(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 998 525 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
23.03.2016 Bulletin 2016/12

(51) Int Cl.:
F01K 13/02 *(2006.01)*

(21) Application number: **15183136.9**

(22) Date of filing: **31.08.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

(30) Priority: **29.08.2014 NL 2013392**

(71) Applicant: **Kema Nederland B.V.**
6812 AR Arnhem (NL)

(72) Inventors:
- **De Boer, Wouter Willem**
6816 PS Arnhem (NL)
- **Duvoort, Martijn Robert**
3544 DH Utrecht (NL)

(74) Representative: **Jacobs, Bart et al**
Arnold & Siedsma
Bezuidenhoutseweg 57
2594 AC The Hague (NL)

(54) A METHOD FOR CONTROLLING ENERGY OUTPUT OF A POWER STATION, AN ENERGY GENERATION SYSTEM, AND POWER STATION COMPRISING THE SAME

(57) A method for controlling energy output of a power station, an energy generation system (1) and to a power station comprising the same comprise a database (4) comprising historic data is used to allow a comparison to be made between recently published data related to the performance in a control area of an electricity grid and the historic data. In this way, a day can be found in the database that corresponds best to the recently published data. Data for this day is used to forecast the behavior in the control area and the energy output of the power station is controlled in accordance with this forecast.

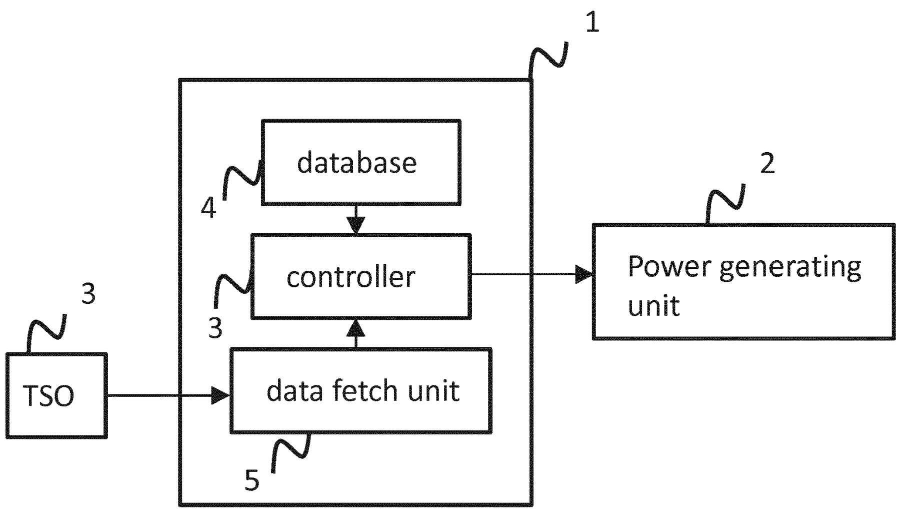

Fig. 1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention is related to a method for controlling energy output of a power station. The invention is further related to an energy generation system, and to a power station comprising the same.

[0002] An electricity grid comprises a plurality of power stations that each generate electricity and an electricity distribution network for distributing the generated electricity to consumers. Normally, different parties are responsible for different parts of the grid. An electricity transmission system operator (TSO) is responsible for the transmission system and system operation within their control area, whereas other parties are responsible for the individual power stations. A control area is a part of the electricity grid for which the TSO is responsible for the energy/power balance.

[0003] To guarantee a particular available power within the control area, balance responsible parties (BRPs) agree on the amount of energy to be delivered to or extracted from the electricity grid during a given amount of time. A BRP, e.g. an operator for a power station, may agree to deliver a certain energy at a certain price. Unfortunately, the actual consumption of electricity cannot be predicted with complete accuracy, resulting in a variable demand. On the other hand, with the introduction of renewable energy, a similar variation is introduced on the supply side. For instance, a wind farm cannot predict with complete accuracy that the wind farm will be able to produce a given power due to uncertainties in wind velocities and direction.

[0004] To cope with the uncertainty on the supply and demand side, a TSO agrees with the BRPs that a particular amount of capacity should be reserved to down regulate the power output of these parties in case too much power is delivered to the electricity grid or to up regulate in case too little power is delivered. This so called balancing capacity and the corresponding price are also agreed upon beforehand. Balancing capacity is most often offered by the traditional, fossil fueled, BRPs. Currently, renewable energy sources are not often used to deliver balancing capacity, or at least to a small extent.

[0005] In case a surplus of power exists in the electricity network, the TSO will start to instruct the BRPs to use their balancing capacity to down regulate their power output. Normally, a merit order exists which indicates which BRP offers what size of balancing capacity at what price. Moreover, a distinction can be made based on the type of regulation, e.g. down or up regulation.

[0006] Table 1 illustrates a table comprising an example of possible prices and power balancing capacity agreed upon between the BRPs and the TSO for down regulation only. Assuming that the energy demand during a given time period, e.g. 15 minutes, is 50MWh instead of the target of 25+25+20=70MWh, a down regulation of 20MWh is required during that time period. The TSO will first use the balancing capacity of BRP A as his regulation price is the highest. To this end, the TSO will send a control signal to BRP A to start deploying the balancing capacity. In response, BRP A will output 25-10=15MWh during the time period. For this production, BRP A will in total receive 25x50-10x40=850 euro. After using this balancing capacity, the surplus in the control area is still not resolved. Next, the balancing capacity of BRP B will be used. That party will subsequently output 25-7.5=17.5MWh at a price of 25x60-7.5x30=1275 euro. However, even after using this balancing capacity, a power surplus still exists. In the end, the TSO will use the balancing capacity of BRP C, which will subsequently output 20-2.5=17.5MWh at a price of 20x55-2.5x-40=1200 euro. Having a negative price for downward regulation, BRP C receives 40 euro per MWh balancing capacity from the TSO.

Table 1

BRP	Target energy during time period [MWh]	Price [euro per MWh]	Downward balancing capacity during time period [MWh]	Downward regulation price [euro per MWh]
A	25	50	10	40
B	25	60	7.5	30
C	20	55	5	-40

[0007] For settlement of imbalances and balancing actions, TSOs use a program time unit (PTU), also known as Imbalance Settlement Period, for instance 15 minutes. The actual prices for settlement are not available real-time. An after calculation is performed based on the PTU. At the same time, a control state is attributed to the control area for each past PTU. The control area, hereinafter also referred to as network, may have had a long position, in which a surplus existed in the network for the entire PTU, a short position, in which a shortage existed in the network for the entire PTU, a balanced state, wherein a balance existed in the network for the entire PTU, and a mixed position, wherein the network had both a long and short position in the PTU.

