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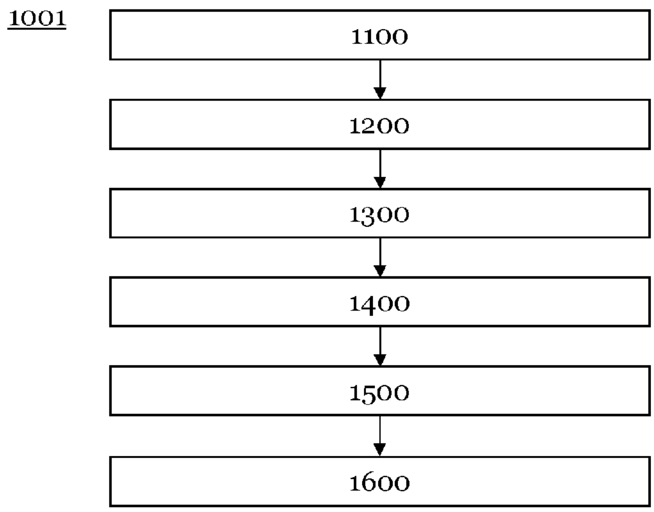

Fig. 1

(57) Abstract: The present invention is directed to a method (1001) for controlling a supply of electric power to an electricity consumer (11) with an electric power consumption P, wherein the electricity consumer (11) comprises a first power grid (10), wherein the first power grid (10) further comprises a renewable energy source (12), an energy storage (13), a non-renewable energy source (14), and a distribution network (15), wherein the distribution network (15) has an interface (16) to a second power grid (20). The method (1001) comprises the following steps: supplying (1100) an electric power Pl of the renewable energy source (12) to the electricity consumer (11); supplying (1200) an electric power P2 of the energy storage (13) to the electricity consumer (11) if the power Pl of the renewable energy source (12) is not sufficient to cover the electric power consumption P; supplying (1300) an electric power P3 of the second power grid (20) to the electricity consumer (11) if the sum of the power P 1 of the renewable energy source (12) and the power P2 of the energy storage (13) is not sufficient to cover the electric power consumption P, and supplying (1400) an electric power P4 of the non-renewable energy source (14) to the electricity consumer (11) if the sum of the power Pl of the renewable energy source (12), the power P2 of the energy storage (13), and the power P3 of the second power grid (20) is not sufficient to cover the electric power consumption P.

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CONTROLLING A SUPPLY OF ELECTRICITY TO AN ELECTRICITY CONSUMER

1. Technical field

The present disclosure relates to a method and a system for controlling a supply of electric power to an electricity consumer.

2. Prior art

Sustainability is increasingly becoming the focus of attention in the generation of electrical energy. Besides rising prices of fossil energy sources and their impact on the climate, regulatory requirements demand the minimization of carbon dioxide emissions for the generation of electrical energy. In addition, efforts are being made to minimize the use of nuclear energy in view of various reasons. For example, due to the high price compared to renewable energy sources such as photovoltaics and/or the high and often complex safety requirements.

Alongside sustainability and security of the energy that utilities generate and feed into the public power grid, the question of how private entities such as companies, that are energy consumers and have renewable and non-renewable energy sources, should utilize their energy sources, and interact with the public power grid is becoming increasingly relevant. This particularly applies regarding the target of using electricity generated with as few emissions as possible.

Currently, many private entities feed their electricity generated from renewable sources directly into the public grid. In addition, they cover most of their electricity needs from the public grid. Since the public grid in most countries is also fed with non-renewable energies, said private entities have no or at least a limited possibility to control and/or optimize their electricity mix.

Thus, at least one first objective of the present invention is to provide a solution that enables private entities to cover their energy consumption with as little carbon dioxide emissions as possible.

In addition, an aspect of why many private entities currently feed their renewable electricity directly into and draw from the public power grid is that distribution networks of said private entities, which themselves have renewable and non-renewable energy sources, are regularly complex and/or inefficient. Accordingly, their operation is often also complex and/or inefficient.

Exemplarily, according to common practice, electric power that is obtained from a solar field is introduced into an DC to AC converter before being distributed. Thus, if the private entity has several solar fields a DC to AC converter is required for each solar field. Furthermore, if for example more than one solar field is utilized to cover the energy consumption of the energy consumer, a complex synchronization of the alternating currents of the different solar fields must be conducted.

Hence, at least one second objective of the present invention is to facilitate the distribution of electric energy for private entities that themselves have renewable and non-renewable energy sources.

Thus, it is an overall object of the present disclosure to provide a method and a system for controlling a supply of electric power to private entities that contribute to reach the above objectives at least partially.

3. Summary of the invention

This overall object is achieved, at least partly, by a method and a system for controlling a supply of electric power to an electricity consumer, as defined in the independent claims. Further aspects of the present disclosure are defined in the dependent claims.

In particular, the object is achieved by a method for controlling a supply of electric power to an electricity consumer with an electric power consumption P, wherein the electricity consumer is comprised by a first power grid, wherein the first power grid further comprises a renewable energy source, an energy storage, a non-renewable energy source, and a distribution network, wherein the distribution network has an interface to a second power grid.

It is understood that controlling the supply of electric power to the electricity consumer may be conducted by a control means which may be a computer or any other processing device. The control means may be comprised by the first power grid. This may be described as the control means not being controlled by control means of the second power grid (called SCADA). However, it is conceivable that in the future the second power grid, i.e. its control means, will be intelligent enough to take into account all local parameters through adapted measurements and/or commissioning. Thus, it is conceivable that in the future the control means may be comprised by the second power grid.

Further, the electricity consumer can be, for example, a production facility, a factory, a refinery, or something similar. Further, it is understood that the electricity consumer may be an association of further energy consumers, such as an entire business park.

Renewable energy sources rely on energy sources that are practically inexhaustible in the human time horizon for sustainable energy supply or are renewed relatively quickly. Examples for such energy sources are bioenergy, geothermal energy, hydropower, ocean energy, solar energy, and wind energy. Hence, a renewable energy source according to the present disclosure may be for example a wind turbine, a photovoltaic plant, and/or a hydroelectric power plant, whereas further details are provided through the present disclosure.

