SIMULATION OF VARIOUS ON-BOARD VEHICLE POWER GENERATION ARCITECTURES FOR STATIONARY APPLICATIONS

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Outline

- Motivation
- Selected architectures for simulation
- Simulation environment overview
- Simulation model constraints
- Simulation results
  - Required engine power
  - System efficiency
  - Estimated fuel consumption
- Vehicle demonstration of most efficient architecture

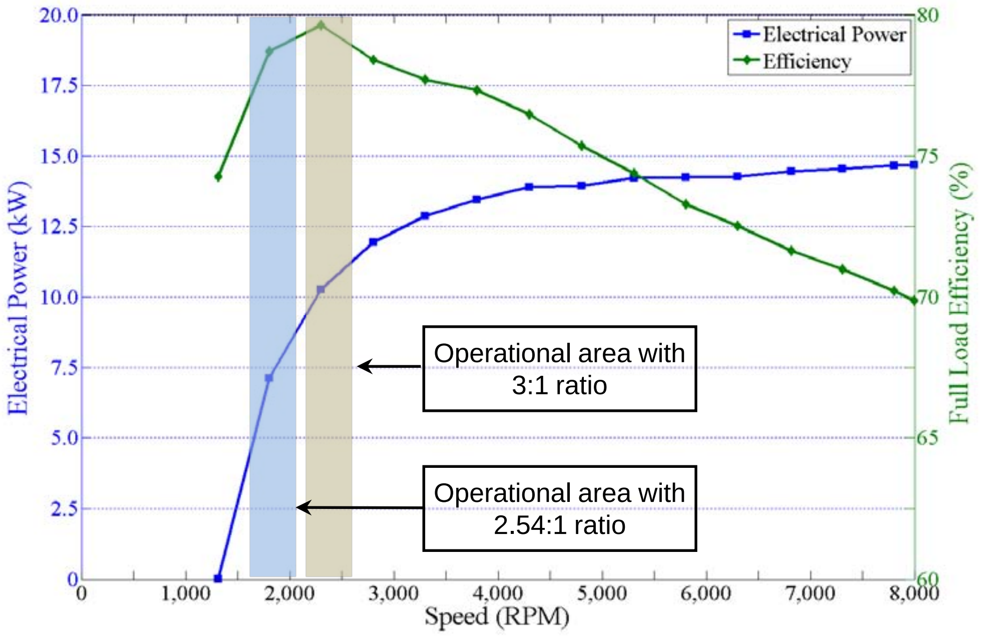
Motivation

- Increased “in-vehicle” electrical presence
  - C4ISR systems
  - Anti-IED systems
  - Climate control systems
- Higher exportable power demand
  - Mobile command stations
  - Radar systems
- Reduction of audible and heat signature using higher efficiency generation systems
- Exploration of power generation systems for greater than 10 kW electrical output at idle through simulation

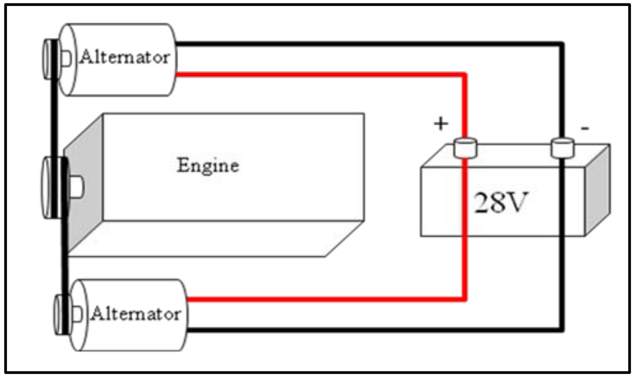
Selected Architectures for Simulation

- Observed three possible architectures
  - Architecture 1: Belt-driven dual alternator system
  - Architecture 2: Belt-driven and PTO-driven alternator system
  - Architecture 3: Belt-driven alternator and PTO-driven Permanent Magnet-Brushless DC (PMDC) Generator
- Selection criteria
  - Serviceability
  - Ease of implementation/integration
  - Utilization of COTS components

