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THE FINANCIAL AND GRID BENEFITS OF BIDIRECTIONAL ELECTRIC VEHICLE CHARGING

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Goal

Bidirectional electric vehicle (EV) charging is when EV batteries are used to not only store energy but also send it back to a home, a building or the grid. The goal of this study was to demonstrate and quantify the potential value of bidirectional charging implementation by emulating uses that would be representative of possible broader deployment.

Methods

Site Selection, Equipment Description and Construction Layout

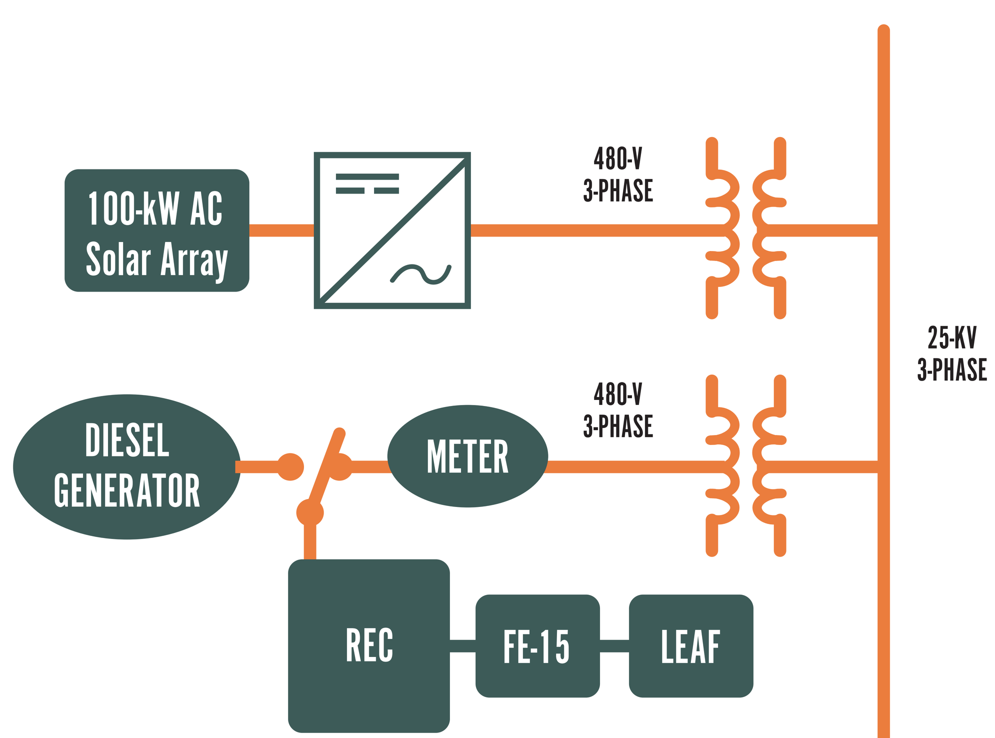
- Testing Site: Roanoke Electric Cooperative's headquarters in Aulander, North Carolina
- Vehicles: Two 2020 Nissan LEAF S Plus electric cars, each with a 62-kilowatt-hour (kWh) battery pack
- Charger: One Fermata Energy FE-15 bidirectional charger, the first chacompliant with UL 9741 and IEEE 1547
- Meter: Measurlogic DTS-310 revenue grade meter using Magnelab RCT-3600 Rope CTs

Use Case Analysis

Three use cases were selected from the final report of the California Joint Agencies Vehicle-Grid Integration Working Group based on the commercial workplace sector: customer bill management, system capacity, and system backup and resiliency.

- Bill Management: Tested using the preprogrammed behavior from the Fermata Energy charger. This behavior monitored the actual facility demand and compared it to the previous peak effective facility demand recorded within that month. The charger would then dispatch to keep the effective facility demand below the previous peak.
- System Capacity: The Fermata Energy charger and Nissan LEAF vehicles were used as distributed energy resources to reduce systemwide peak demand for the North Carolina Electric Membership Corporation. Demand events were communicated via email to Roanoke Electric staff, who automatically forwarded them to Fermata Energy. Fermata Energy then programmed a scripted response to each event.
- System Backup and Resiliency: Testing was performed using the existing diesel backup generator and grid-isolating equipment.

While staff were not directly aware of any peak demand events or system demand reduction calls, they did try to have a vehicle plugged in during common high-demand times, including on winter mornings and summer afternoons.



