Title
Method for controlling an inverter, and inverter

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Abstract:

The invention relates to a method of controlling an inverter (1), and to such an inverter (1). The invention provides for the power supply network (6) to be monitored by a network-monitoring unit (11), and provides that as a function of the power supply network (6), the inverter (1) is switched by the control device (8) between a network-connected operation, in which at least the input DC/DC converter (2) and the output DC/AC converter (4) are activated to feed the inverter-generated AC voltage into the power supply network (6), and an isolated operation, in which the input DC/DC converter (2) and/or an additional storage DC/DC converter (9) connectable to an optional energy storage (10) as well as the output DC/AC converter (4) are activated to feed the inverter-generated AC voltage to the consumers (7).
Method of controlling an inverter, and inverter

The invention relates to a method of controlling an inverter which converts DC voltage generated by an energy source into AC voltage via at least one input DC/DC converter, an intermediate circuit and an output DC/AC converter for feeding consumers and/or for feeding into a power supply network, wherein the components of the inverter are controlled by means of a control device.

The invention likewise relates to an inverter for converting the DC voltage generated by an energy source into an AC voltage via at least one input DC/DC converter, an intermediate circuit and an output DC/AC converter for feeding consumers and/or for feeding into a power supply network, wherein the input DC/DC converter is connected to a control device. The inverter is preferably comprised of a high-frequency (HF) inverter.

The object of the invention is to upgrade a network-connected inverter such that the consumers will be supplied with energy even after a network failure.

JP 2005-137124 A shows a solar plant with an energy storage that is arranged in parallel and controlled appropriately by a power-saving circuit so as to achieve the optimum efficiency to allow for the consumers to be supplied with electrical energy in an optimum and trouble-free manner.

JP 2005-117871 A describes a battery-charging device which detects when a battery to be charged is connected and which, to this end, correspondingly controls a charge pulse generator.

US 6,239,579 B1 relates to a device for managing a battery pack, wherein a control device activates switches appropriately so as to test individual battery modules under load without jeopardizing the charge capacity of the whole battery pack.

JP 2006-320099 A shows a system for storing electrical energy, which system will ensure the supply of at least the most important consumers with electrical energy via a battery after a voltage dip of the power supply network has been detected.

JP 08-223816 A describes an inverter system comprising a battery whose charge condition is monitored so as to allow for an optimum inverter operation.

JP 10-031525 A shows a solar-energy-producing system comprising a storage battery via which changes in the incident so-
lar radiation are balanced.

US 6,081,104 A describes a system for supplying a battery and at the same time an illumination system with electrical energy. Here, the load is operated in an optimum manner while the battery is kept at as high a charge condition as possible.

Finally, JP 2001-095179 A describes an apparatus for supplying a load with electrical energy via a battery, even in case of a network failure.

In terms of method, the object of the invention is achieved in that the power supply network is monitored by a network-monitoring unit, and that as a function of the power supply network, the inverter is switched by the control device between a network-connected operation, in which at least the input DC/DC converter and the output DC/AC converter are activated to feed the inverter-generated AC voltage into the power supply network, and an isolated operation, in which the input DC/DC converter and/or an additional storage DC/DC converter connectable to an optional energy storage as well as the output DC/AC converter are activated to feed the inverter-generated AC voltage to the consumers. What is advantageous here is that the inverter can be operated both in the network-connected operation and in the isolated operation, wherein the components additionally necessary for the isolated operation do in particular not affect the high efficiency of the inverter during network-connected operation. It is likewise of advantage that the large input-voltage range of a network-connected inverter will be maintained. It is furthermore of advantage that switching to the isolated operation allows for at least some of the consumers to be still supplied with electrical energy in case of a power supply failure. It is likewise advantageous that the supply is possible during network-connected operation without the optional energy storage as well. Thus, the expensive energy storage may be refitted if need be only. Finally, the energy storage can advantageously be exchanged or upgraded during operation while the intermediate circuit will not be supplied by the energy storage. The measure of monitoring the power supply network by a network-monitoring unit allows for the information on whether a power supply network is present or not to be available at any time.

