



SCALABLE POWER-COMPONENT MODELS FOR CONCEPT TESTING

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

Motivation and Scope

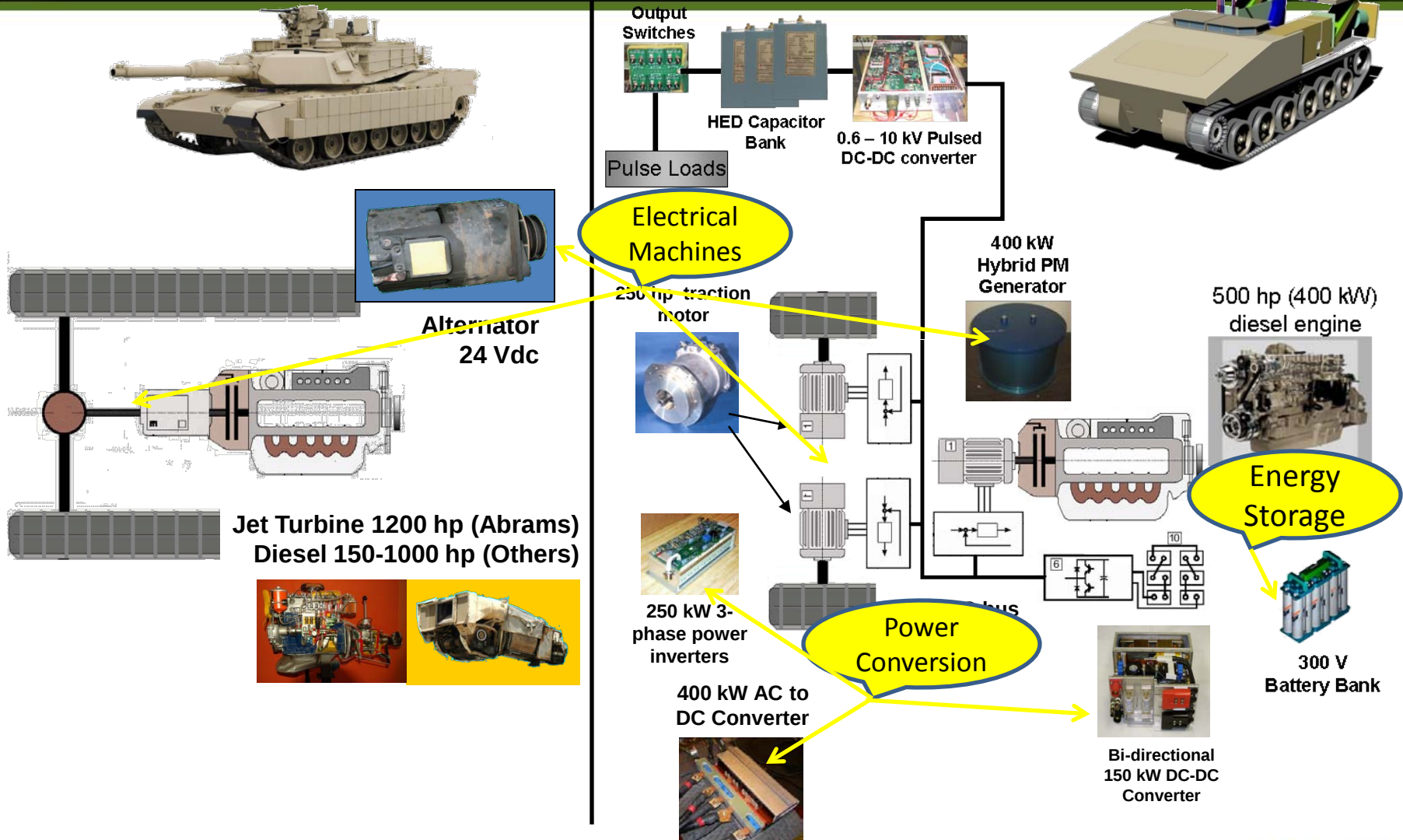


- **Objective:** Support modeling and simulation needs for rapid concept analysis and systems engineering.
- **Scope:** Scalable, generic MATLAB/Simulink models in three areas:
 - Electromechanical machines (Integrated Starter Generators)
 - Energy storage (Batteries)
 - Power conditioning (Converters)
- **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

