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DISTRIBUTED POWER AND CONTROL MANAGEMENT SYSTEM (DPCMS)

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ABSTRACT

Upgrading and modernizing vehicle electrical systems in a cost-effective manner has been an ongoing challenge for PEOs and PMs across multiple services. UEC Electronics' advanced DPCMS achieves that end state.

INTRODUCTION

UEC Electronics' Distributed Power Control and Management System (DPCMS) is a smart power and data acquisition system managing real time power and data control while providing enhanced situational awareness. The system is equally beneficial for new vehicle engineering and development efforts and for upgrading legacy vehicle electrical power systems during modernization. The advanced capabilities of this system provide real-time feedback, power management, and better Reliability/Availability/Maintainability (RAM). Additionally, the system increases the use of rugged, yet readily-available and cost-effective, electrical sensors and Commercial-Off-The-Shelf (COTS) devices while providing MIL-STD-1275 protected power channels.

SYSTEM BASICS

DPCMS is a combination of components which together provide intelligent vehicle power distribution, control, and management. The system begins with the Power Distribution Box (PDB) which receives power from the battery and alternator subsystem and routes a combination of switched and unswitched power for vehicle operations with or without the activation of the master power switch found on the dash. The 100-Amp Solid State Circuit Breaker (SSCB) circuit cards within the PDB route power to the Power Control Modules (PCMs) throughout the system. The PCMs utilize SSCB technology to smartly engage and disengage power channels to each of the effectors (i.e. power utilizing components) within the vehicle. Additionally, the PCMs receive up to six analog or digital sensor inputs. The System Interface Module (SIM) amplifies the analog or digital sensor input to 20 channels to support large subsystems such as the power pack (engine and transmission). The SIM also serves as the Victory-compliant gateway, bridging the power distribution J1939 CAN Bus network to a modern J1939 CAN Bus smart power pack network. This gateway allows only the necessary signals from each network to cross into the other, thus maintaining clean and efficient networks free of cluttered traffic.

The Instrument Panel Assembly (IPA), otherwise known as the Dash or Dashboard, houses the Video Display Unit (VDU) and Human Machine Interface (HMI), which consists of one or multiple keypads used for human control of the system. The VDU provides the situational awareness capability of the system. This includes operator display gauges and maintenance-specific items such as the power consumption of each PCM, raw sensor data values, and trip states of each SSCB. The system can also incorporate multiple video streams or other video outputs from a wide variety of systems. The system controller (i.e. system-wide managing computer) can be embedded within the display or can be maintained as a separate component. The keypads provide pre-configured input into the system and are redundantly backed up within the display via the use of soft keys. This redundancy ensures that a keypad failure does not impact the availability of the system. Two Hubs are also found within the IPA which manage the redundancy features between keypads and the display and determine which system controller is communicating commands onto the CAN Bus.

DPCMS components are comprised of numerous quantities of like core components. For instance, the basic configuration within the system would typically consist of two (2) Hubs, two (2) VDUs, six (6) PCMs in 20-Amp configuration (PCM-20s), and three (3) PCMs in 60-Amp configuration (PCM-60s). Within each family of core components, all of the items are indeed the same component. Their "configuration", however, is different based on where they are located within the vehicle and what effectors they are interfacing with. To allow the interchange (hot-swappable, plug-and-play) of components, a built-in address at each location of the system provides the modules with their actual identity. A Configuration Module (Configurator), which contains the unique configuration of every variation of components within the vehicle, is notified if a module recognizes a new ID. The Address ID is provided to the Configurator and a new configuration is provided to the module over the CAN Bus. Upon receipt of the new configuration, the module restarts itself and begins operations in its new role. This allows the immediate replacement of failed items necessary to perform the critical functions of SHOOT, MOVE, and COMMUNICATE. A good example would be replacing a damaged PCM that is supposed to power engine operations with a functioning module that was previously controlling a non-critical effector, such as exterior lights. In this scenario, the PCM performing external light operations (non-critical) can be unplugged from its current location, plugged into the failed engine operation module's (critical) location, and the PCM will immediately recognize the change. It will then request a new configuration load, reboot, and take over as the engine interfacing PCM, which allows the critical MOVE operation to resume. This also applies to hot-swapping modules across different vehicle platforms altogether (i.e. moving a module from an

AAV to an LAV) when multiple vehicle platforms employ DPCMS. This would also lead to a much-reduced logistical footprint by allowing common spares to be stocked and utilized regardless of vehicle variant or platform.

