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SMART POWER ARCHITECTURE FOR INTELLIGENT POWER DISTRIBUTION

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ABSTRACT

Curtiss-Wright has developed an advanced Smart Power Architecture for Intelligent Power Distribution, based on our Intelligent Power Distribution Demonstration (iPDD) and experience in providing power distribution components specifically for Heavy Brigade Combat Team (HBCT) vehicles. The challenges of power distribution and management in ground vehicles are presented, including issues of scalability, warfighter burden, and the complexity of distributing multiple vehicle power sources. The fundamental building blocks of Smart Power are described, including Power Distribution Units, Power Conditioning Units, and types of Power Conversion Units (AC/DC, DC/DC, DC/AC). A Smart Power Reference Architecture will be presented, showing how it enables scalable and modular power distribution systems. How modular Smart Power Architecture can enable commonality across vehicles and applications. How it can provide automatic and programmable load management, including startup and shutdown sequencing, event triggered load control, and automatic configuration for vehicle operational modes. How multiple power sources can be used to provide uninterrupted vehicle power, including off-vehicle scavenged power. How power sensitive loads can be integrated into traditional unconditioned power, allowing for cost and SWaP savings. How the Smart Power Architecture integrates with the US Army's VICTORY Architecture. How it integrates with and enables vehicle prognostic and diagnostics. How the Smart Power Architecture for Intelligent Power Distribution ultimately provides better value to the warfighter.

INTRODUCTION

Power distribution, monitoring, and control are made more difficult in vehicles by the addition of various C4ISR/EW systems. Traditional power management in vehicles for relatively static loads without complex sequencing requirements is fundamentally physical in nature – bus bars, home-run cabling, switches, and circuit breakers. Modern power distribution and management needs to be smarter to handle the complex set of widely varying loads and sensitivities present on a vehicle with modern electronics.

Curtiss-Wright's Intelligent Power Distribution Demonstrator (iPDD) is a ruggedized power distribution and conditioning device designed for use in military vehicle applications. It is capable of delivering up to 2.75 kW to multiple loads from either of two 18-33 VDC inputs or a 115/220 VAC 50/60 Hz single phase input with uninterrupted transition from one input power source to another. Three types of regulated output voltage are available: Eight channels of 28 VDC, one 12 VDC output and one 115 VAC output. The iPDD interfaces to the core computing element through an Ethernet TCP/IP connection and an open, host level, API for custom application development. An RS-232 serial interface is also provided for channel configuration, monitoring and control through a text based command line interface. A simple GUI facilitates configuration and operation over the Ethernet link during development. Digital inputs and outputs are provided to facilitate individual control of each output channel. The iPDD has been designed with modularity & scalability as primary goals to facilitate use in multiple platforms.

The iPDD served as the foundation demonstrator for the development of the Smart Power Architecture for Intelligent Power Distribution.

KEY ARCHITECTURAL CONCEPTS

For Smart Power Distribution, scalability and modularity are important to consider. Not all vehicles will require the same types of sources, nor will they all have the same number or types of loads. For this reason, the architecture needs to remain as flexible as the traditional physical distribution – lines are run as needed, and bus bars / distribution units are provided at points of load. The

