Special Feature

Distributed Power in Military Systems

SSPC Advancements Enhance Vehicle Power System Designs

Vehicle and power system manufacturers are pressed to deliver huge increases in electric power. New SSPC technology reduces weight and power losses, and increases vehicle adaptability.

Steve Rood Goldman, Marketing Manager
Michael Glass, Principle Marketing Engineer
Data Device Corp.

Developers of electrical power management and distribution systems for current and future force ground vehicles face several challenges. As new applications increase the number and size of electrical loads, vehicle power demand is exceeding generation and storage capability. These limitations impact vehicle operating range and mission effectiveness. Additionally, an overburdened power distribution system results in faults and reduced reliability. Electrical architectures also require flexibility to accommodate system components that are unique to the vehicle.

These challenges are being addressed using smart power management and distribution methods enabled by the latest generation of solid-state power controllers (SSPCs). In addition to providing protection for cable harnesses and loads, smart SSPCs are capable of accurately monitoring power quality and load conditions, permitting the system controller to react to power fluctuations and faults automatically and in real time. SSPCs also provide wide programmability, which allows power management systems to adapt to system reconfiguration and future equipment insertion.

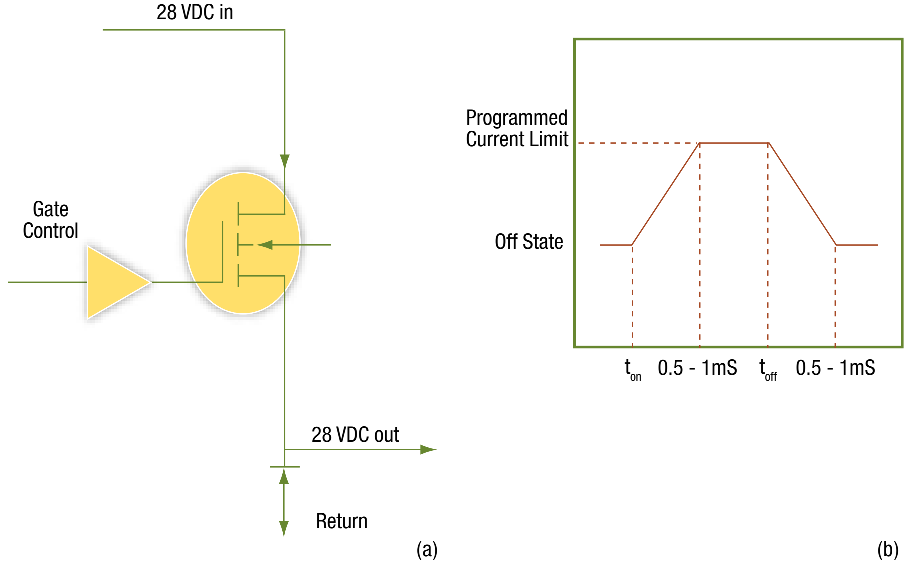

Figure 1

A MOSFET Gate Control is shown on the left (a). Controlled turn-on and turn-off time (b on the right) prevents surges and kickbacks, eliminating EMI and sympathetic tripping.

Migration to Solid-State

Driven by a combination of factors, electrical power distribution and control in ground vehicles has evolved rapidly in recent years. Further, it is anticipated that the need for power technology advancements will continue. The present and projected future needs for the U.S. Army and U.S. Marines are driving technology developments and deployments in applications, hardware (such as C4ISR), networking, computing, power electronics and power distribution technologies. Systems that once relied on traditional electromechanical power distribution architectures and equipment are migrating from purely discrete electrical, mechanical and man-

