

SYSTEM FOR GROUND POWER SUPPLY

TECHNICAL FIELD OF THE INVENTION

The invention relates to a system for ground power supply of aircraft, which comprises the features of the preamble of independent claim 1.

As a general rule, aircraft comprise own generators for power supply. These generators may be driven by the engines of the aircraft. Often, separate combustion engines are provided for driving the generators. Preferably, the power supply of aircraft on the ground is not provided by the own generators of the aircraft to avoid operation of the engines or the separate combustion engines and the emissions associated therewith. Instead, often special systems are used for ground power supply of aircraft on airports, which stand out because of low emissions with regard to both materials and acoustics.

PRIOR ART

Known systems for ground power supply of aircraft comprise mobile units which each include a combustion engine and a generator driven by the combustion engine and, if needed, also a voltage converter for adapting a voltage output by the generator to the needs of the respective aircraft, wherein these components are arranged on a common vehicle chassis. These units are brought into the neighborhood of the aircraft to be supplied with power on the ground by means of towing vehicles which are also used for other purposes on the respective airport, and then connected to the aircraft to be supplied via supply cables. As a rule, a fuel reservoir for supplying the combustion engine is also arranged on the respective vehicle chassis. In modern embodiments, these known systems produce lower emissions than the own power supplies of the aircraft. However, it is of interest to even reduce these emissions or to completely avoid them.

In further known systems for ground power supply of aircraft, mobile units are provided which comprise a battery as an energy store and a voltage converter on a common vehicle chassis. These mobile units are also brought into the neighborhood of the aircraft to be supplied with power on the ground by means of towing vehicles, and connected to the aircraft via connection cables. If the battery of such a mobile unit is exhausted, the mobile unit is exchanged for a mobile unit with a sufficiently charged battery, and moved to a charging station. The re-charging of the battery takes some time. This time is often clearly longer than the time which is needed to refill a fuel

reservoir for supplying a combustion engine. Thus, typically twice as many mobile units with energy storages in form of batteries than aircraft to be supplied with power on the ground have to be provided with this known system.

At least as a concept, systems for ground power supply of aircraft by means of hydrogen fed fuel cells are also known. In mobile units comprising hydrogen fed fuel cells, the provision of the hydrogen is not without problem. For example, the provision of the hydrogen in pressure tanks is forbidden on airports for security reasons. Known metal hydride stores for low pressure storage of hydrogen for mobile units comprising hydrogen fed fuel cells are associated with the drawbacks that metal hydride stores have a comparatively long filling time for refilling them with fresh hydrogen.

In a known system for ground power supply of aircraft comprising a mobile converter unit which includes a vehicle chassis and a voltage converter mounted on the vehicle chassis, two separate batteries are provided as energy stores on the same vehicle chassis, which are alternately, particularly one after the other, connectable to an input of the voltage converter. In operation of this known system for ground power supply, a supply cable from the mobile converter unit leads from an output of the voltage converter to the respective aircraft.

PROBLEM OF THE INVENTION

It is the problem of the invention to provide a system for ground power supply of aircraft which is at least essentially free of emissions in operation and which can nevertheless be realized at more favorable cost than known low emission systems for ground power supply of aircraft.

SOLUTION

The problem of the invention is solved by a system for ground power supply of aircraft comprising the features of independent claim 1. The dependent claims relate to preferred embodiments of this system.

DESCRIPTION OF THE INVENTION

In a system for ground power supply of aircraft according to the invention, the system comprising at least one mobile converter unit which includes a first vehicle chassis and a voltage converter mounted on the first vehicle chassis, and at least two energy stores which can alternately be connected to an input of the voltage transformer in order to supply the voltage transformer with

electric energy, wherein a supply cable for ground power supply of one of the aircraft is connectable to an output of the voltage converter, each of the at least two energy stores is part of one of at least two mobile storage units which each include a second vehicle chassis.

5 That each storage unit includes a second vehicle chassis does not mean that the storage unit has two vehicle chassis but that each storage unit has a second vehicle chassis whereas the at least one converter unit has a first vehicle chassis.

