Electric Vehicle Transportation Center

Semi-annual Program Progress Performance Report for University Transportation Systems

U.S. Department of Transportation
Research and Innovative Technology Administration
1200 New Jersey Avenue, SE
Washington, DC 20590
Federal Grant Number: DTRT13-G-UTC51

Program Director: Dr. David Block
Director Emeritus
Florida Solar Energy Center
block@fsec.ucf.edu
321-638-1001
321-638-1010 (Fax)
321-432-7507 (Cell)

Submission Date: **October 30, 2014**

DUNS Number: 150805653

EIN Number: 59-2924021

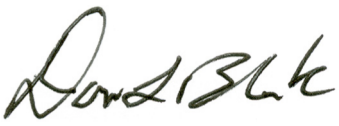
Recipient Organization: University of Central Florida
12201 Research Parkway, Suite 501
Orlando, FL 32816

Recipient ID Number: 20126116

Project Grant Period: October 1, 2013 – September 30, 2017

Reporting Period End Date: **September 30, 2014**

Report Term or Frequency: Semi-annual PPPR#2

Signature: 

University of Central Florida

Semi-annual Program Progress Performance Report for

Electric Vehicle Transportation Center

Submitted by:

University of Central Florida

I. Accomplishments

What are the major goals and objectives of the program?

The Electric Vehicle Transportation Center (EVTC) supports the U.S. Department of Transportation's strategic goal of planning for near-term integration of alternative fuel vehicles as a means to build a sustainable transportation system. The project will evaluate technologies, standards and policies to ensure seamless integration of electric vehicles (EVs) into a complex transportation network and electricity grid. The EVTC will bridge the gap between deployment of electric vehicles and the traditional transportation system.

The EVTC's goals were described in detail in the previous Program Progress Performance Report. These goals have not changed significantly and this report provides updates to each of the following areas: Research and Development, Industry Collaboration, Education and Workforce Development, Technology Transfer and Diversity. Project performance metrics are also identified to drive improvement and characterize progress and effectiveness.

What was accomplished under these goals?

Research and Development Accomplishments

During the first six month period, the research and development (R&D) agenda was initiated and faculty project teams were organized. The R&D agenda identified 21 projects and respective teams have begun the detailed research. Due to an extensive initial learning curve and the need to establish laboratory facilities, there has been some minor shifting in the original projects. Each project has shown accomplishment and the following section presents the 21 projects with objective (in italics) and accomplishments summary to date. Note that the PPPR contains ten referenced publications. These ten publications are presented by reference number in the R&D part with the formal citations and listing in the results dissemination section on page 17.

POLICIES

1. **Implications of Electric Vehicle Penetration on Federal and State Highway Revenues**
   Objective: *Research the impact that increased use of electric vehicles will have on federal and state highway revenue sources. This work will identify existing laws and policies that govern highway, gas, and vehicle taxes and fees imposed on vehicles and summarize current trends and policy recommendations that may influence both the growth of the electric vehicle market and impact highway revenues.*

   Accomplishments: Continued review of existing industry and government reports detailing current and future predicted fuel tax revenues for the federal highway programs and impacts and shortfalls to highway funding as a result of EV market penetration. All research data still points to a critical shortfall in highway funding, however this shortfall is attributed to more

fuel efficient internal combustion engine (ICE) vehicles and the increased cost in highway construction and repairs. EV penetration, although increasing, has not yet made a significant impact on highway fuel tax revenues. Projections are that EVs will become a major player in highway revenue shortfalls within the next 10 years and federal, state and local government policies and laws affecting highway funding must identify how fuel efficient and EVs will help pay for funding shortfalls. Part of this analysis is the continued review of policies that aim to increase revenue streams for highway funding as it relates to increasing EV market penetration. Options already being considered for EV owners are fee based travel, increased direct taxes, and surcharges on purchases. A report detailing findings and recommendations will be available for review in December 2014.

2. **Identify and Analyze Policies that Impact the Acceleration of Electric Vehicle Adoption**
Objective: *Examine state and national regulatory policies to determine their impact on the long term adoption of electric vehicles. This work will include a review of initiatives that have the effect of both encouraging and discouraging the deployment of electric vehicles.*

Accomplishments: Conducted literature review of state and federal legislative initiatives and have developed a compendium for further analysis. Staff has worked with the 43 member Drive Electric Florida initiative and the Central Florida Clean Cities Coalition where an extensive list of policies and incentives has been developed that would support greater adoption of EVs. This list is currently undergoing stakeholder review. A summary report will be produced that reviews the feasibility and potential impacts of implementation.

STANDARDS

3. **Electric Vehicle Charging Technologies and Analysis**
Objective: *Assess existing electric vehicle charger hardware and software, design, standards, and costs. Identify requirements of emerging technologies and applications. Identify and recommend policies and best practices that advance electric vehicle charging technologies and deployment.*

Accomplishments: Currently working with national, regional, and local EV car manufacturers/dealers to understand the general desire of customers for charging at residential, public, and workplace locations. The data shows 8,563 public charging stations with 21,126 outlets in the U.S. Staff has developed contacts with EV charger companies and continues dialogues with energy providers regarding electrical grid demand load due to the presence of Level II and DC fast chargers.

A significant effort on the part of the EVTC staff has resulted in the donation from Nissan of a DC Fast Charge (DCFC) station to be installed on Florida Solar Energy Center (FSEC) property. FSEC will be awarded $25,000 from Nissan for a 50kW DCFC with two years network services. The DCFC station is to be operational by December 1, 2014 and will be available for data analysis and for public use.

A draft project report on Electric Vehicle Supply Equipment (EVSE) and the associated infrastructure is complete, with the expectation that a final report will be published by the end of 2014. The report will include a technical review of EVSE technology, applicable standards and codes, and an analysis of the existing infrastructure development. The report will also identify barriers to continued EVSE infrastructure expansion, and recommendations

for accelerating the expansion of the infrastructure. The University of Hawaii has also conducted EVSE analysis and is preparing a technical report in 2014.

