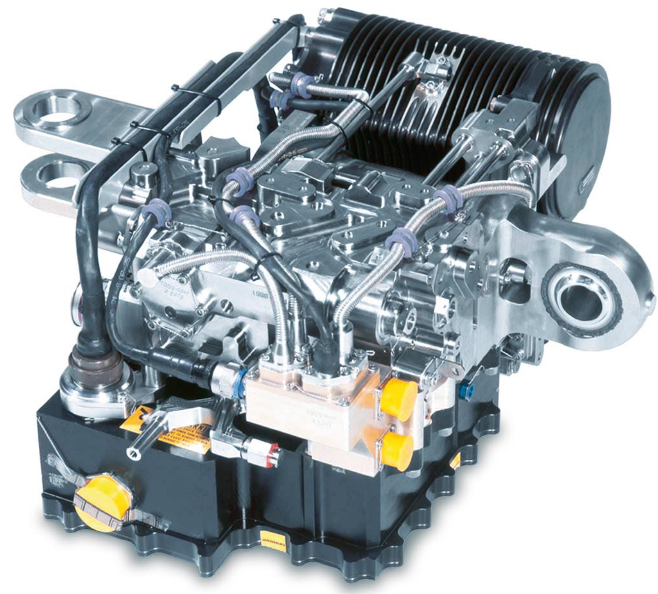
Using active mains filters as a new approach to suppressing interference in aircraft electrical systems

Onboard Power

Reducing aircraft weight decreases kerosene consumption and protects the environment. One method is to use lightweight electrical components instead of heavy hydraulic and pneumatic systems. This means that a high-quality power supply is absolutely essential, and also requires powerful interference suppression. Liebherr-Elektronik GmbH used dSPACE tools to develop a prototype of an active mains filter.



Active mains filters will be used in the future, for example, in the Airbus A380 Electrical-Back Up Hydraulic Actuator.

The Challenge: High-Quality Power Supply on Board

Everyone knows the noises a cell phone causes when it is near a loudspeaker and receives a text message. This interference is audible, but there is also inaudible interference such as that caused by phone battery chargers. These draw nonsinusoidal current from the mains and distort the voltage (figure 1). The fundamental frequency is overlaid by harmonics that negatively affect the entire supply network. They lead to higher losses in transformers, generators and lines; interfere with sensitive devices; and can even cause mains overload. In household appliances this is usually harmless, but in aircraft the resulting malfunctions can have serious consequences. This can be avoided by using an active mains filter that prevents such distortions from getting into the onboard power supply in the first place.

Filters Suppress Interference

In aircraft, electric energy is generated by three-phase generators driven by the turbines. Each electric consumer must first generate direct

The Airbus A380 Electrical-Back Up Hydraulic Actuator

is an electrical, hydrostatic actuator used as a backup system. In normal operation, the pump is switched off, and the actuator is moved by the aircraft's internal hydraulic pressure. If both of the aircraft's hydraulic circuits fail, the electrical pump springs into action to generate the necessary oil pressure directly on the actuator. Liebherr-Elektronik GmbH develops and produces parts for these control and power electronics jointly with dSPACE.
In the future, the active mains filter will be a component in these electronics, where it will rectify the three-phase variable-frequency electrical system (360 - 800 Hz), ensuring that the interference generated in the rectification does not get into the aircraft's power supply. The main aim in using the active filter is to reduce the masses and volumes of the power electronics, which in turn will reduce kerosene consumption.