Thus, in the system according to the invention, the functions of voltage conversion and energy storage are distributed to different units, i.e. the converter unit and the storage units, which have separate vehicle chassis and which, correspondingly, are separately moveable. Thus, the voltage
10 converter of the converter unit may be supplied with electric energy out of energy stores of different storage units. Particularly, one of the at least two mobile storage units may be removed from the converter unit and replaced by another of the at least two mobile storage units, if its energy store is exhausted. The exhausted energy store of the one storage unit may then be moved using the second vehicle chassis of this storage unit to a location remote from the
15 converter unit and be recharged there, whereas the converter unit is supplied out of the not yet exhausted energy store of the other storage unit. If this energy store is exhausted, a further exchange of the storage units may take place, because, typically, this is only the case when the energy store of the one storage unit has already been recharged even if this takes a certain period of time. With very long periods of time for recharging the energy store, three or more storage units
20 may be provided instead of the at least two storage units so that the energy stores of two or more of these storage units may simultaneously be recharged, whereas one further storage unit ensures the supply of the voltage converter of the converter unit with electric energy by means of its energy store.

The investment needed for realizing the system according to the invention is thus restricted to
25 what is technically practically necessary, i.e. to one converter unit per aircraft to be supplied at the same time and to so many storage units as alternately needed for a permanent supply of the voltage converters of the converter units with electric energy. Particularly, in the operation of the system according to the invention, no voltage converters that are not needed in charging the energy stores are moved around with the storage units for charging the energy stores of the
30 storage units. Each of the mobile units of the system according to the invention is completely focused to its respective task of storing energy or converting voltage and thus of limited overall complexity. In practice, one converter unit and one energy supply unit of the system according to the invention may often be provided at even lower cost than a known mobile unit comprising a voltage converter and an energy store. Particular high savings result from the system according

to the invention if only one converter unit and two energy storage units are used in the system according to the invention instead of two known mobile units with voltage converter and energy store.

5 Typically, in the system according to the invention, the energy stores are each connectable to the input of the voltage converter via a connection cable leading from the respective storage unit to the converter unit. Such a connection cable provides for a certain flexibility with respect to relative positioning of the storage unit with respect to the converter unit.

10 It will be understood that, as a rule, at least one charging unit is present in the system according to the invention, to which the energy stores are alternately connectable. As a general rule, this charging unit is stationary, in contrast to the at least one converter unit and the at least two storage units.

15 The energy stores of the at least two storage units may either include an electric battery, or a fuel cell and a fuel reservoir. In other words, the respective energy store may either be an electric battery or a so called fuel cell battery. In both cases, the energy store, as a whole, is an electrochemical energy store.

Independently on the design of the energy stores of the storage units as electric batteries or fuel cell batteries, the converter unit may be the same, i.e. suitable both for usage with storage units comprising electric batteries and for usage with storage units comprising hydrogen batteries.

20 The fuel reservoir of the fuel cell batteries is preferably a metal hydride store to be able to store hydrogen as fuel for the low-emission operation of the fuel cell at as little pressure as possible. In the system for ground power supply of aircraft according to the invention, the long filling times of a metal hydride store are no problem due to the higher number of storage units as compared to the number of converter units.

25 If the energy stores of the at least two storage units each comprise an electric battery, the energy stores may each be connectable to the charging unit via the first connection cable via which the energy stores are also connectable to the voltage converter, or via a second connection cable, wherein the respective connection cable leads from the storage unit to the charging unit. Further, the at least one charging unit may be configured for an input side connection to a local or public power grid.

If, on the other hand, the energy stores of the at least two storage units each comprise a fuel cell and a fuel reservoir, it is preferred if the charging unit is not only provided for refilling the fuel reservoir but also for regenerating the fuel cell. Often, fuel cells can be regenerated with respect to their efficiency by subjecting them to a certain sequence of voltages. Correspondingly, the charging unit is preferably configured for applying such a sequence of voltages to the respective fuel cell. It will be understood that the storage units of the system for ground power supply of aircraft according to the invention, as a rule, do not only comprise a single but several fuel cells, typically a so-called fuel cell stack such that they can provide sufficient electric power.