4. **Electric Vehicle and Infrastructure Safety Requirements and Regulations**
Objective: *Evaluate current and proposed electric vehicle and infrastructure safety standards and policies with respect to cost and applicable codes, and regulations. The results will be used to evaluate the effects of policies/regulations and on the advancement of electric vehicles and supply equipment.*

Accomplishments: Completed literature search of codes and standards that are applicable to vehicle systems, batteries, and vehicle interface and infrastructure requirements. Research and first draft of the evaluation report are substantially complete. The report evaluates Electric Vehicle (EV) manufacturing standards, Electric Vehicle Supply Equipment (EVSE) and infrastructure codes and standards established by the National Highway Safety Administration (NHSTA), the Society of Automotive Engineers (SAE) and others. A final report is expected by the end of 2014.

SUB-SYSTEMS

5. **Prediction of Electric Vehicle Penetration**
Objective: *Identify past and present trends in electric vehicle sales to establish a baseline of electric vehicle penetration and to project electric vehicle sales and sales characteristics within the U.S. Provide projections of sales through the year 2024 for the states of Florida, Hawaii, Alabama, Georgia, California and New York.*

Accomplishments: Previous project results have presented data for electric vehicle yearly sales and cumulative sales through December 31, 2013 and have been published (presented on EVTC and TRIS websites). These results showed that cumulative sales of EVs through 2013 was 167,600 vehicles with 96,700 sold in 2013 showing that 58% of total electric vehicle sales were in 2013. A new update report on EV predictions will be completed next year after the sales data for 2014 has been reported.

The work conducted for the period of January to September 2014, shows that EV sales for 2014 were 88,149 as compared to 67,979 for the same period in 2013, an increase of 30%. These 2014 numbers give cumulative sales in the U.S. of 255,749 electric or plug-in vehicles. The past referenced report predicted a moderate growth rate of 20% which so far appears low. In addition, EVTC staff has determined the number of EVs in Florida (from Florida Power & Light) which shows as of September 30, 2014, there are a total of 9,139 EVs registered in Florida.

6. **Electric Vehicle Life Cycle Cost Analysis**
Objective: *Compare total life cycle costs of electric vehicles, plug-in hybrid electric vehicles, hybrid electric vehicles, and compare with internal combustion engine vehicles. The analysis will consider both capital and operating costs in order to present an accurate assessment of lifetime ownership costs. The analysis will include vehicle charging scenarios of photovoltaic (solar electric) powered charging and workplace charging.*

Accomplishments: A vehicle life cycle cost (LCC) model [1] was developed to compare electric plug-in and hybrid to internal combustion engine (ICE) vehicles. For the specific

case of 12,330 miles driven per year, the LCC results show that higher first cost battery powered vehicles can be lower in life cycle costs than conventional internal combustion vehicles. Results have also been conducted for vehicles traveling 5,000, 10,000 and 15,000 miles and for vehicle lifetimes of 5, 10, and 15 years. The LCC simulation program is included in the report and can be used by an individual for modeling any vehicle.

7. **Assess the SunGuide and STEWARD Databases**
Objective: *Evaluate the feasibility of using the existing Florida Department of Transportation SunGuide® software and STEWARD data base as platforms for analyzing the attributes of electric vehicles within present and future transportation infrastructure.*

Accomplishments: The STEWARD database was reviewed and found to be abandoned by Florida DOT and thus outdated. An alternate RITIS database was used to provide current vehicle information on the Florida Turnpike for a transportation simulation model (Project #13). Multiple measurement locations on the Florida Turnpike provide vehicle volume, speed, and direction for detailed transportation models.

8. **Battery Technologies for Mass Deployment of Electric Vehicles**
Objective: *Assess current and emerging battery technologies and the requirements for their commercialization; align with DOE targets for future EV batteries. Focus will be placed on battery technologies, charging cycles, lifetimes, safety, codes and standards, and economics.*

Accomplishments: Information from the literature have been compiled and analyzed. In the next quarter, additional data will be compiled and analyzed for degradation modes and trends as a function of voltage, usage cycles, temperature and chemistry. The result will form a basis to understand the impacts of degradation modes on the performance of battery systems and cell components. Emphasis will be placed on chemistry and operating temperatures. In addition, R & D results have been made comparing prices and power outputs with U. S. Department of Energy battery goals. Predictions are for cost reductions of 7.5% per year through 2020.

9. **Electric Vehicle Battery Durability and Reliability under Electric Utility Grid Operations**
Objective: *Determine the impact of electric vehicle use on battery life including charging cycles and vehicle-to-grid (V2G) applications. The work will identify conditions that improve battery performance and durability. Focus will be placed on providing battery data for system engineering, grid modeling and cost-benefit analysis.*

Accomplishments: Data have been collected on the factors influencing the degradation of battery systems and cell components. Extensive collaboration and exchange of information amongst teams of researchers from all three participating EVTC universities has been established with regular monthly meetings. A joint review paper on battery degradation based on more than 100 carefully reviewed articles is being prepared. Data collection is now complete and fully digitized. Analysis and reporting will take place in the next quarter. A new battery testing lab is scheduled to be up and running by end of this year, located at HNEI's Hawaii Sustainable Energy Research Facility (HiSERF).

10. **Fuel Cell Vehicle (FCV) Technologies, Infrastructure and Requirements**
Objective: *Identify state-of-the-art fuel cell technologies and vehicles and current*

infrastructure requirements. A comparison with DOE targets for fuel cell vehicles and components will be included.

Accomplishments: An important part of this project has focused on results from past fuel cell and fuel cell hybrid programs. This investigation has included results from GM, Toyota, Honda, Mercedes-Benz, and Hyundai and pilot demonstration programs that have leased vehicles in California. Note is made that GM, Honda, Toyota and Hyundai have all announced plans to make fuel cell vehicles available in the near future (2015-2020).

A fuel cell is used either as the primary source to power the electric motor in a fuel cell electric vehicle (FCV) or used to recharge the battery in a battery electric vehicle (BEV) with a fuel cell range extender. The major difference is that the battery size in a fuel cell vehicle is considerably smaller than that in a fuel cell range extender BEV. In a FCV modeling effort, a 2012 Chevy Volt served as the baseline vehicle to compare vehicle performance and associated costs of using fuel cells as opposed to increased battery size. Simulation results show that the use of a fuel cell stack will significantly increase the fuel economy of the current Chevy Volt. Increased range for a fuel cell does not result in a significant decrease in fuel economy, or a significant increase in cost. Thus, it is possible to achieve greater range more economically by utilizing a fuel cell rather than through adding more batteries. Operation in cold climates is also a benefit of a fuel cell, as the waste heat can be used to heat the vehicle cabin, thereby conserving battery energy for traction. A report entitled "Analysis of Fuel Cell Vehicle Developments" has been completed and is currently under review [2].

