DC Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture

DE-EE0008448

2018 DOE Vehicle Technologies Office Annual Merit Review Presentation

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EPRI

Project ID: elt 236

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Overview

Timeline

- Project start date: Oct 2018
- Project end date: Dec 2021
- Percent complete: <5%

Relevance to DOE Established Barrier

- Enabling Technologies - Establishing a foundational system for DC connected EV-charging that integrates with devices such as distributed energy resources, solar, wind and energy storage.

Budget

- Total project funding
  - DOE share: $2,601,500
  - Contractor share: $2,601,500
- Funding for FY 2017: n/a
- Funding for FY 2018: $0

Partners

- EPRI – Project Lead
- Eaton Corporation
- Tritium
- NREL
- ANL

Relevance

Overall Objective

- Develop and demonstrate medium voltage Silicone Carbide (SiC) -based AC-DC conversion equipment and the DC-to-DC head unit for use in extreme fast charging (XFC) equipment capable of simultaneously charging multiple light duty plug-in electric vehicles (PEV)s at rates of ≥350 kW and a combined power level of ≥1 MW while minimizing the impact on the grid and operational costs.

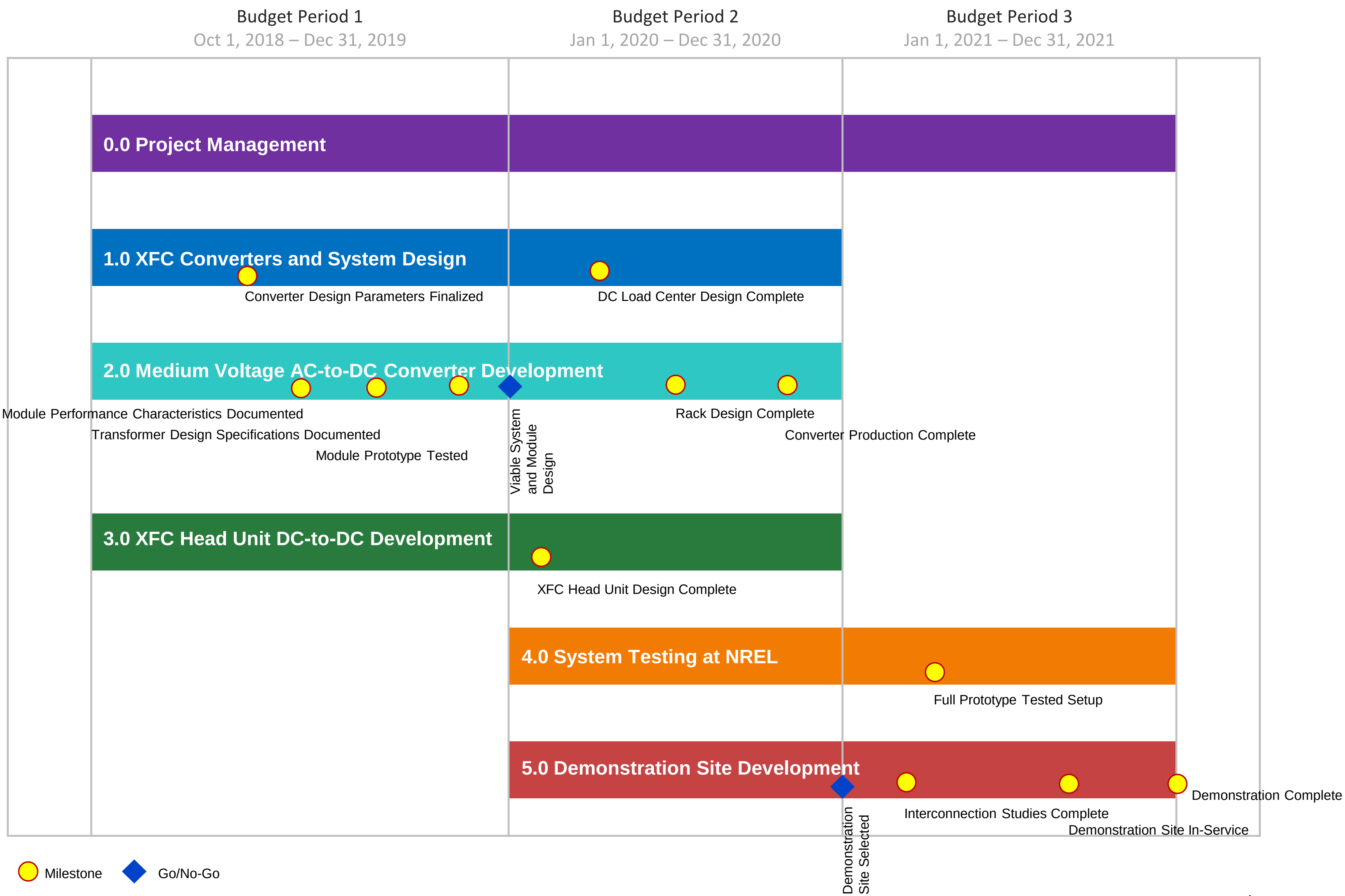
Relevance to DOE's Grid and Charging Infrastructure Program Goals

