# Technology Demonstration Project:

## Modular Micro-Grid DC Charging

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California Public Utilities Commission
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Contact:

Glen Stancil
Vice President, eVgo
Glen.Stancil@nrgenergy.com
713-299-0223

## Project Background

In 2012, NRG Energy, Inc. ("NRG") and the California Public Utilities Commission ("CPUC") entered into that certain Long-Term Contract Settlement Agreement ("NRG / CPUC Agreement")[1] under which NRG will invest approximately $100,000,000.00 over four years in electric vehicle charging infrastructure through its subsidiary, NRG EV Services LLC (d/b/a "eVgo").

As part of the NRG / CPUC Agreement, NRG will invest at least $5,000,000.00 toward the deployment, demonstrating and testing of electric vehicles charging technologies. The following Modular Micro-Grid DC Charging proposal ("Project") is the first proposal for a Technology Demonstration Project under the NRG / CPUC Agreement. NRG requests that the CPUC approve up to $1,924,000.00 for NRG to implement the Project.

## Objective

The objective of the Project is to demonstrate how micro-grid[23] components (including power storage, conversion, generation, and dispensing) can reduce the cost of developing, constructing, and operating DC Fast Chargers when deployed as modules that are custom-combined with the chargers to meet the needs and characteristics of individual properties. Upon successful economic and operational demonstration, NRG intends to commercialize these technologies and integrate them into its broader Freedom Station rollout.[4] Ultimately, NRG believes that this Project will enable faster deployment of DC Fast Chargers by both eVgo and third parties at a wider variety of locations, and for a lower total cost of ownership to property owners and electric vehicle service providers ("EVSPs") alike.

[1] Capitalized terms not otherwise defined herein shall have the meaning ascribed to such terms in the Long-Term Contract Settlement Agreement.

[2] According to the Lawrence Berkeley Lab web site, a "micro-grid" is is a semiautonomous grouping of generating sources and end-use sinks that are placed and operated for the benefit of its members, which may be one utility "customer." While capable of operating independently of the macrogrid, the micro-grid usually functions interconnected, purchasing energy and ancillary services from the macrogrid as economic, and potentially selling back at times. *See* http://der.lbl.gov/microgrid-concept.

[3] In this project the system will operate independently from any grid it is connected to.

[4] To the extent that new technologies developed through the Project are added to the broader Freedom Station rollout, the cost of incorporating those new technologies into such broader Freedom Station rollout will not count against the $1,900,000 attributed to the Technology Demonstration Program Amount.

## Uniqueness

While other projects have tested or are testing micro-grid concepts to assist electric vehicle charging, the Project's focus on a *modular* micro-grid approach to DC charging is unique among other DC charging and storage projects underway in California. This modular approach enables additional levels of flexibility and scalability in deployment, as well as the activation of multiple value streams. Several of the technologies that will be incorporated (e.g. power conversion, DC dispensers) have not been deployed for such multi-value integrated purposes. We anticipate that the combination of these technologies will deliver an exceptional level of efficiency in DC charging and energy storage.

## Value Sources

The modular components used in the Project will allow DC Fast Chargers to better fit into the existing physical and electrical infrastructure of host sites, thereby reducing deployment costs. These components also enable flexible conversion and storage of power to lower operating costs. Furthermore, the flexibility of these components also enables a greater range of services to drivers, hosts and the grid. The data gathered from this project will used to study what level of ancillary services can be provided to different markets, including but not limited to host sites, utilities and the wholesale market. The intention is to build a system that can be used to address these markets but depending on regulations, interconnections and market matureness it may not be possible to immediately begin to offering these services.

***Value Source Detail***

***Reduced Power Demand: Behind-the-meter install lowers cost and time***

> Reduced design/permit/utility time
> Reduced switchgear and interconnect costs
> Reduced demand charges

***Modular Approach: Provide more options, lower labor cost, expandability, and re-use***

> Modules enable more install options
> Modules enable standard trained labor (like solar)
> Modules enable expandability to adapt to more demand
> Modules enable multi-use (e.g. solar and charging)
> Modules can be redeployed to optimize cost and capability

***Micro-Grid Services: New host and grid value streams***

> Host: peak clipping, TOU arbitrage, backup

> Utility and ISO: ancillary services

## Demonstration Configurations

The baseline configuration for a station is what is currently being deployed in markets across the state. This encompasses independent standalone 50kw DC Chargers. Each charger requires 200 amps service each and when combined requires 400 amps utility service. Service at this level requires special equipment and permitting that is cost intensive.