Advantageously, the energy storage that is optionally connectable to the storage DC/DC converter is detected automati-
cally, e.g. via the input voltage applying to the storage DC/DC converter. Thus, there will be no additional effort for the user after the energy storage has been connected.

According to a further feature of the invention, it is provided that the charge condition of the energy storage is detected. This can be done by continuous or cyclic requests.

Advantageously, in the network-connected operation the intermediate circuit of the inverter is fed by the input DC/DC converter, and at least the output DC/AC converter is fed by the intermediate circuit.

Advantageously, the energy storage is charged with energy by the energy source or the power supply network as a function of the charge condition of the energy storage detected. The measure of requesting the charge condition and optionally recharging the energy storage ensures an energy storage which is always fully charged for isolated operation. Advantageously, the storage DC/DC converter is activated as a function of the charge condition of the energy storage for charging the same so that the energy storage is charged via the intermediate circuit and the storage DC/DC converter. The intermediate circuit of the inverter will be loaded to a minimum extent only thanks to the measure that the storage DC/DC converter will be activated as a function of the charge condition of the energy storage only, i.e. only temporarily, so as to compensate for the self discharge of the storage. The high efficiency of the HF inverter during network-connected operation will thus be substantially not affected. This applies in particular due to the measure that the intermediate circuit will continue to supply the output DC/AC converter without any interruptions.

In case of a fully-loaded energy storage the storage DC/DC converter will advantageously be again deactivated.

During isolated operation of the inverter the intermediate circuit is advantageously fed by the input DC/DC converter and/or by the storage DC/DC converter as a function of the power supplied by the energy source, and the output DC/AC converter is fed by the intermediate circuit. This ensures supply of the consumers even if the energy source, e.g. a solar module at night, does not supply any or insufficient energy. The optional energy storage can thus feed the consumers also via the storage DC/DC converter and the output DC/AC converter.
The storage DC/DC converter is advantageously again deactivated as a function of the power delivered by the energy source. Finally, the storage DC/DC converter can be completely activated as a function of the energy-storage charge condition, and of the power supplied by the energy source, and the energy storage can be charged. This is gentle to the energy storage and it can optionally be recharged. Life span of the energy storage and the feed time of the consumers from the energy storage can thus be increased. Furthermore, this also allows for a stable output voltage at any time.

In case a failure of the power supply network has been detected, there will be an advantageously automatic switch from the network-connected operation to the isolated operation. This ensures a substantially interruption-free power supply at least for a limited period of time.

According to a further feature of the invention, it is provided that the inverter will be disconnected from the power supply network after a failure of the power supply network has been detected. This measure allows for the entire energy to be provided to the consumers, and that no energy will be consumed via the power supply network.

In case a present power supply network has been again detected, there will be an advantageously automatic switch of the inverter from isolated operation to network-connected operation. As soon as a power supply network is again available, the inverter-generated energy will be fed into the former. The provided energy is usually financially compensated for by the operators of the power supply network, which is why the inverter operation is more economical for the user.

If the inverter is being connected to the power supply network and a present power supply network is detected, the power supply network and the consumer can be correspondingly supplied with energy.

The measure that the components of the inverter communicate via a data bus allows for optimization of the energy management and/or the flow of energy in both operational modes, i.e. the network-connected operation and the isolated operation.

The measure that the information on the present energy storage is forwarded via the data bus allows for a switch to the isolated operation, and for the energy storage to be charged.
The inventive object is also achieved by an above-mentioned inverter, wherein a storage DC/DC converter is provided which is connected to the intermediate circuit, on the one hand, and connectable to an optional energy storage, on the other hand, the storage DC/DC converter being connected to the control device, and wherein a network-monitoring unit is furthermore provided which is connected to the control device for monitoring the power supply network and for switching between a network-connected operation, in which at least the input DC/DC converter and the output DC/AC converter are activated to feed the inverter-generated AC voltage into the power supply network, and an isolated operation, in which the input DC/DC converter and/or an additional storage DC/DC converter as well as the output DC/AC converter are activated to deliver the inverter-generated AC voltage to the consumers, as a function of the power supply network monitored. The advantages arising therefrom can be learned from the advantages already listed with respect to the method steps, and from the following description.