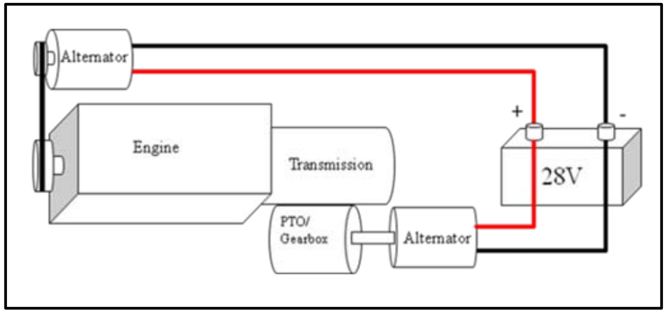
Selected Architectures



Architecture 1

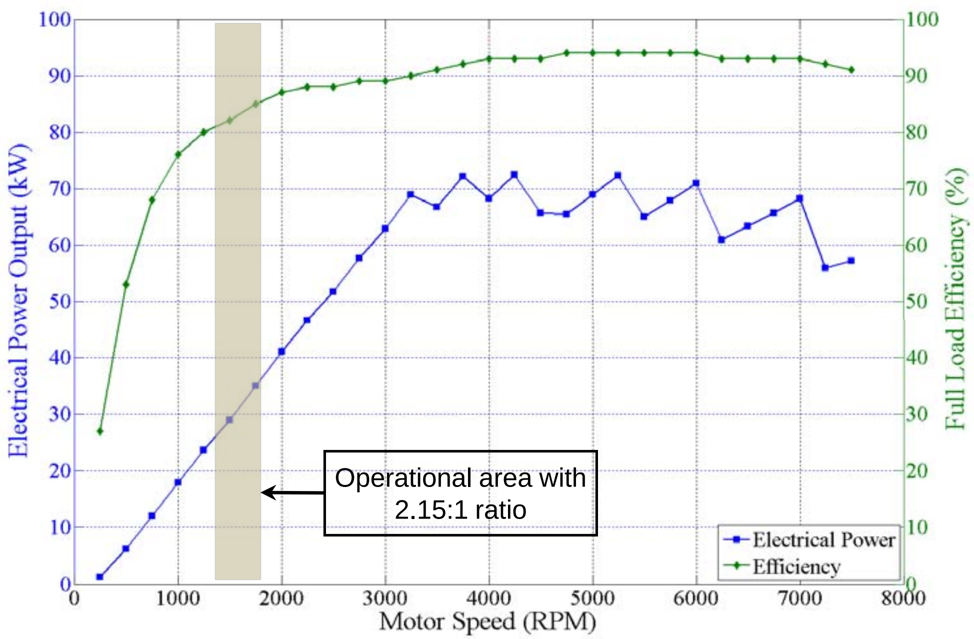


Architecture 2

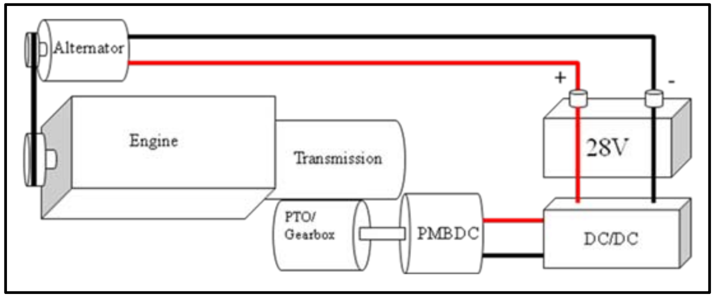


- All architectures use 520 A Niehoff alternator
- Use standard alternator to engine pulley ratio of 3:1 with 95% power transfer efficiency
- PTO/Gearbox assembly uses a pulley ratio of 2.54:1 from alternator to engine with an efficiency of 97%

