Office of Naval Research
Maneuver Science and Technology Programs in Fuel Efficiency and Battlefield Power

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Office of Naval Research
• Exportable Power Program Overview

• Transmission Integral Motor/Generator
  – HMMWV On-Board Vehicle Power System (OBVP) Overview
  – 3000 Series Transmission Integral Generator ("3TIG")
  – Electric Torque Assist

• Medium Tactical Vehicle Replacement (MTVR) OBVP

• MTVR “Hybrid” OBVP

• Medium Electromechanical Infinitely Variable Transmission

• Summary & Link to ONR Long Range BAA
Exportable Power Program Overview

**DRS HMMWV**
- PM Generator Integrated Into HMMWV Mechanical Transmission
- Power Electronics Converter For Fixed Frequency (60 Hz) Export And Mobile Power Over Range Of Engine Speed
- 30kW Of Static Exportable Power, 35kW Of Static Power Surge, 10.5kw Of Mobile Power

**Oshkosh MTVR**
- Implements ProPulse Electric Propulsion System
- 280 kW Generator, Configurable For 208/480 VAC
- 120kW Static Exportable Power, 21 kW Of Mobile Power
HMMWV On-Board Vehicle Power System Overview

- Transmission Integral Generator (TIG) exportable power approach
  - Up to 30kW stationary exportable power
  - 10 kW mobile exportable power
  - Retrofit “Kit” Approach
HMMWV On-Board Vehicle Power Logistics Savings

Existing Configuration to Deliver 30 kW with HMMWV Class Vehicle

- HMMWVs
- 15 Kilowatt Generators
- Soldiers

USMC OBVP Equipped HMMWV Configuration to Deliver 30 kW

- HMMWV OBVP
- Soldier

Significant logistics savings achieved using HMMWV OBVP

- Weight Reduction
- Volume Reduction
- Manning Reduction
Scalability of Transmission Integral Generator Concept

- Installs at factory or depot using standard tools and mounts
- More than 125 kW of continuous electric power while stationary
- No impact to the vehicle driveline
- High voltage output available (300 VDC to 600 VDC)
- 120/208 VAC at 50/60 Hz
Electric Torque Assist

Exportable Power System Components Leveraged for Vehicle Fuel Efficiency Gain

- Electric Assist Components
  - Base HMMWV OBVP Kit
  - Accelerator Pedal and Other Sensors
  - Motor/Generator Controller (bidirectional power converter)
  - Battery System
  - Hybrid Electric Vehicle Controller

- Load Split Algorithm
  - System uses the electric machine as generator to charge the battery when drive system is operating at high efficiency
  - System uses the battery and electric machine as motor to assist when drive system is operating at low efficiency

- Additional Efficiency Through Regenerative Braking
- Improve Efficiency of Exportable Power Transient Performance

Approach Applicable for other Transmission Integral Motor/Generator Systems
Diesel electric Propulsion
120kW stationary exportable power
20kW mobile exportable power
Engine Speed is independent of Vehicle Speed

Energy Storage enables Regenerative Braking

Engine

Mechanical Link

Generator

Energy Storage Device

Electrical Power Link

Traction Motors

Accessory Load Control

Shifter RND

Throttle Input
• **Technical Approach**

  – Build on MTVR OBVP ProPulse® Drive System, capitalizing on continuously variable nature of series electric drive through the addition of regenerative braking and selecting a power dense (vs. torque dense) engine.

  – **“Hybridize”** with Regenerative Braking Subsystem
    – Capacitor based energy storage modules
    – Develop charge/discharge control algorithms to optimize regenerative braking

  – **“Repower”** with power dense engine
    – Continuously variable nature of series electric drive allows prime mover to make requisite mobility power at any optimum efficiency speed
    – No low end torque requirement allows lighter weight options.
    – Decrease in engine weight achievable
Oshkosh Electromechanical
Infinitely Variable Transmission

- Alternative powertrain for medium vehicles
- Transfers weight from front axle
- Improves weight distribution for Air Transportability
- Enables Exportable Power
Electronically controlled engine / electric machines
System architecture yields efficient, redundant operation
Power management algorithms optimize efficiency
• Preliminary comparison between conventional powertrain and EMIVT
• Simulation of cruising “steady state, flat road” operation - no energy storage
• Addition of energy storage can further improve mpg by 10-15% depending on drive cycle

• EMIVT shows an overall improvement in mpg on MTVR
• Sawtooth pattern on the six speed conventional transmission due to discrete gear shift points
• Only one shift needed on EMIVT
Oshkosh EMIVT
Control Schematic

Future Options

• Regenerative Braking with the addition of Energy Storage option for Improved Fuel Economy

• Export Power capability with addition of DC to AC inverter
  • 150kW stationary power
  • 30kW mobile power

Both electromagnetic machines may be operated as generators
ONR Fuel Efficiency and Battlefield Power Program Summary

• Marine Corps Expeditionary Energy Strategy
  – “By 2025... the only liquid fuel needed (by Marine Expeditionary Forces) will be for mobility systems, which will be more energy efficient than systems are today.”
  – Mobility systems will also provide exportable power for battlefield needs.
• Integration of electromechanical power systems (generation, storage, conversion, and control) with vehicle drive systems enables fuel efficient mobility and exportable power.
  – Series Electric Drive – High Power Applications
  – Transmission Integral Motor/Generators – Small/Medium Applications
  – EM IVT – Alternative Mobility/Exportable Power System
  – Future Capability Enabler – Directed Energy, Energy Based Survivability
• Other Applicable Approaches
  – Fuel Cells, Auxiliary Power Units
• Science and Technology Needs – High Temp, Power Dense Components
• COST - Acquisition Cost as Important as Lifecycle Cost Savings
• ONR Long Range BAA