distribution module **200**, the power generation module **208**, and the power transmission module **226** regarding the transfer of power requirement **144**.

[0067] The transaction resolution component **220** at least performs the function of comparing the commodity selling and purchase price ranges from each of the power distribution module **200** and the power generation module **208** and resolving a final price for power to be generated from each renewable energy resource **114** for the specific period of time to satisfy the power requirement **144**. The final price is communicated to both the power distribution module **200** and the power generation module **208**.

[0068] The transaction resolution component **220** also determines the amount of power to be produced for each component **116** within the power capacity **148** and relative to the power requirement **144** and final price for power to be produced from each renewable energy resource **114**. The amount of power is contemplated to be expressed in ranges of amounts that represent proposed levels of operation for each component **116**. This is communicated to the power production transmission and delivery component **222**, which generates signals to the power generation module **208** to begin producing power from the renewable resource components **116**, to the power distribution module **200** to begin preparing to deliver power to each microgrid **108**, and to the power transmission module **226** to begin preparing for transmission.

[0069] The power settlement module **218** therefore communicates, via the communications component **224**, signals to the power generation module **208** the amount of power to be generated from each of the renewable energy resource components **116**, responsive to which renewable energy resources **114** have been purchased and in what amounts the respective components **116** are to generate power. Each renewable resource component control system **214** takes these signals as input data to further determine which specific apparatus is to generate power, and instructs each controller and/or sub-control system in each specific apparatus to be used to operate. In this manner, each renewable energy resource component **116**, and indeed each apparatus therein, can be independently and variably controlled to produce the desired power requirement **144**.

[0070] The power settlement module **218** also includes performs the function of communicating start and stop instructions in one or more signals to the power transmission module **226**. These instructions serve to prepare the power transmission module **226** and its components and transmission control system **220** to prepare to transmit the power being generated by the renewable energy resource components **116**.

[0071] FIG. 2D is a conceptual diagram of components in a power transmission module **226** according to the present invention. The power transmission module **226** is a series of processes performed across one or more processors within the renewable resource energy management system **100** and is responsible for various transmission-side functions governing the transmission system **106** over which the power requirement **144** is to be sent. The transmission system **106** is a high voltage direct current (HVDC) system that includes a common direct current bus to which a system of voltage source converters (VSCs) **156** and each power output circuit **142** of each apparatus is coupled. The power transmission module **226** includes a transmission control component **228**, which receives signals from the power settlement module **218** via a communications component **234** as input data instructive of several processes to be performed in the transmission of the power requirement **144**. The transmission control component **228** includes a transmission control system **230** which performs system check functions such as monitoring the power outputs of each apparatus for any over-production or under-production of power and suggesting adjustments to the renewable energy resource control systems **214**, and also ensures that power production matches the capacity of the HVDC transmission system **106**. The transmission control component **228** also is responsible for beginning and ending power transmission over the specific period of time.

[0072] The power transmission module **226** includes a voltage source converter (VSC) component **232** configured to operate and monitor the system of voltage source converters **156** coupled to the power output circuits **142** of each apparatus in the renewable energy resource components **116**. The VSC component **232** helps to ensure that each apparatus and each renewable energy resource component **116** produces the desired output by adjusting the voltage step-up, voltage step-down, and rectification components of the system of voltage source converters **156** in response to signals communicated from the power settlement module **218** and also from output data of the transmission control component **228**.

[0073] The power transmission module **226** also includes a communications component **234** which includes one or more processes and circuit elements configured to manage communications and operations within, to and from the power transmission module **226**. This includes receiving and processing data from the power settlement module **218** to activate the system of voltage source converters **156** through the VSC converter component **232**, and providing input data for the transmission control system **230** and initiating starts and stops in the HVDC transmission system **106** through the transmission control component **228**.

[0074] The present invention includes at least three types of control systems—the microgrid control systems **110**, the renewable energy resource control systems **214**, and the transmission control systems **230**. Each of the microgrid control systems **110**, the renewable energy resource control systems **214**, and the transmission control system **230** operate within the distribute computing infrastructure **150** to receive input data from various sources as discussed herein, mathematically model physical systems to be analyzed, and produce specific output signals that help to operate the renewable energy resource management system **100** to generate the power requirement **144** over the specific period of time to achieve one or more objectives of the present invention.

[0075] Each microgrid control system **110** is responsible, in conjunction with the load control component **202**, for controlling each microgrid **108** and each power customer **112** coupled to each microgrid. Because of the decoupled nature of each microgrid **108**, there must be a dedicated system capable of performing one or more control functions, such as assessing the power demand **146** of each microgrid **108**, managing power delivery to each customer **112** of the microgrid **108**, decoupling each microgrid **108** to assume control over distribution and delivery where the need arises, and determining and pushing instructions to each device, meter, or customer **112** if needed. Each microgrid control system **110** receives as input data signals from multiple sources and models several different systems to produce output signals to perform these functions.

[0076] To determine power demand **146**, for example, each microgrid control system **110** receives input data from the one or more power customers **112** coupled to each microgrid **108**. This input data may be generated and communicated by customers **112** themselves, by microgrid controllers operable to collect usage data, and by one or more devices having controllers thereon and coupled to each customer **112**. The usage data may be requested by the microgrid control system **230** or communicated automatically via communications component **206**.

[0077] Collectively, this usage data reflects many different variables, such as customer type, importance level, specific requirements, usage history, usage type, any fluctuation tolerance, and a number and type of devices used by each customer **112**. The microgrid control system **110** performs system modeling with these variables for its microgrid **108** and generates an output signal to the load control component **202** indicative of, for the specific period of time, the power demand **146** for that microgrid **108**.

[0078] Each microgrid control system also receives input data in signals from the load control component **202** that includes the amount of power to be delivered to the intelligent power distribution network **102** and compositions that power delivery will have with regard to renewable energy resources **114**, such as for example alternating current or direct current. The microgrid control systems **110** perform system modeling of this data to determine a most appropriate distribution across the customers **112** coupled to each microgrid **108**, and generates output signals that instruct one or more infrastructure components such as receiving stations, substations, transformers, and other such components how and where to distribute and delivery power to microgrids **108** and customers **112**.

[0079] This has particular import in the case of decoupling of microgrids **108**. Each microgrid control system **110** is responsible for decoupling each microgrid **108** as the need arises. In this embodiment, the microgrid control system **110** receives input data in a signal from the load control component **202** to decouple and continue to distribute and deliver power to one or more of the microgrids **108** as directed. Similar to above, the microgrid control system **110** analyzes this input signal with the modeled system of the decoupled microgrid **108**, and determines a most appropriate distribution across customers **112** who are to continue receiving power.

[0080] Each renewable energy resource control system **214** is responsible for controlling each respective renewable energy resource component **116** to which they belong. Each renewable energy resource control system **214** receives input signals from on-board controllers in each apparatus, comprised of data representing one or more operational power capacity characteristics, such as for example the type of apparatus, the time of day, recent performance history, current operating condition, upcoming scheduled maintenance, current weather conditions, and any other variable effecting operability and availability. The renewable energy resource control system **214** uses the input data to create a system model of how each apparatus will perform over the specific period of time, and generates an output signal for the renewable resource control component **212** to generate a power capacity **148** forecast.

[0081] In the reverse direction, each renewable energy resource control system **214** receives an input signal comprised of data representing instructions from renewable energy resource control component **212** for operation of each renewable energy resource component **116**. The renewable energy resource control system **214** responsible for each component **116** then models each component **116** with the input data to determine output characteristics regarding operating each component, such as which apparatus(es) to operate to generate power, at what speed and capacity, for how much time, and in what combination. This information is contained within output signals generated for each component **116** and each controller in each apparatus.

[0082] The transmission control system **230** performs a system of checks to ensure proper functioning of both the power outputs of each renewable energy resource component **116** and the HVDC transmission system **106**. The transmission control system **230** receives input data in signals from the power output circuits **142** of each apparatus or each renewable energy resource component **116** or both, prior to connection with the system of voltage source converters **156**. The transmission control system **230** compares this data with information from both the power generation module **208** and the power settlement module **218** regarding the known power requirement **144** to determine whether or not power is being under-produced or over-produced. One of two outcomes are decided upon—in the case of a match, the transmission control system **230** does nothing and continues onto the next system check. In the event of a power over or under-production, the transmission control system **230** generates an output signal to one or more of the renewable energy resource control systems **214** to adjust power output up or down. In this way, the transmission control system **230** acts as a feedback loop to one or more of the renewable energy resource control systems **214**.

[0083] The transmission control system **230** also receives input signals from the output circuits of each voltage source converter **156** after voltage has been stepped or down in response to signals from the VSC component **232**. The transmission control system **230** models the voltage source converter **156** output data with known tolerance characteristics of either or both of the power requirement **144** and the HVDC transmission system **106**, and determines whether or not voltage levels are within expected tolerances. If they are, the transmission control system **230** does nothing and continues with the further system checks. If they are outside expected tolerances, the transmission control system **106** generates an output signal to the VSC component **232** to adjust voltage step and voltage step down where needed in the voltage source converter system **156**.

[0084] The transmission control system **230** further receives data in input signals relative to the power output from the common direct current bus **158**, and models this data with known load characteristics of the HVDC transmission system **106**. This modeling is performed to ensure the power output being transmitted, either in terms of total capacity or voltage levels, does not exceed the load capacity of the HVDC transmission system **106**. If there is a mismatch where load capacity will be exceeded, an output signal is generated either to one or more of the renewable energy resource control systems **214** or to the VSC component **232** to make appropriate adjustments as discussed above. The transmission control system **230** may also generate an output signal activating a power feedback loop to remove excess capacity from the HVDC transmission system **106**. The power feedback loop may route excess capacity to storage in a temporary battery or to an installation sub-station configured to provide power to the one or more of the renewable energy resource components

116 or to another component area of the multi-resource offshore renewable energy installation **104**.

[0085] FIG. **3** is a system diagram of an electricity grid infrastructure **300** according to another embodiment of the present invention. The electricity grid infrastructure **300** comprises an intelligent power distribution network **102** as part of a renewable energy-based electricity grid that comprises of one or more microgrids **108** each having a power customer **112** coupled thereto, a multi-resource offshore renewable energy installation **104**, an HVDC transmission system **106**, and in one aspect, a distributed management system **302** configured to perform one or more functions such as settling a transaction in which power consumption is substantially balanced to power production.

