2021 DOE Vehicle Technologies Office Annual Merit Review

CHARGING INFRASTRUCTURE TECHNOLOGIES: SMART VEHICLE-GRID INTEGRATION – ANL

Keith Hardy
Argonne National Laboratory
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Project ID: elt201

Overview

Timeline

- 3-yr Smart Vehicle-Grid Integration (VGI) project began in FY 2019
- Some tasks will extend into FY 2022 (Q2) due to COVID-related delays

Barriers/Challenges

- Lack of consensus on EV-EVSE-grid protocols and devices with ‘smart’ non-proprietary interfaces
- EV/charging infrastructure’s ability to respond adequately to support grid services/resiliency
- Smart, interoperable connectivity and diagnostic tools for grid integration

Budget

- FY 2019-21: $1700K + 300K (INL) annually

Partner

- Idaho National Laboratory

Collaborators

- US and European vehicle and EVSE OEMs, communication software providers, energy providers/utilities, research organizations

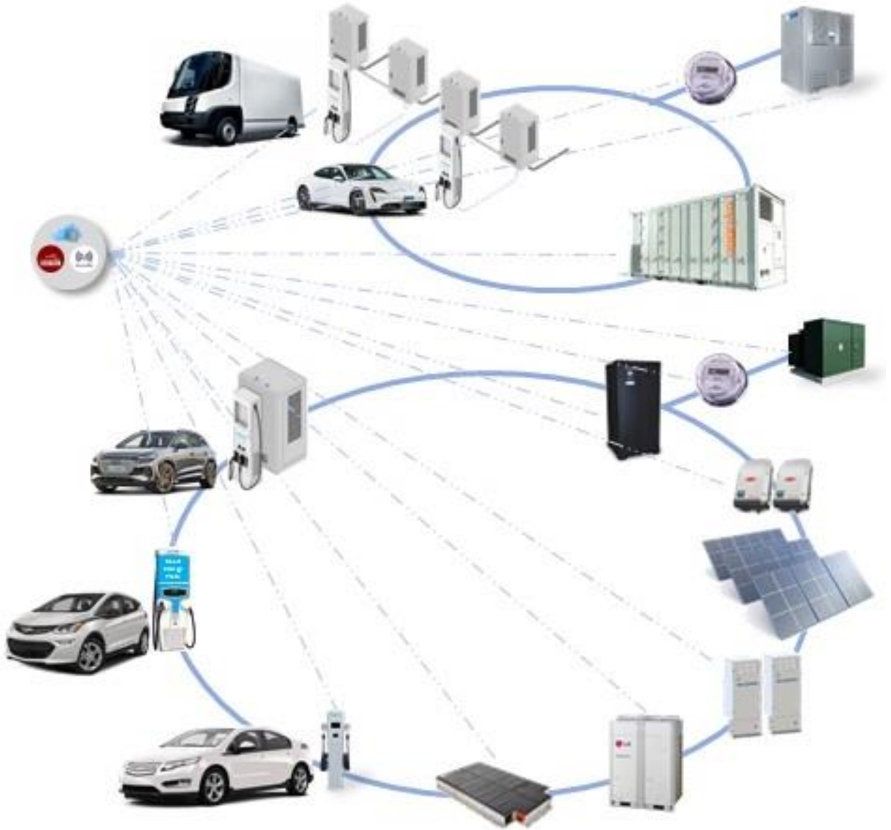
Relevance

Directly supports VTO's '*focus on smart-charging technology to support secure and cost-effective charging of large volumes of PEVs*'

Objective – Demonstrate integrated smart charging and energy management of a network of grid-connected devices, i.e., the 'grid of things' concept

- Integrated communication and control of EVSE, building systems, solar PV and energy storage … using **non-proprietary protocols and interfaces**
- GMLC use cases/grid services with controlled and **smart charging**
- Support grid resiliency via **dynamic responses to external grid conditions**
- **Enabling technologies for VGI** (sensing, communication, control and diagnostics)

Argonne Energy Plaza Network of Devices



Relevance

Technical achievements – tasks requiring access to the Energy Plaza were delayed due to COVID, but …