The present invention will be explained in more detail by way of the annexed schematic drawings. Therein:

Fig. 1 shows a schematic overview of a conventional inverter; and

Fig. 2 shows a schematic overview of the inventive inverter.

Initially, it is pointed out that the same parts of the exemplary embodiment are denoted by the same reference numbers.

Fig. 1 shows a conventional structure of an inverter 1 in schematic representation. Since the individual components and units and functions of inverters 1 are already known from the prior art, they will not be addressed in detail hereinafter.

The inverter 1 which is preferably comprised of an HF inverter 1 has at least one input DC/DC converter 2, an intermediate circuit 3, and an output DC/AC converter 4. An energy source 5 or an energy generating means is connected to the input DC/DC converter 2, the former being preferably formed by one or several solar modules connected in parallel and/or in series. The output of the inverter 1 and/or of the output of the DC/AC converter 4 is connected either to a power supply network 6, e.g. a public or private AC voltage supply network or multi-phase network, or to one or several electrical consumers 7 which constitute a load. The consumers 7 are for example comprised of an en-
gine, a refrigerator, a radio device, etc. The consumer 7 can likewise be a domestic supply system. Furthermore, the individual components of the inverter 1, such as the input DC/DC converter 2, etc., are connected to a control device 8 via a data bus 12.

The energy management of this so-called network-connected inverter 1 is optimized in that as much energy as possible is fed into the power supply network 6. As known from the prior art, the consumers 7 are supplied with electrical energy via the power supply network 6. Also, e.g., several inverters 1 can of course be connected in parallel. This allows for more energy to be provided for operation of the consumers 7.

The control device 8 or the controller of the inverter 1 is comprised, e.g., of a microprocessor, a microcontroller or a computer. The individual components, e.g. the input DC/DC converter 2 or the output DC/AC converter 4, in particular the switching elements arranged therein, can be suitably controlled via the control device 8. To this end, the individual control procedures are stored by appropriate software programs and/or data and characteristic curves in the control device 8.

Fig. 2 shows an inventive inverter 1 which is upgraded with a storage DC/DC converter 9 to which an energy storage 10 can optionally be connected. This results in that the inverter 1 has the functionality not only of a network-connected inverter 1 but also of a so-called electrically isolated inverter.

In general, an inverter 1 having these functionalities is called hybrid inverter. But what is essential in the inventive inverter 1 is that the functionalities are completely decoupled. That is, they can work independently from each other, whereby the efficiency of each individual functionality can be utilized best, and that the flow of energy can be adapted ideally to each functionality.

This is in particular achieved by the storage DC/DC converter 9 which is connected to the intermediate circuit 3. Thus, the input DC/DC converter 2 and/or the storage DC/DC converter 9 can feed the intermediate circuit 3, wherein the storage DC/DC converter 9 takes the required energy from the energy storage 10. The storage DC/DC converter 9 is preferably connected to a connection socket 14 which is integrated in the housing of the inverter 1 for connection of the external energy storage 10. If
need be, the user can thus optionally connect the energy storage 10. The energy storage 10 is comprised of a battery or the like, e.g. In the network-coupled operation and optionally in the isolated operation, the inverter 1 can be operated without the energy storage 10. This results in several possibilities of supplying the consumers 7 in the isolated operation, and of charging the energy storage 10 during network-connected operation or isolated operation.

The inventive inverter 1 operates basically in the network-connected operation. Here, the input DC/DC converter 2 converts the voltage delivered by the energy source 5, e.g. the solar modules, into a higher and constant intermediate-circuit voltage so that the output DC/AC converter 4 can feed the power supply network 6 with a network-compatible voltage and provide the same to the consumers 7. Yet, the consumers 7 are preferably fed from the power supply network 6. Accordingly, this operational mode does not depend on whether an energy storage 10 is connected to the storage DC/DC converter 9.