[0086] Use of the term "intelligent power distribution network" herein implies that portion of the electricity "grid" which consumes power delivered from any number of sources. Conventional electricity or power "grids" are interconnected networks configured to deliver electricity from suppliers to consumers, or in other words, from sellers to buyers. Typical grids include generating components that produce electricity, transmission components that carry electricity from supplier to receiving locations, and distribution components that carry out activities necessary to ensure that electricity is delivered in the form needed to consumers. Current electricity grid infrastructure is aging and in substantial need of improvement to keep up with a myriad of issues such as increased power demand, instability from fluctuations in power flow, sophisticated end-use technologies, and escalating security concerns.

[0087] The electricity generation portion of a typical grid topology includes generating plants, which act as sellers, that connect to the transmission portion to move power across distances. The transmission portion connects the sellers with buyers, which are wholesale customers such as companies or municipalities responsible for distribution of power to consumers, to transfer power. Distribution of power involves many different technologies, such as for example substations, transformers, and power lines that ultimately deliver power to end users.

[0088] One type of electricity grid is a "smart" grid which is capable of predicting behavior of power consumers to achieve policy objectives such as enhancing infrastructure stability, reducing peak demand, and managing overall energy consumption and infrastructure performance. Smart electricity grids do this by attempting to increase automation and communication between the various infrastructure components.

[0089] An intelligent power distribution network **102** of an electricity grid infrastructure **300** according to the present invention may be thought of in a number of ways. It may be comprised of one or more electricity grids, and also as (or instead as) composed of one or more smaller micro-electricity grids, or microgrids **108**. Microgrids **108** may represent many different aspects of the overall consumptive framework of the intelligent power distribution network **102**. For example, microgrids **108** may be configured to represent different customers or consumers **112** of power which is delivered to the overall intelligent power distribution network **102**, such as different types of consumers, consumers in different geographical locations, consumers with specific and similar power needs, consumers for whom delivery of power is a public security issue, etc.

[0090] The term "microgrid" is usually understood to mean a subset of an area within a utility grid, and most often, areas embedded in local or small-scale electricity environments, such as buildings or neighborhoods. The term is also often used to refer to micro-site generation of power particular resources, such as solar panels mounted on buildings.

[0091] Microgrids **108** as contemplated by the present invention are expanded to be areas not necessarily limited by geographical region. Instead, microgrids **108** according to the present invention, while remaining subsets of the larger utility grid, may be separate systems that are coupled to, and capable of being decoupled from, the larger utility grid so that power can be separately delivered thereto. Microgrids **108** may also be allocated for any type of power consumer **112**, in any location, and relative to any reason for segregating the broader utility grid into smaller microgrids **108**.

[0092] It is to be understood that regardless of the embodiment referenced, the present invention contemplates that the one or more smaller microgrids **108** which comprise the intelligent power distribution network **102** are separately configured so as to be decoupleable from the intelligent power distribution network **102** as the need arises. Such a decoupling could be performed for many different reasons as discussed herein. Microgrids **108** may also be comprised of one or more sub-microgrids that are configured to communicate power needs of specific things that comprise the broader microgrid **108** to which they are a part. The present invention also contemplates that microgrids **108** can be formed, dissolved, and reconfigured at any time by one or more of the modules and microgrid control systems **110** disclosed herein.

[0093] Microgrids **108** therefore have utility in a variety of ways within the present invention. In addition to ensuring that a real-time power requirement **144** is discerned and supplied over a specific time period, other utilities include ensuring grid infrastructure security and providing specific types of power to different microgrids **108** that need such specialized service. Examples of this are microgrids representing semiconductor-based facilities that specifically requires direct current-based power, and microgrids representing specific components of the intelligent power distribution network itself, such as receiving locations **236**, substations, relays, and transformers. Regardless, each microgrid **108** is connected through at least one computing network **152** to perform the variety of task as discussed herein. For example, a microgrid **108** representing a residential neighborhood would be configured to communicate, using one or more interconnected computing networks **152**, the neighborhood's power needs, based on signals received from and/or sent to one or more devices capable of reading, calculating, and predicting the real-time power needs of each resident of the neighborhood.

[0094] One example of an intelligent power distribution network **102** is an electricity grid that is responsible for supplying power to the entire western United States. Such an intelligent power distribution network **102** would be comprised of many microgrids **108** that represent each sub-region, state, or city in that geographical area, and within that, microgrids **108** that represent specific types of power consumers **112**. Each of these microgrids **108** would be separately coupled to the intelligent power distribution network **102** so that power requirement **144** for each would be delivered according to the load control component **202** and a respective microgrid control system **110**. In this embodiment, the distributed load management system **302** of the electricity grid infrastructure **300** is responsible coordinating a power delivery to each microgrid **108** together with the microgrid control system **110** in an amount that satisfies real-time needs.

[0095] Infrastructure security is easily facilitated by the microgrid **108** framework according to the present invention. A microgrid **108** may be representative of key public infrastructure installations, such as for example ports, military sites, water installations such as reservoirs and dams, high-speed rail lines, canals, metro systems, other power generation facilities, manufacturing and production facilities, etc. By allowing for the immediate decoupling of a microgrid **108** in the event of security issue with the overall intelligent power distribution network **102** or to another microgrid **108**, power can be continually supplied to a particular microgrid **108**, and its represented customers **112** who need power to keep public services smoothly operating in the event of such a security issue.

[0096] The power distribution module **200**, and the distributed load management system **302**, together with each microgrid **108** and with each microgrid control system **11**, coordinate and carry out any decoupling as the need arises. It is therefore to be understood that electricity grid topology according to the present invention is integrated to support such an interconnected and coupled framework that is at the same time capable of being fragmented in real time to deliver power separately to specific microgrids **108** should the need arise

[0097] The present invention further contemplates that because power is generated and transmitted entirely in direct current form by the HVDC transmission system **106**, it is possible for power to be supplied to microgrids **108** requiring direct current directly without having to process and transform incoming power at a receiving location **236**. This can be done, for example, in a situation where the receiving location itself is under a security threat. Microgrids **108** can be configured, via the power distribution module **200**, distributed load management system **302**, and microgrid control systems **110**, to operate entirely on direct current that can be supplied directly by the multi-resource offshore renewable energy installation **104**.

[0098] The present invention also further contemplates that an intelligent power distribution network **102**, and microgrids **108**, may be configured to either run entirely on direct current, or to be able to easily switch from requiring alternating current to requiring direct current as the need arises at receiving locations **236** or substations serving particular microgrids **108**. For example, in a security situation where the power transformation at the main network-level receiving location **236** from direct current to alternating current has been disabled, power can be delivered to key microgrids **108** directly in direct current. It is contemplated that a microgrid **108** may have the ability to switch its represented customers **112** to a direct current model, either permanently or temporarily, in such a situation.

[0099] Accordingly, electricity grid infrastructure **300** according to the present invention is to be configured so that microgrids **108** can be quickly decoupled from the main intelligent power distribution network **102** and supplied with direct current power via the HVDC transmission system **106** in the event of an incident requiring such a decoupling and continued supply of uninterrupted power. In this way, the electricity grid infrastructure **300** is a flexibly topology that is capable of expanding and contracting and that supports resiliency and stability when problems that threaten the supply of power arise.

[0100] As the world becomes increasingly dependent on non-renewable and carbon-based energy resources, and substantial supply, price, and geopolitical stability problems attendant thereto proliferate, it is apparent that there is a strong need for a system and method of providing power generated entirely from renewable energy resources **114**. In another embodiment of the present invention, a multi-resource offshore renewable energy installation **104** and method of operation provide an intelligent power distribution network **102** with all of its power needs from one source that generates energy from multiple renewable energy resources **114**.

[0101] FIG. **4** is a system diagram of a multi-resource offshore renewable energy installation **104**. The multi-resource offshore renewable energy installation **104** is an apparatus or series of apparatuses that includes multiple renewable energy resource components **116** for generating power that are each derived from a particular renewable energy resource **114**. The multi-resource offshore renewable energy installation **104** is contemplated to be a deep-ocean, marine installation at sites located far from land, typically in the range of greater than 50 km from the nearest onshore intelligent power distribution network **102**. However, it is within the scope of the present invention that such a multi-resource offshore renewable installation **104** could be a marine installation located near to the shore and also on freshwater bodies such as lakes and rivers, whether naturally occurring or man-made.

[0102] The multiple renewable energy resource components **116** include a wind component **118** deriving power from wind energy, a solar component **122** deriving power from solar energy, a hydrokinetic component **128** deriving power from wave and tidal current energy, and a solar thermal component **136** deriving power from the process of heating ocean water using solar thermal energy. The present invention may also include an ocean thermal energy conversion component **140**. Each of the wind component **118**, the solar component **122**, the hydrokinetic component **128**, the solar thermal component **136**, and the ocean thermal energy conversion component **140** include an array of apparatuses each coupled to a respective renewable energy resource control system **214**.

[0103] In accordance with other aspects and embodiments of the present invention, the multi-resource renewable energy installation **120** is configured so that a maximum efficient operational power-generating capacity of each apparatus, and each renewable energy resource component **116**, is achieved. The multi-resource offshore renewable energy installation **104** is therefore intended to present a solution to the problem of inefficiencies that are naturally present in renewable resource components **116** generating power from resources such as wind, solar, hydrokinetic, and solar thermal energy.

[0104] The present invention contemplates that there are numerous ways in which components capable of generating power from multiple renewable energy resources **114** can be configured on such multi-resource offshore renewable energy installation **104**. For example, the installation may be a large-scale energy farm with hundreds or thousands of apparatuses working to generate power. Each of the components **116** may be configured in any number of ways in such a large-scale energy farm to generate power and take advantage of fluctuations in weather conditions. The multi-resource offshore renewable energy installation **104** is therefore completely scalable from an ultra-high capacity multi-megawatt or gigawatt installation to serve large-scale power consumers **112**, to a medium to low-capacity installation to serve power consumers **112** with smaller demand. FIG. **6** and FIG. **7** show overall perspective and top plan views of embodiments of the multi-resource renewable energy installation **104**.

[0105] The multi-resource offshore renewable energy installation **104** may be both permanent and temporary and have both permanent and temporary components **116** as portions thereof to achieve the scalability contemplated herein. It may be entirely fixed so that it anchors to the ocean floor and is therefore a permanent installation. It may also be a floating structure, in whole or in part, with temporary anchoring mechanisms and with some or all of the components **116** being movable to other locations as needed. It may further be a combination of permanent and temporary components, for example in a configuration in which power transmission components are in fixed portion while power generating components **116** are temporary components that can "dock," as in the case of one or more barges having components installed thereupon, to the permanent components or to other mobile components. Regardless of possible configuration, the present invention considerably reduces construction and operating costs by implementing technologies that substantially reduce the possibility of lasting environmental damage. With the present invention, there is no need to drill for non-renewable carbon-based resources that may pollute environment as such an installation site.