VGI use cases

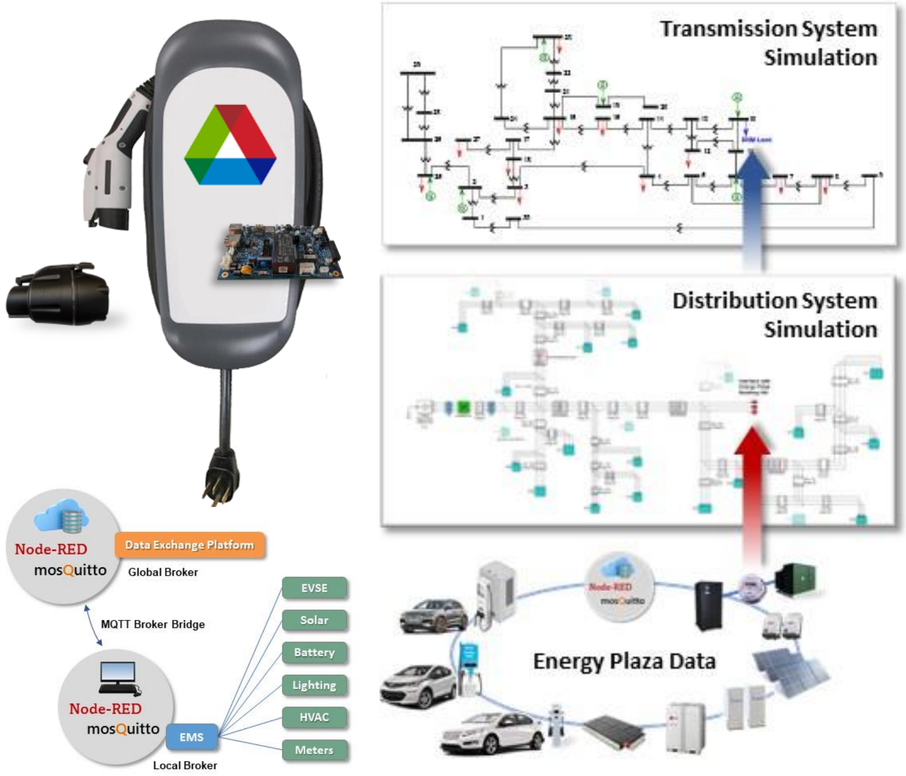
- Most GMLC use cases w/ smart charging

Optimized Control for Grid Resiliency

- Energy Plaza linked to enhanced Distributed Network Model (DNM); DNM load linked to INL transmission model for grid interaction analysis

Enabling Technologies

- Beta versions of ISO 15118 ecosystem (w/EVSE, charge scheduler and UI), diagnostic EV adaptor, SpEC II communication controller, containerized CIP.io and the charge reservation system
- Commercialization pathways established via TCFs and ongoing DOE projects



Approach

Develop integrated control of the charging infrastructure, building systems, solar PV and energy storage to meet customer and grid needs … as well as enabling technologies for VGI

Tasks 1 & 2. Use cases with 'smart' charging

Barriers: Lack of EVs and EVSE with open access or smart protocols

Solution: Developed a 'smart' charging ecosystem using Argonne technology

Task 3. Optimized control for grid resilience and impact of EVs @ scale

Barriers: Unknown ability of charging infrastructure to support grid; impacts at scale

Solution: Energy Plaza node in DNM; DNM load linked to INL transmission model

Task 4. Enabling technologies for VGI

Barriers: Lack of interoperable communication/control technologies and applications

Solutions: Open-source energy management system, SpEC II communication controller, diagnostic EV adapter, ISO 15118 EVSE reference design, ISO 15118/OCPP 2.0 charge scheduler, charge reservation system

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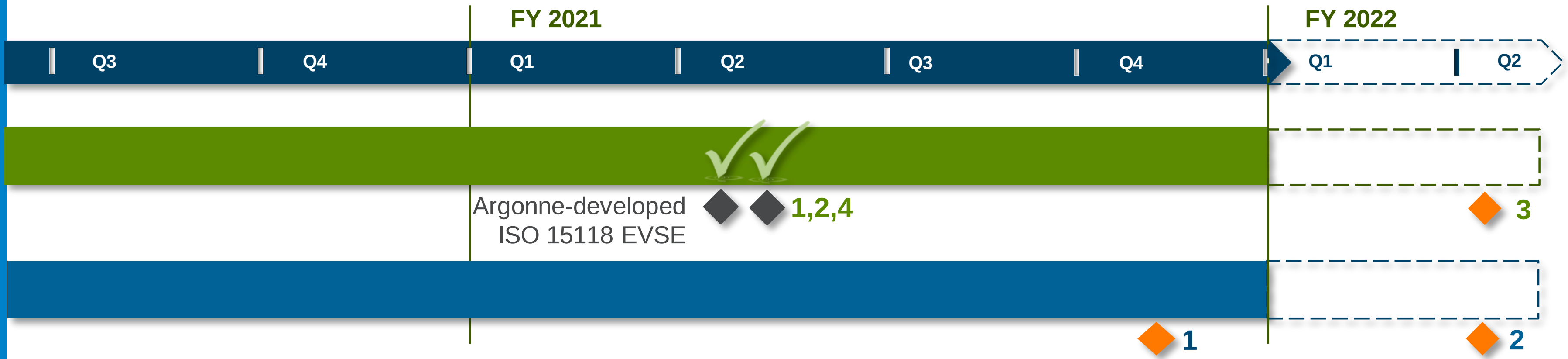
Technical Accomplishments and Progress

