Abstract: The present invention relates to the operational control of a Ground Power Unit (GPU) and/or a cable storage unit supplying power to a parked aircraft by provision of a power cable for interconnection of a ground power unit with an aircraft, the power cable having a transmitter positioned at the output end of the power cable for wireless transmission of control signals to the ground power unit.
WIRELESS INTERCONNECTION OF
CONTROL SIGNALS FOR A GROUND POWER UNIT

The present invention relates to the operational control of a Ground Power Unit (GPU) and/or a cable storage unit supplying power to a parked aircraft.

During flight, one or more generators tied to the output of the aircraft propulsion system generate the electrical power required in the aircraft. On the ground, however, a GPU that converts the line voltage available in the airport into the AC or DC supply voltage required by the aircraft's electrical system is necessary.

GPUs of this type are well known. Typically, the units are driven by a 50 Hz or 60 Hz 3-phase input voltage and generates a desired 3-phase 400 Hz alternating output voltage or a desired DC voltage. Combined unit providing both an AC and a DC voltage are also known.

The distance between a GPU and the power receptacle of a parked aircraft varies with different types of aircraft and actual parking positions and the positioning of the GPU.

Typically, power cables of a length of 20 to 30 meters are required for interconnection of the aircraft with the GPU. Cable hoists, cable retrievers, cable winders, cable drums, and scissor systems, scissor extensions, or crocodiles are known for interconnection between the aircraft and the GPU for provision of the desired length of power cable and for stowing the cable when it is not used.

The power cable is provided with an aircraft connector for connection with a corresponding socket in the aircraft for supply of the output voltage to the aircraft while the other end of the cable is fixedly connected with the frequency converter output.

Typically, the power cable has at least one conductor for each phase of the converter output voltage and at least one neutral conductor. Further, the power cable has a number of wires for interconnection of control signals. For example, a wire for the interlock control signal is provided. The interlock signal, typically a 28 VDC signal, is forwarded from the aircraft to the GPU and indicates that the aircraft receives the required voltage quality. If the GPU does not receive the interlock signal, the GPU output is disconnected.

Wires for other control signals may also be provided. For example, the aircraft connector may be provided with a user panel comprising push buttons for entrance of user commands to the GPU and/or cable storage unit.
Thus, complex and costly cables of high quality that can withstand the harsh environment of an airport are required for supplying the aircraft on the ground.

There is a need for an improved system in which simpler cables may be used thereby lowering the cost and increasing the reliability of such systems.

According to the present invention, the above-mentioned and other objects are fulfilled by substitution of the wires for control signals in the power cable with a wireless link for wireless communication of the signals from equipment at one end of the power cable to equipment at its other end.

Thus, according to a first aspect of the invention, a power cable for interconnection of the power output of a GPU with a parked aircraft is provided, the power cable having a transmitter positioned at the aircraft end of the power cable for wireless transmission of control signals to the GPU.

The transmitter may further be adapted for transmission of control signals to a cable storage unit for accommodation of the power cable and for dispensing and retracting the power cable for provision of an adjustable length of the power cable allowing a variable distance between the aircraft power socket and the GPU.

The GPU and the cable storage unit may be integrated into a single unit.

At the output, the GPU may provide an AC voltage, such as a 3-phase 400 Hz/1 15 V\textsubscript{ms} AC voltage, etc., or a DC voltage, such as a 28 V\textsubscript{dc}, a 270 V\textsubscript{dc}, voltage, etc., or a combination of AC and DC voltages.

The power cable may further have a receiver positioned at the aircraft end of the power cable for wireless reception of monitor signals from the GPU. Preferably, the receiver and the transmitter are integrated into a single unit.

According to a second aspect of the invention, a GPU is provided with a receiver for wireless reception of control signals to the GPU.

The GPU may further have a transmitter for wireless transmission of monitor signals from the GPU.

According to a third aspect of the invention, a cable storage unit, such as a cable hoist, a cable retriever, a cable winder, a cable drum, a scissor system also called a scissor extension or a crocodile, etc., is provided for accommodation of the power cable and for dispensing and retracting the power cable, the unit having a receiver for wireless reception of control signals to the cable storage unit.
The cable storage unit may further have a transmitter for wireless transmission of monitor signals from the cable storage unit.

It is an important advantage of the invention that provision of wireless transmission of control and monitor signals between equipment at the ends of the power cable eliminates the need for control and monitor wires in the power cable. Thus according to the invention, standard industrial cables can be used for the power cable between the GPU and the aircraft. The reduction of the complexity of the power cable significantly reduces the cost of the power cable. Further, the lifetime of the power cable is increased due to absence of monitor and control wires, since these have a tendency to break before the cable is worn-out.