[0106] Costs can be further minimized due to the ability to maximize operational power-generating capacity. In the present invention, power production is substantially balanced with power consumption, so that only an amount of power required is produced over the specific period of time, at least in part because the renewable energy resource control systems **214**, responsive to signals regarding settled transactions, can variably and separably operate each apparatus within each component **116**. Therefore, present invention may not require large, expensive, and environmentally damaging power storage components at either the multi-resource offshore renewable energy installation **102** or the intelligent power distribution network **102**.

[0107] The multi-resource offshore renewable energy installation **104** may be a purpose-built semi-submersible production platform that is a floating vessel capable of supporting the renewable energy resource components **116** in multiple configurations in deep water and other harsh offshore environments. This provides a mobile yet stable operational platform needed to produce power at the multi-resource offshore renewable energy installation **104** and that is capable of being deployed in different locations, regardless of whether each of the renewable energy resource components **116** are permanently part of the multi-resource offshore renewable energy installation **104** or removably and/or temporarily coupled thereto, such as for example on separate pontoons or barges.

[0108] Stability in such a mobile semi-submersible platform according to this embodiment results from, when in an operational position, a hull structure being submerged at a deep draft so that the multi-resource offshore renewable energy installation **104** is less susceptible to wave loadings. Operational components of the semi-submersible platform remain well above the ocean surface. The mobile semi-submersible production platform acquires buoyancy from ballasted components below the surface, and one or more support columns connecting the operational components and the ballasted components. Other anchoring components may also be utilized for further stability of the mobile semi-submersible platform.

[0109] Draft can be adjusted by deballasting the below-surface components so that the mobile semi-submersible production platform becomes a surface vessel capable of deployment to a different location. In this regard, a mobile semi-submersible production platform as described may be transportable using a heavy-lift installation transport vessel. Such a heavy-lift installation transport vessel is able to move all or part of the installation **104** by ballasting itself to submerge a majority of its structure, maneuvering beneath the multi-resource offshore renewable energy installation **104**, and then deballasting to lift up all or part of the multi-resource offshore renewable energy installation **104** as cargo.

[0110] In a further embodiment, where each of the renewable energy resource components **116** are separately coupled to form the multi-resource offshore renewable energy installation **104**, the installation **104** may also comprise one or more offshore support vessels that perform various roles, such as operational activities, transmission system support, and emergency support. Each such vessel may be separately mobile so that the multi-resource offshore renewable energy installation **104** is composed of many interchangeable parts. Each renewable energy resource component **116** may itself be embodied on a mobile semi-submersible platform as well. Therefore, the entire multi-resource offshore renewable energy installation **104** can be thought of as a being deployable in any configuration necessary to meet the objectives of the present invention.

[0111] Offshore support vessels such as a transmission system support vessel may be a key consideration for engineers and planners in the mobile aspect of the semi-submersible production platform that forms all or part of a multi-resource offshore renewable energy installation **104**. Transmission system support is a consideration in order to ensure that regardless of where the multi-resource offshore renewable energy installation **104** and/or the multiple renewable energy resource components **116** are deployed, access to the high voltage direct current transmission system **106** is available to transfer power to the intelligent power distribution network **102**. In one embodiment, vessels such as those providing transmission system support may provide node-based transmission cables for easy and remote access to a main undersea transmission line, particularly where the multi-resource offshore renewable energy installation **104** is mobile semi-submersible production platform. The present invention therefore contemplates that the multi-resource offshore renewable energy installation **104** may include a main operational platform, semi-submersible or otherwise, where multiple mobile semi-submersible production platforms connect to a main transmission line supported by such offshore support vessels. Such a configuration permits the multi-resource offshore renewable energy installation **104** to include multiple mobile semi-submersible production platforms supporting renewable energy resource components **116** that may be spread out over hundreds of kilometers and connected by transmission cables that are branches of the node at the main operational platform.

[0112] The multi-resource offshore renewable energy installation **104** includes a solar component **118** for generating power from solar energy. Components generating power from solar energy are known as photovoltaics, which convert solar rays into electricity using panels, or modules, composed of solar cells containing a photovoltaic material. The present invention contemplates that the solar energy component **118** is comprised of many such photovoltaic modules **124** mounted on one or more mounting systems **126**. Mounting systems **126** may be either tracking or fixed mounting systems and photovoltaic modules **124** may be mounted in any configuration thereon, such as for example in portrait configuration or landscape configuration, or any combination thereof.

[0113] The present invention contemplates that at least one of the circuits connecting an array of photovoltaic modules **124**, the tracking mounting systems **126**, and individual photovoltaic modules **124** include one or more controllers capable of sending input data in signals to a renewable energy resource control system **214**, as well as capable of receiving signals therefrom. These controllers are capable of moving or tilting an angle of inclination of each array of photovoltaic modules **124** on a tracking mounting system **126** operable at the multi-resource offshore renewable energy installation **104** in response to an output signal of a renewable energy resource control system **214**.

[0114] Therefore, one or more renewable resource control systems **214** are configured to control the photovoltaic modules **124** and tracker mounting systems **126** and communicate with controllers coupled to each to maximize operational capacity of the solar component **118**. Where control systems **214** operate to generate responses in the photovoltaic modules **124** directly, it is contemplated that control over specific photovoltaic modules and in arrays of photovoltaic modules **124** as a whole are both within the scope of the present invention. The controllers in each photovoltaic module or in each array of photovoltaic modules **124** are configured, in one aspect, to communicate at least a real-time operational ability and power capacity **148** of each photovoltaic module or array of photovoltaic modules **124** and real-time sunlight availability conditions, and in another aspect, to respond to output signals generated by the control system **214** to perform a host of actions, such as for example controlling power output circuits **142** in response to instruction from the power settlement module **218**. Similarly, controllers in each tracking mounting system **126** are configured, in one aspect to, communicate at least a real-time operational availability of each tracking mounting system **126** and real-time sunlight availability conditions, and in another aspect, to respond to output signals generated by the control system **214** to perform actions such as adjusting the angle of inclination, or switching power generation circuits on or off where multiple photovoltaic modules **124** are connected together thereon.

[0115] Photovoltaic modules **124** are solid state devices that typically generate a power output as direct current electricity. Because of this, the power output of each array of photovoltaic modules **124** can be provided directly to the system of voltage source converters **156** and the common direct current bus **158** in the HVDC transmission system **106**, eliminating the need for further components such as inverters to convert from one current form to another. The HVDC transmission system **106** must still account for variances in both the voltage output of each photovoltaic module or array of photovoltaic modules **124** and with power outputs of other components **116**, depending on the output configuration, and therefore the transmission control system **230** monitors the power output of each as discussed here. The transmission control system **230** may act as feedback for the renewable energy resource control system **214** where power output needs to be adjusted to ensure common voltage levels across the common direct current bus **158**, may therefore generate an output signal to adjust one or more components of the solar component **118** accordingly. The transmission control system **230** may also monitor and instruct the system of voltage source converters **156** to either step up the output voltage or step down the output voltage as needed to ensure a uniform voltage level across the common direct current bus **156**. Regardless, the present invention ensures that the power output is properly monitored and adjusted for transmission, distribution and delivery.

[0116] The present invention further contemplates that in this manner, as with other renewable energy resource components **116**, both the power generation module **208**, the renewable energy resource control systems **214**, transmission control system **230**, and the voltage source converters **156** allow for very flexible operation of photovoltaic modules **124** to arrive at a proper power production capacity that satisfies the power requirement **144** over the specific period of time, as other systemic objectives such as transmission system stability.

[0117] This flexibility allows for substantial design freedom in selecting components. Solar cells forming photovoltaic modules **122** may be made of any material suitable for installation in deep-ocean conditions so that the photovoltaic modules **122** are able to maintain operating capacity in potentially difficult weather conditions far from shore. Materials typically must have characteristics matched to the spectrum of available light at the installation site, but it is contemplated that where a large number of photovoltaic modules **124** are installed at the multi-resource offshore renewable energy installation **104**, many different types of photovoltaic modules may be combined and utilized to achieve optimal efficiency.

[0118] In one embodiment, materials such as nanocrystalline silicon in which the photovoltaic materials embedded with nanonparticles may have particular utility in installations such as those disclosed herein, where weather conditions make maintenance a significant challenge. Nanoparticles may be further embedded with components such as microcontrollers which are capable of communicating certain operating conditions to the renewable resource control system **214** responsible for the photovoltaic module **124**, array of photovoltaic modules **124**, and tracking mounting system **126** having photovoltaic modules **124** installed thereon. Use of photovoltaic modules **124** fabricated of materials of this type may increase the ability to assess real-time operational availability and real-time weather conditions, and increase overall durability of the solar component **118**.

[0119] Photovoltaic modules **124** and mounting systems **126** may be either fixed or permanent components of the multi-resource offshore renewable energy installation **104**, or temporarily coupled thereto so as to be mobile and deployable to different locations or as needed. Regardless, an array of photovoltaic modules **124** may also be part of a floating installation of renewable resource components **116**, or a fixed installation with support that is permanently anchored to the seabed. Floating installations do not require permanent anchoring mechanisms and can be positioned, for example, on pontoon-based supports or on barges, reducing the environmental impact and increasing the scalability of the multi-resource offshore renewable energy installation **104**. Floating installations may also be capable of being raised and lowered as needed to protect photovoltaic modules **124** and mounting systems **126**, and keep them operational, in the event of storms, rough seas, very large waves, or other adverse environmental conditions.

[0120] Cooling of photovoltaic modules **124** can be achieved from winds at the installation site or from the ocean water itself, particularly where ocean thermal energy conversion components are implemented that produce desalinized water from heating ocean water. Floating or temporary structures also provide the benefit of allowing photovoltaic modules **124** to be installed and used to generate power in locations, particularly very deep ocean waters, where seabed anchoring is not feasible.

[0121] The wind component **118** is comprised of a plurality of large-scale, large capacity, commercial high-speed wind turbines **120**. Each wind turbine **120** includes a rotor with blades turning about either a horizontal or vertical axis, and has a controller resident within a nacelle, coupled to operational and power-generating circuit elements. The present invention contemplates that the wind component **118** is comprised of an array of wind turbines **120** each coupled to a respective renewable energy resource control system **214**.

[0122] One or more of the renewable resource control systems **214** are configured to control the wind turbines **120** by receiving input data from and sending output signals to controllers coupled to operational and power-generating output circuits inside each nacelle. They are configured, in one aspect, to communicate at least a real-time operational availability and power capacity **148** of each wind turbine **120**, and in another aspect, to respond to output signals generated by control system **214** to perform a host of actions, such as for example turning an power output circuit **142** on or off, adjusting rotor speed, or where applicable, rotating each rotor to maximize operations under changing wind conditions, in response to instruction from the power settlement module **218**.