In contrast to renewable energy sources, non-renewable energy sources rely on finite or slowly regenerating energy carriers. Accordingly, a non-renewable energy source according to the present disclosure may be for example a diesel engine, a gasoline engine, and/or a gas turbine.

Said energy storage generally serves to capture energy produced at one time for use at a later time. Exemplarily the energy storage may comprise a mechanical energy storage such as a flywheel, an electrochemical energy storage such as a rechargeable battery, and/or an electrical storage such as a capacitor. Thereby it is understood that a variety of further energy storages may be used.

The distribution network according to the present disclosure may distribute the electric power withing the first power grid. Further with the interface to the second power grid the distribution network according to the present disclosure may allow for electric power from the second power grid to be introduced into the first power grid. Hence, it is apparent that the distribution network may comprise transmission elements, such as cables, and other required electrical components.

The term “power grid” as used in the present disclosure may be also referred to as “electrical grid”. Accordingly, it is understood that particularly the second power grid may comprise a transmission network and a distribution network as generally known in practice.

The method according to the present disclosure comprises the following steps:

(A) supplying an electric power P1 of the renewable energy source to the electricity consumer.

(B) supplying an electric power P2 of the energy storage to the electricity consumer if the power P1 of the renewable energy source is not sufficient to cover the electric power consumption P. Hence, the electric power P2 may serve to cover the difference between the electric power consumption P and the electric power P1. However, the electric power P2 may not necessarily serve to only cover the difference between the electric power consumption P and the electric power P1. This is as a different prioritization may be chosen, for example, based on how time-stable the energy storage system allows for storing energy.

(C) supplying an electric power P3 of the second power grid to the electricity consumer if the sum of the power P1 of the renewable energy source and the power P2 of the energy storage is not sufficient to cover the electric power consumption P. Thus, the electric power P3 may serve to cover the difference between the electric power consumption P and sum of the electric power P1 and the electric power P2. However, the electric power P3 may not necessarily serve to cover the difference between the electric power consumption P and the sum of the electric power P1 and the electric power P2, as a different prioritization may be chosen. Exemplarily, during daytime more electric power P3 may be supplied if the electric power from the second power grid is estimated to be based on a high amount of renewable energy. Accordingly, a higher filling of the energy storage for the night may be achieved. Estimating the ratio of renewable electric power to non-renewable electric power provided by the second power grid is set out below.

(D) supplying an electric power P4 of the non-renewable energy source to the electricity consumer if the sum of the power P1 of the renewable energy source, the power P2 of the energy storage, and the power P3 of the second power grid is not sufficient to cover the electric power consumption P. It is understood that the electric power P4 may serve to cover the difference between the electric power consumption P and sum of the electric power P1, the electric power P2, and the electric power P3.

The method according to the present disclosure has different advantages, wherein two of them are lined out in the following in more detail.

Firstly, the method enables private entities to cover their energy consumption with as little carbon dioxide emissions as possible. Especially after an independent energy management can be operated and thereby a precise coordination between the energy consumer and the energy sources, as well as the energy storage can take place. This allows the reduction of carbon dioxide emissions through demand-driven resource planning in the first power grid.

Secondly, a more independent and/or safer power supply to the electricity consumer is enabled. It is understood that further advantages may be inherent in the method and the aforementioned advantages may apply in different manifestations to the following embodiments.

The first power grid may be independently operable from the second power grid. This may refer to the aspect that the elements of the first power grid are not controlled by any means of the second power grid. Hence, there may be a need for said control means to control the first power grid. In detail, the renewable energy source, the energy storage, the non-renewable energy source, the distribution network, and the interface to the second power grid may be independently operable from the second power grid. Thus, they may be controlled by the control means that may be comprised by the first power grid. The first power grid being independently operable from the second power grid has the advantage that in the first power grid an independent energy management can be operated and a precise coordination between the energy consumer and the energy sources, as well as the energy storage can take place. This allows the reduction of carbon dioxide emissions through demand-driven resource planning in the first power grid.

The method may further comprise the steps of estimating a ratio of renewable electric power to non-renewable electric power provided by the second power grid, and based on this ratio adjusting a ratio of the supplied electric power P3 to the supplied electric power P4.

The ratio of renewable electric power to non-renewable electric power provided by the second power grid may be estimated by considering a variety of different factors singularly or in combination with each other.

Exemplarily, a first factor may be the weather. For example, if wind and/or a low cloud cover is detected, a high ratio of renewable to non-renewable energy may be derived.

Further exemplarily, a second factor may be the time of day and/or the season. For example, in the northern hemisphere, less solar insolation can be assumed during the winter months, so that a low ratio of renewable to non-renewable energy may be derived. Apparently also during nighttime, a low ratio of renewable to non-renewable energy may be derived.

Even further exemplarily, a third factor may be the price called for energy from the second power grid. Since renewable energy sources regularly provide electric energy at lower cost than non-renewable energy sources, a high price called for energy from the second power grid may hint at a low ratio of renewable to non-renewable energy. The third factor may be of particular relevance if the price called for energy from the second power grid is determined by merit order, as for instance in Germany.

As above, the different factors may be combined. For instance, if no wind is detected during nighttime and the price called for electric energy from the second power grid is relatively high, a low ratio of renewable to non-renewable energy provided by the second power grid is estimated.

Adjusting the ratio of the supplied electric power P3 to the supplied electric power P4 may refer to the aspect that the electric power P4 does not only serve to cover the difference between the electric power consumption P and sum of the electric power P1, the electric power P2, and the electric power P3. Rather, the amount of the supplied electric power P3 may be decreased, whereas the the amount of the supplied electric power P4 is indirectly proportional increased.

The above-described further method steps of estimating and adjusting have the advantage that in the first power grid it is possible to react to the energy mix provided by the second power grid. Hereby the method further enables private entities to cover their energy consumption with as little carbon dioxide emissions as possible. This is explained in more detail below.

