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(54) **Title**: METHOD AND SYSTEM FOR PLANNING AND CONTROLLING POWER GENERATORS

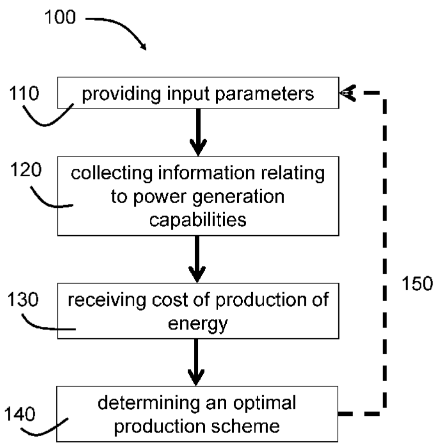

FIG. 2

(57) **Abstract**: The present invention relates to a method and system for determining a production scheme for production of electrical power from a plurality of power generating sources each connected to a utility grid. The power generating sources may be wind farms each comprising a number of wind turbines. The method is based on several parameters including a set of input parameters; information relating to power generation capabilities for each of said plurality of power generating sources,cost of production of energy from each power generating source, and price for energy and amount of power required to be delivered to the utility grid.

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Method and system for planning and controlling power generators

FIELD OF THE INVENTION

The present invention relates to a method for controlling a wind power park, which comprises a plurality of wind turbines and is connected to a utility grid

BACKGROUND OF THE INVENTION

During recent years, the worldwide number of power generation sources, including wind turbines producing electric power, has grown considerably.

Typically, a plurality of electricity producing wind turbines are assembled in so-called wind park or farm, the wind turbines in a wind farm are connected to a utility grid through a common connection rather than the individual wind turbines being connected directly to the utility grid one by one. In the present description the terms wind park and wind farm are used interchangeably and are meant to cover the same concept.

Also, during recent years, the view on such wind power plants have changed from considering them merely as negative loads on the utility grids to considering them as power plants contributing actively to the stability of the utility grids. This development has entailed a large amount of restrictions and requirements to be fulfilled by the wind farms connected to the utility grids.

Furthermore, a still more complex and complicated price structure has developed, the price for the delivered energy often being related to the fulfilment of at least some of those restrictions and requirements.

This increasingly complex business environment has given rise to the need for new control methods for operating the wind power parks in order to keep the energy production stable and efficient under due considerations to the restrictions and requirements imposed.

It is an object of the present invention to provide a control and planning method for a wind farm, which method establish a plan or scheme for a more

cost-efficient operation of the wind farm than other methods previously known in the art.
It is a further object of the present invention to provide an alternative to the prior art.

In particular, it may be seen as an object of the present invention to provide a method for determining a production scheme for production of electrical power from a plurality of power generating sources each connected to a utility grid that solves the above mentioned problems of the prior art.

SUMMARY OF THE INVENTION

Thus, the above described object and several other objects are intended to be obtained in a first aspect of the invention by providing a method

The invention is particularly, but not exclusively, advantageous for obtaining an improved schedule of operation for a set of wind farms. The production scheme may be determined based on a set of restrictions or requirements where the method optimizes the schedule with due care to these requirements and restrictions.

In a first aspect, the invention relates to a method for determining a production scheme for production of electrical power from a plurality of power generating sources each connected to a utility grid, said plurality of power generating sources each comprising a number of wind turbines. The power generating sources may be wind farms each comprising a number of wind turbines. The number of wind turbines in each wind farm need not be identical between the wind farms. As mentioned the wind turbines are usually not individually connected to the power grid, but usually via a common connection. The method comprising the steps of providing a set of input parameters for basing a determined optimal production plan, collecting information relating to power generation capabilities for each of said plurality of power generating sources, receiving cost of production of energy from each power generating source, receiving price for energy and amount of power required to be delivered to the utility grid, determining for each of the plurality of power generating sources an optimal production scheme based on price for energy and cost of production of energy.

