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MODELING AND SIMULATION, TESTING AND VALIDATION



SCALABLE POWER-COMPONENT MODELS FOR CONCEPT TESTING

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Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 12 AUG 2011		2. REPORT TYPE Briefing Charts		3. DATES COVERED 06-04-2011 to 09-07-2011	
4. TITLE AND SUBTITLE SCALABLE POWER-COMPONENT MODELS FOR CONCEPT TESTING				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Michael Mazzola; G Molen; Stephen Phillips; Denise Kramer; Mike Pozolo				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Center for Advanced Vehicular Systems ,Mississippi State University,200 Research Blvd,Starkville,MS,39759				8. PERFORMING ORGANIZATION REPORT NUMBER ; #22206	
				10. SPONSOR/MONITOR'S ACRONYM(S) TARDEC	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000				11. SPONSOR/MONITOR'S REPORT NUMBER(S) #22206	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES For GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM (GVSETS), SET FOR AUG 2011					
14. ABSTRACT briefing charts					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Public Release	18. NUMBER OF PAGES 12	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

- Motivation and Scope
- Integrated Starter Generator Model
- Battery Model
- Power Converter Model
- Summary

Motivation and Scope

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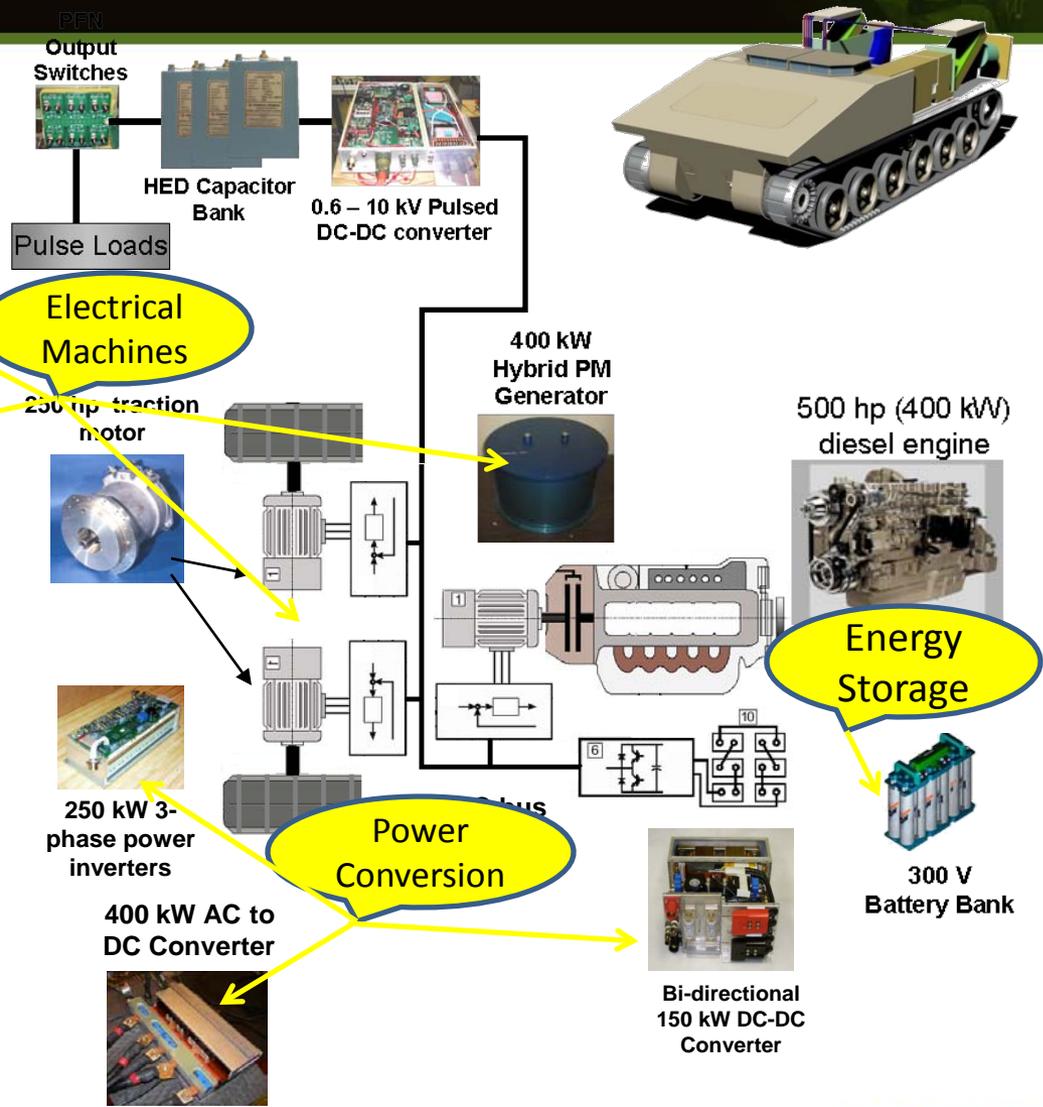
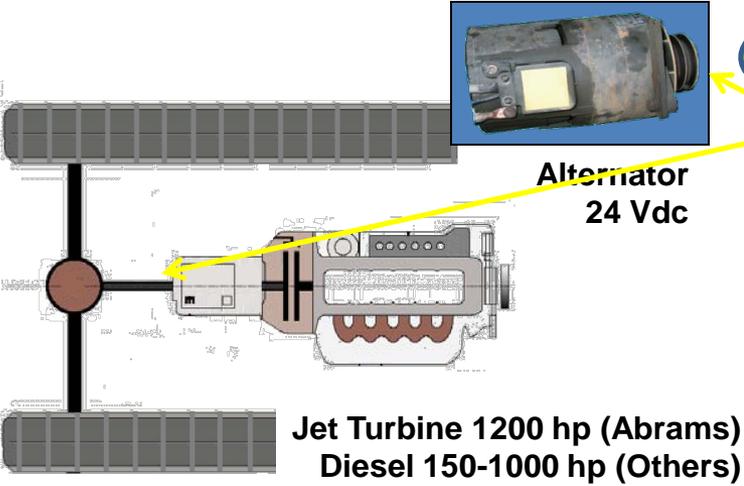