- Extreme Fast Charging – Develops and tests Direct Current technologies for Extreme Fast Charging while minimizing impacts to the grid. Research could be serve to identify opportunities for interoperability and technical transfer activities.
- EV Grid Integration and Services – Direct Current technologies could facilitate the integration of distributed energy resource to minimize the impact on the grid.

Potential Impacts (project will investigate these aspects)

- Reduce the Total Cost of Ownership (including Demand Charges) for XFC site hosts and utilities
- Improve efficiency and reduce losses
- Reduce footprint of equipment
- Provide a single point of grid integration for distributed energy resources
- Provide new capabilities for grid integration (power factor correction, VAR compensation, disturbance isolation, …)
- Optimization of equipment sizing for upstream power supplies that serve XFC equipment

Milestones



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Approach

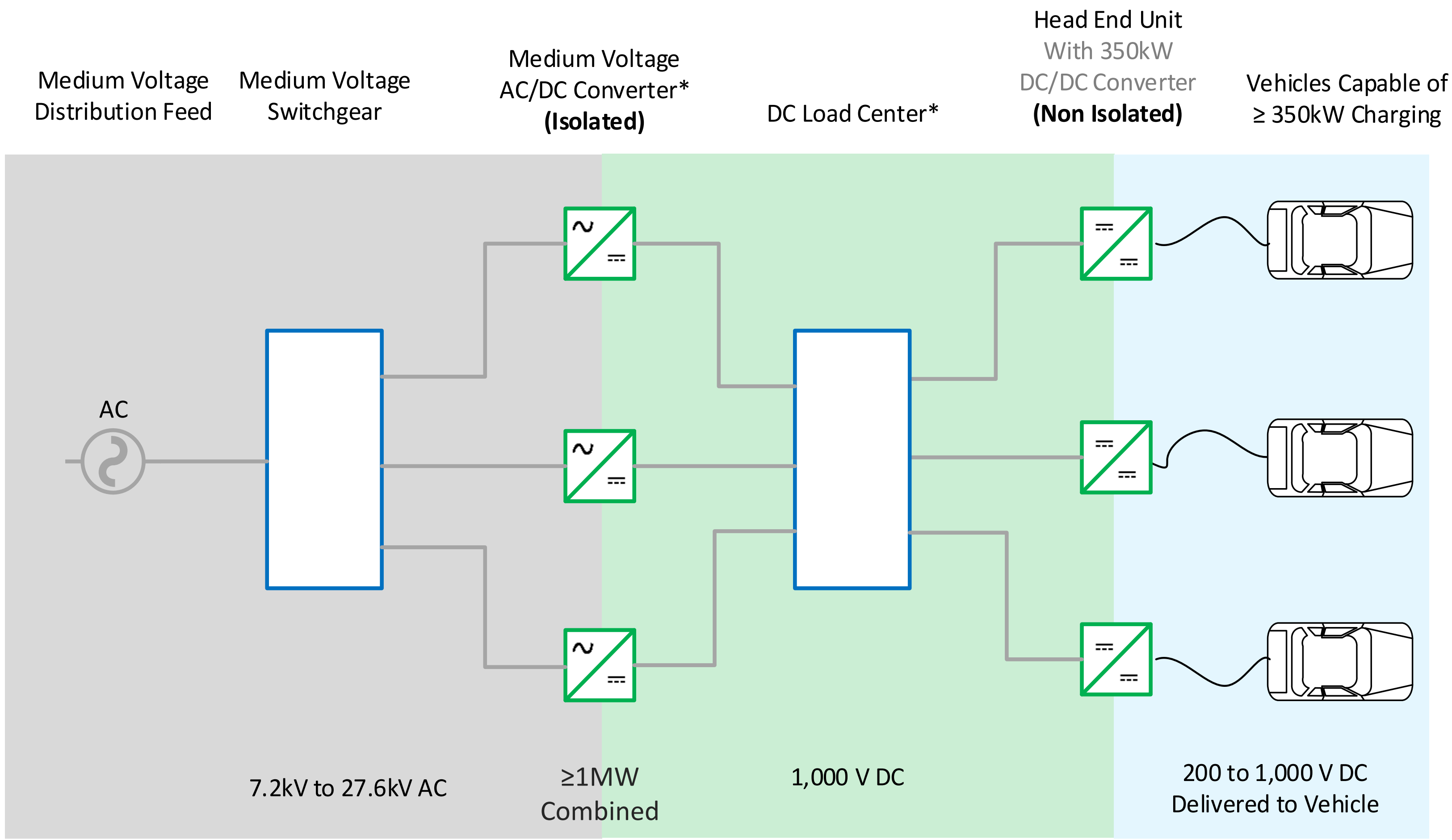
Project Teaming Strategy

- Power Electronics - System specifications determined collaboratively, while the development of the two major power electronics pieces are designed by suppliers focused on the two different businesses
  - Eaton is leading the work on the Medium Voltage AC to DC converters
  - Tritium is leading the work on the DC to DC converters
- Testing - Three levels of testing included in project
  - Component level testing and end-of-line production testing performed by respective manufacturer
  - System testing to occur at NREL laboratory with simulated and actual vehicles
  - Demonstration site testing in collaboration with host utility with actual vehicles