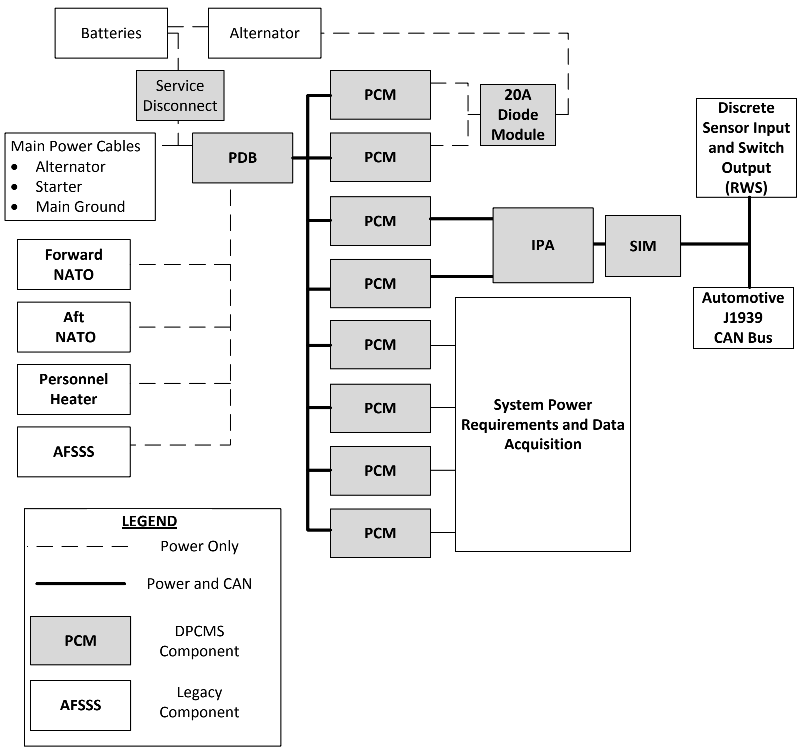

Figure 1. Base System

BENEFITS

The System Controller allows for the automatic control of functions designed to increase the reliability of legacy items within the system. On the Assault Amphibious Vehicle (AAV), the power cycling of fuel and bilge pumps was one such item. The intelligence of the controllers allows the system to differentiate between pumps when running wet and when running dry. When this difference in current draw is detected, the system can disable the dry pump and maintain it in the off position until acted upon by a new stimulus. In the case of the AAV, this new stimulus was a timer based on duty cycles of the pump. Therefore, during the dry cycle a timer was set and once it expired the pump was enabled and a new current draw was evaluated and the cycle repeated.

The intelligent system can also load shed during critical phases of operations. Load shedding is simply removing non-critical items from the power bus until a more appropriate time is available. The software programming for the Light Armored Vehicle (LAV) and AAV DPCMS systems kept the alternator excitation circuit disabled until the stimuli Oil Pressure and Engine Revolutions Per Minute (RPM) are achieved. The benefits are realized as the power draw during start and the Electromagnetic Interference (EMI) noise from the alternator starting at lower RPMs is mitigated until the system is at standard idle.

Automatic controls of key items, particularly during critical phases of operations reduces task overload of the operator and can be a key factor in reducing crew tasking and eventually crew manning. One specific instance demonstrated within DPCMS is fuel transfer between fuel tanks. During operations when an imbalance of 20% is detected, the system automatically disables the fuel pump from the emptier tank and the closes the return fuel line to the fuller tank. This allows the fuller tank to be utilized for operations and the significant flow of return fuel from the high pressure diesel engine to empty into the lower tank. The system can be manually disabled to run on left or right tank when desired by the crew. For amphibious operations, a tank imbalance, realized at 7 pounds a gallon across two nearly 100-gallon capacity tanks, greatly shifts the lateral center of gravity to a location detrimental to stable operations.

Standard electrical systems shut off immediately upon selecting the power or master off switch. Like office computers, immediate loss of power can impact mission capability by “corrupting” or damaging key computer and communication gear. For example, computers risk missing a save cycle and losing valuable mission data if the power is cut too soon. The Soft Off capability of DPCMS is akin to the Shut Down feature on your Windows desktop computer and allows the system to process and store required information in a smart and strategic manner prior to cutting the power. The system will start the disable process but will retain power to certain specified effectors until impacted by specific stimuli – meaning the computers and communications systems have completed their shut down sequence. In the event of an emergency, an E-STOP feature is available to immediately cut power to the system.