Selected Architectures



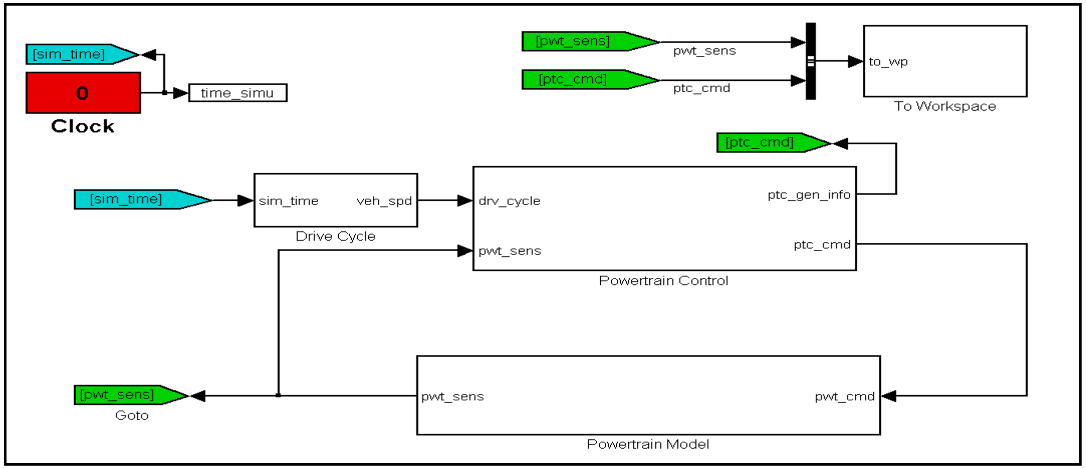
Architecture 3



- Architecture 3 uses a belt-driven 520 A Niehoff alternator and 75 kW UQM PMDC motor/generator
- Alternator connected using a 3:1 pulley ratio
- PMDC connected using a combined PTO/Gearbox ratio of 2.15:1 with efficiency of 97%

Simulation Environment

- Created in MATLAB/Simulink environment
- Environment uses a forward-looking approach
  - Driver requests are passed from Powertrain Controller to the Powertrain Model
  - Powertrain sensors are used to adjust the driver request to match the desired speed request
- Power generation components are controlled using torque command sent from powertrain control subsystem

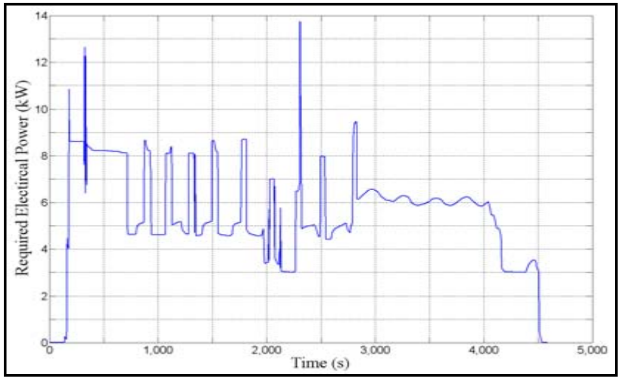


Simulation Model Constraints

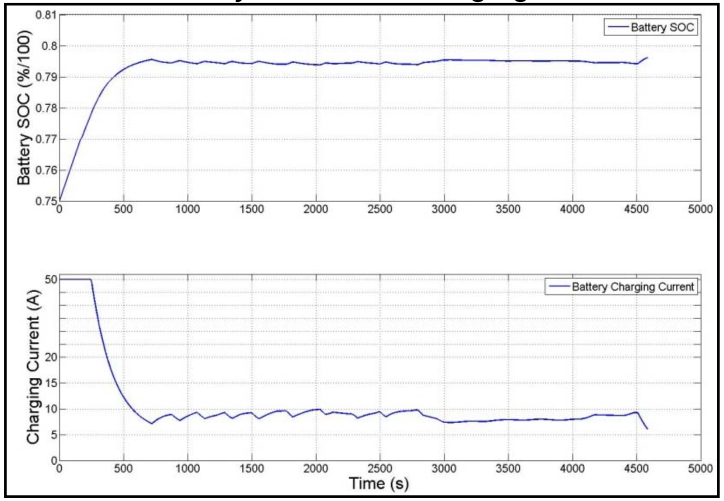
MSTV
MODELING AND SIMULATION, TESTING AND VALIDATION

- Radar load profile used. Requires power levels both above and below the rated output for any single component [1]
- Power train controller limits the minimum power of the alternator to 1 kW to ensure proper charging of battery
- Simulation utilizes a battery SOC target of 80% and an initial SOC of 75%
- SOC mismatch causes the power train controller to provide additional power to charge 28 V battery to desired SOC

