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Methods for operating a separate power supply system

The present invention relates to a method for operating an electrical grid, in particular island grid, and the operation of at least one wind energy installation connected thereto and of a charging station connected to the grid. The present invention additionally relates to such a grid, a corresponding charging station and a corresponding wind energy installation, and a wind farm comprising such wind energy installations that is connected to the grid.

An electrical island grid should be understood to mean in this respect an electrical grid which is separate from a large grid such as the European interconnected grid, for example, and operates autonomously. Such an island grid is usually actually situated on islands or island groups in the geographical sense. However, it can also be an isolated, autonomously operating grid, particularly in a remote region.

The operation of island grids is known and is described e.g. in the two USA patent applications US 10/380,786 and US 10/506,944, which describe, in particular, providing as much energy as possible from wind energy installations for an island grid. If said wind energy installations do not supply enough energy, energy is supplemented from energy stores, and if even that does not suffice, a diesel generator can be supplementarily connected. Documents US 2011/273129 A1, WO 2014/071459 A1 and US 2012/323396 A1 disclose further examples for operating an electrical grid, wherein a rise limiting gradient and/or a decrease limiting gradient are taken into account when changing terms of a feed-in power.

What may be disadvantageous here is that primary consumption of the energy of a battery shortens, sometimes significantly shortens, the lifetime of said battery. Besides the costs that would then arise for exchanging a battery, it is also undesirable, precisely in the case of island grids, to have to carry out unnecessary maintenance or repair measures. That is inexpedient particularly if the operation of the island grid is thereby jeopardized at times.

Strictly demand-dependent operation of a diesel generator can also constitute inexpedient loading for the latter which in the long run can also shorten its expected life or maintenance cycles. An additional factor is that diesel generators frequently operate not only with particularly little wear but also particularly economically with a specific rotational speed. In other words, it is advantageous for the diesel generator, too, if the properties thereof are concomitantly taken into account during the operation of an island grid.

The present invention is therefore based on the object of addressing at least one of the problems mentioned above. In particular, the intention is to propose a solution with which the battery and the diesel generator in the island grid are operated with the greatest

possible care. At the very least, the intention is to propose an alternative solution to previous solutions.

According to the invention, therefore, a method according to Claim 1 is proposed, namely a method for operating an electrical charging station at an electrical grid, in particular an island grid, comprising, alongside electrical loads, at least one regenerative generator, in particular a wind energy installation or a wind farm, at least one generator operated by fossil fuels, in particular diesel generator, and at least the electrical charging station for storing and re-emitting electrical power, comprising the following steps:

- 10 - generating electrical power by means of the at least one wind energy installation and feeding the electrical power into the island grid,
- storing electrical power not consumed by the loads in the charging station,
- feeding in electrical power by means of the charging station if the loads consume more power than is fed into the grid jointly by the at least one regenerative generator and the at least one conventional generator,

wherein

- in a first configuration of the grid, a feed-in power fed into the grid is a sum of
 - the power of the at least one regenerative energy generator and
 - the power of the charging station and optionally in addition
- 20 - the power of the at least one further generator assigned to the charging station,

wherein the charging station is controlled in such a way that the feed-in power is limited in terms of its change over time,

wherein the power to be emitted or taken up by the charging station is altered by a compensation value depending on a state of charge in order to approximate the present state of charge to a predefined target state of charge,

- 25 wherein for limiting the change over time of the feed-in power, two limiting gradients are predefined, namely

- a rise limiting gradient, which determines with what change per time the feed-in power is intended maximally to increase, and
- 30 - a decrease limiting gradient, which determines with what change per time the feed-in power is intended maximally to decrease,

and wherein the charging station is controlled in such a way

- that the change of the feed-in power is guided within a positive and negative limit or within the rise limiting gradient and the decrease limiting gradient and that
- 35 for the case of the first configuration

- the change of the feed-in power is positive if the charging station has a state of charge that is above a predefined target state of charge, or
- the change of the feed-in power is negative if the charging station has a state of charge that is below a predefined target state of charge.

5 In this respect, the charging station is a system comprising one or a plurality of batteries that can be charged and discharged. The charging and discharging thus take place via the connection to the electrical island grid. The battery can therefore be charged in the case of a power surplus in the grid and discharged in the opposite case, in order thereby to feed power into the grid. In this case, discharging also describes a process in which the
10 battery is discharged only partly and, if appropriate, also only to the extent of a small portion. The electrical island grid is referred to here for simplification simply as grid. Such island grids are also operated as AC voltage grids and the charging station is correspondingly also prepared to feed an electrical AC current into the grid. The invention is provided particularly for an island grid, but in principle can also be employed in a different electrical
15 supply grid.

By means of the at least one regenerative generator, in particular of a wind energy installation or of a wind farm, electrical power is generated from regenerative energy sources and fed into the island grid, which is mentioned here in a manner representative of other grids as well. In this case, the generation of electrical power denotes for simplification the
20 conversion of mechanical or other power, e.g. solar energy, into electrical power. Correspondingly, here mechanical or other energy is converted into electrical energy. When electrical power is stored, instantaneous power is drawn from the grid by the charging station and is stored in the charging station, in particular in batteries, such that energy is stored as a result.

25 For feeding regenerative energy into the island grid, at least one wind farm comprising a plurality of wind energy installations is preferably provided here. As an exception, if the island grid is correspondingly small or the wind energy installation is correspondingly large, e.g. the use of just a single wind energy installation could also be sufficient.

Furthermore, a diesel generator is present, which here is also representative of other
30 possible generators that are operated by fossil fuels. These might be e.g. a generator operated with oil or gas. Any subsequent explanations, unless expressly explained oth-

erwise, which are made concerning a diesel generator also apply in principle to other possible generators that are operated or driven by fossil fuels.

It is an aim of the invention, then, to operate the charging station and thus the batteries present there with the greatest possible care or at least with more care than heretofore and in this context to carry out feeding into the grid as continuously as possible. For this purpose, especially the state of charge of the relevant batteries should be taken into account. In principle, it is inexpedient if such batteries are completely discharged, that is to say that especially a so-called deep discharge should be avoided. Complete charging of a battery to 100 per cent can also be inexpedient. An additional factor is that extreme states of charge, that is to say almost complete charging or almost complete discharging, restrict the handleability of the charging station. By way of example, an almost completely discharged charging station cannot provide power for regulating the feeding-in.

The invention now proposes, for the charging or discharging of the charging station, that is to say ultimately the battery or a plurality of batteries of the charging station, predefining maximum gradients, namely limiting gradients, which can also be referred to illustratively as maximum edges.

Therefore, an edge is predefined with which the power fed into the grid by the charging station is intended to maximally increase. That is also referred to here as a rise limiting gradient. In addition, a value is predefined with which that power which is drawn from the grid by the charging station and with which the batteries are then charged is intended maximally to increase. In other words, therefore, the dynamic range of the change is predefined here. Surprisingly, this has now also made it possible to influence the absolute charging level of the charging station or of the batteries thereof, which is also referred to here as the state of charge. Appropriate selection of these two maximum values makes it possible to achieve for a longer period of time a situation in which the charging level tends rather to vary upwards or tends rather to vary downwards, or to a mean value. The charging level can thereby be controlled to an upper limit, to a lower limit or to a different range.

Such upper and lower limits can be predefined in order to prevent complete full charging of the battery or complete discharging of the battery. If the charging level tends toward the lower limit, for example, what can be achieved by a decrease of the gradient for the feeding-in of electrical power by means of the charging station is that the charging level

no longer tends toward said lower limit or tends toward the latter to a lesser extent. That can therefore be achieved by a flattening of the maximum edge for feeding electrical power into the grid by means of the charging station.

It is thereby possible to regulate the charging station in such a way that the state of charge remains between these two predefined limit values, without the state of charge being evaluated directly for control purposes. Of course, it is also possible to provide a safety interrogation that prevents the lower charging level limit value from being under-shot or the upper charging level limit value from being exceeded. However, this should be an exceptional emergency measure and the constant regulation can rather dispense therewith and guide the charging level within the desired limits during normal operation of the island grid, without in this case directly monitoring these limits each time.

In this case, the proposed method can be used in principle for two configurations. In the case of the first configuration, the feed-in power is composed of the power of the at least one regenerative generator and the power of the charging station. These regenerative generators and the charging station are combined in this respect. By way of example, the charging station can be part of a wind farm comprising a plurality of wind energy installations. If the wind power, to stay with this example, fluctuates to an excessively great extent, the charging station can take corresponding countermeasures. The feed-in power that is fed in can be constituted from the power of said wind energy installations and the charging station. Therefore, if the wind power falls to a great extent, the sum of the feed-in power can comply with the desired predefined limit of the change by means of a corresponding rise in the emitted power of the charging station.

As a result, this combination of the regenerative generators and the charging station then jointly feeds a power limited in terms of its change into the grid. In this case, especially the grid perceives this combined feed-in power as exhibiting little fluctuation and accordingly need not compensate for an excessively great fluctuation.

Such a combination of regenerative generator and the charging station, that is to say e.g. wind farm with charging station, can also be supplemented by a conventional or other further generator. Such a generator would then be assigned to said charging station. That means, in particular, that the power of the corresponding regenerative energy generators, the power of the charging station and the power of said additional generator feed into the grid jointly via a common grid connection point.

In another configuration, the power fed into the grid by at least one conventional generator is regarded as feed-in power and its changes are kept small. This feed-in power of the at least one conventional generator is taken into consideration in the case of this configuration. The conventional generator can run permanently stably and uniformly, in principle.

5 Fluctuations in its feed-in power occur, however, if it, e.g. as a diesel generator or gas-fired power plant, counteracts fluctuations in the grid. The consideration of an island grid is taken as a basis especially here, although this is not restrictive here either. If e.g. the loads of the grid jointly tap off more power than a moment ago, the conventional generator takes countermeasures and increases its feed-in power in order to compensate for
10 this increased consumption.

The charging station is then used for this case, said charging station feeding so much power into the grid that it compensates for at least a portion of these power fluctuations in the grid. As a result, the at least one conventional generator can then be operated with little change.

15 As a result, especially said at least one conventional generator is subjected to less loading. In this case, such a conventional generator is also representative of such generator stations which comprise a plurality of such generators. A great rise in the power to be fed in, that is to say in the feed-in power, regularly has the effect that a further generator is supplementarily connected in such a generator station. In the case of a corresponding fall
20 in the power to be emitted, at least one generator is correspondingly disconnected. Especially such excessively frequent supplementary connection and disconnection of conventional generators is avoided particularly for this second configuration.

At all events, however, the load-relieving action by the charging station is carried out in such a way that the feed-in power is limited in terms of its change over time, that is to say
25 does not rise to an excessively great extent and does not fall to an excessively great extent either.

Preferably, for limiting said change over time of the feed-in power, at least one limiting gradient is predefined. The latter can be a rise limiting gradient, which determines with what change per time the feed-in power is intended maximally to increase. As second
30 limiting gradient, a decrease limiting gradient is proposed, which determines with what change per time the feed-in power is intended maximally to decrease. Depending on the

application, it is also envisaged that only one of these two limiting gradients is predefined, but it is preferred for both of said limiting gradients to be predefined.

As a result, the limiting of the power change can be controlled and, at the same time, the selection of these limiting gradients also affords the possibility of influencing this contribution providing support by the charging station. In particular, the selection of the limiting gradients can influence the profile of the state of charge of the charging station.

Preferably, the rise limiting gradient and the decrease limiting gradient differ from one another. It is thereby also possible, inter alia, to influence the mean state of charge of the charging station that is established over the course of time. In this context, over the course of time denotes especially the time segment of a day.