Future plans are to perform a case study on the fuel cell range extender hybrid bus at NASA - Kennedy Space Center to evaluate FCV technologies with regard to fuel cell system efficiency, range, durability, and lifespan given the present state-of-the-art for membrane electrode assembly and hydrogen storage technologies. Research will also identify obstacles for mass production of fuel cell vehicles.

ELECTRIC VEHICLE SUPPLY EQUIPMENT ANALYSIS

11. Electric Vehicle Grid Experiments and Analysis

Objective: *Provide experimental data from vehicle-to-grid laboratory simulations. The results of the experimental data will be used in the EVTC techno-economic simulation project.*

Accomplishments: The initial phase of project development concentrated on different battery types and on electric vehicle chargers (type, rating, programmability). In the past six months, the task efforts have concentrated on developing a building energy management system (EMS) that is directed toward processes for reducing building peak demand for an office building. The FSEC office building has been selected for this analysis. Also measured are existing PV array energy outputs. The FSEC facility is now instrumented so that energy is measured on a three minute basis through the installation of an FPL utility meter enhancement. The future plans are to couple the EMS system to the building energy profile, to the EV charging station demands, and to PV production output. These loads will then be brought together, with computers located at each of the three locations, by the EMS system that provides information to a central computer control system. The EMS system can then follow building loads (primarily monthly peak loads) and make informed decisions on methods to reduce building peak demand for times when EVs are using the DC fast charger

(480V at 60 amp) or other peak loads are occurring. A battery backup load reduction system is also under consideration.

12. **Electric Vehicle Interaction at the Electrical Circuit Level**
Objective: *Investigate the effect of electric vehicle adoption on the circuit level utility distribution grid for both residential and commercial applications by determining the impact of electric vehicle charging and discharging to the grid.*

Accomplishments: A literature review was conducted on the current state of EV charger technology, focusing on power ratings, control capabilities, embedded sensors, and international standards. The results of this study along with various categorizations of charging station standards are included in a preliminary report. A literature review and report have also been prepared on over-voltage mitigation at the sub circuit level of electricity grids with high photovoltaic (PV) to load ratios. Both reports will be made available on the EVTC website. Additionally, a transient time domain model of a sub circuit service area has been developed, which includes EV charging and integrated PV load generation. The next steps will be to model EV charging as a means of mitigating over-voltage in various scenarios, using the sub circuit model. A report will be prepared with outcomes of the modeling efforts, including EV charging, its integration into the grid at the sub circuit level, and PV inverter technology. The objective is to find potential solutions that EV charging offers while mitigating transient over-voltages at the sub circuit level.

SPECIALIZED ELECTRIC VEHICLE APPLICATIONS

13. **Optimal Charging Scheduler for Electric Vehicles on the Florida Turnpike**
Objective: *Develop the methodology for analyzing the roadway traffic patterns and expected penetration and timing of electric vehicles (EVs) on the Florida Turnpike. The work will determine the requirements for electric vehicle supply equipment at turnpike plazas, the options for equipment siting and the economics.*

Accomplishments: The Florida Turnpike network has been examined. Real-world data were collected and compiled from a Florida traffic database (Project #7). Research has been conducted to develop an average dynamic model of EV traffic flow passing through entrances and exits. A queuing model for potential service stations was developed. Further research will study the waiting time of EVs at any given service station given the number of chargers available. The researchers have also investigated problems of designing a distributed scheduling algorithm for optimizing the overall transportation network and a cooperative control for individual drivers to make their decisions. One relevant conference paper was accepted for publication [3].

14. ***Electric Vehicle Bus Systems***
Objective: *Model public electric bus transportation systems. The analysis will include route distance and timing, charging times, impact of type of chargers, maintenance and operational characteristics and economic comparison with diesel powered buses. The first project will be to analyze the City of Tallahassee's Star Metro electric bus fleet.*

Accomplishments: Five Tallahassee StarMetro electric buses (EB) manufactured by Proterra (model EcoRide™ BE-35) were delivered in March 2012 and two were delivered in June 2013. The buses employ Altairnano lithium titanate 72 kWh battery packs and

regenerative braking technology. The battery technology enables the Proterra FastFill^{TM} fast charging without compromising the battery life. The charging station is comprised of a 500 kW charger, a charger head, and a bus communication system. The bus can be charged from 10%-95% state of charge in less than 10 minutes. The operational data of mileages, energy consumption, electricity cost, maintenance record, and out of service reasons were collected and analyzed. Five 2010 diesel buses were chosen as baseline comparison vehicles.

Between July 2013 and July 2014, the average monthly mileage was 980 miles for each electric bus and 3495 miles for each diesel bus (electric bus usage was 28% of diesel buses). There are a number of reasons for the low usage of the electric buses such as charging station malfunction, entrance door issues, accidents, and battery and air conditioning issues and the shortage of trained drivers. Based on the operational data, the average electricity-mileage of the electric buses was calculated to be 2.5 kWh/mile. This energy conversion efficiency is almost four times greater than the average diesel bus' which is 9.6 kWh/mile. The average monthly maintenance cost was $979, which was significantly lower than that of the baseline diesel buses of $1469. The cumulative mileage of the five electric buses was 58785 miles. The tailpipe carbon dioxide (CO2) reduction was 173 tons and the overall CO2 reduction was 96 tons when accounting for CO2 associated with electricity production.

Future plans are to continue collection and analysis of the operational data, to conduct a second national survey to determine the readiness for electric bus adoption by transit agencies and to develop a MATLAB model to simulate and optimize the routes, stops, passenger pick-up and drop-off schedules, and charging of the StarMetro electric buses.

15. **EV and Wireless Charging Laboratory**

Objective: *Furnish and equip an EV and Wireless Charging Laboratory within the FSEC laboratory facilities. This facility will function as a laboratory where EV vehicles are charged and discharged through a computer assisted communication network via the vehicle's charging port. The lab will also conduct wireless charging tests to experimentally document testing protocols and evaluate standards, maintenance techniques, operation conditions, electrical characteristics, weather effects, and infrastructure or operational related wireless charging characteristics.*

Accomplishments: The EV laboratory was configured in April 2014 and has conducted experiments on an EV vehicle (presently a Nissan Leaf) which is connected electronically through its CHAdeMO charging port to become part of a computer based communications network. The lab staff has also investigated wireless charging products and their respective manufacturers for writing purchase specifications. Future plans are to purchase three wireless charging products that will be used to perform the wireless experiments.