Furthermore, a network-monitoring unit 11 can be integrated in the inverter 1 which monitors availability of the power supply network 6 during operation of the inverter 1. If the power supply network 6 fails and the supply of the consumers 7 is consequently interrupted, the network-monitoring unit 11 will inform about this fact via the data bus 12 of the control device 8 so that the inverter 1 can be switched to isolated operation. Here, the same consumers 7 as in the network-connected operation will be fed.

To allow for a stable isolated operation, certain requirements have to be met. On the one hand, a stable isolated operation can be ensured if the energy source 5 supplies sufficient power to feed the consumers 7. In case a sufficient supply is ensured, activation of the storage DC/DC converter 9 is not necessary since the inverter 1 behaves as during network-connected operation. However, if the energy source 5 supplies insufficient or no power for a stable isolated operation, the storage DC/DC converter 9 has to provide compensation so as to feed the consumers 7 with sufficient electrical energy. Accordingly, what is anticipated here is that the optional energy storage 10 is connected to the storage DC/DC converter 9.

The detection whether an energy storage 10 is connected to
the storage DC/DC converter 9 is preferably done automatically, for example by the voltage applying thanks to the connection of the energy storage 10 to the input of the storage DC/DC converter 9 activating the same at least such that the control device 8 can be informed about the presence of the energy storage 10. In this case, i.e. if besides the energy from the energy source 5 additional energy is required during isolated operation, the storage DC/DC converter 9 takes energy from the energy source 10 which should of course be fully charged so as to bridge the failure of the power supply network 6 as long as possible.

The energy storage 10 is basically charged via the storage DC/DC converter 9 which is connected to the energy storage 10 arranged outside of the inverter 1. The energy storage 10 can be charged during network-connected operation. During this operational mode, the storage DC/DC converter 9 is inactive. By this measure the storage DC/DC converter 9 is appropriately activated by the control device 8 via the data bus 12 to preferably cyclically request the charge condition of the energy storage 10 and/or measure its input voltage that corresponds to the voltage of the energy storage 10. If charging of the energy storage 10 is required, the storage DC/DC converter 9 will be fully activated and receive the current necessary for charging the energy storage 10 from the intermediate circuit 3 fed by the energy source 5, e.g. the solar modules, or the input DC/DC converter 2. By this measure the intermediate circuit 3 will be loaded to a minimum extent, this having no appreciable influence of the efficiency during network-connected operation. After the energy storage 10 has been fully loaded, the storage DC/DC converter 9 will be again deactivated. Here, the energy storage 10 will nevertheless still be continuously or cyclically monitored and charged, if necessary.

The energy storage 10 can also be charged during isolated operation in the almost same manner if the energy source 5 or the solar modules can feed the consumers 7 and additionally still provide sufficient power at the intermediate circuit 3 to charge the energy storage 10 via the storage DC/DC converter 9. This energy management is done by the control device 8 which receives the necessary data from the individual components of the inverter 1 via the data bus 12.
A further possibility of charging the energy storage 10 is to take the current from the power supply network 6. Here, the intermediate circuit 3 will be fed via the output DC/AC converter 4 so that the storage DC/DC converter 9 will in turn be able to charge the energy storage 10. Use of this possibility is made in particular if the energy source 5 or the solar modules, for example, have delivered insufficient or no energy over a longer period of time so as to charge the energy storage 10.

Thus, it is ensured that the energy storage 10 is always charged so as to allow for a switch of the inverter 1 to the isolated operation in case of a failure of the power supply network 6 at any time.

If the network-monitoring unit 11 detects a failure of the power supply network 6, the connection between the power supply network 6 and the output DC/AC converter 4 will be interrupted via the switch 13. It is thus ensured that the consumers 7 will be fed by one source only, in this case by the energy source 5 or the solar modules. The safety requirements are thus likewise met so that, e.g., maintenance work on the power supply network 6 is safe. The network-monitoring unit 11 furthermore ensures that the inverter 1 will not be loaded by the power supply network 6 during isolated operation and that the efficiency will thus not be affected.