The above and other features and advantages of the present invention will become more apparent to those of ordinary skill in the art by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

Fig. 1 shows an integrated GPU and cable drum according to the invention mounted underneath a passenger boarding bridge,

Fig. 2 shows a prior art power cable with control and monitor wires, and

Fig. 3 shows an integrated GPU and cable drum with a power cable according to the present invention.

The figures are schematic and simplified for clarity, and they merely show details which are essential to the understanding of the invention, while other details have been left out. Throughout, the same reference numerals are used for identical or corresponding parts.

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

Fig. 1 shows a typical mounting position of an integrated GPU and cable storage unit according to the present invention, namely underneath a passenger boarding bridge. In the illustrated example, the cable storage unit is a cable drum integrated with the GPU in the GPU housing 20. The power cable 14 is shown with a maximum length
wound onto the cable drum (not visible) with its connector 16 hanging in a reachable position. The cable has a diameter of app. 4 cm and contains cable conductors for the 400 Hz 3-phase 115 V\textsubscript{rms} AC power supply. Alternatively, the GPU may provide a DC supply voltage, e.g. 28 V\textsubscript{DC}, 270 V\textsubscript{AC}, etc., or both an AC and a DC output voltage. The power cable 14 enters the GPU housing through a vertical slot 18 in the housing.

Fig. 2 shows a prior art power cable 14 without its connector. The complexity is apparent. The illustrated power cable 14 has six power conductors 22a, 22b, 22c, and a neutral 26 and a large number of control wires 24. The prior art power cables are special purpose cables manufactured in small numbers leading to high cost. Further, malfunctioning of a prior art power cable is typically caused by a broken control wire 24.

Fig. 3 shows schematically an integrated GPU and cable drum 10 with a power cable 14 according to the present invention. A transmitter 30 for wireless transmission of control signals for the integrated GPU and cabled drum 10 is mounted on the power cable 14 proximate the connector 16 for the airplane. The transmitted control signals are received by the receiver 34 mounted in the GPU housing 20, possibly connected to an external antenna (not shown).

Transmitter and receiver circuits well-known to the person skilled in the art of wireless transmission systems and being approved for use in airports may be used in the present invention. The transmission is preferably performed in frequency bands that can be used without a user license, such as 430 MHz, 433 MHz, 900 MHz, 2.4 GHz etc.

The transmitter and receiver may be a Bluetooth class 1 device, i.e. having a range of at least 100 m.

In the illustrated example, the transmitter housing has four push buttons 32. One push button may be pressed to unwind the power cable from the cable drum. Another push button may be pressed to wind the power cable onto the cable drum. Yet another push button may be pressed to apply the output voltage to the aircraft upon connection with the aircraft, and a push button may be pressed to turn the output voltage off before disconnecting the connector from the aircraft.

When the integrated GPU and cable drum 10 is not in use, the power cable is wound onto the cable drum as shown in Fig. 1. In order to connect an aircraft, a desired length of the cable 14 is unwound from the cable drum controlled by the operator using the
push buttons 32 on the transmitter 30, and the cable connector 16 is inserted in a corresponding receptacle in the aircraft to be connected with the GPU. The cable drum is rotated by a motor controlled by the GPU.

The transmitter 30 is also adapted to transmit other control signals to the receiver 34. For example, the interlock signal is transmitted wirelessly to the receiver. Typically, the interlock signal is a 28V DC signal supplied from the aircraft when it receives the required voltage quality from the GPU. The transmitter converts the 28 V DC signal to a wireless signal. If the GPU does not receive the interlock signal, the GPU output voltage is turned off.

The power cable connector may comprise a detector providing a control signal when the connector is engaged with the aircraft socket, a so-called 90 % switch. The GPU may be adapted for controlling turn on of the output voltage in such a way that turn on is inhibited until receipt of the engagement signal. Further, the control signal may be provided to the passenger boarding bridge controller so that movement of the passenger boarding bridge is inhibited until disconnection of the power cable from the aircraft socket.

The control signal may be provided to the passenger boarding bridge controller through a cable connection between the GPU and the passenger boarding bridge, or the transmitter 30 may be further adapted to transmit the control signal to a receiver mounted at the boarding bridge and interconnected with the boarding bridge controller.