[0008] Although the final prices for regulation are not available real-time, TSOs do publish an indication for the regulation price quasi real-time, i.e. with some minutes delay. It does not account for any future energy demand or supply variations within the same PTU. In addition, the TSO may publish the current control state quasi real-time that may differ from the final control state attributed to a PTU, the amount of down and up regulation power used at the time of publication and/or a balance signal representing the net power surplus or shortage in the network. Typically, these parameters are published every minute or at least periodically and more than once during each PTU.

[0009] BRPs can use these parameters to control their energy position. This is referred to as passive control. In practice, a BRP may examine the published regulation price together with the control state and adjust its power production or consumption accordingly. For instance, if the network has a long position, a BRP may reduce its power production to improve profit and/or profit margin.

[0010] The introduction of renewable energy power stations that use sun light, water, or wind for generating energy introduces a large variation in power output on the supply side. Consequently, a large balancing capacity must be reserved and the occurrence of situations having a regulation price below a certain threshold will increase. These situations are very tempting for passive control approaches.

[0011] The demand for electricity may strongly fluctuate throughout the day. In the past, TSOs and BRPs were able to predict these fluctuations to a large extent. However, the introduction of renewable energy sources makes the fluctuations more unpredictable. BRPs may be expected to use passive control to react to these unpredictable fluctuations in energy demand.

[0012] An energy surplus and shortage may occur in a single PTU. In this case, the network has a so called mixed position. To prevent excessive regulation during a PTU in which the network has a mixed position, a TSO may have special arrangements, for instance that every BRP has to pay if the target output deviates from the actual power agreed upon beforehand. Hence, if a BRP participated in passive control, it will have to pay instead of receive money for the output power regulation. Other incentives exist that all aim to reduce speculative passive control during PTUs in which the network has a mixed position.

[0013] Unfortunately, whether the network has a mixed position during a given PTU or not can only be determined after the PTU. Moreover, as stated above, the introduction of renewable energy sources increases the unpredictability in the network. Consequently, more PTUs with mixed positions will occur and/or differences between a predicted demand/supply and actual demand/supply will rise.

[0014] An object of the present invention is to provide a solution in which output energy regulation is limited to only those situations in which regulation is desired, or at least to a large extent. This object is achieved with a method for controlling energy output of a power station as defined in claim 1.

[0015] According to the present invention, the method comprises providing a database comprising historic data for the control state and at least one of the balance signal and the down/up regulation power, wherein the historic data relates to a plurality of days, preferably to at least one year. The method further comprises obtaining at least one of the published balance signal and the published down/up regulation power for a first predetermined time interval prior to a forecasting time, and comparing the at least one of the published balance signal and the published down/up regulation power in the first predetermined time interval with the corresponding historic data to determine a day for which the historic data matches best to the obtained at least one of the published balance signal and the published down/up regulation power in the first predetermined time interval. Then, the historic data in a second predefined time interval after the forecasting time corresponding to the determined day is used to forecast the control state for the same second predefined time interval. A setting point for controlling the power output of the power station is calculated based on the published regulation price and the predicted control state.

[0016] According to the invention, a database is provided that comprises historic data for the control state and at least one of the balance signal and the down/up regulation power. These data normally correspond to previously published data. The database preferably holds data related to at least one year.

[0017] In case a prediction should be made for the second predetermined time interval, e.g. 11:00-11:15, a match should be found for historic data in the first predetermined time interval, e.g. 10:30-11:00. According to the invention, a day in the historic database will be found that has the highest similarity with respect to at least one of the balance signal and the down/up regulation power in the time interval 10:30-11:00. Once such a day is found, the historic data for a subsequent time interval, e.g. 11:00-11:15, is used for predicting the control state in that time same interval. Other parameters (e.g. at least one of the balance signal and the down/up regulation power) may be forecasted as well.

[0018] Because a prediction is now available, the system may refrain from down regulating its power output in case an attractive regulation price exists in combination with a long position of the network in situations wherein a change in control state is to be expected within the PTU. Because the published parameters suffer from a delay, a risk of counter regulating always exists. A change in the demand of power is only reflected in the published parameters with a given delay. In the mean time, passive control could dictate regulation. However, due to the delay, instead of balancing the electricity grid, more imbalance is potentially created. This problem is mitigated according to the invention by using predicted data. The applicant has found that by using predicted data a more adequate, i.e. beneficial for the control area, balancing action can be obtained than by using passive control based on published data only. This is based on the insight that most strong imbalance variations have a daily pattern and are therefore predictable.

[0019] The control state may be forecasted using the historic control state in the second predefined time interval after the forecasting time corresponding to the determined day. Alternatively, the control state may be forecasted by forecasting the balance signal and/or down/up regulation power based on the historic balance signal and/or down/up regulation power in the second predefined time interval after the forecasting time corresponding to the determined day, and by subsequently determining the forecasted control state based on the forecasted balance signal and/or down/up regulation power. A TSO uses an algorithm to determine the control state that is attributed to a given time period from the down/up regulation power and/or balance signal. This same algorithm can be applied to determine the forecasted control state. In addition, it is possible to forecast the balance signal and/or the down/up regulation power for a time interval for which published data is already partially available and to scale or shift the forecasted data to reduce a difference between the forecasted data and the published data in the time interval for which published data is available. For instance, a forecast can be made at 9:58 for a time interval 10:00-10:15, wherein published data is already available for 9:50-9:56. The forecasted data can now be scaled or shifted such that a difference between the last minute of the published data and first minute of the forecasted data is minimized. For instance, a constant value can be added to or subtracted from each of the forecasted data or each of the forecasted data is divided by or multiplied with a constant value.

