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(54) Benævnelse: **Fremgangsmåde til drift af et fluktuerende energiproduktionsanlæg**

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Method for operating a fluctuating energy generation system

The invention relates to a method for operating a fluctuating energy generator system, in particular a wind turbine or a photovoltaic system.
More particularly the invention relates to a method of providing control power, more particularly primary control power, secondary control power or minute reserve power for an electrical energy generator and distribution network, to which a multitude of energy generators, for example wind turbines, photovoltaic systems etc. are connected. Such energy generation and distribution networks are stable when the energy supplied by the energy generators corresponds to the take-off energy of the consumers. If the actual energy production deviates from the energy use by a certain amount, in such a system control energy is needed in order to offset fluctuations in the network frequency. In Germany therefore the currently four transmission system operators are required to restore the network balance by obtaining control energy (control power).
As regards the reaction time, one distinguishes three types of control power:
Primary control power
Secondary control power
Minute reserve power
The control energy may be divided into positive and negative control energy. Positive control energy is always required when the energy use is greater than the energy generation. Positive control energy is provided by turning on or raising the power of generation systems or disconnecting or reducing the consumers of electrical energy.
Negative control energy is always required when the energy use is less than the energy generation. Negative control energy is provided by disconnecting or reducing the power of energy generation systems or raising the power of users of electrical energy.
On the generation side, control energy to this point has always been provided by controllable and continuously generating current generation systems. These include more particularly gas power plants, pump storage power plants, and biogas systems. These systems can make their power available using firmly predefined working points. Here the provision of negative control power is by means of reduction of the working point, thus power reduction by a defined value on a firmly defined working point over a specified period of time (negative control power band).
Provision of positive control power here occurs by increasing the working point, thus the power increase by a specified value at a firmly defined working point over a specified period of time (positive control power band).

It is increasingly the case that fluctuating energy generation systems are connected to the energy generation and distribution network. Fluctuating energy generation systems include wind power or photovoltaic systems, for example. In contrast to the previously named systems, these have no firm working point. Their energy generation depends on external influences (for example wind speed, air pressure, or solar radiation) and are therefore discontinuous (fluctuating). For this reason, to this point fluctuating energy generation systems have not been considered for the control energy market.

This is due in particular to the fact that as soon as a power change (for example a power reduction) occurs in the system, no reliable statement can be made regarding the maximally available system power (Pmax theoretical; power without an undertaken power change) can be made. It can therefore not be specified how the energy generation system may be controlled so that the required constant band of negative or positive control power is continuously provided.

In the document "Wind Turbines Connected to grids with Voltages above 100kV" (Internet Citation, December 3 2004 (2004-12-03), pages 1-34, XP002542209), control requirements for wind farms are described as they were predefined by the network operators Eltra and Elkraft for the Danish electricity market. A control function described therein called the "Delta Production Constraint" foresees a possible reduction in the power production of a wind farm by a predefined value as compared to the maximal electricity production possible under the existing conditions. Here the power reduction can be given in megawatts. By operation of the wind turbine system at reduced power, a control reserve can be provided for critical power requirements. As more particularly may be understood from figure 2 of attachment 2 (paragraph 2 "Delta Production Constraint"), control proceeds in such a way that the reduced power follows in the maximal possible power of the wind farm with a constant difference. The document thus describes a possible way to operate a wind energy system under the given wind conditions at a power which, in comparison with the maximally available power ($P_{possible}$), is reduced ($P_{set\ point}$) to the extent that provision of predefined positive control power is possible at any time.

Document DE 20 2010 016 207 U1 discloses a photovoltaic system whose maximally producible electric power can be specified even when there is a throttled working point of the photovoltaic system. Here a reference unit is provided which is operated at least at times at the maximal working point. By means of subsequent throttling of the working point of the reference unit to the throttled working point of the photovoltaic system, a ratio of the maximal possible power and the power at the throttled working point can be obtained for the reference unit. This ratio can be transferred to the photovoltaic system, so that for a known power of the photovoltaic system at a throttled working point, its maximal power in the maximal working point can be specified.

It is therefore the object of the invention to provide a method for operating a fluctuating energy generation system such that it may be effectively included in the provision with positive or negative control power.