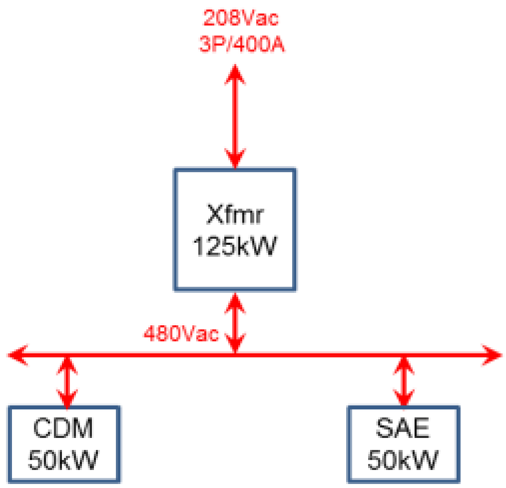



Figure 1. Base Line Configuration

For the Project, NRG is proposing to demonstrate the integration of five (5) components in seven (7) configurations across two (2) phases.

***Components:***

>Solar – PV Solar panels

>Battery Storage – new batteries and used automotive batteries

>Power Converters – multi-port, bi-directional power converters

>DC Dispensers – CHAdeMO and SAE Combo dispensers

>DC Chargers – CHAdeMO and SAE Combo DC Chargers

***Phases:***

>A. AC tied chargers

>B. DC tied dispensers

***Configurations:***

Phase A:

>A1. Single CHAdeMO charger with stationary batteries

>A2. Single CHAdeMO charger with solar and $2^{nd}$ use auto batteries

>A3. Single CHAdeMO and Single SAE Combo charger with solar and $2^{nd}$ use auto batteries

Phase B:

>B1. Single low-power (Lower amperage power converter) CHAdeMO port with solar and $2^{nd}$ use auto batteries

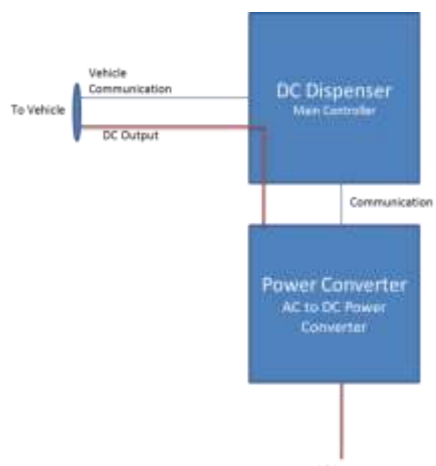
>B2. Single high-power (Higher amperage power converter) CHAdeMO port with solar and $2^{nd}$ use auto batteries

>B3. Dual high-power CHAdeMO and SAE Combo ports and $2^{nd}$ use auto batteries

>B4. Quad CHAdeMO and SAE Combo ports and $2^{nd}$ use auto batteries

*Each of these Configurations is visually illustrated in the Appendix.*

This project will make use of a distributed charging system. Typically a DC charger is an all in one device: the controller and the power electronics. The controller manages the high level activity such as the user interface, safety circuit and communication to the vehicle. The power electronics performs the AC/DC conversion and delivers this DC power at a rate requested by



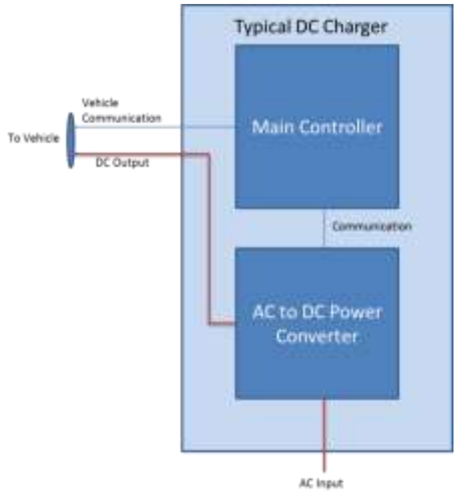

the vehicle. A charger is fully integrated unit which houses both main components.

In this project we will explore breaking these components up so we can leverage the power converters handling the solar system and battery systems to also provide DC charging capability. The controller portion of the charger will be packaged separately and become the dispenser. The dispenser will be responsible for user interface, safety circuit, vehicle connector and communication to the vehicle. This will allow for a smaller footprint of the overall system and flexibility in choosing the DC charging standard being deployed

## Project Approach

In the Project, NRG will utilize a single Development Site and 3-5 Deployment Sites.