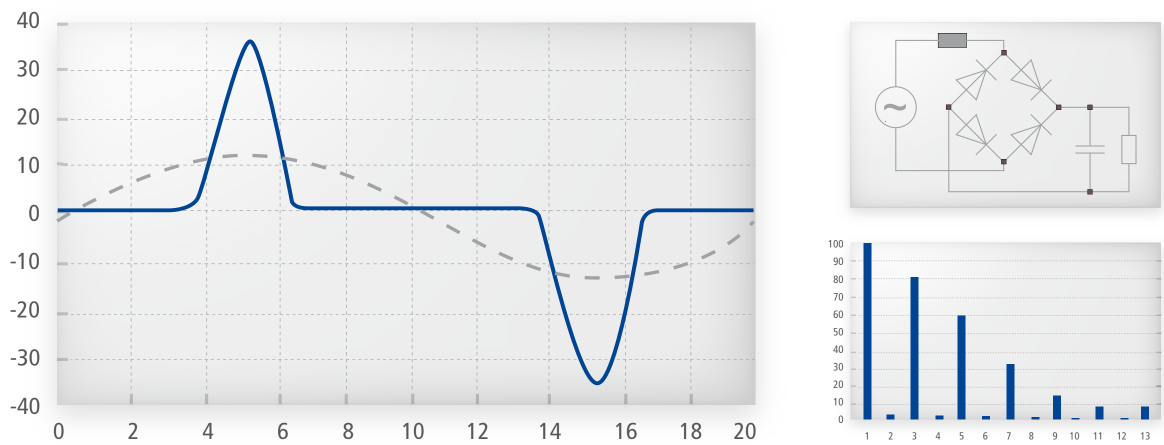


Figure 1: The rectifier shown here draws nonsinusoidal current from the supply mains (upper right). This causes additional losses in transformers and "dents" in the phase voltage. The ideal current is shown as a dotted line (left). The total range indicates the large harmonics content (lower right).

> "With the dSPACE prototyping system, we were able to develop a fully functioning active mains filter for aircraft in just a few months."
>
> *Sebastian Liebig, Liebherr-Elektronik GmbH*

current from the three-phase variable-frequency network (360 to 800 Hz). Up to now, this was done by 12-pulse rectifiers (special rectifiers with a 12-pulse transformer) or by active power factor correction (PFC). An active mains filter is a superior alternative to PFC because it can compensate for single harmonics, reactive power, asymmetrical voltages or even overvoltages, depending on how it is designed.

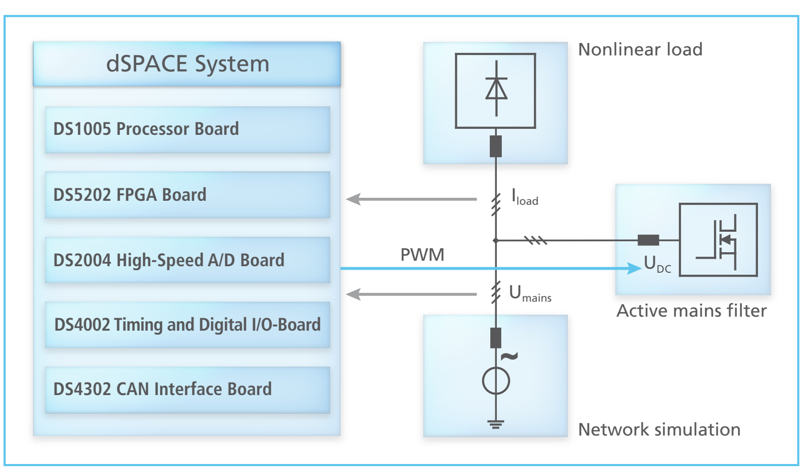
Active Mains Filters Improve Network Quality

Active mains filters have not been used in aircraft yet because the high frequency of the aircraft electrical system (800 Hz, relevant harmonics up to 10 kHz) requires extremely quick control. But now new, fast-switching semiconductors are making active mains filters a viable proposition. The ability to suppress interference in several devices simultaneously by means of one active mains filter is particularly attractive. This is much more economical than installing a separate filter for each device. Moreover, the active mains filter only has to be designed for the currents that need correcting, so its dimensions and weight are much lower than in an active PFC, which is designed for all currents. In addition, the high switching frequencies make it possible to use compact semiconductor switches.