According to the invention, the charging station is controlled in such a way that the change of the feed-in power is guided within the rise limiting gradient and the decrease limiting gradient and that the change of the feed-in power is positive if the charging station has a state of charge that is above a predefined target state of charge, or that the change of the feed-in power is negative if the charging station has a state of charge that is below a predefined target state of charge. The decrease limiting gradient is a negative value here, of course, in this respect. Illustratively, therefore, the rise limiting gradient predefines a rising edge and the decrease limiting gradient predefines a falling edge as limit. The change of the feed-in power is thus kept within a positive and negative limit.

While the feed-in power is kept or guided within these two limits, the charging station still has latitude in the concrete guidance. It is proposed here, then, that it utilizes this latitude in such a way that the change of the feed-in power is rather positive if the charging station is charged well, to put it simply. In this situation, the charging station has available a large amount of stored energy and as a result can tend to feed in somewhat more power and thereby reduce its state of charge in addition in the direction of the target state of charge.

Otherwise, if the state of charge is comparatively low, the charging station can utilize its latitude in such a way that it tends rather to feed in less power, which, of course, also includes tending rather to take up more power from the grid and store it. As a result, the state of charge is guided in the direction toward the target state of charge.

It should be taken into consideration that it is nevertheless possible that, in the case of a particularly great fall in power that has to be counteracted by the charging station, power is fed into the grid by the charging station even though the state of charge is comparatively low, but is at least below the predefined target state of charge, since complying with the maximum changes is of primary importance.

The underlying insight, however, is that over relatively long operation, that is to say in particular over a day, it is possible to influence the development of the state of charge of the charging station substantially toward the predefined target state of charge. On average statistically, said target state of charge, that is to say e.g. 50% of full charge, could always be achieved in principle. However, the fluctuations that occur continuously precisely in the case of wind energy installations may prove to be such that the state of charge nevertheless does not tend toward the target state of charge, but rather toward a maximum or minimum state of charge. As one possibility for counteracting that, it is proposed to alter the limiting gradients or at least one of the limiting gradients, that is to say the rise limiting gradient or the decrease limiting gradient.

Preferably, at least one of the limiting gradients is set adaptively. The limiting gradient or the limiting gradients can then in other words be altered during operation e.g. depending on the state of charge. Therefore, if e.g. the state of charge is generally very high, namely above the target state of charge, then the rise limiting gradient could be increased or the decrease limiting gradient could be decreased in order that the charging station tends to feed in more stabilizing power compared with the amount of stabilizing power it draws from the grid and stores, to name just one example.

Preferably, the limiting gradient or the limiting gradients is/are set depending on a mean state of charge of the charging station. Therefore, e.g. with the aid of a filter or an integration, over a relatively long period of time such as e.g. a few hours or a day, the development of the state of charge is observed and averaged in order to obtain a mean state of charge. Depending thereon, the limiting gradients, or at least one of them, can then be set.

To a similar extent, a maximum state of charge that is intended not to be exceeded can preferably also be predefined. The same similarly applies to the predefinition of a predetermined minimum state of charge. The setting can preferably be carried out in such a

way that the mean state of charge tends to assume a predetermined charging setpoint value, which can also be referred to as target state of charge.

In this case, the concrete setting of the limiting gradients can be tested beforehand e.g. in a simulation. Additionally or alternatively, it is also envisaged to change the limit values
5 somewhat gradually, e.g. day by day, and to observe the development of the state of charge of the charging station and then to select a corresponding limiting gradient or corresponding limiting gradients.

In accordance with one embodiment, it is proposed that at least one of the limiting gradients is calculated from a predefined basis limiting gradient multiplied by at least one
10 weighting factor. Here, especially as basis limiting gradient, a limiting gradient, that is to say rise limiting gradient or decrease limiting gradient, can be predefined as limit that must absolutely be complied with. A weighting factor, or the product of a plurality of weighting factors together, can then be selected in such a way that it maximally assumes the value 1. Consequently, the basis limiting gradient would not be exceeded, or not be
15 undershot in the case of a negative value for the decrease limiting gradient. In both cases, therefore, the absolute value would no longer be increased, but rather at most decreased by a factor that is less than 1.

Preferably, at least one of the weighting factors is dependent on the state of charge of the charging station. Additionally or alternatively, at least one of the weighting factors can
20 vary in the range of 0 to 1. In that case, therefore, it cannot increase the basis limiting gradient in terms of absolute value.

Preferably, a further weighting factor can be selected in such a way that it has at least the value 1, in particular is in the range of 1 to 10. Preferably, two weighting factors can be combined, of which one is in the range of 0 to 1 and the other is in the range above 1, in
25 particular in the range of 1 to 10. If these are jointly multiplied by the basis limiting gradient and if said basis limiting gradient is intended not to rise, the selection of these two weighting factors may prove to be such that their product does not become greater than 1.

One embodiment proposes that

- 30 - the charging station emits electrical power which is fed into the grid together with electrical power of the at least one regenerative energy generator if the electrical

power of the regenerative energy generator decreases with a gradient which, in terms of absolute value, is greater than the predefined decrease limiting gradient, or that

- the charging station takes up electrical power in order to decrease the electrical power of the at least one regenerative energy generator that is fed into the grid if the electrical power of the regenerative energy generator increases with a gradient which, in terms of absolute value, is greater than the predefined rise limiting gradient.

Accordingly, the charging station emits electrical power if the electrical power of the regenerative generator, in particular of the wind energy installation or of the wind farm, decreases to an excessively great extent or too rapidly. The charging station can thereby take countermeasures. Conversely, it is proposed here that the charging station takes up electrical power if the power of the regenerative energy generator increases to an excessively great extent or too rapidly. In both cases, the feed-in power fed in overall is kept within the desired limits as a result.

Preferably, it is additionally proposed that a time difference between a present second point in time and an earlier first point in time is taken into account for controlling the charging station, and that at the earlier first point in time, as earlier feed-in gradient, account is taken of a gradient of the power which was fed into the grid at the first point in time jointly by the at least one regenerative energy generator and the charging station and, if appropriate, at least one further generator.

For controlling the charging station, therefore, measurements at two points in time are taken as a basis, including the time difference between these points in time. A gradient of the power at a previous point in time is taken as a basis here. In particular, at this earlier point in time, the gradient is used without said time difference being used for this purpose.

Preferably, the power to be emitted or taken up by the charging station at the second point in time is calculated proceeding from these two measurement points in time, the time difference and the earlier feed-in gradient. This is preferably carried out depending on the state of charge of the charging station. For this purpose, it is proposed that this power to be emitted or taken up at the second point in time is calculated from a product composed of

- the time difference and
- a difference between
 - the absolute value of the rise limiting gradient and
 - the earlier feed-in gradient if
- 5 the charging station has a state of charge that is above a predefined target state of charge, or otherwise from a product of
 - the negative time difference and
 - the sum
 - of the absolute value of the decrease limiting gradient and
 - 10 - the earlier feed-in gradient.

Accordingly, the rise limiting gradient is used if the charging station has a comparatively high state of charge, and the decrease limiting gradient is used if the charging station has a comparatively low state of charge, expressed illustratively.

15 By means of this calculation, the limiting gradients, that is to say rise limiting gradient and decrease limiting gradient, are complied with and, at the same time, the power of the charging station that is to be emitted or taken up is calculated depending on the state of charge of said charging station. At the same time, therefore, insofar as it is permitted by the situation, the development of the state of charge of the charging station is influenced in order to control it as far as possible into a desired range.

20 Preferably, different measurement locations are also taken as a basis at the different measurement points in time. It is proposed to select a measurement value of a first measurement point at the first point in time and to use a measurement value of a second measurement point at the second point in time. In the course of operation, therefore, measurement is carried out simultaneously at the first and second measurement points or
 25 measurement locations, but respectively the measurement value of the first point in time, that is to say the earlier measurement value, is used by the first measurement point and the measurement value of the second point in time, that is to say the present measurement value, is used at the second measurement point. The earlier measurement value and thus the first measurement point relate to the earlier feed-in gradient. The latter is
 30 correspondingly measured at the feed-in point into the grid, or at a place in the vicinity via which the same power is transmitted.

At the first measurement point and at the first point in time, in this case the present power emission or uptake of the charging station is measured in order to set, on the basis thereof, the then newly calculated power to be emitted or taken up by the charging station. In this respect, the measurement at the first point in time at the first measurement point particularly influences the concrete setting of the power to be provided by the charging station. Accordingly, it is also proposed that the second measurement point is arranged at the output of the charging station. Such a measurement at different locations at different times may, if appropriate, prevent an instability that could arise as a result of the immediate use of a measurement value in a calculation which directly influences said measurement value.

In accordance with a further embodiment, it is proposed that the power to be emitted or taken up by the charging station is altered by a compensation value depending on a state of charge in order to approximate the present state of charge to a predefined target state of charge. It is thus proposed, independently of the control of the charging station such that the limiting gradients are complied with, to charge or discharge the charging station to a small extent. By way of example, the charging station can be charged with a low power while it is not active at all for control anyway, for example when there is no wind at the wind farm if the latter forms the regenerative generator. It is thereby possible to counteract a situation in which the state of charge moves further and further away from the desired target state of charge. That may also be a phenomenon that occurs for example only on one day.

In accordance with one embodiment, it is proposed that

- the charging station feeds electrical power into the grid if the electrical power fed into the grid by the at least one conventional generator increases with a gradient which, in terms of absolute value, is greater than the predefined rise limiting gradient, or that
- the charging station takes up electrical power from the grid if the electrical power fed into the grid by the at least one conventional generator decreases with a gradient which, in terms of absolute value, is greater than the predefined decrease limiting gradient.

This embodiment is proposed especially for the case when the at least one conventional generator and the charging station do not feed into the grid via a common feed-in point. In

other words, the charging station feeds into the grid in such a way that it compensates for at least a portion of the power fluctuations in the grid in such a way that a demand for an excessively great power change no longer arises for the conventional generator.

One embodiment proposes that the at least one regenerative generator, in particular the
5 wind energy installation,

- momentarily increases its fed-in power above the power maximally available from the wind at the moment,
- 10 - momentarily increases its fed-in power above the instantaneously fed-in power,
- momentarily decreases its fed-in power below the power maximally available from the wind at the moment, or
- 15 - momentarily decreases its fed-in power below the instantaneously fed-in power,

in order thereby to decrease power spikes to be compensated for by the charging station or by the at least one conventional generator.

The invention proposes an advantageous limiting of power changes of fed-in power by
20 corresponding control of a charging station. It has been recognized, however, that this can be associated synergistically with a control of the regenerative generator, in particular with a control of one or a plurality of wind energy installations. Regenerative generators, in particular wind energy installations, preferably generate as much power as is possible on the basis of the present conditions. A wind energy installation therefore generates as
25 far as possible as much power as can be drawn from the wind at the present moment. Resultant fluctuations can be limited by the use of the charging station. Nevertheless it may be helpful also to use the wind energy installation for control. Particularly if the charging station has an inexpedient state of charge, it can be helpful for the control to be momentarily taken over or supplemented by the wind energy installation. In this case, the
30 wind energy installation can increase or decrease its power. It can increase or decrease the power above or below the present value or, alternatively, increase or decrease the power above or below the available power from the wind. Such an increase is possible at particularly short notice by the use of kinetic energy of the rotor of the wind energy installation.

As a result, what can also be achieved, inter alia, is that the charging station is implemented smaller and more cost-effectively. A charging station can be dimensioned in such a way that it can fulfil its task for example on 95% of all days in the year. In order to cover this last 5% of the days in the year as well, it would have to be designed possibly to be
5 significantly larger. It would be unnecessary if the wind energy installation or installations as an exception take(s) over or supplement(s) the task of the charging station in this case.