In case the energy source 5 is implemented by solar modules the necessary energy can be received from these solar modules in the daytime. If this energy is sufficient, activation of the storage DC/DC converter 9 is not necessary. Yet, if the solar modules are capable of providing only part of the energy necessary for the consumers 7 via the input DC/DC converter 2, the intermediate circuit 3 and the output DC/AC converter 4, the lacking energy will be added from the energy storage 10. To this end, the storage DC/DC converter 9 will be activated and deliver the additional energy necessary to the intermediate circuit 3 so as to allow for the output DC/AC converter 4 to feed the consumers 7 with the appropriate energy. If a consumer 7 is turned off or if more energy is supplied from the solar modules, the storage DC/DC converter 9 can again be deactivated. Here, the solar modules continuously feed the consumers 7 with electrical energy. This is gentle to the energy storage 10, prolonging its service life and allowing for a network failure to be bridged
for a longer period of time. If, e.g., a consumer 7 is connected, energy can in turn be taken from the energy source 10.

If the power supply network 6 fails at night, the consumers 7 must be fed completely from the energy storage 10. In this case the input DC/DC converter 2 will be deactivated and the storage DC/DC converter 9 will supply the intermediate circuit 3, and the output DC/AC converter 4 will thus feed the consumers 7.

The charge condition of the energy storage 10 can also be monitored if energy is taken therefrom. This ensures that the energy storage 10 will not be fully discharged and that recharging is possible. This is gentle to the energy storage 10 and prolongs its service life.

If the network-monitoring unit 11 again detects the presence of the power supply network 6, the switch 13 will again be closed so that the consumers 7 will be supplied by the power supply network 6. The inverter 1 will be switched from isolated operation to network-connected operation by the control device 8. The energy storage 10 can be recharged so that it will be available for the next switch to isolated operation in fully recharged condition. Such keeping of the energy storage 10 at a certain charge level prolongs its service life.

As can be learned from the above description, the storage DC/DC converter 9 is constructed particularly bidirectionally, i.e. it allows a current flow from the intermediate circuit 3 to the energy storage 10 and from the energy storage 10 to the intermediate circuit 3.

The output DC/AC converter 4 can likewise fulfil this function to feed the intermediate circuit 3 with energy from the power supply network 6 if necessary so as to allow for the energy storage 10 to be charged via the storage DC/DC converter 9.

It is also possible to arrange several inventive inverters 1 in parallel and to switch between the network-connected operation and the isolated operation.
Claims:

1. A method of controlling an inverter (1) which converts DC voltage generated by an energy source (5) into AC voltage via at least one input DC/DC converter (2), an intermediate circuit (3) and an output DC/AC converter (4) for feeding consumers (7) and/or for feeding into a power supply network (6), wherein the components of the inverter (1) are controlled by means of a control device (8), characterized in that the power supply network (6) is monitored by a network-monitoring unit (11), and that as a function of the power supply network (6), the inverter (1) is switched by the control device (8) between a network-connected operation, in which at least the input DC/DC converter (2) and the output DC/AC converter (4) are activated to feed the inverter-generated AC voltage into the power supply network (6), and an isolated operation, in which the input DC/DC converter (2) and/or an additional storage DC/DC converter (9), connectable to an optional energy storage (10), as well as the output DC/AC converter (4) are activated to feed the inverter-generated AC voltage to the consumers (7).

2. The method according to claim 1, characterized in that the energy storage (10) that is optionally connectable to the storage DC/DC converter (9) is detected automatically.

3. The method according to claim 2, characterized in that the energy storage (10) is detected automatically by the storage DC/DC converter (9) by detecting an input voltage applying to the latter.

4. The method according to any one of claims 1 to 3, characterized in that the charge condition of the energy storage (10) is detected.

5. The method according to any one of claims 1 to 4, characterized in that in the network-connected operation the intermediate circuit (3) is fed by the input DC/DC converter (2), and at least the output DC/AC converter (4) is fed by the intermediate circuit (3).
6. The method according to claim 4 or 5, characterized in that the energy storage (10) is charged with energy by the energy source (5) or the power supply network (6) as a function of the charge condition of the energy storage (10) detected.