16. **Electric Vehicle Fleet Implications and Analysis**

Objective: *Evaluate the effectiveness of electrical vehicles use in fleet system operations to include electric school buses. The focus of this work is to examine route travel distances, battery usage and lifetimes, charging station requirements and economics, as well as how fleet adoption will impact overall rate of market penetration of electric vehicles.*

Accomplishments: Fleet outreach efforts revealed that public and private fleet transition to electric vehicles is limited by a number of factors, including incentives, procurement barriers,

and infrastructure limitations. Lack of readily available and understandable information further limits alternative fuel vehicle adoption in this sector. Because the quantity of vehicle procurement in the public and private fleet sector, and the leadership example that it can provide to the general public, this is a critical target market for expansion of EV use. For this reason, the EVTC has begun outreach efforts to fleets to assist them as they evaluate future fleet procurement. As part of this project, EVTC staff will provide summaries of fleet outreach and the results of EVTC assistance. Barriers to adoption in each case will be identified with recommendations for further action.

SOCIO-ECONOMIC IMPLICATIONS

17. Electric Vehicle Energy Impact

Objective: *Evaluate the impacts of electric vehicles and associated renewable power generation on reduction of petroleum imports to Hawaii. The analysis will concentrate on the Island of Oahu and will include the effects of number of vehicles, charging strategies, renewable energy penetration levels and green-house gas reductions.*

Accomplishments: The Hawaii Natural Energy Institute (HNEI) and General Electric International, Inc. (GE) have previously completed a high fidelity dispatch model. ("Oahu Electric Vehicle Charging Study", 2013). Further modeling efforts developed this period are summarized in the 2014 "Hawaii RPS Roadmap Study". This modeling study is focused at the whole island transmission system level. Results of the study reveal that significant reductions in curtailed energy can be achieved with operational changes to the electricity grid and power generation systems on the islands of Oahu and Maui (without the addition of costly energy storage systems). Curtailment was found to range from a modest 1% to 8% with scenarios of up to 1 GW of renewable energy (on a grid with ~ 1 GW of demand). The study reveals that Oahu can achieve delivered renewable energy approaching 34% with on-island resources. If the electric grids on the islands of Oahu and Maui are interconnected, this can increase the delivered renewable energy to 50% for both islands.

The next steps for this EVTC project are to make use of these modeling results to update estimates of the amount of curtailed energy that could be captured by strategically charging EVs, the impact of EV fleets on reducing petroleum imports to Hawaii, and a comparison with other alternate fuel vehicles and fuels. Additionally, literature on the state of EV integration in Hawaii has been collected, and a report will be prepared to summarize the progress on EV adoption in Hawaii, including current infrastructure and challenges.

18. Socio-economic Implications of Large-scale Electric Vehicle Systems

Objective: *Develop models to evaluate the socio-economic implications of a large-scale electrified transportation sector. Model factors include effects of vehicle and infrastructure safety requirements, standardization of vehicle components for safety and charging, electric vehicle supply and after-market economies, displacement of petroleum fuels and impacts of sustainable development (social, environmental and economic).*

Accomplishments: The state specific carbon and energy footprint calculations of alternative passenger vehicles including hybrid, plug-in hybrid, and battery electric vehicles are completed. The results were submitted to the *Journal of Energy*, and are currently in revision. In addition to environmental impacts, the social and economic impacts associated with alternative passenger vehicles are also quantified. Optimum vehicle mix in the United

States is estimated based on their socio-economic benefits versus environmental impacts. The trade-off among these bottom lines (macro-level economic, social, and environmental aspects) was analyzed. These results were submitted to the *Journal of Transportation Research Part A: Policy and Practice*, and the *International Journal of Cleaner production*. Both manuscripts are currently under review. In addition, other segments of alternative vehicle technologies such as commercial medium duty trucks and public buses are being analyzed. These studies aim to quantify the environmental impact reduction potentials of alternative vehicle options in these segments [4] [5] [6].

19. **Economic Impacts of Electric Vehicle Adoption**.
Objective: *Project will examine likely levels of EV adoption in order to estimate the impact to the State of Hawaii's economy, and to determine the level of opportunity in EV's as a grid stabilization tool. Analysis will include the determination of a set of scenarios for EV adoption in Hawaii over time based on consumer vehicle preferences, identifying the impact of EV penetration to the electric sector in terms of electricity generation, costs and GHG emissions, and estimating the effect of EV adoption to the state economy in terms of impacts to gross state product, sector activity and household welfare.*

Accomplishments: Literature has been collected on vehicle adoption rates and practices. Data has been requested and received from the Hawaii Department of Transportation on Hawaii's existing registered vehicle fleet (over a million vehicles). Data includes vehicle make, type, model year, fuel code, and special vehicle code. This data will be used to develop forecasts of EV adoption in Hawaii. Currently the database is being statistically "cleaned". The next steps of this project are to write the literature review and calibrate a Logit model based on existing data. This will be used to develop scenarios of EV adoption over time in Hawaii and then used as alternative scenarios within the economic analysis.

TECHNO-ECONOMIC SYSTEMS ANALYSIS

20. **Techno-economic Analyses of Large-scale Electric Vehicle Systems**
Objective: *Develop a computer model to evaluate the techno-economic implications of a large-scale electrified transportation sector. The model factors include developing a network of electric vehicles that interact with the electric grid, the infrastructure for electric vehicle charging, integrating the transportation and power systems into the urban setting, studying the impact of distributed energy storage and determining the economic impact of increased renewable energy and EVs on the electricity grid.*

Accomplishments: A four-year plan was developed to subdivide the project into manageable milestones identified as: 1) start the development of a scalable model of large-scale EV and power grid systems. Partner: Florida Turnpike Authority, 2) work on developing and optimizing both grid to vehicle (G2V) charging and vehicle to grid (V2G) feeding algorithms, and 3) optimizing both the transportation network and electric power grid.