[0123] Wind turbines **120** commonly generate a power output in alternating current form. The power output of each wind turbine **120** therefore needs to be rectified to direct current prior to connection to the common direct current bus **158**, and voltage source converters **156** adjust the voltage level with either voltage step-up or step-down transformers to ensure a compatible voltage level. Power outputs of all of the wind turbines **120**, and the voltage output level of the system of voltage source converters **156**, are monitored by the transmission control system **230**, in addition to the power outputs of all other apparatuses that are being operated to generate power, to make further adjustments if necessary as discussed herein.

[0124] If it is the case that power is generated as direct current, no inverter is needed for connection of the power output circuitry to the common direct current bus **158** and the HVDC transmission system **106**. The transmission control system **230** must still however account for variances in the voltage of each such power output, and therefore would monitor the power output and voltage source converters **156** as above, in conjunction with power output of other apparatuses of other renewable energy resource components **116** and in conjunction with each renewable energy resource control system **214**, and make adjustments accordingly.

[0125] The present invention further contemplates that in this manner, as with other renewable energy resource components **116**, both the power generation module **208**, the renewable energy resource control systems **214**, transmission control system **230**, and the voltage source converters **156** allow for very flexible operation of the wind turbines **120** to arrive at a proper power production capacity that satisfies the power requirement **144** over the specific period of time, as other systemic objectives such as transmission system stability.

[0126] This flexible operational approach allows for many different configurations of the wind component **118** within the scope of the present invention. For example, wind turbine rotors may be axially rotatable to maximize capacity where wind direction changes over time. One or more rotors on a wind turbine tower may also be movable so that it can either function as a wind turbine **120** or wave turbine **130** or **134** as further discussed herein. Multiple rotors on each tower may be used for to function as power generating devices for both sources, so that one rotor is a wind turbine **120**, while the other is a wave turbine **130** or **134**.

[0127] As with photovoltaic modules **124**, wind turbines **120** may be coupled so as to be either a fixed or permanent components of the multi-resource offshore renewable energy installation **104**, or temporarily coupled thereto so as to be mobile and deployable to different locations or as needed. Regardless, an array of wind turbines **120** may also be mounted on a floating structure that allows each wind turbine **120** to generate electricity in deep ocean waters where seabed anchors or piles are not feasible, or on a fixed structure with support that is permanently anchored to the seabed. The fixed structure may be the tower supporting the wind turbine **118** itself. Floating installations do not require permanent anchoring mechanisms and can be positioned, for example, on pontoon-based supports or on barges, reducing the environmental impact and increasing the scalability of the multi-resource offshore renewable energy installation **104**.

[0128] The hydrokinetic component **128** may include multiple types of apparatuses, each of which utilize some type of wave conversion to harness energy from movement of water, whether based on surface waves, sub-surface currents, or tides, to generate electrical power output. These wave energy conversion devices are well-suited for deep water applications as disclosed herein, as deep water waves and currents generate greater energy and therefore are more useful at generating power in high-capacity installations. The present invention includes at least one of surface wave turbines **130**, oscillating water columns **132** and sub-surface or undersea wave turbines **134** within the hydrokinetic component **128**.

[0129] The surface and sub-surface wave turbines **130** and **134** are contemplated to be large-scale, large capacity, commercial turbines each having a rotor with blades turning about either a horizontal or vertical axis to generate power. Each turbine has a controller resident within a nacelle, coupled to operational and/or power-generating output circuits. Oscillating water columns **132** generate power as waves enter and exit a partially submerged collector, causing a water column inside the collector to rise and fall and drive air inside the column into a turbine. The turbines have controllers coupled to operational and/or power-generating output circuits therein. The present invention contemplates that the hydrokinetic component **128** is comprised of an array of each of the surface wave turbines **130**, oscillating water columns **132**, and sub-surface wave turbines **134**.

[0130] Each surface wave turbine **130**, oscillating water column **132**, and sub-surface turbine **134** is coupled to one or more renewable energy resource control systems **214** configured to control the hydrokinetic component **128** and generate output signals to controllers coupled to each surface wave turbine **130**, oscillating water column **132**, and sub-surface turbine **134** to separably and variably operable each apparatus. The controllers are configured, in one aspect, to communicate at least a real-time operational availability and power capacity **148** of each surface wave turbine **130**, oscillating water column **132**, and sub-surface turbine **134**, and in another aspect, to respond to output signals generated by the renewable energy resource control system **214** to perform a host of actions, such as for example turning power output circuits **142** on or off, adjusting rotor speed, adjusting a water depth at which ocean water is obtained in the case of the oscillation water columns **130**, or where applicable, rotating each rotor to maximize operations under changing surface wave or ocean current conditions, in response to instruction from the power settlement module **218**. Factors having substantial influence on operational availability and power capacity **148** of each surface wave turbine **130**, oscillating water column **132**, and sub-surface wave turbine **134**, and the ability to variably operate each, are meteorological conditions such as surface wave and sub-surface ocean current strength, which may be continuously measured at the offshore multi-resource renewable energy installation **120**.

[0131] The hydrokinetic components **128** are assumed to generate a power output in alternating current form. Where this is the case, the power output of each surface wave turbine **130**, oscillating water column **132**, and sub-surface turbine **134** therefore needs to be rectified to direct current prior to connection to the common direct current bus **158**, and voltage source converters **156** adjust the voltage level with either voltage step-up or step-down transformers to ensure a compatible voltage level. Power outputs of all of the surface wave turbines **130**, oscillating water columns **132**, and sub-surface wave turbines **134**, and the voltage output level of the system of voltage source converters **156**, are monitored by the transmission control system **230**, in addition to the power outputs of all other apparatuses that are being operated to generate power, to make further adjustments if necessary as discussed herein.

[0132] If it is the case that power is generated as direct current, no inverter is needed for connection of the power output circuitry to the common direct current bus **158** and the HVDC transmission system **106**. The transmission control system **230** must still however account for variances in the voltage of each such power output, and therefore would monitor the power output and voltage source converters **156** as above, in conjunction with power output of other apparatuses of other renewable energy resource components **116** and in conjunction with each renewable energy resource control system **214**, to make adjustments accordingly.

[0133] The present invention further contemplates that in this manner, both the power generation module **208**, the renewable energy resource control systems **214**, transmission control system **230**, and the voltage source converters **156** allow for very flexible operation of the surface wave turbines **130**, oscillating water columns **132**, and sub-surface turbines **134** to arrive at the proper power production capacity that satisfies the power requirement **144** over the specific period of time, as well as transmission system stability and other objectives.

[0134] This flexible operational approach allows for many different configurations of the hydrokinetic components **128** within the scope of the present invention. For example, surface or sub-surface wave turbine rotors may be axially rotatable to maximize capacity where wave or current direction changes over time. One or more rotors on a turbine tower may also be movable so that it can either function as a wind turbine **120** or wave turbine **130** or **134**. Multiple rotors on each tower may be used for to function as power generating devices for both sources, so that one rotor is a wind turbine **120**, while the other is either a surface wave turbine **130** or a sub-surface wave turbine **134**.

[0135] The various apparatuses comprising the hydrokinetic component **128** may also be coupled so as to be either a fixed or permanent component of the multi-resource offshore renewable energy installation **104**, or temporarily coupled thereto so as to be mobile and deployable to different locations or as needed. Regardless, any of the surface wave turbines **130**, oscillating water columns **132**, and sub-surface wave turbines **134** may also be mounted on a floating structure that allows each apparatus to generate electricity in deep ocean waters where seabed anchors or piles are not feasible, or on a fixed structure with support that is permanently anchored to the seabed. The fixed structure may also be a tower supporting a surface turbine **130** or sub-surface wave turbine **134** itself. Floating installations do not require permanent anchoring mechanisms and can be positioned, for example, on pontoon-based supports or barges, reducing the environmental impact and increasing the scalability of the multi-resource offshore renewable energy installation **104**. Pontoons and barges floating on the ocean surface may support any of the surface wave turbines **130**, oscillating water columns **132**, or sub-surfaces wave turbines **134**, either separately or in combination.

[0136] A platform of multiple oscillating water columns **132**, whether floating or fixedly positioned, may also be capable of being raised or lowered as necessary to protect the equipment to keep them operational, such as in case of storms, rough seas, very large waves, or other adverse environmental conditions. This helps to ensure that waves are capable of entering and exiting the water column **130** to ensure continued operation of this portion of the hydrokinetic component **128**, allow for easier maintenance, and to ensure that damage does not occur.

[0137] The solar thermal component **136** utilizes thermal energy, or heat, harnessed from solar energy. The solar thermal component **136** includes an array of high-temperature solar thermal collectors **138** that use lenses and mirrors to capture and intensify the sun's rays to heat ocean water, which generates steam that drives a turbine generator.

[0138] High-temperature solar thermal collectors **138** according to this embodiment include intake systems through which ocean water is collected and transported to be heated. These can be configured to collect ocean water at variable water depths to maximize the operational performance of each collector **138**, since the temperature of ocean water various according to depth, time of year, current patterns, and other variables.

[0139] High-temperature solar thermal collectors **138** may be mounted on tracking-type mounting systems to maximize operational efficiency, so that the angle of tilt or inclination is moveable to account for different positions of the sun at different times of the day and year. Lenses and mirrors may also be mounted on movable systems to increase the ability of each collector **138** to maximize its operating efficiency. High-temperature solar thermal collectors **138** may be of any conventional design suitable for durable use in deep-ocean, weather intensive environments. Typical conventional designs include parabolic troughs, towers, parabolic dishes, Fresnel reflectors, and other design capable of high-temperature operation.

[0140] One or more renewable resource control systems **214** are configured to control the high temperature solar thermal collectors **138**, the system of mirrors and lenses, and the tracking mounting systems on which both are mounted, and communicate with controllers coupled to operational and power-generating output circuits. The controllers are configured, in one aspect, to communicate at least a real-time operational availability and power capacity **148** of each apparatus and real-time sunlight availability conditions, and in another aspect, to respond to output signals generated by the control system **214** to perform a host of actions, such as for example turning power output circuits **142** on or off in response to instruction from the power settlement module **218**, and rotating, turning, or adjusting the angle of inclination of any of the high-temperature solar thermal collectors **138**, system or mirrors and lenses, and tracking mounting systems.