This object is achieved in that first an actual power value of the energy generation system is obtained. The actual power value can hereby constitute for example the theoretical maximal power that an energy generation system can supply for given conditions. For a wind power system this means that the energy generation system under the given wind conditions and depending on its technical configuration could output a specified actual power value. It is also conceivable that the actual power value lies below the theoretical maximal power so as to achieve an operating mode for provision of positive control power. The actual power value is thus obtained in a first step. Then the actual power output of the energy generation system is controlled by a control circuit depending on a control value. The control value here is continuously obtained from the sum (positive control power) or difference (negative control power) of the actual power value and a predefined constant control power.

For example, figure 1 shows the approach for providing negative control power. In this illustration, in a power/time diagram the actual power value (Pmax theoretical) as well as the control value (Psoll neg) of the energy generation system are shown. This diagram further shows the negative control power. The actual power value in the present exemplary embodiment corresponds to the theoretical maximum available system power for the predefined environmental influences (for a wind power system, the wind speed and/or air pressure). As is clear from this diagram, the actual power value (Pmax theoretical) follows a discontinuous curve. If now the transmission system operator, starting from time t2 requests a negative control power of -5 MW in the exemplary embodiment, starting from time t1 the control circuit of the energy generation system begins with system derating. Here the system power is reduced. For wind power systems this can be achieved by varying the setting of the rotor blades. Here the adjustment is made such that the current power output (≙ Psoll neg) of the energy producing system that is ultimately supplied to the energy generation and distribution network deviates by a constant amount in comparison with the actual power value (Pmax theoretical), as the two corresponding curves in figure 1 illustrate. This difference then represents a constant negative control power. The constant curve progression is shown in figure 1 as a parallel line to the time axis (negative control power). The transmission system operators are thus supplied the requested negative control power of -5 MW over the time between t2 and t9. The figure 2 shows the approach in providing positive control power by means of a fluctuating system. As is clear from this illustration, the theoretical maximum available power value (Pmax theoretical) of the system is once again shown in the form of a discontinuous graph. The current power output (Psoll pos2) of the energy generation system is controlled depending on the control value which is obtained from the sum of the reduced actual power value Psoll pos1 and a predefined constant control power (positive control power). In the operating mode for providing positive control power, especially energy-efficient operation is achieved in that the energy generation system is operated on an actual power value (Psoll Pos 1) which is lower than the theoretical maximal available power value (Pmax theoretical) of the energy generation system. Thus when the energy generation system has to be available for provision of positive control powers, it is operated in a reduced power range in comparison with the theoretical maximum possible power value (Pmax theoretical) which is shown by the curve representing the actual power value (Psoll pos1). The positive control power obtained from the network operator is added to these actual power values (Psoll pos1), so that as shown in figure 2, a constant separation between the Psoll pos1 and Psoll pos2 results. Here the layout is selected such that the curve Psoll pos 2 maintains a safety margin from the curve which represents the maximum theoretical power value (Pmax theoretical). In this way, over the time t2 to t9, a positive constant control power of 5 MW is made available. The uprating or downrating of the energy generation system takes place within a time interval (uprating t1 to t2; downrating t9 to t10).

For wind power systems in particular, with the given wind fluctuations with established control electronics, a reliable system control can be simply achieved when it is provided that the difference value between the theoretically maximum power value (Pmax theoretical) and the actual power value (Psoll pos2) is kept constant or kept constant or constant within a fluctuation band of +/- 20%.

With a negative control energy retrieval a high energy efficiency is ensured in that the actual power value corresponds to the theoretical maximum power value (Pmax theor). Here it can be provided that the actual power value corresponds to the theoretical maximum power value (Pmax theor) with a fluctuation band of up to 20%.

According to a preferred embodiment of the invention, it can be provided that the actual power value (Pmax theoretical) is obtained from a characteristic value, obtained by s sensor system, of the energy driving the energy generation system. For wind power systems the sensor can for example have an air speed sensor and/or an air pressure sensor. In a photovoltaic system, for example, the sensor can be a solar radiation sensor, which obtains the solar radiation per surface, for example.

Various methods can be used to obtain the actual value (Pmax theoretical). For example, it is conceivable that the actual power value is obtained on a reference system. The determination of Pmax here is based theoretically on the assumption that an individual energy generation system or a part of a farm of fluctuating energy systems (for example a wind farm or a solar farm) will have behaviour (relative power change) similar to the other individual systems or the sum of all individual systems. With this method, the reference system is not regulated or controlled, so that it produces the same energy quantity independently of a control retrieval. The reference system serves in a control energy retrieval as a reference magnitude for the entire farm. Using the current power values of the reference system, Pmax theoretical is continuously recalculated. For this, the current power values of the reference system are extrapolated to the total power of the farm. The derived or calculated setpoint (necessary working point) for the other generating systems of the farm is finally transmitted to the system control. The reference system can be operated in direct spatial association to the energy generation system, so that optimal comparison values result.