MSTV

MODELING AND SIMULATION, TESTING AND VALIDATION



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



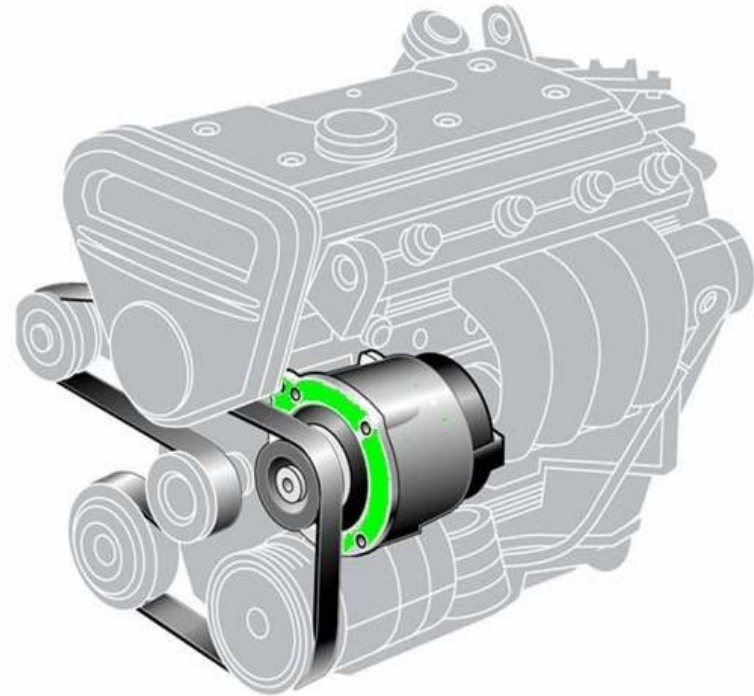


- **Internally** Integrated ISG
 - Machine that is integrated into the driveline of the vehicle
 - Scalable to power levels in 40-110 kW range
 - Examples:
 - GM Silverado – 7 kW system
 - DRS HMMWV – 30 kW system





- **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



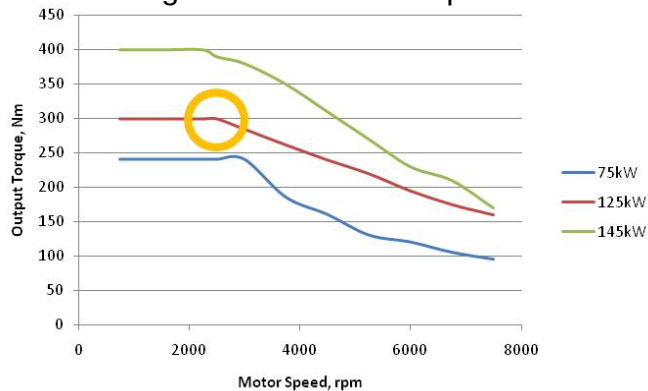
ISG Block, Rev. 2.0

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MODELING AND SIMULATION, TESTING AND VALIDATION

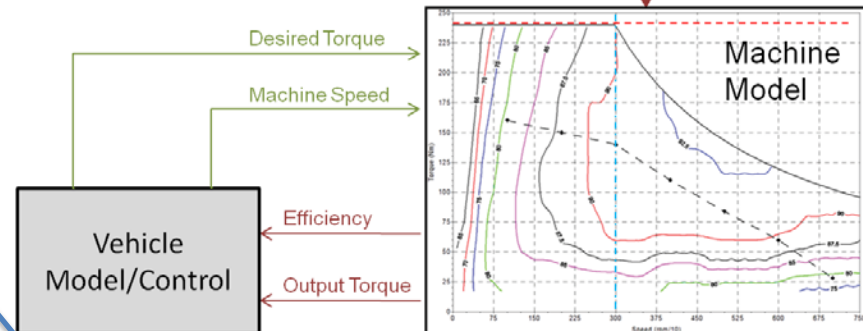
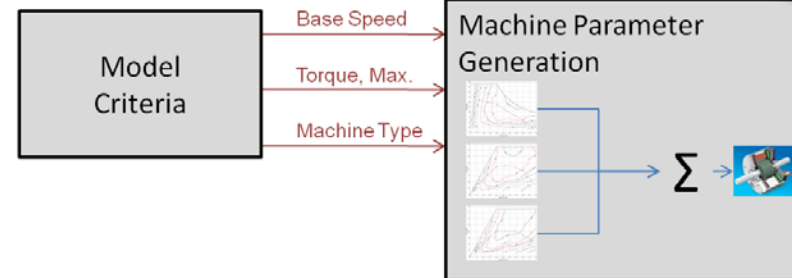