- Vehicles - Supporting automakers (Hyundai America Technical Center and Fiat Chrysler Automobiles) are included in project to support testing. If vehicles capable of charging at 350kW and above are unavailable for testing from supporting automakers, EPRI will identify and obtain vehicles from other vehicle manufacturers.
- Demonstration Site - EPRI has more the three supporting utilities interested in hosting the demonstration site. The decision on the actual demonstration site will be based on specific site characteristics identified by the utilities, anticipated vehicle charging to occur at site and the site development budget.

Unique Aspects of Work (beyond the barriers described in "Relevance" slide # 3)

- Pathway to Commercialization - Seeking to develop equipment, standards and techniques that exhibit possible pathways to commercialization
- Interoperability – Seeking to develop system that is capable of operating with power conversion equipment and head end units from multiple manufacturers
- Technology Transfer – EPRI will be collaborating with industry participants throughout the project process
- Diverse Project Team - Project partners from various perspectives (utilities, hardware manufactures, automotive manufacturers, national laboratories,

Technical Design – System Level



* Key system design considerations currently under review

- The number and sizing of the Medium Voltage AC/DC converters to achieve ≥1MW
- The DC Load Center design will be based on vehicle-to-vehicle galvanic isolation requirements (single bus, switchable links, or novel protection system)
- The full project team meets on May 15th through 17th to discuss these system design issues