If the above sensor systems for obtaining the actual power value are used, the actual power value can be computed as a calculation of the characteristic value obtained by the sensors and a system-specific set of characteristic curves. For example, with this method, for a wind power system which obtains the average wind speed at the hub height of the specific wind power system for a defined period of time. In photovoltaic systems for example the average solar radiation perpendicular to the module surface of the photovoltaic system can be obtained by the sensor system. From the measured characteristic value for the solar radiation, and with allowance for a system-specific set of characteristic curves, Pmax theoretical is then obtained.

According to the invention it is provided that the actual power value is measured as the average within a predefined time interval which preceded the current time. According to this for example the maximally available power can be an output signal of the control or regulating unit of the fluctuating energy generation system. The provided control power is deducted from or added to the power of the prior interval (negative control power or positive control power). This then provides the set point to be produced, which can be transmitted to the system.

In order to be able to ensure a constant control procedure, it is provided that the control value (Psoll neg, Psoll pos) of the control of the energy generation system in each case is predefined in successive periods of the same duration.

So as to be able to react to changing parameters of the driving energy of the energy generation system with adequate control speed, the time interval for obtaining the actual power value Pmax theoretical; Psoll pos1 must be as small as possible. Time intervals with a duration of ≤ 60 seconds are especially suitable. This corresponds to the requested temporal resolution (within provision of the control energy). The predefined time interval for obtaining the actual power value (Pmax theoretical; Psoll Pos 1) or the control value (Psoll neg; Psoll pos) therefore corresponds to a requested temporal resolution during provision of control energy.

With the control procedure according to the invention, fluctuating energy generation systems can be included in the provision of the control energy, wherein said energy producing systems do not require extensive technical refitting.

One variant according to the invention is based on the basic notion that the average power in a time interval tn differs only slightly from the average power in the time interval tn-1. The change in power between the two time intervals in the addition is even smaller when one considers a pool of several farms (for example wind farms, solar farms) (Pool effect). Thus basically a high level of control precision can be achieved.

Fremgangsmåde til drift af et fluktuerende energiproduktionsanlæg

Patentkrav

1. Fremgangsmåde til drift af et fluktuerende energiproduktionsanlæg, navnlig et vindkraftanlæg eller et fotovoltaisk anlæg, hvor der beregnes en faktisk effektværdi (Pmax teoretisk; Pindstillingsværdi Pos 1), hvor energiproduktionsanlægget drives på en faktisk effektværdi (Pindstillingsværdi Pos1), der er mindre end den teoretisk maksimale effektværdi (Pmax teoretisk) for energiproduktionsanlægget, og/eller at den faktiske effektværdi (Pmax teoretisk) svarer til den teoretisk maksimale effektværdi (Pmax teoretisk), kendetegnet ved, at den aktuelle afgivne effekt (Pindstillingsværdi neg, Pindstillingsværdi pos2) for energiproduktionsanlægget reguleres afhængigt af en indstillingsværdi, der beregnes kontinuerligt af summen af eller differencen mellem den faktiske effektværdi (Pmax teoretisk; Pindstillingsværdi pos1) og en fastsat konstant kontroleffekt (negativ kontroleffekt; positiv kontroleffekt), at indstillingsværdien fastsættes i energiproduktionsanlæggets styring i respektive på hinanden følgende perioder af uændret varighed, at den faktiske effekt (Pmax teoretisk; Pindstillingsværdi pos 1) blev målt som gennemsnitsværdi inden for et fastsat tidsinterval, der blev lagret forud for det aktuelle tidspunkt, og at det fastsatte tidsinterval til beregning af den faktiske effektværdi (Pmax teoretisk; Pindstillingsværdi pos 1) eller indstillingsværdien (Pindstillingsværdi neg; Pindstillingsværdi pos) svarer til en krævet tidsopløsning ved tilvejebringelse af kontrolenergi.
2. Fremgangsmåde ifølge krav 1, kendetegnet ved, at differensværdien mellem den teoretisk maksimale effektværdi (Pmax teoretisk) og den faktiske effekt (Pindstillingsværdi pos1) konstant reguleres enten konstant eller med en udsvingsmargen på +/- 20 %.
3. Fremgangsmåde ifølge et af kravene 1 eller 2, kendetegnet ved, at den faktiske effektværdi (Pindstillingsværdi pos1) svarer til den teoretisk maksimale effektværdi (Pmax teoretisk) med en udsvingsmargen på op til -20 %.
4. Fremgangsmåde ifølge et af kravene 1 til 3, kendetegnet ved, at den faktiske effektværdi (Pmax teoretisk, Pindstillingsværdi pos1) beregnes ud fra en sensorberegnet karakteristisk værdi for den energi, der driver energiproduktionsanlægget.
5. Fremgangsmåde ifølge krav 4, kendetegnet ved, at sensorudstyret beregner vindhastigheden og/eller lufttrykket.
6. Fremgangsmåde ifølge krav 4, kendetegnet ved, at sensorudstyret beregner solstrålingen.