The output voltages of the power terminals of the power cable connector 16 may be monitored during power supply of the aircraft, and the transmitter 30 may be adapted to convert the output voltage signals from voltage sensors in the connector 16 into wireless signals that are transmitted to the receiver 34 in the GPU. The GPU controller may further be adapted to control the output voltages at the power cable connector 16 in response to the sensed output voltages in order to maintain the output voltages within the prescribed range thereby compensating the impedance of the power cable and possible asymmetric loads.

A circuit at the power cable connector 16 may further be adapted to compare the neutral conductor voltage at the cable connector 16 with an artificial neutral voltage. The artificial neutral voltage may be formed by interconnection of the power cable phase outputs with resistors in a star coupling with a central star point that defines the artificial neutral voltage. If the difference between the neutral conductor voltage and the artificial neutral voltage exceeds a predetermined threshold voltage, e.g. 10 V, for a
certain time period, the circuit generates a neutral conductor breakage alarm signal that is transmitted wirelessly to the GPU by the transmitter. In this way, a possible breakage of the neutral conductor may be detected. The GPU output voltage is turned off upon reception of the neutral conductor breakage alarm signal.

The temperature of the power terminals of the power cable connector 16 may be monitored during power supply of the aircraft. The transmitter 30 may be adapted to convert the temperature signal from a temperature sensor in the connector 16 into a wireless signal that is transmitted to the receiver 34 in the GPU.

The transmitter housing may further comprise a display (not shown), e.g. a flat panel LCD display, LED display, a display with separate LEDs, etc., for displaying monitor signals to the user. A GPU monitor signal, e.g. a 'power on' signal, may be converted into a wireless signal by a transmitter (not shown) in the GPU and transmitted to a receiver (not shown) positioned at the connector 16 and preferably integrated with the transmitter in a common housing. The receiver converts the received signal into a signal controlling the display, e.g. thereby turning on a 'power on' indicator of the display, for example a 'power on' indicating LED. Control signals from the aircraft may also be displayed, e.g. presence of the interlock signal may be indicated in the display.

The transmitter 30 and the possible transmitters in the GPU and cable storage unit may further be adapted to transmit a respective identifier together with transmitted control signals, and the respective receivers may be adapted to receive and recognize the identifiers and respond to a specific identifier only. In this way, the receiver is adapted to respond to signals transmitted by the transmitter positioned at the other end of the power cable 14 and ignore signals from other possible transmitters whereby interference from other transmitters is avoided. The identifier may be the frequency of the carrier wave of the transmitter. Alternatively, the identifier may be a digital number appended to the transmitted signal information.

The transmitter 30 may be powered from a battery. In a preferred embodiment, the transmitter 30 is powered from a rechargeable battery. The rechargeable battery may be charged by a control signal, e.g. the interlock signal, from the aircraft when the power cable is connected to the aircraft.
CLAIMS

1. A power cable for interconnection of a ground power unit with an aircraft, the power cable having a transmitter positioned at the output end of the power cable for wireless transmission of control signals to the ground power unit.

2. A power cable according to claim 1, wherein the control signals include an interlock signal.

3. A power cable according to claim 1 or 2, wherein the control signals include a power connector temperature sensor signal.

4. A power cable according to any of the preceding claims, wherein the control signals include a power output voltage sense signal.

5. A power cable according to any of the preceding claims, wherein the control signals include a neutral conductor breakage alarm signal.

6. A power cable according to any of the preceding claims, wherein the control signals include an engagement signal.

7. A power cable according to any of the preceding claims, further comprising a receiver positioned at the output end of the power cable for wireless reception of monitor signals from the ground power unit.

8. A power cable according to any of the preceding claims, wherein the transmitter further comprises a display for displaying control signals to the user.

9. A power cable according to any of the preceding claims, wherein the transmitter is further adapted to transmit an identifier together with transmitted control signals.

10. A power cable according to any of the preceding claims, wherein the transmitter is powered from a rechargeable battery and the rechargeable battery is interconnected with a control signal circuit for recharging of the battery.

11. A ground power unit interconnected with a power cable according to any of the preceding claims, the ground power unit further comprising a receiver for wireless reception of signals from the transmitter.

12. A ground power unit according to claim 11, further comprising a transmitter for wireless transmission of monitor signals from the ground power unit.
13. A cable storage unit for accommodation of a power cable according to any of claims 1 - 9 and for dispensing and retracting the power cable, the unit having a receiver for wireless reception of signals from the transmitter.

14. A cable storage unit according to claim 13, further comprising a transmitter for wireless transmission of monitor signals from the cable storage unit.

15. A passenger bridge with a receiver for reception of a control signal from a power cable according to any of claims 1 - 10.