NRG anticipates that the Development Site will implement each of the seven (7) configurations through a progressive installation process occurring over the course of approximately fifteen (15) months; however, if the development process suggests that other configurations are more worthy of exploration or that one of the seven identified configurations is not worth pursuing, then NRG reserves the right to modify the list of configurations that it will pursue.[5] If the CPUC has specific request for modification to the program plan (to the extent that it is reasonable, does not adversely affect the cost or the timeline and is aligned with the overall project goals)




[5] NRG will notify and request approval from the Commission prior to pursuing these material modifications.

NRG will work to accommodate the request. These progressive installations will identify key implementation, technology, operations, and economic issues. NRG intends to use the University of California, San Diego (UCSD) campus as the Development Site for this Project in order to speed permitting and interconnection issues throughout this progression. NRG has been working with Bill Torre, Kevin Norris, and Byron Washom at UCSD during the preliminary planning stages for the Project. NRG will finalize arrangements for the UCSD Development Site after receiving CPUC approval of the Project. SDG&E will play an advisory role in the project. The installation will occur on the UCSD campus which is not part of the SDG&E territory. Many of the deployment sites will be in San Diego so having SDG&E in an advisory role will help develop the requirements needed from a utility perspective. Also their input on the overall effectiveness of the system will be vital in order to determine the reduction in operational cost.

The Deployment Sites will implement selected configurations from the Demonstration Site that exhibit strong operational and economic potential based on host specific characteristics such as geographical, electrical and vehicle use. : Each configuration will be evaluated for its value from both an economic and customer benefit standpoint. Some of the criteria used in the evaluation criteria include, but are not limited to, geographical issues, electrical impact, driver impact, vehicle use, host value and operational cost. The Deployment Sites will allow for longer-term testing in a more commercial environment. The Deployment Sites will be consumer-facing locations that are appropriate for the deployment of DC fast charging.

## Project Timing

***Development Site***

Assuming CPUC approval of the Project by January 31, 2014, NRG intends to begin the Project by installing Phase A configurations at the UCSD Development Site beginning March 1, 2014.

After completing installation of Phase A configurations, NRG intends to begin installing Phase B configurations at the UCSD Development Site beginning September 1, 2014. The installation of the Phase B configurations is projected to continue through February 2015.

***Deployment Sites***

Beginning July 1, 2014, NRG intends to begin installation of selected Phase A configurations at Deployment Sites. NRG has not yet selected Deployment Sites, but intends to focus on areas in Southern California to achieve efficiencies through relative geographic proximity. Installation of selected Phase A configurations is projected to occur through February 2015. NRG intends to pursue installation of selected Phase B configurations from March 2015 through December 2015. Each deployment site will have different characteristics and limitations. They can include utility policy, AHJ rules, power availability, space restrictions, etc. Depending on these factors one of the proven configurations from the project will be used to achieve the goal of providing a cost effective DC charger while still delivering the same level of service to the end EV customer.

***Testing***

Testing of the various configurations will begin upon installation at the Development Site and will continue during the course of the Project at both the Development Site and Deployment Sites. As discussed above, NRG will test at Deployment Sites only those configurations which exhibit strong operational and economic potential.

***Conclusion of Project***

NRG intends to conclude all installations and testing at the Deployment Sites on or before December 31, 2015. At the end of the Project, those configurations that NRG has deemed to be commercially feasible will remain in the Deployment Sites. Components at sites deemed not commercially feasible we be reused at other sites with the settlement areas.

These timelines are dependent on NRG's current expectation of product availability from technology partners, as well as the expected data gathering windows for each configuration. These timelines and windows are subject to change. An estimated timeline is included in Appendix B.

## Results Analysis

NRG will engage Research Partners to analyze the economic and operational results of this technology demonstration. The analysis will focus on assessing the potential value creation and customer impact of commercial deployment. Value creation will include *lower* equipment, installation, and operating costs as well as new revenue streams from the host, the utility, and the California Independent System Operator ("CAISO") as compared to the baseline. The results analysis will also determine the key variables (e.g. driver, host, utility, and CAISO) that drive the installation configuration (e.g. power and energy) for the various components (e.g. solar, power conversion, battery, dispenser).

