Bi-Directional Wireless Power Flow for Medium Duty Vehicle-Grid Connectivity

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Project ID: GI188

Overview

Timeline

- Project start date: May 2017
- Project end date: June 2019

Barriers

- Risk aversion
- Cost
- Constant advances in technology
- Computational models, design, and simulation methodologies

Budget (DOE share)

- Total project funding: $2,631,321
  - Federal/DOE - $1,949,007
  - Cost Share - $682,314

Partners

- United Parcel Service
- Cisco Systems
- Oak Ridge National Laboratory

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Relevance

- **Objective:**
  - The objective of this project is to develop and demonstrate a bi-directional wireless power transfer system for plug-in hybrid electric medium duty delivery trucks with a charge rate of 20 kW. The wireless power transfer system will be demonstrated in a vehicle to evaluate reverse power flow capability from the vehicle to the grid and to assess the battery life impacts.
- **How:**
  - An integrated > 20 kW wireless charging system
  - High efficiency (85%) wireless charging at a nominal ground clearance of approximately eleven (11) inches
  - Vehicle-to-grid mode 6.6 kW wireless power transfer to building or grid loads
  - Provide grid support functions
  - Integration of the BWPT system into the vehicle
  - Model and analyze the benefits of the BWPT system
- **Why:**
  - The fuel economy of medium and heavy duty vehicles are much less than passenger vehicles → more petroleum displacement if electrified.
  - Much higher average fleet emissions
  - Often a known route, predictable installation locations, and power ratings and infrastructure usage.
  - Bidirectional capability allows for integration with other renewables, provides emergency backup power, can support the microgrid operation or provide grid support services.

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Milestones FY17 – FY19

(Dates to be shifted due to late start)

Milestone Name/Description	Original Planned End Date	Milestone Type
Hold Kickoff meeting and also report the status of Phase I Technology Development tasks for the design and development of the power electronics system, coils, and controls and communications system	03/31/2017	Q
Review and analysis on system power conversion stages including grid-side power electronics, vehicle-side power electronics, and coupling coils	06/30/2017	Q
Report on bidirectional wireless power transfer architecture selected	09/30/2017	A
OEM vehicle integration support and guidance	12/31/2017	Q
Report on the design and development of bidirectional power transfer system power conversion stages	03/31/2018	Q
Report on design and development of the complete BWPT power management system	06/30/2018	Q
Report that outlines the vehicle integration of the bidirectional WPT system, and experimental test results for Phase II Technology Integration	09/30/2018	A
Provide a status report on the completion of vehicle integration with integrated and tested controls and communications interfaces	12/31/2018	Q
Assist in preparation of demonstration site	03/31/2019	Q
Provide assistance during bidirectional WPT vehicle demonstration and summarize the collected data for progress reporting	06/30/2019	Q
Analyze and report on the benefits of grid, cost and benefits to the customer, and the impact on battery lifetime due to bidirectional power flow for selected grid support services	09/30/2019	A

Approach/Strategy

- Project will start with a comprehensive literature review, modeling, analysis, and design work.
- Power electronics architectures and coupling coil configurations will be selected and designed.
- Designed power stages will be built and test bench experiments will be performed.
- Design improvements will be made based on the operational characteristics. This will be applied to all power stages and also the resonant stage.

- Power stages will be integrated in a laboratory setup.
- Operation will be validated, integrated system will be fine tuned.
- Vehicle integration will be performed.
- Vehicle integrated BWPT system will be tested.