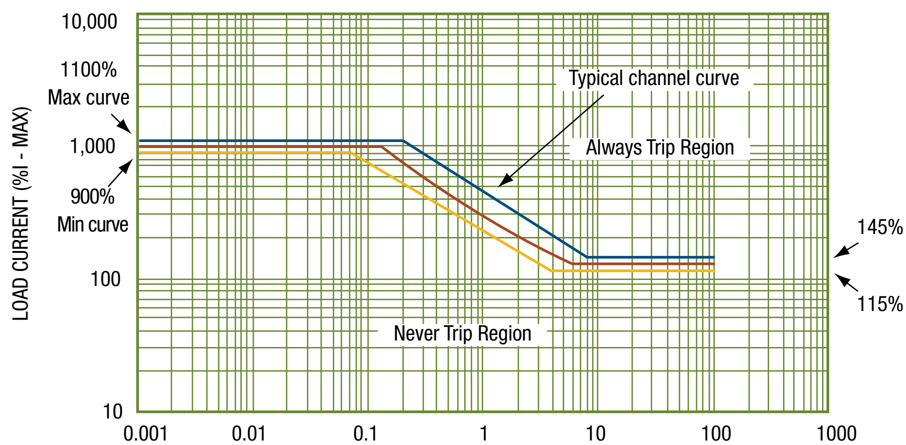

Figure 2

I^2T curves mimic the Time-Current Curves of mechanical breakers. The curves are factory settable to application requirements.

ual control to network-based, solid-state power distribution and control systems.

Solid-state power controller (SSPC) designs use microprocessors to manage the operation of high-efficiency switching MOSFETs. Their basic operation is to perform on/off control of the load and to protect wiring harnesses and loads from short circuit and overload conditions. SSPCs eliminate the EMI associated with the rapid changes in currents during on/off transitions of mechanical breakers, switches and relays. As shown in Figure 1, MOSFET gate drives can be designed to control the rise and fall time of channel currents. In comparison to electromechanical switching and protection, SSPC short circuit and overload protection is precise (typically ± 5 percent) and reliable. Additional protection is provided by series flyback diodes on the load side of each MOSFET to prevent inductive voltage transients from damaging the SSPC when the MOSFET deactivates or there's an abrupt open-circuit fault in the wiring or load.

Figure 2 shows the I^2T curve implemented by the SSPC to mimic the time-current behavior of a thermal mechanical breaker, including the high instant trip value needed to accommodate capacitive loads. A well-designed I^2T circuit will deliver ten or more times the channel's maximum steady state current rating before the instant trip mechanism opens the MOSFET switch to protect the load and itself. The value of the maximum steady state operating current for a given SSPC channel is programmed by the user as a percentage of the maximum current allowed for the given channel. Further, this type of "electronic thermal memory" enables SSPCs to mimic the desirable characteristics of thermal mechanical breakers. If an overload or short circuit fault is followed by a subsequent event, the second trip will occur more quickly than the first, protecting against heat accumulation in the wiring.

More Reliable Operation

SSPCs eliminate the deleterious effects of unpredictable contact closure time and contact chatter characteristic of thermal, high-performance thermal (temperature compensating, in other words), magnetic, thermal magnetic, hydraulic magnetic and remote controlled circuit breakers. Opening and closing circuits electronically, whether for on/off control or for load and wire protection purposes, eliminates the need for moving parts such as solenoid cores, springs, latches, hinges, bi-metallic strips and contacts. This eliminates components whose normal operation includes compression, friction, heat and arcing.

Electromagnetic arcing is a fundamental characteristic of the circuit breaker contact make/break cycle. The greater the current level, the larger the arcs, resulting in pit formations and carbon buildup. A common specification for mechanical breakers is the manufacturer's anticipated number of on/off cycles. Breaker "life" ("cycles" or "endurance") is adjusted according to percentages of the device's maximum rating or specified interrupt currents.

While there will always be uses for mechanical breakers, reliability is paramount for applications where lives and mission outcomes are directly at stake. Reliability predictions favor solid-state power controllers, especially those designed, qualified and tested in accordance with military standards. The inherent reliability advantage of SSPCs over mechanical devices becomes more pronounced in the harsh operating environment of military ground vehicles.

The Data Device Corporation EDGE Power Controller card, shown in Figure 3, is an example of a multichannel SSPC. The card, which was designed to efficiently support high load density power distribution systems, is network-enabled, and provides accurate load quality monitoring.