Independently on whether the storage units include electric batteries or full cell batteries, the at least two mobile storage units of the system according to the invention may each be devoid of voltage converters, particularly devoid of voltage converters for electric power output by the energy stores and, in case of an electric battery as an energy store, also for electric power to be fed into the battery for charging it.

Storage units of the system for ground power supply of aircraft according to the invention, which are suitable for application in a commercial airport, have storage capacities in the range from 20 kWh to 300 kWh. More particular, storage units with storage capacities between 80 kWh and 100 kWh are usable without permanent exchange but nevertheless quickly rechargeable and available at acceptable cost.

The at least one converter unit of the system according to the invention may be completely devoid of energy sources for the ground power supply of one of the aircraft. This does, however, not exclude that the converter unit has a buffer store at the input of the voltage converter, like for example a dc voltage link having a high electric capacity to bridge an exchange of a storage unit with exhausted energy store for a storage unit with a fresh energy store. However, as a rule, the converter unit does not comprise an electrochemical energy store for the ground power supply of one of the aircraft. On the other hand, also as a rule, the converter unit will comprise an electrochemical energy store for supplying a controller of the converter unit and the like.

In order to allow for a trouble-free change between different storage units during ground power supply of an aircraft by means of the converter unit, the at least one converter unit of the system according to the invention may comprise a alternating switch which alternately connects two connectors, which are each provided for one of the at least two storage units, to the input of the voltage converter of the at least one converter unit. Herein, the connection of the respective aircraft via the supply cable to the converter unit persists which is at any time connected to one

of the storage units via a respective first connection cable and temporarily even to both of the least two storage units.

Because commercial aircraft typically have an onboard grid of an alternating voltage of 400 Hz, the voltage converter of the at least one converter unit typically has an inverter which outputs a
5 supply alternating voltage of typically 400 Hz for the ground power supply of one of the aircraft.

The absolute number of the converter units and the storage units of a system according to the invention will typically be higher than 1 and 2, respectively. This means that the at least one mobile converter unit, as a rule, is one of several equal mobile converter units of the system, and the at least two mobile storage units, as a rule, are two of many equal mobile storage units of the system,
10 wherein per each converter unit of the several equal mobile converter units, as a rule, two of the storage units of the many equal mobile converter units are provided. In a same way, the at least one charging unit may be one of several equal charging units of the system, wherein per each converter unit of the several equal mobile converter units one of the charging units of the several equal charging units may be provided.

15 With respect to their first and second vehicle chassis, the converter units and the storage units may comply with a local standard of vehicle chassis of units which are movable in the surroundings of the aircraft on the ground. In any case, the first and second vehicle chassis of the converter units and the storage units may generally be equal.

Advantageous developments of the invention result from the claims, the description and the
20 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
30 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.

- 5 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 a fuel cell is mentioned, this is to be understood such that there is exactly one fuel cell or there are two fuel cells or more fuel cells. Additional features may be added to these features, or these features may be the only features of the
10 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

- 15 In the following, the invention is further explained and described with respect to preferred exemplary embodiments illustrated in the drawings.

- Fig. 1** is a schematic side view of a first embodiment of a system for ground power supply of aircraft according to the invention.
- Fig. 2** is a top view of a second embodiment of the system for ground power supply of aircraft according to the invention.
- 20 **Fig. 3** illustrates a detail of a converter unit and a storage unit of a further embodiment of the system for ground power supply of aircraft according to the invention.
- Fig. 4** illustrates details of another storage unit of the system for ground power supply of aircraft according to the invention; and
- 25 **Fig. 5** illustrates details of an alternating switch of a converter unit according to the invention of a further embodiment of the system for ground power supply of aircraft according to the invention.