The invention additionally proposes an electrical supply grid, which can also be referred to simply as electrical grid. In particular, an electrical island grid is proposed. This grid is
10 prepared to be operated by a method according to any of the above embodiments.

The invention additionally proposes a charging station prepared to be operated in the proposed grid.

The invention additionally proposes a wind energy installation prepared to be operated in said electrical grid.

15 The invention also proposes a wind farm prepared to be used as a regenerative generator in an electrical grid as described above.

The invention is explained in greater detail by way of example below on the basis of exemplary embodiments with reference to the accompanying figures.

Figure 1 shows a wind energy installation schematically in a perspective illustration.

20 Figure 2 shows a wind farm comprising a plurality of wind energy installations in a schematic illustration.

Figure 3 shows an electrical grid comprising a wind energy installation, a charging station, a conventional generator and loads in accordance with a first configuration.

25 Figures 4 to 9 illustrate the control of a charging station in accordance with one embodiment and for the configuration in accordance with Figure 3 for different states or boundary conditions with respect to predefined limiting gradients.

Figure 10 shows the temporal profile of some powers for different parameterizations of the control of the charging station.

Figure 11 shows the temporal profile of a state of charge of the controlled charging station in each case in regard to the control taken as a basis in Figure 10.

- 5 Figure 12 shows an electrical grid comprising a wind energy installation, a charging station, a conventional generator and loads in accordance with a second configuration.

Figure 1 shows a wind energy installation 100 comprising a tower 102 and a nacelle 104. A rotor 106 comprising three rotor blades 108 and a spinner 110 is arranged on the nacelle 104. The rotor 106 is caused to effect rotational motion by the wind during operation and thereby drives a generator in the nacelle 104.

Figure 2 shows a wind farm 112 comprising for example three wind energy installations 100, which can be identical or different. The three wind energy installations 100 are therefore representative of fundamentally any desired number of wind energy installations of a wind farm 112. The wind energy installations 100 provide their power, namely in particular the generated current, via an electrical farm grid 114. In this case, the respectively generated currents or powers of the individual wind energy installations 100 are added and a transformer 116 is usually provided, which steps up the voltage in the farm in order then to feed it into the supply grid 120 at the feed-in point 118, which is also generally designated as PCC. Figure 2 is merely a simplified illustration of a wind farm 112 showing no control, for example, even though a control is present, of course. Moreover, by way of example, the farm grid 114 can be designed differently, for example by a transformer also being present therein at the output of each wind energy installation 100, to mention just one other exemplary embodiment.

25 The present invention thus concerns a strategy for charging and discharging an energy store coupled to a grid, which strategy makes it possible to limit power gradients which can arise for example as a result of renewable energy generators such as wind energy installations or photovoltaic installations, for example.

The energy store is also designated here as charging station or simply as battery. In this case, however, the energy store or the charging station can comprise control means for controlling the charging and discharging.

Various grid configurations can be taken as a basis, which can be characterized by the interconnection of the wind energy installation, the charging station or battery and the conventional generator. A grid configuration illustrated in Figure 3 is taken as a basis below for exemplary explanation of the invention.

An electrical supply grid 1 which is intended to supply loads 2 with electric current is illustrated schematically in accordance with Figure 3. As energy generator, a conventional generator 4 is connected to the grid 1. Moreover, at least one wind energy installation 6 and a charging station 8 are connected to the grid via a grid feed-in point 10. All of the schematically illustrated parts of the grid 1, namely loads 2, conventional generator 4, wind energy installation 6 and charging station 8, can also in each case comprise a plurality of such elements of their type or be representative thereof. In particular, the wind energy installation 6 is also representative of a wind farm 6.

The wind energy installation 6 provides a power $P_{wec}(t)$ and the charging station 8, which can also be referred to as battery 8 for simplification, provides a power $P_{bat}(t)$. These powers can thus vary over time and their sum is fed into the grid 1 at the grid feed-in point 10. Both the power of the wind energy installation $P_{wec}(t)$ and the power of the charging station $P_{bat}(t)$ can both be fed into the grid and be drawn from the grid. In the case of being drawn from the grid, that means for the power $P_{bat}(t)$ of the charging station 8 that the charging station or a battery in the charging station is charged thereby. The wind energy installation 6 substantially feeds power in but, via chopper resistors or buffer stores, for example, could also tap off and thereby consume power from the grid or buffer-store it, if this is necessary or helpful for grid support. Moreover, Figure 3 symbolically illustrates various switches S that can isolate the respective element from the grid.

In the case of this configuration in accordance with Figure 3, a feed-in power fed into the grid 1 is the sum of the power P_{wec} of the wind energy installation 6 and the power P_{bat} of the charging station 8. This sum can also be designated as P_{grid} . That is therefore the power which is fed into the grid, or is drawn from there in the case of a negative sign, at the grid feed-in point 10. The conventional generator 4 also feeds in power, but the latter is not mentioned in the consideration on which Figure 3 is based.

Optionally, the wind energy installation 6 and the charging station 8 could be assigned a further conventional generator, the power of which would then also be part of the feed-in power P_{grid} fed in at the grid feed-in point 10. Such a conventional generator, that is to say in particular diesel generator, could be supplementarily connected e.g. if the wind were
 5 not very strong, to give just one example.

In the case of this configuration, it is then proposed that the feed-in power P_{grid} is limited in terms of its change over time. It is therefore proposed that at the grid feed-in point 10 power changes and thus power gradients of the power fed in there are kept within limits. That can be carried out according to the invention by means of a corresponding control of
 10 the charging station 8.

In accordance with Figure 3, one or a plurality of wind energy installations 6 and the battery system 8, which can also be referred to as charging station, feed into an electrical grid 1 via a common grid feed-in point 10, said electrical grid additionally comprising a conventional generator 4 and various loads.

15 A power gradient $\left. \frac{\Delta P}{\Delta t} \right|_{\text{grid}}(t)$ at the point in time t which is fed in at the grid feed-in point 10 can be defined as follows:

$$[1] \quad \left. \frac{\Delta P}{\Delta t} \right|_{\text{grid}}(t) = \frac{P_{\text{wec}}(t_2) - P_{\text{grid}}(t_1)}{\Delta t}$$

wherein $P_{\text{wec}}(t_2)$ is the wind farm power measured at the point in time t_2 , and $P_{\text{grid}}(t_1)$ is the feed-in power measured at the grid feed-in point at the point in time t_1 . In this case, t_2
 20 is the present point in time succeeding t_1 . Δt is the time step chosen for determining the power gradients and results from the difference between t_2 and t_1 .

If the active power gradient fed in at the grid feed-in point is intended to be limited to a maximum and respectively minimum limit value $\left(\left. \frac{\Delta P}{\Delta t} \right|_{\text{lim}}^{\text{down}}, \left. \frac{\Delta P}{\Delta t} \right|_{\text{lim}}^{\text{up}} \right)$ or be kept within such limit values, then a specific active power (P_{bat}) must be fed to the grid or drawn from the
 25 grid, depending on the type (positive or negative) and absolute value of the gradient (above or below the limit value). For such a power, it is proposed that the latter can be taken up or emitted by an energy storage system, which in this application is designated

synonymously as charging station 8 and e.g. can be embodied as a battery or can comprise a battery.

Figure 4 illustrates both the wind energy installation power P_{wec} and the power at the grid feed-in point P_{grid} at the successive points in time t_1 and t_2 . In this case, P_{grid} is composed additively of P_{wec} and P_{bat} .

The power $P_{grid}(t_1)$ at the grid feed-in point and the wind energy installation power $P_{wec}(t_1)$ are assumed to be identical at the point in time t_1 in said Figure 4 and also in Figures 5 to 9. The wind energy installation power $P_{wec}(t_2)$ shall be manifested at the point in time t_2 . From Equation [1], the power gradient $\left. \frac{\Delta P}{\Delta t} \right|_{(t_2)}$ then results, which in the example in accordance with Figure 4 is greater than the upper limit value $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up}$, which is given as an upper limit value, namely as a rise limiting gradient.

In order to ensure a power gradient of $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up}$ at the grid feed-in point, the battery must take up the power $P_{bat}(t_2)$ at the point in time t_2 . Said power is negative in the case described and is calculated as

$$[2] \quad P_{bat}(t) = \left(\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up} - \left. \frac{\Delta P}{\Delta t} \right|_{grid}(t) \right) \cdot \Delta t;$$

The capacity of an energy store which allows the battery power P_{bat} to be provided is limited. The availability of the battery power P_{bat} is dependent on the state of charge of the battery, this being designated as SoC . If the store is uncharged ($SoC=0\%$), no additional power can be fed in. If the store is completely charged ($SoC=100\%$), no additional power can be taken up.

Therefore, it is proposed to operate the store during operation with a state of charge SoC that is as constant as possible between the two extreme states of charge. Such a target state of charge can be predefined as a setpoint value SoC_{target} . In order that the temporal profile of the state of charge SoC deviates as little as possible from the setpoint state of charge SoC_{target} , it is proposed that charging and discharging powers correspond to one another on average over time.

It has been recognized that the absolute value of the limiting gradients $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{down}$ and $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up}$, which can be predefined as decrease limiting gradient $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{down}$ and rise limiting gradient $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up}$, respectively, has the following influence on battery operation:

- It affects the probability of battery charging or discharging
- It affects the power to be provided or taken up by the battery

It is proposed, then, to influence the state of charge of the battery by corresponding selection of the limiting gradients.

That is to say that a lower or upper limit value ($\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{down}$ or $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up}$) of a power gradient is selected depending on the difference between the state of charge SoC and the setpoint state of charge SoC_{target} . As a result, it is possible to control whether the battery is charged with a maximum/minimum power or is discharged with a maximum/minimum power.

Figures 4 to 9 illustrate for three exemplary situations of a power gradient $\left. \frac{\Delta P}{\Delta t} \right| (t)$, namely for the feed-in power P_{grid} , resulting battery powers $P_{bat}(t)$ that are achieved by means of the proposed method. The basic type of illustration has already been explained in part above with regard to Figure 4 and is also analogously applicable to the other Figures 5 to 9.

These three exemplary situations are also representative, in principle, of three possible situations of the power gradient and they are:

1. The power gradient $\left. \frac{\Delta P}{\Delta t} \right| (t)$ is greater than the upper limiting gradient $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up}$
2. The power gradient $\left. \frac{\Delta P}{\Delta t} \right| (t)$ is less than the lower limiting gradient $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{down}$
3. The power gradient $\left. \frac{\Delta P}{\Delta t} \right| (t)$ is less than the upper limiting gradient $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up}$ and greater than the lower limiting gradient $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{down}$

The upper limiting gradient $\frac{\Delta P}{\Delta t}_{lim}^{up}$ is also designated synonymously as the rise limiting gradient, and the lower limiting gradient $\frac{\Delta P}{\Delta t}_{lim}^{down}$ is synonymously also designated as the decrease limiting gradient.

5 In addition to the abovementioned possible situations of the power gradient, the state of charge of the charging station or of its battery or batteries has an influence. For explanation purposes, reference will also simply be made to the battery, for simplification. The state of charge is designated as SoC in the figures and considered in relation to a target state of charge, designated therein as SoC_{target}.