7. The method according to claim 5 or 6, characterized in that the storage DC/DC converter (9) is activated as a function of the charge condition of the energy storage (10) for charging the same so that the energy storage (10) is charged via the intermediate circuit (3) and the storage DC/DC converter (9).

8. The method according to any one of claims 5 to 7, characterized in that the storage DC/DC converter (9) is deactivated in case of a fully-charged energy storage (10).

9. The method according to any one of claims 1 to 8, characterized in that during isolated operation the intermediate circuit (3) is fed by the input DC/DC converter (2) and/or by the storage DC/DC converter (9) as a function of the power supplied by the energy source (5), and the output DC/AC converter (4) is fed by the intermediate circuit (3).

10. The method according to claim 9, characterized in that the storage DC/DC converter (8) is deactivated as a function of the power supplied by the energy source (5).

11. The method according to any one of claims 9 and 10, characterized in that the storage DC/DC converter (9) is completely activated as a function of the charge condition of the energy storage (10), and of the power supplied by the energy source (5), and the energy storage (10) is being charged.

12. The method according to claims 1 to 11, characterized in that in case a failure of the power supply network (6) has been detected, there will be an automatic switch from the network-connected operation to the isolated operation.

13. The method according to claim 12, characterized in that the inverter (1) will be decoupled from the power supply network (6) in case a failure of the power supply network (6) has been de-
14. The method according to any one of claims 1 to 13, characterized in that in case a present power supply network (6) has been detected, there will be an automatic switch from the isolated operation to the network-connected operation.

15. The method according to claim 14, characterized in that the inverter (1) will be connected to the power supply network (6) in case a present power supply network (6) has been detected.

16. The method according to any one of claims 1 to 15, characterized in that the components of the inverter (1) communicate via a data bus (12).

17. The method according to claim 16, characterized in that the information on the present energy storage (10) is forwarded via the data bus (12).

18. An inverter (1) for converting the DC voltage generated by an energy source (5) into an AC voltage via at least one input DC/DC converter (2), an intermediate circuit (3) and an output DC/AC converter (4) for feeding consumers (7) and/or for feeding into a power supply network (6), wherein the input DC/DC converter (2) is connected to a control device (8), characterized in that a storage DC/DC converter (9) is provided which is connected to the intermediate circuit (3), on the one hand, and connectable to an optional energy storage (10), on the other hand, the storage DC/DC converter (9) being connected to the control device (8), and that a network-monitoring unit (11) is furthermore provided which is connected to the control device (8) for monitoring the power supply network (6) and for switching between a network-connected operation, in which at least the input DC/DC converter (2) and the output DC/AC converter (4) are activated to feed the inverter-generated AC voltage into the power supply network (6), and an isolated operation, in which the input DC/DC converter (2) and/or an additional storage DC/DC converter (9) as well as the output DC/AC converter (4) are activated to feed the inverter-generated AC voltage to the consumers (7), as a function of the power supply network (6) moni-
19. The inverter (1) according to claim 18, characterized in that the energy storage (10) is arranged externally and is connectable to the storage DC/DC converter (9) via a connection socket (14).

20. The inverter (1) according to claim 18 or 19, characterized in that a device is provided for detecting the connection of the energy storage (10) with the storage DC/DC converter (9).

21. The inverter (1) according to any one of claims 18 to 20, characterized in that a device is provided for detecting the charge condition of the energy storage (10).

22. The inverter (1) according to any one of claims 18 to 21, characterized in that a switch (13) controlled by the network-monitoring unit (11) is provided for disconnection from the power supply network (6) so that in case a failure of the power supply network (6) has been detected the latter will be disconnectable from the inverter (1).

23. The inverter (1) according to any one of claims 18 to 22, characterized in that a data bus (12) is provided which is connected to the input DC/DC converter (2), the output DC/AC converter (4), the storage DC/DC converter (9) and optionally the control device (8) and the network-monitoring unit (11).

24. The inverter (1) according to any one of claims 18 to 23, characterized in that the energy source (5) is formed by solar modules.