Basing the optimal production scheme on price for energy and cost of production of energy it is also possible to establish a scheme where one or more wind turbines are overrated even if this shortens the lifetime of one or more components in the wind turbine, e.g. blades, gear or the like. It is thus not always the optimal solution to schedule production at a relatively low level to reduce wear and prolong component lifetime.

The method may be executed by computer implemented software on a server being in communication with the wind farms. The method may also be used for establishing the scheme; and the scheme may then be distributed to each of the power generating sources where an operator or control computer then operates the individual power generating source based on this scheme. The information relating to power generation capabilities for each of said plurality of power generating sources may be automatically exchanged between a server and the power generating source.

The information relating to power generation capabilities for each of the plurality of power generating sources may include meteorological conditions at the location of the power generating source. The information may also include information on individual wind turbines, e.g. maximum power generation capabilities, state of the wind turbine, planned maintenance etc. The collection of information related to meteorological data should be understood to be performed by means of a control system being able to actively retrieve the meteorological information and/or by the meteorological information being provided to the system, e.g. directly from measurement arrangements or from external meteorological information providers. This meteorological information may include measurements of wind speed, precipitation and/or wind direction, prediction of wind speed, wind direction, wind fields etc.

In a similar fashion information related to energy prices and possible requirements relating to the amount of power delivered from the wind power park may also be actively retrieved by the control system and/or be provided to the control system, e.g. by a wind power park owner or manager, a grid operator, etc.

The information needed to execute the method optimally via a computer may be retrieved or provided directly from the source of information, alternatively the information may be retrieved or provided via databases, external (to the wind power park) control systems controlling the utility grid or meteorological information, etc. All communication may e.g. be performed via secure data communication. The information may be supplied in real-time or on-demand.

The method may additionally comprise for each of the plurality of power generating sources recording the environmental impact of production of energy, and using the environmental impact of production of energy in estimating for each of the plurality of power generating sources the optimal production scheme. When determining the production set point and production schedules to fulfil the power demands, the system may take the environmental impact of the operation of a power plant into the consideration. This could include, but is not limited to:

- CO2 emission – To minimize the CO2 emission by optimizing the power plant
- Shadow control – To consider the shadow control to minimize the shadow effect on the surrounding
- Noise control – To include the control strategy to minimize the noise from the wind turbine or turbines
- Icing control – To consider the icing condition to turbine blades and tower to ensure human, material and environmental safety
- Lightning protection – To ensure the human and material safety due to lightning conditions.
- Typhoon and hurricane protection - To ensure the human and material safety due to Typhoon and hurricane conditions.
- Bat protection – To minimize the risk of loss of bat and birds lives

The individual aspects of the present invention may each be combined with any of the other aspects. These and other aspects of the invention will be apparent from the following description with reference to the described embodiments.

BRIEF DESCRIPTION OF THE FIGURES

The method according to the invention will now be described in more detail with regard to the accompanying figures. The figures show one way of implementing the present invention and is not to be construed as being limiting to other possible embodiments falling within the scope of the attached claim set.

Figure 1 is a schematic view of a wind turbine,
Figure 2 is a schematic view of steps of a method, and
Figure 3 is a schematic view of a system interface.

DETAILED DESCRIPTION OF AN EMBODIMENT

The method according to the present disclosure may be implemented by means of hardware, software, firmware or any combination of these. The method or some of the features thereof can also be implemented as software running on one or more data processors.

The individual elements of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way such as in a single unit, in a plurality of units or as part of separate functional units. The invention may be implemented in a single unit, or be both physically and functionally distributed between different units and processors.

The embodiments of the present invention pertain to a power system with a plurality of wind turbine generators (e.g. a variable-speed wind turbine generator). The power system seeks to provide frequency support to the electrical grid to which it is connected.

The wind turbine generator (e.g. a variable-speed wind turbine generator) which supplies power to an electric grid may be equipped with other regulation capacity against grid-frequency and active power fluctuations. "Electric grid" or "grid" is a utility grid outside the boundary and point of common coupling of a wind power plant; when reference is made to the grid within a wind power plant an expression with explicit indication to the wind power plant is made, e.g., "wind-park grid". Regulation capacity against grid-frequency fluctuations is, e.g., provided by a certain fraction (typically about 10%) of primary controllers, which are typically conventional producers, which may use steam- or gas- driven turbines and fossil energy sources, or hydropower). The primary controllers increase power output when the frequency falls below the nominal value (e.g. 50 or 60 Hz) and decrease power output when it rises above the nominal value.