The battery can be in the following two states of charge:

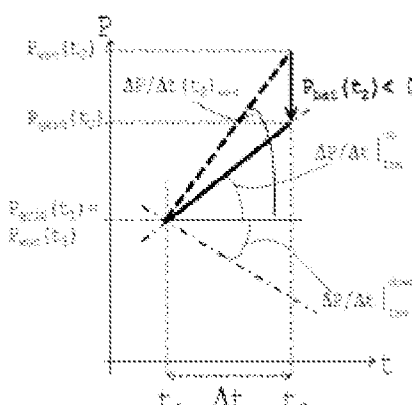
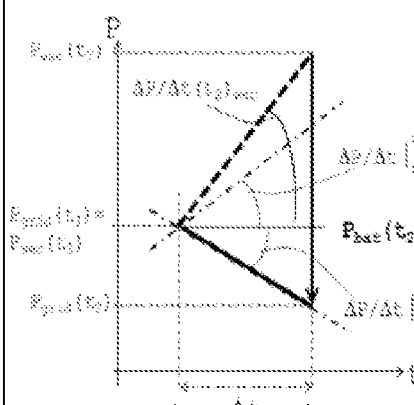
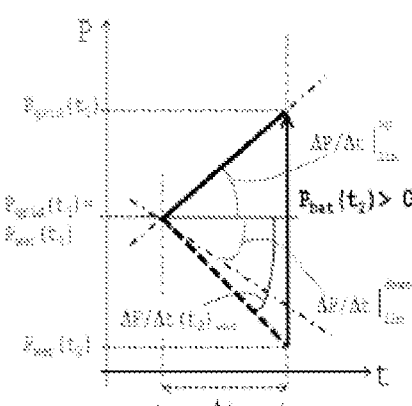
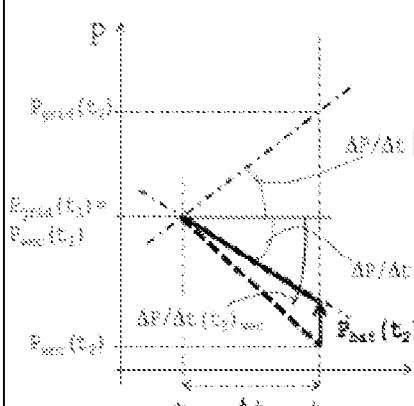
- 10 1. SoC > SoC_{target}
 2. SoC ≤ SoC_{target}

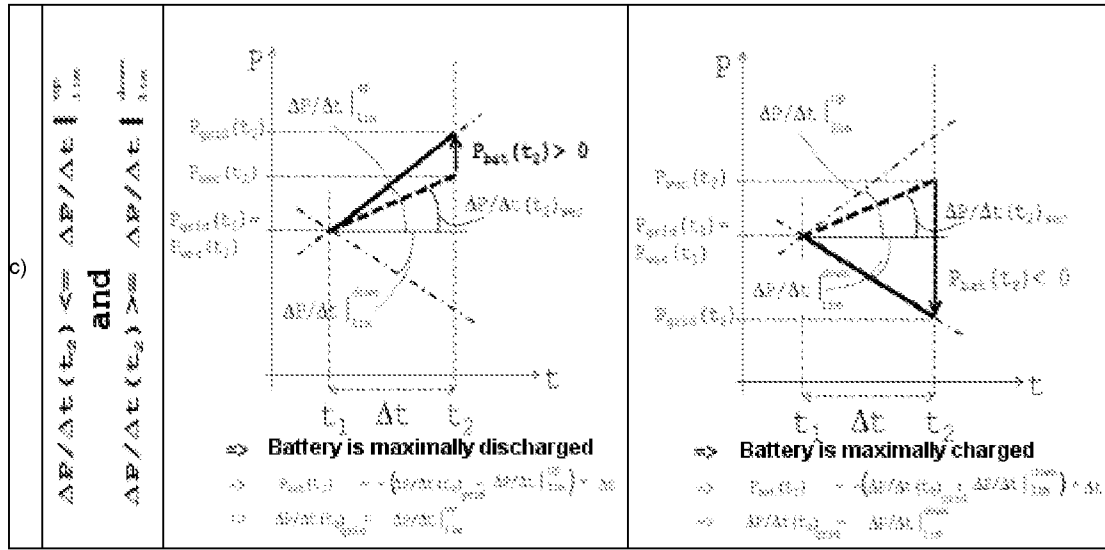
The theoretical state that the state of charge corresponds exactly to the target charge (SoC = SoC_{target}) has been assigned here to the second variant, this not being essential.

15 It is thus possible to combine six possible cases with regard to the power gradient and state of charge, which are shown in Table 1 and Figures 4 to 9.

Table 1 indicates for these six cases the equations in accordance with one embodiment by means of which the battery power $P_{bat}(t)$ is determined in order to cause the state of charge SoC to converge as much as possible toward the target state of charge SoC_{target}. The table also indicates the figures which show the corresponding power gradients for
 20 these six different cases.

Table 1

		I) SoC > SoC _{target}	II) SoC ≤ SoC _{target}
a)	$\Delta P / \Delta t(t_2) > \Delta P / \Delta t \Big _{lim}^{up}$	 $\Rightarrow$ Battery is minimally charged $\Rightarrow P_{bat}(t_2) = -\left(\Delta P / \Delta t(t_2)_{lim} - \Delta P / \Delta t \Big _{lim}^{up}\right) \cdot \Delta t$ $\Rightarrow \Delta P / \Delta t(t_2)_{lim} = \Delta P / \Delta t \Big _{lim}^{up}$	 $\Rightarrow$ Battery is maximally charged $\Rightarrow P_{bat}(t_2) = -\left(\Delta P / \Delta t(t_2)_{lim} - \Delta P / \Delta t \Big _{lim}^{down}\right) \cdot \Delta t$ $\Rightarrow \Delta P / \Delta t(t_2)_{lim} = \Delta P / \Delta t \Big _{lim}^{down}$
b)	$\Delta P / \Delta t(t_2) < \Delta P / \Delta t \Big _{lim}^{down}$	 $\Rightarrow$ Battery is maximally discharged $\Rightarrow P_{bat}(t_2) = -\left(\Delta P / \Delta t(t_2)_{lim} - \Delta P / \Delta t \Big _{lim}^{down}\right) \cdot \Delta t$ $\Rightarrow \Delta P / \Delta t(t_2)_{lim} = \Delta P / \Delta t \Big _{lim}^{down}$	 $\Rightarrow$ Battery is minimally discharged $\Rightarrow P_{bat}(t_2) = -\left(\Delta P / \Delta t(t_2)_{lim} - \Delta P / \Delta t \Big _{lim}^{up}\right) \cdot \Delta t$ $\Rightarrow \Delta P / \Delta t(t_2)_{lim} = \Delta P / \Delta t \Big _{lim}^{up}$



The cases shown in Table 1 can be summarized such that the power $P_{bat}(t)$ to be provided by the battery can be calculated as follows:

$$[3] \quad P_{bat}(t) = - \left(\frac{\Delta P}{\Delta t}|_{lim}^{down} + \frac{\Delta P}{\Delta t}|_{grid}(t) \right) \cdot \Delta t; \text{ for } SoC_{bat}(t) < SoC_{target}$$

$$5 \quad [4] \quad P_{bat}(t) = \left(\frac{\Delta P}{\Delta t}|_{lim}^{up} - \frac{\Delta P}{\Delta t}|_{grid}(t) \right) \cdot \Delta t; \text{ for } SoC_{bat}(t) \geq SoC_{target}$$

The temporal deviation of the battery state of charge $SoC(t)$ around the target value SoC_{target} depends on how the wind power changes, which leads to unforeseeable power changes and thus power gradients. In other words, said temporal deviation depends on a stochastic sequence of negative or positive power gradients. The latter are intended to be limited by the battery operation. The more often negative gradients are compensated for, the more likely the store will be drained, and vice versa.

Figures 4 to 9 reveal that the charging station is controlled in such a way that a gradient of the the feed-in power is brought to in a range which is defined by the rise limiting gradient and the decrease limiting gradient. In this case, an attempt is made to change the gradient either to the rise limiting gradient or to the decrease limiting gradient. The decision between them depends on the state of charge. If the latter is above its target value, the rise limiting gradient is selected, otherwise the decrease limiting gradient is selected.

It is furthermore proposed to approximate the feed-in power P_{grid} to the time-averaged power profile of the wind farm $\widetilde{P_{wec}}$. This can be achieved if the battery is charged or discharged with an average power $\widetilde{P_{bat}}(t)$. This power can be superposed on the dynamic power emitted or taken up by the battery in accordance with Figures 4 to 9. It is proportional to the difference between $\widetilde{P_{wec}}$ and P_{grid} and it can be set as follows by means of the use of a weighting F :

$$[5] \quad \widetilde{P_{bat}}(t) = (\widetilde{P_{wec}}(t2) - P_{grid}(t1)) \cdot F$$

The weighting F is thus a suitable proportionality factor to be selected.

In order both to ensure compliance with limiting power gradients with the aid of the battery, particularly as described in association with Figures 4 to 9, and at the same time to ensure operation of the storage medium with a stable state of charge, it is proposed to predefine for the storage medium a setpoint power $P_{bat_total}(t)$, which results from the superposition of $P_{bat}(t)$ and $\widetilde{P_{bat}}$ as follows:

$$[6] \quad P_{bat_gesamt}(t) = P_{bat}(t) + \widetilde{P_{bat}}(t)$$

In order to improve the feed-in behaviour of the wind energy installation together with the battery, it is also proposed to adapt the limiting gradients $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{down}$ and $\left. \frac{\Delta P}{\Delta t} \right|_{lim}^{up}$ in Equations [3] and [4] depending on the state of charge SoC. It has been recognized that the state of charge, in particular the mean state of charge, can thereby be influenced, at any rate at least if the charging station is controlled in the manner as described with regard to Figures 4 to 9.

Figure 10 shows by way of example for the configuration in accordance with Figure 3 two temporal power profiles, namely of the power P_{wec} of the at least one wind energy installation and of the total feed-in power P_{Grid} of wind energy installation and charging station or battery jointly. In principle, two parameterizations are taken into consideration. The first parameterization sets the abovementioned weighting factor F to zero and two identical and constant values for the rise limiting gradient and the decrease limiting gradient are also taken as a basis. This configuration is defined mathematically below as “parameterization 1”.

Preferably, however, a parameterization designated as “parameterization 2” is used, which is designated as “wind+battery (optimized)” for simplification in Figures 10 and 11. In this preferred embodiment, the weighting factor F is not set to zero and different and variable values for the rise limiting gradient and the decrease limiting gradient are taken
 5 as a basis. Figures 10 and 11 show results only for this second parameterization.

Figure 11 shows the profile of the state of charge of the battery for the second configuration of the control of the power feed-in. In the illustration, a target state of charge of 50% is depicted and designated as “SoC target”.

• **Parameterization 1:**

10 Wind+battery: $F=0$ (Equation [5]) and $\frac{\Delta P_{lim}^{down}}{\Delta t}, \frac{\Delta P_{lim}^{up}}{\Delta t} = \text{constant}$

• **Parameterization 2:**

Wind+battery (optimized): $F \neq 0$ (Equation [5]) and $\frac{\Delta P_{lim}^{down}}{\Delta t}, \frac{\Delta P_{lim}^{up}}{\Delta t} = \text{variable}$

F in the second parameterization is thus variable over time and dependent on:

- the instantaneous state of charge SoC,
- 15 ○ the target state of charge “SoC target” and/or
- the time-averaged power profile of the wind farm $\overline{P_{WSC}}$.

The dimensionless, positive factor F varies between the values 0 and 1 (or greater) over time, depending on the application. The greater the difference between the present state of charge SoC and the target state of charge SoC_target, the greater, at any rate in
 20 accordance with one preferred embodiment, the factor F is chosen to be. In this case, the factor F is altered or set depending on the state of charge.

$\frac{\Delta P_{lim}^{down}}{\Delta t}, \frac{\Delta P_{lim}^{up}}{\Delta t}$ in the case of parameterization 2 is likewise variable over time and dependent on the difference between the present state of charge SoC and the target state of charge SoC_target.