- **Objective:** Support modeling and simulation needs for rapid concept analysis and systems engineering.
- **Scope:** Scalable, generic MATLAB/Simulink models in three areas:
 - Electromechanical machines (Integrated Starter Generators)
 - Energy storage (Batteries)
 - Power conditioning (Converters)
- **Challenges:**
 - Creating generic, scalable models of “appropriate fidelity”
 - Providing diversity of technologies and ratings while managing fidelity
- **Importance to the Warfighter:** Providing more electrical power for loads ranging from C⁴ISR to anti-IED to soldier “hotel.” Improving fuel efficiency through electrification produces a stronger force through reduced logistics requirements.
 - Planning for future ground vehicle systems, whether legacy or new, is essential
 - M&S is cost effective tool for concept evaluations

Legacy & Future Army Vehicles

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ISG Model



- ISG model and its associated controls system
 - Automatic scaling
 - Scope of machines relevant to modern and legacy vehicles
 - Power levels between 4-110 kW
- Features
 - Coupled electrical and thermal models
 - Simulation driven scaling
- Use available machines to validate model
 - UQM Power Phase 75



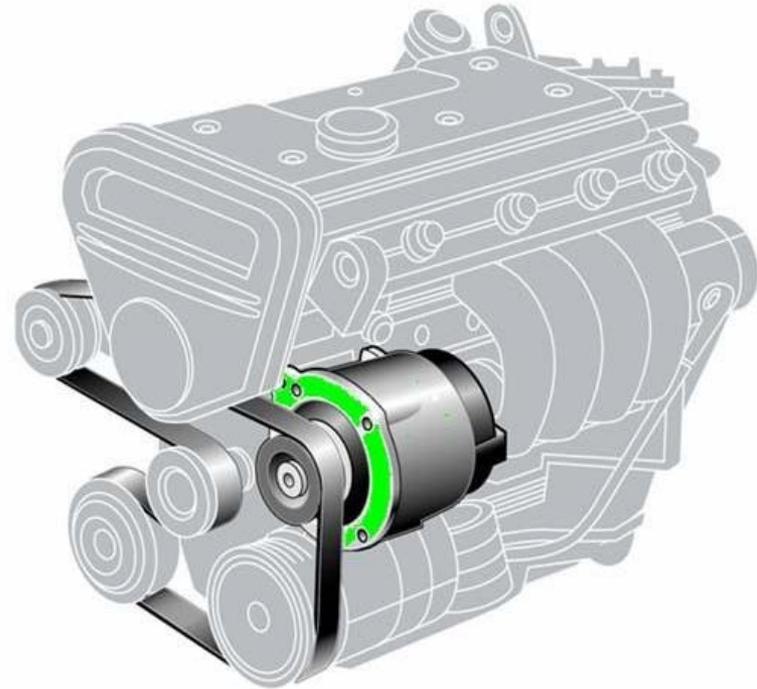


- **Internally** Integrated ISG
 - Machine that is integrated into the driveline of the vehicle
 - Scalable to power levels in 40-110 kW range
 - Examples:
 - GM Silverado – 7 kW system
 - DRS HMMWV – 30 kW system