Technical Design – During Proposal Stage

A system of isolated and non-isolated converters is proposed to reduce size, cost and increase efficiency (Option 1 below)

	Medium Voltage AC-to-DC Converter	Head End Unit	DC Distribution	Impact on Objectives
Option 1	• 1,000 V • Isolated converter	• Non-isolated converters • Voltage regulated for vehicle (200 to 1,000 V)	• Common Bus, if code allows • Switchable links for galvanic isolation • Common Bus with novel protection system for galvanic isolation	• **Special controls and/or switches required for interoperability, microgrid and multi-use applications if required for galvanic isolation** • **Cost, size and efficiency advantages**
Option 2	• 1,000 V • Isolated converter	• Isolated converters • Voltage regulated for vehicle (200 to 1,000 V)	• Common Bus	• **Good interoperability, microgrid and multi-use applications** • **Cost, size and efficiency disadvantages**
Option 3	• Voltage regulated for vehicle (200 to 1,000 V) • Isolated converter	• No converter required	• Switchable links only	• **Limited interoperability, microgrid and multi-use applications** • **Cost, size and efficiency advantages**

Responses to Previous Year Reviewers' Comments

- *This is a new project, therefore it was not reviewed last year*

Collaboration and Coordination with Other Institutions

Project Team

EPRI	Prime – Leading DC load center design, DC microgrid controls and demonstration site development
EATON	Subrecipient – Leading Medium voltage AC to DC converter design and production
TRITIUM	Subrecipient – Leading head unit DC to DC converter design and production
NREL	Subrecipient – Leading laboratory testing of XFC system
Argonne National Laboratory	Subrecipient – Leading DC metering activities

Key Utility Collaborators

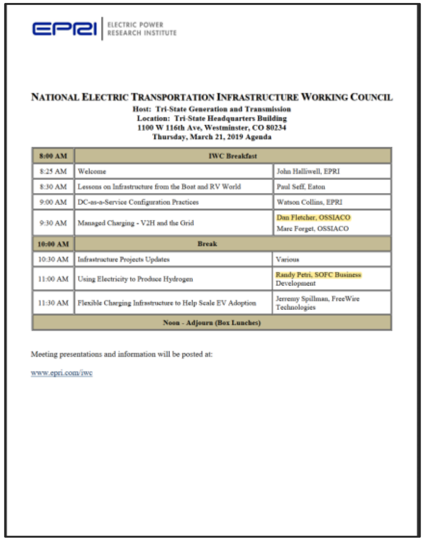
Duke Energy, Seattle City Light, National Grid, Southern California Edison, Pacific Gas and Electric Company

Other Collaborators

Hyundai Motor Group (Hyundai America Technical Center, Inc.), Massachusetts Clean Cities, FCA (Fiat Chrysler Automobiles)

Industry Collaboration

EPRI is collaborating with utilities and other organizations to grow industry engagement



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NATIONAL ELECTRIC TRANSPORTATION INFRASTRUCTURE WORKING COUNCIL

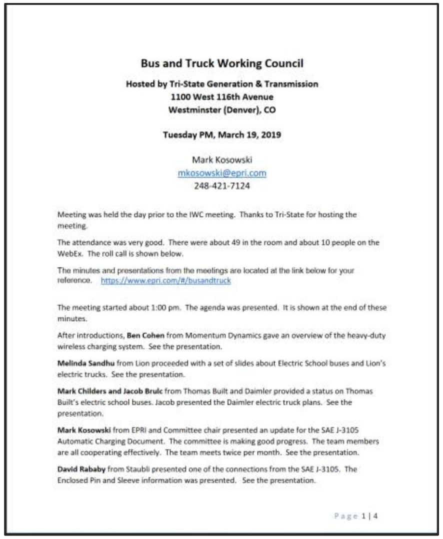
Host: Tri-State Generation and Transmission
Location: Tri-State Headquarters Building
1100 W 116th Ave, Westminster, CO 80234
Thursday, March 21, 2019 Agenda

