Optimizing Aircraft Power

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Aircraft power systems present a unique set of power quality problems in an environment that demands the highest level of reliability of the equipment being powered. Due to the ever increasing amount of microprocessor-based flight systems, navigation and communications equipment being incorporated into today's aircraft, power quality is of the utmost importance. Equipment designed for use in aircraft is typically very robust, being designed in accordance with Federal Aviation Administration (FAA) and military standards, and are tolerant of most power quality anomalies. Retrofit of older aircraft, the integration of COTS equipment, or the implementation of new technology into existing aircraft can be another story. Following is a brief overview of the aircraft power system as well as the most commonly occurring power quality problems and their possible effects. We also will discuss new technology available that can provide solutions to the most troublesome problems.

A typical aircraft power system is a multiple generator-based system consisting of:

- A ground based generator or inverter source that supplies power to the aircraft systems during maintenance, prior to departure and after arrival.
- An Auxiliary Power Unit (APU) generator, which supplies engine starting power and emergency power to the primary electrical system in the event of main generator or an engine failure.
- The main engine generator(s) supplies the system power after disconnection from ground power throughout the remaining flight sequence.
- The main power bus supplied by these generators is a 115/200Vac, 400Hz, 3Ø bus. From this bus, other power buses are derived supplying 115Vac, 400Hz 1Ø, 115Vac, 60Hz 1Ø, 26Vac, 400Hz, 28Vdc and 270Vdc. The aircraft structure serves as the neutral conductor of the three-phase power system, DC load return conductor in addition to the safety ground.

Equipment connected to these buses is routinely subjected to power disturbances created by the start, stop and the voltage transfers inherent in the multiple generator system design. Short-duration voltage sags, dropouts and DC offset are common. "Power interruptions to the control system and avionics can cause loss of flight data, system malfunction, and

disruption of operation." [1] These systems incorporate sensitive microprocessor-based equipment with volatile memory that is susceptible to voltage dropouts resulting in memory errors, equipment hangs and restarts. DC offset can cause abnormal tripping of relays, contactors and circuit breakers.

Aircraft generators are relatively small, and as such, subject to voltage and frequency variations resulting from changes in engine speed or the momentary high current demands of other large devices such as pumps, motors, compressors operating on the various voltage buses. The high current demands of these devices are a source of high voltage transients and waveform distortion.

An ever increasing number of loads on the aircraft are switch-mode power supplies. Due to their small size and light weight, they are incorporated in most of the electronics and computer subsystems throughout the aircraft. Due to their input rectification and filter capacitor stage, they draw current from the aircraft power sources in a non-linear manner, demanding most of the current near the peaks of the sinewave. Non-linear loads can generate a large amount of harmonics on the aircraft's power buses. Power bus harmonics are a key concern in aircraft because harmonics can cause reduced utilization capacity and adversely affect the overall reliability of power system.

The military's move to implementing low cost single-phase COTS equipment into aircraft and other 400Hz three-phase mobile applications is exacerbating voltage and current imbalance. The primary concern of voltage imbalance is harmonics and the resulting heating effect as well as the reduction in service life of thee-phase motors on the same power bus.

A small voltage imbalance of 1% results in a 5-6% current imbalance and may be problematic. A solution to this problem would be to incorporate an active phase/frequency converter, such as the Falcon Electric ED4-2400RM-3/1-4. The device connects to three-phase, 400Hz aircraft power. Through the use of double-conversion and Pulse Width Modulated Inverter (PWM) technologies, the Falcon unit converts the incoming power to a DC voltage, regulates the DC and recreates new single-phase, 50, 60 or 400Hz output power with a superior ±3% voltage regulation. The unit operates over a wide input voltage range while maintaining a balanced load on the three-phase 400Hz bus. The unit steadfastly provides clean, regulated single-phase sinewave power to the critical load. An optional external battery module is available providing several minutes of ride-through in the event of a momentary or sustained loss of aircraft bus power.