- **Externally** Integrated ISG
 - External machine that attaches to standard driveline
 - Power levels limited to components (i.e. belts) that attach the system to the standard driveline
 - Example: BAS System – 3 kW system



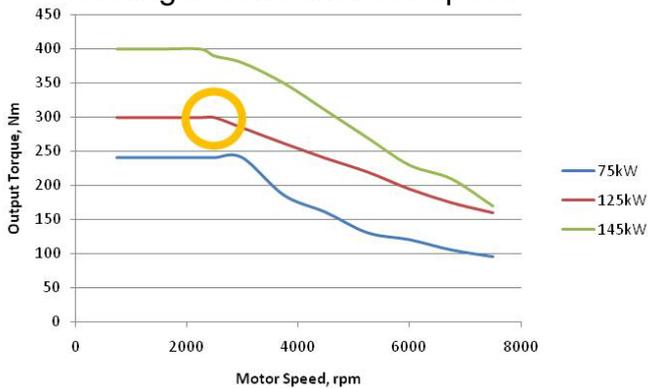
ISG Block, Rev. 2.0

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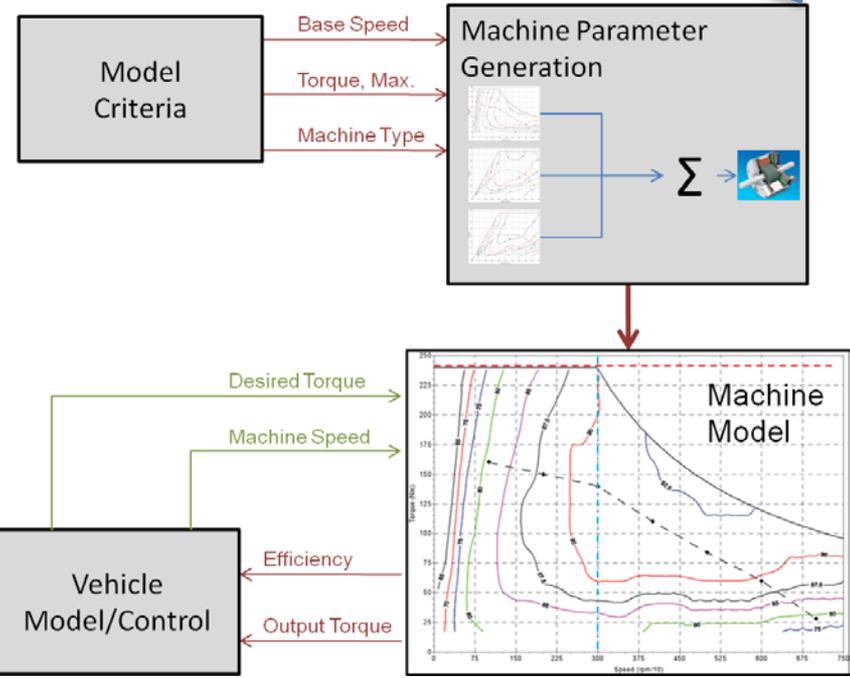


Scaling at constant base speed



Revision 2.0

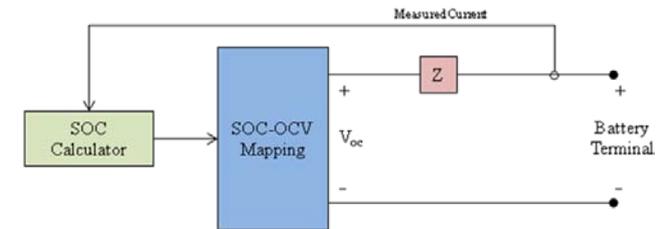
- Four quadrant
- PM Brushless Machine
- Speed-Torque and Thermal Load



Battery Model

- Battery model including charge storage and dynamic impedance

- Independent of chemistry
- Scale parameters, not complexity
- Energy levels between 0.2-20 kWh



- Features

- Polynomial-based state-of-charge to open-circuit voltage model
- State-variable dynamic impedance model
- Easy provision for lifetime and reliability model

- Use available batteries to validate model

- UBBL10, 0.1 kWh, 16 V, LCO
- A123, 21 kWh, 360 V, LPO
- Prius, 1.3 kWh, 200 V, NiMH