Scaling at constant base speed



Revision 2.0

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

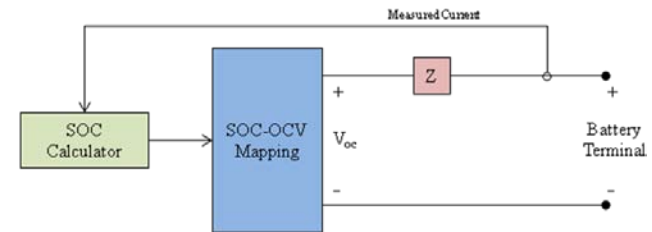


GVSETS

Battery Model

- Battery model including charge storage and dynamic impedance

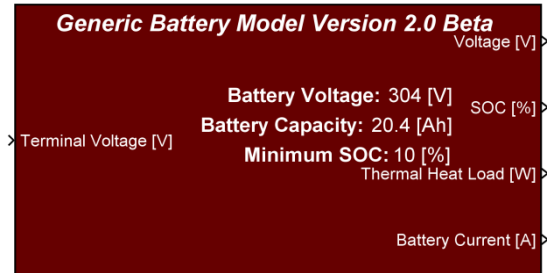
- Independent of chemistry
- Scale parameters, not complexity
- Energy levels between 0.2-20 kWh



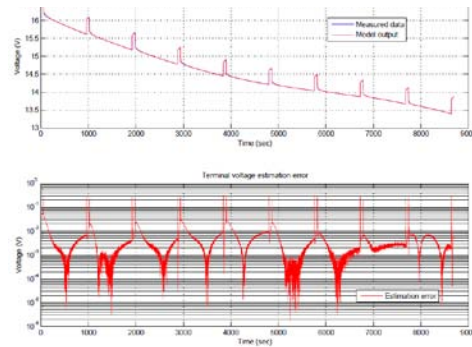
- Features
 - Polynomial-based state-of-charge to open-circuit voltage model
 - State-variable dynamic impedance model
 - Easy provision for lifetime and reliability model
- Use available batteries to validate model
 - UBBL10, 0.1 kWh, 16 V, LCO
 - A123, 21 kWh, 360 V, LPO
 - Prius, 1.3 kWh, 200 V, NiMH



Battery Block, Rev. 2.0

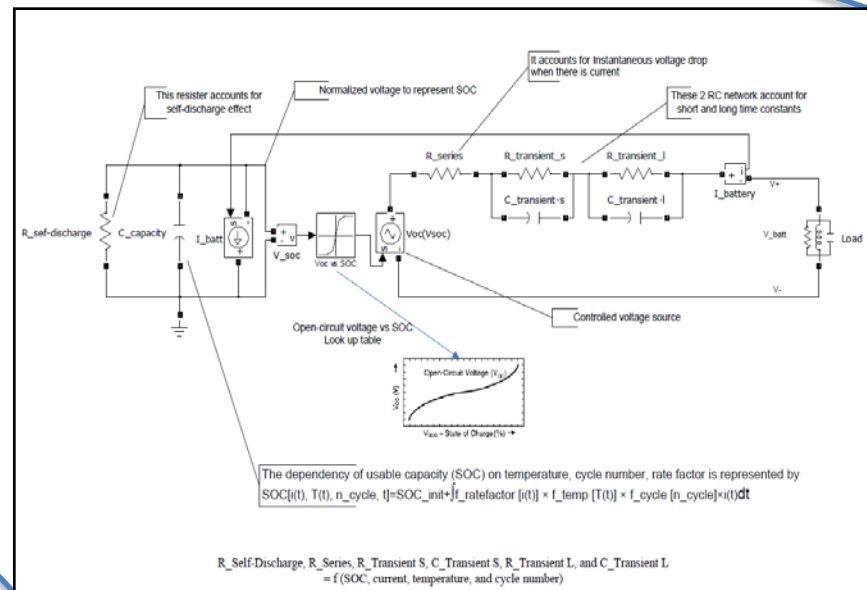


Approximation by Method of Bandwidth Limited Parameter Estimation



Revision 2.0

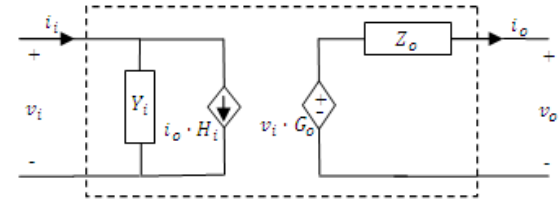
- Scale by capacity and voltage
- Select by chemistry
- Charge-counting or Self-consistent



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