NRG intends to engage Dr. Tim Lipman from UC Berkeley to lead this portion of the project.

NRG shall notify the Commission upon the conclusion of testing at the Deployment Sites, estimated to be approximately December 31, 2015. Within six months after notification of conclusion, NRG shall submit a report, with confidential and redacted versions, to the Commission prepared by the lead individual representing the Research Partners summarizing the results analysis, provided, however, that information deemed confidential under the NRG/CPUC Agreement need not be disclosed.

Without waiving the confidentiality protections afforded under the NRG/CPUC Agreement, the report shall include the following information:

1) Collecting quantitative demonstration activity data by site:
    a) EV charge events, battery charge events, battery discharge events;
    b) average system demand, peak period of charge events;
    c) battery capacity at beginning, capacity at end; and
    d) maintenance and repair events summary.

2) Collecting demonstration financial data:
    a) pay per use charge revenue;
    b) utility cost, service and support cost;
    c) development, equipment, installation costs.
3) Qualitative evaluations:
    a) Key implementation process assessment:
        i. Include timeline of major events related to: base infrastructure design and permitting; interconnection studies; equipment testing; execution of agreements.
    b) Lessons learned: Including technical, business operations, legal, and regulatory issues and policy implications; customer experience and satisfaction.

## Key Partners

The successful completion of the Project is dependent on several technology and service partners. The selection was based on several factors which included but were not limited to commercially available product, technical capabilities, experience with similar developments and cost. Wherever possible and practical, NRG has selected partners with a presence in California. Below is a list of the key partners that NRG currently expects to engage on the Project.

| Name | Location | Role |
|---|---|---|
| UCSD | San Diego, CA | Development site |
| TBD | California | Deployment sites |
| Tim Lipman | Berkeley, CA | Academic support for results analysis |
| EV Grid | Palo Alto, CA | Energy Storage |
| IPC | Austin, TX | Power Converters |
| ETL | Costa Mesa, CA | Field certification of deployment sites |
| Solarrus | Irvine, CA | Permitting/Design/Construction/Installation |
| TBD | TBD | Switching DC Combiner |
| TBD | TBD | Power Coordinator |
| TBD | TBD | DC Power Dispenser and Fixture |

## Budget

NRG anticipates an overall budget of $1,924,000.00 to complete the Project. This amount includes $500,000.00 on development, $624,000.00 on testing, and $800,000.00 on deployment. The details of this budget are outlined in the Appendix.

## Reporting

NRG will provide periodic reports to the CPUC during the course of the Project. NRG proposes that such reporting should be conducted based on milestones. Specifically, NRG proposes providing reports within three (3) months following NRG achieving the following milestones:

- The conclusion of Phase A configurations at Deployment Sites (estimated February 27, 2015);
- The conclusion of Phase B configurations at Deployment Sites (estimated December 31, 2015).

The final report will be submitted to the Commission no later than 6 months after the estimated completion date.

## Approval Request

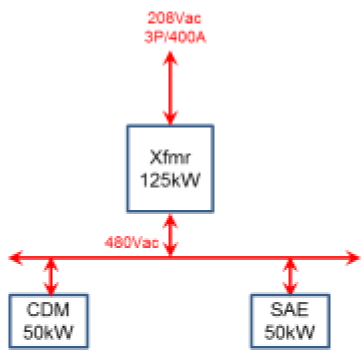
NRG respectfully requests that the CPUC approve the Project on or before January 31, 2013. If approved, NRG will be authorized to spend up to $1,924,000.00 on the Project, which will be credited against the Technology Demonstration Program Amount in the NRG / CPUC Agreement.

## Appendix A: Demonstration Configurations

In the following diagrams IHC refers to the power converter AC to DC and DC to AC. Efficiency has been estimated using manufacturer published data and from partner technical information. They are estimates only.