Without a computer, pressure differentials are calculated with expensive and cumbersome sensors – typically managed in a maintenance laptop which requires being stored and presented during maintenance operations. However, DPCMS’ intelligent system is able to utilize a simple mathematic formula to calculate the difference between the high and low side of a filter and provide a differential output reading on the operator’s display. This will allow maintainers to identify filter replacement needs more precisely than typical replacement cycles based on time of use.

The PCM contains software-enabled, Solid-State Circuit Breaker (SSCB) functions. The SSCB functionality allows the designer to program a channel to a traditional circuit breaker trip curve. For example, a PCM channel can be programmed to be tripped instantaneously when a current level 9 times above the configured maximum current setting is detected. The SSCBs use the common I^2T trip algorithm, which compares amperes over time in the equation: $E = {I_{th}}^2 \times T_{td}$ (where E = energy, I_th is the trip threshold current, in Amps and T_td is the trip delay, in seconds).

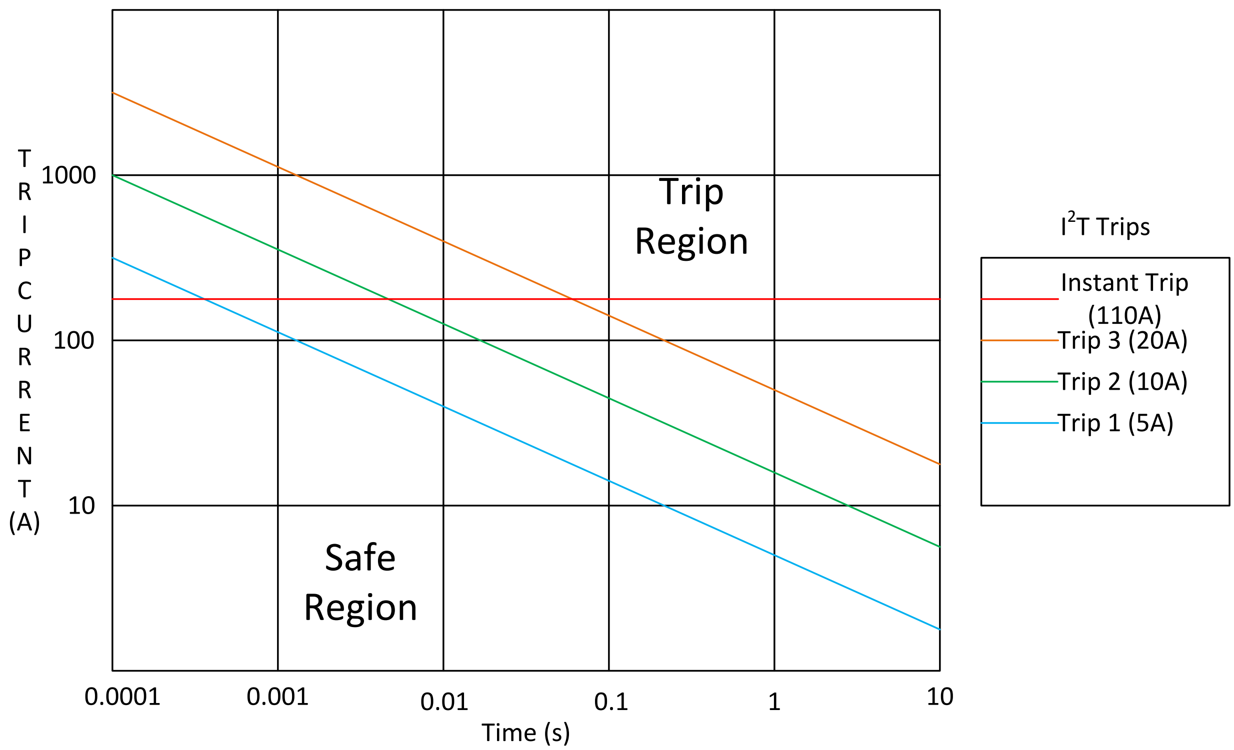

Figure 2. I^{2}T Trip Curve

The software SSCB function is also capable of supporting in-rush currents from prematurely faulting the output while providing protection of the system from short circuit conditions. Whereas in a traditional thermal circuit breaker trip curve the overcurrent is not consistently repeatable, the DPCMS system's circuit control provides predictable overcurrent based on the magnitude and length of time the circuit was in the overcurrent condition.