[0141] The solar thermal energy components **134** contemplated herein are assumed to generate a power output in alternating current form. Where it is generated as alternating current, the power output of each high-temperature solar thermal collector **138** therefore needs to be rectified to direct current prior to connection to the common direct current bus **158**, and voltage source converters **156** adjust the voltage level with either voltage step-up or step-down transformers to ensure a compatible voltage level. Power output of all of the high-temperature solar thermal collectors **138**, are monitored by the transmission control system **230**, in addition to the power outputs of all other apparatuses that are being operated to generate power, to make further adjustments if necessary as discussed herein.

[0142] If it is the case that power is generated as direct current, no inverter is needed for connection of the power output circuitry to the common direct current bus **158** and the HVDC transmission system **106**. The transmission control system **230** must still however account for variances in the voltage of each such power output, and therefore would monitor the power output and voltage source converters **156** as above, in conjunction with power output of other apparatuses of other renewable energy resource components **116** and in conjunction with each renewable energy resource control system **214**, to make adjustments accordingly.

[0143] As with other renewable energy resource components, both the power generation module **208**, the renewable energy resource control systems **214**, transmission control system **230**, and the voltage source converters **156** allow for very flexible operation of high-temperature solar thermal collectors **138** to arrive at the proper power production capacity that satisfies the power requirement **144** over the specific period of time, as well as transmission system stability and other objectives. This flexible operational approach allows for many different configurations of the high-temperature solar thermal collectors **138** within the scope of the present invention. For example, different types of collector designs may be used in combination, together with different types and configurations of mirrors and lenses.

[0144] High-temperature solar thermal collectors **138** according to one embodiment may also be coupled so as to be either a fixed or permanent components of the multi-resource offshore renewable energy installation **104**, or temporarily coupled thereto so as to be mobile and deployable to different locations or as needed. Regardless, any of the high-temperature solar thermal collectors **138**, lenses and mirrors, and mounting systems may also be mounted on a floating structure that allows each apparatus to generate electricity in deep ocean waters where seabed anchors or piles are not feasible, or on a fixed structure with support that is permanently anchored to the seabed, or both.

[0145] Floating installations do not require permanent anchoring mechanisms and can be positioned, for example, on pontoon-based supports or on barges, reducing the environmental impact and increasing the scalability of the multi-resource offshore renewable energy installation **104**. Floating installations may also be capable of being raised and lowered as needed to protect equipment, components and mounting systems, and keep them operational, in the event of storms, rough seas, very large waves, or other adverse environmental conditions. Cooling capability can be generated from the ocean water itself, particularly in floating structures and particularly where ocean thermal energy conversion components are implemented that produce desalinized water from heating ocean water.

[0146] High-temperature solar thermal collectors **138** may be used to generate power either during the day or at night, since heat can be stored in large quantities to be supplied to the steam cycle of the collectors at night. The present invention therefore contemplates, that heat storage tanks may be also components on the multi-resource offshore renewable energy installation **104**.

[0147] The multi-resource offshore renewable energy installation **104** may also be configured to include an ocean thermal energy conversion component **140** to generate a power output based on differences between cooler deep water and warmer shallow or surface water. This difference is used to generate steam which operates a turbine to generate electricity. Different types of systems may be incorporated, such as closed, open, or hybrid systems which take advantage of the water temperature variations in different ways. One such closed-loop system boils warm surface seawater directly in a low-pressure container. The resulting expanded steam, which becomes pure fresh water as a result of losing its salt, drives a turbine attached to an electrical generator. It can then be condensed into a liquid by exposure to cold temperatures from waters found greater depths in a different chamber. This has the potential to produce desalinized fresh water, suitable for drinking water at the offshore installation site or transmission for onshore use.

[0148] In addition to provide an additional source of power for the power requirement **144**, this renewable resource **114** can be used to self-power the offshore multi-resource renewable energy installation **120**, together with any feedback loop incorporated in any of one of the power output circuits **142** to make use of excess capacity generated. This component is well-suited for such uses, because the temperature variances between water at different depths may be not enough for large-capacity power production. However, it is likely that at deep ocean installations, water depths will be great enough to generate some notable difference in temperatures, thereby providing at least one source of power for the multi-resource offshore renewable energy installation **104** itself. Use of a renewable energy resource component **116** to self-power the multi-resource offshore renewable energy resource installation **120** reduces the environmental impact of the installation by reducing the need for connecting to a non-renewable source of power.

[0149] As with other renewable resource components **116**, the ocean thermal energy component **140** may communicate with one or more renewable resource control systems **214** and the transmission control system **230** to generate power to satisfy the power requirement **144**. These control systems are configured to control the ocean thermal energy component **140** and communicate with controllers coupled to operational and power-generating output circuits inside each apparatus to separably and variably operate each one. The controllers are therefore configured, in one aspect, to communicate at least a real-time operational availability and power capacity **148** of an ocean thermal energy component **140**, and in another aspect, to respond to output signals generated by the renewable energy resource control system **214** to perform actions such as turning power output circuits **142** on or off, and adjusting a water depth at which ocean water is obtained in response to instruction from the power settlement module **218**. Meteorological conditions such as changes in sea water temperature at different depths have substantial influence on the operational availability of each ocean thermal energy component **140** and the ability to variably operate each, and therefore these are continuously measured at the offshore multi-resource renewable energy installation **120**.

[0150] The ocean thermal energy components **140** contemplated herein are also assumed to generate a power output in alternating current form, and therefore the power outputs needs to be rectified to direct current prior to connection to the common direct current bus **158**, and voltage source converters **156** adjust the voltage level with either voltage step-up or step-down transformers to ensure a compatible voltage level. Power outputs of all of the ocean thermal energy components **140** are monitored by the transmission control system **230**, in addition to the power outputs of all other apparatuses that are being operated to generate power, to make further adjustments if necessary as discussed herein.

[0151] As with other components **116**, where it is the case that power is generated as direct current, no inverter is needed for connection of the power output circuitry to the common direct current bus **158** and the HVDC transmission system **106**. The transmission control system **230** must still however account for variances in the voltage of each such power output, and therefore would monitor the power output and voltage source converters **156** as above, in conjunction with power output of other apparatuses of other renewable energy resource components **116** and in conjunction with each renewable energy resource control system **214**, to make adjustments accordingly.

[0152] Ocean thermal energy components **140** may be either fixed or permanent components of the multi-resource offshore renewable energy installation **104**, or temporarily coupled thereto so as to be mobile and deployable to different locations or as needed. Regardless, they may also be part of a floating installation of renewable resource components **116**, or a fixed installation with support that is permanently anchored to the seabed. Floating installations do not require permanent anchoring mechanisms and can be positioned, for example, on pontoon-based supports or on barges, reducing the environmental impact and increasing the scalability of the multi-resource offshore renewable energy installation **104**. Floating installations may also be capable of being raised and lowered as needed to protect ocean thermal energy converters **140**, and keep them operational, in the event of storms, rough seas, very large waves, or other adverse environmental conditions.

[0153] As referenced herein, the various embodiments of the present invention can be configured in many different ways. In one embodiment, the present invention is contemplated to be available as a "packaged" configuration of multiple processes, hardware, and apparatuses that together act as a self-contained system. Such a self-contained system can be deployable and scalable for temporary uses, such as to provide power grid infrastructure such as in a field military base or large-scale disaster response situations.

[0154] Distributed computing infrastructure **150** provides a computing and network operational architecture for the renewable resource energy management system **100**, multi-resource offshore renewable energy installation **104**, and electricity grid infrastructure **300** of the present invention. The distributed computing infrastructure **150** utilizes the combined computing power of multiple interconnected computing networks **152** to manage data flow, perform data processing functions, and facilitate communications in the present invention. It also provides the power distribution module **200**, the power generation module **208**, the power settlement module **218**, and power transmission module **226** with flexibility to perform the critical power grid infrastructure functions with which they are assigned. The distributed computing infrastructure **150** is therefore a high-level computing architecture designed to spread computational power around multiple computing environments in a distributed fashion and which aggregates the many interconnected computing networks **152** to perform the multiple processes needed to host and perform the present invention.

[0155] The various modules and control systems of the present invention may therefore be thought of as utilizing one or more available computing resources as needed from across the distributed computing infrastructure **150**, regardless of where particular elements of each are stored. Alternatively, system elements such as control systems may be thought of as being "embedded" at various points within the distributed computing infrastructure **150**, such as for example renewable energy resource control systems **214** may be embedded within one or more controllers capable of operating each renewable energy resource component **116**. Regardless, it is to be understood that many different configurations are possible and contemplated within the distributed computing infrastructure **150**.

[0156] In one embodiment, the distributed computing infrastructure **150** employs cloud computing principles and technology to provide a distributed platform and resources for hosting multiple modules and data access, processing, modeling, and storage, as well as communication between infrastructure systems and components, so that no one portion of the overall renewable energy resource management system **100**, multi-resource offshore renewable energy installation **104**, or electricity grid infrastructure **300** is required to host, process, or store information. The distributed computing infrastructure **150** may also be thought as a grid computing architecture in which middleware provides the link between the various modules and control systems of the present invention to facilitate distributed data processing. Regardless, the present invention employs the cloud-based or grid-based distributed computing infrastructure **150** and interconnected computing networks **152** in multiple ways to meet the operational functions and objectives disclosed herein. Additionally, it is to be understood that communications with the distributed computing infrastructure **150** may be through both wired and wireless means.

[0157] Microgrid control systems **110**, for example, each perform the critical task of determining real-time power needs of customers **112** coupled to each microgrid **108** without needing a physical location near a microgrid **108** or its customers **112**. Microgrid control systems **200** may be resident anywhere within the cloud or grid-based distributed computing infrastructure **150** and utilize interconnected computing networks **152** and controllers to collect input data regarding the microgrid **108** and the power customers **112** coupled thereto, mathematically model power needs relative to physical characteristics of the microgrid system they are responsible for controlling, and generate output data used in one aspect to arrive at the power demand **146** for the microgrid **108**, and in another aspect, to manage delivery of the necessary power requirement **144** to each microgrid **108** as discussed herein.

[0158] Furthermore, the distributed computing infrastructure **150** may be a privately-hosted, shared computing environment in which secure data communications, processing, and storage necessary to accomplish the present invention are possible. Effectively a private, secure cloud, the distributed computing infrastructure **150** according to this aspect of the present invention has substantial application in supporting enhancements in power grid infrastructure security given the increasing need to protect power grid infrastructure from security threats as noted in detail herein.