# Base Line Configuration

**Configuration:**
> Two DC Chargers



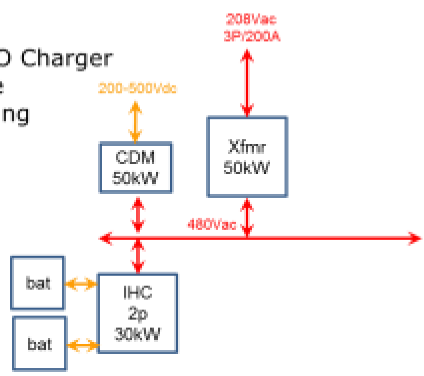

**Components:**
1 x 125kW Xfmr
1 x CDM 50kW DC Charger
1 x SAE 50kW DC Charger

**Efficiency:**
Charger ->EV ~90%

**Dependencies:**
None

# Test Configuration A1

**Configuration:**
> Single CHAdeMO Charger
> 20 kWh Storage
> Host peak clipping




**Components:**
1 x 50kW Xfmr
1 x 30kW IHC 2p
2 x 10 kWh batteries
1 x CDM 50kW Chargers

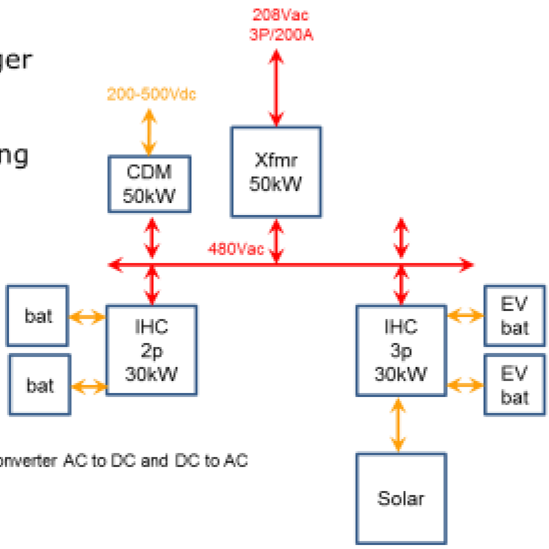
**Efficiency:**
Grid->EV ~90%
Bat->EV ~86%

**Deper**
None

IHC refers to the power converter AC to DC and DC to AC

# Test Configuration A2

**Configuration:**
> CHAdeMO Charger
> 70 kWh Storage
> 20 kW Solar
> Host peak clipping
> Solar Storage




IHC refers to the power converter AC to DC and DC to AC

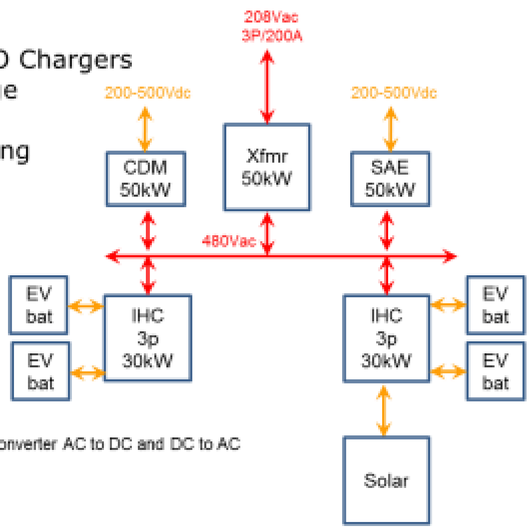
**Components:**
1 x 50kW Xfmr
1 x 30kW IHC 2p
1 x 30kW IHC 3p
2 x 10 kWh batteries
2 x 25 kWh EV batteries
1 x CDM 50kW Chargers
1 x 20 kW solar

**Efficiency:**
Grid->EV ~90%
Bat->EV ~86%
PV->EV ~86%

**Dependencies:**
1. 30kW IHC 3-port
2. EV Battery interface

# Test Configuration A3

**Configuration:**
> SAE & CHAdeMO Chargers
> 100 kWh Storage
> 20 kW Solar
> Host peak clipping
> Solar Storage




IHC refers to the power converter AC to DC and DC to AC

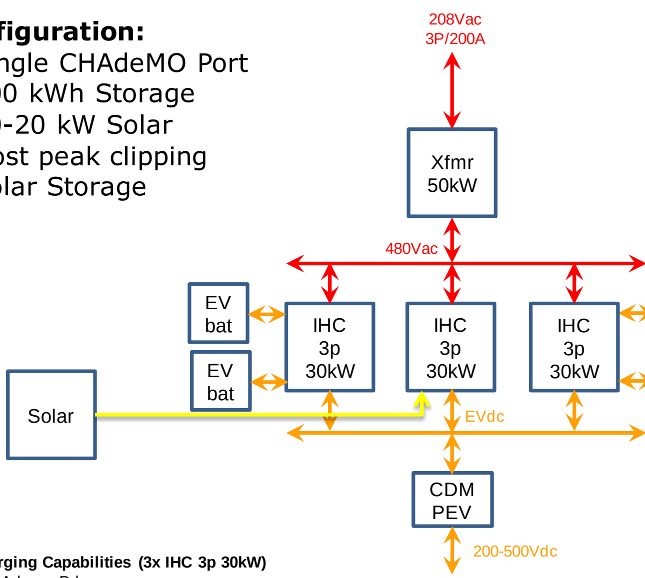
**Components:**
1 x 50kW Xfmr
2 x 30kW IHC 3p
4 x 25 kWh EV batteries
2 x CDM 50kW Chargers
1 x 20 kW solar