The ratio of the supplied electric power P3 to the supplied electric power P4 is optionally decreased if the estimated ratio of renewable electric power to non-renewable electric power provided by the second power grid is relatively low. The estimated ratio of renewable electric power to non-renewable electric power provided by the second power grid may be referred to as being “relatively low” or “low” if a predetermined threshold value is undershot.

Exemplarily, if the non-renewable energy source supplying the electric power P4 is a combined cycle power plant and the non-renewable energy sources of the second power grid are primarily based on coal, decreasing the ratio of the supplied electric power P3 to the supplied electric power P4, if the estimated ratio of renewable electric power to non-renewable electric power provided by the second power grid is relatively low can contribute to reduced carbon dioxide emissions. This is as combined cycle power plants are known for their relatively low carbon dioxide emissions compared to coal plants. Accordingly in this case the above-mentioned predetermined threshold value may depend on the estimated ratio of renewable electric power to non-renewable electric power provided by the second power grid and the efficiencies of the non-renewable electric power sources of the first and the second power grid.

In summary, decreasing the ratio of the supplied electric power P3 to the supplied electric power P4 if the estimated ratio of renewable electric power to non-renewable electric power provided by the second power grid is relatively low may contribute to reduced carbon dioxide emissions, at least in the first power grid.

Further, supplying the electric power P2 of the energy storage to the electricity consumer may be limited if a state of charge of the energy storage is below a predetermined threshold value and/or during predetermined times.

Limiting supply of electric power P2 to the electricity consumer if a state of charge of the energy storage is below a predetermined threshold value can ensure that at times when the second power grid regularly provides power that comes from non-renewable sources, less power needs to be drawn from the second power grid, for example at night. Further, limiting supply of electric power P2 to the electricity consumer if a state of charge of the energy storage is below a predetermined threshold value can ensure that fluctuations of the renewable energy source, e.g. caused by wind lulls and/or interruptions in irradiation, may be compensated. Hence, carbon dioxide emissions may be further minimized.

Further, limiting supply of the electric power P2 to the electricity consumer during predetermined times may exemplarily avoid that before nightfall the energy storage is empty and a lot of electric power coming from non-renewable sources must be drawn from the second power grid during nighttime. Thus, carbon dioxide emissions may be minimized. Thereby it is understood that the predetermined times may depend on solar insolation.

The method may further comprise the step of supplying an electric power P10 of the renewable energy source to the energy storage if a total power of the renewable energy source exceeds the electric power consumption P, and/or if the supply of electric power P1 of the renewable energy source to the electricity consumer is limited. The first power grid is thus able to store surplus energy. This allows the use of electricity produced with non-renewable energy to be avoided, e.g. during nighttime. In addition, internal transmission constraints in the first power grid can be compensated, ensuring the self-sufficiency of the first power grid.

The method may further comprise the step of supplying an electric power P11 of the renewable energy source to the second power grid if a total power of the renewable energy source exceeds the electric power consumption P and/or if the energy storage has no further capacity. It is understood that this can contribute to a better carbon footprint of the entire power system. Furthermore, supplying an electric power P11 of the renewable energy source to the second power grid allows for a further balancing option in the first power grid which can increase stability.

Optionally the second power grid is a public power grid, wherein the first power grid further optionally is a private power grid. A public power grid according to the present disclosure is operated by a DSO (Distribution System Operator). A private power grid within the meaning of the present disclosure is not operated and maintained by the same DSO as the second grid, i.e. the public power grid. Hence, as above-mentioned, there may be a need for control means to control the first power grid. In detail, the renewable energy source, the energy storage, the non-renewable energy source, the distribution network, and the interface to the second power grid may be independently operable from the second power grid. Thus, they may be controlled by the control means that may be comprised by the first power grid. The first power grid being independently operable from the second power grid has the advantage that in the first power grid an independent energy management can be operated and a precise coordination between the energy consumer and the energy sources, as well as the energy storage can take place. This allows the reduction of carbon dioxide emissions through demand-driven resource planning in the first power grid.

The renewable energy source may comprise a wind turbine, a photovoltaic plant, a hydroelectric power plant, a geothermal power source, and/or a biomass power plant. Further, it is understood that the wind turbine may be an on shore or an offshore wind turbine. Moreover, the photovoltaic plant may comprise floating solar panels. Further, it is understood that also green hydrogen may serve as renewable energy source.

The distribution network may comprise an electric connection between the electricity consumer and at least one of the following: the energy storage, the renewable energy source, the non-renewable energy source, and the interface to the second power grid.

The distribution network may comprise an electric connection between the renewable energy source and at least one of the energy storage and the interface to the second power grid.

Moreover, the distribution network may comprise a DC to AC converter, wherein the distribution network comprises an electric connection between the renewable energy source and the DC to AC converter, wherein the distribution network comprises an electric connection between the energy storage and the DC to AC converter, wherein electric power is transferred between the renewable energy source, the energy storage, and the DC to AC converter as direct current.

Said DC to AC converter may provide an alternating current to the electricity consumer. Further the DC to AC converter may be located closer to the electricity consumer than to the renewable energy source. Exemplarily the DC to AC converter may be at least twice as close to the electricity consumer than to the renewable energy source. Further exemplarily the DC to AC converter may be located at least four times, optionally at least six times, and further optionally at least eight times closer to the electricity consumer than to the renewable energy source. Accordingly, it is understood that electric power provided by the renewable energy source may be transferred to the electricity consumer primarily by means of DC transmission.

Generally, by primarily distributing electric power as direct current (DC) the number of power lines required can be reduced. Especially since DC transmission requires two conductors, whereas AC transmission regularly requires three.

Further, as mentioned in the introduction, if the renewable energy source comprises, for example, several spaced-apart photovoltaic plants, each of which is equipped with a DC to AC converter, a complex synchronization of the AC currents of the various photovoltaic plants must be carried out. This can be avoided by primarily relying on DC transmission. Moreover, no DC to AC converter and/or energy storage must be provided for each photovoltaic plant. Rather only one DC to AC converter and only one energy storage may be sufficient. Hence, the number of required electrical components may be reduced.