As the present text deals with active power rather than reactive power, active power is briefly referred to as "power", or "output power".

There is an upper limit to the output power which can be produced by the wind turbine generator according to the embodiments, e.g. due to structural limits and a current limit in the wind turbine generator's electric converter. This amount of power is referred to as "nominal power". The wind speed sufficient for the wind turbine generator to produce the nominal power is referred to as "nominal wind speed". When the wind turbine generator according to the embodiments operates at wind speeds above the nominal wind speed, only that fraction of the available wind power is transformed to electric output power which corresponds to the nominal power. This reduction of power production is, e.g., achieved by gradually changing the rotor-pitch angle towards the so-called flag position. In other words, the wind turbine generator intentionally is not operated at optimum efficiency. In some embodiments the wind turbine generator is also operated at a sub-optimal tip-speed ratio so as to reduce structural loads.

Figure 1 schematically illustrates an exemplary variable-speed wind turbine generator (WPS) 1 is one of a plurality of wind turbine generators of a wind power plant (WPP) 2 or wind farm. The WPS has a rotor 3 with a hub to which, e.g., three blades 4 are mounted. The pitch angle of the rotor blades 4 is variable by means of pitch actuators. The rotor 3 is supported by a nacelle 5 and drives a generator 12 via a main shaft 8, a gearbox 10, and a high speed shaft 11. This structure is exemplary; other embodiments, for example, use a direct-drive 15 generator.

The generator 12 (e.g. Induction or synchronous generator) produces electrical output power of a frequency related to the rotation speed of the rotor 3, which is converted to grid frequency (e.g. about 50 or 60 Hz) by a converter 19. The voltage of the electric power thus produced is up-transformed by a transformer 9. The output of the transformer 9 is the wind turbine generator's terminals 9a. The electric power from the wind turbine generator 1 and from the other wind turbine generators of the wind power plant 2 is fed into a wind-park grid 18 (symbolized by "a" in Fig. 1). The wind power plant grid 18 is connected at a point of common coupling 21 and an optional further step up transformer 22 to a wind power plant external electrical utility grid 20. The grid 20 is equipped with regulation capacity against grid-frequency fluctuations, e.g. in the form of conventional producers which can increase and lower production on a short-time scale to control frequency. A wind-park controller 23 receives signals representative of the voltage, current and frequency at the point of common coupling 21 (parameters which may be considered to represent the voltage, current and frequency in the utility grid 20).

A control system includes a wind-turbine controller 13 and a wind power plant controller 23. The wind-park or wind farm controller 13 controls operation of the individual wind turbine generator 1, e.g. selects the full-load or partial-load operation mode, depending on schedule as described throughout the present description.

Although the wind turbine generator 1 shown in Figure 1 is expected to have three blades 4, it should be noted that a wind turbine generator may have different number of blades. It is common to find wind turbine generators having two to four blades. The wind turbine generator 1 shown in Figure 1 is a Horizontal Axis Wind Turbine (HAWT) as the rotor 4 rotates about a horizontal axis. It should be noted that the rotor 4 may rotate about a vertical axis. Such a wind turbine generators having its rotor rotate about the vertical axis is known as a Vertical Axis Wind Turbine (VAWT). The embodiments described henceforth are not limited to HAWT having 3 blades. They may be implemented in both HAWT and VAWT, and having any number of blades 4 in the rotor 4.

As mentioned a wind farm is a common designation of a number of wind turbines located in a limited geographically area and in some way commonly connected to a utility grid. The wind farm may include a variety of number of WPS.

Figure 2 schematically illustrates steps of a method 100 for establishing a scheme for power production from a number of power generation sources. The method comprises a step 110 of providing a set of input parameters for basing a determined optimal production plan. This may be input by a user or operator operating a central monitoring system, e.g. at a central location controlling a number of wind farms or wind parks. The operator may not need the option to control an individual wind turbine in a specific wind park but defines over-all parameters relevant to the power generation sources that he/she controls.

