Utilizing the Traction Drive Power Electronics System to Provide Plug-in Capability for PHEVs

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2009 DOE Hydrogen Program and Vehicle Technologies AMR

Overview

Timeline

- Start – Oct. 2006
- Finish – Sept. 2011
- 50% complete

Budget

- Total project funding
  - DOE share – 100%
- Funding received in FY08
  - $664K
- Funding received for FY09
  - $647K
- Funding requested for FY10
  - $699K

Barriers

- On-board Standalone Battery Chargers
  - Add a significant cost (projected at $300~400 vs. $660 for DOE 2015 cost target for entire traction drive system)
  - Have limited charging capability and long charging times
    - Not suitable for opportunity charging
    - Not suitable for future PHEVs with longer EV distances
  - Unidirectional (can only charge the battery)
    - Incapable of mobile power generation
    - Incapable of V2G support

Partners

- OEMs – Safety issues

Objective

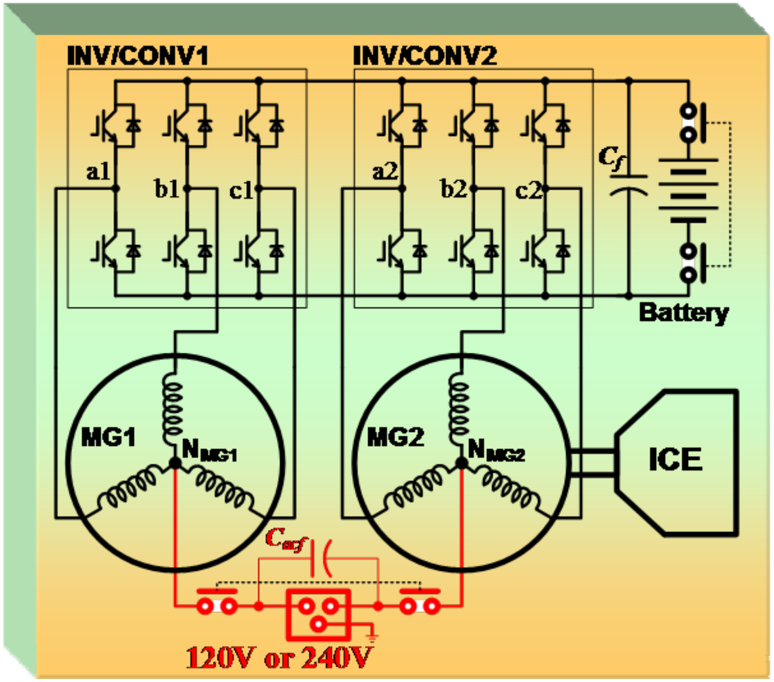
- Develop a drive prototype comprised of a 55 kW motor inverter and a 30 kW generator inverter that is capable of
  - Level 1 and level 2 charging rates (1.8 ~ 19.2 kW)
  - A 90% reduction in cost and volume compared to on-board standalone battery chargers
  - Mobile power generation up to 20 kW
  - V2G support
- Objective for FY08
  - Design, build and test a prototype and demonstrate level 1 and level 2 charging capability with efficiency greater than 92% and 95%, respectively
- Objectives for FY09
  - Modify the prototype developed in FY08 to implement and demonstrate mobile generator capability
  - Assess safety requirements and issues