25 The result in Figure 10 shows that the proposed control of the charging station 8, namely a control on the basis of the parameterization 2, makes it possible to achieve a greatly stabilized feed-in power in comparison with the feed-in of the wind energy installation without a battery.

Figure 11 shows the associated profile of the state of charge SoC with respect to the profile of the total feed-in power P_{Grid} from wind energy installation and charging station together in accordance with Figure 10. Figure 11 reveals that the parameterization 2, that is to say the preferably proposed control, makes it possible to operate the battery with a comparatively stable state of charge. If the state of charge of the battery falls owing to a momentary dip in the wind energy installation power, which is the case for instance at $\approx 550\text{s}$, the state of charge converges toward its target value $\text{SoC}_{\text{target}}$ again after a short time.

Figure 12 shows, in contrast to Figure 3, a second configuration of an underlying or considered grid 201. This grid 201 basically also comprises the elements or participants explained in Figure 3, namely loads 202, a wind energy installation 206, which can also be representative of a wind farm, a battery 208, which here is also representative of the charging station, and at least one conventional generator 204.

For this configuration, it is proposed, then, to control the charging station 208 or battery 208 in such a way that the power P_{Gen} fed into the grid by the generator 204 is limited in terms of its change over time. This power P_{Gen} fed into the grid by the generator forms in this respect the feed-in power that is limited in terms of its change over time. Here the consideration taken as a basis, then, is that fluctuations in the load 202 and also fluctuations in the fed-in power P_{wec} of the wind energy installation 206 without a charging station 208 or battery 208 would have the effect that these fluctuations would have to be compensated for by the power P_{Gen} fed in by the generator. If these changes over time are too great, the conventional generator has to change its load too rapidly or, in the case of generator banks, that would mean that generators must be supplementarily connected or disconnected too rapidly. Particularly for motors based on fossil fuels, that is to say in particular diesel motors, that is very inexpedient for their lifetime. The charging station or battery 208 is intended to compensate for that. For this purpose, the change of the feed-in power P_{Gen} is detected and the charging station or battery 208 is controlled accordingly.

If the loads 202 substantially tap off their power in a constant manner, this configuration and corresponding control of the battery 208 or charging station 208 can lead to results very similar to those in the case of the configuration in accordance with Figure 3. This is because in this case the power fluctuations mentioned arise merely as a result of power fluctuations of the wind energy installation 206. Therefore, in this case, too, the battery

208 or charging station 208 would prevent an excessively great power change of the wind energy installation 206.

For the case where the loads also fluctuate, however, the battery 208 will detect and take account of the total power fluctuation arising as a result of the loads 202 and the wind
5 energy installation 206.

For further details, reference is then made to the text above, to the parts of the general description which describe features and embodiments concerning this second configuration.

Patentkrav

1. Fremgangsmåde til drift af en elektrisk ladestation (8) ved et elektrisk net (1), der udover elektriske belastninger (2) omfatter mindst én regenerativ energigenerator (6), mindst én konventionel generator (4), der drives af fossile brændstoffer, og mindst den elektriske ladestation (8) til lagring og frigivelse af elektrisk effekt,

omfattende følgende trin:

- generering af elektrisk effekt ved hjælp af den mindst ene regenerative energigenerator (6) og tilføre den elektriske effekt til nettet (1),

- lagring af elektrisk effekt, der ikke forbruges af belastningerne (2) i ladestationen (8),

- tilførsel af elektrisk effekt til nettet (1) ved hjælp af ladestationen (8), hvis belastningerne (2) forbruger mere effekt, end der tilføres nettet (1) i fællesskab af den mindst ene regenerative generator (6) og den mindst ene konventionelle generator,

hvor

- i en første konstellation af nettet (1) er en tilført effektforsyning til nettet (1) en sum af

- effekten af den mindst ene regenerative energigenerator (6) og

- effekten af ladestationen (8) og eventuelt derudover

- effekten af den mindst én yderligere generator, der er tildelt ladestationen (8), hvor ladestationen (8) styres på en sådan måde, at effektforsyningen er begrænset med hensyn til dens ændring over tid,

og hvor den effekt, der skal udsendes eller optages af ladestationen (8), ændres af en kompensationsværdi afhængig af en opladningstilstand for at tilnærme den nuværende opladningstilstand til en foruddefineret målopladningstilstand,

og hvor to begrænsende gradienter er foruddefinerede for at begrænse ændringen over tid af effektforsyningen, nemlig

- en stigningsgrænsegradient, der bestemmer den maksimale ændring pr. tid, som effektforsyningen skal stige med, og
- en reduktionsgrænsegradient, der bestemmer den maksimale ændring pr. tid, som effektforsyningen skal reduceres med,

5 **kendetegnet ved, at**

ladestationen (8) styres på en sådan måde,

- at ændringen af effektforsyningen styres inden for en positiv og negativ grænse eller inden for stigningsgrænsegradienten og reduktionsgrænsegradienten, og at

10 i tilfælde af den første konstellation

- ændringen af effektforsyningen er positiv, hvis ladestationen (8) har en opladningstilstand, der er over en foruddefineret målopladningstilstand, eller
- ændringen af effektforsyningen er negativ, hvis ladestationen (8) har en opladningstilstand, der er under en foruddefineret målopladningstilstand.

15

2. Fremgangsmåde ifølge krav 1,

kendetegnet ved, at

stigningsgrænsegradienten og reduktionsgrænsegradienten adskiller sig fra hinanden med hensyn til absolut værdi.

20

3. Fremgangsmåde ifølge et af de foregående krav,

kendetegnet ved, at

mindst én af de begrænsende gradienter

- er indstillet adaptivt,

25

- indstilles afhængigt af en gennemsnitlig opladningstilstand for ladestationen (8),

- er indstillet på en sådan måde, at ladestationen (8) ikke falder under en forudbestemt minimumsopladningstilstand,

- er indstillet på en sådan måde, at ladestationen (8) ikke overstiger en forudbestemt maksimal opladningstilstand, og/eller

30

- indstilles på en sådan måde, at en gennemsnitlig opladningstilstand for ladestationen (8) antager en forudbestemt ladeindstillingsværdi, SoC_target.

4. Fremgangsmåde ifølge et af de foregående krav,

5 **kendetegnet ved, at**

mindst én af de begrænsende gradienter beregnes ud fra en foruddefineret basisbegrænsende gradient ganget med mindst én vægtningsfaktor, hvor især

- mindst én af vægtningsfaktorerne er afhængig af ladestationens (8) opladningstilstand, SoC,

- 10
- mindst én af vægtningsfaktorerne kan variere i intervallet 0 til 1,
 - mindst én af vægtningsfaktorerne har en værdi på mindst 1, især er i intervallet 1 til 10, og/eller
 - der anvendes mindst to vægtningsfaktorer til beregning af en respektive begrænsende gradient.

15

5. Fremgangsmåde ifølge et af de foregående krav,

kendetegnet ved, at i tilfælde af den første konfiguration

- ladestationen (8) afgiver elektrisk effekt, som tilføres nettet (1) sammen med elektrisk effekt fra den mindst ene regenerative energigenerator, hvis den elektriske effekt af den regenerative energigenerator (6) falder med en gradient, der i absolut værdi er større end den foruddefinerede stigningsgrænsegradient, eller at

20

- ladestationen (8) optager elektrisk effekt (P) for at reducere den elektriske effekt (P) af den mindst ene regenerative energigenerator (6), der tilføres nettet (1), hvis den elektriske effekt (P) af den regenerative energigenerator (6) stiger med en gradient, der i absolutte værdi er større end den foruddefinerede reduktionsgrænsegradient.

25

6. Fremgangsmåde ifølge et af de foregående krav,

30 **kendetegnet ved, at**

en tidsforskel mellem et nuværende andet tidspunkt og et tidligere første tidspunkt tages i betragtning ved styring af ladestationen (8),
 og at på det tidligere første tidspunkt tages der som tidligere tilførselsgradient hensyn til en gradient af den effekt, der på det første tidspunkt blev tilført nettet
 5 i fællesskab af den mindst ene regenerative energigenerator og ladestationen
 og i givet fald mindst en yderligere generator.

7. Fremgangsmåde ifølge krav 6,

kendetegnet ved, at i tilfælde af den første konfiguration

- 10 den effekt, der skal afgives eller optages af ladestationen (8) på det andet tidspunkt, beregnes ud fra et produkt af
- tidsforskellen og
 - en forskel mellem
 - den absolutte værdi af stigningsgrænsgradienten og
 - 15 - den tidligere tilførselsgradient, hvis
- ladestationen (8) har en opladningstilstand, SoC, der er over en foruddefineret målopladningstilstand, SoC_target eller på anden måde fra et produkt af
- den negative tidsforskel og
 - summen
 - 20 - af den absolutte værdi af reduktionsgrænsgradienten og
 - den tidligere tilførselsgradient, hvor yderligere eller alternativt
- en måleværdi af et første målepunkt anvendes på det første tidspunkt, og en måleværdi af et andet målepunkt anvendes på det andet tidspunkt.

25 8. Fremgangsmåde ifølge et af de foregående krav,

kendetegnet ved, at

den mindst ene regenerative generator (6), især vindmøllen (6),

- øger midlertidigt sin tilførte effekt over den effekt, der er maksimalt tilgængelig fra vinden i øjeblikket,
- 30 - øger momentant sin tilførte effekt over den øjeblikkeligt tilførte effekt,

- sænker momentant sin tilførte effekt under den effekt, der er maksimalt tilgængelig fra vinden i øjeblikket, eller

- sænker midlertidigt sin tilførte effekt under den øjeblikkeligt tilførte effekt, for derved at mindske effektspidser, der skal kompenseres af ladestationen eller af den mindst ene konventionelle generator, og/eller

at også den mindst ene regenerative energigenerator, især en vindmølle, styres på en sådan måde, at effektforsyningen begrænses i sin ændring.

9. Elektrisk net (1), især et uafhængigt net (1), der er forberedt til at blive drevet ved en fremgangsmåde ifølge et af de foregående krav,

hvor der i stedet for den første konstellation foreslås en anden konstellation af netværket (1), i hvilken den tilførte effektforsyning til nettet (1) er den effekt, der genereres af den mindst ene konventionelle generator (4).

10. Elektrisk net (1) ifølge krav 9, **kendetegnet ved, at**

det elektriske net forberedt til en fremgangsmåde ifølge et hvilket som helst af kravene 1 til 4 for tilfældet med den anden konfiguration

- ladestationen (8) udsender elektrisk effekt til nettet (1), hvis den elektriske effekt, der tilføres nettet (1) af den mindst ene konventionelle generator, stiger med en gradient, som i absolut værdi er større end den foruddefinerede stigningsgrænsegradient, eller at

- ladestationen (8) optager elektrisk effekt fra nettet, hvis den elektriske effekt, der tilføres nettet (1) af den mindst ene konventionelle generator, aftager med en gradient, som i absolut værdi er større end den foruddefinerede reduktionsgrænsegradient.

11. Ladestation (8), forberedt til brug i et net (1) ifølge krav 9 eller 10.

12. Vindmølle(6), forberedt til brug i et elektrisk net (1) ifølge krav 9 eller 10.

13. Vindmøllepark (112) forberedt til brug som regenerativ energigenerator (6)
i et elektrisk net (1) ifølge krav 9 eller 10.