The method comprises a step 120 of collecting information relating to power generation capabilities for each of the plurality of power generating sources. This may include a parks maximum power generation capabilities, information regarding current maintenance. The specific information may be pre-stored in a data storage device in communication with a server where the method is being executed. The information may be supplied from the individual power generation sources when available, so that the scheme may be adapted in case a wind turbine needs to be repaired or the like. Further, local wind conditions may be relevant to the current power generation capabilities and this may require the scheme to be updated or changed. Basing the optimal production scheme on price for energy and cost of production of energy also allows to establish a scheme where one or more wind turbines, e.g. an entire park, operate in conditions where one or more components are stressed or loaded to a degree where this shortens the lifetime of the components in the wind turbine, e.g. blades, gear or the like. In the overall picture it is thus not always the optimal solution to schedule production at a relatively low level to reduce wear and prolong component lifetime.

The method comprises a step 130 of receiving cost of production of energy from each power generating source. This may include information that a specific power generation causes wear to the wind turbines, which in turn may accelerate the need for maintenance, thereby increasing the cost of production. As price of electrical power varies over time, in some periods significantly, this may be used to be considered in view of the cost of production to establish an optimal production scheme.

The method comprises a step 140 of determining for each of the plurality of power generating sources an optimal production scheme based on price for energy and cost of production of energy. The individual schemes are determined in view of the overall requirements to production and cost as mentioned.

The steps 110 to 140 may be repeated as indicated by the punctured line 150 to establish a reoccurring control loop where the scheme is updated or modified a number of times, e.g. periodically or according to any other suitable schedule, or in response to events, such as changes in power prices, such as changes in power prices with certain limits, e.g. a change of more than a given percentage of the price at a given point in time. Similar options apply to prices for production of power.

Generally the present method and system provides automated control and optimization of power output for a portfolio of energy sources based on the input parameters from energy marked. The solution may be embodied as a computer based system that has communication to a plurality of power plants in an energy portfolio and an algorithm to optimize the revenue for the portfolio. The method may also minimize the environmental impact when producing energy.

The system receives the energy demands, maintenance plan for the power plants and the energy price as input parameters and provide the production level and production scheme for each power plant in the portfolio as output parameters. Based on the selected input criteria the system calculates the production set point and a production scheme for each power plant to ensure the necessary level of production to fulfil the requirements in the input parameters.

The system ensures that the set points are communicated to each power generation source which is responsible to maintain the production level as specified by the system. The frequency of production set point calculation can vary from power generation source to power generation source and may be defined by the user and the level of available data from each power generation source.

In Figure 3 a schematic view of an exemplary user interface is illustrated. Here a user may in an easy manner define which optimization parameters are to be used for generating a production scheme and set points for production. Here the user has chosen to: 'optimize revenue', 'minimize environmental impact', 'allow overrating', 'minimize load', 'include maintenance plan', 'Include Power forecast', 'auto schedule advisor', but not 'include power price' and 'auto active set points'.

The user has freedom to choose which parameters to set or not to set. Further, the user may define for which wind parks this system is to operate on, e.g. the user may control several wind farms, but choose to use this system on a sub-set of these. There may be left some autonomy to the individual power generation sources as the system may be used for overall production planning, but the system may be adapted to control each individual power producing unit in one or more of the power generation sources.

Although the present invention has been described in connection with the specified embodiments, it should not be construed as being in any way limited to the presented examples. The scope of the present invention is to be interpreted in the light of the accompanying claim set. In the context of the claims, the terms "comprising" or "comprises" do not exclude other possible elements or steps. Also, the mentioning of references such as "a" or "an" etc. should not be construed as excluding a plurality. The use of reference signs in the claims with respect to elements indicated in the figures shall also not be construed as limiting the scope of the invention. Furthermore, individual features mentioned in different claims, may possibly be advantageously combined, and the mentioning of these features in different claims does not exclude that a combination of features is not possible and advantageous.

