

Integrated Power Distribution Unit (IPDU): Point-of-Use Power Conversion, Management, Distribution, and Protection for Aircraft Electric Power Systems

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ABSTRACT

This paper presents the Integrated Power Distribution Unit (IPDU) concept, which brings together major electric power Conversion, Distribution, Management, and Protection (*CDMP*) functions in a single lightweight LRU. The IPDU enables *CDMP* functionality to be physically located at points-of-use nodes, while maintaining unified control among the several IPDUs used in an Electric Power System. IPDU functions include input power quality sensing, power conversion (Inverter, TRU, Frequency Converter, DC-DC Converter), power management (AC and DC SSPCs and Hybrid Contactors), and a control function consisting of a databus R/T, DSP control core, and a voltage-frequency-current sensor suite. The IPDU is currently being applied as a major electrical power system element within a new aircraft dual channel EPS.

The three major goals of the IPDU design are Improved power management functionality (fully observable system), enhanced reliability, and reduced size and weight.

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INTRODUCTION

Integration and modularization of aerospace electric power systems has long been a goal of advanced research in EPS design^{1, 2}. A great deal of work has been done in this area targeting large transport aircraft, due to the potential for major savings in fuel and maintenance costs³. The work presented here addresses similar concerns as applied to smaller regional transport aircraft, rotorcraft, and general aviation platforms.

The IPDU concepts presented here are characterized as containing a power management and distribution function along with one or more power conversion functions within a single LRU. In addition, primary power distribution and protection functions, such as bus tie contactors, RCCBs, and bus transfer contactors may also be included in the IPDU.

Power conversion functions include AC-DC conversion (TRU), DC-AC conversion (Inverter), AC-AC conversion (Frequency Converter), and DC-DC conversion elements. One or more power conversion elements within an IPDU perform point-of-use power processing and regulation in close proximity with the utilization and system loads. This approach is in contrast with bulk power conversion at a single site within the EPS, connected to a lengthy distribution network.

IPDU ARCHITECTURE

Figure 1 describes a legacy secondary power management channel as applied to an AC/DC EPS. An RCCB provides switching and feeder protection, a TRU converts AC to DC, and supplies both AC and DC power to the Electric Load Management Center. SSPCs within the ELMC switch and protect load feeders supplying power to aircraft system and utilization equipment loads. These three elements are typically located in close proximity to one another, and interconnected with wire harnesses. Databus communication is usually provided only to the ELMC. Certain discrete signals are shared between the three components, but data collection and decision processes depend upon the data bus latency times as well as host processor utilization.

At its simplest, the IPDU concept brings these three elements (and possibly more) into a single LRU, as shown in Figure 2. The immediate benefits are elimination of interconnect wiring harnesses, reduces enclosure size and weight, and reduced EMI/EMP susceptibility. Another important byproduct of this architecture is the ease by which all system states can be sensed and reported on a databus. This leads to realizing a fully observable EPS, and the ability to implement optimal control strategies.