Network Control, Monitoring and Alarms

SSPCs provide network connectivity for programming, remote control of the loads, and monitoring of load status and power quality. Most vehicle power systems use SAE J1939-compatible CANbus as the network interface to the system controller. Interface communications over Ethernet, RS-232/422/485, or MIL-STD-1553 are other common choices. Traditional distribution systems using mechanical breakers and switches would use a manually operated control panel to control vehicle loads. Load shedding, to save electrical energy or extend mission radius, required intervention by the crew to control individual loads. With SSPC-enabled distribution systems, multiple channels or channel groups can be designated for autonomous control according to mission profiles and programmed into the system, thereby offloading work performed in real time by the crew.

Through their proximity to the system loads, SSPCs are able to monitor power quality parameters such as current, voltage and load temperature. These values can be continuously reported via network to the system controller or alternatively, the SSPC can generate an autonomous alarm to warn the system controller of out-of-bounds load parameters. The SSPC also continuously reports BIT results to the system controller indicating the proper operation of all channels.

SSPC load monitoring and network connectivity enable enhanced power system diagnostics and prognostics, which ensure mission readiness and timely maintenance, respectively. Since critical load parameters are monitored continuously, the system controller can diagnose the system state and respond to failure conditions in real time. The system controller can also log steady state and transition data to produce load signatures. This information is then made available at the depot to apply a condition-based maintenance (CbM) approach. When suitable algorithms to analyze logged load signatures are added to the mix, predictive maintenance (PdM) becomes realizable.

Mechanical, Power and Architectural Advantages

In vehicles using traditional distribution architectures, power is bussed from the electric generation and storage equipment to a main power distribution panel and, perhaps, sub-panels. When the panels are not readily accessible to the crew, switch loops, routed to the cabin, may be necessary for breaker resetting and on/off control. The switch loop conductors will be sized in accordance with the full load currents plus an overhead rating likely in the range of 30 to 50 percent. This architecture is functional but mechanically complex, heavy with wiring weight, and lacks sufficient flexibility for rapid changes and upgrades.

SSPCs are available in a variety of form factors ranging from Point of Load (PoL) modules to multichannel circuit cards, which may be open or enclosed, including ingress protection up to IP-67 or IP-68. System designers now have many options for location, mounting, environmental protection and cooling of power control devices. Multichannel SSPCs are typically used for high-density load centers, which may be centrally located

Figure 3

EDGE Power Controllers deliver 16 programmable channels.

or distributed throughout the vehicle as multiple power distribution units (PDUs). As the name implies, PoL modules are located at the load and are useful for higher current requirements or when the load is in a remote location such as a turret. Newer power distribution architectures typically use a semi-distributed architecture, which employs a combination of modules and multichannel SSPCs.

Modern SSPC implementations, which use extremely low RDS-ON MOSFETs, can be 50 percent or more energy efficient than thermal circuit breakers. As an example, a fully loaded 16-channel SSPC board from Data Device Corporation will dissipate less than 2 watts per 25-amp channel and can operate within a conduction-cooled enclosure. As with weight and power savings, SSPC technology enables direct volumetric savings as the result of reduced component sizes, wiring and equipment for heat transfer. However, the greatest savings are afforded by the design options made available.

Innovation Continues

The military ground vehicle requirement for solid-state power controllers originated two decades ago. This was in response to the EMI, reliability, and remote control challenges of the time. The efficacy of the technology, along with its battle-proven use on the M1A2 Abrams and Bradley platforms, has ensured the adoption of SSPC technology for smart power management in equipment upgrades and for new vehicle programs.

Historically, there was a significant cost premium for SSPC technology and the perception of prohibitive cost still exists today. However, two significant factors have contributed to a sharp reduction in SSPC cost. First are incremental improvements in SSPC design and implementation, which have eliminated expensive components and reduced assembly cost. Next, and most significant, is the adoption of SSPC for tactical wheeled vehicle platforms. These high-volume applications have completely changed the game, leading to greater economies of scale, which have driven down the impact of SSPC on PDU cost to within 25 percent of mechanical implementations.

Data Device Corp.
Bohemia, NY.
(631) 567-5600.
[www.ddc-web.com].