DESCRIPTION OF THE DRAWINGS

Fig. 1 depicts an aircraft 1 at a ground 2 which is supplied with power via a supply cable 3. The supply cable 3 leads from a mobile converter unit 4 to the aircraft 1. A mobile storage unit 5 is connected to the mobile converter unit 4 via a connection cable 6. The mobile storage unit 5 supplies the converter unit 4 with electric energy and has an energy store for this purpose. A further equal mobile storage unit 5 is connected to a stationary charging unit 7 via its connection cable 6 to charge its energy store. When the energy store of the storage unit 5 connected to the converter unit 4 is exhausted, and the energy store of the storage unit 5 connected to the charging unit 7 is charged, the storage units 5 can be exchanged, wherein, temporarily, both storage units 5 may be connected to the converter unit 4. Thus, the converter unit 4 is suitable for continuous ground power supply of aircraft 1.

Fig. 2 shows a system for ground power supply of aircraft 4 with a total of two converter units 4 and five storage units 5 and two charging units 7. Here, one storage unit 5 is provided as a backup, in case that the energy store of one of the storage units 5 connected to the converter units 4 is exhausted, before the energy store of the alternately used storage unit 5 connected to the charging unit 7 is recharged. If there are more than two aircrafts 1 to be simultaneously supplied with power on the ground 2 as depicted in Fig. 2, correspondingly more converter units 4, storage units 5 and charging units 7 are to be provided.

Fig. 3 schematically illustrates the interior construction of one converter unit 4 and of one storage unit 5 connected there to. The converter unit 4 has a voltage converter 8. The voltage converter 8 includes an input side step up converter 10 which is generally optionally, a dc voltage link 9 connected to the output of the step up converter 10, and an inverter 11 connected with its input to the dc voltage link 9. For example, the inverter 11 is configured to output alternating current at a frequency of 400 Hz via the supply cable 3. The battery store 12 of the storage unit 5 is an electric battery 13 with a plurality of interconnected battery cells 14. Both units 4 and 5 comprise equal vehicle chassis 15 and 16 and can each be coupled via a tongue 17 to a towing vehicle not depicted here and moved with the towing vehicle on the ground 2.

Fig. 4 schematically illustrates an alternative embodiment of the energy store 12 of a storage unit 5 as fuel cell battery 18 having a fuel cell 19 indicated as a fuel cell stack and a fuel reservoir 20, which particularly is a metal hydride storage for hydrogen. Not only the fuel reservoir 20 via a fuel line 21 but also the fuel cell 19 via the connection cable 6 is connected to the charging unit 7 depicted in Fig. 4. This serves for regenerating the fuel cell 19 by subjecting it to certain voltages during refilling the fuel reservoir 20. Further, the fuel cell 19 is indicated as breathing air 22 out of the surroundings.

Fig. 5 illustrates an input side alternating switch 23 which is connected upstream of the input side of the dc voltage link 9 of the converter unit 4. The alternating switch may be provided as alternative or an addition to the step up converter according to Fig. 3, and, particularly, be provided at the input side of the step up converter. The alternating switch 23 has two connectors DC1 and DC2 for two storage units 5 providing direct voltages. By a control unit 24, the connectors DC1 and DC2 are alternately connected to the dc voltage link 9 via power switches QA1 und QA2, wherein the connectors DC1 and DC2 are additionally decoupled by diodes D1 and D2. Further, for each of the connectors DC1 and DC2, a pre-charging circuit A1 and A2 is provided, respectively, which includes a voltage measuring to, if necessary, pre-charge the dc voltage link 9 prior to closing the respective switch QA1 or QA2, respectively, in order to avoid over currents. The switches QA1 and QA2 may be power switches, connectors or relays. By means of the control unit 24, it is possible to switch over between two storage units 5 connected to the connectors DC1 and DC2 for charging the dc voltage link 9, without interrupting the energy supply of the voltage converter 9 connected to the dc voltage link and thus the ground power supply of the aircraft 1 connected thereto. The point in time of switching over between these storage units 5 may be set manually or according to a control program that exactly switches over when the energy storage 12 of the hitherto used storage unit 5 is exhausted, i.e. de-charged down to a defined level.