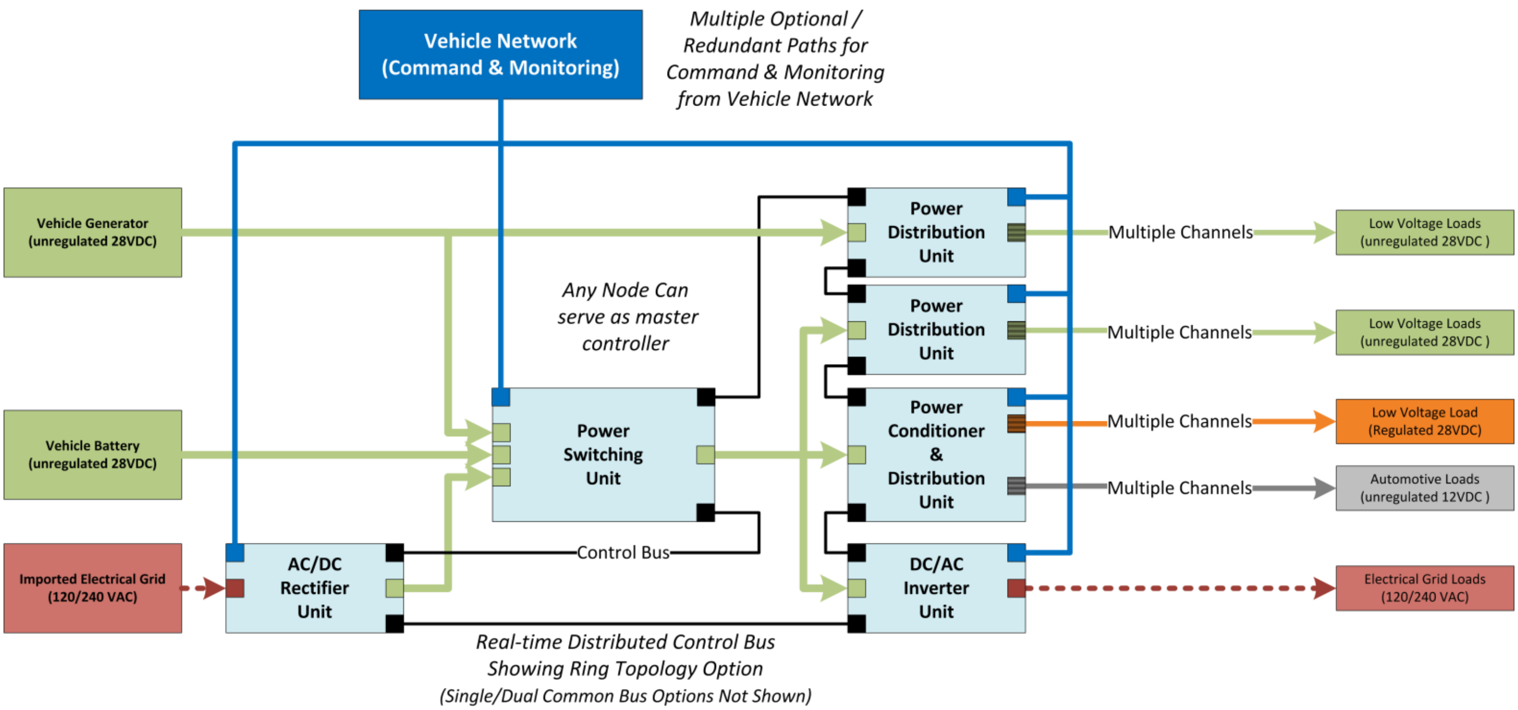

Figure 1: Smart Power Architecture for Intelligent Power Distribution

Architecture considers these varying needs, and provides the flexibility for the designer through a set of building blocks, as shown in Figure 1, and are described below.

Control and Monitoring

Each element of the Smart Power Architecture is connected on a distributed real-time control bus, optimized and configured for the specific vehicle requirements (cost, flexibility, redundant operation, etc.). At least one element of the Smart Power Architecture is connected to the Vehicle Network through open standards, such as the VICTORY standards definition for Power Subsystems interface, in order to provide high level command and monitoring of the power subsystem. Multiple elements can be connected as well, providing multiple paths into the Smart Power Architecture.

The overall control of the Smart Power Architecture can remain distributed to each device, or one or two devices on the control network can act as the master device. This is a design option, optimized for the specific vehicle requirements.

Power Distribution Unit

The fundamental building block of the Smart Power Architecture is the Power Distribution Unit (PDU). This device provides a set of channels (e.g. 8 channels) from a common input. The device provides little to no conditioning nor regulation of the power, as it serves to be a SWaP and cost effective unit. Power Distribution Units may contain channels of different capacities, along with options for ganging channels for increased capacity; however, the core function remains the same. Each channel is individually monitored, controlled, and protected (e.g. I^2T trip profiles) within the unit. An embedded controller provides the control network and vehicle network interfaces.

Power Conditioner & Distribution Unit

Augmenting the PDU is the optional Power Conditioner & Distribution Unit (PCDU). This is an advanced version of the PDU, providing specific regulation for sensitive or unique loads, such as sensitive ISR or EW gear, requiring stable 28VDC, or for commercial / consumer equipment running on 12VDC (commercial automotive) or 5VDC (USB) power. This device, expected to be more complex, driving up SWaP and cost, is only used as required in a vehicle. Like the PDU, it provides a set of individually monitored, controlled, and protected channels and an embedded controller provides the control network and vehicle network interfaces.

Power Switching Unit

An advanced building block of the Smart Power Architecture is the optional Power Switching Unit (PSU). This building block provides encapsulation of the originating power source, abstracting the source power from the view of the loads. This is critical for seamless power switch-over such as in the cases of generator to battery, or battery to scavenged / shore power. By maintaining the constant output to the loads, complex power down and power up sequences can be skipped. Since the Power Switching Unit contains an embedded controller providing the control network and vehicle network interfaces, it can provide intelligence to the rest of the Smart Power Architecture as to the overall source capacity, source selection, and source health, allowing distribution units and loads (through the vehicle network) to understand the current operating state of the vehicle, and to react accordingly.