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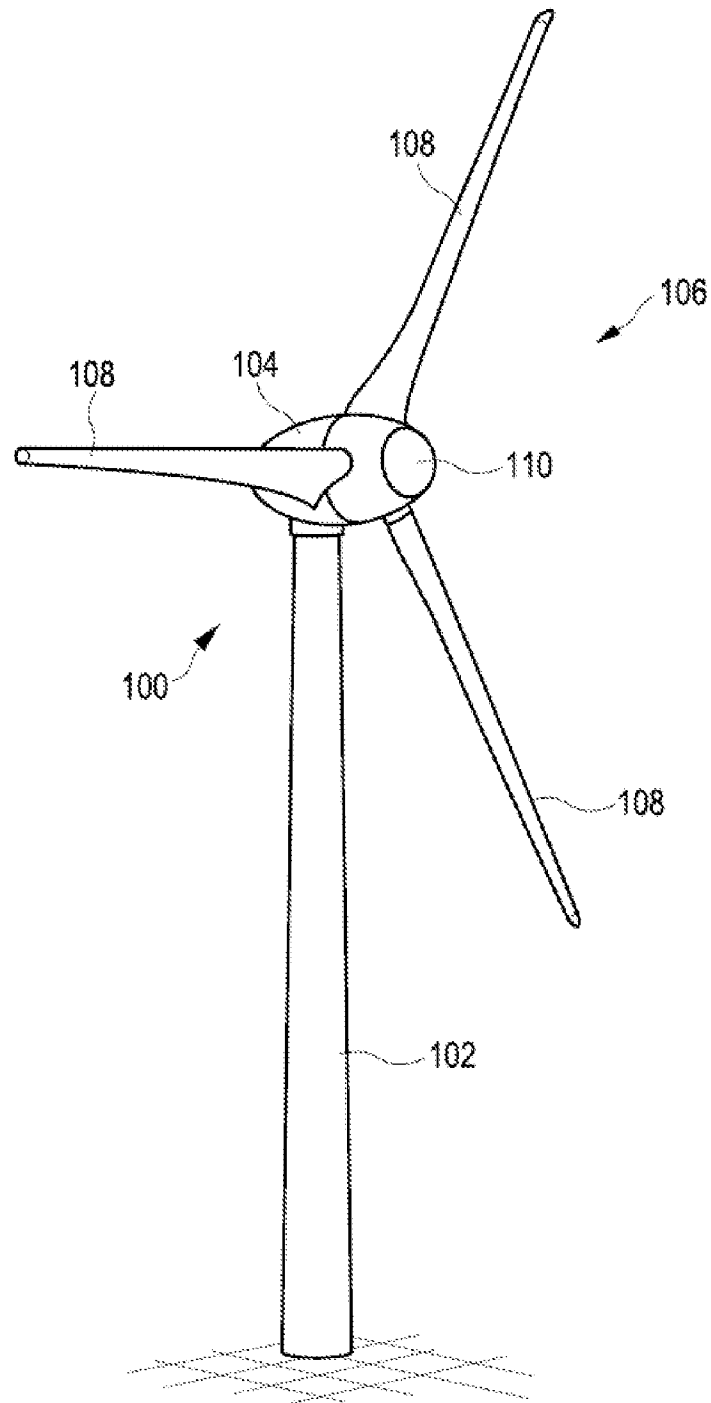


Fig. 1

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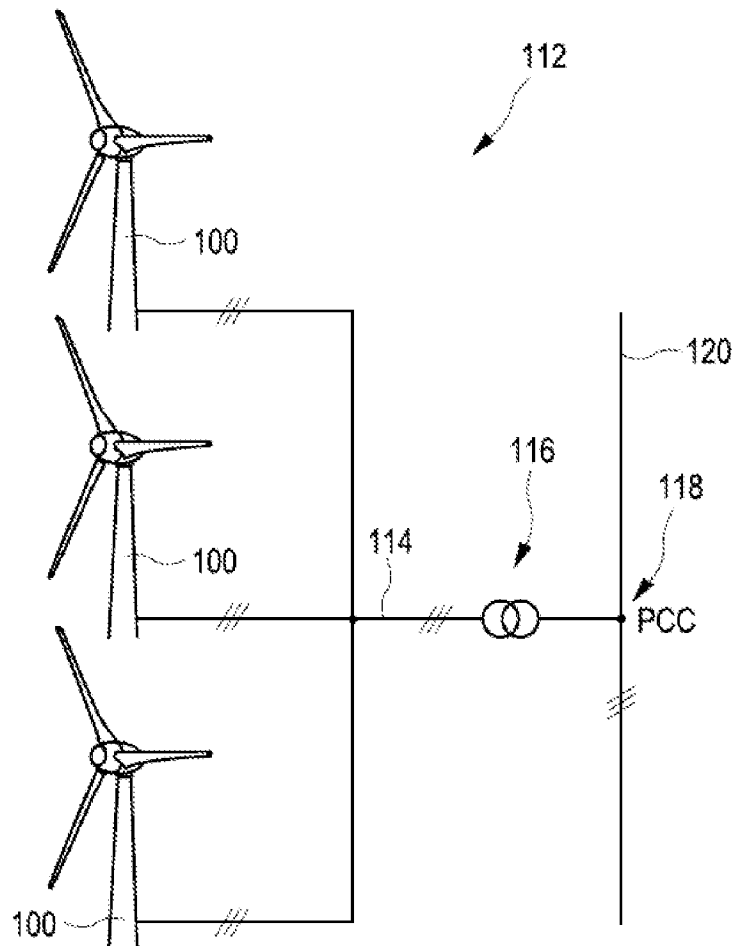


Fig. 2

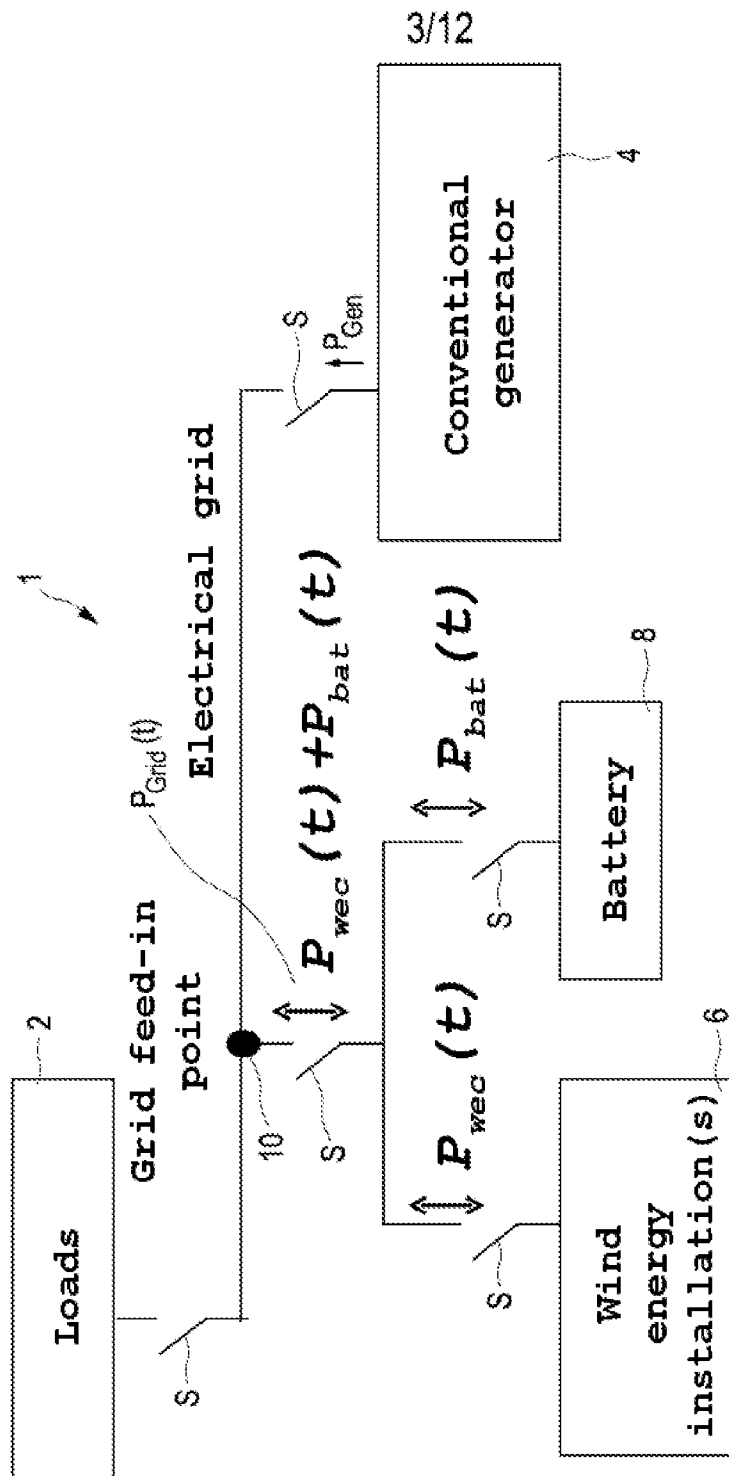
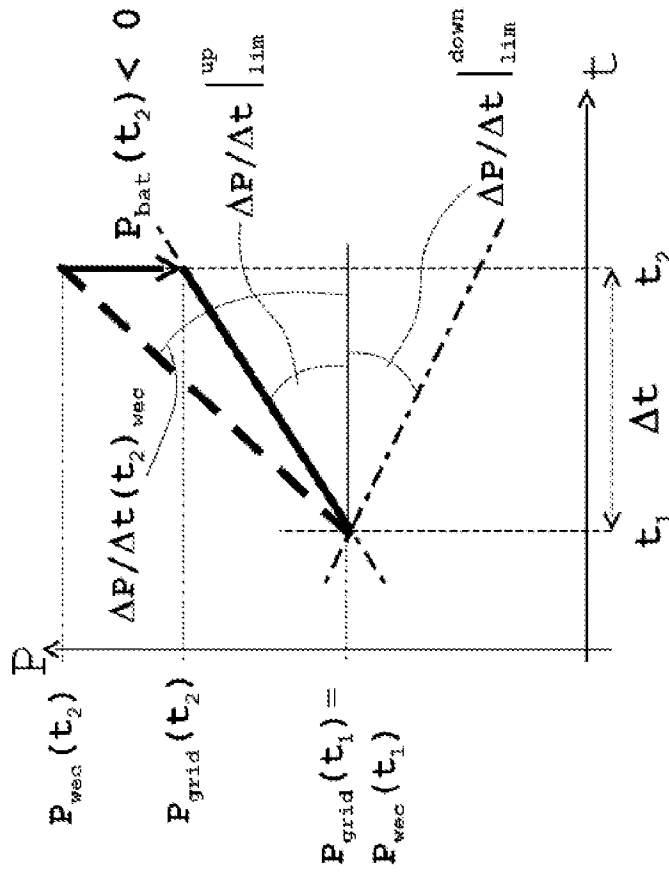