Electrical Load Profile



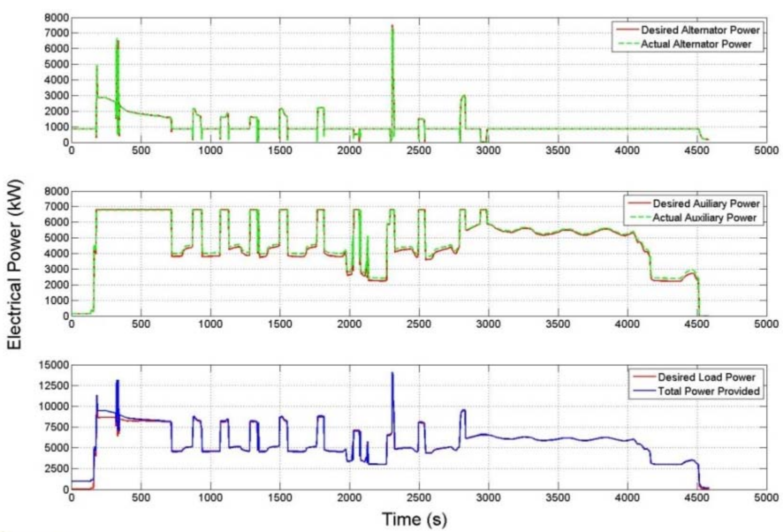
28V Battery SOC and Charging Current

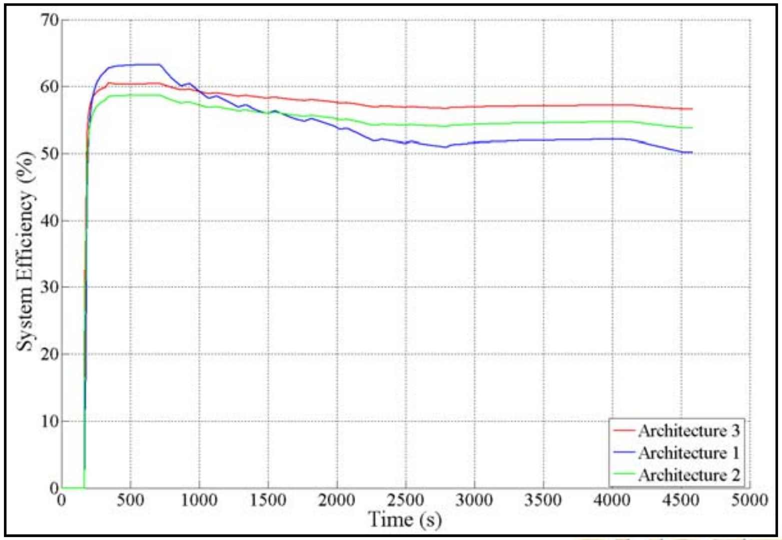


[1] Marshall Molen, *R&D Final Report for Advanced Power Distribution Prototyping, Evaluation, and Simulation for the U.S. Army Space and Missile Defense Command Contract #DASG60-00-C-0074*, May 2009.

Simulation Results

- Simulation calculates system efficiency defined as ratio of electrical load power to engine output
- Model limits the PMDC output power based on maximum rating of DC/DC converter

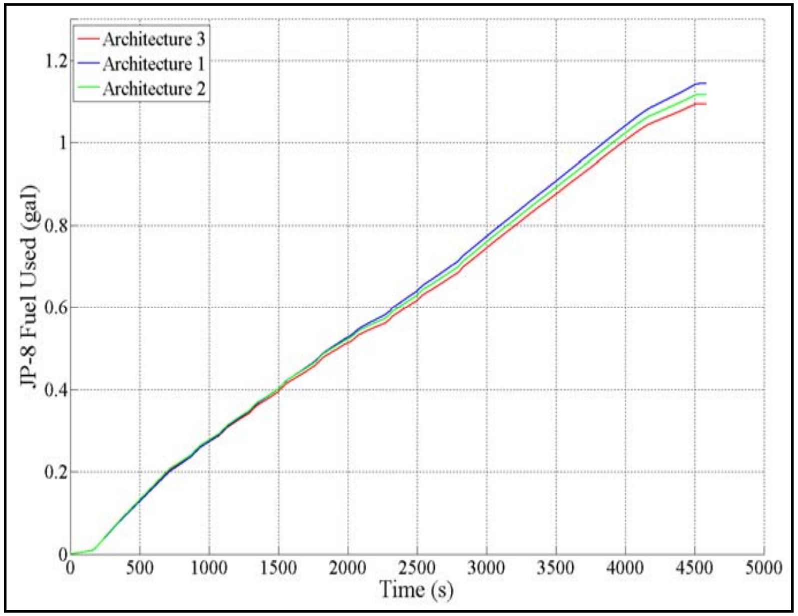




Simulation Results

- Fuel consumption calculated based on the required engine energy output
- Engine efficiency was assumed to be constant at 25%
- Used JP8 energy density to calculate estimated fuel consumption:

