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Paired Power Comments - RFI for EPIC Initiative 14 Direct Current Systems for Efficient Power Delivery

Please refer to the attached document.

Additional submitted attachment is included below.

August 7, 2023

To: California Energy Commission Docket Unit, MS-4 Docket No. 23-ERDD-01,
715 P Street, Sacramento, California 95814

From: Tom McCalmont, CEO

Thank you for the opportunity to respond to your Request for Information regarding DC powered buildings.

About Paired Power (PP):

Paired Power develops and delivers innovative products that pair solar energy with EV charging, energy storage, and the grid. Paired Power is a manufacturer of solar powered electric vehicle charging facilities (EVCF) and is a registered U.S. small business.

Founded in 2015, Paired Power pioneered and developed the technology to charge EVs directly from solar panels. Paired Power patented the direct-DC approach to EV charging via solar energy in 2018 (U.S. patent no. 9,868,357) and has been the leading innovator in this space since its founding. The Paired Power team has decades of expertise in the solar industry including over 125 years of combined solar and energy storage engineering experience, and has directly contributed to 12 gigawatts (GW) of solar designs and installations (over 1,500 solar and storage projects) completed throughout the U.S., including at U.S. military sites.

Paired Power is the recipient of multiple California state and regional awards for its innovative off-grid EV charging technology supporting workplace and fleet EV charging projects. All of Paired Power's equipment is designed and manufactured in California, USA.

We have reviewed the RFI and answered where we feel qualified to provide information. Thank you for the opportunity to provide comment.

DC Components, Equipment, End-Use Devices, and Technologies
1. What DC components and equipment are needed to enable more efficient integration of DC devices with other DC devices? What is the current technology readiness level (TRL) of these devices? What specific research is needed to advance the TRL (e.g., design work, laboratory testing, pilot and/or commercial demonstration)?

<u>PP Response</u>:

One of the most useful and important DC applications is for charging of electric vehicles (EVs). However, the application of such uses has been siloed to-date in limited forms.

For example, many EVs provide DC input ports for directly connecting to the battery of the EV. However, since EVs are relatively new, standards are still emerging in this area. There are at least three DC standards in common usage at the moment: Chademo (developed by the Japanese for the Nissan Leaf and other cars), CCS1 or Combined Charging Standard (used in many U.S. EVs including Chevy Bolts, Ford Mach-E's, and Ford F-150's), and NACS (developed by Tesla). Given the youth of the EV market, it is not yet clear which of these standards will "win" in the market and be most widely adopted nor is it clear if other standards will yet emerge. Therefore, solicitations and grant funding for opportunities to make use of such standards should not dictate the particular standard or standards that must be used (in other words, don't pick market winners before those are known).

In addition, although the DC interface to EVs is often used for fast charging, it is not necessary to do so. The approach Paired Power has pioneered is to us the DC port for an all-day or "top up" charge powered with 100% clean solar energy. This approach should be encouraged and not limited by grant funding opportunities as it avoids the fossil fuel use inherent in traditional grid-connected EV charging.

In addition to the suggestions above, there is a strong market need for high-powered DC-DC converter technology that is fully galvanically isolated. Although DC-DC converter technology is widely available at low power levels, relatively few components and approaches are yet available that are capable of converting high voltage and high current applications directly from solar cells (for example) into the voltages and currents necessary to charge batteries quickly. More investment is needed in this area to encourage new innovation and deployment of such applications. Research into power management techniques, high-powered semiconductors, and intelligent management systems is needed to facilitate better solutions.

2. What are the TRL, cost effectiveness, efficiency, and availability of the following technologies?
a. DC-DC converters that provide high voltage and high current to enable high power transfer or bi-directional transfer between various DC equipment.

<u>PP Response</u>:

Per the above, more research is needed to develop high voltage, high current technologies that are capable of sustained operation over many hours without overheating. Galvanic isolation is particularly important as most of the commercially available solutions for high-powered DC conversion are not well galvanically isolated (which is necessary to, for instance, directly charge batteries via solar cells).

b. Solid-state transformers for integration of renewables, electric vehicles (EV), and energy storage.

PP Response:

Similar to the above response, more research is needed into high-powered DC conversion technologies, and solid-state transformers would be an excellent area for the CEC to provide funding and support.

c. DC revenue-grade meters to measure, collect, and store real-time data for DC power systems.

PP Response:

DC revenue-grade meters that are capable of operating at high power levels are also needed to go along with the DC conversion technologies mentioned above.

d. DC power systems for buildings that can be directly coupled with distributed energy resources (DERs) to reduce energy losses with fewer redundant stages of power conversions.

PP Response:

This is a good area for additional research. DERs on buildings are subject to Code requirements such as rapid-shutdown (known as RSD) that have been developed to protect firefighters. However, RSD often interferes with voltage conversion technologies that are necessary to integrate DERs with DC power systems for buildings. Therefore, additional research is needed into techniques for integrating RSD with other forms of DC power – in particular, techniques for RSD that do not normalize to a single voltage and that allow conversion of a range of voltages across both devices (source and destination).

e. DC-based end-use equipment (e.g., refrigeration, cooktops, lighting, motor-driven loads) that can be integrated into an efficient DC-based power system.