- Most deliverables were met despite COVID delays, though some tasks extended to FY 2022
- Energy Plaza, ANL and INL models linked; grid interaction analysis currently underway
- Enabling technologies
  - ISO 15118 ecosystem developed for 'smart' use case demonstrations
  - Beta versions of communication, integration and diagnostic devices for VGI
  - Established commercialization pathways via DOE Technology Commercialization Fund (TCF) and leveraging ongoing developments

Milestones: Use Cases w/Smart Charging



Task 1 – GMLC use cases

1. Demand response
2. Demand charge mitigation
3. Frequency regulation*
4. Charging capacity deferral

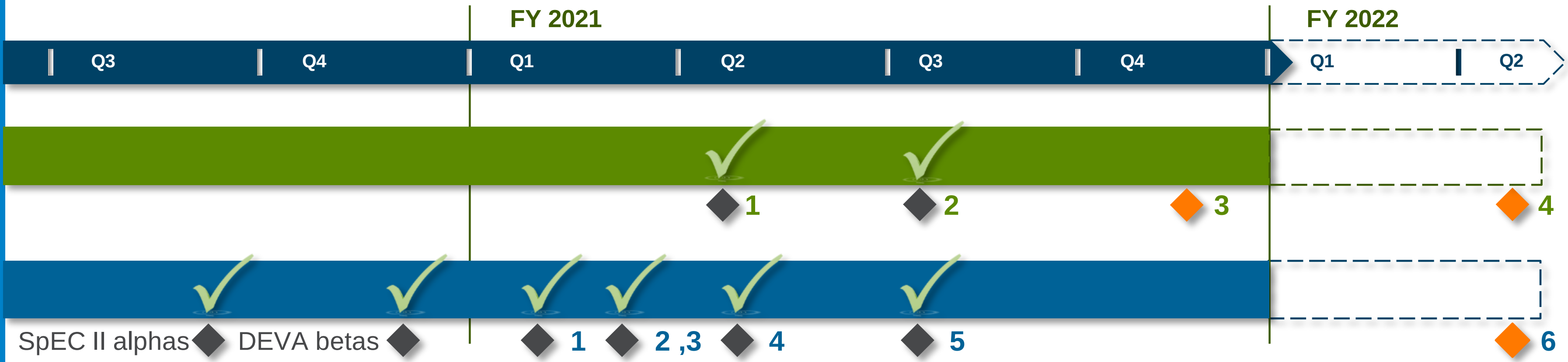
* Smart ED message repetition rate inadequate for fast frequency regulation; use case will be attempted with Porsche Taycan

Task 2 – GMLC+ use cases

1. Smart charging linked to PV
2. Plug'n Charge (PnC)**

** TBD – Smart ED not capable of PnC; use case will be attempted with Porsche Taycan

Milestones: Grid Resilience and Enabling Technologies



Task 3 – Optimized control for grid resilience

1. EV charging infrastructure in DNM* (L2 AC EVSE, DCFC, XFC, BESS)
2. DNM load linked to INL transmission system model
3. Energy Plaza response time
4. Energy Plaza response to dynamic grid conditions