**Efficiency:**
Grid->EV ~90%
Bat->EV ~86%
PV->EV ~86%

**Dependencies:**
1. 30kW IHC 3-port
2. EV Battery interface

# Test Configuration B1

**Configuration:**
> Single CHAdeMO Port
> 100 kWh Storage
> 10-20 kW Solar
> Host peak clipping
> Solar Storage




**Components:**
1 x 50kW Xfmr
3 x 30kW IHC 3p
4 x 25kWh EV batteries
1 x CDM PEV I/F
1 x 20kW Solar

**Efficiency:**
Grid->EV ~94%
Bat->EV ~96%
PV->EV ~96%

**Dependencies:**
1. 30kW IHC 3-port (8/13)
2. EV Battery I/F (8/13)
3. CDM PEV I/F (8/13)

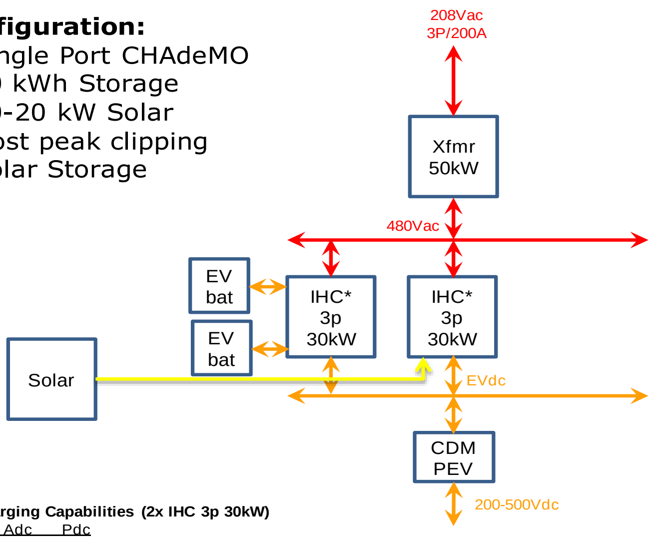
**EV Charging Capabilities (3x IHC 3p 30kW)**

| Vdc | Adc | Pdc |
|---|---|---|
| 300 | 180 | 54kW |
| 400 | 180 | 72kW |
| 500 | 180 | 90kW |

*Note: Assumes existing 60Amp DC current limit for IHC product.*

# Test Configuration B2

**Configuration:**
> Single Port CHAdeMO
> 50 kWh Storage
> 10-20 kW Solar
> Host peak clipping
> Solar Storage




**Components:**
1 x 50kW Xfmr
2 x 30kW IHC* 3p
2 x 25kWh EV batteries
1 x CDM PEV I/F
1 x 20kW Solar

**Efficiency:**
Grid->EV ~94%
Bat->EV ~96%
PV->EV ~96%

**Dependencies:**
1. 30kW IHC 3-port (8/13)
2. EV Battery I/F (8/13)
3. CDM PEV I/F (8/13)
4. Higher amp IHC (10/13)

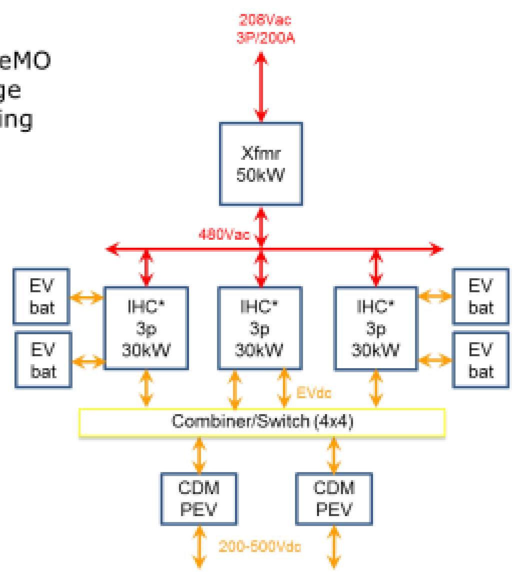
**EV Charging Capabilities (2x IHC 3p 30kW)**

| Vdc | Adc | Pdc |
|---|---|---|
| 300 | 140* | 42kW |
| 400 | 130* | 52kW |
| 500 | 120 | 60kW |