[0020] As stated above, a day is normally divided into a plurality of preferably consecutive Program Time Units (PTU). A PTU has a length of typically 5, 10, 15, 30 or 60 minutes. At least the step of forecasting the control state is preferably performed during a current PTU for at least one PTU following the current PTU and/or for a remainder of the current PTU. More in particular, a single control state is forecasted for a PTU. The provisional control state is normally published with a higher resolution, for instance every minute. However, the TSO determines the final control state after the PTU has expired, normally with a delay of hours to days. The forecasted control state is preferably aimed to be forecasted such that it has the same value as the final PTU control state. This has the advantage that a mixed position of the network is forecasted such that down or up regulation can be stopped or prevented in those situations.

[0021] In view of above, it is preferred if the historic data for the control state comprised in the database is divided in PTUs, wherein the control state has a single value within a single PTU.

[0022] The invention is not limited to forecasting data for a next PTU only. It is also possible that the forecasting is performed in a current PTU for a remainder of the current PTU. This allows the control state to be predicted or updated in case a previous forecasting was made, using a mixture of published data and forecasted data. For instance, assume that a PTU starts at 08:00 and ends at 08:15. A forecast was made in the previous PTU, which indicated that the control state for the next (current) PTU corresponds to a long position of the network. The BRP is then inclined to down regulate its energy/power output for the current PTU. However, a forecasting performed at 08:04 for the current PTU may indicate that in fact a mixed position is to be expected. This would trigger the BRP to regulate its energy/power output to previously agreed values. Such forecasting could be based on published data for time instants 08:00-08:02, which were published at 08:02-08:04, respectively, and forecasted data for time instants 08:03-08:14. Here, it is assumed that data is published each minute with a delay of two minutes.

[0023] As stated above, the system operator usually publishes the parameters with a given delay. In this case it is preferred when the step of forecasting the control state for the at least one PTU following the current PTU and/or for the remainder of the current PTU is performed at least a first amount of time before the start of the PTU directly following the current PTU, wherein the first amount could correspond to the delay. For instance, parameters are published at 11:00, which is the start of a new PTU ending at 11:15, relate to a previous PTU. With a delay in data publication of 2 minutes, and taking into account that the forecasting should have been performed and completed before the start of the new PTU, the prediction for the new PTU performed in the current PTU will be based on historic data until 10:58 at the latest.

[0024] Controlling the power output of the power station may comprise down regulating the power output during the at least one PTU and/or during the remainder of the current PTU if during the at least one PTU and/or during the remainder of the current PTU a regulation price is published that is lower than a first threshold, and if the forecasted control state indicates a surplus of energy in the respective control area of the electricity grid during the entire at least one PTU and/or during the entire remainder of the current PTU. The first threshold preferably has a negative value. Using the present invention, a BRP may decide to down regulate thereby improving the balance in the control area. This allows even BRPs of renewable energy to participate in restoring or improving the balance in the control area. The first threshold value may be used for the regulation price. In this way, the power output will only be controlled if a price is detected that is below the first threshold value to ensure robustness.

[0025] The power station may operate in one or combinations of the following modes. In a first mode, the power station will regulate its power output to correspond with the agreed power output, regardless of the control state and any prediction thereof. In a second mode, the power station will decrease its power output when a regulation price below a certain threshold is detected and when the predicted control state indicates a power surplus in the control area. In a third mode, the power station will increase its power output when a regulation price above a certain threshold is detected and when the predicted control state indicates a power shortage in the control area. In a fourth mode, the power station will regulate its power output whenever possible to correspond with the agreed power output if the predicted control state indicates either or both a power surplus and shortage in the control area during the same PTU. In a fifth mode, the power station will regulate its power output whenever possible to correspond with the agreed power output if the predicted control state indicates both a power surplus and shortage in the control area during the same PTU or if the predicted control state indicates a power shortage in the control area. In the second and third modes, the power setting point can be predefined, e.g. a power setting point corresponding to a predefined percentage of the agreed power output such as 150 percent, 50 percent or 0 percent, or corresponding to the agreed power output reduced or increased with a predefined percentage of the most recently published or predicted balance signal. Switching between modes may be performed by an operator of the power station or the switching may occur automatically based on published or predicted data.

[0026] In addition, a probability can be attributed to the predicted control state, which indicates a likelihood that the predicted control state corresponds to the actual control state determined afterwards. The probability may for instance depend on the similarity between the published data and the historic data to which the published data is matched. The probability may influence the setting of the power setting point allowing a stronger regulation to take place when the probability is high.

[0027] In the third mode, power is up regulated when the control state indicates that a power shortage exists in the network. Assuming that a BRP has agreed to deliver 25MWh at 50 euro per MWh, and to offer 10MWh upward balancing capacity at an upward regulation price of 40 euro per MWh, a BRP will receive 25x50+10x40=1650 euro. Hence, when the regulation price is above a certain threshold, it will become attractive for the BRP to regulate its power output.

[0028] TSOs may publish separate data for up and down regulation of power. For instance, separate prices may exist for up and down regulation of power. The invention is not limited to down regulation per se as the inventive concept may equally be applied to up regulation of power.

[0029] The method may further comprise determining a current power output of the power station and determining a power output imbalance using a previously agreed amount of energy to be delivered by the power station of the BRP and the current power output. In this case, the setting point for controlling the power output of the power station is calculated based on the published regulation price, the predicted control state and the determined power imbalance. Furthermore, controlling the power output of the power station may comprise down regulating the power output during the at least one PTU following the current PTU and/or during the remainder of the current PTU if during the at least one PTU and/or during the remainder of the current PTU a down regulation price is published that is lower than a first threshold, if the forecasted control state indicates a surplus of energy in the respective control area of the electricity grid during the entire at least one PTU and/or during the entire remainder of the current PTU, and, preferably, if the determined power output imbalance is positive, i.e. the power station delivers more than agreed up beforehand. It may be advantageous to allow the controlling only to be performed during the at least one PTU following the current PTU and/or during the remainder of the current PTU when a price below the first threshold is published during that PTU at least a second amount of time after the start of said PTU, wherein the second amount of time preferably corresponds to the delay. In this manner it can be made possible that the regulation of power in a given PTU is based on regulation prices relevant to that PTU only.

[0030] Controlling may be performed only when a price below the first threshold is published prior to a third amount of time before the end of the at least one PTU following the current PTU and/or before the end of the current PTU to avoid controlling power output during very short periods of time. For instance, if power is controlled based on a price publication 1 minute prior to the end of a PTU, the actual power output adjustment may occur only during a very short period of time or during the next PTU. By limiting the time window in which power control can be triggered, it can be assured that control is not triggered for very short periods of time.