PP Response:

Similar response to the above. Currently, most RSD systems for DERs will interfere with any form of DC conversion for other uses such as refrigeration or lighting.

DC Adoption Pathways and Use Cases

3. What are the most likely commercial applications for DC-based power systems in the short (3-5 years) and long terms (5+ years)?

PP Response:

Short-term: Direct-DC conversion of DERs (primarily solar) to other loads (BESS, DC building power, refrigeration, etc.), including high-power management, metering, and range-of-voltage (not uni-voltage as with many RSD devices).

Long-term: The age-old battle between the inventors Edison (DC systems) and Tesla (AC systems) may finally resolve to a combination of both types of solutions for a variety of benefits to society.

4. What are the recommended ideal locations (e.g., where on the distribution grid, geographically, or at particular facility types like electric vehicle supply equipment stations) to deploy DC-based power related demonstrations and what technology(ies) would ideally be demonstrated?

<u>PP Response</u>:

The public gets most direct benefit in terms of understanding and education from distributed energy applications and demonstrations. That is not to minimize the importance of utility-scale applications, but those are much less visible to the public. As we evolve towards a smart grid that combines elements of both, it is important that DERs are fully supported for the value they deliver and the consciousness they raise with the public.

5. What kind of buildings/facilities are the best fit for early DC-based implementation and why?

<u>PP Response</u>:

Locations with a growing and sustained need for EV charging are excellent locations for direct-DC (DER to EV or DER to load) applications. Mid- to large-sized commercial establishments are excellent fits for such applications, including public buildings, stadiums, community centers, R&D facilities, government facilities, and universities.

6. What are potential DC adoption pathways for residential and commercial buildings, and how could we structure a solicitation to best inform that transition to greater adoption?

<u>PP Response</u>:

Encourage adoption of standards but do not limit or constrain the applications based on the standards. For example, for EV chargers, allow EV charger solutions that support CCS1, Chademo, and NACS (not all three or just one or two of the three). Also encourage emerging industry standards such as Sunspec (but again, do not limit the solicitations based on emerging standards that may change.

7. What research is required to directly connect an EV via a DC bus to a residential/commercial building allowing for a more flexible and efficient bi-directional power flow? What components/equipment and research are required to accelerate the adoption of DC bi-directional power flow equipment in residential/commercial buildings and improve the overall system efficiency?

PP Response:

Until very recent history, it was not possible to connect a vehicle directly to the utility grid. Therefore, there are few codes or standards that have been developed to enable such applications. As an example, the Chademo DC-powered EV charging standard was developed prior to 2010 and it included so-called Vehicle-to-Grid (V2G) capability that has been present and built into Nissan Leafs since 2012. However, here we are 13 years later and there are still no standards or even well-understand interfaces for connecting a Nissan Leaf to the utility grid. There are issues of isolation, grounding, and ground-faults that need to be researched and better understood to protect humans and also to limit current flows from the vehicle to the building in a safe and code-compliant manner. Although the technology for making such an interface has existed for over a decade now, there are few standards or well-understood applications for implementing the interface.

8. What are the research opportunities to demonstrate DC building blocks for a local DC microgrid that increase the overall system efficiency and reliability when compared to a similar alternating current (AC) system?

PP Response:

There are many benefits of directly managing solar resources and taking advantage of the unique characteristics of solar power (shoulder effects throughout the day, managed clipping at peak times, time-shifting of the solar peak, manipulation of the solar I-V curve to better integrate it with batteries, etc.). This is a rich area for new research and innovation to better take advantage of these unique characteristics that are not as easily implemented in an AC system.

Near-Term (3-5 Years) Opportunities

9. What are the high priority DC-related technologies and/or research needs to successfully integrate or transition to DC-based power distribution networks?

PP Response:

Better high-powered DC conversion technologies, better integration of rooftop DERs (with RSD) with DC power applications, clearer interconnection and revenue-realization rules for companies investing in new technical approaches so they can be attached to the utility grid, more research in safety and standards of EV interfaces to the utility grid (V2G).

10. What specific DC equipment (e.g., DC-DC converters) and components are required to serve as an enabling device for the integration of DERs with a microgrid or DC-related infrastructure?

PP Response: Covered above in prior answers.

a. What are the research opportunities to advance the TRL to simplify the interconnection of microgrids to the grid in one package using only DC-DC related components and equipment and eliminating DC-to-AC followed by AC-to-DC conversion?

PP Response:

Significant opportunities for direct DC-DC applications such as solar-powered EV charging (without using the grid as the intermediary with the attendant DC-AC and AC-DC round-trip losses).

b. What additional research is required to maintain the quality and reliability of DC-DC converters while minimizing unnecessary costs and improving the efficiency of the converters?