**Note: Assumes IHC 3p offers higher current at lower voltages. Need to verify with systems.*

# Test Configuration B3

**Configuration:**
> Dual Port CHAdeMO
> 100 kWh Storage
> Host peak clipping




**Components:**
1 x 50kW Xfmr
3 x 30kW IHC* 3p
4 x 25kWh EV batteries
2 x CDM PEV I/F
1 x Combiner/Switch

**Efficiency:**
Grid->EV ~94%
Bat->EV ~96%

**Dependencies:**
1. 30kW IHC 3-port
2. EV Battery Interface
3. CDM PEV Interface
4. High amp Power Converter
5. Combiner/Switch

**EV Charging Capabilities (3x IHC 3p 30kW)**

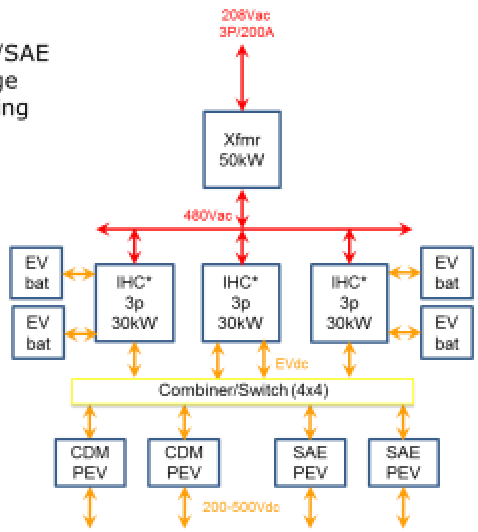
| Vdc | Adc | Pdc |
|---|---|---|
| 300 | 210* | 63kW |
| 400 | 195* | 78kW |
| 500 | 180 | 90kW |

IHC refers to the power converter AC to DC and DC to AC

*Note: Assumes IHC 3p offers higher current at lower voltages. Need to verify with systems*

# Test Configuration B4

**Configuration:**
> Quad Port CDM/SAE
> 100 kWh Storage
> Host peak clipping




**EV Charging Capabilities**
**(3x IHC 3p 30kW)**

| Vdc | Adc | Pdc |
|---|---|---|
| 300 | 210* | 63kW |
| 400 | 195* | 78kW |
| 500 | 180 | 90kW |

IHC refers to the power converter AC to DC and DC to AC

*Note: Assumes IHC 3p offers higher current at lower voltages. Need to verify with systems*

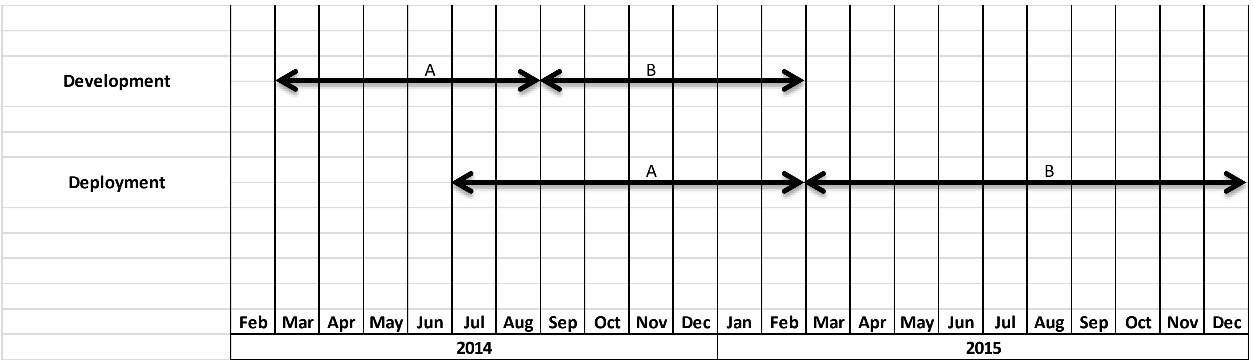
**Components:**
1 x 50kW Xfmr
3 x 30kW IHC* 3p
4 x 25kWh EV batteries
2 x CDM PEV Interface
2 x SAE PEV Interface
1 x Combiner/Switch

**Efficiency:**
Grid->EV ~94%
Bat->EV ~96%

**Dependencies:**
1. 30kW IHC 3-port
2. EV Battery Interface
3. CDM PEV Interface
4. High amp Power Converter
5. Combiner/Switch
6. SAE PEV Interface

# Appendix B: Project Timeline

The timeline for this project allows for enough charger utilization to work out any systems issues and determine the viability of any one configuration.