Claims

1. A method for determining a production scheme for production of electrical power from a plurality of power generating sources each connected to a utility grid, said plurality of power generating sources each comprising a number of wind turbines, said method comprising the steps of:
- providing a set of input parameters for basing a determined optimal production plan,
- collecting information relating to power generation capabilities for each of said plurality of power generating sources,
- receiving cost of production of energy from each power generating source,
- receiving price for energy and amount of power required to be delivered to the utility grid,
- determining for each of the plurality of power generating sources an optimal production scheme based said input parameters, said information relating to power generation capabilities, on price for energy and amount of power required and cost of production of energy.

2. The method according to claim 1, further comprising:
- for each of the plurality of power generating sources recording the environmental impact of production of energy,
- using the environmental impact of production of energy in estimating for each of the plurality of power generating sources the optimal production scheme.

3. The method according to claim 1 or 2, further comprising using maintenance plan for the power generating sources when estimating the optimal production scheme.

4. The method according to any one of claims 1-3, wherein the remaining expected life time usages of different components of the power generating sources are calculated using life time usage models for the different components under different operational conditions.

5. The method according to claim 4, wherein the production costs per unit energy for a given power generating source is calculated as a sum of marginal costs for a number of components of the respective power generating source, each marginal cost being calculated as the product of a price of a component and a fraction of the lime time usage for the respective component calculated using the respective life time usage mode.

6. The method according to any one of claims 1-5, further comprising collecting information relating to meteorological conditions at the location of the power generating sources, and estimating for each the of power generating source the production costs per unit energy at different load levels of the respective power generating source taking into account the information on the present meteorological conditions

7. The method according to any one of claims 1-6, further comprising using a parameter relating to minimization of load on one or more of the power generating source when estimating the optimal production scheme.

8. The method according to any one of claims 1-7 further comprising controlling the power generation sources by deciding on a total amount of power to be delivered from the power generating sources and distributing the decided power production between individual power generating sources taking into account the estimated production cost per unit energy.

9 The method according to any one of claims 1-8, further comprising repeating the above steps in order to obtain a dynamic control of the power generating sources.

10. The method according to any one of claims 1-9, wherein the power generating sources are different wind turbine parks located at geographically remote locations.

11. The method according to any one of claims 1-10, wherein the frequency of determining production schemes is defined for each power generation source by a user.

12. The method according to any one of claims 2-11, wherein the environmental impact includes at least one of: CO2 emission, shadow control, noise control, icing control, lightning protection, typhoon and hurricane protection, and Bat protection.

13. A system for determining a production scheme for production of electrical power from a plurality of power generating sources each connected to a utility grid, said plurality of power generating sources each comprising a number of wind turbines, said system comprising:
- a set of input parameters for basing a determined optimal production plan,
- information relating to power generation capabilities for each of said plurality of power generating sources,
- cost of production of energy from each power generating source,
- price for energy and amount of power required to be delivered to the utility grid,
- a computation device configured to, for each of the plurality of power generating sources, calculate an optimal production scheme based on said input parameters, said information relating to power generation capabilities, on price for energy and amount of power required and cost of production of energy.

14. The system according to claim 13, wherein the system is configured to perform steps corresponding to any one of claims 2-12.