Milestones

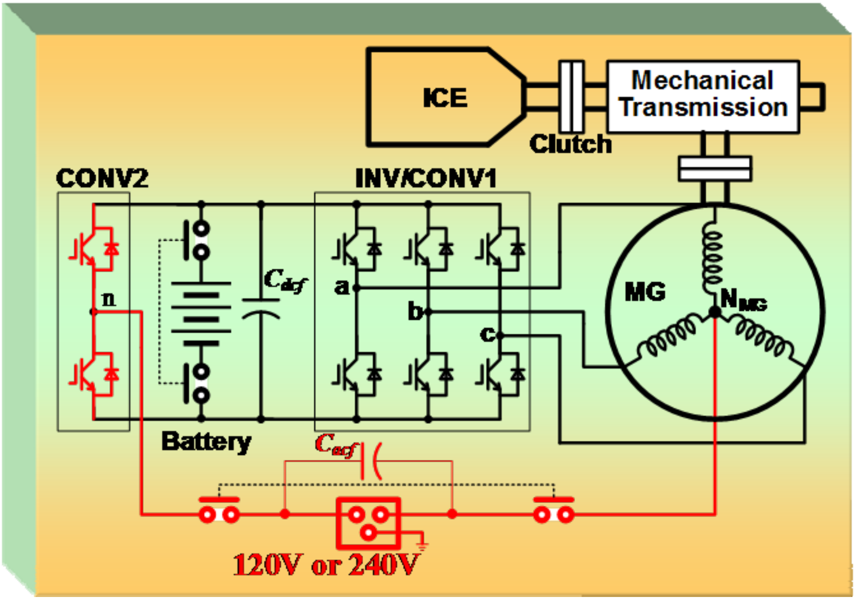
Month/Year	Milestone or Go/No-Go Decision
Apr-08	Milestone: Complete design and fabrication of a prototype consisting of 55 kW motor inverter and 30 kW generator inverter, with a rated charging power of 19.2 kW at 240 V.
Jun-08	Milestone: Complete development of control algorithm and DSP (digital signal processor) control code.
Sept-08	Go/No-Go Decision: Complete prototype tests and measure efficiency, power factor and current distortion factor. A go/no-go decision will be made based on the relative cost and measured performance information.
Feb-09	Milestone: Complete hardware modification of the prototype built in FY08 for mobile power generation operation tests.
May-09	Milestone: Complete DSP code development for mobile power generation operation tests.
Sept-09	Go/No-Go Decision: Complete characterization of traction motor leakage current and assessment of safety requirements. A decision to pursue the proposed approach will be made based on the safety assessment.

Approach

- For HEVs using multiple inverters and motors



- For HEVs using single inverter and motor
  - Add two additional switches



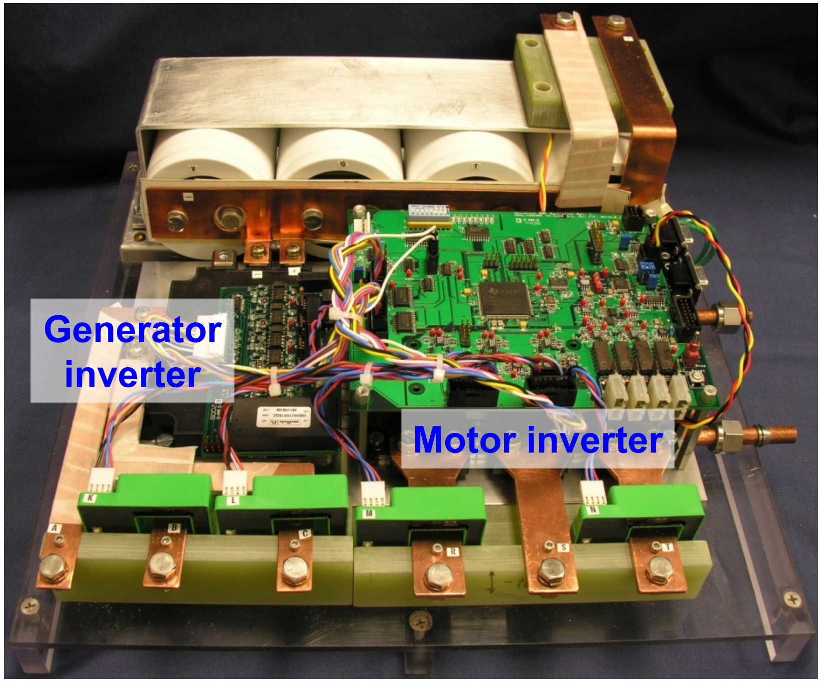
- Utilize onboard inverters and motors for charging/sourcing; no additional switch or filter inductor components (added components shown in red)
  - Each INV/CONV functions as a switch leg while splitting the current among the 6 switches
  - Machine zero-sequence inductance is utilized as filter inductor
- The two motors need not to be rated at the same power level
- Mobile power generation can be powered by the battery for short periods of time or by the ICE for long durations

Technical Accomplishments/Progress

- Demonstrated a prototype comprised of a 55 kW motor inverter and a 30 kW generator inverter with plug-in charging capability of 20 kW.
  - Max efficiency: 93% at 120V, 97% at 240V
  - Power factor: > 98%
  - Current total harmonic distortion (THD): < 10% at charging rates great than 25% of rated power
- Completed hardware modification of the prototype built in FY08 for mobile power generation operation tests.
- Compiled information on UL leakage current test requirements
- Held discussions with OEMs and industry people on safety issues

Technical Accomplishments

- **FY08 Prototype Test Setup**
  - A traction drive prototype comprised of a 55 kW motor inverter and a 30 kW generator inverter
  - Test motor 1: 11.2 kW induction motor
  - Test motor 2: 8.2 kW PM motor