[0159] Microgrid **108** decoupling has specific application in grid infrastructure security, together with the distributed, decentralized nature of the computing environment. The distributed computing infrastructure **150** allows communication and connectivity of modules and control systems, and data functions and services managed and controlled by them, to be re-routed and re-deployed where necessary, permitting power to continue to be delivered uninterrupted in the event of a major security threat or attack intended to disrupt flow of power to key public infrastructure. Extra layers further solidify the security aspects of the present invention, as the privately-hosted, shared distributed computing infrastructure **150** allows easier integration of specific information security measures designed to limit the possibility that systems can be penetrated and increasing the difficulty in locating and disrupting distributed services.

[0160] The distributed computing infrastructure **150** is capable of facilitating access and communication with one or more external computing networks **154** to carry out one or more tasks in practicing the present invention. Data from these types of external networks **154** provide information needed by one or more modules and control systems of the present invention. An example an external computing network **154** is an energy commodity trading platform **160** or other public or private exchange involving commodities and capable of providing pricing of commodities. Another example is a weather satellite system **162** capable of providing meteorological data. Yet another example is a database **164**, public or private, that tracks regulatory requirements for purchasing renewable energy resources as well as public or private databases for tracking contractual requirements for the same.

[0161] In the present invention, there are several reasons for monitoring, modeling, and forecasting data relative to meteorological conditions and energy commodity prices. Within both the renewable resource energy management system **100** and the electricity grid infrastructure **300** embodiments of the present invention, it is imperative to assess energy commodity prices to arrive at an optimized purchase price for each renewable energy resource **114** to be purchased. This is influenced by many factors, such as purchasing conditions related to contractual and regulatory requirements obligating the purchase of particular renewable energy resources **114** at particular times and in particular quantities, such as for example commodity price signals, or other conditions such as tariffs. Meteorological conditions may also be a factor in energy commodity prices over the specific period of time, and therefore meteorological condition models for each renewable energy resource **114** may be components in mathematical models of energy commodity prices over the period of time to be assessed.

[0162] Similarly, within both the renewable energy management system **100** and the multi-resource offshore renewable energy installation **104** embodiments of the present invention, it is imperative to assess both meteorological conditions and energy commodity prices to arrive at both an optimized sale price for each renewable energy resource **114** to be purchased and an efficient operational availability and power capacity **148** for each renewable resource component **116**. For example, an operator of a multi-resource offshore renewable energy resource installation **120** may model meteorological conditions at the installation site and energy commodity prices to forecast an operational availability and power capacity **18** of each renewable energy resource component **116** at the installation.

[0163] Monitoring and modeling meteorological conditions is a function performed by one or more of the power generation module **208**, the power distribution module **200**, and the power settlement module **218** in the renewable energy resource management system **100**, by one or more renewable resource control systems **214** in the multi-resource offshore renewable energy installation **104**, and by one or more of various modules and control systems in the distributed management system **302** in the electricity grid infrastructure **300** according to different embodiments of the present invention. This function is used to forecast of meteorological conditions over the specific period of time so that the power requirement **144** can be satisfied, so that the operational power capacity **148** of each renewable resource component **116** at a multi-resource offshore renewable energy installation **104** is maximized to ensure efficiency and cost-effectiveness, and to balance power production with power consumption.

[0164] Many different measurements of meteorological conditions are contemplated with the scope of the present invention, and therefore it is possible that many external networks **154** are to be used to access such data. Among the different meteorological conditions to be measured include wind speed and direction influenced by weather patterns indicating storms, sunlight conditions including time of sunrise and sunset, cloud patterns, surface and sub-surface ocean wave, current and tidal conditions and patterns, ocean temperature at various depths, humidity, barometric pressure, precipitation, and many other variables, each of which alone or in combination affect the performance, availability, and capacity of the renewable energy resource components **116** available at the multi-resource offshore renewable energy installation **104**.

[0165] Similarly, monitoring and modeling renewable energy resource commodity pricing is also a function performed by one or more of the power generation module **208**, the power distribution module **200**, and the power settlement module **218** in the renewable energy resource management system **100**, by one or more renewable resource control systems **214** in the multi-resource offshore renewable energy installation **104**, and by one or more of various modules and control systems in the distributed management system **302** of the electricity grid infrastructure **300** according to different embodiments of the present invention. This function is used to forecast both a commodity purchase price, in the case of the intelligent power distribution network **102**, and a commodity selling price, in the case of the multi-resource offshore renewable energy installation **104**, over the specific period of time, for each renewable energy resource **114** available to satisfy the power requirement **144**.

[0166] Commodity pricing is a component of satisfying the power requirement **144** because energy prices fluctuate widely over time and for each type of renewable energy resource **114**, whether it be solar, wind, hydrokinetic, solar thermal, ocean thermal, or any other energy resource. Incorporating a commodity pricing component allows an efficient operational power capacity **148** of each renewable energy resource component **116** to be achieved, and informs a cost-effective, efficient exchange of resources by allowing both the buyer of power and the seller of power arrive at a price point for each resource. Therefore, monitoring and modeling renewable energy commodity prices helps the power requirement **144** to be satisfied, and helps to predict the operational power capacity **148** of each renewable resource component **116** to maximize efficiency and cost-effectiveness. It is contemplated that least some of the renewable energy resources **114** from which power is to be generated are traded within one or more energy commodities exchanges. It is therefore further contemplated that a forecast of commodity prices must take into account at least those that are traded on exchanges.

[0167] Types of external computing networks **154** that may be accessed to monitor and forecast meteorological conditions include, but are not limited to, proprietary weather assessment networks, sites capable of accessing data from weather satellites, governmental weather system portals, other particular weather-related websites, and any other networks capable of aggregating useful data relative to assessing and predicting meteorological conditions. Types of external computing networks **154** that may be accessed to monitor and forecast energy commodity prices include, but are not limited, proprietary commodities exchange trading platforms, particular commodities pricing information sites, and any other networks capable aggregating useful commodity price information that can be used to assess and predict energy commodity prices.

[0168] The distributed computing infrastructure **150** may also host one or more artificial neural networks tasked with heuristically modeling data within the present invention to perform a variety of functions, such as predicting commodity pricing and meteorological conditions, assessing power usage patterns and power **146** customers, and assessing power capacity **148** of the renewable energy resource components **116**. These artificial neural networks introduce data modeling tools to the framework of the various embodiments of the present invention to heuristically model the complex relationships between inputs and outputs of data and to identify and take advantage of data patterns. Artificial neural networks may take on many forms within the distributed computing infrastructure **150**, such as for example multiple remote computing environments or program calls that are accessed when needed by the modules and control systems within the present invention.

[0169] Artificial neural networks therefore may perform a critical role in increasing and improving the efficiency of the present invention by, for example, heuristically assessing weather conditions at the deep-ocean location of the multi-resource offshore renewable energy installation **104** site to learn how to predict when weather conditions are most and least favorable for operation of a particular renewable resource component **116**, and by heuristically assessing future trends in energy commodity prices to learn how to predict when pricing of commodities is most and least favorable for operation of the particular renewable resource component **116** and predict a range of prices at which commodities are to be both bought and sold, and combining the two concepts to further increase efficient performance within the present invention.

[0170] Heuristic modeling in artificial neural networks can be performed alone or as part of the many variables and characteristics that comprise modeling and forecasting for energy commodity prices and meteorological conditions. It may also help to identify instances where one or more of the modules and control systems operative within the present invention should buy, sell, or trade, financial instruments in conjunction with commodity prices of renewable energy resources **114**. Artificial neural networks may therefore be a useful tool, incorporated with other mathematical modeling within the present invention, to predict energy commodity pricing trends and when hedging may be advantageous.

[0171] In one example of the use of an artificial neural network, where a microgrid control system **110** responsible for assessing power usage patterns to determine a power demand **146** of power customers **112** coupled to a microgrid **108**, the microgrid control system **110** may initiate a program call to introduce a separate predicted assessment of power usage as part of a closed-loop system of analyzing output signals of the microgrid control system **110**. Such a program call initiates a heuristic assessment of data aggregation reflecting different usage components, usage type, any fluctuation tolerance over the specific period of time at issue which may influence load variances, and other possible variables affecting power demand **146** as noted herein. This effectively introduces a data modeling tool to act as a comparative check of the assessed power demand **146**, to ensure accurate data collection and sampling. Artificial neural networks may therefore have significant application acting as data modeling checks to ensure, for example, that error rates are properly managed.

[0172] Energy installations located offshore face the significant problem of transferring power to the onshore power consumer in an efficient manner. For deep-sea installations, this may be done using an undersea direct current transmission link, since long-distance alternating current transmission systems suffer losses that are unacceptably high. However, modern electricity grid infrastructure requires substantially all power in alternating current form for downstream delivery to consumers thereof. Power consumers that do require direct current power rely on substations to ensure they are getting the correct form of electricity. Additionally, many wind, hydrokinetic, and solar thermal manufacturers configure their apparatuses to generate power in alternating current form to easily meet the needs of the electricity grid consumers. Providers therefore have the problem of components generating a mix of AC and DC power, which must be transferred as DC, and then delivered as AC and then rectified later if necessary.

[0173] FIG. **5** is a system diagram of components of a power transmission system in accordance with the various embodiments of the present invention, indicating power outputs of the renewable energy resource components **116** connected to an HVDC transmission system **106**, which includes a sub-sea high-voltage direct current link that transfers power generated by the multi-resource offshore renewable energy installation **104** to the intelligent power distribution network **102**. Power output circuits **142** feed into a system of one or more voltage source converters **156** that ensure that each renewable energy resource component **116**, and each apparatus therein, produces a power output in the proper current at a common or constant voltage level for connection to a common direct current bus **158** connected to the HVDC transmission system **106**. All renewable energy resource components **116** and apparatuses of the multi-resource offshore renewable energy installation **104** are directly connected to the system of voltage source converters **156** and the common direct current bus **158** in the HVDC transmission system **206**, either in series or in parallel depending on the power output of each, so that a direct current power output is fed into the voltage source converters **156** and the common direct current bus **158** of the HVDC transmission system **106**. Where a power output circuit **142** generates AC-based power, it first passes through a rectifier circuit prior to entering a voltage source converter **156** to ensure all electricity entering the common bus **158** is direct current.

[0174] The HVDC transmission system **106** also allows each renewable energy resource component **116** to be independently and variably operated because the system of voltage source converters **156**, together with any rectifiers needed to convert AC to DC, conduct the necessary power output transformation to ensure consistent and common voltage and current. The HVDC transmission system **106** therefore supports full operational variability of the renewable energy resource components **116** at the multi-resource offshore renewable energy installation **104** to adjust power capacity **148** as needed to satisfy the power requirement **144** relative to all other considerations discussed herein, since designers need not be primarily concerned with the effects of adjusting power capacity **148** on voltage levels.