AC/DC Rectifier Unit

Augmenting on the onboard power sources with external grid power (100-240VAC @ 50/60Hz) provides an important flexibility for vehicles. An AC/DC Rectifier Unit (ADRU) provides this straightforward optional function. Multiple units can be ganged on the output to provide higher capacity. Monitoring and Control is provided by an embedded controller provides the control network and vehicle network interfaces.

DC/AC Inverter Unit

Complementary to the AC/DC Rectifier Unit is the optional DC/AC Inverter Unit (DAIU). This provides on-board sources with standard grid power (100-240VAC @ 50/60Hz) for devices expecting standard grid power. Trade of SWaP and cost for quality of output waveform (e.g. square versus pure sine) provides flexibility to the designer. Multiple units can be used for varying loads (both in sensitivity and capacity) higher capacity. Monitoring and Control is provided by an embedded controller provides the control network and vehicle network interfaces.

ADVANCED CONCEPTS

Commonality

Given the building block nature of the Smart Power Architecture, the same Power Distribution Units, as well as the advanced building blocks, can be used across multiple vehicles, becoming ubiquitous and vehicle non-specific. In addition, common loads across multiple vehicles can be coupled with a common set of sequencing and control instructions, encapsulating the power up and power down of that subsystem as a fully integrated functional unit.

Automatic Load Management

A critical issue is load automatic load management. The Smart Power Architecture can leverage knowledge of origination source, load and source health, and interconnection with other vehicle systems through the vehicle network (e.g. VICTORY) to automatically configure loads and shedding priorities based on the current state of the vehicle. This is not possible with traditional lines, bus-bars, and switches without physical manipulation by the warfighter, manually sequencing loads based on checklists and procedures. By moving the load management into software on the control network, the vehicle user community, integrator, and subsystem vendors can instead provide the scenarios and load configurations as software configurations during vehicle design time, or even as upgrades / alterations in the field.

An important feature of this is contingency load management, reacting to specific events, such as roll-over detection and shutdown of undesired systems (such as jammers). By providing the vehicle with automatic load management programmed for various failure modes, the vehicle can alleviate the need for the warfighter to manually handle switches and indicators during a high stress situation.

Load Sequencing

The complexity and interactions of C4ISR/EW equipment can often lead to lengthy power up and power down sequences. By programming automatic sequencing, including device feedback detection, into the Smart Power Architecture, these lengthy and error prone checklists can be avoided. Typical in networked environments is the need to wait for the network infrastructure (switches, routers, network attached storage) to be running before powering up devices which need it. Since the elements of the Smart Power Architecture are also connected to the vehicle network, feedback (such as ping responses) can be waited on before proceeding to the next power up step in the sequence (e.g. turn on mission computer). This load sequencing can also ensure that over-current / in-rush conditions are avoided by ensuring that power up of heavy loads are sufficiently staggered.

Maximum Load Sizing

Intelligent Power Distribution provides both Automatic Load Management and Load Sequencing. Both of these capabilities change the maximum load size driving maximum power generation capacities. Automatic Load Management can ensure that loads which never have need to be in use at the same time will never be, and Load Sequencing can ensure that in-rush and start-up currents are properly sequences to prevent peak loads. This allows the designer to size the onboard generation based on the maximum actual operational load sizing, instead of the summation of all maximum unit loads and unit in-rushes, based on the assumption that all loads can be on and be turned on simultaneously. This is a critical advantage in controlling the overall SWaP-C burden of onboard power generation.

Prognostics / Diagnostics

The networked embedded controller aspect of the Smart Power Architecture provides a rich set of data for prognostics through load characteristics analysis (e.g. current analysis for motors loads). Diagnostics are made simpler since each node in the architecture provides internal monitoring and control, helping to rapidly isolate a problem to a specific channel. Logging of data provides the diagnostics team a clear understanding of the power events surrounding equipment failure. These benefits of the Smart Power Architecture ultimately serve the warfighter through increased availability of vehicles.

CONCLUSION

Curtiss-Wright's Smart Power Architecture for Intelligent Power Distribution provides and an open, flexible, capable, scalable, and robust approach for vehicle electronics. It provides a clear path forward to intelligent and scalable power management on vehicles, whether through incremental modernization efforts or new designs. The straightforward modular approach allows designers to select, size, and optimize the system as needed for a vehicle or a family of vehicles.

Automatic Load Management and Load Sequencing relieve significant power management task burdens from the warfighter as well as ensuring that onboard power generation is right-sized instead of over-sized for the vehicle. Rich data from monitoring elements ultimately lead to greater availability of vehicle and equipment.

With transitions to more complex C4ISR/EW equipment and other electronic systems on vehicles, such as Remote Weapons Stations, the power systems must evolve as well. The Smart Power Architecture for Intelligent Power Distribution is well suited to the growth and complexity of these modern loads.