Thus, in summary, the distribution of electric energy for private entities that themselves have renewable and non-renewable energy sources is facilitated.

In a preferred embodiment, the DC to AC converter may be the interface to the second power grid. This is as electric power from the renewable energy source of the first grid may be then transferred into the second power grid with only one conversion. Namely a DC to AC conversion at said DC to AC converter.

It is to be noted that switching, power matching, current and voltage measurement, interconnection, and/or control can be accomplished by standard electrical equipment such as switchgear, relays, power transformers, high voltage fuses and circuit breakers, lightning arrestors, power factor correction capacitors, and/or power measurement systems. Some of these devices may be located in substations and manage the various electrical interfaces between different grid types. The required communication protocols may be based on the IEC61850 protocol, a modern communication protocol for electrical networks that handles real-time events, commissioning, operation and maintenance.

The electricity consumer may comprise a plurality of spaced apart electricity consumption units, wherein the renewable energy source is located to reduce transmission losses from the renewable energy source to the plurality of electricity consumption units. Exemplarily, said spaced apart electricity consumption units may be separate production facilities. It is understood that a renewable energy source not being located to reduce transmission losses may be identified in that a substantial relocation of this renewable energy source allows for substantially reduced transmission losses.

Different approaches for locating the renewable energy source to reduce transmission losses exist. Exemplarily, the renewable energy source may be substantially located in a barycenter of the plurality of electricity consumption units, wherein said barycenter is weighted by an average electric power required by each of the plurality of electricity consumption units. Thereby “substantially” may refer to the aspect that not a precise location in a geometrical sense is required. Further exemplarily, the renewable energy source may be located in dependence of the quality of the transmission infrastructure in order to reduce transmission losses.

By locating the renewable energy source such that transmission losses from the renewable energy source to the plurality of electricity consumption units are reduced, the method allows for a more efficient supply of the electric power P1 of the renewable energy source. Particularly when compared to grids, such as public grids, where renewable energy sources are located without considering transmission losses, e.g. caused by long transmission distances.

The above-mentioned overall object is further achieved, at least partly, by a system for controlling a supply of electric power to an electricity consumer. As will become apparent in view of the following description of the system, the same terms as for the method are used. Further, the system is configured to perform the method as described above. Hence the features and/or advantages as described above with respect to the method apply for the system as well.

The system comprises a first power grid comprising an electricity consumer with an electric power consumption P, a renewable energy source, an energy storage, a non-renewable energy source, and a distribution network with an interface to a second power grid. Further the system further comprises a control means configured for

(A) supplying an electric power P1 of the renewable energy source to the electricity consumer.

(B) supplying an electric power P2 of the energy storage to the electricity consumer if the power P1 of the renewable energy source is not sufficient to cover the electric power consumption P.

(C) supplying an electric power P3 of the second power grid to the electricity consumer if the sum of the power P1 of the renewable energy source and the power P2 of the energy storage is not sufficient to cover the electric power consumption P.

(D) supplying an electric power P4 of the non-renewable energy source to the electricity consumer if the sum of the power P1 of the renewable energy source, the power P2 of the energy storage, and the power P3 of the second power grid is not sufficient to cover the electric power consumption P.

The first power grid may be independently operable from the second power grid.

The control means may be configured for estimating a ratio of renewable electric power to non-renewable electric power provided by the second power grid, and based on this ratio adjusting a ratio of the supplied electric power P3 to the supplied electric power P4.

The control means may be configured such that the ratio of the supplied electric power P3 to the supplied electric power P4 is decreased if the estimated ratio of renewable electric power to non-renewable electric power provided by the second power grid is relatively low.

The control means may be configured such that supplying the electric power P2 of the energy storage to the electricity consumer is limited if a state of charge of the energy storage is below a predetermined threshold value and/or during predetermined times.

The control means may be configured for supplying an electric power P10 of the renewable energy source to the energy storage if a total power of the renewable energy source exceeds the electric power consumption P, and/or if the supply of electric power P1 of the renewable energy source to the electricity consumer is limited.

The control means may be configured for supplying an electric power P11 of the renewable energy source to the second power grid if a total power of the renewable energy source exceeds the electric power consumption P and/or if the energy storage has no further capacity.

The second power grid optionally is a public power grid, wherein the first power grid further optionally is a private power grid.

The renewable energy source may comprise a wind turbine, a photovoltaic plant, a hydroelectric power plant, a geothermal power source, and/or a biomass power plant.

The distribution network may comprise an electric connection between the electricity consumer and at least one of the following: the energy storage, the renewable energy source, the non-renewable energy source, and the interface to the second power grid.

The distribution network may comprise an electric connection between the renewable energy source and at least one of the energy storage and the interface to the second power grid.

The distribution network may comprise a DC to AC converter, wherein the distribution network comprises an electric connection between the renewable energy source and the DC to AC converter, wherein the distribution network comprises an electric connection between the energy storage and the DC to AC converter, wherein electric power is transferred between the renewable energy source, the energy storage, and the DC to AC converter as direct current.

The DC to AC converter may be configured to provide an alternating current to the electricity consumer. Further the DC to AC converter may be located closer to the electricity consumer than to the renewable energy source.

The electricity consumer may comprise a plurality of spaced apart electricity consumption units, wherein the renewable energy source is located to reduce transmission losses from the renewable energy source to the plurality of electricity consumption units.

The renewable energy source may be substantially located in a barycenter of the plurality of electricity consumption units, wherein said barycenter is weighted by an average electric power required by each of the plurality of electricity consumption units.

Furthermore, the above-mentioned object is further achieved, at least partly, by a computer program, comprising instructions that when carried out by at least one processor, cause the at least one processor to perform for performing a method as described above.

The above-mentioned object is further achieved, at least partly, by a non-transitory computer readable medium having stored thereon software instructions that, when carried out by at least one processor, cause the processor to perform for performing a method as described above.