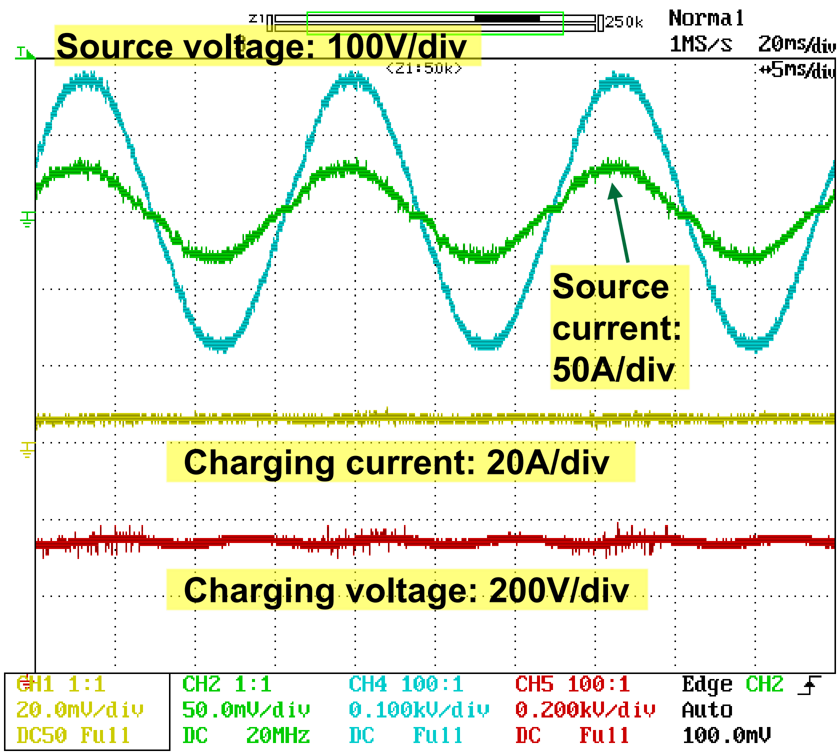


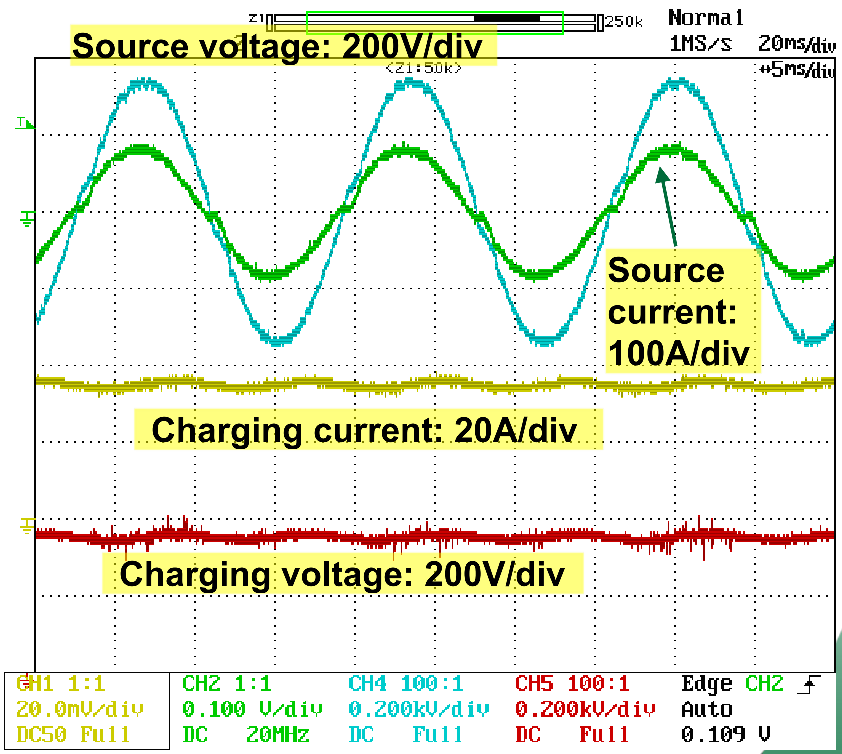
Heat sink: 12” x 7”

Technical Accomplishments

- **Charging at 2.1 kW from a 120V source**
  - Efficiency: 92.6%
  - Power factor: 99%
  - Current THD: 9.7%