Simplified One-Line Diagram of the Host Facility, Charger and Grid Connection

Results

Peak Load Reduction

The bidirectional charging system lowered demand charges for Roanoke Electric in eight of the 12 months of testing. These events showed the system operating as desired, with an average demand reduction of 11.4 kilowatts (kW), 95% confidence interval (C.I.; 8.18 kW, 14.5 kW).

The other four months saw missed opportunities or increased demand charges. For two of the months, the vehicles were unplugged. For the other two, the building peak was exacerbated by charging scheduled in advance of a planned system demand reduction call. These two charging events increased building demand by 6.2 and 3.9 kW, respectively. Including these four events reduced the average demand reduction to 6.73 kW, 95% C.I. (1.87 kW, 11.6 kW).

Response to Demand Reduction Calls

Between February 18, 2021, and February 15, 2022, Roanoke Electric received 52 demand reduction calls covering 142 hours. Of those, Fermata was successfully notified of 50 events (136 hours) and responded to 47 events (128 hours). Across "All," "Notified-of" and "Responded-to" events, the charger delivered an average of 12.96 kW, 13.43 kW and 14.25 kW, respectively.

	All	Notified	Responded
N (hrs.)	141	136	128
Mean (kW)	12.96	13.43	14.25
Std. Dev. (kW)	4.51	3.84	1.95
95% C.I. (kW)	±0.75	±0.65	±0.34
High (kW)	13.71	14.08	14.59
Low (kW)	12.21	12.78	13.91

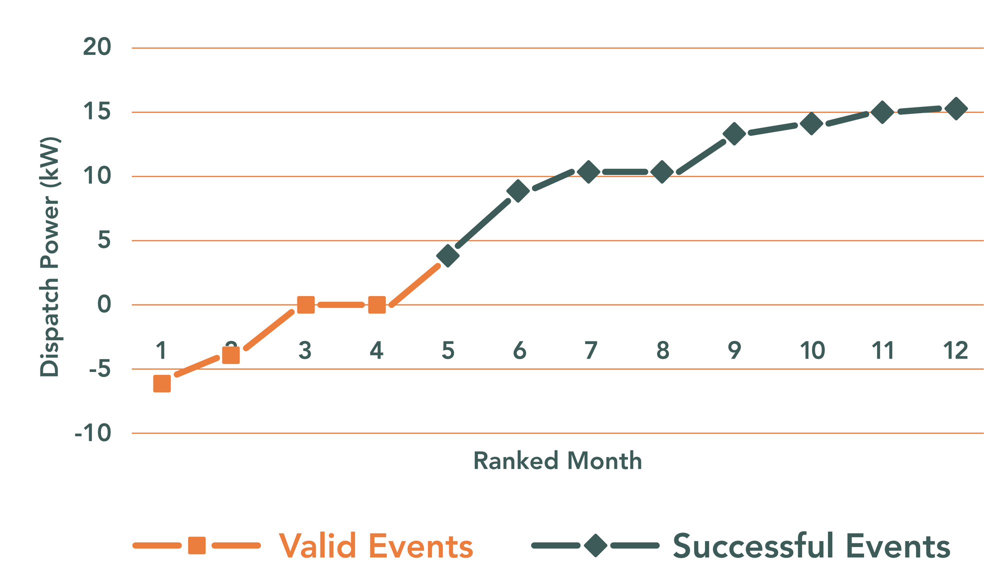
We also examined the performance of the charging equipment by event hour. Across all events, the Fermata Energy charger was able to provide, on average, 12 kW or more of demand response for three hours. Performance was best in the first hour and decreased in the second and third hours. This pattern corresponds with observed charger behavior, where the vehicle battery was less likely to be charged sufficiently to support longer-duration events. We observed a 10-12% decrease in average power dispatch over three hours in all event categories.

Value Stream Calculations

We valued avoided site peak load at $9.50 per kW and avoided system demand during a reduction call at $15.71 per kW. The eight successful peak load reduction events generated, on average, $107.94 in savings per month, 95% C.I. ($77.75, $138.14). Average savings from the successful demand reduction calls equaled $223.93 per month, 95% C.I. ($218.58, $229.28).