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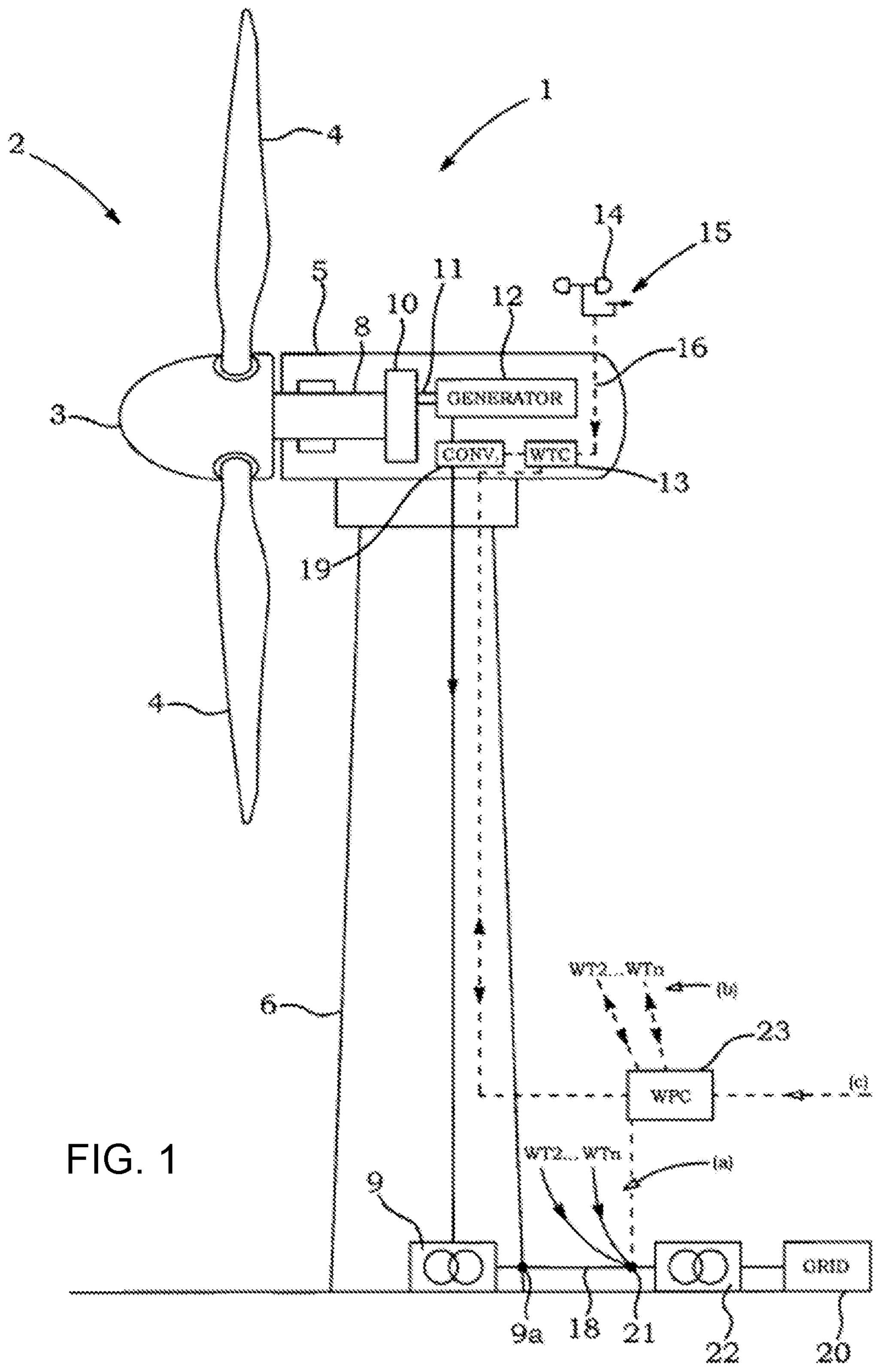
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16
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CONV.
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(b)
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(c)
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18
21
22
20