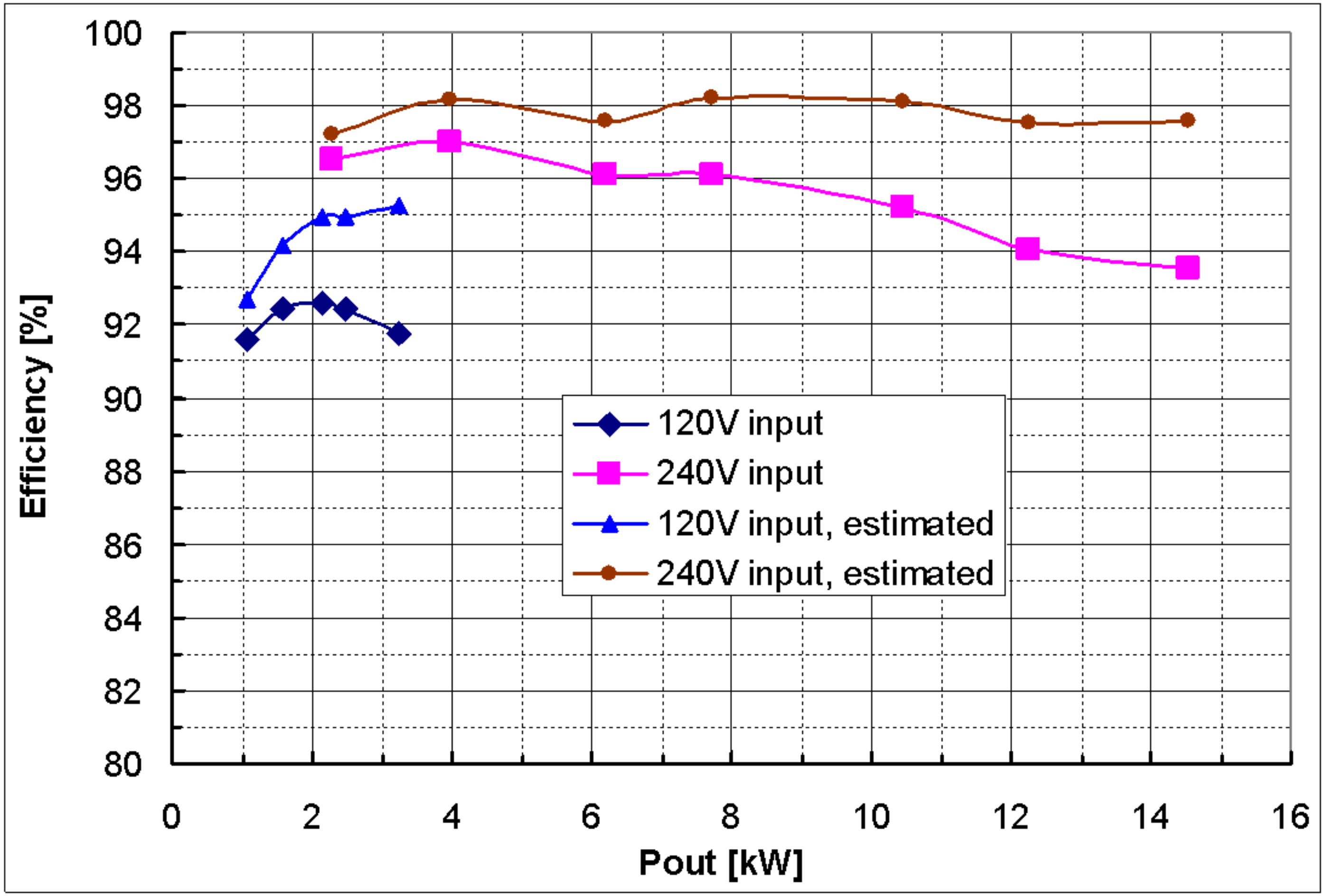
- **Charging at 12.4 kW from a 240V source**
  - Efficiency: 94.1%
  - Power factor: 99%
  - Current THD: 9.0%