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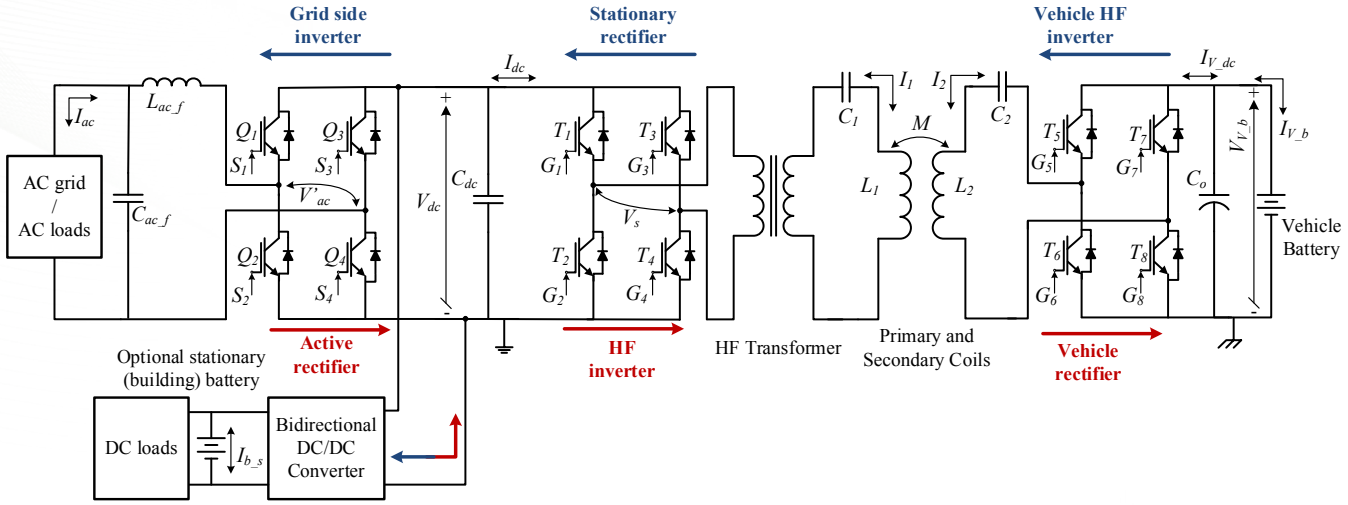
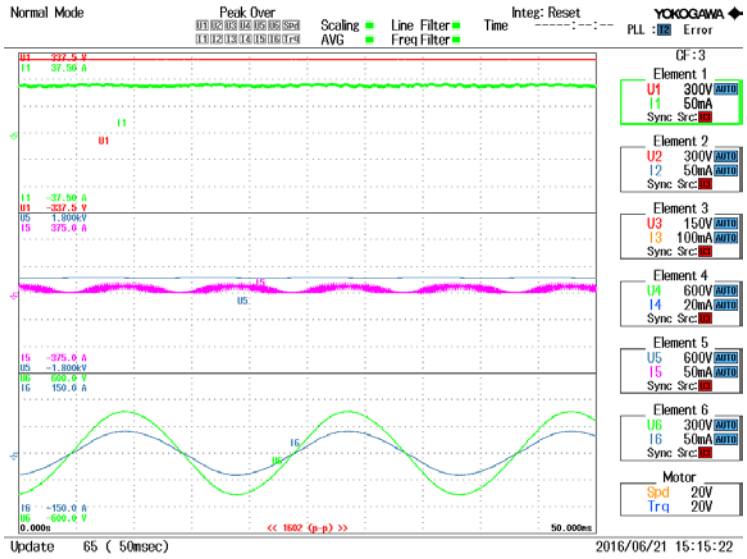
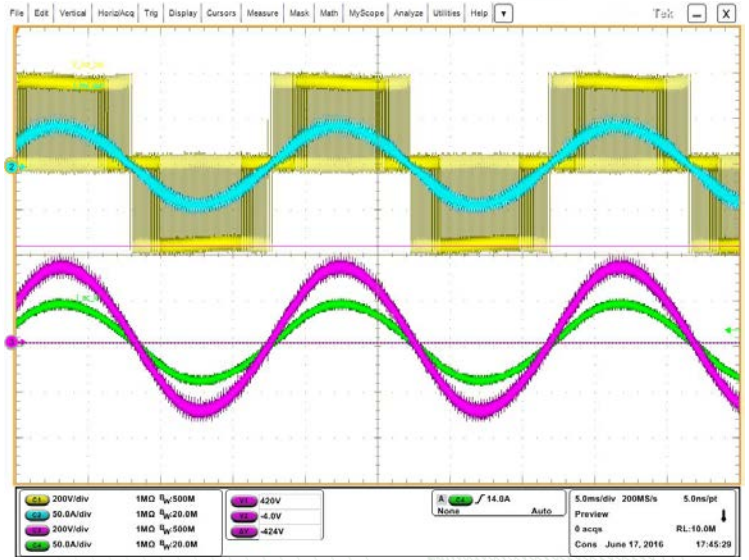
Approach: Bidirectional WPT for Residential Use