[0175] This design allows for scalability of the multi-resource offshore renewable energy installation **104** to accommodate hundreds and thousands of apparatuses within each component **116**. Traditional and existing installations are usually single-resource and are connected to electricity grids either in close proximity thereto and/or under the assumption that because of the small percentage of its relative share of the overall power supply, its size and influence require less stringent attention to connection requirements. However, as electricity grids require more and more power from renewable resources, and multi-resource installations become economically feasible both onshore and at deep sea locations far away from land, the design importance of power electronics considerations increases dramatically.

[0176] The voltage source converters **156** allow system designers to reduce the complexity of output circuits **142** of each apparatus of each renewable energy resource component **116**, since extra converters in power output circuits **142** are not necessary. This allows for much easier independent and variable operation of apparatuses and devices that produce power from renewable energy resources.

[0177] HVDC transmission provides direct current electricity to one or more onshore receiving locations **236** prior to delivery to the intelligent power distribution network **102**. The present invention contemplates that electricity can be inverted to AC for those portions of the intelligent power distribution network **102** needing AC, diverted to selected DC-only or DC-specific microgrids **108** or to other DC-only buyers, or transmitted further onward in DC form to other receiving locations of other downstream intelligent power distribution networks **102** for later decision whether to invert to AC or divert for DC-only needs. The framework of the intelligent power distribution network **102**, together with the plurality of microgrids **108**, supports both AC and DC-based electricity grids and allows power to delivered and consumed in either AC or DC, as needed and instructed by each microgrid **108**. DC-only microgrids **108** can therefore receive power directly from the offshore provider without needing to employ a system of rectifiers and inverters.

[0178] Because some components can be configured to generate power in DC, a voltage source converter **156** may not be needed with every power output circuit **142** except to regulate any output prior to linking with the common direct current bus **158**. Since power output levels may be monitored in conjunction with the transmission control system **230**, a bypass circuit may be included to circumvent the VSC system **232** where voltage levels and direct current output are already compatible with requirements of the common direct current bus **158**.

[0179] The HVDC transmission system **106**, in addition to monitoring the voltage source converters **156** and power output circuits **142** of each apparatus to ensure compatible current and voltage levels, may also monitor, together with the transmission control system **220**, the power output of each apparatus within each component **116** to determine, as an additional system check, whether an over or under-production of power is being generated for the specific period of time. This adds an additional layer of analysis to ensure a power balance matching power production to power consumption is being achieved, and so that a minimal battery storage requirement at both the multi-resource offshore renewable energy installation **104** and the one or more receiving locations **236** of the intelligent power distribution network **102** is maintained. Where an under-production is detected, the transmission control system **230** is capable of working with specific modules, controllers and with other control systems **212** to increase power production somewhere among the renewable resource components **116**. Similarly in the case of a power over-production, power production can be decreased in the same manner.

[0180] The present invention also contemplates that one or more feedback loops may be utilized to either transfer power to a temporary battery for storage of the excess power, or to the multi-resource offshore renewable energy installation **104** itself to self-power the installation and its renewable energy resource components **116**. In this regard, the HVDC transmission system **106** may act as a source of power for the multi-resource offshore renewable energy installation **104**, either directly or from the temporary battery, so that no or very limited additional sources of power are needed to power the installation itself.

[0181] Excess power production may also be routed to one or more energy storage facilities that provide backup or alternate sources of power for electricity grids. Such grid-scale batteries may serve one or more broader electricity grids or one or more microgrids **108**, and may utilize power over-production from renewable energy resources as an additional layer of power supply in the event of sudden and/or localized variances to the amount of power needed, such as in emergency situations. Where excess power is transferred to grid-scale energy storage facilities, it may be routed thereto from either the multi-resource offshore renewable energy installation **104** upon output signals from the transmission control system **230** or from the intelligent power distribution network **102** at the receiving location **236** or some other component thereof.

[0182] Power transmission in the present invention can also be configured so that power is delivered from the multi-resource offshore renewable energy installation **104** to the intelligent power distribution network **102** using wireless systems and methods. One example of wireless energy transfer is through electromagnetic radiation, such as with lasers. Power can be transmitted by converting electricity into laser beams that can be transmitted using a laser emitter to an antenna at one or more receiving locations **236** of the intelligent power distribution network **102**. The antenna receives the laser beam and converts the light to direct current-based power to be delivered and routed to microgrids **108** as discussed herein.

[0183] The laser beam emitter may be located in a fixed configuration at the multi-resource offshore renewable energy installation **104**, or in a temporary configuration that may be deployable as needed. Regardless, it is contemplated that despite possible deep-ocean locations that may result in long distances between the multi-resource offshore renewable energy installation **104** and receiving locations **236**, the distance will not result in a substantial loss of power, and laser beam emitters are to be configured to emit laser beams that will not result in a large loss over the distance transmitted.

[0184] Where a laser beam-based wireless energy transmission is utilized, the transmission system **106** must account for any power loss that will be encountered with converting power produced at the multi-resource offshore renewable energy installation **104** into a laser beam. Accordingly, power outputs of the renewable energy resource components **116**, and the power output circuits **142**, may have to be adjusted, either through variable operation of the renewable energy resource components **116** or through the voltage source converters **156**.

[0185] The type of power transmission can be managed so that the present invention is capable of either by undersea HVDC transmission link, by wireless energy transmission methods as discussed herein, or both. In one embodiment, the transmission control system **230** performs the function of selecting the appropriate transmission method, based on input data from the intelligent power distribution network **102**, by the power distribution module **200**, power generation module **208**, power settlement module **218**, or power transmission module **226** of the renewable resource energy management system **100**, by the distributed management system **302**, or by any another source of such input data. One or more of these or other modules may also be configured to manage the task of determining which method of transmission is to be used.

[0186] Use of wireless energy transmission may be utilized where a security or maintenance issue arises with the HVDC transmission system **106**. In such situations, wireless energy transmission ensures uninterrupted flow of power from the multi-resource offshore renewable energy installation **104** to the intelligent power distribution network **102** and to the electricity grid infrastructure **300**.

[0187] FIG. **6** and FIG. **7** are overview perspective and top plan views of the present invention, showing a multi-resource offshore renewable energy installation **104** connected to an intelligent power distribution network **102** via a transmission system **106**. FIG. **6** and FIG. **7** show different embodiments of the multi-resource offshore renewable energy installation **104**. FIG. **6** shows an embodiment in which multiple floating apparatuses, such as platforms or barges, can produce power from multiple renewable energy components **116** to an intelligent power distribution network **102**. FIG. **7** shows another embodiment in which a mobile, semi-submersible production platform provides support for a number of such multiple floating apparatuses. The multi-resource offshore renewable energy installations **104** in FIG. **6** may therefore be coupled in any number to a mobile semi-submersible production platform as shown in FIG. **7**. Regardless, it is to be understood that numerous configurations of the present invention are contemplated and possible to achieve the various objectives discussed herein.

[0188] The present invention contemplates many other embodiments that are within the scope of this disclosure. For example, in one such embodiment, systems and methods of determining, on one side, an optimal power demand and on the other side, an optimal supply within an electricity grid infrastructure. This includes a method of determining an optimal delivery of power to be generated entirely from renewable resources for an electricity grid infrastructure. Another method according to this embodiment involves determining an optimal generation of power to be delivered to an electricity grid infrastructure. Yet further methods involve settling a transfer of power that is entirely generated from renewable resources and satisfies a power requirement of an electricity grid infrastructure, and transmitting an optimal delivery of power to customers of an electricity grid infrastructure.

[0189] In another such embodiment, the present invention discloses a system and method of balancing power production with power consumption in an electricity grid infrastructure. This embodiment includes a method of adapting renewable resource energy production to energy consumption, a method of minimizing storage of electricity for delivery to an electricity grid infrastructure, and a balanced renewable resource-based energy management system comprising a source of power generated entirely from renewable energy resources and a consumer of power having a predictable power demand over any given period of time, wherein the power transmitted satisfies the entire power requirement only from renewable energy resources and at an operational level that maximizes the efficiency of each renewable energy resource.

[0190] In yet another embodiment, the present invention discloses a system and method of enhancing grid infrastructure security. This embodiment includes methods of improving electricity grid security and securely delivering power to an electricity grid infrastructure. The embodiment may also include a security system for ensuring delivery of power to an electricity grid infrastructure.

[0191] It is to be understood that still other embodiments will be utilized and structural and functional changes will be made without departing from the scope of the present invention. The foregoing descriptions of embodiments of the present invention have been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed.

Accordingly, many modifications and variations are possible in light of the above teachings. It is therefore intended that the scope of the invention be limited not by this detailed description.

1. A method of processing data for determination and delivery of a demand response within a renewable energy-based electricity grid infrastructure, comprising:

aggregating data defining a power requirement over a specified power of time of one or more microgrids among a plurality of microgrids forming an intelligent power distribution network, each microgrid capable of being separately decoupled and separately generating and communicating data defining the power requirement, and additional input data for a plurality of mathematical modeling functions, from across a shared, secure and privately-hosted computing environment forming a distributed computing infrastructure in which the data defining the power requirement and the additional input data are stored;

assigning a plurality of computing resources within the shared, secure and privately-hosted computing environment to perform the plurality of mathematical modeling functions on aggregated data defining the power requirement and the additional input data within a dedicated demand response service of the shared, secure and privately-hosted computing environment, the assigning the plurality of computing resources including

integrating the plurality of computing resources so that the dedicated demand response service is configured with at least one processor and at least one memory module for performing the plurality of mathematical modeling functions embodied by one or more program instructions, the plurality of computing resources aggregated to form a real-time grid data analytics module of data processing functions for performing the dedicated demand response service within the shared, secure and privately-hosted computing environment to provide a dynamic demand response to the power requirement,

the real-time grid data analytics module configured to execute the program instructions to continuously determine the dynamic demand response to the power requirement with at least one of modeling commodity pricing of available renewable energy resources utilized among multiple renewable energy resource components configured at a common installation site, modeling meteorological conditions at the common installation site, modeling power usage patterns of the one or more microgrids in the intelligent power distribution network, modeling a power production capacity of the multiple renewable energy resource components configured at a common installation site, and modeling a load capacity of a power transmission system coupling the plurality of renewable energy resource components and the intelligent distribution network,

the real-time grid data analytics module outputting one or more resulting data sets defining a plurality of instructions for the dynamic demand response to the power requirement; and

configuring the dynamic demand response to the power requirement from the one or more resulting data sets, the dynamic demand response embodied as input data from the plurality of instructions for optimizing an efficient power production capacity and an efficient transmission load capacity to deliver the dynamic demand response from the multiple renewable energy resource components to the intelligent power distribution network.