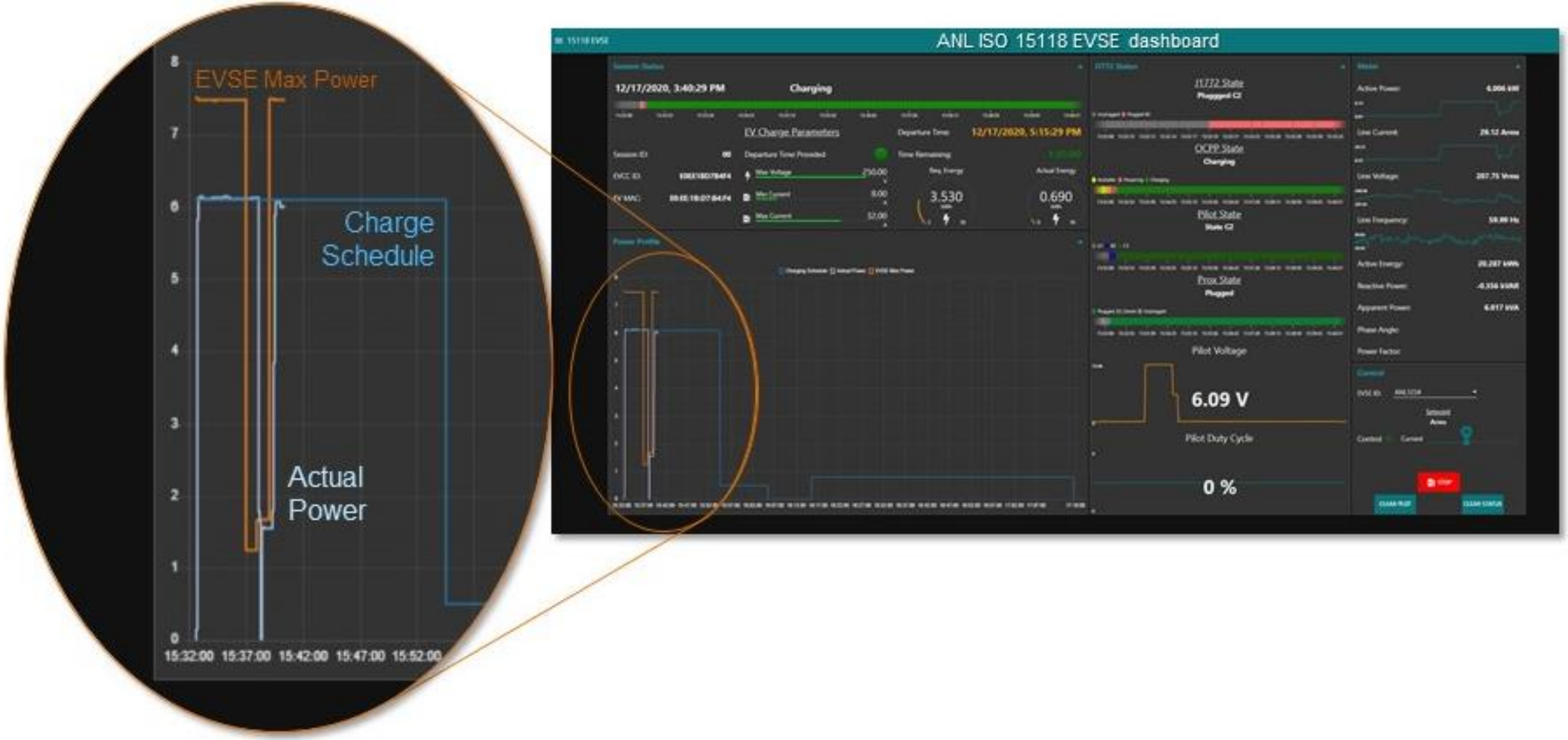
* Argonne Distributed Network Model

Task 4 – Early-Stage R&D

1. SCA pilot with Argonne employees initiated
2. Beta SpEC II module
3. Beta DEVA with CIP.io
4. Beta 15118 EV charge scheduler application
5. Beta containerized CIP.io
6. Charge reservation system pilot