Battery Block, Rev. 2.0

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Generic Battery Model Version 2.0 Beta

Voltage [V] >

Battery Voltage: 304 [V] SOC [%] >

Battery Capacity: 20.4 [Ah] >

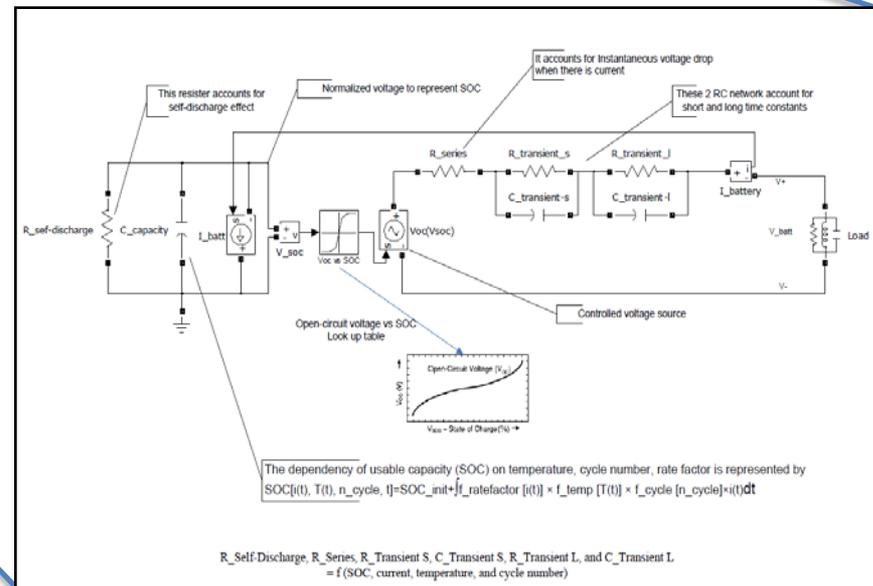
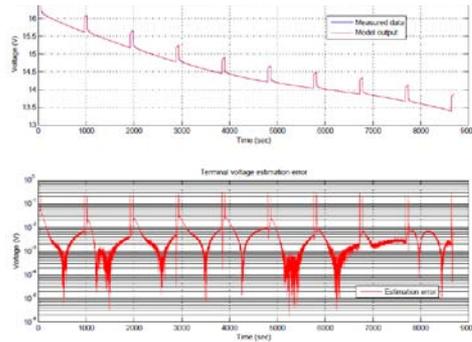
Terminal Voltage [V] >

Minimum SOC: 10 [%] >

Thermal Heat Load [W] >

Battery Current [A] >

Approximation by Method of Bandwidth Limited Parameter Estimation

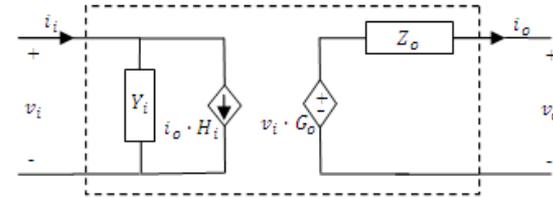


Revision 2.0

- Scale by capacity and voltage
- Select by chemistry
- Charge-counting or Self-consistent

Converter Model

- Converter model including averaged electrical & thermal response
 - Large signal and small signal effects
 - Scale parameters, not complexity
 - Power levels between 5-110 kW
- Features
 - System description at terminals
 - Closed-loop control response embedded
- Use available converters to validate model
 - Absopulse, 7-kW, 300-V to 28-V, dc/dc
 - UQM 100-kW, 300-V, dc/ac





- Developed ISG and Battery beta models in Simulink.
 - Scalable ISG Ver. 2.0
 - Technology: Permanent Magnet Brushless DC machine
 - Model: Self-generating torque-speed-efficiency map
 - Future improvements: Induction machine
 - Scalable Battery Ver. 2.0
 - Technology: Lithium-Ion
 - Lithium-Cobalt-Oxide LiCoO_2
 - Lithium-Iron-Phosphate LiFePO_4
 - Model: Electrical Analogue, bandwidth-limited approximation
 - Charge-counting mode
 - Self-consistent mode
 - Future improvements: NiMH, LiMn_2O_4 (spinel), Lead Acid
- Near-term Future work
 - Scalable Converter Ver. 1.0
 - Technology: Semiconductor switched, DSP controlled dc/dc or dc/ac (TBD)
 - Model: Black-box averaged