[0031] When the forecasted control state in said at least one PTU following the current PTU and/or in said remainder of the current PTU indicates a shortage of energy or a mixture of shortage and surplus of energy in said at least one PTU and/or said remainder of the current PTU, controlling the output power may comprise controlling the output power such that it corresponds a previously agreed amount of energy to be delivered by the power station during said at least one PTU and/or during said remainder of the current PTU.

[0032] Controlling the output power may comprise regulating the output power in dependence of the time interval between a point in time at which the published regulation price was below the first threshold in the at least one PTU and/or in the remainder of the current PTU for the first time and the end of that PTU. Alternatively or additionally, the method may further comprise using at least one of the balance signal and the down/up regulation power in the database in the second predefined time interval after the forecasting time corresponding to the determined day to forecast at least one of the balance signal and the down/up regulation power for the same second predefined time interval. In this case, a setting point for controlling the power output of the power station may be calculated based on the published regulation price, the predicted control state, and preferably the predicted and/or published at least one of the balance signal and the down/up regulation power. For instance, if a large imbalance is forecasted, the down regulation may be stronger than in case of a small imbalance. Instead of forecasted data, published data for at least one of the balance signal and the down/up regulation power may be used to determine the setting point.

[0033] The method described above may comprise comparing the historic data of the balance signal with published data, determining a difference between the historic data and the published data for each time instant at which the data was published, accumulating the determined difference for each of the time instants comprised in the first predetermined time interval, ranking the days in the database based on the accumulated difference, and selecting the highest ranked day for said forecasting. The ranking may comprise applying heuristic rules to promote the ranking of one or more days.

[0034] The difference may be determined using a weighing, wherein data corresponding to time instants closer to the forecasting time are given a different weight, such as a higher weight, than data corresponding to time instance more distant from the forecasting time.

[0035] Additionally or alternatively, the ranking may further include promoting the rank of days for which the control state indicated a surplus of power in the first predetermined time interval compared to days for which the control state did not indicate a surplus of power in the first predetermined time interval.

[0036] Additional or alternative heuristic rank promotions may be implemented. For instance, a pre-selection can be made of about 10-15 days which provide the best match. Should the last day of the database occur in this pre-selection, this day is dropped and the remaining days are used for further selection. Should the first day of the database occur in the remaining selection, and if the prediction is to be carried out for one of the first three PTUs of a day, the first day is dropped and the remaining days are used for further selection. This selection is normally based on which remaining day provides the best match. However, if in a current PTU, all the published balance signal values equal either a zero, positive or negative value, and if for one or more days among the remaining days the corresponding last two values in the first predetermined time interval are also all zero, positive or negative values respectively, those days will be used for further selection. A final selection can then be based on which day provides the best match.

[0037] According to a second aspect, the present invention provides an energy generation system for managing the power output of a power generating unit in a power station. The energy generation system comprises a controller provided with a processing unit that is configured to calculate a power setting point. The power generating unit is configured to generate electrical power based on the power setting point. According to the invention, the energy generation system further comprises a data fetching unit for retrieving a time series of at least one of a balance signal and a down/up regulation power for a first predetermined time interval prior to a forecasting time, wherein the balance signal and/or the down/up regulation power are published by an electricity transmission system operation in addition to a control state and a regulation price. The system further comprises a database comprising historic data for the control state and at least one of a balance signal and a down/up regulation power, wherein the historic data relates to a plurality of days, preferably to at least one year. The controller is configured to implement the method as described above for calculating the power setting point.

[0038] The energy generation system can be part of the power station and/or it can be implemented as a module in an existing energy generation system. Alternatively, the energy generation system can be a system remote from the power station. In this case, the energy generation system sends the calculated power setting point to an energy generation system of the power station.

[0039] The power station may be a wind farm, a solar plant, or a hydroelectric power plant.

[0040] According to a third aspect, the present invention provides power station comprising the energy generation system as defined above.

[0041] Next, the invention will be described in more detail referring to the figures, wherein:

Figure 1 illustrates an embodiment of a power station according to the invention;
Figure 2 illustrates an example of published data by a TSO;
Figure 3 illustrates an example of a database;
Figure 4 illustrates an example of a structure of the database in figure 3;
Figure 5 illustrates a time line for the power control in accordance with the present invention;
Figure 6 illustrates the combination of forecasted and published data to predict a control state of a PTU; and
Figure 7 illustrates an example flow graph in accordance with the present invention.

[0042] Figure 1 illustrates an embodiment of a power station according to the invention. It comprises an energy generation system 1 that is connected to a power generating unit 2. Energy generation system 1 receives data that is published by a TSO 3. Energy generation system 1 comprises a controller 3, a database 4, and a data fetch unit 5 for retrieving the published data. Controller 3 comprises a processing unit (not shown) to calculate a power setting point which is fed to power generating unit 2. The latter will then output power corresponding to the power setting point. Energy generation system 1 can be embodiment by a computer or computer system. Next, the operation of controller 3 will be described in more detail.

[0043] Figure 2 illustrates an example of published data by a TSO. It comprises data for two successive PTUs, each PTU having a duration of 15 minutes, wherein data for the second PTU is only partially indicated. The control state is expressed in a value, wherein "-1" indicates surplus of power, i.e. the network has a long position, and "1" a shortage of power, i.e. the network has a short position. In addition to "1" and "-1" other values may occur such as "0", indicating the network was in balance, and "2", indicating that network had a mixed position, i.e. both a surplus and shortage of energy existed at different times in the same PTU. The down regulation power (expressed in MW) and up regulation power (expressed in MW) correlate with the control state. The balance signal corresponds to the difference between the up regulation power and down regulation power. In fact, a control state is attributed to a given PTU based on the published data after that PTU has passed. Hence, a control state is determined ex post facto by the TSO. The preliminary regulation price (expressed in euro per MWh) is indicative for the costs involved in regulation of the output power. The final regulation price that will be used to calculate the prices for regulation are also determined ex post facto by the TSO. Typically, the balance signal, the down/up regulation power, the regulation price, and/or the control state are cumulative. This means that a value corresponding to the end of a PTU takes into account the behavior of the network in that PTU so far and will therefore more likely correspond to the final values. It may be stated that a value for the control state corresponding to a particular time instant relates to the final control state in the hypothetical situation that the PTU ends at that time instant.