PP Response:

Still an emerging area with few standards yet. Encouragement by the CEC of broad-based solicitations that will help such standards emerge will be helpful, including research into intelligent controls systems.

11. What advancements are required in power electronics to enable DC and mixed DC/AC microgrid topologies that can reduce power conversion, increase efficiency, and improve reliability?

PP Response: Covered above in prior answers.

12. What power electronics need to be advanced and demonstrated to provide reliability and stability to DC systems?

PP Response: More research into hybrid inverters capable of supporting direct integration of solar, storage, and EV charging (as well as DC loads), especially for larger scale applications (current hybrid inverter technology is mostly limited to smaller systems).

13. What are the enabling or emerging technologies that can: a. Advance adoption pathways for DC power in buildings?

PP Response:

As mentioned above, research into how to support both rapid shutdown (RSD), which is required by code for rooftop solar, and integration with DC power conversion devices necessary for DC power in buildings.

b. Accelerate DC-based power distribution networks for efficient DC- DC integration of DERs?

PP Response: No further response.

c. Enable residential/commercial buildings to better serve as DC building blocks for local DC microgrids?

PP Response: No further response.

14. What are the opportunities for EVs to directly support a residential/commercial building directly via a DC bus that eliminates the requirement of an inverter and increases system efficiency and reliability?

PP Response:

This is an excellent area for new applications as described earlier above, but requires greater development of code and safety standards, as well as technical innovation, to support safe delivery of power from a vehicle to a building.

Longer-Term (5+ Years) Opportunities

15. What are the opportunities for standardizing DC voltages and system design across various DERs, end uses, and DC plug-in electric vehicle chargers? How can research help to accelerate this process?

PP Response:

We recommend that the CEC not engage in pushing particular standards, voltages, design approaches, etc. across a complex technology spectrum that is fast-moving. Instead, the CEC should support an "all of the above" approach that encourages the market to innovate new technologies and approaches and allows the standards that emerge from that to do so naturally and without mandates.

16. What areas of research are required to potentially accelerate adoption of DC buildings and related technologies by residential and commercial developers and customers?

PP Response: No further response.

17. What pertinent data (e.g., performance and cost) are required to accelerate large-scale commercialization and deployment of DC-based end-use equipment?

PP Response: No further response.

18. What current or upcoming communication standards or protocols should be demonstrated and/or developed to ensure successful DC-DC integration and interoperability?

PP Response:

We recommend that the CEC not engage in pushing particular standards, voltages, design approaches, etc. across a complex technology spectrum that is fast-moving. Instead, the CEC should support an "all of the above" approach that encourages the market to innovate new technologies and approaches and allows the standards that emerge from that to do so naturally and without mandates.

19. What specific codes and standards will the deployment of a DC-based power system help inform?

PP Response:

Existing standards such as Sunspec, IEEE 1547, and UL 1741 will be served and augmented by a DC-based power system. However, the CEC should not mandate any particular standards and should instead adopt an "all of the above" approach to encouraging market growth while allowing the market to work out the standards that will apply based on adoption.

Safety and Protection

20. What power electronic solutions are needed and required to enhance the safety of a DC microgrid?

PP Response: See earlier responses on grounding and ground-fault protection, particularly as it relates to interfacing vehicles to buildings.

21. What protection equipment is needed to interface with a DC/AC microgrid that will enable the reliable operation of the microgrid during disaster events?

PP Response:
Off-grid solutions are going to be increasingly important in a fractious world of climate change where the grid can become unstable due to fires or other emergencies. The

CEC should do a better job of allowing and encouraging off-grid approaches to delivery of all energy systems including DC power systems. Often your solicitations are written in such a way that precludes off-grid approaches, and these will be critical in the all-electric world we all imagine we're headed towards.

22. What are the opportunities to advance DC components/equipment to improve the protection and coordination and increase the resiliency and interoperability of multiple connected DERs?

PP Response: Encourage support of off-grid power solutions, which increase resiliency of the overall power network through protection during emergencies.

23. For DC-DC converters, what are the safety mechanisms (e.g., NFPA 79) that are required in manufacturing, and how can research help address issues related to fire protection and health and safety?

PP Response: No further response.

24. What emerging technologies can be demonstrated to reduce the safety and electric shock risks associated with higher DC voltage operations?

PP Response: No further response.

25. What further research and/or analyses are required to ensure DC components/equipment protection is developed and proper guidelines are established?

PP Response: No further response.

EPIC Program Area and Funding

26. For each suggested area of research above, what are the initial and concluding TRLs of the technologies being recommended? What is required to advance each technology's market readiness?

PP Response: Many of the technologies discussed above are new enough that they will still be at fairly low TRLs (and that should be permitted by the solicitations).

27. For each suggested area of research above, what is the recommended CEC funding amount? What percentage of the funds should be provided by the recipient in terms of match?

PP Response: Minimum $500K per opportunity for most of these as the R&D required to develop them is substantial. 20% to 25% match is preferable.