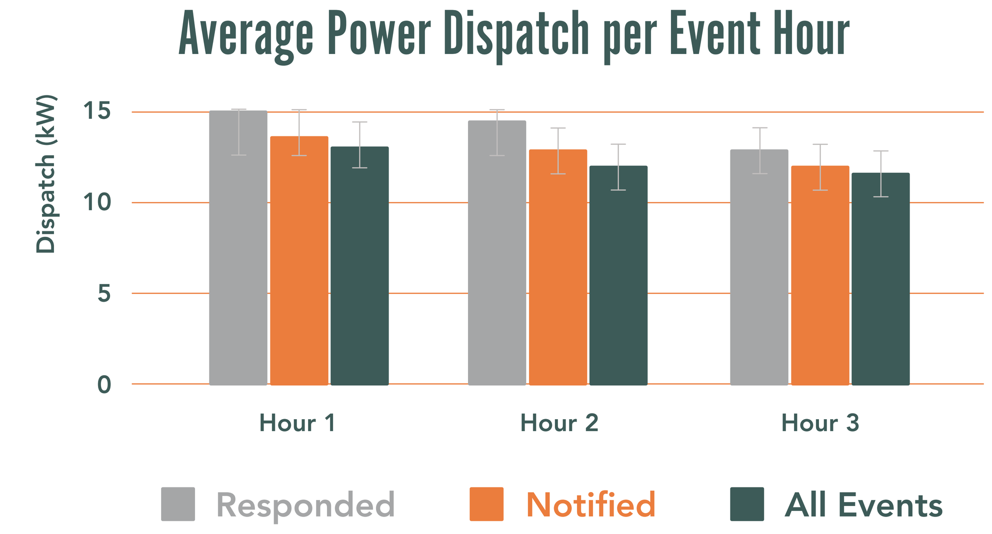
	All Events	Successful Events
Peak Load Reduction	$63.97	$107.94
Demand Reduction Calls	$203.57	$223.93
Total	$267.54	$331.87

Ranked Event Performance



Significant Impact on Overall Performance Is Seen from Counter-Productive and Unproductive Events

Average Power Dispatch per Event Hour



Cumulative Performance by Event Hour

Event Hour	Dispatch (kW)	Capacity Factor (%)	N (hrs.)
All Events			
1	13.50	90.0%	52
2	13.16	87.8%	51
3	12.12	80.8%	39
Notified Events			
1	14.04	93.6%	50
2	13.70	91.3%	49
3	12.44	83.0%	38
Responded Events			
1	14.93	99.6%	47
2	14.59	97.3%	46
3	13.14	87.6%	36

Study Partners

- Roanoke Electric Cooperative
- Advanced Energy
- Fermata Energy
- Enpira
- NC Clean Energy Technology Center
- Environmental Defense Fund
- Clean Energy Works

Conclusions

This study illustrated one of the first examples of bidirectional EV charging in the U.S., showing three use cases and two value streams for a prototypical corporate electric fleet vehicle. We found an average peak load reduction of 6.73 kW, or $63.97 per month, and demand response capacity of 12.96 kW, or $203.57 per month. We also demonstrated the possibility of exercising both value streams simultaneously. Together, these savings total $267.54 per month, 95% C.I. ($219.89, $315.19) and an annual potential value of $3,210.48, 95% C.I. ($2,638.68, $3,782.33).

We observed opportunities to improve communications protocols, hardware and software reliability, and multiuse case management algorithms that would benefit the potential value of vehicle-to-grid services. If these opportunities were implemented, our study suggests the potential annual value of services would increase to $3,982.44, 95% C.I. ($3,614.40, $4,350.48).

Summary of Results

- Bidirectional EV chargers can unlock new value streams through use cases for residential and commercial buildings.
- Using only vehicle-to-building applications, Roanoke Electric demonstrated combined value streams that produced gross savings of more than $3,200 per year per charger, exceeding the monthly lease cost of the vehicle.
- Findings underscored opportunities to reduce the cost of integrating EVs and renewable energy into the grid.

Additional Areas to Explore

Access and Equity for Rural Communities

Quantifying these value streams allows utilities to begin considering incentive payments and other EV program options for customers and members. These programs could be particularly effective in low- and moderate-income areas and help customers overcome the upfront cost barriers to purchasing an EV.

Opportunities with Other Vehicle Types

Medium- and heavy-duty vehicles with intermittent use are ideal candidates for bidirectional charging, as commercial or industrial facilities would be able to self-consume any dispatch.

Fleet Vehicle Operations

This study demonstrated a use case for sites and entities operating fleet vehicles throughout Roanoke Electric's service territory. Primary operators for this application could include municipal and government buildings, schools, churches and more.

Vehicle Cost Savings

In cases where the upfront cost of an EV may be cost-prohibitive or where the cost to install and operate a DC fast charger may be too high, this project reveals reduced operating costs of a vehicle and offers an opportunity for non-residential utility members, customers and the community to benefit from electric transportation technologies.