The current research focuses upon several innovative aspects of G2V charging and V2G feeding development, including such advances as plug-and-play operation, load/generation estimation through integrating renewable energy, distributed protection algorithm, and improving electric grid efficiency and delivery capacity by enabling reactive power compensation and voltage control (which does not affect battery life). Four relevant journal/conference papers are published or currently under review [7] [8] [9] [10].

21. **Effect of Electric Vehicles on Power System Expansion and Operation**

Objective: *Examine the effects of electric vehicles on electric power systems and their operation. This work includes using an existing Hawaii developed model that will be validated against a large scale utility model. The work will evaluate the benefits of optimally-timed EV charging, the requirements and costs of electric grid infrastructure to serve different types of vehicle fleets, and the effects of battery duty cycles used in the vehicle and in vehicle-to-grid applications.*

Accomplishments: The second two quarters of the project were spent preparing and debugging an early working version of the SWITCH power system model for Oahu. All significant data sources have been identified and processed, and model run-time and qualitative results have been assessed. The same datasets and scripts can be used to prepare an all-islands model later in the project. The model has been initialized with the data needed for analyzing future energy scenarios on Oahu. The model was also tested and performed as expected when the cost of fuels or access to various technologies were adjusted.

Graduate students completed a literature review including the utilities' Integrated Resource Planning (IRP) documents and Federal Energy Regulatory Commission (FERC) filings, and several papers that prepared EV charging profiles based on National Household Travel Survey data. Next steps are to integrate this information into the model, develop profiles of EV charging availability based on National Household Travel Survey (2009), prepare datasets for neighbor islands, and begin analyzing the effect of optimal timing of EV charging on power system operation and design. Additionally, SWITCH will be used to reproduce analysis previously done with GE high fidelity dispatch models, in order to test SWITCH's effectiveness.

Industry Collaboration Accomplishments

Industry collaborations included:

- Introductory meetings with Mike Scarpino, DOT Volpe Center (May 1, 2014)
- Discussions with three electric bus manufacturers, Joe Lunny of Proterra (June 5 and July 30, 2014), Brian Barrington of TransTech (June 30, 2014), and Patrick Dunn of BYD (July 9, 2014).
- A collaboration meeting with David Dunn, Division Manager of Orlando, FL Fleet & Facilities (July 17, 2014)
- Meeting with Ralph Wilder, Superintendent of Transit Maintenance for StarMetro, in Tallahassee, FL (June 9, 2014).
- Two meetings with the EVTC utility working group of FPL, Duke, TECO and OUC (May 8 and June 11, 2014).
- Telephone conferences with Darryll Dockstader, Research Center Manager at FDOT (July 30 and September 25, 2014).
- Meetings with the Orlando transit agency and UCF campus to discuss the potential for introducing Proterra buses.
- Two meetings were held with Mr. Bruce Chesson at the NASA Kennedy Space Center, and David Mandernack at Energy Florida, to discuss the collaboration on NASA's recently acquired Proterra fuel cell hybrid bus (June 27, 2014 and July 18, 2014).

- Meetings were held between representatives of Alabama Power Company (Cedric Daniels, Kenny Keenan, Blair Farley, Will Hobbs, Pradeep Vitta, Foster Ware, Tony Smoke, Steve Sherman and Phillip Wiedmyer) and Tuskegee University (Sharma, Kumar and Chen) to seek their contribution to the project. The Alabama Power Company has been involved in course development and outreach programs.

Education and Workforce Development Accomplishments

1. University of Central Florida

A new course on distributed optimization and control for smart grid is being developed at UCF and will be offered in spring 2015 as an undergraduate elective and an entry-level graduate course. The course will specifically address G2V and V2G operations and will be broadcast to 8 universities as part of a U.S. Department of Energy project at UCF.

The EVTC has participated in the development of a two hour webinar that covers the basics of Electric Drive Vehicles. The webinar was a cooperative effort of the EVTC, the Central Florida Clean Cities Coalition and Jason Gaschel, an instructor certified by the National Alternative Fuel Training Consortium (NAFTC). The webinar is available on demand to Clean Cities and EVTC stakeholders and partners. It has also been used as a prerequisite for First Responder Safety Training – Electric Drive Vehicles, a one day course for firefighters and emergency service personnel that has been conducted several times this quarter in cooperation with the region's workforce agency. The course uses NAFTC and U.S. Department of Energy approved curriculum. Through this effort nearly 100 emergency service personnel have been trained, including 31 as trainers who will teach others in their departments. Safety training of first responders is considered to be an essential component of increased EV adoption so that drivers and responders are confident that EV incidents and emergencies will be handled according to industry safety standards.

2. University of Hawaii

University of Hawaii at Manoa faculty delivered two keynote lectures. The first was on renewable energies including transportation and electric vehicles to approximately 30 middle school teachers at a STEM workshop in Hawaii in summer 2014. The second was on battery modeling for academic and industrial applications at the Battery Modeling for Industrial Applications Symposium, at the University of Warwick (UK), in September 2014. The symposium was designed to engage industry and academia, and to facilitate discussion, interaction, and sharing of work between the two groups. The discussion centered around models to understand behavior in applications including "electric people movers", electric power grid support, renewable energy integration, micro grid, and local building support.

3. Tuskegee University

Tuskegee University has accomplished seamless integration of EVTC projects in the senior level Physics course curriculum in both fall 2013 and spring 2014 semesters. In spring 2014, Dr. Sesha Srinivasan included the topic "Alternative Electric Vehicle" as part of the Modern Physics course PHYS 502, and 6 students successfully completed the course.

Based on the EVTC projects, these students with other Physics majors have successfully won Sigma Pi Sigma Undergraduate Research Award and Marsh M. White Outreach Award from Society of Physics Students National Office in Washington DC. Ms. Leah Sanks was also

nominated for the Presidents All-STAR Students' Recognition in fall 2013. In spring 2014, Ms. Leah Sanks and Mr. John Scruggs presented their posters at the Joint Annual Research Symposium, Tuskegee University (Feb. 2014) and Alabama Academy of Science 91st Annual Meeting, Auburn University, AL (Mar. 2014).

Future education and outreach activities from Tuskegee include; 1) "Tuskegee University Electric Vehicle Day" will be organized on November 6, 2014 at Kellogg Conference Center on Tuskegee campus, 2) Plans are to work with Alabama Power and Alabama Department of Transportation (AL-DOT) to enhance the STEM curriculum, education and research training on EVTC in the coming academic year (Fall 2014-Spring 2015), 3) Basic and applied research at the undergraduate level will be conducted in summer 2015, 4) The outreach activities will be continued and extended to middle schools, and 5) The summer workshop in 2015 will be organized for participants from local high school and university students.