2. The method of claim 1, wherein the multiple renewable energy resource components are configured on a multi-resource offshore renewable energy installation and include at least two of a wind component comprising at least one wind turbine, a photovoltaic component comprising at least one photovoltaic module, a hydrokinetic component comprising at least one of a surface wave turbine, an oscillating column, and an undersea wave turbine, and a solar thermal energy component comprising at least one high-temperature solar thermal collector.

3. The method of claim 1, wherein the plurality of computing resources comprise at least one artificial neural network capable of heuristically modeling the data defining the power requirement and the additional input data within the grid data analytics module.

4. The method of claim 1, wherein the configuring the dynamic demand response further comprises communicating with one or more components in the multiple renewable energy resource components and the power transmission system to deliver the dynamic demand response to the one or more microgrids, the dynamic demand response comprising at least one instruction to the multiple renewable energy resource components to produce power for transmission to the intelligent power distribution network and at least one instruction to the transmission power system to transmit power from the plurality of renewable energy resource components to the intelligent power distribution network.

5. The method of claim 1, wherein the configuring the dynamic demand response further comprises communicating with one or more components in the multiple renewable energy resource components and the power transmission system to deliver the dynamic demand response to the one or more microgrids, the dynamic demand response comprising at least one instruction to the multiple renewable energy resource components to produce power for transmission to each decoupled microgrid requiring power and at least one instruction to the power transmission system to separately transmit power to each decoupled microgrid requiring power.

6. The method of claim 1, further comprising receiving data indicative of a request for at least one of a delivery of power to specific decoupled microgrids in the one or more microgrids, a delivery of power in direct current form only to a specific decoupled microgrid, and a delivery of power in at least one specified amount from one or more components in the multiple renewable energy resource components.

7. The method of claim 1, wherein the integrating a plurality of computing resources within the shared, secure and privately-hosted computing environment to perform the plurality of mathematical modeling functions on the aggregated data defining the power requirement further comprises modeling weather conditions over the specified period of time at a deep-ocean location of a multi-resource offshore renewable energy installation site hosting the multiple renewable energy resource components to predict most favorable weather conditions and least favorable weather conditions for optimal operation of a specific renewable energy resource component, modeling future trends in energy commodity prices over the specified period of time to predict most favorable commodity pricing and least favorable commodity pricing to develop a range of commodity pricing for optimal operation of a specific renewable energy resource component, and modeling the power production capacity of the multiple renew-

able energy resource components by assessing an operational availability of each specific renewable energy resource component.

8. The method of claim **1**, wherein the integrating a plurality of computing resources within the shared, secure and privately-hosted computing environment to perform the plurality of mathematical modeling functions on the aggregated data defining the power requirement further comprises modeling the load capacity of the power transmission system by communicating with at least one transmission control system to monitor a power output circuit of each renewable energy resource component and an output of each voltage source converter in a system of voltage source converters so that a combined power output of the multi-resource offshore renewable energy installation is within the load capacity of the high voltage direct current transmission system to ensure a stable power transmission link between the multi-resource offshore renewable energy installation and the intelligent power distribution network.

9. The method of claim **1**, wherein the shared, secure and privately-hosted computing environment is configured to maximize data protection and minimize disruption of the delivery of a dynamic demand response from a loss of data.

10. A method of aggregating distributed processing resources for modeling and delivering a demand response as a service within a renewable energy-based electricity infrastructure, comprising:

determining a data processing requirement for modeling a dynamic demand response to data representative of a power requirement over a specified power of time of one or more microgrids among a plurality of microgrids forming an intelligent power distribution network, each microgrid capable of being separately decoupled and separately generating and communicating data defining the power requirement, the data representative of the power requirement communicated by the one or more microgrids and disparately and remotely stored within a shared, secure and privately-hosted computing environment forming a distributed computing infrastructure, the data processing requirement to be accessed in a distributed fashion to execute a plurality of mathematical modeling functions embodied to form a dedicated grid data analytics module as a dedicated demand response service that ensures data privacy and data security within an energy management system of the renewable energy-based electricity grid infrastructure;

identifying available data processing resources comprising at least one processor component, one or more memory modules, and program instructions for performing the plurality of mathematical modeling functions to meet the data processing requirement from within the shared, secure and privately-hosted computing environment forming the distributed computing infrastructure;

isolating and aggregating the identified available data processing resources so that the at least one processor component, the one or more memory modules, and the program instructions identified for the data processing requirement form the dedicated grid analytics module configured to execute the program instructions to disparately model the data defining the power requirement in the dedicated demand response service for modeling and delivery of the dynamic demand response;

applying the data defining the power requirement in the specific grid analytics module to continuously model the dynamic demand response to the power requirement with at least one of modeling commodity pricing of available renewable energy resources utilized among multiple renewable energy resource components configured at a common installation site, modeling meteorological conditions at the common installation site, modeling power usage patterns of the one or more microgrids in the intelligent power distribution network, modeling a power production capacity of the multiple renewable energy resource components configured at the common installation site, and modeling a load capacity of a power transmission system coupling the multiple renewable energy resource components and the intelligent distribution network to generate a set of output data defining a plurality of instructions for the dynamic demand response to the power requirement; and

communicating the set of output data defining the plurality of instructions to a transmission module and to a power generation module among the energy management system for delivery of the dynamic demand response as a distributed energy generation to the one or more microgrids.

11. The method of claim **10**, further comprising requesting and receiving the additional input data from additional computing networks to perform the mathematical modeling functions, the data being requested and received from at least one external computing network, the at least one external computing network including at least one of a commodity trading platform capable of communicating data relative to a forecast of variable purchase price ranges and variable selling price ranges for each renewable energy resource at the common installation site over the specific period of time, a weather satellite network capable of communicating data relative to a forecast meteorological conditions for each renewable energy resource at the common installation site over the specific period of time, a plurality of renewable energy component control systems capable of communicating data relative to an operational capacity of the multiple renewable energy components, and a plurality of transmission control systems capable of communicating data relative to an operational capacity of a high-voltage direct current transmission network.

12. The method of claim **10**, wherein the identified available data processing resources comprise at least one artificial neural network capable of heuristically modeling the dynamic demand response in the dedicated grid analytics module.

13. The method of claim **10**, further comprising continuously performing checks of the dynamic demand response to ensure proper minimization of an error rate with a plurality of additional mathematical modeling functions performed on the data defining the power requirement and the additional input data within the dedicated grid analytics module.

14. The method of claim **10**, further comprising receiving data indicative of a request for at least one of a delivery of power to specific decoupled microgrids in the one or more microgrids, a delivery of power in direct current form only to a specific decoupled microgrid, and a delivery of power in at least one specified amount from one or more components in the multiple renewable energy resource components.

15. The method of claim **10**, wherein the applying the data defining the power requirement in the specific grid analytics module to continuously model the dynamic demand response to the power requirement further comprises modeling weather conditions over the specified period of time at a deep-ocean location of a multi-resource offshore renewable energy installation site hosting the multiple renewable energy resource components to predict most favorable weather conditions and least favorable weather conditions for optimal operation of a specific renewable energy resource component, modeling future trends in energy commodity prices over the specified period of time to predict most favorable commodity pricing and least favorable commodity pricing to develop a range of commodity pricing for optimal operation of a specific renewable energy resource component, and modeling the power production capacity of the multiple renewable energy resource components by assessing an operational availability of each specific renewable energy resource component.

16. An energy management system comprising:

a plurality of memory modules operably coupled to a plurality of processors, the plurality of memory modules and the plurality of processors capable of being accessed in a distributed fashion within a plurality of remote interconnected computing networks in a shared, secure and privately-hosted computing environment forming a distributed computing infrastructure in which data defining a power requirement of an intelligent power distribution network is disparately stored and processed;

one or more program instructions accessible by the plurality of memory modules, the plurality of processors being operable to execute the one or more program instructions, the one or more program instructions configured to perform a plurality of mathematical modeling functions on aggregated data defining the power requirement and additional input data within a dedicated demand response service of the shared, secure and privately-hosted computing environment,

the plurality of processors, plurality of memory modules, and program instructions forming a plurality of dedicated computing resources aggregated within the distributed computing infrastructure to form a real-time grid data analytics module of data processing functions for performing the dedicated demand response service within the shared, secure and privately-hosted computing environment to provide a dynamic demand response to the power requirement in a renewable energy-based electricity grid infrastructure;

the real-time grid data analytics module configured to execute the program instructions to continuously determine a dynamic demand response to the power requirement over the specific period of time with at least one of modeling commodity pricing of available renewable energy resources among multiple renewable energy resource components configured at a common installation site, modeling meteorological conditions at the common installation site, modeling power usage patterns of the one or more microgrids in the intelligent power distribution network, modeling a power production capacity of the multiple of renewable energy resource components configured at the common installation site, and modeling a load capacity of a power transmission system coupling the plurality of renewable energy resource components and the intelligent distribution network; and

one or more resulting data sets defining a plurality of instructions for the dynamic demand response to the power requirement, generated by the real-time grid data analytics module as an output of the dedicated dynamic demand response service, the output configuring to embody the dynamic demand response to the power requirement in the plurality of instructions for optimizing an efficient power production capacity and an efficient transmission load capacity to deliver the dynamic demand response to the intelligent power distribution network in a distributed energy generation of power from the multiple renewable energy resource components.

17. The energy management system of claim **16**, wherein the data defining the power requirement is communicated from a power distribution module communicatively couple with a plurality of microgrids, each microgrid capable of being separately decoupled and separately generating and communicating data defining the power requirement over the specific period of time.

18. The energy management system of claim **16**, wherein the grid data analytics module performs each dedicated dynamic demand response service within at least one artificial neural network that includes the plurality of processors, at least one memory module, and program instructions, the program instructions configured to heuristically model the dynamic demand response within the at least artificial neural network.

19. The energy management system of claim **16**, wherein the real-time grid data analytics module is configured to execute the program instructions to models weather conditions over the specified period of time at a deep-ocean location of a multi-resource offshore renewable energy installation site hosting the multiple renewable energy resource components to predict most favorable weather conditions and least favorable weather conditions for optimal operation of a specific renewable energy resource component, models future trends in energy commodity prices over the specified period of time to predict most favorable commodity pricing and least favorable commodity pricing to develop a range of commodity pricing for optimal operation of a specific renewable energy resource component, and models the power production capacity of the multiple renewable energy resource components by assessing an operational availability of each specific renewable energy resource component.

20. The energy management system of claim **16**, wherein the shared, secure and privately-hosted computing environment is configured to maximize data protection and minimize disruption of the delivery of a dynamic demand response from a loss of data.

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