Accomplishments – GMLC Use Cases

Demand response example



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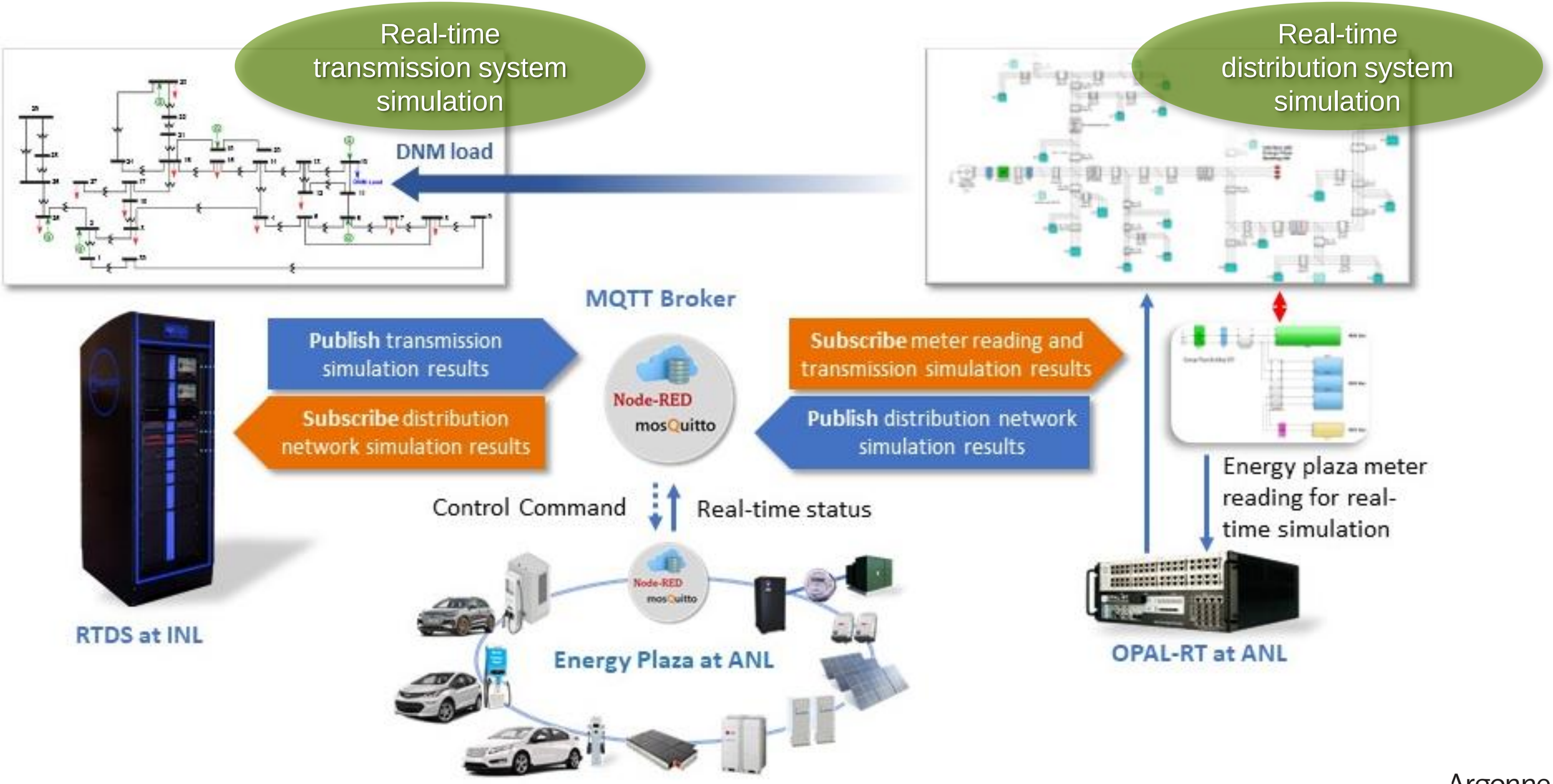
Labs Linked for Grid Interaction Analysis

ANL Energy Plaza data and distribution model; INL transmission model



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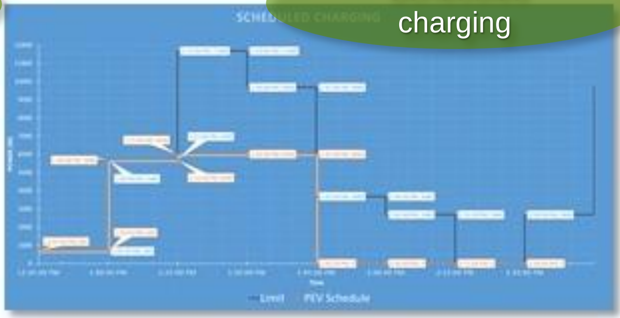
Enabling Technologies

ISO-15118 ecosystem developed out of necessity

Beta



Enabling Technologies

- ISO 15118/OCPP 2.0 EVSE
- ISO 15118 EVSE dashboard
- PEV charge scheduler algorithm
- OCPP 2.0 PEV charge scheduler application and dashboard

GMLC Use Cases w/ISO 15118

- Demand Response
- Demand Charge Mitigation
- Charging Capacity Deferral
- Frequency Regulation*