The above-mentioned object is further achieved, at least partly, by a control means for controlling a supply of electric power to an electricity consumer, the control means comprising at least one processor and a memory coupled with the at least one processor; the at least one processor and memory configured to perform a method as described above. It is understood that the control means may be configured as described above throughout the description. Particularly, the control means may be comprised by the first power grid. This may be described as the control means not being controlled by control means of the second power grid (called SCADA). However, it is conceivable that in the future the control means may be comprised by the second power grid.

4. Brief description of the accompanying figures

In the following, the accompanying figures are briefly described:

Fig. 1 shows, a first exemplary method according to the present invention;

Fig. 2 shows, a second exemplary method according to the present invention;

Fig. 3 shows, a third exemplary method according to the present invention;

Fig. 4 shows, a first exemplary system according to the present invention, and

Fig. 5 shows, a second exemplary system according to the present invention.

5. Detailed description of the figures

Fig. 1 shows a first exemplary method 1001 for controlling a supply of electric power to an electricity consumer 11 with an electric power consumption P.

As depicted e.g. in the system 101 of **Fig. 4** the electricity consumer 11 is comprised by a first power grid 10, wherein said first power grid 10 further comprises a renewable energy source 12, an energy storage 13, a non-renewable energy source 14, and a distribution network 15. Thereby the distribution network 15 has an interface 16 to a second power grid 20.

Said method 1001 comprises the following steps:

(A) supplying 1100 an electric power P1 of the renewable energy source 12 to the electricity consumer 11.

(B) supplying 1200 an electric power P2 of the energy storage 13 to the electricity consumer 11 if the power P1 of the renewable energy source 12 is not sufficient to cover the electric power consumption P.

(C) supplying 1300 an electric power P3 of the second power grid 20 to the electricity consumer 11 if the sum of the power P1 of the renewable energy source 12 and the power P2 of the energy storage 13 is not sufficient to cover the electric power consumption P.

(D) supplying 1400 an electric power P4 of the non-renewable energy source 14 to the electricity consumer 11 if the sum of the power P1 of the renewable energy source 12, the power P2 of the energy storage 13, and the power P3 of the second power grid 20 is not sufficient to cover the electric power consumption P.

As further depicted in **Fig. 1**, the method 1001 comprises the optional steps of

(E) estimating 1500 a ratio of renewable electric power to non-renewable electric power provided by the second power grid 20, and based on this ratio

(F) adjusting 1600 a ratio of the supplied electric power P3 to the supplied electric power P4.

Figs. 2 and 3 show a second 1002 and a third 1003 exemplary method for controlling a supply of electric power to an electricity consumer 11 with an electric power consumption P.

The method 1002 shown in **Fig. 2** comprises the step of supplying 1100 an electric power P1 of the renewable energy source 12 to the electricity consumer 11. It is understood that the further steps performed by the method of Fig. 1 are not performed as the power P1 of the renewable energy source 12 is sufficient to cover the electric power consumption P. However, the method 1002 further comprises the step of supplying 1110 an electric power P10 of the renewable energy source 12 to the energy storage 13, as a total power of the renewable energy source 12 exceeds the electric power consumption P. Even further, the method 1002 comprises the optional step of supplying 1120 an electric power P11 of the renewable energy source 12 to the second power grid 20 as the energy storage 13 has no further capacity.

The method 1003 shown in **Fig. 3** also comprises the step of supplying 1100 an electric power P1 of the renewable energy source 12 to the electricity consumer 11, wherein it is understood that the further steps performed by the method of Fig. 1 are not performed as the power P1 of the renewable energy source 12 is sufficient to cover the electric power consumption P. The method 1003 further comprises the steps of supplying 1110 an electric power P10 of the renewable energy source 12 to the energy storage 13 and supplying 1120 an electric power P11 of the renewable energy source 12 to the second power grid 20 as a total power of the renewable energy source 12 exceeds the electric power consumption P.

Moreover, **Figs. 4 and 5** each depict a system 101; 102 for controlling a supply of electric power to an electricity consumer 11. The depicted systems 101; 102 comprises a first power grid 10 comprising an electricity consumer 11 with an electric power consumption P, a renewable energy source 12, an energy storage 13, a non-renewable energy source 14, and a distribution network 15 with an interface 16 to a second power grid 20. Further the systems 101; 102 comprise a control means 30 configured for performing a method as described above.

The first power grid 10 is independently operable from the second power grid 20. Particularly, the second power grid 20 is a public power grid, wherein the first power grid 10 is a private power grid.

As further depicted in **Fig. 4**, the distribution network 15 comprises an electric connection between the electricity consumer 11 and each of the energy storage 13, the renewable energy source 12, the non-renewable energy source 14, and the interface 16 to the second power grid 20.

As depicted in **Fig. 5**, the distribution network 15 comprises an electric connection between the electricity consumer 11 and each of the energy storage 13, the renewable energy source 12, the non-renewable energy source 14, and the interface 16 to the second power grid 20. Thereby a DC to AC converter 17 is interposed, as set out in further detail below.

Moreover, in **Figs. 4 and 5** the distribution network 15 comprises an electric connection between the renewable energy source 12 and both of the energy storage 13 and the interface 16 to the second power grid 20. Thereby in the system 102 of Fig. 5 the DC to AC converter 17 is interposed.

Furthermore, as depicted in **Fig. 5**, the distribution network 15 of the system 102 comprises a DC to AC converter 17. Thereby the distribution network 15 comprises an electric connection between the renewable energy source 12 and the DC to AC converter 17, wherein the distribution network 15 comprises an electric connection between the energy storage 13 and the DC to AC converter 17, wherein electric power is transferred between the renewable energy source 12, the energy storage 13, and the DC to AC converter 17 as direct current. Further, the DC to AC converter 17 is configured to provide an alternating current to the electricity consumer 11. Additionally, the DC to AC converter is located closer to the electricity consumer 11 than to the renewable energy source 12.