Fig. 3

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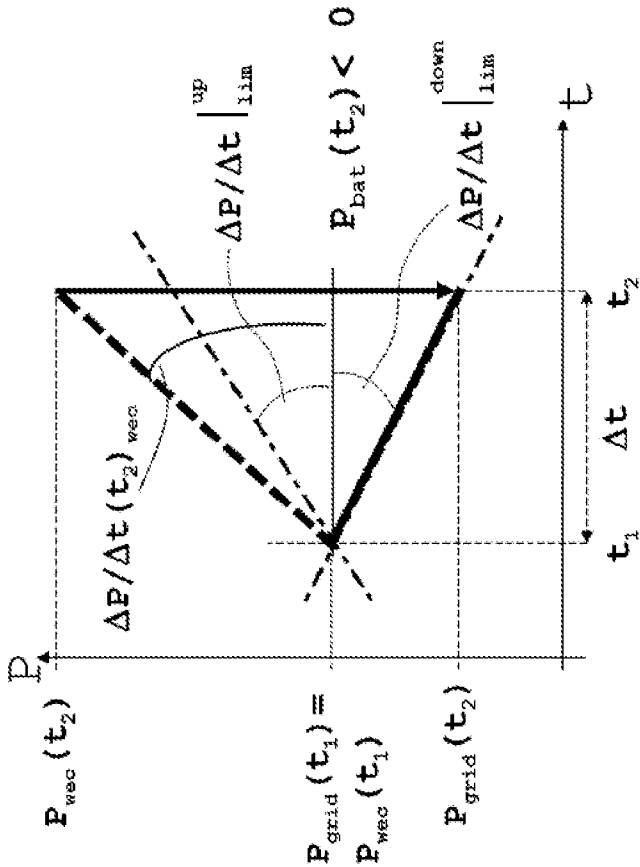
$\text{SoC}(t_1) > \text{SoC}_{\text{target}}$ and $\Delta P / \Delta t(t_2) > \Delta P / \Delta t \Big|_{\text{lim}}^{\text{up}}$



- => Battery is minimally charged
- => $P_{\text{bat}}(t_2) = -(\Delta P / \Delta t(t_2)_{\text{grid}} - \Delta P / \Delta t \Big|_{\text{lim}}^{\text{up}}) * \Delta t$
- => $\Delta P / \Delta t(t_2)_{\text{grid}} = \Delta P / \Delta t \Big|_{\text{lim}}^{\text{up}}$

Fig. 4

$$\text{SoC}(t_1) \leq \text{SoC}_{\text{target}} \text{ and } \Delta P / \Delta t(t_2) > \Delta P / \Delta t \Big|_{\text{lim}}^{\text{up}}$$



- => Battery is maximally charged
- => $P_{\text{bat}}(t_2) = -(\Delta P / \Delta t(t_2)_{\text{grid}}^{\text{up}} + \Delta P / \Delta t|_{\text{lim}}^{\text{down}}) * \Delta t$
- => $\Delta P / \Delta t(t_2)_{\text{grid}}^{\text{down}} = \Delta P / \Delta t|_{\text{lim}}^{\text{down}}$

Fig. 5

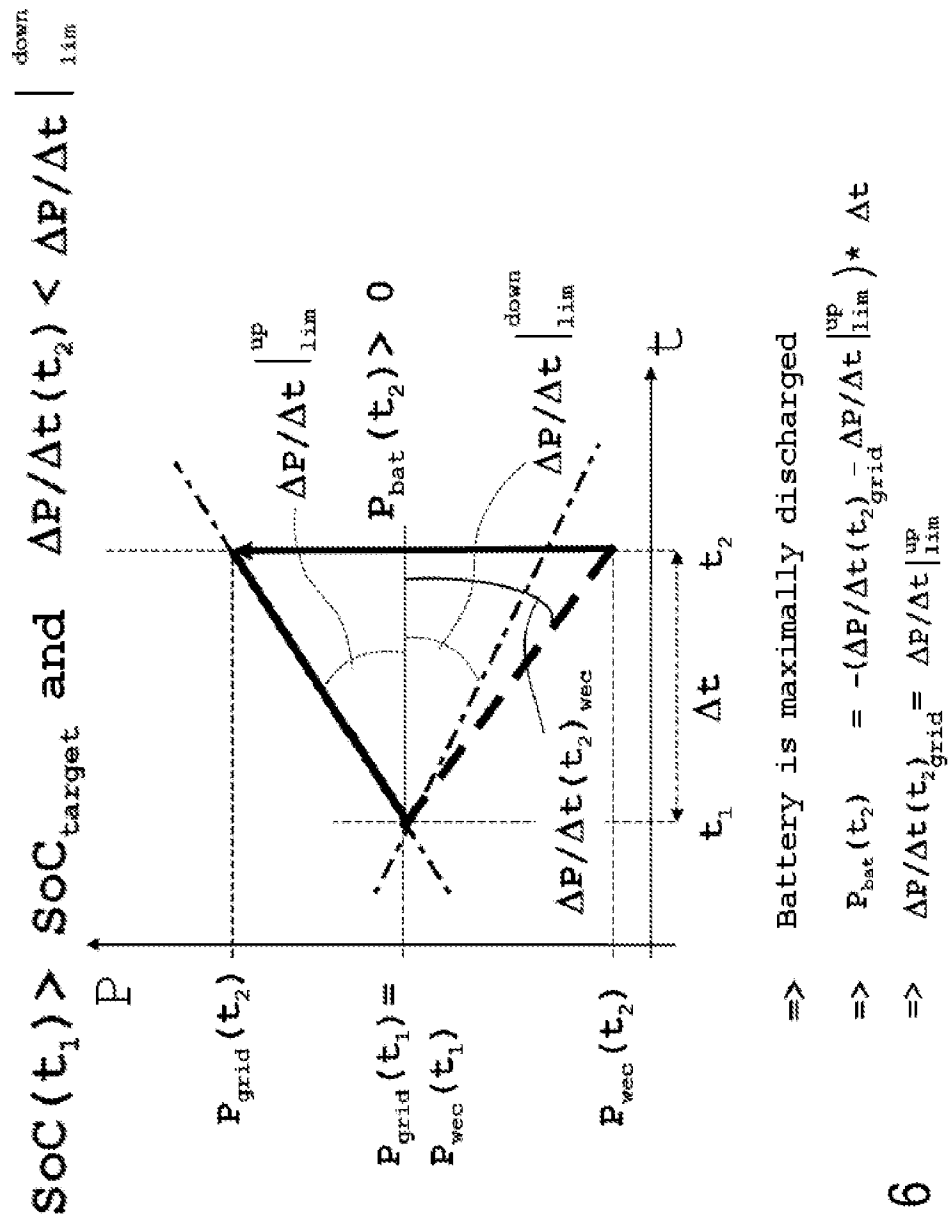
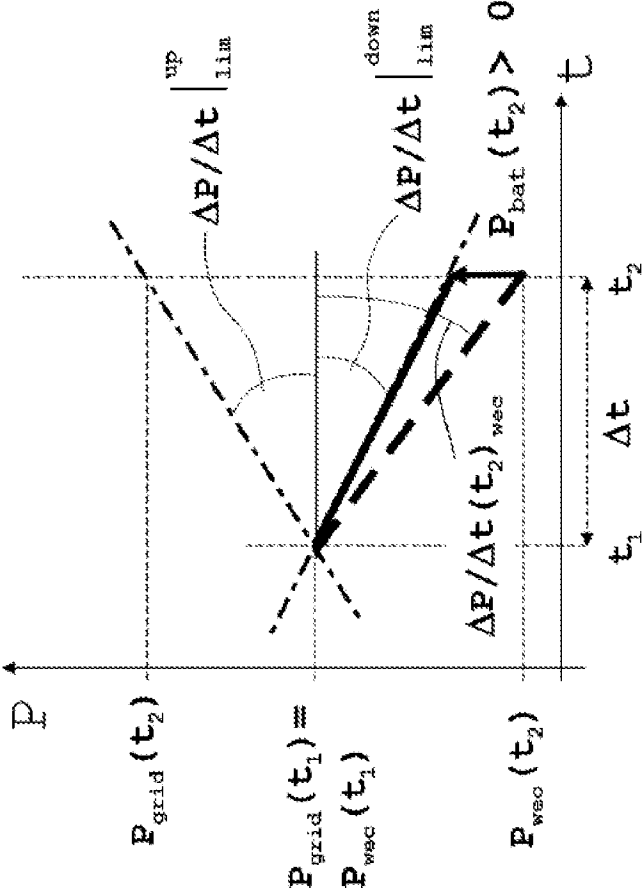


Fig. 6

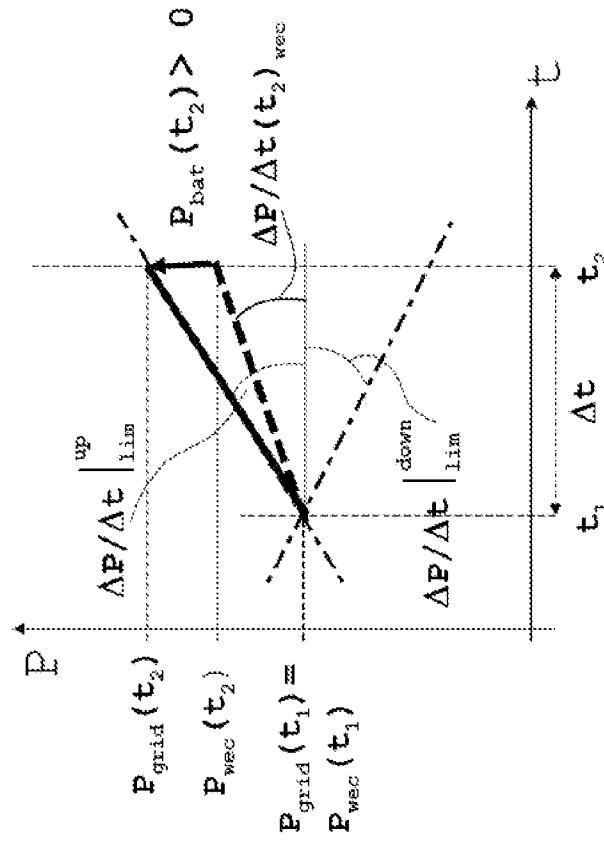
$\text{SoC}(t_1) \leq \text{SoC}_{\text{target}}$ and $\Delta P / \Delta t(t_2) < \Delta P / \Delta t \Big|_{\text{lim}}^{\text{down}}$



- => Battery is minimally discharged
- => $P_{\text{bat}}(t_2) = - \left(\Delta P / \Delta t(t_2) + \Delta P / \Delta t \Big|_{\text{lim}}^{\text{down}} \right) * \Delta t$
- => $\Delta P / \Delta t(t_2)_{\text{grid}} = \Delta P / \Delta t \Big|_{\text{lim}}^{\text{down}}$

Fig. 7

$$\begin{array}{l} \text{SoC}(t_1) > \text{SoC}_{\text{target}} \quad \text{and} \quad \Delta P / \Delta t(t_2) <= \Delta P / \Delta t \Big|_{\lim_{\text{up}}} \\ \text{and} \quad \Delta P / \Delta t(t_2) >= \Delta P / \Delta t \Big|_{\lim_{\text{down}}} \end{array}$$



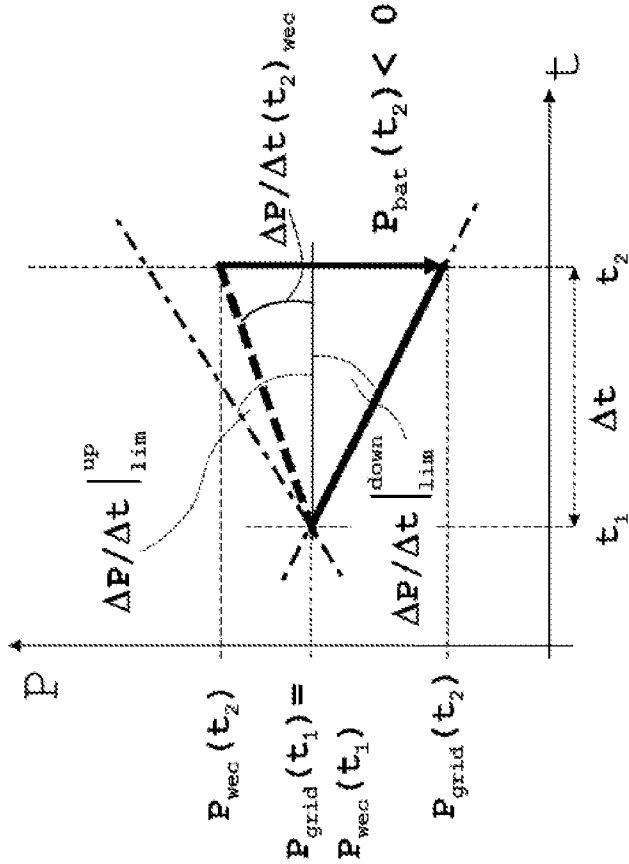
=> Battery is maximally discharged

$$\Rightarrow P_{\text{sat}}(t_2) = - \left(\Delta P / \Delta t(t_2) - \Delta P / \Delta t \right)_{\text{grid}}^{up} * \Delta t$$

$$\Rightarrow \Delta P / \Delta t(t_2)_{\text{grid}}^{\text{up}} = \Delta P / \Delta t \Big|_{\text{lim}}^{\text{up}}$$