[0044] Figure 3 illustrates an example of a database comprising historic data of the control state and balance signal. Contrary to the published data illustrated in figure 2, the control state in figure 3 remains constant during an entire PTU. In other words, the control state in the database corresponds to the control state which is determined by the TSO afterwards.

[0045] The database may comprise other fields in addition to the fields shown. For instance, the down regulation power, the up regulation power, the regulation price(s), may all be included in the database.

[0046] Figure 4 illustrates an example of a structure of the database after pre-processing in figure 3. The structure represents a single parameter only, e.g. the control state. Figure 4 indicates that the database comprises a matrix of the control state having 3x24x60 rows, wherein each row comprises the control state for 365 days at a given moment in time, for instance 06:30:00. It should be apparent, that a single column may be added to indicate the time and day number.

[0047] The structure in figure 4 can be modified to account for odd days and for changes between summer time and winter time. In the structure, the data in each column should correspond to consecutive moments in time where the control state and/or other parameters were published. The number of days in the matrix should be sufficiently large to allow a good match to be found and may therefore be much larger than 365 days.

[0048] As will be elucidated later, the matching process uses a matching window 6 to find patterns in the historic data that resemble currently observed patterns. For instance, if at 01:58:00 a matching process is started, the historic database is scanned with a matching window starting at 01:43:00 and ending at 01:58:00, assuming that the matching window is 15 minutes. A problem occurs when starting the matching process at 00:13:00 on the first day of the year, for this would require data from another year. This problem is solved in figure 4 by imposing that the day preceding the first day of the year corresponds to the last day of the year. Vice versa this applies when predicting from the last PTUs of the year.

[0049] Figure 5 illustrates a time line for the power control in accordance with the present invention, whereas figure 6 illustrates an example flow graph in accordance with the present invention.

[0050] At t=t1, corresponding to step S1, the matching process will start. More in particular, the matching process will start D1 minutes prior to the start of PTU n+1. D1 should be sufficiently large to allow the setting point to be implemented before the start of PTU n+1.

[0051] At t1, corresponding to S2, the balance signal data from the previous 30 minutes is compared to historic data corresponding to the same time interval. A matching window is constructed ranging from for instance t1 minus 30 minutes up to t1. The database will be scanned and for every day a difference will be computed. This difference may be weighed using weighting coefficients W_i. For instance, a difference for a given day can be computed as the sum of squared weighted differences between the historic data (H_i) and the current data (D_i) in the same time interval consisting of the sum of $(W_i(H_i-D_i))^2$ for the i elements in scanning window, with i=30 in this case. Here, weighting coefficients W_i corresponding to data relatively closer to t1 can be given a higher value.

[0052] After calculating the sum of squared weighted distances, a preliminary ranking results, indicating which day comes closest to the recently observed balance signal. Next, an optional adjustment of the ranking can be performed in which days in which a down regulation occurred, e.g. a control state of "-1" are given a higher ranking than days for which such regulation did not occur.

[0053] Once the best match has been found, the control state for that particular day for the time interval to be forecasted is used to predict the control state in step S3. This would correspond to the time for PTU n+1 in figure 5. Similarly, other parameters, such as the balance signal and/or the down/up regulation power can be predicted using corresponding data from the best match in step S4. For instance, assuming that PTU n+1 starts at 15:00, the control state data from the best match for the time points 15:00, 15:01..15:14 will be used. It is noted that this control state will display a single value, although the invention is not limited thereto. Instead of the control state assigned to a given PTU by the TSO afterwards, the published control state may equally be used in the database. It is further noted that parameters may be predicted for more than one next PTU.

[0054] As a next step, PTU n+1 will start. Once an amount of time, denoted by D2, has passed, it is detected whether during a detection window between t2 and t3 in step S5 a negative regulation price is detected in step S6. This detection is based on the published regulation price, which suffers from a delay of approximately 2 minutes. For this reason, D2 is usually made equal to the delay but may well be zero. On the other hand, D3, indicating the time interval between t3 and the start of PTU n+2, is related to the speed at which a new power setting point can be implemented and avoids changing set point for a very short time.

[0055] Figure 6 illustrates the combination of forecasted and published data to predict a control state of a PTU. Dots indicate the start of a PTU. Here, a forecast for PTU n+1 is made at time t4 in PTU n. Assume that this forecast indicates a control state "-1" for PTU n+1, which starts at t5. Consequently, a BRP may down regulate its energy/power output to restore the balance in the network. However, due to unforeseen circumstances, more power is generated than required in PTU n+1. This is reflected in the published data. More in particular, data related to time instants between t6 and t5 indicates a power shortage occurring or starting to occur in the network.

[0056] According to the invention, a forecasting can be made at any time. In this situation, a forecasting can be made at a time t6. At t6, published data for PTU n+1 is available for time instants from t5 up to t6 minus the publication delay. The remaining data for PTU n+1 can be forecasted based on historic data. For instance, the balance signal and/or down/up regulation power can be forecasted. Combined with the published data, a control state can be forecasted for PTU n+1 and a power regulation strategy can be chosen accordingly. As an example, the balance signal is used to forecast the control state. For PTU n+1, published data for the balance signal is combined with forecasted data. Subsequently, the control state is determined as if the combined data corresponded to the actual data. An algorithm similar to the algorithm used by the TSO to determine the control state may be used. It should be obvious that such forecasting may be performed every time that new data is published. Such approach is particularly useful for preventing energy regulation in PTUs which are later assigned to a mixed position. It even allows BRPs to compensate any initial regulation that was performed. For instance, a BRP may down regulate during the start of the PTU based on a forecasted control state of "-1". During this PTU, the forecast is adjusted to "2". In response to this forecast, the BRP may up regulate its power output such that the energy output during the PTU corresponds to the amount agreed beforehand. In other words, the BRP corrects down regulation with up regulation such that no net regulation has occurred in the PTU with the mixed position.

[0057] The present invention proposes the following power regulation strategies based on the detection of the regulation price during the detecting window. As a first strategy, only when a price is detected that is below a certain threshold, preferably a negative threshold, in step S6, and when a control state is predicted that corresponds to a surplus, as determined in step S7, the setting point for controlling the output power of the power station is lowered in step S8. The amount by which the setting point is lowered can be made dependent on the published or predicted balance signal and/or the published or predicted down regulation power and/or the time interval between the moment in time when a price below the threshold is detected first and the end of PTU. The process of detecting a regulation price below a threshold will continue until the detection window has passed. If a surplus is not detected in step S7 the process will stop and the process will repeat during a next cycle of matching.