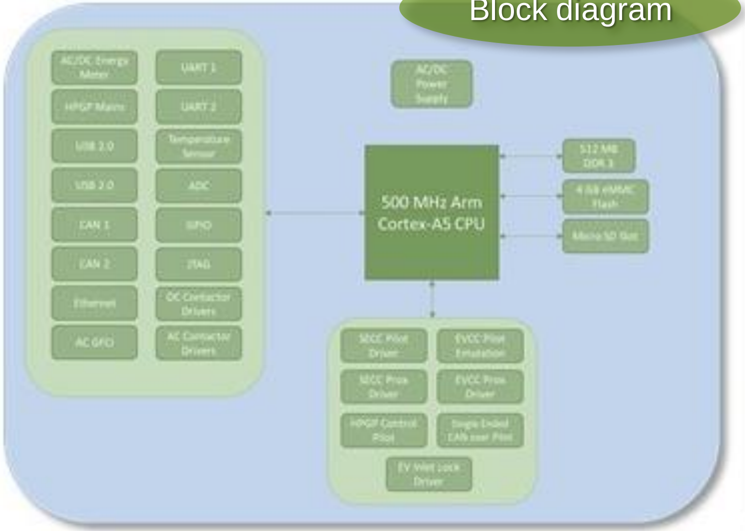
* Smart ED unable to provide this service via 15118 due to inadequate message repetition rate

Enabling Technologies

Communication Control Module (SpEC II)

Beta

Block diagram



Specs

Environmental	Operating Temperature	-40°C to +85°C
	Storage Temperature	-40°C to +105°C
Memory and Storage	SDRAM Memory	512 MB DDR3 @ 166MHz
	Flash Memory	4 GB eMMC Flash onboard with additional external micro SD card slot
Interfaces	Power Line Communication	HomePlug Green PHY: AC Mains HomePlug Green PHY: Control Pilot
	USB 2.0	2 HOST controllers
	Ethernet	RJ-45 10/100 Ethernet interface
	Control Pilot	Generation (EVSE) and Emulation (PEV)
	Proximity	Monitoring and Generation
	CAN	2 CAN interfaces
	Tesla (Single Ended Can)	Rx/Tx Single Wire Can over Pilot
	AC Current	Input for CT to measure AC current (AC charging)
	DC Current	Input for DC current sensor to measure DC current (DC charging)
	AC Voltage	Input for AC Voltage for AC meter
	DC Voltage	Input for DC Voltage for DC meter
	12VDC Switches	Dual 2A, 12VDC switches for contactors
	DPDT AC Relays	Quad SPST SSR's for driving external AC contactors
	EV Inlet Lock Driver	12VDC Driver for EV inlet lock
	Temperature Sensor	external input and onboard temperature sensor
	GFCI	Ground Fault Interrupt CT input
	GPIO	5 externally accessible GPIO
	ADC	4 externally accessible ADC
	JTAG	JTAG for Debugging
	UARTS	2 UARTS for serial communication
Power	AC Input Voltage	85-265 VAC
	DC Input Voltage	9-24 VDC
	Quiescent Current	< 200μA in ultra-low power mode
Modes of Operation	EVCC	Electric Vehicle Communication Controller
	SECC	Supply Equipment Communication Controller

Features of SpEC I module *plus*

- Sub-metering (AC/DC)
- AC coupled HPGP circuit for power line communication (PLC)
- SAE J2411 (CAN) communication

SpEC II can be utilized as EVCC or SECC

Used in Argonne Smart EVSE

Enabling Technologies

Diagnostic Electric Vehicle Adaptor (DEVA)

Beta

Connectivity and communication diagnostics

- Smart Charge Adaptor (SCA) Mk III hardware
- ISO 15118 AC EVSE emulator w/ sniffer under development
- Oscilloscope Mode to sample EVSE or PEV pilot/prox (real-time) w/ sampling of AC voltage/current waveform under development

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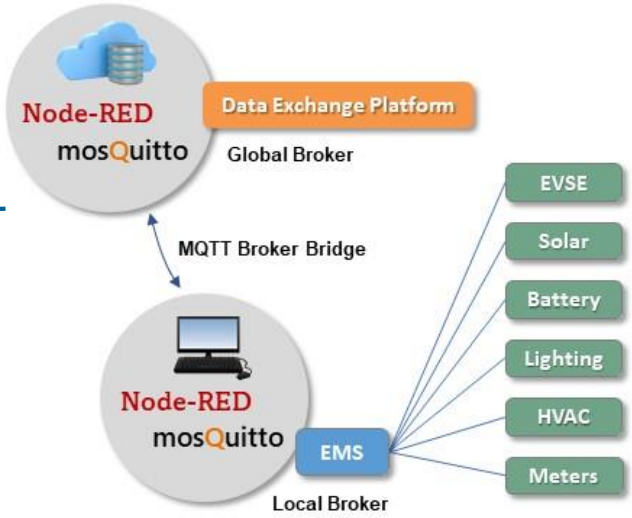
Enabling Technologies

