

DEVICE FOR UNINTERRUPTIBLE SUPPLY OF POWER, COMPRISING AN ENERGY STORAGE MEANS AND A ROTATING ELECTRIC MACHINE

TECHNICAL FIELD OF THE INVENTION

The invention relates to an apparatus for uninterruptible power supply comprising a rotating electric machine having a generator winding and a motor winding which is electrically insulated from the generator winding, and an energy storage for electric energy which is connected to the motor winding via an inverter outputting an alternating current.

By means of such an apparatus for uninterruptible power supply which is here also shortly designated as UPS, it is not only possible to at least temporarily supply an electric load with electric power in case of breakdown of a supply grid. If the generator winding is, for example, connected to a tap of a grid choke between the supply grid and the load, the apparatus also enhances the quality of the energy supply of the load by the supply grid in that it levels voltage variations of the supply grid.

When the UPS overtakes the power supply of the load in case of a breakdown of the supply grid, it takes the required electric energy out of the energy storage. Even in switching-on the energy storage, there is a positive effect of the enhancement of the quality of the power supply by the rotating electric machine.

PRIOR ART

The product UBTD+ of the applicant is an UPS comprising the features of the preamble of independent claim 1. The generator winding is provided for connection to a tap of a grid choke, which is closer to the load to be supplied than to the supply grid.

Either a fly wheel or a battery is connected as an energy storage to the generator winding via the inverter. The rotor of the electric machine can also be coupled to a diesel motor to be able to supply the load with electric energy not only for a short term but also over longer periods of time. The respective energy storage may be charged out of the supply grid via the generator winding and the motor winding. For this purpose, the inverter via which the energy storage is connected

to the motor winding has to be made bi-directional, and, during the charge process, the generator winding is used as a motor winding and the motor winding is used as a generator winding. However, it is also possible to charge the energy storage via a further inverter directly out of the supply grid. In the known UPS, the generator winding and the motor winding are designed for low voltages of less than 1,000 V, typically of about 600 V. If the known UPS is connected to a medium voltage grid, a transformer is connected between the generator winding and the grid choke. The known product UBTD+ may provide powers of up to 3,000 kW. In order to cover a higher demand of power, several such products are connected in parallel, wherein the electric powers provided by the individual UPSs have to be coordinated.

WO 2019/088498 A1 discloses an power generation system using energy storage devices. The power generation system includes a generator shaft on which a drive motor is mounted and rotates, a plurality of no-load DC or AC generators installed on the generator shaft to produce electricity, a connection circuit board for receiving DC or AC electricity generated from the no-load DC or AC generators, a plurality of energy storage devices connected in parallel to the connection circuit board to store and supply electricity, and a main energy storage device connected in series with one or more dedicated energy storage devices selected from the energy storage devices to supply power to the drive motor. In case of the AC generators there is an additional AC/DC converter for receiving AC electricity from the connection circuit board and converting it into DC electricity, and a plurality of energy storage devices is connected in parallel to the AC/DC converter.

OBJECT OF THE INVENTION

It is the problem of the invention to provide an apparatus for uninterruptible power supply of the kind described at the beginning which is suitable for providing higher electric powers and furthermore also for direct connection to a medium voltage grid.

SOLUTION

The problem of the invention is solved by an apparatus for uninterruptible power supply comprising the features of independent claim 1. The dependent claims relate to preferred embodiments of the apparatus according to the invention.

DESCRIPTION OF THE INVENTION

In an apparatus according to the invention for uninterruptible power supply, a rotating electric machine comprises a generator winding and several motor windings which are electrically insulated from the generator winding and from one another. Per each motor winding, an energy storage for electric energy and an inverter outputting an alternating current, via which the energy storage is connected to the respective motor winding, are present.

In that the UPS according to the invention comprises several energy storages at several motor windings, which are each connected via an inverter, the electric power of the UPS can be multiplied using hitherto used energy storages, i.e. without increasing the power of the individual energy storages. The inverters and motor windings assigned to the individual energy storages may also remain the same. There is no need to configure them for a higher power than hitherto. Essentially, only the generator winding has to be adapted to the higher power. Because the electric power flowing via the generator winding no longer needs to flow via an inverter but may directly or via a grid choke flow to the load to be supplied, this can be handled with known means. Instead of multiplying all of its components, the higher electric power of the new UPS is achieved by only multiplying its motor windings and its energy storages inclusive of the associated inverters.