[0058] As a second strategy, only when a price is detected that is below a certain threshold, and when a control state is predicted that corresponds to a surplus, and when the power station is delivering more output power than previously agreed upon, the setting point for controlling the output power of the power station is lowered. Similar to the first strategy, the amount by which the setting point is lowered can be made dependent on the power output agreed upon, the published or predicted balance signal and/or the published or predicted down regulation power and/or the time interval between the moment in time when a price below the threshold is detected first and the end of PTU.

[0059] If a price below a certain threshold is not detected, power regulation may not be performed as described above. Similarly, if the control state is not indicative of surplus, but indicates any one of balanced, shortage or a combination of shortage and surplus, power regulation may not performed as described above. In these situations, and in particular when the predicted control state corresponds to the combination of shortage and surplus, power regulation may comprises trying to reduce any power output imbalance between actual power output and the power output agreed upon.

[0060] It should be clear to the skilled person that the invention is not limited to the embodiments and examples shown above but that the scope of protection of the invention is determined by the appended claims.

Claims

1. A method for controlling energy output of a power station that delivers electrical power to a control area of an electricity grid that is managed by an electricity transmission system operator, said operator periodically publishing the following parameters associated with a performance in the control area during a predefined interval:

a balance signal associated with the net surplus or shortage of power in the control area and/or down/up regulation power representing the surplus or shortage of power during the interval;
a control state representing whether during the interval the control area encountered a surplus, a shortage, a surplus and a shortage, or if the control area was balanced;

a regulation price representing costs/revenues associated with adjusting the surplus or shortage of energy; wherein the method comprises:

providing a database comprising historic data for the control state and at least one of the balance signal and the down/up regulation power, wherein the historic data relates to a plurality of days, preferably to at least one year;
obtaining at least one of the published balance signal and the published down/up regulation power for a first predetermined time interval prior to a forecasting time;
comparing the at least one of the published balance signal and the published down/up regulation power in said first predetermined time interval with the corresponding historic data to determine a day for which the historic data matches best to the obtained at least one of the published balance signal and the published down/up regulation power in the first predetermined time interval;
using the historic data in a second predefined time interval after the forecasting time corresponding to the determined day to forecast the control state for the same second predefined time interval;
calculating a setting point for controlling the power output of the power station based on the published regulation price and the predicted control state; and
controlling the power output based on the calculated setting point.

2. The method according to claim 1, wherein the control state is forecasted using the historic control state in the second predefined time interval after the forecasting time corresponding to the determined day; or
wherein the control state is forecasted by forecasting the balance signal and/or down/up regulation power based on the historic balance signal and/or down/up regulation power in the second predefined time interval after the forecasting time corresponding to the determined day, and by subsequently determining the forecasted control state based on the forecasted balance signal and/or down/up regulation power.

3. The method according to claim 1 or 2, wherein a day is divided into a plurality of consecutive program time units PTUs, and wherein at least the step of forecasting the control state is performed during a current PTU for at least one PTU following the current PTU and/or for a remainder of the current PTU.

4. The method according to claim 3, wherein a single control state is forecasted for a PTU.

5. The method according to claim 3 or 4, wherein the control state comprised in the database has a single value within a single PTU.

6. The method according to any of the claims 3-5, wherein the operator publishes the parameters with a given delay, and wherein the step of forecasting the control state for the at least one PTU following the current PTU and/or for the remainder of the current PTU is performed at least a first amount of time before the start of the PTU directly following the current PTU.

7. The method according to any of the claims 3-6, wherein said controlling the power output of the power station comprises down regulating the energy output during said at least one PTU and/or during the remainder of the current PTU if during said at least one PTU and/or during said remainder of the current PTU a down regulation price is published that is lower than a first threshold, and if the forecasted control state indicates a surplus of energy in the respective control area of the electricity grid during the entire at least one PTU and/or during the entire remainder of the current PTU, wherein the first threshold preferably has a negative value.

8. The method according to any of the claims 3-7, the method further comprising:

determining a current power output of the power station;
determining a power output imbalance using a previously agreed amount of energy to be delivered by the power station and the current power output;
wherein the setting point for controlling the power output of the power station is calculated based on the published regulation price, the predicted control state and the determined power output imbalance;
wherein said controlling the power output of the power station comprises down regulating the energy output during said at least one PTU following the current PTU and/or during the remainder of the current PTU if during said at least one PTU and/or during said remainder of the current PTU a down regulation price is published which is lower than a first threshold.

9. The method according to claim 7 or 8, wherein said controlling is performed during the at least one PTU following the current PTU and/or during the remainder of the current PTU only when a price is published during that PTU which is below the first threshold at least a second amount of time after the start of said PTU, said second amount of time preferably corresponding to said delay;
wherein said controlling is preferably performed only when a price below the first threshold is published prior to a third amount of time before the end of the at least one PTU following the current PTU and/or before the end of the current PTU.

10. The method according to any of the claims 3-9, wherein, when the forecasted control state in said at least one PTU following the current PTU and/or in said remainder of the current PTU indicates a shortage of energy or a mixture of shortage and surplus of energy in said at least one PTU and/or in said remainder of the current PTU, said controlling the output power comprises controlling the output power such that it corresponds a previously agreed amount of energy to be delivered by the power station during said at least one PTU and/or during the remainder of the current PTU.

11. The method according to any of the claims 3-10, wherein said controlling the output power comprises regulating the output power in dependence of the time interval between a point in time at which the published regulation price was below the first threshold in the at least one PTU and/or in the remainder of the current PTU for the first time and the end of that PTU.

12. The method according to any of the claims 3-11, the method further comprising:

using at least one of the balance signal and the down/up regulation power in the database in the second predefined time interval after the forecasting time corresponding to the determined day to forecast at least one of the balance signal and the down/up regulation power for the same second predefined time interval;
wherein said calculating a setting point for controlling the power output of the power station is based on the published regulation price, the predicted control state, and preferably one of the predicted and/or published at least one of the balance signal and the down/up regulation power.