Prototype Development with a dSPACE Processor Board

The primary requirement for implementing an active mains filter is powerful hardware, needed to achieve high switching frequencies of up to 100 kHz and compute the complex control algorithms in real time. The dSPACE system (figure 2) consists of a DS1005 Processor Board and several I/O boards. These include the new DS5202 FPGA Base Board with the EV1048 piggyback module, which enables pulse width modulation (PWM) with center-aligned sampling of clocked currents

Figure 2: The laboratory setup consists of a three-phase network simulation, a nonlinear consumer (rectifier with ohmic load), the active mains filter and the dSPACE Expansion Box, which is operated from ControlDesk on a laptop.



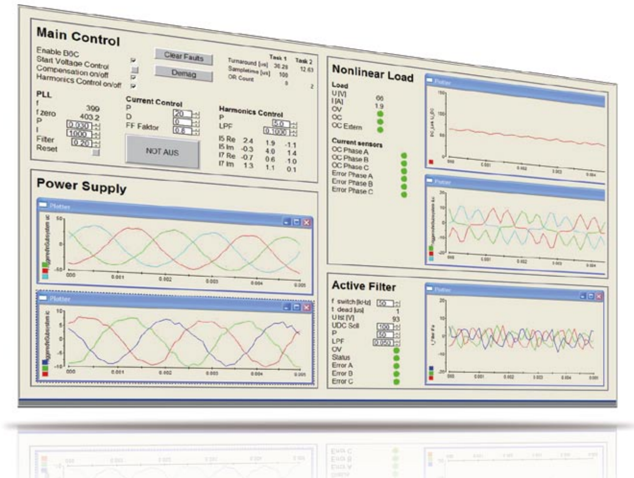


Figure 3: ControlDesk layout showing the measured voltages and currents and the correction signals.

and voltages. Further analog signals such as load currents I_{Load} or temperature sensors are read in via the DS2004 High-Speed A/D Board. The system currently achieves a switching frequency of 50 kHz with ease, so the entire control algorithm is computed in less than 20 µs. Thanks to multitasking, the computing power can be distributed flexibly, meaning that less important digital I/Os and temperature signals can be evaluated at considerably lower speeds, allowing additional resources to be assigned to more important tasks. After controller design is completed in MATLAB®, all the sensor signals and arbitrary virtual variables can be observed during run time by means of dSPACE ControlDesk®, which is an extremely convenient way to perform error detection and parameter optimization (figure 3).

Result

With the aid of the dSPACE rapid prototyping system, it was shown that an active mains filter can be used reliably despite a variable electrical system frequency. The harmonics are successfully compensated for. Measurements confirmed that a device with an active mains filter fulfills the relevant standards. This is a major step along the long road to aviation approval.

Outlook

The next task will be to optimize the algorithm in order to increase the 50 kHz switching frequency. This is important for downsizing passive components such as inductivities and intermediate circuit capacitors and for enhancing operational safety. The more frequently the model is computed, the better unexpected events such as voltage transients or phase failures can be detected and compensated for. The high safety levels required in aviation make such robustness an absolute necessity.
The active filter is put into series production with a digital signal processor (DSP) from Texas Instruments. The developed algorithms are turned into production code for this DSP by means of dSPACE TargetLink®. ■

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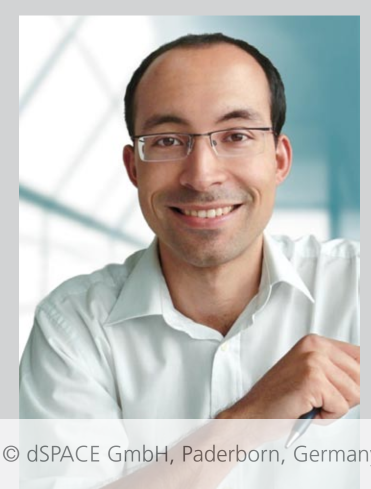

Conclusion

- The electrification of aircraft makes new measures for high-quality electrical systems essential.
- An active mains filter can be included in the architecture of an aircraft's electrical system, and complies with the mandatory limits.
- The go-ahead has been given to use TargetLink to develop the system up to production level.