8:00 AM	**IWC Breakfast**	
8:25 AM	Welcome	John Halliwell, EPRI
8:30 AM	Lessons on Infrastructure from the Boat and RV World	Paul Seff, Eaton
9:00 AM	DC-as-a-Service Configuration Practices	Watson Collins, EPRI
9:30 AM	Managed Charging - V2H and the Grid	Dan Fletcher, OSSIACO Marc Forget, OSSIACO
10:00 AM	**Break**	
10:30 AM	Infrastructure Projects Updates	Various
11:00 AM	Using Electricity to Produce Hydrogen	Randy Petri, SOFC Business Development
11:30 AM	Flexible Charging Infrastructure to Help Scale EV Adoption	Jerremy Spillman, FreeWire Technologies
Noon - Adjourn (Box Lunches)		

Meeting presentations and information will be posted at:

www.epri.com/iwc

Infrastructure Working Council (IWC)



Bus and Truck Working Council

Hosted by Tri-State Generation & Transmission
1100 West 116th Avenue
Westminster (Denver), CO

Tuesday PM, March 19, 2019

Mark Kosowski
mkosowski@epri.com
248-421-7124

Meeting was held the day prior to the IWC meeting. Thanks to Tri-State for hosting the meeting.

The attendance was very good. There were about 49 in the room and about 10 people on the WebEx. The roll call is shown below.

The minutes and presentations from the meetings are located at the link below for your reference. https://www.epri.com/#/busandtruck

The meeting started about 1:00 pm. The agenda was presented. It is shown at the end of these minutes.

After introductions, **Ben Cohen** from Momentum Dynamics gave an overview of the heavy-duty wireless charging system. See the presentation.

Melinda Sandhu from Lion proceeded with a set of slides about Electric School buses and Lion's electric trucks. See the presentation.

Mark Childers and Jacob Brulc from Thomas Built and Daimler provided a status on Thomas Built's electric school buses. Jacob presented the Daimler electric truck plans. See the presentation.

Mark Kosowski from EPRI and Committee chair presented an update for the SAE J-3105 Automatic Charging Document. The committee is making good progress. The team members are all cooperating effectively. The team meets twice per month. See the presentation.

David Rababy from Staubli presented one of the connections from the SAE J-3105. The Enclosed Pin and Sleeve information was presented. See the presentation.

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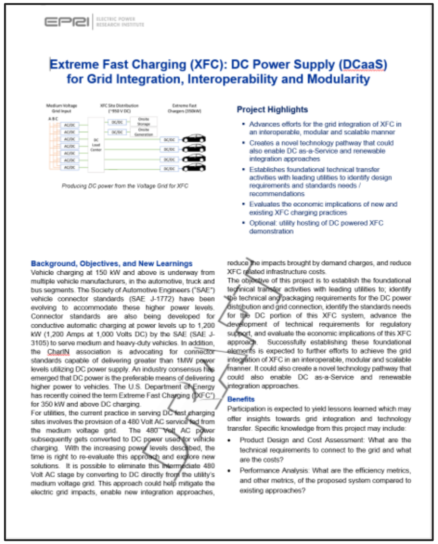
Bus and Truck Working Council



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Extreme Fast Charging (XFC): DC Power Supply (DCaaS) for Grid Integration, Interoperability and Modularity

Producing DC power from the Voltage Grid for XFC

Project Highlights

- Advances efforts for the grid integration of XFC in an interoperable, modular and scalable manner
- Creates a novel technology pathway that could also enable DC as-a-Service and renewable integration approaches
- Establishes foundational technical transfer activities with leading utilities to identify design requirements and standards needs / recommendations
- Evaluates the economic implications of new and existing XFC charging practices
- Optional: utility hosting of DC powered XFC demonstration