13. The method according to any of the previous claims, wherein said comparing the at least one of the published balance signal and the published down/up regulation power in said first predetermined time interval with the corresponding historic data, comprises:

comparing the historic data of the at least one of the balance signal and the down/up regulation power with published data;
determining a difference between the historic data and the published data for each time instant at which the data was published;
accumulating the determined difference for each of the time instants comprised in the first predetermined time interval;
ranking the days in the historic database on the accumulated difference, said ranking optionally comprising applying heuristic rules to promote the ranking of one or more days;
selecting the highest ranked day for the forecasting;
wherein the difference is preferably determined using a weighing and squaring, wherein data corresponding to time instants closer to the forecasting time are given a different weight than data corresponding to time instants more distant from the forecasting time;
the method preferably further including promoting the rank of days for which the control state indicated a surplus of power in the first predetermined time interval compared to days for which the control state did not indicate a surplus of power in the first predetermined time interval.

14. An energy generation system for managing the power output of a power generating unit in a power station, wherein the power generating unit is configured to generate electrical power based on a power setting point, the system comprising:

a controller provided with a processing unit that is configured to calculate the power setting point;
a data fetching unit for retrieving a time series of at least one of a balance signal and a down/up regulation power for a first predetermined time interval prior to a forecasting time, wherein the balance signal and/or the down/up regulation power are published by an electricity transmission system operation in addition to a control state and a regulation price;

a database comprising historic data for the control state and at least one of a balance signal and a down/up regulation power, wherein the historic data relates to a plurality of days, preferably to at least one year;
wherein the controller is configured to implement the method according to any of the previous claims for calculating the power setting point;
wherein the energy generation system is preferably part of the power station and/or wherein it is implemented as a module in an existing energy generation system of the power station, or wherein the energy generation system is preferably a system remote from the power station, wherein the energy generation system is configured to send the calculated power setting point to an energy generation system of the power station;
wherein the power station is preferably a wind farm, a solar plant, or a hydroelectric power plant.

15. A power station comprising the energy generation system according to claim 14.

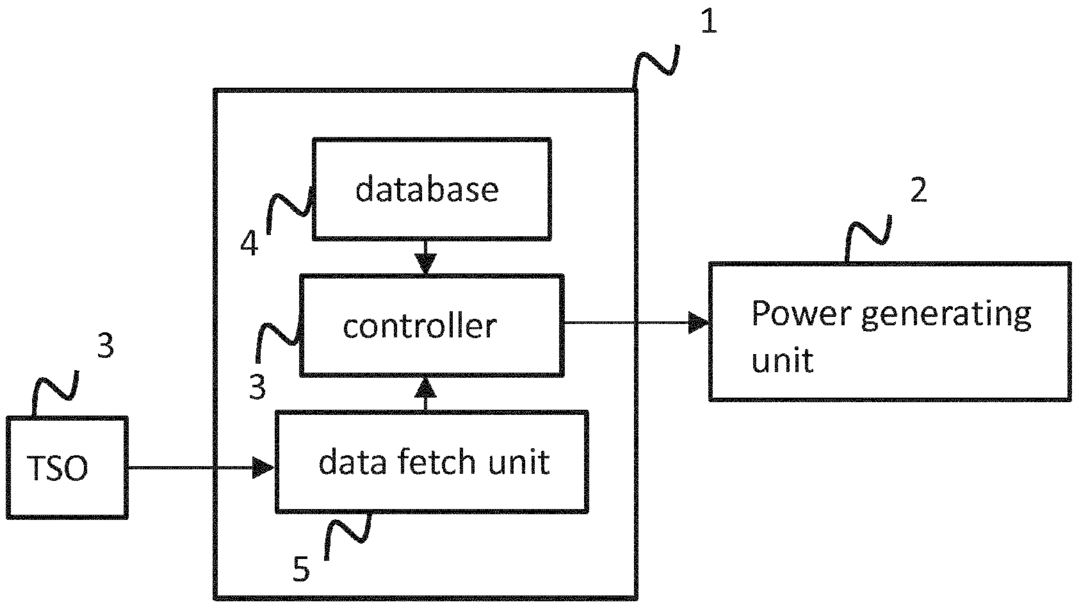
1
database
4
controller
3
2
Power generating unit
3
TSO
data fetch unit
5

Fig. 1

PTU x

PTU x+1

time	control state	down reg power	up reg power	balance signal	reg price
08:00:00	-1	10	0	10	-5
08:01:00	-1	8	0	8	-2
08:02:00	-1	6	0	6	0
08:03:00	-1	11	0	11	-5
08:04:00	-1	12	0	12	-6
08:05:00	-1	5	0	5	1
08:06:00	-1	6	0	6	0
08:07:00	-1	11	0	11	-5
08:08:00	-1	21	0	21	-9
08:09:00	-1	23	0	23	-10
08:10:00	-1	15	0	15	-6
08:11:00	-1	10	0	10	-5
08:12:00	-1	4	0	4	2
08:13:00	-1	3	0	3	4
08:14:00	-1	2	0	2	6
08:15:00	-1	1	0	1	2
08:16:00	1	0	5	-5	4
08:17:00	1	0	4	-4	5
08:18:00	1	0	9	-9	8

Fig. 2

PTU y

PTU y+1

6

time	control state	balance signal
10:58:00	-1	-10
10:59:00	-1	-5
11:00:00	-1	-6
11:01:00	-1	-5
11:02:00	-1	-2
11:03:00	-1	-1
11:04:00	-1	-4
11:05:00	-1	-10
11:06:00	-1	-8
11:07:00	-1	-4
11:08:00	-1	-20
11:09:00	-1	-16
11:10:00	-1	-14
11:11:00	-1	-12
11:12:00	-1	-11
11:13:00	-1	-6
11:14:00	1	1
11:15:00	1	4
11:16:00	1	5
11:17:00	1	8
11:18:00	1	5
11:19:00	1	4