In the apparatus according to the invention, the several motor windings are preferably equal or equivalent. The connected energy storages as well as the inverters which connect the energy storages to the motor windings may also be equal or at least equivalent. With an equal configuration of the individual energy storages, these energy storages may be controlled in a similar way. Generally, however, it is also possible to combine different energy storages in the apparatus according to the invention, like, for example, a flywheel which here always refers to the flywheel inclusive of its electric machine, and a battery to provide electric power very quickly on the one hand and for a longer term on the other hand, or to protect the battery against power variations.

In a same way as the generator winding, the motor windings and the inverters of the apparatus according to the invention connected thereto may each be single phase or three-phase. Generally, a two-phase configuration or a mixture of differently phased motor windings is also possible. However, a uniform single phase or three-phase configuration is preferred. Whether a single phase or a three-phase configuration is more suitable depends on the electric power of the individual energy storages. For a higher electric power, a three-phase configuration of the

individual motor windings is more suitable due to the lower current through the individual phase windings at a same voltage.

The individual motor windings of the apparatus according to the invention may be configured for current feed at offset phases or synchronous phases. With a current feed at offset phases, the even speed of the rotating electric machine can be optimized. Motor windings for a current feed at synchronous phases may result in a more simple overall construction of the rotating electric machine.

Corresponding to the configuration of the motor windings, the individual inverters of the plurality of energy storages of the apparatus according to the invention have to be synchronized with or without a phase offset.

In the apparatus according to the invention, the rotating electric machine is configured as a rotating transformer which transforms a motor alternating voltage present across the motor windings into an at least three times as high generator alternating voltage present across the generator winding. The transformation ratio may even be at least five or at least ten. The transformation ratio of the rotating electric machine of the apparatus according to the present invention is indicated by the fact that the generator winding has at least three times or at least five times or at least ten times as many windings per phase as each of the motor windings.

The apparatus according to the invention may particularly be designed such that the inverters provide low voltages as motor alternating voltages at the motor windings and that the electric machine outputs a medium voltage as a generator alternating voltage at the generator winding. Thus, the generator winding may be directly connected to a medium voltage grid even without a transformer.

Besides the transformation, the electric machine of the apparatus according to the invention may also effect a frequency conversion between the motor windings and the generator winding. Thus, for example, the inverters may each be designed for motor alternating voltages of 400 Hz which are reduced by the rotating electric machine to a generator alternating voltage of 50 Hz.

As already mentioned, the generator winding is typically connected to a tap of a grid choke which is connectible between a supply grid and a load to be supported, wherein the tap, as a rule, is closer to the load than to the supply grid.

Particularly, the grid choke may be a medium voltage grid choke which is connectible between a medium voltage grid and a medium voltage load.

5 In detail, the electric machine of the apparatus according to the invention may comprise a synchronous machine having a common stator onto which the several motor windings and the generator winding are wound and a brushlessly excited rotor common for the motor windings and the generator winding. Due to the different motor windings, the electric machine is a custom machine. However, each individual winding may have a conventional design.

10 As already indicated, the energy storages may, for example, include static energy storages, like for example batteries, and rotating energy storages, like for example flywheels. In this context, supercapacitors also belong to the batteries. In any case, the present invention is not limited to a certain kind of energy storage. Particularly, there is no need that the energy storages provide a direct voltage which is then inverted into an alternating voltage by the associated inverter. The energy storage may also supply an alternating voltage, like for example a flywheel with an electric machine in form of an alternating voltage generator.

15 In the apparatus according to the invention, a coupling may be provided via which an output shaft of a combustion engine can be coupled to the rotor of the electric machine to operate it driven by the electric machine as a generator for longer terms than it would be possible out of the energy storage connected to the motor windings.

20 Advantageous developments of the invention result from the claims, the description and the drawings.

The advantages of features and of combinations of a plurality of features mentioned at the beginning of the description only serve as examples and may be used alternatively or cumulatively without the necessity of embodiments according to the invention having to obtain these advantages.