List of reference signs

101	first system
102	second system
10	first power grid
11	electricity consumer
12	renewable energy source
13	energy storage
14	non-renewable energy source
15	distribution network
16	interface
17	DC to AC converter
20	second power grid

1001	first method
1002	second method
1003	third method
1100	supplying an electric power P1
1110	supplying an electric power P10
1120	supplying an electric power P11
1200	supplying an electric power P2
1300	supplying an electric power P3
1400	supplying an electric power P4
1500	estimating a ratio of renewable electric power to non-renewable electric power
1600	adjusting a ratio of the electric power P3 to the electric power P4

Abu Dhabi National Oil Company August 4, 2022
A166684WO MAJ/Srl

CLAIMS 1 to 31

1. A method (1001; 1002; 1003) for controlling a supply of electric power to an electricity consumer (11) with an electric power consumption P, wherein the electricity consumer (11) is comprised by a first power grid (10), wherein the first power grid (10) further comprises a renewable energy source (12), an energy storage (13), a non-renewable energy source (14), and a distribution network (15), wherein the distribution network (15) has an interface (16) to a second power grid (20), wherein the method (1001; 1002; 1003) comprises the following steps:

supplying (1100) an electric power P1 of the renewable energy source (12) to the electricity consumer (11);

supplying (1200) an electric power P2 of the energy storage (13) to the electricity consumer (11) if the power P1 of the renewable energy source (12) is not sufficient to cover the electric power consumption P;

supplying (1300) an electric power P3 of the second power grid (20) to the electricity consumer (11) if the sum of the power P1 of the renewable energy source (12) and the power P2 of the energy storage (13) is not sufficient to cover the electric power consumption P, and

supplying (1400) an electric power P4 of the non-renewable energy source (14) to the electricity consumer (11) if the sum of the power P1 of the renewable energy source (12), the power P2 of the energy storage (13), and the power P3 of the second power grid (20) is not sufficient to cover the electric power consumption P.

2. The method (1001; 1002; 1003) according to the preceding claim, wherein the first power grid (10) is independently operable from the second power grid (20).

3. The method (1001) according any one of the preceding claims, wherein the method (1001) further comprises the steps of

estimating (1500) a ratio of renewable electric power to non-renewable electric power provided by the second power grid (20), and based on this ratio adjusting (1600) a ratio of the supplied electric power P3 to the supplied electric power P4.

4. The method (1001) according to the preceding claim, wherein the ratio of the supplied electric power P3 to the supplied electric power P4 is decreased if the estimated ratio of renewable electric power to non-renewable electric power provided by the second power grid (20) is relatively low.

5. The method (1001) according to any one of the preceding claims, wherein supplying (1200) the electric power P2 of the energy storage (13) to the electricity consumer (11) is limited

if a state of charge of the energy storage (13) is below a predetermined threshold value and/or

during predetermined times.

6. The method (1002; 1003) according to any one of the preceding claims, wherein the method (1002; 1003) further comprises the step of

supplying (1110) an electric power P10 of the renewable energy source (12) to the energy storage (13)

if a total power of the renewable energy source (12) exceeds the electric power consumption P, and/or

if the supply of electric power P1 of the renewable energy source (12) to the electricity consumer (11) is limited.

7. The method (1002; 1003) according to any one of the preceding claims, wherein the method (1002; 1003) further comprises the step of

supplying (1120) an electric power P11 of the renewable energy source (12) to the second power grid (20)

if a total power of the renewable energy source (12) exceeds the electric power consumption P and/or

if the energy storage (13) has no further capacity.

8. The method (1001; 1002; 1003) according to any one of the preceding claims, wherein the second power grid (20) is a public power grid, wherein the first power grid (10) optionally is a private power grid.

9. The method (1001; 1002; 1003) according to any one of the preceding claims, wherein the renewable energy source (12) comprises a wind turbine, a photovoltaic plant, a hydroelectric power plant, a geothermal power source, and/or a biomass power plant.

10. The method (1001; 1002; 1003) according to any one of the preceding claims, wherein the distribution network (15) comprises an electric connection between the electricity consumer (11) and at least one of the following: the energy storage (13), the renewable energy source (12), the non-renewable energy source (14), and the interface (16) to the second power grid (20).

11. The method (1001; 1002; 1003) according to any one of the preceding claims, wherein the distribution network (15) comprises an electric connection between the renewable energy source (12) and at least one of the energy storage (13) and the interface (16) to the second power grid (20).

12. The method (1001; 1002; 1003) according to any one of the preceding claims, wherein the distribution network (15) comprises a DC to AC converter (17), wherein the distribution network (15) comprises an electric connection between the renewable energy source (12) and the DC to AC converter (17), wherein the distribution network (15) comprises an electric connection between the energy storage (13) and the DC to AC converter (17), wherein electric power is transferred between the renewable energy source (12), the energy storage (13), and the DC to AC converter (17) as direct current.

13. The method (1001; 1002; 1003) according to the preceding claim, wherein the DC to AC converter (17) provides an alternating current to the electricity consumer (11), and wherein the DC to AC converter (17) is located closer to the electricity consumer (11) than to the renewable energy source (12).

14. The method (1001; 1002; 1003) according to any one of the preceding claims, wherein the electricity consumer (11) comprises a plurality of spaced apart electricity consumption units, wherein the renewable energy source (12) is located to reduce transmission losses from the renewable energy source (12) to the plurality of electricity consumption units, wherein optionally the renewable energy source (12) is

substantially located in a barycenter of the plurality of electricity consumption units, wherein said barycenter is weighted by an average electric power required by each of the plurality of electricity consumption units.