4. Workforce Development

A workforce development plan is an integral component of the overall program. A review of knowledge, skills and abilities for practitioners in the EV industry has provided a foundation for a database of requirements for entry into EV careers. EVTC Staff has established a relationship with CareerSource Brevard, our local workforce agency, for the purpose of accessing their connections and programs in the workforce development area. In addition, the Central Florida Clean Cities Coalition is playing a major role in workforce development efforts using U.S Department of Energy approved curriculum for training of new and incumbent workers in alternative fuel vehicles.

Technology Transfer Accomplishments

The University of Central Florida's startup business incubator reported its latest economic impact estimates. It has 250 startup tenants at eight locations across the region; 3,600 sustained jobs; $1.5 billion in revenues; and $2.5 billion in overall economic impact. This growth has been spurred by tapping into UCF mentoring services, training and other infrastructure. The incubator program has locations at the Central Florida Research Park, UCF's photonics research college on campus in Apopka, Daytona Beach, Kissimmee, St. Cloud, Winter Springs and UCF's digital media school in downtown Orlando. In addition, UCF has just launched a NSF funded program that is focused on assisting with commercialization of university research. The program is called NSF I-Corps and UCF is one of 15 universities across the U.S. who was funded to provide this program. UCF will be supporting a total of 96 teams (consisting of a faculty/researcher PI, a student/entrepreneur lead, and an industry mentor) over a three year period (see: http://icorps.cie.ucf.edu/). The EVTC has reached out to these programs for assistance in identifying EV industry startups.

At FSEC, C. Kettles serves as the Coordinator of the U.S. DOE-funded Central Florida Clean Cities Coalition and conducts EVTC research. The Clean Cities Coalition represents 35 alternative fuels related organizations and its activities include facilitating the adoption of alternative fuel vehicles (AFVs); assisting in the development of AFV infrastructure; conducting public education and outreach programs; organizing and hosting stakeholder meetings and events; and, providing technical assistance and special training to early adopters of AFVs.

In the case of battery technologies, related literature has been digitized and uploaded to a Matlab database. More than 110 scientific articles have been critically reviewed and digitized. The collected data focuses on lifetime experiments of commercially available lithium-ion batteries, and encompasses parameters such as battery chemistry, charge/discharge cycle lifetime, calendar lifetime, and operational temperatures. The next reporting period will focus on compiling information that will enable researchers to identify failure modes as a function of either cycling or calendaring lifetime as well as the temperature and battery chemistry. Also, Hawaii Natural Energy Institute faculty delivered a keynote presentation at a symposium in September, focused on battery modeling for industrial applications.

Diversity Accomplishments

UCF has major programs and activities in the diversity areas. One STEM program activity is called iSTEM (Initiatives in STEM) and is a joint effort between the College in Science (COS) and the College of Engineering and Computer Science (CECS) to improve collaboration in STEM-related activities. The National Science Foundation has funded this effort at $1.8 million. The iSTEM program incorporates career planning as soon as freshman students begin classes at the university. iSTEM has four primary goals: to bring coherence to the many STEM funded projects at UCF, to increase grant and philanthropic funding efforts that support STEM education and research, to position UCF in Florida and nationally as a hub for STEM education and related research and to improve the STEM pipeline and produce a better STEM workforce.

The second related UCF program is Women in Electrical Engineering and Computer Science (WEECS) which is a student organization. WEECS exists to foster community activities among women with the aim to bring more women into the field and to do all that it can do to provide students with the resources they need to be successful. Dr. Parveen F. Wahid of UCF Electrical Engineering (EVTC partner) is faculty advisor (See: http://women.eecs.ucf.edu/).

The third activity is the UCF Office of Diversity and Inclusion which was created with the purpose of recruiting and retaining minorities, women, and underrepresented groups into the fields of engineering and computer science at undergraduate and graduate levels. The Office of Diversity is further committed to mentor underrepresented engineer and computer science students to foster professional growth, life-long learning and help them become professional engineers of tomorrow. Dr. Fidelia (Ola) Nnadi, P.E., a faculty member of the UCF Department of Civil, Environmental, and Construction Engineering (EVTC partner) is Director of the Office of Diversity. See: http://diversity.cecs.ucf.edu/main/default.aspx

ICubed is a 5-year National Science Foundation Innovation through Institutional Integration funded project that partners with several units within UCF including engineering. The project goal is to ensure broader impact of NSF funded projects through coordination and integration of educational research aimed at increasing participation in STEM fields. It was also created to help prepare non-STEM citizens to better make political and social decisions that influence the nation's future competitiveness in the global economy.

The EXCEL program started as a NSF funded STEM activity. The primary intent of EXCEL is to increase student success in the first two years of their college career in a STEM discipline. More detailed information about the program can be found at its website https://excel.ucf.edu/. Impressive accomplishments in improving retention and graduation resulted in EXCEL institutionalization by UCF and it is now supported by UCF, Duke Energy, and Boeing.

GEMS (Girls EXCELing in Math and Science), is a NSF funded program to increase female student success in the first two years of their college career in a STEM discipline by providing enhanced educational opportunities and support. The GEMS participants are EXCEL female students. For a more detailed description of GEMS (See: http://gems.excel.ucf.edu/).

Science Olympiad is a competition for elementary, middle, and high school students where students engage in hands-on, interactive, inquiry-based activities that are lab-based, research-based, or prebuilt. Teams compete in 23 different events in the areas of physics, chemistry, earth space science, biology and engineering. UCF's STEM Research and Education Council was involved in hosting the 28th Annual NSO Tournament in May 2012, where more than 7,000 high school students, families, and teachers from across the U.S. competed in the largest science tournament of its kind in the country.

The final UCF diversity program is UCF's membership in the newly formed University Innovation Alliance (See: www.theuia.org). The cooperative group of eleven nation-wide universities has the goal of increasing the rate at which students from low-income and minority backgrounds graduate.