25 The following applies with respect to the disclosure - not the scope of protection - of the original application and the patent: Further features may be taken from the drawings, in particular from the illustrated designs and the dimensions of a plurality of components with respect to one another as well as from their relative arrangement and their operative connection. The combination of features of different embodiments of the invention or of features of different claims independent

of the chosen references of the claims is also possible, and it is motivated herewith. This also relates to features which are illustrated in separate drawings, or which are mentioned when describing them. These features may also be combined with features of different claims. Furthermore, it is possible that further embodiments of the invention do not have the features mentioned in the claims which, however, does not apply to the independent claims of the granted patent.

The number of the features mentioned in the claims and in the description is to be understood to cover this exact number and a greater number than the mentioned number without having to explicitly use the adverb "at least". For example, if an inverter is mentioned, this is to be understood such that there is exactly one inverter or there are two inverters or more inverters. The features listed in the claims may be supplemented by further features or be the only features of the respective product.

The reference signs contained in the claims are not limiting the extent of the matter protected by the claims. Their sole function is to make the claims easier to understand.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention is further explained and described by means of preferred embodiment examples depicted in the figures.

Fig. 1 is a schematic single line circuit diagram of a first embodiment of an apparatus according to the invention for uninterruptible power supply, and

Fig. 2 is a schematic single line circuit diagram of a second embodiment of the apparatus according to the invention.

DESCRIPTION OF THE DRAWINGS

The apparatus 1 for uninterruptible power supply depicted in **Fig. 1**, which in the following will also shortly be called UPS 1, includes, as a central element, a rotating electric machine 2 having a generator winding 3 or G and, in the present case, four motor windings 4 to 7 or M1 to M4. The generator winding 3 and the motor windings 4 to 7 are electrically insulated from one another,

and they may be single phase or multi-phase windings. Typically, both the generator winding 3 and each of the motor windings 4 to 7 are three-phase windings. The windings 3 to 7 are wound onto a common stator of the electric machine 2. The generator winding 3 is coupled with the motor windings 4 to 7 via a rotor 30 of the electric machine 2. The electric machine 2 is designed as a rotating transformer which upwardly transforms a motor alternating voltage present at the motor windings 4 to 7 in the lower voltage range of, for example, 600 V into a generator alternating voltage at the generator winding 3 in the medium voltage range of, for example, 10 kV. Thus, the electric machine 2 is provided for connection to a tap 8 of a medium voltage grid choke 9. The medium voltage grid choke 9 is connected between a medium voltage supply grid 10 and a medium voltage load 11. The tap is closer to the medium voltage load 11 than to the supply grid 10, and a disconnect switch 12 which has to be open in case of a breakdown of the medium voltage supply grid 10 is on that side of the medium voltage grid choke 9 facing towards the medium voltage supply grid 10. In an optional bypass 13 bypassing the medium voltage grid choke 9, a bypass switch 29 for activating and deactivating the bypass is provided. In grid operation, the grid alternating voltage of the medium voltage grid 10 is present at the generator winding 3 even if only the bypass switch 29 is closed. Then, the generator winding 3 serves as a motor winding for the electric machine 2. Using the motor windings 4 to 7 as generator windings, energy storages 18 to 21 for electric energy may be charged via bidirectional AC/AC-inverters 14 to 17. This electric energy is then available in case of a breakdown of the supply grid 10. Depending on the type of the energy storage, the inverters 14 to 17 may alternatively be DC/AC-inverters. Here, the AC/AC-inverters are adapted to rotating energy storages 18 to 21 in form of electric machines with flying masses coupled to their rotors. In case of a breakdown of the supply grid 10, the electric energy out of the energy storages 18 to 21 is fed into the motor windings 4 to 7 via the associated inverters 14 to 17, and supplied to the load 11 via the generator winding 3 and the medium voltage grid choke 9. Additionally, a combustion engine 23 can be coupled to the rotor 30 of the electric machine 2 via a coupling 22 to be able to even bridge longer term breakdowns of the supply grid 10 by means of the UPS 1. Due to the plurality of the motor windings 4 to 7 and the connected energy storages 18 to 21 the power of the UPS 1 is multiplied as compared to a single motor winding with a single energy storage. At the same time, the electric machine designed as a rotating transformer replaces an additional static transformer to transform the input side lower voltage of the electric machine 2 into an output side medium voltage.