LIST OF REFERENCE NUMERALS

1	aircraft
2	ground
3	supply cable
4	transformer unit
5	storage unit
6	connection cable
7	charging unit
8	voltage transformer
9	dc voltage link
10	step up converter
11	inverter
12	energy store
13	electric battery
14	battery cell
15	(first) vehicle chassis
16	(second) vehicle chassis
17	tongue
18	fuel cell battery
19	fuel cell
20	fuel reservoir
21	fuel line
22	air
23	alternating switch
24	control unit
DC1	connector
DC2	connector
D1	diode
D2	diode
QA1	power switch
QA2	power switch
A1	pre-charging circuit
A2	Pre-charging circuit
C	capacity of the dc voltage link 9

CLAIMS

1. System for ground power supply of aircraft (1), the system comprising
 - at least one mobile transformer unit (4) having a first vehicle chassis (15) and a voltage transformer (8) mounted on the first vehicle chassis (15), and
 - at least two energy stores (12) which can alternately be connected to an input of the voltage transformer (8) in order to supply the voltage transformer (8) with electric energy, wherein a supply cable (3) for ground power supply of one of the aircraft (1) is connectable to an output of the voltage transformer (8),
characterised in that each of the at least two energy stores (12) is part of one of at least two mobile storage units (5) which each include a second vehicle chassis (16).
2. System of claim 1, **characterised in** that the energy stores (12) are each connectable to the input of the voltage transformer (8) via a first connection cable (6) leading from the respective storage unit to the transformer unit (4).
3. System of claim 1 or 2, **characterised in**
 - that at least one charging unit (7) is provided to which the energy stores (12) can be connected alternately,
 - wherein, optionally, the at least one charging unit (7) is stationary.
4. System of any of the preceding claims, **characterised in** that the energy stores (12) of the at least two storage units (5) each comprise
 - an electric battery (13) or
 - a fuel cell (18) and a fuel reservoir (20), wherein, optionally, the fuel reservoir (20) includes a metal hydride store.
5. System of claim 3, in so far as depended on claim 2, wherein the energy stores (12) of the at least two storage units (5) each comprise an electric battery (13), **characterised in** that the energy stores (12) are each connectable via the first or a second connection cable (6) to the charging unit (7), wherein the respective connection cable (6) leads from the storage unit (5) to the charging unit (7).

6. System of any of the claims 3 and 5, **characterised in** that the at least one charging unit (7) is configured for being connected to a power grid at its input site.
7. System of claim 3, wherein the energy stores (12) of the at least two storage units (5) each comprise a fuel cell (12) and a fuel container (20), **characterised in** that the charging unit (7) is configured for regenerating the fuel cell (19).
8. System of any of the preceding claims, **characterised in** that the at least two mobile storage units (5) are devoid of voltage transformers (8).
9. System of any of the preceding claims, **characterised in** that the at least two mobile storage units (5) each have a storage capacity in a range from 20 kWh to 300 kWh or from 80 kWh to 100 kWh.
10. System of any of the preceding claims, **characterised in** that the at least one transformer unit (4) is devoid of energy sources for the ground power supply of one of the aircraft (1).
11. System of any of the preceding claims, **characterised in** that the at least one transformer unit (4) includes an alternating switch which connects two connectors for each of the at least two storage units (5) alternately with the input of the voltage transformer (8) of the at least one transformer unit (4).
12. System of any of the preceding claims, **characterised in** that the voltage transformer (8) of the at least one transformer unit (4) comprises an inverter (11) which outputs a supply AC voltage for the ground power supply of one of the aircraft (1).
13. System of any of the preceding claims, **characterised in**
 - that the at least one mobile transformer unit (4) is one of a plurality of equal mobile transformer units (4) of the system,
 - that the at least two mobile storage units (5) are two of many equal mobile storage units (5) of the system,
 wherein per transformer unit (4) of the plurality of equal mobile transformer units (4) at least two of the storage units (5) of the many equal mobile storage units (5) are present.
14. System of claim 13, so far as directly or indirectly depended on claim 3, **characterised in** that the at least one charging unit (7) is one of several equal charging units (7) of the system.

15. System of any of the preceding claims, **characterised in**
- that the first and second vehicle chassis (15, 16) correspond to a local standard of vehicle chassis (15, 16) of units movable in the surroundings of the aircraft (1) on the ground and/or
 - that the first and second vehicle chassis (15, 16) are equal.