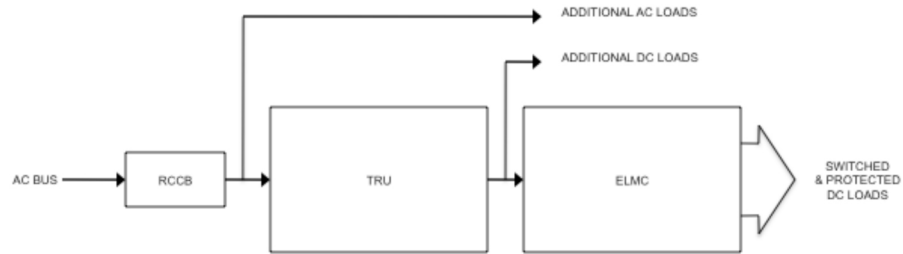


Figure 1. Baseline Power Conversion, Management & Distribution

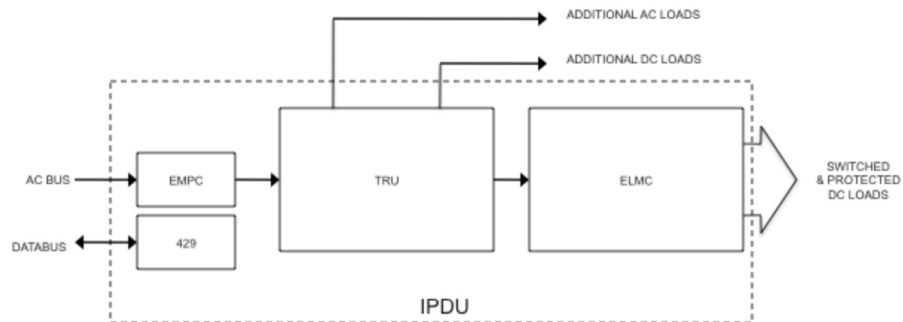


Figure 2. Integrated Power Conversion, Management, & Distribution

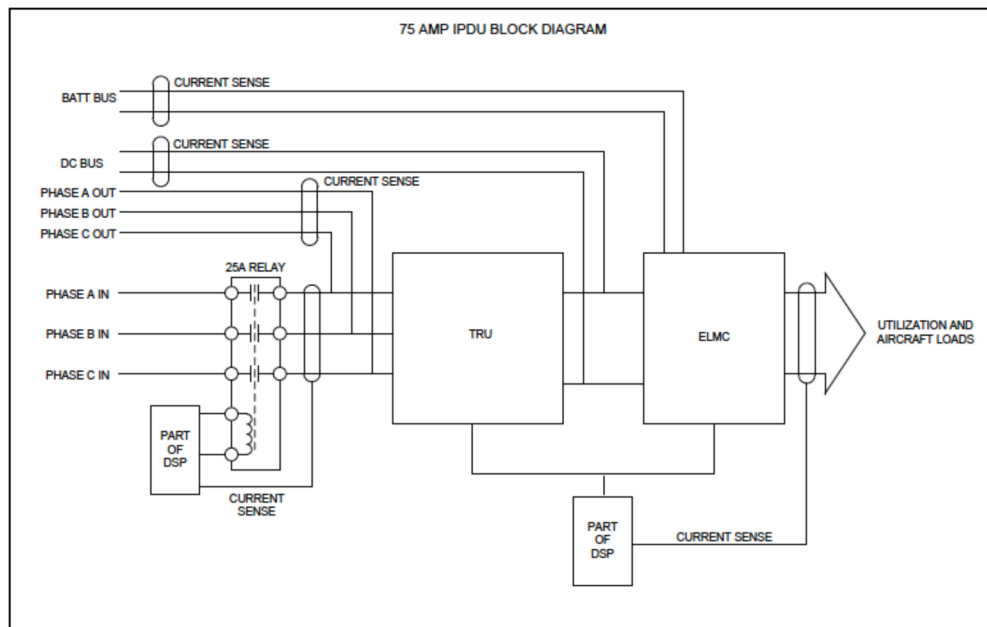


Figure 3. IPDU Architecture

Figure 3 looks at the IPDU architecture in more detail. An electromechanical power controller now accomplishes the input bus switching and protection function previously performed by an RCCB. This EMPC consists of a contactor, voltage and current sensors, and a digital controller. The EMPC overcurrent protection is implemented in software as an I^2T trip curve, which can be tailored in both the time and current dimensions. Co-location of all three major power

control functions within the same LRU eliminates the need for most discrete signals between these functions external to the LRU, saving weight and lessening the chances of signal corruption due to EMI and lightning.

All power feeder inputs and outputs are sensed, enabling multilevel differential fault sensing at the LRU level. Because of the high level of functional integration within the IPDU, all electrical and thermal parameters can be sensed and