Containerized CIP.io energy management system

Beta

- **Energy Plaza controller with built-in capabilities**
  - Node-Red
  - InfluxDB
  - Mosquitto
  - Grafana
  - MongoDB
- **Standardized central communications via MQTT**
- **Open-source; runs on single board computer**
- **Customizable via Node-Red flows; example flows provided**
- **Auto-loads Argonne custom nodes**
  - OCPP
  - OpenADR
  - Modbus



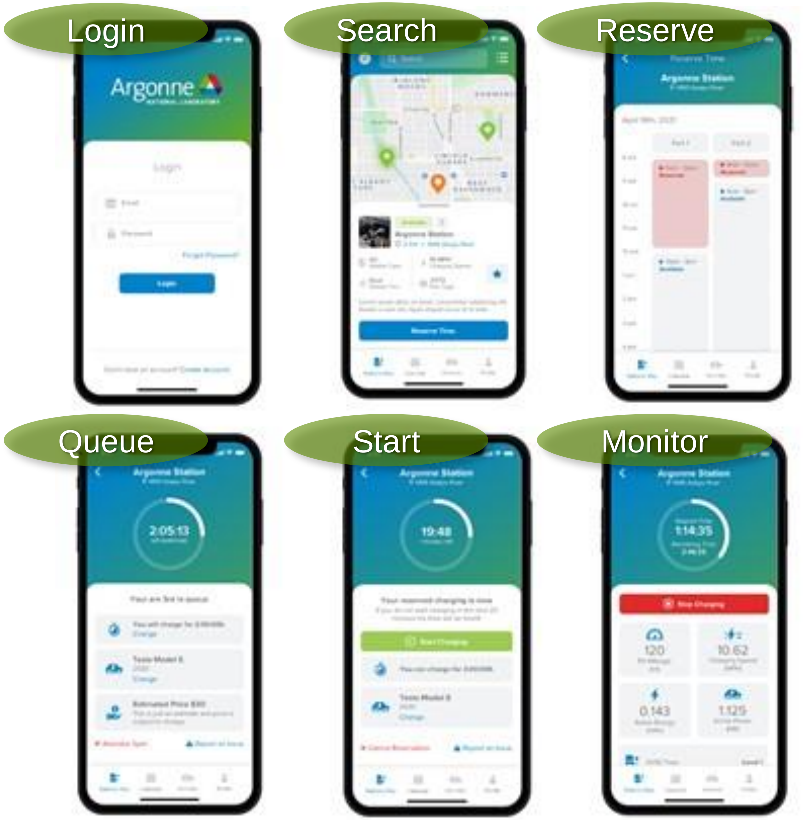
Protocols
Modbus
BACnet
OCPP
ChargePoint
OpenADR
IEEE 2030.5

Enabling Technologies

Charge Reservation System

Beta

- **Leveraging SCA/OCPP cloud platform (via TCF)**
- **EV driver mobile app**
  - Instant, scheduled, and queued charging
  - Data aggregation for ML model predictions (load forecasting, driver statistics, station usage, etc.)
- **Argonne-owned production software allows for unconstrained experimentation and research**
- **Use cases: workplace, public, semi-public, fleet**
- **Beta pilot at Argonne planned for FY 2022 (Q2)**



Responses to Previous Reviewer Comments

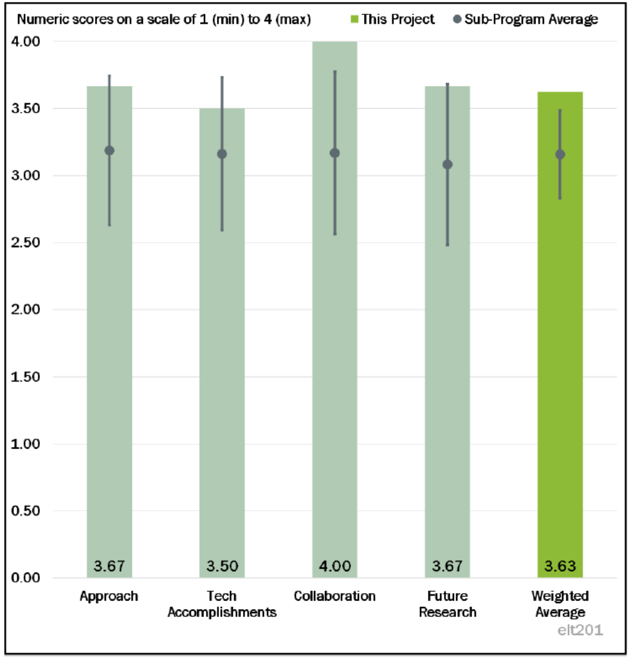


Figure 4-14 - Presentation Number: elt201 Presentation Title: Charging Infrastructure Technologies: Smart Vehicle-Grid Integration–ANL Principal Investigator: Keith Hardy (Argonne National Laboratory)