## Appendix C: Budget Detail

| | | | | |
|---|---|---|---|---|
| Develop | Storage | Battery-Converter Integration | $ 150,000 | |
| | | | | |
| | Dispenser | CDM/SAE Dispenser Research | $ 65,000 | |
| | | CDM Dispenser Development | $ 50,000 | |
| | | SAE Dispenser Development | $ 50,000 | |
| | | Combiner/Switch Development | $ 50,000 | |
| | | High Current IHC 3-port 30kW | $ 50,000 | |
| | | Dispenser Fixture Development | $ 35,000 | |
| | | Controller Development | $ 25,000 | |
| | | Total | $ 325,000 | |
| | | | | |
| | Research Support | Throughout program | $ 25,000 | |
| | | | | |
| | Total Develop | | | $ 500,000 |
| | | | | |
| Test | UCSD Installation A | Transformers and Switching | $ 10,000 | |
| | | Power Converters - IHC 3P | $ 52,000 | |
| | | Stationary Storage | $ 25,000 | |
| | | EV Storage | $ 32,500 | |
| | | Solar | $ 60,000 | |
| | | DC Chargers | $ 35,000 | |
| | | Design/Installation | $ 125,000 | |
| | | Total | $ 339,500 | |
| | | | | |
| | UCSD Installation B | Power Converters - IHC 3P | $ 80,000 | |
| | | 2 x CDM Dispensers | $ 30,000 | |
| | | 2 x SAE Dispensers | $ 30,000 | |
| | | Dual Fixtures | $ 20,000 | |
| | | Combiner/Switch | $ 20,000 | |
| | | Installation | $ 54,500 | |
| | | Total | $ 234,500 | |
| | | | | |
| | Research Support | | $ 50,000 | |
| | | | | |
| | Total Test | | | $ 624,000 |

| | | | | |
|---|---|---|---|---|
| Deploy | Site #1 (A2) | Power Converters | $ 18,000 | |
| | | EV Storage | $ 32,500 | |
| | | DC Charger | $ 17,500 | |
| | | Solar | $ 40,000 | |
| | | Installation | $ 60,000 | |
| | | NRTL Approval (UL or ETL) | $ 5,000 | |
| | | Total | $ 173,000 | |
| | | | | |
| | Site #2 (A3) | Power Converters | $ 36,000 | |
| | | EV Storage | $ 65,000 | |
| | | DC Chargers | $ 35,000 | |
| | | Installation | $ 50,500 | |
| | | NRTL Approval (UL or ETL) | $ 5,000 | |
| | | Total | $ 191,500 | |
| | | | | |
| | Site #3 (B3) | Power Converters | $ 54,000 | |
| | | EV Storage | $ 65,000 | |
| | | Combiner/Switch | $ 10,000 | |
| | | SAE Dispenser | $ 5,000 | |
| | | CDM Dispenser | $ 5,000 | |
| | | Fixture | $ 2,500 | |
| | | Installation | $ 40,000 | |
| | | NRTL Approval (UL or ETL) | $ 5,000 | |
| | | Total | $ 186,500 | |
| | | | | |
| | Site #4 (B4) | Power Converters | $ 54,000 | |
| | | EV Storage | $ 65,000 | |
| | | Combiner/Switch | $ 10,000 | |
| | | SAE Dispenser | $ 10,000 | |
| | | CDM Dispenser | $ 10,000 | |
| | | Fixtures | $ 5,000 | |
| | | Installation | $ 40,000 | |
| | | NRTL Approval (UL or ETL) | $ 5,000 | |
| | | Total | $ 199,000 | |
| | | | | |
| | Research Support | | $ 50,000 | |
| | | | | |
| | Total Deploy | | | $ 800,000 |
| | | | | |
| | | | | |
| Total Project | | | | $ 1,924,000 |