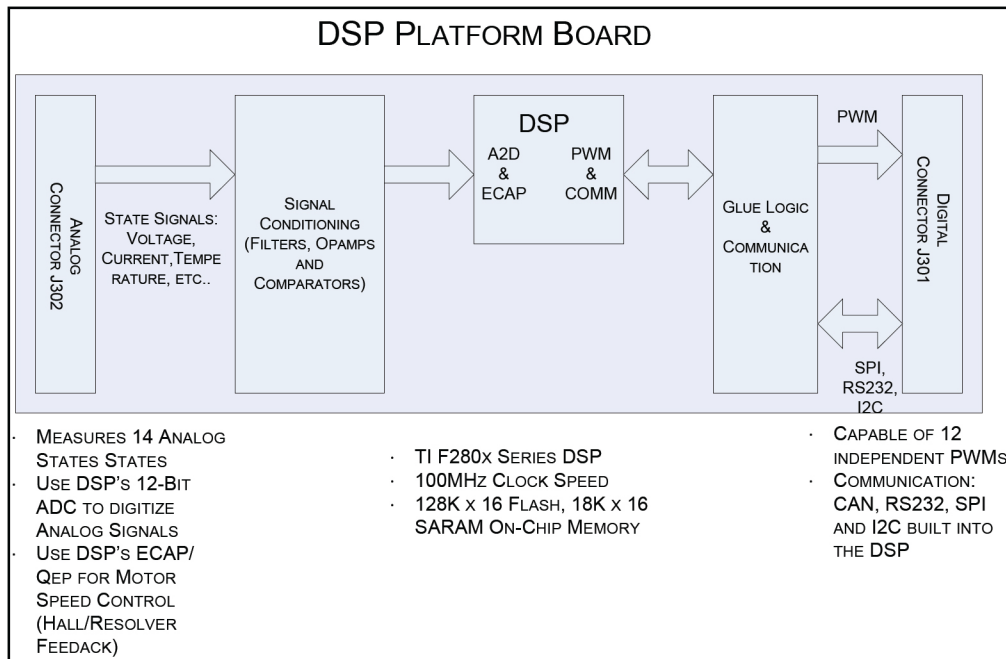


Figure 4. IPDU Communications and Control Processor

reported via a single databus R/T, bring the EPS closer to the goal of being a fully observable system.

Control of the IPDU is accomplished by a high-speed digital signal processor platform-shown in Figure 4. This DSP handles databus I/O tasks, state sensing and MUXing, discrete signal management, power conversion and management, internal LRU CAN bus control, and diagnostics and self-test. All software used in the IPDU is qualified to DO-178B, Level B or C. Level A qualification is available as well.

The TI TMS320 family of digital signal processor chip sets was selected for this program. Of the many variations that exist within this basic family, memory, I/O, clock speed, and bus speed form the trade space for specific applications. The control function implemented with this DSP provides various I/O ports that service the power converter PWM controls, SSPC I/O, sensor data, data bus, diagnostic registers, and effector outputs. A standardized PCB containing these functions and has been produced, which is used in a variety of power conversion products.

TRU-BASED IPDU

The IPDU may be configured in many ways to accomplish specific power conversion and management tasks, and these variations will be discussed later in this paper. The TRU-based architecture shown in Figure 5 and Figure 6 is one of the most popular configurations of the IPDU, and is used in AC-based power systems to manage power to both AC and DC loads.

In this form, the IPDU can control up to 100 Amps of AC power as well as 200 Amps of LVDC (28VDC) power. Pass-through monitoring of an additional 100 Amps of uncontrolled AC power to specific loads can also be accommodated within the IPDU. This AC pass-through feed is monitored for voltage and current system states, helping to form a better picture of the EPS behavior at any instant in time.

IPDU VARIATIONS

In addition to the TRU-based IPDU described above, other power conversion and management options can be included in specific IPDU architectures. Figure 7 shows two additional IPDU options that include HVDC power conversion and DC-AC power conversion. This example EPS is derived from a special mission platform that requires HVDC as well as 115VAC/60Hz power for utilization equipment operation.

POWER AND SIGNAL ISOLATION

The related issues of power bus isolation, signal isolation, and fault isolation were addressed from the outset in the IPDU configuration and design studies. Redundant channels and feeders are provided for flight-critical and mission-critical power and data. Physical and electrical segregation within the IPDU LRU is also used to mitigate fault propagation and aid in automated EPS recovery. Care is taken to isolate critical functions from single-point failures, and such failures are considered in the design of the control software configuration.