Technical Accomplishments

- **Measured efficiency and estimated with Camry motors**

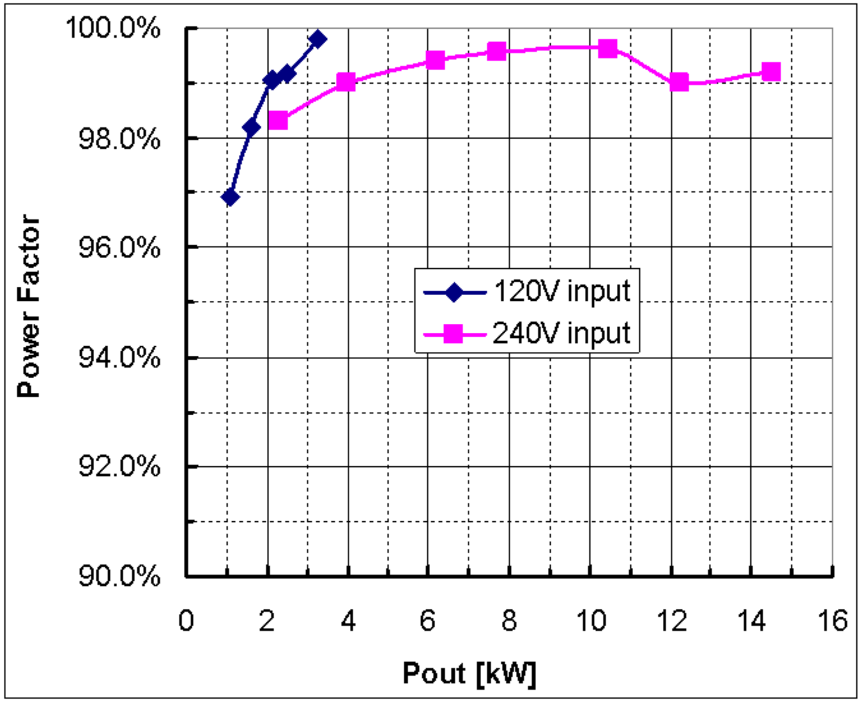


Combined resistance of test motors: 189.54 mΩ

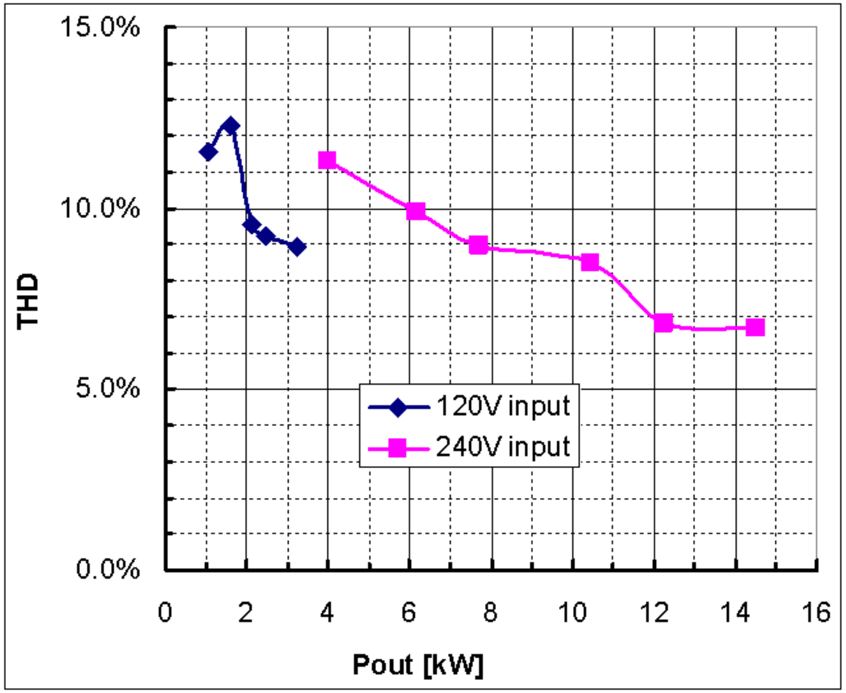
Combined resistance of Camry motors: 32.32 mΩ

Technical Accomplishments

- **Power factor:**
  - 96.9 ~ 99.8% at 120V, 98.3 ~ 99.2% at 240V
- **Current THD:**
  - 8.9~11.6% at 120V, 6.7 ~11.3% at 240V



Measured power factor



Measured current THD

Future Work

- Remainder of FY09
  - Demonstrate mobile generator capability of up to 20 kW
  - Complete characterization traction motor leakage current and assessment of safety requirements
- FY10
  - Demonstrate a prototype that can meet UL safety and leakage current requirements
  - Determine cooling strategy for rapid charging and mobile generation operations
  - Assess the interface protocols for smart charging to determine the requirements of hardware and software for implementing the protocols

Summary

- By utilizing the traction drive inverters and motors, virtually no additional components are needed to provide plug-in charging capability and enable enhanced functionalities
  - Rapid charging capability for use at high power charging stations (opportunity charging)
  - Mobile power generation or V2G capability

- Impacts
  - A significant reduction (90%) in the battery charging related cost and volume
  - Enhanced vehicle value and acceptance due to the added capabilities

- Prototype tests show very promising performances
  - High efficiency: 92~98% (vs. 80~85% for COTS chargers)
  - High power factor (>98%) and low harmonic distortion (<10%)