Background, Objectives, and New Learnings

Vehicle charging at 150 kW and above is underway from multiple vehicle manufacturers, in the automotive, truck and bus segments. The Society of Automotive Engineers ("SAE") vehicle connector standards (SAE J-1772) have been evolving to accommodate these higher power levels. Connector standards are also being developed for conductive automatic charging at power levels up to 1,200 kW (1,200 Amps at 1,000 Volts DC) by the SAE (SAE J-3105) to serve medium and heavy-duty vehicles. In addition, the CharIN association is advocating for connector standards capable of delivering greater than 1MW power levels utilizing DC power supply. An industry consensus has emerged that DC power is the preferable means of delivering higher power to vehicles. The U.S. Department of Energy has recently coined the term Extreme Fast Charging ("XFC") for 350 kW and above DC charging.

For utilities, the current practice in serving DC fast charging sites involves the provision of a 480 Volt AC service fed from the medium voltage grid. The 480 Volt AC power subsequently gets converted to DC power used for vehicle charging. With the increasing power levels described, the time is right to re-evaluate this approach and explore new solutions. It is possible to eliminate this intermediate 480 Volt AC stage by converting to DC directly from the utility's medium voltage grid. This approach could help mitigate the electric grid impacts, enable new integration approaches, reduce the impacts brought by demand charges, and reduce XFC related infrastructure costs.

The objective of this project is to establish the foundational technical transfer activities with leading utilities to; identify the technical and packaging requirements for the DC power distribution and grid connection, identify the standards needs for the DC portion of this XFC system, advance the development of technical requirements for regulatory support, and evaluate the economic implications of this XFC approach. Successfully establishing these foundational elements is expected to further efforts to achieve the grid integration of XFC in an interoperable, modular and scalable manner. It could also create a novel technology pathway that could also enable DC as-a-Service and renewable integration approaches.

Benefits

Participation is expected to yield lessons learned which may offer insights towards grid integration and technology transfer. Specific knowledge from this project may include:

- Product Design and Cost Assessment: What are the technical requirements to connect to the grid and what are the costs?
- Performance Analysis: What are the efficiency metrics, and other metrics, of the proposed system compared to existing approaches?

Project with Supporting Utility Members

Infrastructure Working Council (IWC)

- Industry dissemination of project activities will occur at each of the regular IWC meetings (3 times/year)
- Discussion of related projects and feedback will be sought from participants

Bus and Truck Working Council

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Project with Supporting Utility Members

- Collaborative process to document technical requirements, utility / interconnection requirements and identify recommended standards and gaps
- Study of the economic implications of DC based system

Proposed Future Research

May 15th to 17th project technical kick-off meeting at NREL's facility, topics include;

- System architecture, focusing on galvanic isolation strategies and other system level considerations
- AC design requirements and utility distribution engineering input
- DC design requirements and DC load center approaches
- Schedule, Risk Management and other coordination processes
- Testing plans

Key Decision Points

Decisions related to galvanic isolation will guide the project's development pathway. The project team has a workable approach, but will be considering alternatives prior to pursuing additional development activities.

Decisions related to the converter topology, semiconductor choice and medium / high frequency transformer will be evaluated during the simulations. Decisions will be pursued that balance the objectives of the project with the technology readiness of the these components.

Both of these decisions will be documented.

FY 2019 Proposed work

- 1.0 XFC Converters and System Design
  - Finalize system sizing and key component design parameters
  - Determine galvanic isolation needs and establish approaches to address
  - Document utility requirements for medium voltage connected equipment
- 2.0 Medium Voltage AC-to-DC Converter Development
  - Perform designs and simulations for converter modules
  - Study controls and protection for power electronics converters
  - Evaluate medium / high frequency transformer alternatives
- 3.0 XFC Head Unit DC-to-DC Development
  - Develop design for DC-to-DC head unit using non-isolated converters
  - Evaluate approaches to address galvanic isolation needs