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$$\text{SoC}(t_1) \leq \text{SoC}_{\text{target}} \text{ and } \Delta P / \Delta t(t_2) \leq \left. \Delta P / \Delta t \right|_{\text{lim}}^{\text{up}}$$
$$\text{and } \Delta P / \Delta t(t_2) \geq \left. \Delta P / \Delta t \right|_{\text{lim}}^{\text{down}}$$



=> Battery is maximally charged

=> $P_{\text{bat}}(t_2) = - \left(\Delta P / \Delta t(t_2) + \left. \Delta P / \Delta t \right|_{\text{lim}}^{\text{down}} \right) * \Delta t$

=> $\Delta P / \Delta t(t_2)_{\text{grid}}^{\text{down}} \approx \left. \Delta P / \Delta t \right|_{\text{lim}}^{\text{down}}$

Fig. 9

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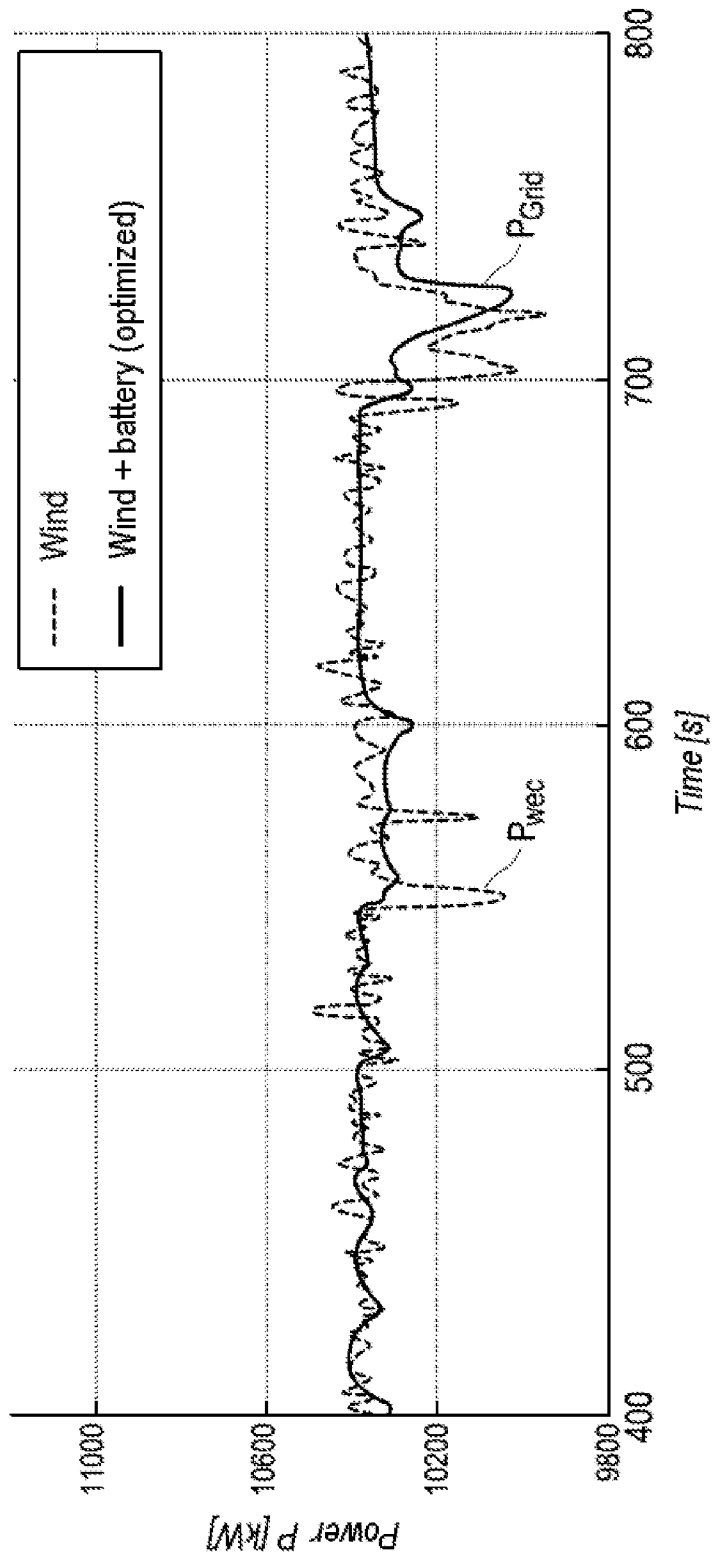


Fig. 10

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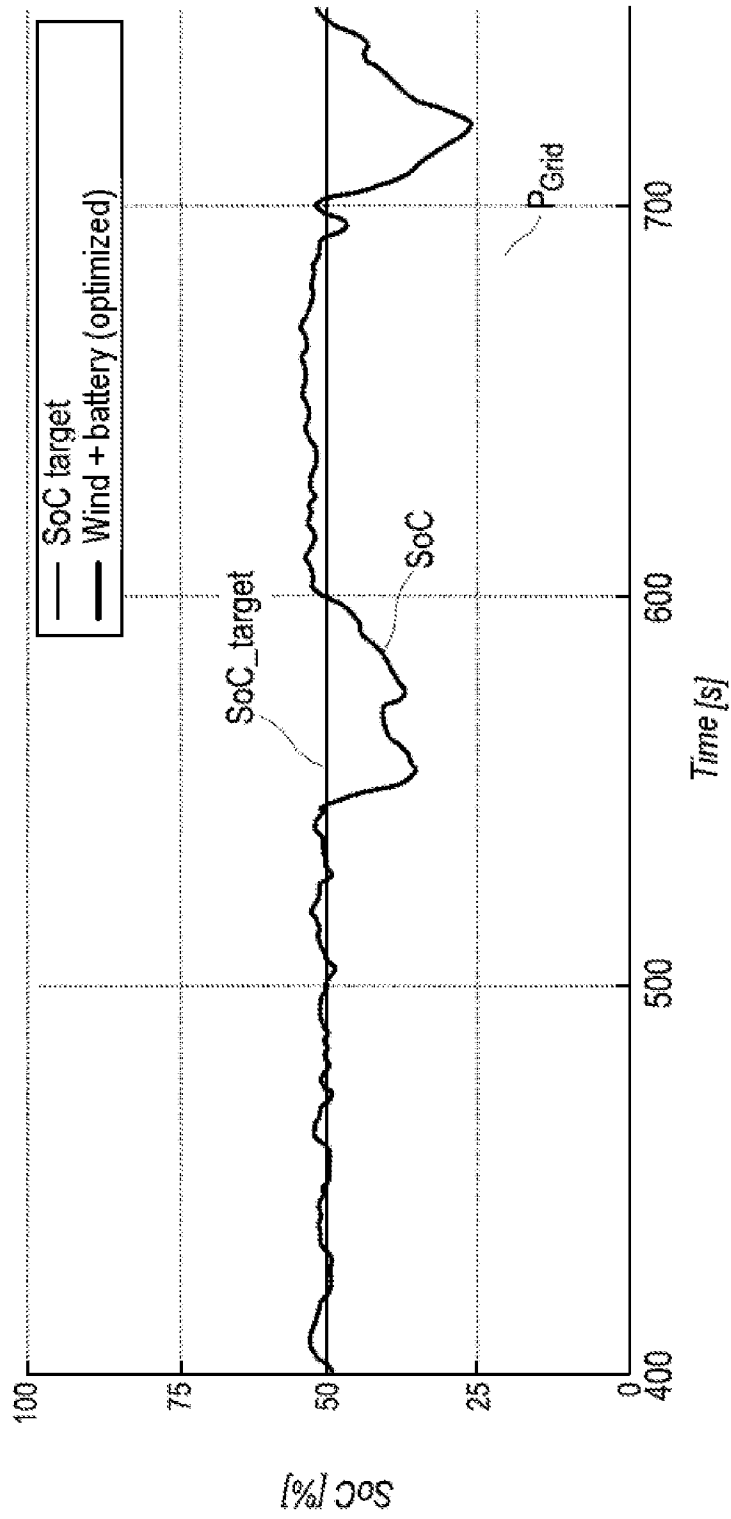


Fig. 11

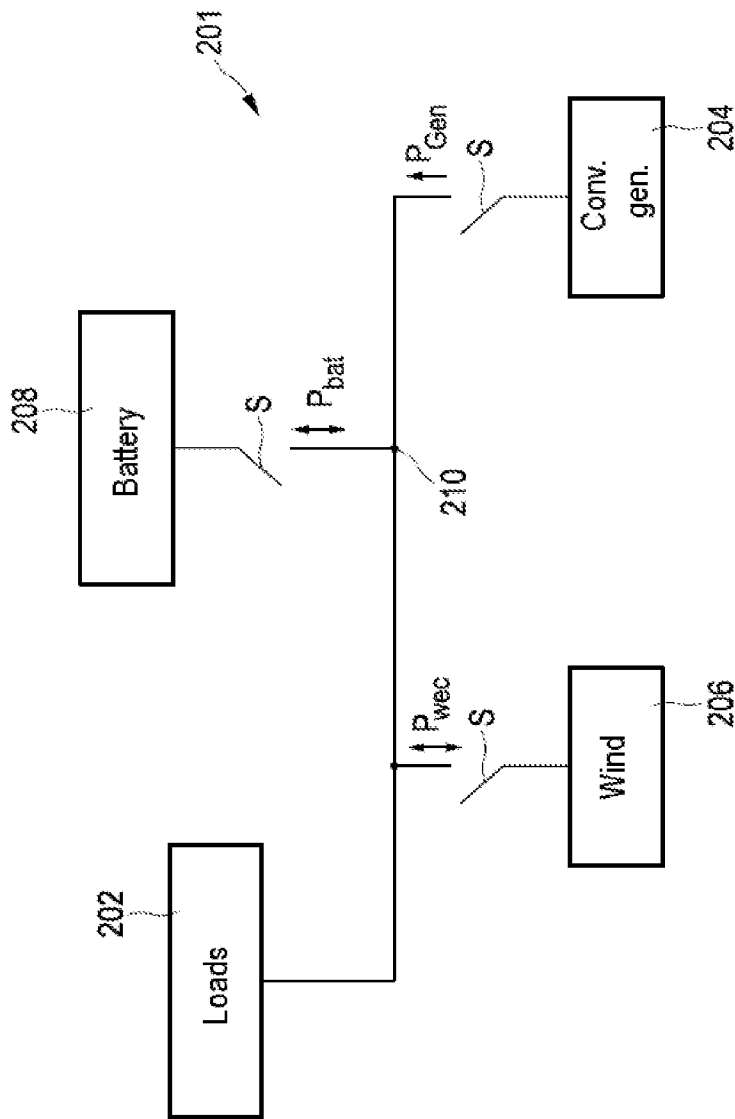


Fig. 12