Approach to performing the work
"… excellent", "… addressing the barriers to smart grid energy management mixing EVs and other energy sources on the electrical grid"

Technical accomplishments and progress toward overall project goals
"… outstanding by addressing challenges of high-power charging … smart charge adapter to provide a full solution for monitoring the charging communication ... demonstration of various protocols is critical"

Collaboration and coordination across project team
" … impressive … covering the gamut of potential stakeholders"

Proposed future research
" … outstanding position for future research … will be able to validate updates to standards and identify issues to improve interoperability"

Relevance
"… supports DOE objectives … to improve and expand the communication and equipment standards. Developing diagnostics and metering equipment complements this by providing solutions for the industry."

Resources
"… appear to be sufficient"

Collaboration and Coordination

Team Members	Roles	Responsibilities
ANL **INL** **EC-JRC**	Lead Lab partner Collaborator	Management, development, integration and testing Grid modeling and simulation Interoperability, smart home and XFC testing experience
Automotive OEMs, California Energy Commission, ELAAD NL, Open Charge Alliance	Technical advisors	Use cases, interface requirements, OCPP developments and certification tool
BTC Power, Tritium, Porsche	Suppliers	Charging equipment, interface specifications, FW/SW updates
2G Engineering, EVoke Systems, Qmulus, Zen Ecosystems, Enersponse, PDT Astronics, Farshore	TCF partners	Hardware/software development, demonstration and commercialization

Remaining Challenges and Barriers

Lack of standard communication protocols and non-proprietary interfaces

- **EV-EVSE-network communication protocols**; How can smart charge management be implemented within the capabilities/constraints of SAE, ISO and IEC standard protocols?
- **Proprietary communication protocols of charging networks** will continue for business reasons; Can locally controlled smart charging or energy management be accomplished with this constraint?
- **EVSE with network interoperability**; Is universal communication possible without consensus on protocols?

EV/charging infrastructure's ability to support grid services

- **Standard metrics for communication and control response times** of vehicles, EVSE, networks and aggregator pathways … to determine compatibility with specific grid service response requirements
- **Interoperable building/workplace energy management system** with adaptive interfaces for network devices and standard Energy Services Interface, e.g., CIP.io with OpenFMB
- **Optimal control of high-power charging and battery storage** to support local demands and variable grid conditions, i.e., Can battery storage realistically support both charging and grid services?
- **DCaaS and battery storage**; Does DC coupling offer practical advantages for VGI over AC?

Diagnostic interoperability tools for VGI

- **Interoperability testing**; standards/test procedure development; less expensive field-testing equipment for AC and DC charging

Proposed Future Research

	FY 2022	FY 2023
GMLC smart use cases	Smart charging coordinated with PV	
	Frequency regulation	
	Plug 'n Charge	
Grid-related HIL studies	Energy Plaza response time to grid signals	
	Energy Plaza response time to dynamic grid conditions	
Enabling technologies	AC DEVA	
	SpEC II	Interoperable EVSE
	Containerized CIP.io	Charge Res System pilot

Beyond Smart VGI Project

- Pilot and commercialize enabling technologies … DEVA, sub-meters
- Integrate XFC and battery storage in the Energy Plaza controller CIP.io
- Interoperability testing of components/systems to support high-power DC grid integration (e.g., MW+, DCaaS)
- Codes and standards development support …
- Cybersecurity assessment … EVSE and adjacent networks, authentication and authorization boundaries

Any proposed future work is subject to change based on funding levels.

Summary

Accomplishments

Developed and demonstrated the technology to integrate communication and control of the charging infrastructure, building systems, solar PV and energy storage using non-proprietary protocols and interfaces

Linked Energy Plaza with distribution network and transmission models to assess the ability to respond to grid demands at the local level and larger scale grid impacts

Demonstrated GMLC use cases with controlled and smart charging; developed smart charging ecosystem out of necessity

Developed enabling technologies … progressing toward commercialization with industry partners

Collaboration
Industry relationships continue via commercialization activities and ongoing DOE programs

Future work
Complete extended tasks in FY 2022 (Q2); Support tech transfer to industry partners and ongoing DOE programs; support development and integration of AC/DC systems … codes and standards, enabling technologies, system integration, cybersecurity and interoperability testing

Any proposed future work is subject to change based on funding levels.