15. A system (101; 102) for controlling a supply of electric power to an electricity consumer (11), wherein the system (101; 102) comprises

a first power grid (10) comprising

an electricity consumer (11) with an electric power consumption P;

a renewable energy source (12) ;

an energy storage (13);

a non-renewable energy source (14), and

a distribution network (15) with an interface (16) to a second power grid (20), wherein the system (101; 102) further comprises

a control means (30) configured for

supplying an electric power P1 of the renewable energy source (12) to the electricity consumer (11);

supplying an electric power P2 of the energy storage (13) to the electricity consumer (11) if the power P1 of the renewable energy source (12) is not sufficient to cover the electric power consumption P;

supplying an electric power P3 of the second power grid (20) to the electricity consumer (11) if the sum of the power P1 of the renewable energy source (12) and the power P2 of the energy storage (13) is not sufficient to cover the electric power consumption P, and

supplying an electric power P4 of the non-renewable energy source (14) to the electricity consumer (11) if the sum of the power P1 of the renewable energy source (12), the power P2 of the energy storage (13), and the power P3 of the second power grid (20) is not sufficient to cover the electric power consumption P.

16. The system (101; 102) according to the preceding claim, wherein the first power grid (10) is independently operable from the second power grid (20).

17. The system (101; 102) according to any one of the preceding claims, wherein the control means (30) is configured for

estimating a ratio of renewable electric power to non-renewable electric power provided by the second power grid (20), and based on this ratio

adjusting a ratio of the supplied electric power P3 to the supplied electric power P4.

18. The system (101; 102) according to any one of the preceding claims, wherein the control means (30) is configured such that the ratio of the supplied electric power P3 to the supplied electric power P4 is decreased if the estimated ratio of renewable electric power to non-renewable electric power provided by the second power grid (20) is relatively low.

19. The system (101; 102) according to any one of the preceding claims, wherein the control means (30) is configured such that supplying the electric power P2 of the energy storage (13) to the electricity consumer (11) is limited

if a state of charge of the energy storage (13) is below a predetermined threshold value and/or

during predetermined times.

20. The system (101; 102) according to any one of the preceding claims, wherein the control means (30) is configured for

supplying an electric power P10 of the renewable energy source (12) to the energy storage (13)

if a total power of the renewable energy source (12) exceeds the electric power consumption P, and/or

if the supply of electric power P1 of the renewable energy source (12) to the electricity consumer (11) is limited.

21. The system (101; 102) according to any one of the preceding claims, wherein the control means (30) is configured for

supplying an electric power P11 of the renewable energy source (12) to the second power grid (20) if a total power of the renewable energy source (12) exceeds the electric power consumption P and/or

if the energy storage (13) has no further capacity.

22. The system (101; 102) according to any one of the preceding claims, wherein the second power grid (20) is a public power grid, wherein the first power grid (10) optionally is a private power grid.

23. The system (101; 102) according to any one of the preceding claims, wherein the renewable energy source (12) comprises a wind turbine, a photovoltaic plant, a hydroelectric power plant, a geothermal power source, and/or a biomass power plant.

24. The system (101; 102) according to any one of the preceding claims, wherein the distribution network (15) comprises an electric connection between the electricity consumer (11) and at least one of the following: the energy storage (13), the renewable energy source (12), the non-renewable energy source (14), and the interface (16) to the second power grid (20).

25. The system (101; 102) according to any one of the preceding claims, wherein the distribution network (15) comprises an electric connection between the renewable energy source (12) and at least one of the energy storage (13) and the interface (16) to the second power grid (20).

26. The system (102) according to any one of the preceding claims, wherein the distribution network (15) comprises a DC to AC converter (17), wherein the distribution network (15) comprises an electric connection between the renewable energy source (12) and the DC to AC converter (17), wherein the distribution network (15) comprises an electric connection between the energy storage (13) and the DC to AC converter (17), wherein electric power is transferred between the renewable energy source (12), the energy storage (13), and the DC to AC converter (17) as direct current.

27. The system (102) according to the preceding claim, wherein the DC to AC converter (17) is configured to provide an alternating current to the electricity consumer (11), and wherein the DC to AC converter (17) is located closer to the electricity consumer (11) than to the renewable energy source (12).

28. The system (101; 102) according to any one of the preceding claims, wherein the electricity consumer (11) comprises a plurality of spaced apart electricity consumption

units, wherein the renewable energy source (12) is located to reduce transmission losses from the renewable energy source (12) to the plurality of electricity consumption units, wherein optionally the renewable energy source (12) is substantially located in a barycenter of the plurality of electricity consumption units, wherein said barycenter is weighted by an average electric power required by each of the plurality of electricity consumption units.

29. A computer program, comprising instructions that when carried out by at least one processor, cause the at least one processor to perform for performing a method (1001; 1002; 1003) accruing to any one of claims 1 to 14.

30. A non-transitory computer readable medium having stored thereon software instructions that, when carried out by at least one processor, cause the processor to perform for performing a method (1001; 1002; 1003) accruing to any one of claims 1 to 14.

31. A control means for controlling a supply of electric power to an electricity consumer (11), the control means comprising at least one processor and a memory coupled with the at least one processor; the at least one processor and memory configured to perform a method (1001; 1002; 1003) accruing to any one of claims 1 to 14.