7. Fremgangsmåde ifølge et af kravene 1 til 6, kendetegnet ved, at den faktiske effektværdi (Pmax teoretisk, Pindstillingsværdi pos1) beregnes på et referenceanlæg.
8. Fremgangsmåde ifølge krav 7, kendetegnet ved, at referenceanlægget drives i umiddelbar geografisk tilknytning til energiproduktionsanlægget.
9. Fremgangsmåde ifølge et af kravene 4 til 8, kendetegnet ved, at den faktiske effektværdi (Pmax teoretisk; Pindstillingsværdi pos1) beregnes som modregning af den sensorberegnede karakteristiske værdi og et anlægsspecifikt karakteristikfelt for energiproduktionsanlægget.
10. Fremgangsmåde ifølge et af kravene 1 til 9, kendetegnet ved, at det fastsatte tidsinterval til beregning af den faktiske effektværdi (Pmax teoretisk; Pindstillingsværdi Pos 1) eller indstillingsværdien (Pindstillingsværdi neg; Pindstillingsværdi pos) er ≤ 60 sekunder.

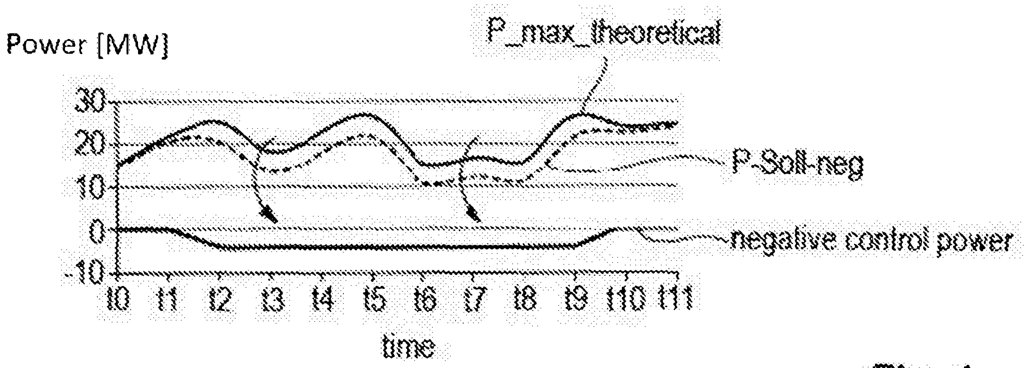
Power [MW]
P_max_theoretical
30
20
10
0
-10
P-Soll-neg
negative control power
t0 t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11
time

Fig. 1

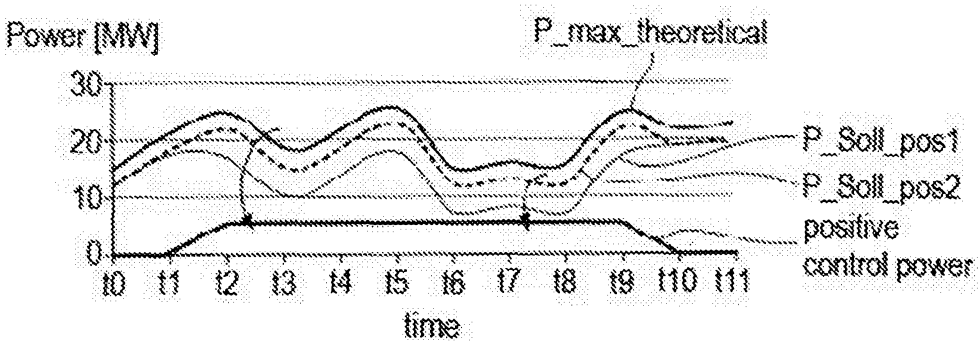
Power [MW]
P_max_theoretical
30
20
10
0
P_Soll_pos1
P_Soll_pos2
positive control power
t0 t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11
time

Fig. 2