The embodiment of the UPS 1 depicted in **Fig. 2** differs from the embodiment according to Fig. 1 with regard to the following details. The electric machine 2 does not comprise four but three motor windings 4 to 6 or M1 to M3, respectively, to which three energy storages 18 to 20 are connected

each via an inverter 14 to 16. Further, the optional bypass 13 bypassing the medium voltage grid choke 9 is not present. The energy storages 18 to 20 are two batteries 24 or battery banks and one flywheel 25 with a flywheel mass 28 coupled to the rotor 26 of an electric machine 27, here. The flywheel 25 may particularly be provided for short time providing varying electric power, whereas the batteries 24 provide a relatively constant basic power.

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LIST OF REFERENCE NUMERALS

1	apparatus for uninterruptible power supply (UPS)
2	rotating electric machine
3	generator winding
4 to 7	motor winding
8	tap
9	medium voltage grid choke
10	medium voltage grid
11	medium voltage load
12	disconnect switch
13	bypass
14 to 17	inverter
18 to 21	energy storage
22	coupling
23	combustion engine
24	battery
25	flywheel
26	rotor
27	electric machine
28	flywheel mass
29	bypass switch
30	rotor

CLAIMS

1. Apparatus (1) for uninterruptible power supply, comprising
 - a rotating electric machine (2) having a generator winding (3) and a motor winding (4-7) which is electrically insulated from the generator winding (3), and
 - an energy storage (18-21) for electric energy which is connected to the motor winding (4-7) via an inverter (14-17) outputting an alternating current,**characterized in**
 - that the rotating electric machine (2) has at least one further motor winding (4-7) which is electrically insulated from the generator winding (3) and the motor winding (4-7) and to which at least one further energy storage (18-21) for electric energy is connected via a further inverter (14-17) outputting a further alternating current; and
 - that the rotating electric machine (2) is made as a rotating transformer which transforms a motor alternating voltage that is present at the motor winding (4-7) into a generator alternating voltage that is present at the generator winding (3) and that is at least three times as high as the motor alternating voltage.
2. Apparatus (1) of claim 1, **characterized in** that the motor winding (4-7) and the at least one further motor winding (4-7) are equal.
3. Apparatus (1) of claim 1 or 2, **characterized in** that the motor winding (4-7) and the inverter connected thereto as well as the at least one further motor winding (4-7) and the further inverter (14-17) connected thereto are single phase or three-phase.
4. Apparatus (1) of any of the preceding claims, **characterized in** that the motor winding (4-7) and the at least one further motor winding (4-7) are configured for current feed at offset phases or synchronous phases.
5. Apparatus (1) of claim 4, **characterized in** that separate inverters (14-17) of the energy storage (18-21) and the at least one further energy storage (18-21) are synchronized with or without a phase offset.

6. Apparatus (1) of any of the preceding claims, **characterized in** that the generator alternating voltage that is present at the generator winding (3) is at least five times or at least ten times as high the motor alternating voltage that is present at the motor winding (4-7).
7. Apparatus (1) of any of the preceding claims, **characterized in** that the generator winding (3) has at least three times or at least five times or at least ten times as many windings per phase as the motor winding (4-7) or as each of the motor winding (4-7) and the at least one further motor winding (4-7).
8. Apparatus (1) of any of the preceding claims, **characterized in** that the inverter (14-17) and the further inverter (14-17) provide low voltages of, for example, 600 V as motor alternating voltages at the motor winding (4-7) and the at least one further motor winding (4-7), and that the electric machine (2) outputs a medium voltage of, for example, 10 kV as a generator alternating voltage at the generator winding (3).
9. Apparatus (1) of any of the preceding claims, **characterized in** that the generator winding (3) is connected to a tap of a grid choke which is connectable between a supply grid and a load to be supported.
10. Apparatus (1) of claim 9, **characterized in** that the grid choke is a medium voltage grid choke which is connectable between a medium voltage grid and a medium voltage load.
11. Apparatus (1) of any of the preceding claims, **characterized in** that the electric machine (2) is a synchronous machine having a common stator onto which the motor winding (4-7), the at least one further motor winding (4-7) and the generator winding (3) are wound, and a brushlessly excited rotor common for the motor windings (4-7) and the generator winding (3).
12. Apparatus (1) of any of the preceding claims, **characterized in** that the energy storage (18-21) and the at least one further energy storage (18-21) are selected from static and rotating energy storages.
13. Apparatus (1) of at least one of the preceding claims, **characterized in** that a coupling (22) is provided via which an output shaft of a combustion engine (23) can be coupled to the rotor (30) of the electric machine (2).