1001

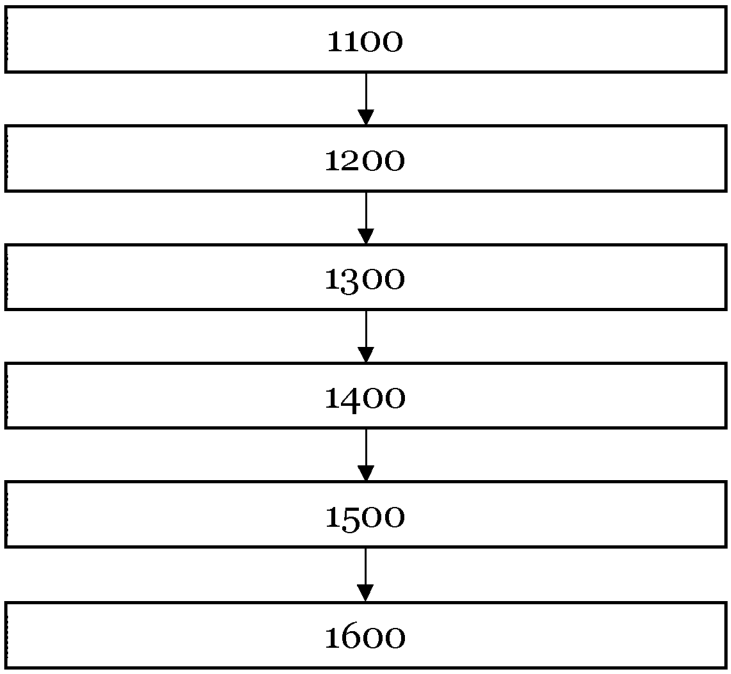

Fig. 1

1002

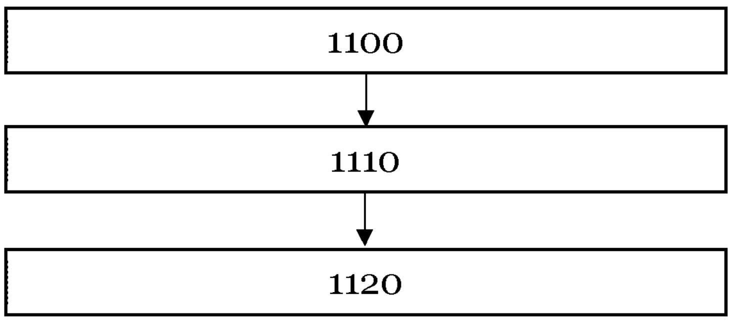

Fig. 2

1003

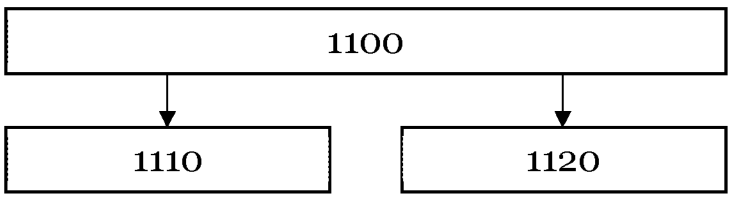

Fig. 3

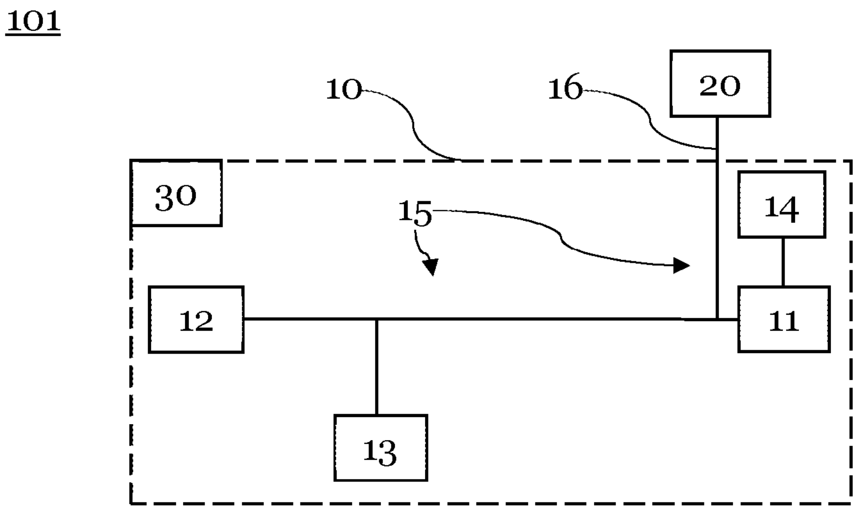

Fig. 4

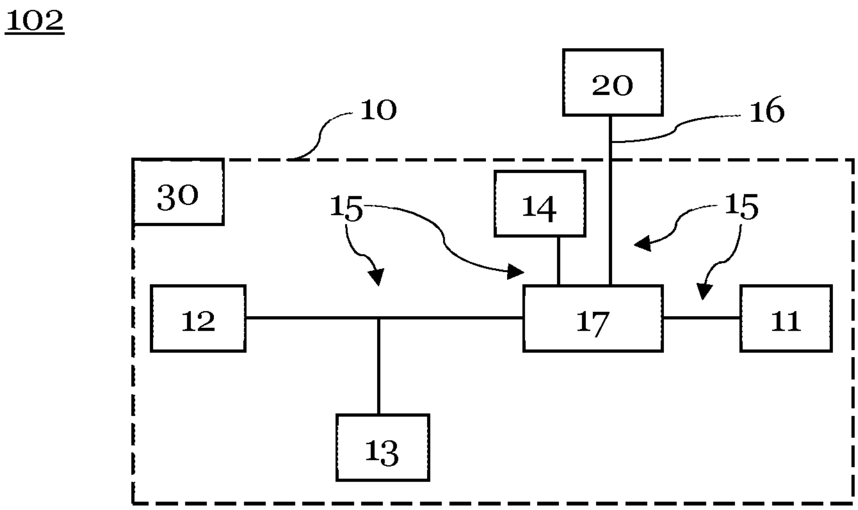

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 2022/057257

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***H02J 3/38*** (2006.01); ***H02J 3/28*** (2006.01); ***H02J 3/32*** (2006.01); ***H02J 3/46*** (2006.01); ***H02J 1/14*** (2006.01); *G06Q 50/06* (2012.01)

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

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
H02J, G06Q

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 2017366011 A1 (LI TING-KUAN [TW], CHEN YEN-HAW [TW], CHANG CHUN-DER [TW], WANG WEN-CHIEH [TW], TSAI SUNG-FENG [TW], LIN CHENG-SHAN [TW], LU SU-YING [TW]) 21 December 2017 (21.12.2017) abstract; Figs. 1, 4A, 4B; paragraphs [0017], [0028] - [0029], [0068] - [0069]	1 - 31
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Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 March 2023 (31.03.2023)	06 April 2023 (06.04.2023)

Name and mailing address of the ISA/AT	Authorized officer
Austrian Patent Office Dresdner Straße 87, A-1200 Vienna Telephone No. +43 (1) 53424 342	Englisch Martin Telephone No. +43 1 534 24 565

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