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Multiphysics Simulation and Control Development Environment for Modern Hybrid Electric Drive Military Vehicles

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ABSTRACT

This paper describes how modeling and simulation tools are being developed and used to support the design and control of a hybrid electric drive (HED) for future military ground vehicles as well as retrofit to existing vehicles. These include modular component and controls models that can be assembled into system level simulation models. The objective models must predict system performance adequately to support the making of engineering design decisions concerning HED architecture, component selection and control algorithms.

The adoption of HED technology has become an important trend in the commercial automotive industry. The benefits of HED technology and their realization have been demonstrated in recent research and development [1][2]. While there is no military production vehicle with HED, there have been several military vehicle prototypes demonstrating the application and potential benefits of HED for military vehicles. Next generation military vehicles will most likely use hybrid electric drives [3][4]. These hybrid vehicles present different needs and challenges than commercial vehicles.

While the hybrid electric propulsion system performs all of the functions of the traditional mechanical transmission, it does much more than replace the engine and transmission.

- ✓ Provides integral power management and energy storage to meet the peak demands of weapons, propulsion and the ever increasing electrical power requirements in modern combat vehicles (e.g., communications, environmental control, surveillance, countermeasures, electro-magnetic armour, etc.).
- ✓ Provides better fuel economy through electrical regeneration during braking and operating the engine at its most fuel efficient conditions.
- ✓ Provides better automotive performance than mechanical drives for the same engine power. Acceleration and speed on slopes are faster due to the combined power from the engine/generator and the energy storage system.

BAE Systems has over 40 years of experience in the development of HED technology for military vehicles. The BAE M113 Electric Drive Demonstrator was constructed in 1963 under Tank Automotive Command (TACOM) sponsorship. Over the years, turbine, rotary and diesel prime power systems have been successfully tested. More recently, BAE has extended its HED technological advancement and applied it to future military ground vehicles.

HED propulsion system models have been constructed based on the BAE proprietary HED component library that contains physics-based models across multiple disciplines. This model library includes motors/generators, inverter, dc-dc converter, high-voltage electric bus, battery, heat exchangers, fans, pumps, motor controller, power management, vehicle, and transmission as well as a navigator which dynamically controls the accelerator and steer commands to follow the prescribed courses. The propulsion system models and most of the HED library components have been developed under the Matlab/Simulink [5] computing environment. The system models have been applied to HED configuration trade studies, component sizing, component vendor selection and more recently to system power management development, subsystem controller performance evaluation and integrated HED control system verification.

The objective of power management is to match the power produced to the power demand while allocating the sources of the power so as to optimize system efficiency and performance. The power management algorithms minimize fuel consumption while meeting or exceeding all power requirements and managing the battery's state of charge. Power management and electric bus voltage regulation are closely coupled: excess power to bus results in voltage rise and insufficient power leads to voltage fall. Maintaining a stable bus voltage is crucial to electrical component operations. Bus voltage regulation is integrally achieved by power management and component controllers.

After being verified by system simulations, the power management algorithms are automatically translated from Matlab/Simulink models into software function codes using Real-Time Workshop [5]. These algorithm function codes are then directly integrated into propulsion control software and tested on vehicle propulsion hardware prototypes.

This modelling and simulation environment has been proven useful and effective throughout the life cycle, from concept-proving, design and development to product implementation and improvement, of hybrid electric drives for military vehicles

REFERENCES

[1] McGee, R., Duoba, M., and Theobald, M., session co-organizers, 2005, Advanced Hybrid Vehicle Powertrains, Society of Automotive Engineers, SP-1973.

[2] Jurgen, R. K., editor, 2002, Electric And Hybrid Electric Vehicles, Society of Automotive Engineers, Progress in Technology Automotive Electronics Series, PT-85.

[3] Smith, W. and Wehmueller, K., 2002, "Detailed Simulation and Development of Hybrid Power System Energy Management Architectures," 4th International All Electric Combat Vehicle Conference 2002 (AECV 2002), Noodwijkerhout, Netherlands.

[4] Frazier, G., Danielson, E., Mohler, T., and Khalil, G., 2002, "The Combat Hybrid Power System (CHPS) Program", 4th International All Electric Combat Vehicle Conference 2002 (AECV 2002), Noodwijkerhout, Netherlands.

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