Due to the amount of power source switching that normally takes place in aircraft applications, the ability of the installed electronic systems and equipment to maintain enough stored energy to ride-through brief interruptions and reliably operate in the environment is essential. The requirements for equipment ride-through are outlined in FAA standard FAA-G-2100G and military standard MIL-STD-704F. All electronic equipment and flight systems installed on aircraft must meet these standards. However, there is a growing requirement by the military to install COTS computer-based systems essential to military operations that are not covered under these standards. This decision is necessary to rapidly install, develop, test and deploy the latest technologies. As this equipment is not related to the flight operations or air worthiness of the aircraft and is used purely for military operations, it does not fall directly under these standards. Often during the implementation stage, it is determined that this class of equipment will not operate reliably due to sensitivity to the aircraft's power disruptions. This leaves the engineers searching for a solution.

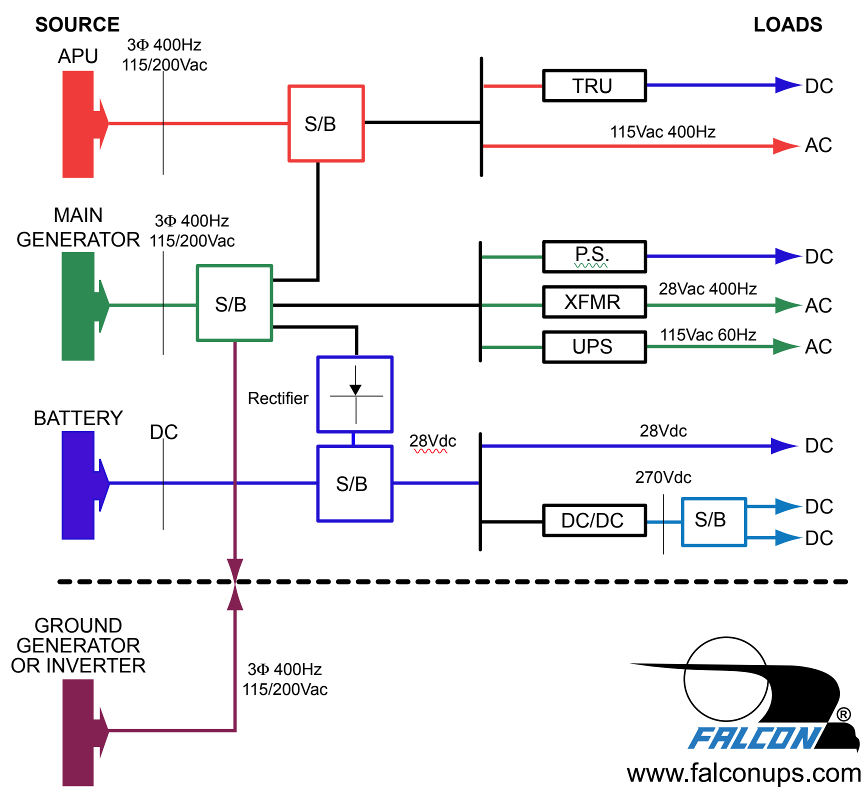
The solution usually is in the form of an off-the-shelf single-phase on-line Uninterruptible Power Supply (UPS). From the power protection standpoint, the on-line UPS utilizes a double-conversion design, which will provide reliable power.

However, there are several problems that may be encountered in this approach. First, most off-the–shelf on-line UPS units available are designed to operate from a single-phase 60Hz power source only and will not operate from a single- or three-phase 400Hz source. As the UPS is a single-phase device, it will contribute to phase imbalance. Second, the electrical and mechanical construction of these UPS units is intended for use in a computer room or office environment. The units cannot withstand the shock and vibration inherent in aircraft installations. Internal components such as batteries may not meet the required altitude or temperature ratings. The internal UPS wiring and external line cord are constructed using Poly Vinyl Chloride (PVC) insulation, which is banned from use on aircraft.

To better meet the military requirements, a few UPS manufacturers offer military COTS power conversion and UPS products that are specifically designed to be cost-effective, yet meet the basic requirements of military aircraft or field applications. These rugged units have been designed and constructed to meet the basic military application requirement – without the large added costs associated with a custom military specification UPS, Frequency or Phase Converters.

[1] Power Anomaly Effects and Costs in Low-Voltage Mobile Power Systems, Singer, Shengyi and Dougal

Typical Aircraft Power System



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