FIG. 1

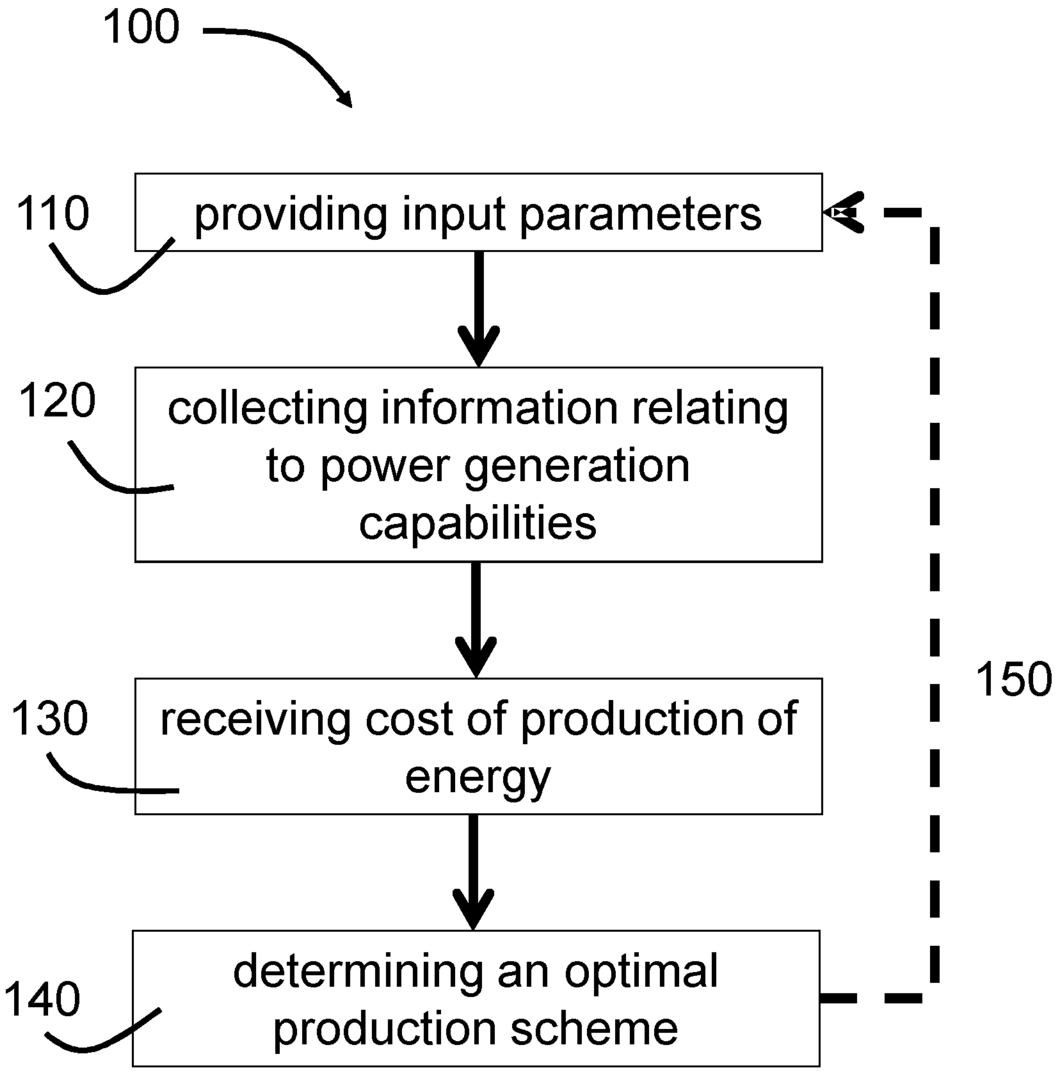
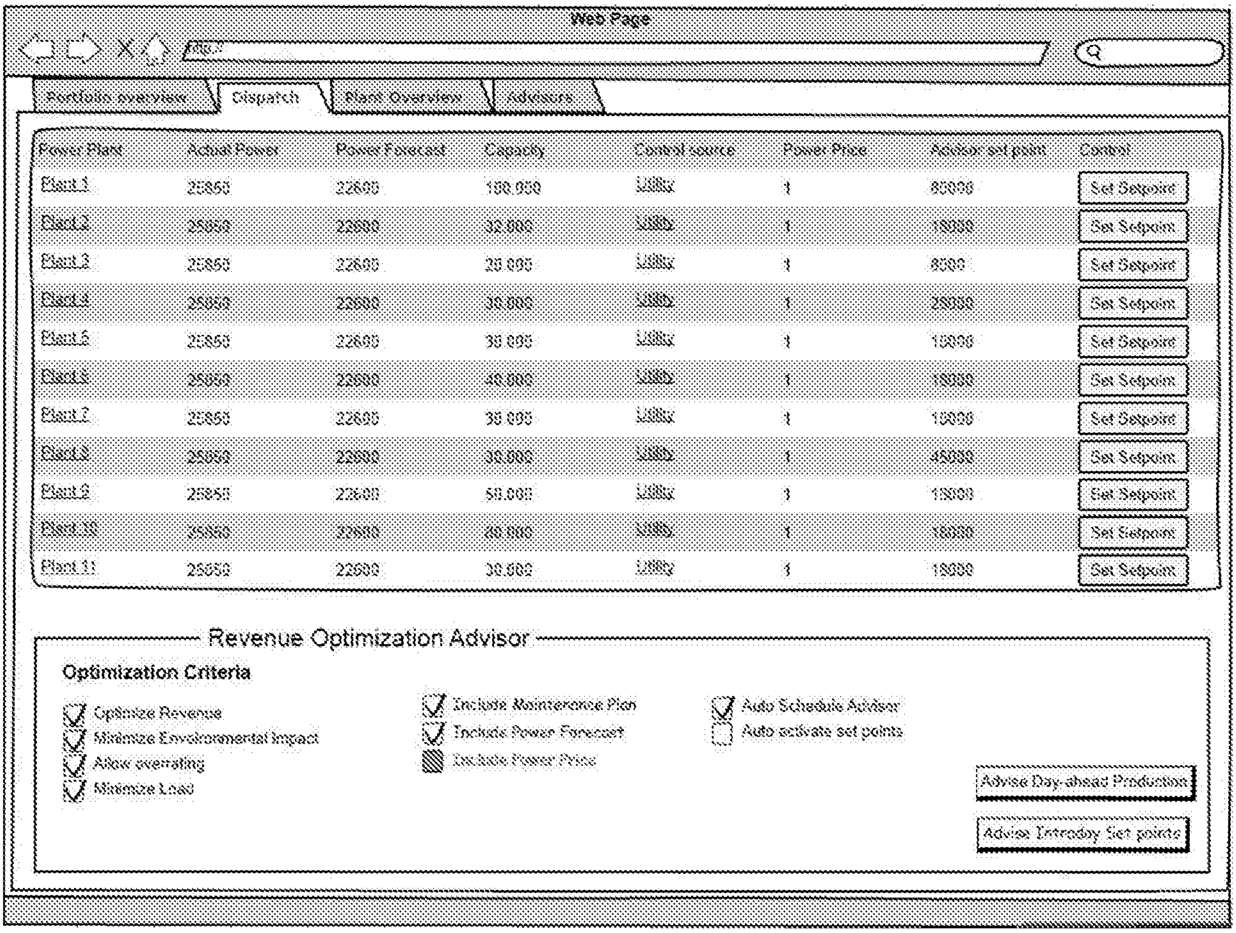