A STEM workshop presentation was delivered by Hawaii Natural Energy Institute faculty on renewable energies including transportation and electric vehicles to approximately 30 middle school teachers in Oahu on June 28, 2014. Hawaii public schools have a diversity score of 0.68, which is higher than the national average of 0.48 (as measured by the chance that two students selected at random would be members of a different ethnic group, scored from 0 to 1, with a score closer to 1 indicating a more diverse student body.)

The following outreach activities have been performed by Tuskegee University this reporting period. The solar vehicle demonstration was conducted by Drs. Chen and Kumar for elementary school students last semester. The activity received overwhelming response and interest by elementary school students. Another demonstration of EVTC and other Renewable Energy, Hydrogen Fuel Cell Technology, Solar/Electric Powered Vehicle in Joint Annual Research Symposium held at Tuskegee University was performed before over 150 university level students and faculty. A high school senior worked on the project during June-July, 2014. Dr. Srinivasan was invited to present his EVTC related demonstrations at the American Association of Physics Teachers Alabama Chapter meeting in Mobile, AL.

Metrics

Performance metrics for the EVTC project are designed to drive improvement and characterize progress and effectiveness. This report marks the first year of operation and the metrics performance table with evaluation criteria is provided below.

Metric	Research Activities	Industry Collaboration	Educ. & Workforce Dev.	Tech. Transfer	Diversity
Productivity	EG	S	S	S	S
Timeliness	S	NI	S	NI	S
Quality	S	EG	S	S	S

NI - Needs improvement, S - Satisfactory, EG - Exceeds goals, or C - Completed.

In addition to the above metrics, a part of EVTC peer review and best practices procedures is the guidance by a Steering Committee, comprised of the UCF PI (the EVTC Director), UCF Co-PIs and the PIs from the two partner universities and the EVTC Oversight Committee.

The Oversight Committee is an external review committee, was organized in April 2014, and held its first meeting on July 22, 2014. Its members are:

- Darryll Dockstader, Research Center Manager, FDOT, Tallahassee, FL
- Mike Faas, Sr. Project Manager, Facilities Administration, Publix Groceries, Lakeland, FL
- Roger Jenkins, Power and Energy, Concurrent Technologies Corp., Arlington, VA
- Jenny Liu, Assistant Professor, Dept. of Civil and Environmental Engineering, University of Alaska, Fairbanks, AK
- Helda Rodriguez, President, NovaCharge Inc., Oldsmar, FL
- Lisa Rice, CareerSource Brevard, Rockledge, FL
- Jennifer Szaro, Orlando Utilities Commission, Orlando, FL
- Richard Kimball, University of Maine, Orono, ME
- Cedric Daniels, Alabama Power Corporation, Birmingham, AL
- Thomas Wilke, Business Development and Concessions Manager, Florida Turnpike Enterprise, Ocoee, FL

The meeting discussed EVTC projects, partnerships, committee actions, correspondence and future meetings. Meeting minutes were distributed to committee members.

What opportunities for training and professional development has the program provided?

Training and professional development activities have been provided by the three partner universities and its students, by the electric vehicle webinar, and by first responder training, all of which have been previously presented in the Education and Workforce Development Accomplishment section above.

How have the results been disseminated?

Project results have been disseminated by presentations, publications, workshops and conferences. Details follow:

Presentations:

1. EV Readiness and Sustainability to the city of Orlando, FL, facilities director David Dunn. Presenter: Richard Raustad (UCF).
2. EVTC on Fox News, Channel 3, Orlando,FL See: http://www.myfoxorlando.com/video?autoStart=true&topVideoCatNo=default&clipId=10161864, May 14, 2014
3. City of Melbourne Green Team Meeting. Presenter: Richard Raustad (UCF), August 6, 2014.
4. Central Florida Transportation Planning Group. Presenter: Dr. David Block, Orlando, FL, August 7, 2014.
5. EVTC Projects and Research Opportunities. Presenter: Dr. David Block, Florida Department of Transportation Research Program, September 25, 2014.

6. Battery Modeling for Academic and Industrial Applications at the Battery Modeling for Industrial Applications Symposium at the University of Warwick (UK). Presenter: Reza Ghorbani (UH), September 24th 2014.
7. Ninety-First Annual Meeting of AAS at Auburn University. Presenter: Dr. Leah Sanks (Tuskegee University), Alternative Electric Vehicles, March 12-14, 2014.

Publications/References:

1. Raustad, R., Fairey, P. (September 2014). "Electric Vehicle Life Cycle Cost Assessment," EVTC Report Number FSEC-CR-1984-14. Cocoa, FL: Florida Solar Energy Center.
2. Qin, N., Raissi, A., Brooker, R., (September 2014). "Analysis of Fuel Cell Vehicle Developments," Report No. FSEC-CR-1987-14, Cocoa, FL: Florida Solar Energy Center.
3. Azwirman Gusrialdi, Zhihua Qu, and Marwan A. Simaan, "Scheduling and Cooperative Control of Electric Vehicles' Charging at Highway Service Stations", *the 53rd IEEE Conference on Decision and Control*, Los Angeles, California, USA, December 15-17, 2014.
4. Onat, N., Kucukvar, M., and Tatari, O. (2014). "Electric Conventional, Hybrid, Plug-in Hybrid or Electric Vehicles? State-based Comparative Carbon and Energy Footprint Analysis in the United States." Energy, Elsevier. (In Revision)
5. Onat, N., Kucukvar, M., and Tatari, O. (2014). "Towards Life Cycle Sustainability Assessment of Alternative Passenger Vehicles." Sustainability. (Under Review)
6. Ercan, T., and Tatari, O. (2014). "Environmental Life Cycle Assessment of Public Transportation Buses with Alternative Fuel Options." International Journal of Life Cycle Assessment, Springer. (Under Review)
7. Zhihua Qu and Marwan A. Simaan, "Modularized Design for Cooperative Control and Plug-And-Play Operation of Networked Heterogeneous Systems," *Automatica*, vol.50, no.9, pp.2405-2414, September 2014.
8. Huanhai Xin, Yun Liu, Zhihua Qu, and Deqiang Gan, ``Distributed Estimation and Control for Optimal Dispatch of Photovoltaic Generations," *IEEE Transactions on Energy Conversion*, accepted and to appear.
9. Mohamed Al Hosani, Zhihua Qu, and Hatem Zeineldin, "Development of Current Dynamic Estimator for Islanding Detection of Inverter Based Distributed Generation," *IEEE Transactions on Power Delivery*, accepted and to appear.
10. Hamed Valizadeh Haghi and Zhihua Qu, ``Stochastic Distributed Optimization of Reactive Power Operations Using Conditional Prediction Intervals of V2G Capacity," submitted to *American Control Conference*, Chicago, June, 2015.