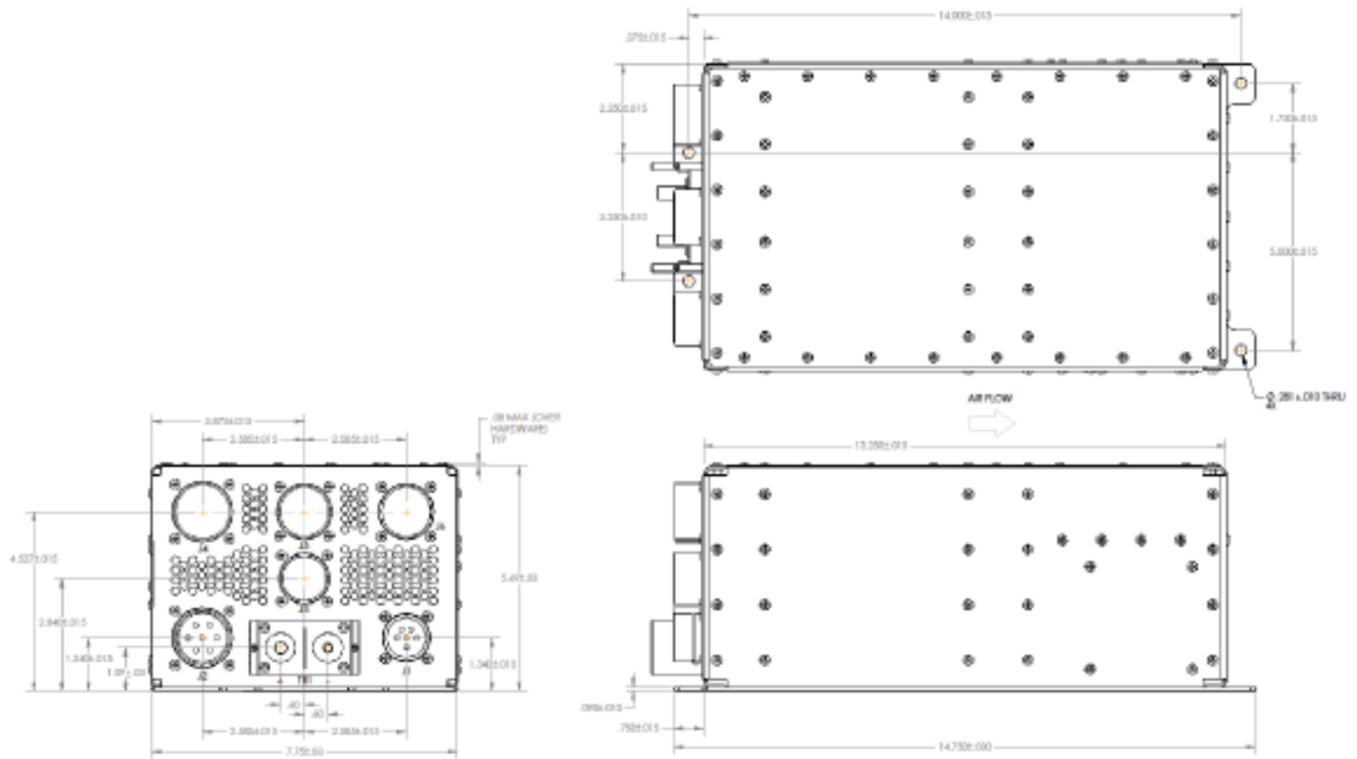


Figure 5. Outline diagram of TRU-based IPDU

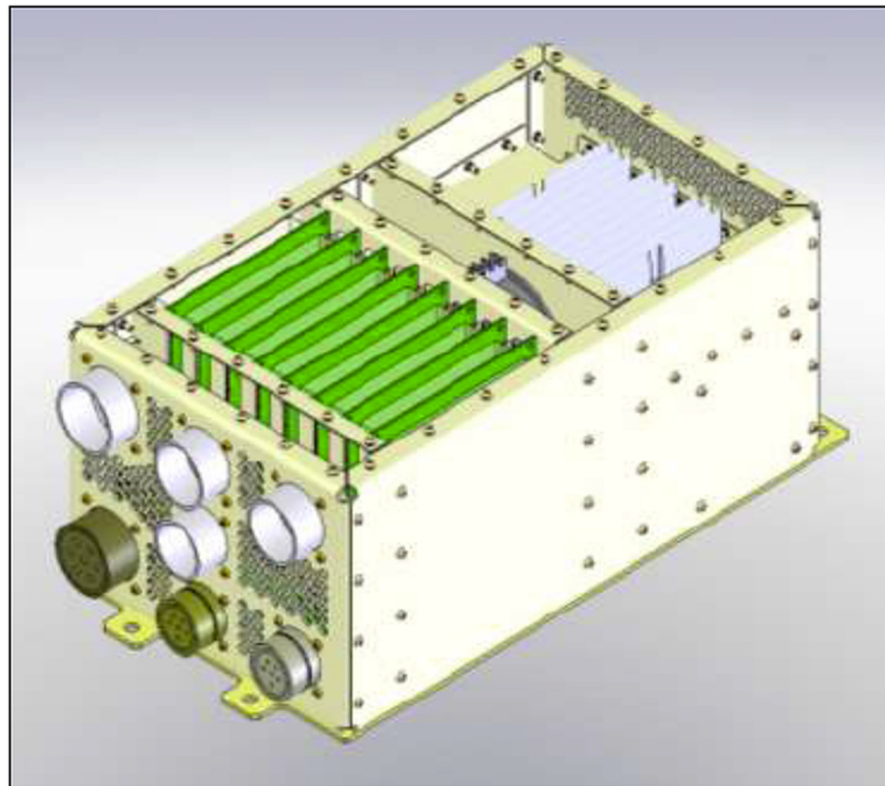


Figure 6. IPDU LRU 3D Rendering