100
110
providing input parameters
120
collecting information relating to power generation capabilities
130
receiving cost of production of energy
140
determining an optimal production scheme
150

FIG. 2

3/3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Portfolio overview
Dispatch
Plant Overview
Advisors
Power Plant
Actual Power
Power Forecast
Capacity
Control source
Power Price
Advisor set point
Control
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Plant 2
Plant 3
Plant 4
Plant 5
Plant 6
Plant 7
Plant 8
Plant 9
Plant 10
Plant 11
Set Setpoint
Revenue Optimization Advisor
Optimization Criteria
Optimize Revenue
Minimize Environmental Impact
Allow overrating
Minimize Load
Include Maintenance Plan
Include Power Forecast
Include Power Price
Auto Schedule Advisor
Auto activate set points
Advise Day-ahead Production
Advise Intraday Set points

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2013/050158

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J3/00 G06Q50/06
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02J G06Q

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	The claimed subject-matter, with due regard to the description and drawings in accordance with Rule 33.3 PCT, relates to processes comprised in the list of subject-matter and activities for which no search is required under Rule 39 PCT. The information technology employed as an enabler for carrying out said processes is conventional. Its use for carrying out non-technical processes forms part of common general knowledge and it was widely available to everyone at the date of filing of the present application. No documentary evidence is therefore considered necessary. (See Official Journal EPO 11/2007, pages 592ff and 594ff) -----	

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
4 February 2014	17/02/2014

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