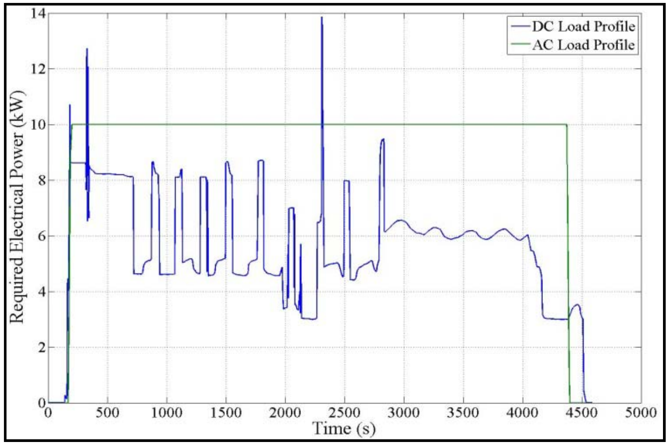
Estimated Fuel Consumption



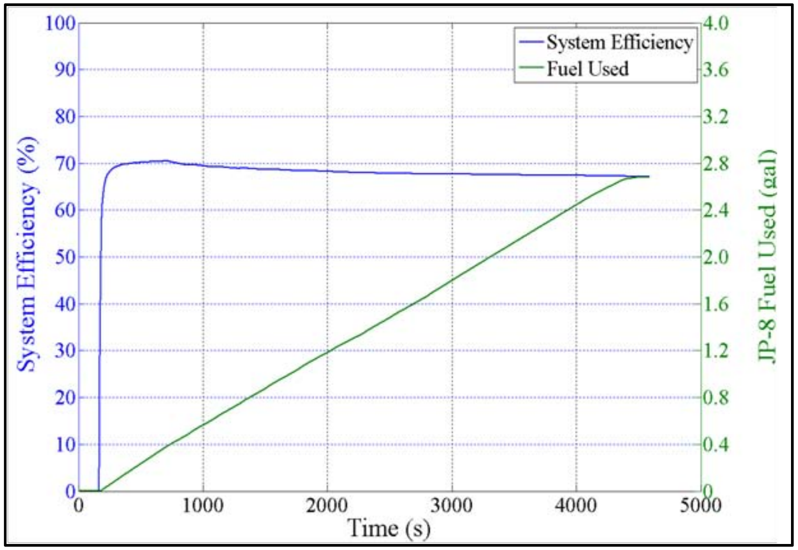
$$Fuel\,Used = \frac{Engine\,Requried\,Energy\,[BTU] * \dfrac{1}{0.25}}{JP8\,Energy\,Density\left[\dfrac{BTU}{gal}\right]}$$

Simulation Results

- Architecture 3 was used in a second simulation which employed an additional 10 kW AC load connected to PMDC (better utilization of available load capacity)
- Simulation computed a higher system operating efficiency while under heaver loads
- Adding 10 kW load possible only with Architecture 3



Architecture 3 System Efficiency and Fuel Used



Results Summary

Architecture	Fuel Consumption	System Efficiency
1 (Dual alternators)	1.14 gals	50.2 %
2 (Belt-driven and PTO-driven alternators)	1.12 gals	53.7 %
3 (Belt-driven alternator and PTO-driven PMDC)	1.09 gals	56.6 %
3+(Belt-driven alternator and PTO-driven PMDC) with additional 10 kW AC load	2.69 gals	67.1 %

Architecture Implementation

- Architecture 3 was selected for a feasibility test on a Mine Resistant Ambush Protected (MRAP)
- Tests were conducted to observe potential issues driving the PMDC via a transmission PTO port
- Architecture was tested from 100 A to 600 A in 50-A steps
- Transit points were selected at 250 A and 400 A to observe system response to load transients
- Excellent performance was observed during “in-vehicle” testing

Questions