Summary

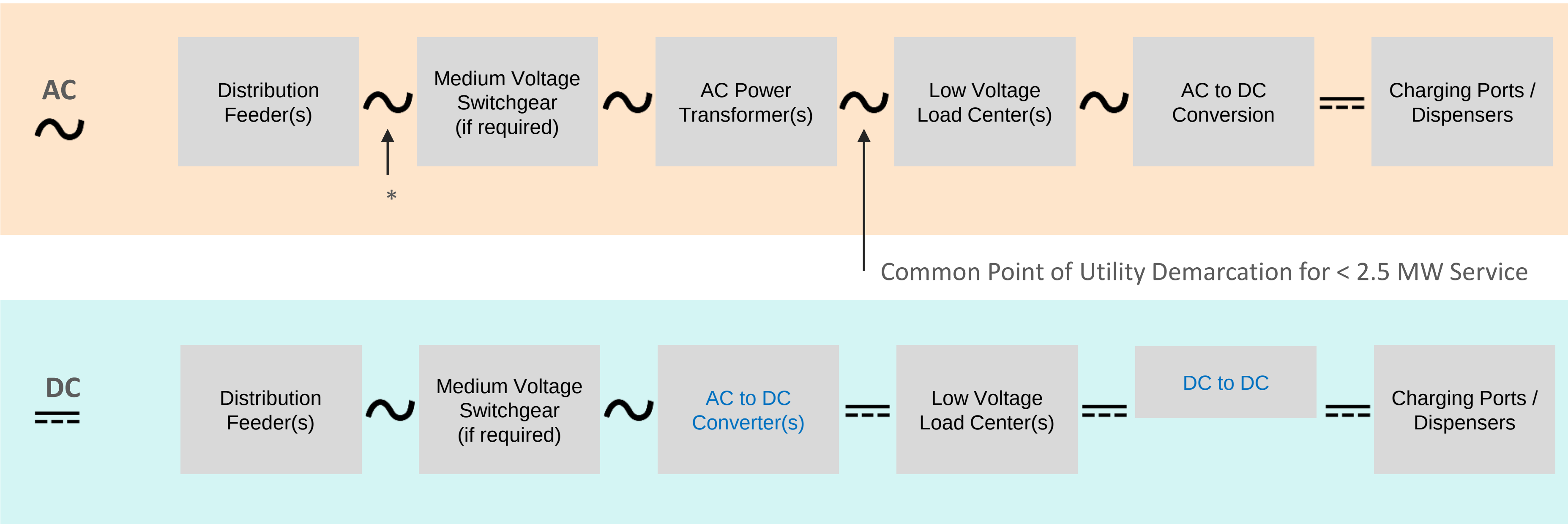
- Key technical decisions for the project will be made during FY 2019.
- Technology transfer objectives will be a driving objective of the project.
- The application of medium voltage connected DC conversion equipment may also be useful for other electric vehicle DC fast charging power levels and for integration of distributed energy resources.
- The use of distinct power strings may be required for sites that use more than ~3 MW.

Technical Back-Up Slides

Electrical Requirements For Charging at an Electric Bus Depot

	Pilot Project Experience	Projects Beyond Pilots
Charging Characteristics at Sites	50 – 500 kW, less than 10 ports	50 – 500 kW+, 100 ports or more
Site Load	< 2.5 MW	> 10 MW
On-Site Power Distribution	• 480 V 3Ø • Single Bus Configuration	• **Multiple power strings** • 480 V 3Ø AC or 1,000 V DC
Utility Service	• Secondary metered service • Typically able to connect to 11kV and above distribution feeders if circuit is near site	• **Multiple distribution feeders may be required or a new substation** • DC as-a-Service potential • Opportunity for new system integration strategies (reliability, efficiency, space, cost savings, grid integration, …)

AC and DC Approaches for DC Fast Charging



- Smaller
- More Efficient
- Increased Functionality

- Capable of connecting to storage and other DERs with simple DC to DC converters

- Smaller
- More Efficient
- Less Expensive

* Point of Utility Demarcation for Primary Service

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