Electrical system designs are hindered by in-rush current demand. The in-rush is the immediate and high current draw from an effector required during initial start-up. This phenomenon typically leads to handicapping design architecture to account for its occurrence. These items require a larger percentage of power to start than they do to sustain operation. DPCMS performs Pulse Width Modulation (PWM), whereby voltage is "throttled" to minimize the current demand and draw, slowly powering the item into operation. This PWM process occurs in under 250 milliseconds and is typically not noticeable by the operator. PWM is limited to the maximum draw of the effector. During design of DPCMS for the AAV, the crew vent fan exceeded the PWM capability of the PCM directly, however the intelligent system countered with a synchronized start sequence. When the high fan selection is enabled the system actually activates the low fan system to enable the fan at a lower current and allows the fan to spin to full low speed RPM. Once this time delay is realized, the low power selection is disabled, a 100ms delay occurs, and then the high fan speed power setting is enabled. This synchronized start up sequence technique, demonstrated in Figure 3, was able to reduce the in-rush current from 388 Amps to 150 Amps.

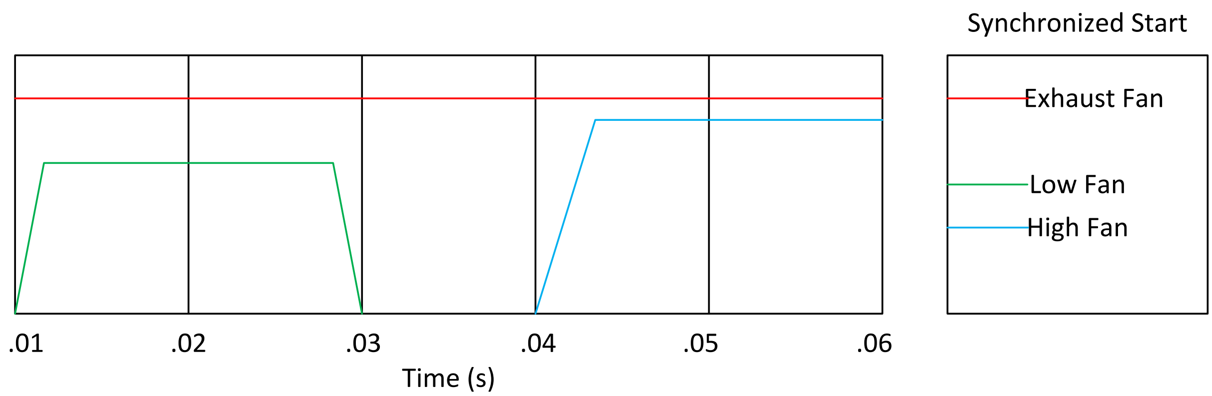

Figure 3. Synchronized Start of Crew Fan to Minimize In-Rush

In an effort to reduce electromagnetic interference (EMI) "noise" on the vehicle, each effector has a power return (ground) back to the system via a discrete return wire. Hull returns are no longer required. In both the LAV and AAV DPCMS systems, non-replaced legacy items had to be isolated from the hull to remove the chassis grounds and allow for the returns to be pulled back into the harness. Harnesses are EMI shielded to exceptional dB values utilizing light-weight materials which adapt to the harness under the heat shrink.

The redundant and distributed control features of DPCMS start just beyond the batteries and run throughout the system, providing redundant power to key effectors impacting the critical functions of SHOOT, MOVE, and COMMUNICATE. Items requiring redundancy receive power through two separate PCM modules. These modules maintain separate cable runs until just before the effector when they are combined into the single power channel which intercepts the effector at the Dual Redundancy Module (DRM). These modules have diode and other circuit card protections to minimize the cascading effects of short-to-ground failures on one of the redundant power runs from affecting the other. After the DRM, a single channel interfaces with the effector. The displays manage the system effectors and also are dual-redundant. More than 3 displays can be added to the system and their controller / non-controller status is maintained by the Hub module which intercedes between their power and network interface. The Hub identifies which display should be in control and allows the second and third display to make management decisions. However, the Hubs interfacing and talking between themselves mask or do not allow the non-controller's messages from entering the data network. If the Hub identifies a failure of the controller display, it will allow one non-controller to access the bus as the controller and begins masking the failed display's commands.