Workshops:

1. Electric Vehicle Technologies Workshop at Argonne National Laboratory, April 22-23. 2014. Attendees: Richard Raustad (UCF) and Dr. Ali Raissi (UCF).

Conferences:

1. Department of Transportation University Transportation Center Conference, Atlanta, GA, March 24-25, 2014. Attended by Dr. Nan Qin.
2. Council of University Transportation Center Summer Meeting, Lincoln, NE, June 2-5, 2014. Attended by Dr. David Block and Kevin Schleith.
3. 2014 Transportation Summit, Orlando, FL, July 16-18, 2014. Attended by Dr. Nan Qin.

What do you plan to do during the next reporting period to accomplish the goals?

The R&D program has been the major focus of the past six month period. The research accomplishments for each of the 21 projects are presented in the Accomplishments Section. It is also noted that in all of the project accomplishments, future activities are presented and reference is made to these previous sections.

As a follow-up and part of this PPPR, a detailed evaluation will be conducted on all program activities and staff. The results of this evaluation will then be used to either add or delete activities and staff to more appropriately meet the program goals and objectives. This review should be completed by the end of 2014. The EVTC management plan requires quarterly reporting from each partner institution throughout the entire program effort. Adherence to these criteria will be strictly enforced and will be used as another measure to monitor and manage project performance.

II. Products

List of products resulting from the program during the reporting period.

The section on "How have results been disseminated?" has presented the information on results dissemination which is also applicable to this section. Thus, reference is made to the section. The other major product activity is the updated EVTC website and the TRIS database. These websites have been kept current with a web coordinator individual assigned to post all information.

The EVTC web site was developed to provide researchers and interested parties detailed information on this project. The site includes a listing of the current research projects being conducted as well as educational information, technology transfer, news and events, publications, and resources applicable to the overall EVTC project. The site can be accessed at http://evtc.fsec.ucf.edu.

Transportation Research Board of the National Academies Transportation Research Information Services (TRIS) database has EVTC developed research papers that are posted on the TRIS database.

An electric vehicle webinar has been developed by both the EVTC and Clean Cities programs. The webinar is completed, is two hours in length and covers the topics of environmental effects,

hybrid vehicles, alternative fuel vehicles and battery electric vehicles (http://www.fsec.ucf.edu/en/education/cont_ed/brevardwf/index.htm).

III. Participants & Collaborating Organizations

What organizations have been involved as partners?

The three universities of the EVTC are:

1. University of Central Florida --The lead for the EVTC is the University of Central Florida. The three active participants within UCF are:
   - Florida Solar Energy Center
   - Civil, Environmental and Construction Engineering Department
   - Electrical Engineering and Computer Science Department
2. University of Hawai'i at Manoa and the Hawai'i Natural Energy Institute (HNEI)
3. Tuskegee University

Organizations up to this date that have supplied direct funding to the EVTC are:

1. Nissan Motors – Supplying equipment and funds for installation of a DC fast charging station at FSEC. Scheduled for completion on December 1, 2014.
2. Nova Charge Inc. – Coordination with Nissan Motors for DC fast charging station.
3. General Electric Corporation –Computer analysis of Hawaii electrical grid.

What organizations have been involved as collaborative partners?

Industry collaboration efforts have centered on establishing partnerships in areas that have EVTC related projects. These projects and the collaborative partners are:

1. **Identify and Analyze Policies that Impact the Acceleration of EV Adoption (Project #2)**
   This project works with Drive Electric Florida which is a 43 member organization chaired bAnne Louise Seabury of Florida Power and Light. Members are from a variety of EV related organizations that include FPL, Duke Energy, Orlando Utilities Commission, NovaCharge, GM, Ford, Nissan, several Florida counties and the Florida Clean Cities Coalitions.

2. **Electric Vehicle Charging Technologies and Analysis (Project #3)**
   Partners are: Cornelius Willingham, EV Operations Nissan Motors; Helda Rodriguez, President, NovaCharge Inc.; Mike Fass, Publix Supermarkets; Jennifer Szaro, Orlando Utilities; and Utah State University

3. **Battery Technologies for Mass Deployment of Electric Vehicles (Project #8)**
   Tony Markel, National Renewable Energy Laboratory

4. **Electric Vehicle Grid Experiments and Analysis (Project #10)**
   Ken Srebnik, Russell Vare, Nissan-USA, Tony Markel, National Renewable Energy Laboratory, Paul Bundschuh, Ideal Power, and Dave Margolius, Green Charge Networks

5. **Electric Vehicle Grid Experiments and Analysis (Project #11)** Partners are Greg Weyl of CODA Energy, lab visit with Tony Markel, NREL

6. **Optimal Charging Scheduler for Electric Vehicles on the Florida Turnpike (Project #13**) Florida Turnpike Authority. Partner: Thomas Wilke , Manager, Environmental Management Office, Florida Turnpike Headquarters

7. **Electric Vehicle Bus Systems (Project #14)** – Tallahassee StarMetro Bus Authorities – Partners are: Ralph Wilder, StarMetro Transit Agency, Tallahassee, FL, Steve Clermont, Project Management, Technical Assistance, Data Collection and Analysis Center for Transportation and the Environment (CTE), Atlanta, GA, Leslie Eudy, Hydrogen Technologies and Systems Center, Hydrogen Technology Validation, National Renewable Energy Laboratory.

8. **EV and Wireless Charging Laboratory (Project #15)** - Partners are Jeremy McCool of HEVO, Inc., Ashely Davey of Evatran Plugless and Utah State University

IV. Changes/Impact

There are no anticipated problems or changes in the EVTC developed programs. One change has been done in the R&D program area. Project #15 on buses was combined with Project #16 on fleet vehicles and replaced with a new Project #15 that creates a new EV and Wireless Charging Laboratory. This change was required in order to produce experimental data for use in other EVTC projects.

V. Changes/Problems

There are no changes or problems.

VI. Special Reporting Requirements

New and updated reports are uploaded to DOT's RiP and TRIS databases. Project reporting is also published on the EVTC website.