Circuit schematic of a BWPT with wireless link between vehicle battery to AC the grid though a grid side regulator/inverter





Bi-Directional Wireless Power Flow for Medium Duty Vehicle-Grid Connectivity

Accomplishment

- Kick-off meeting – January 2017
- Meeting at the Workhorse R&D Center
  - ORNL staff and Workhorse engineers met to discuss the project tasks and vehicle integration plans.
  - ORNL and Workhorse outlined a collaboration plan based on vehicle specifications, requirements, constraints, and project targets.
  - Workhorse will provide engineering and vehicle hardware and software integration support to ORNL.

Responses to Previous Year Reviewers' Comments

- The project started in FY17 - Not reviewed last year

Partners/Collaborations

- **CALSTART – Project Lead**
  - Responsible overall project management and coordination.

- **ORNL – Technical Lead**
  - Design, development, and integrate BWPT technology for project.

- **UPS – Vehicle, Fleet Data, and Demonstration Site**
  - Provide fleet data and demonstration site.
  - Provide medium duty parcel delivery vehicle for BWPT integration.

- **Workhorse Group – Vehicle Engineering and Integration Support**
  - Provide vehicle technical specifications and engineering support
  - Provide vehicle network communication information and integration.

- **Cisco Systems – Wireless Communications**
  - Provide hardware, software, and engineering support for wireless communications between vehicle and infrastructure.
  - Lead cybersecurity effort for project.

Remaining Challenges and Barriers

- **11 inches of airgap separation**
  - Potentially high field emissions
  - Potentially reduced coil-to-coil efficiency.
  - How the design can be improved to overcome these issues?
- **20 kW grid-to-vehicle and 6.6 kW vehicle-to-loads/grid operation**
  - How to change the power flow immediately, when needed, without manual disconnection and reconnection?
- **The need for an outer energy management strategy.**
  - When to charge/discharge the vehicle with what operational characteristic

Future Work/Upcoming Tasks

(Dates to be shifted due to late start)

- FY17
  - ORNL: Start the project.
  - ORNL: Power stages (modeling, analysis, simulations, design)
- FY18
  - ORNL: Prototyping the power stages, bench setup testing
  - CALSTART/UPS: Identification of demonstration site
  - Cisco Systems: Development of wireless communication hardware and software
- FY19
  - ORNL: Vehicle integration and testing, prepare for demonstration
  - ALL: Demonstration

Summary

- **Relevance:**
  - The objective of this project is to develop and demonstrate a bi-directional wireless power transfer system for plug-in hybrid electric medium duty delivery trucks with a charge rate of 20 kW.
  - The wireless power transfer system will be demonstrated in a vehicle to evaluate reverse power flow capability from the vehicle to the grid and to assess the battery life impacts.
- **Approach:**
  - Power electronics architectures and coupling coil configurations will be selected, designed, and tested.
  - Design improvements will be made based on the operational characteristics based on performance testing.
  - Operation will be validated, integrated system will be fine tuned.
  - Vehicle integration will be performed.
  - Vehicle integrated BWPT system will be tested.
- **Collaborations:**

CALSTART | OAK RIDGE National Laboratory | UPS | WORKHORSE | CISCO SYSTEMS

- **Technical Accomplishments:**
  - Kick-off meeting – January 2017
  - Meeting at the Workhorse R&D Center
- **Future Work:**
  - Development and validation of power stages for bi-directional wireless power transfer (BWPT) system.
  - Identification of demonstration site
  - Vehicle integration of BWPT system
  - Full demonstration of system