Fig. 3

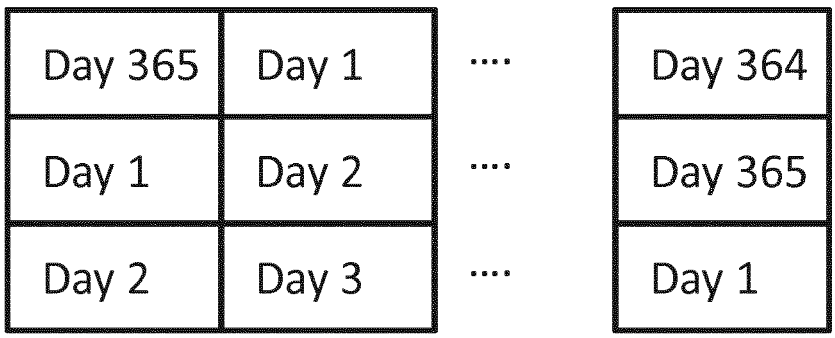

Fig. 4

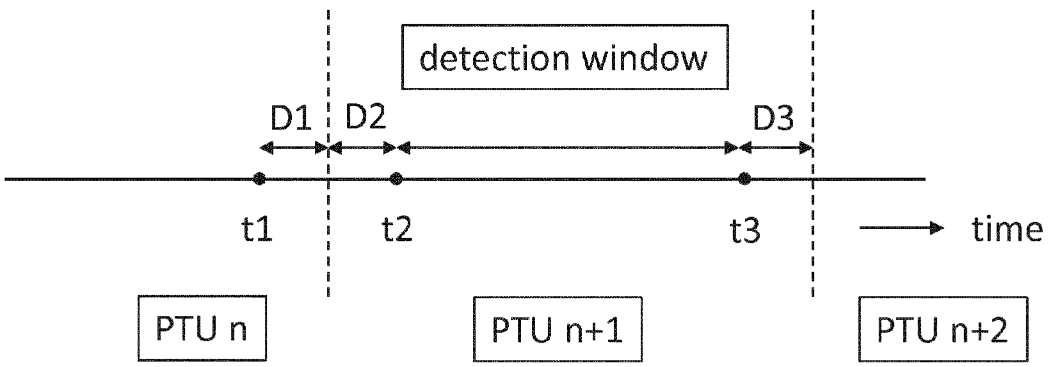

Fig. 5

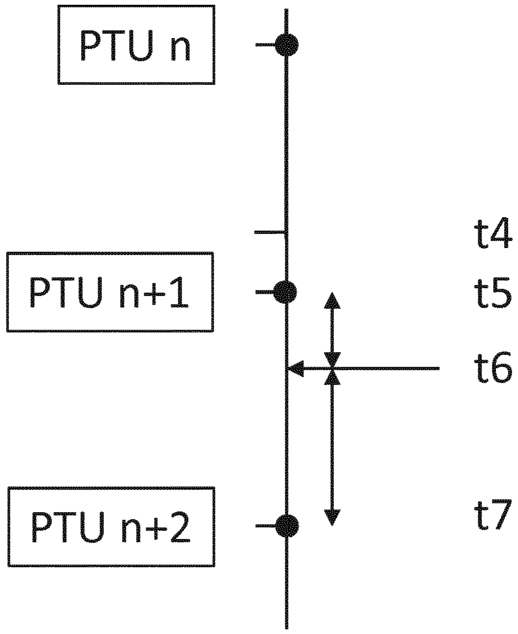

Fig. 6

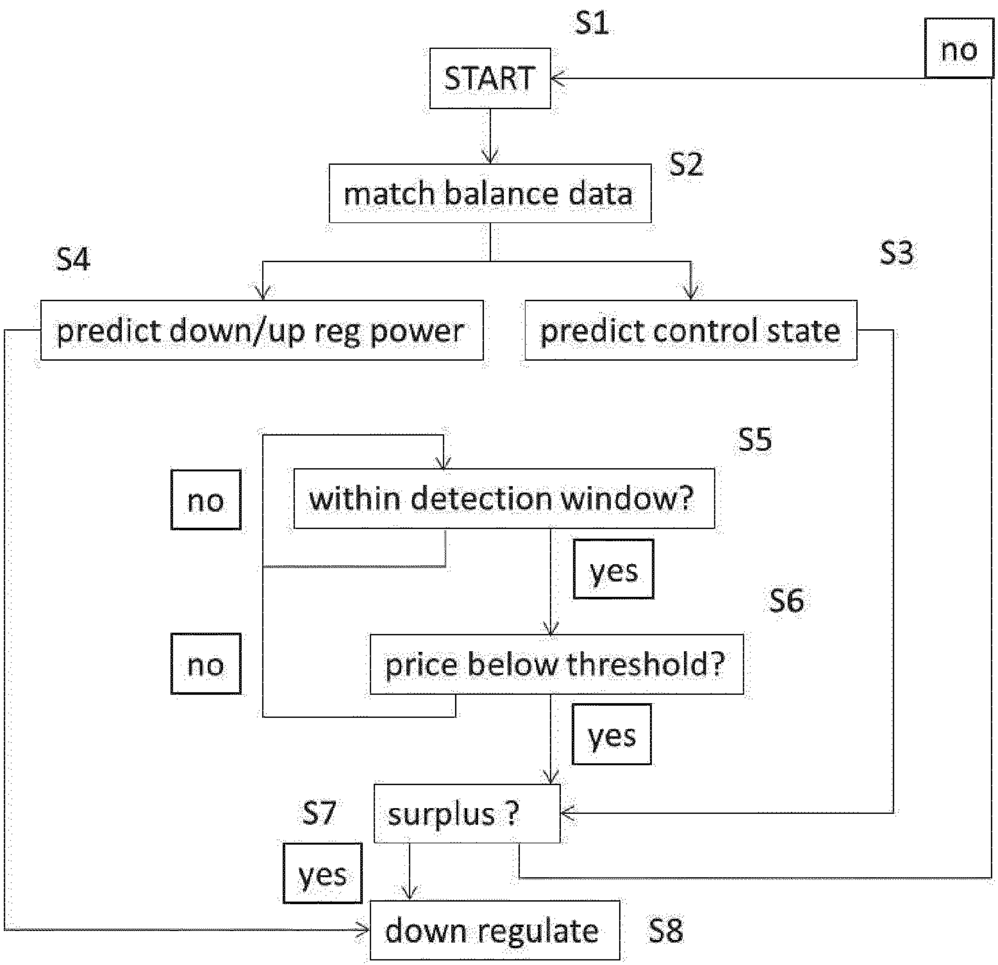
S1
START
no
match balance data
S2
S4
S3
predict down/up reg power
predict control state
S5
no
within detection window?
yes
S6
no
price below threshold?
yes
S7
surplus ?
yes
down regulate
S8

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 15 18 3136

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