DPCMS has the technical hooks, i.e. functionality provided by the software, that allow for the implementation of remote, and eventually autonomous, system operation. The autonomous system is based on the same principles which allow the display to function identically to the keypads via the redundant control. A wire-tethered controller was implemented within the LAV and AAV projects for engineering use during vehicle shakedown testing. This controller provided full operational control and awareness of the system's status to the shakedown team. Operating with a long tether to move about the vehicle, the engineers could exercise components and identify key performance parameters more easily. A remote system can replace the tether and the same functionality would be available. Just as certain functions are automated for the operator such as fuel balancing, the same principles can apply to autonomous control of the vehicle. The system can be provided a certain list of parameters and function without direct human-in-the-loop operation.

The dual-redundant Controller Area Network (CAN) bus provides the data network for all the DPCMS components to interface with one another, receive control, and provide information. The CAN Bus networks run independently of one another and are routed and managed separately within the vehicle. The two CAN Bus networks interface independently with each DPCMS component and messages are combined internally with UEC proprietary hardware and software. Additionally, COTS items such as the displays, can have their single CAN Bus interface made dual-redundant with the addition of the Hub which performs the duties outlined above. The Display's Hub also routes additionally protected power for the COTS display's usage.

Situational Awareness (SA) may experience the greatest enhancement from the DPCMS upgrade, particularly from the crew's vantage point. The low-cost VDUs are rugged and protected by unique PCM output power channels which mitigate voltage spikes realized in military combat vehicles and outlined in MIL-STD-1275. This protected power source allows for industrial rugged displays and other COTS items versus the tens-of-thousands of dollars of military protected and designed displays. The additional advantage is the reduction of vehicle real-estate required of the large military displays.

At the present time the displays serve a dual purpose and are also the controller of the intelligence center. However, by utilizing an internationally recognized software standard, multiple COTS or in-house design solutions could be made available if and when separating of this function is required. The standardized software allows for easy modernization of both the functionality "control" software or the actual display of Graphical User Interface (GUI) information. This open architecture allows the OEM to design and develop the system, but allows the government to support the program as necessary in the future.

Key to the SA enhancements DPCMS brings is the diagnostics capability to an operator or maintainer. The electrical interfaces are each visible within the display's maintenance pages. These pages can be left available to the operator or can be secured with passwords or other limiting capabilities to reduce the operator's tampering with maintenance operations. Each input to the system shows the true data and voltage from the sensor. Each output from the system shows the current draw in real time with 0.3-Amp accuracy. With a read out of the SSCB, each output can provide short circuit, open, short-to-ground definitions and can be manually reset or simply turned on if the maintainer or operator desires to activate a system without the proper interlocks or stimuli. Of course these can be restricted on a case-by-case basis. However, the ability to start the engine when the transmission neutral interlock is invalid can save vehicles and perhaps crew lives in a battle. With a simple understanding of the system, a maintainer can determine if a sensor is bad, unconnected, a light bulb is burn out, or even if a fan is in need of near-term future replacement just with the basic outputs from these screens. Future enhancements to the system can allow for warnings and pop-up maintenance information to predict the likely future failure based on current draw or other historical data collected by the intelligent system.

Figure 4. Maintenance Display Screen for a PCM

Currently the system provides basic State of Health battery monitoring. This is a comparison of voltage and current of the batteries by internal voltage measurement capabilities and a current sensor placed directly upon the battery. After some further studies, an algorithm can be applied to provide a percentage of health, allowing for better maintenance action planning for potentially failing batteries.

A Hatch Interlock capability provides a sensor on each hatch, ramp, and door/access to the outside for use when in Interior Light Black-Out Mode. In this mode, the system will remove power to the primary area and crew light (dome lights) when any of the access points are opened in order to minimize light pollution. Prior to water operations in the AAV, these sensors can provide hatch status to the crew in addition to the visual/physical inspection. Likewise, the Plenum Door locations are sensed to provide verification that the plenum is in the proper location for the required mode of operation. In the event that the Plenum Doors are in an improper setting, the driver is notified on the display screen.

CONCLUSION

UEC Electronics' DPCMS modernized electrical system is capable of maximizing the use of available technology in a robust, redundant, and proficient manner and provides the best capability to our warfighters in a cost effective manner.