400Hz Ground Support Equipment Charging Infrastructure

Final Report

1002653

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1002653

Technical Update, October 2002

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ABSTRACT

Project Outline:

- Demonstrate the feasibility of powering electric Ground Support Equipment (GSE) rapid chargers using existing centralized, 400Hz, and airport infrastructure
- Install a demonstration system at Los Angeles International Airport (LAX) using existing, centralized 400Hz power
- Carefully track and report installation costs in accordance with the test plan
- Recommend installation procedures to minimize costs
- Recommend charger changes to minimize cost and maximize utilization
- Collect, analyze, and report on data as identified on list of parameters to be measured on page six of test plan

CONTENTS

1 400HZ GSE CHARGING INFRASTRUCTURE PROJECT

Figure 1-1
400 Hz GSE Charger (2 ports shown)

Participants:

Participants in this project included: AeroVironment Inc, American Airlines, Bellenger Consulting, EPRI (Electric Power Research Institute), INET Airport Systems, Los Angeles Department of Water and Power, NEETRAC, New York Power Authority, and Southern Company.

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2 OBJECTIVES AND BENEFITS

Objectives:

1. To demonstrate the use of existing, centralized 400Hz utility to power efficient, electric ground support equipment (GSE) rapid chargers, and
2. Demonstrate and evaluate the impact on infrastructure cost to install GSE rapid chargers utilizing centralized 400Hz power system

Benefits:

The 400Hz GSE Charging Infrastructure Project demonstrated the benefits of simultaneously rapid charging electric ground support equipment using centralized 400Hz power which:

- Maximized use of existing utility infrastructure
- Significantly lowered installations costs
- Charged two to four times faster than conventional charging systems
- Charged all battery-electric vehicles in the airline ground support equipment fleet

3 PROJECT DETAILS

Background:

Airport facilities throughout the U.S. are under intense pressure to significantly reduce pollution. Airlines, in turn, are asked to plan for emission reductions of tons per day. After thorough review and analysis, airlines have decided that emission reductions can best be achieved by converting existing ground support fleets to zero-emission electric vehicles.

In the first stages of implementing electric vehicles, a barrier was identified. Many airports do not have available utility capacity to power electric vehicle chargers. The use of high-efficiency, parallel rapid chargers has reduced infrastructure requirements by 80%, however more breakthroughs are required for wide spread use of electric vehicles at airports.

AeroVironment's PosiCharge system uses a single utility connected "PowerServer" to distribute power to "PowerStations" which independently control the charging process to each connected battery. The available charging power is controlled by the master PowerStation and prioritized based on the number of vehicles connected and the battery state-of-charge of the vehicles.

A conventional 80-volt charger can require a 20 to 25 amp utility service for each charger. In a ten vehicle scenario, the conventional system would require 200 to 250 amps of service, while the PosiCharge system would only require 100 amps, significantly reducing the installation costs. The PosiCharge provides improved power quality and high-energy efficiency (this statement sounds more like a sales document than a technical report). In fact, many airports are now requiring that chargers must meet certain power quality standard, such as THD less than 10%, to be used at new installations.

Project Outline:

- Demonstrate the feasibility of powering electric GSE rapid chargers using existing centralized, 400Hz airport infrastructure
- Install a demonstration system at LAX using existing, centralized 400Hz power
- Carefully track and report installation costs in accordance with the test plan
- Recommend installation procedures to minimize costs
- Recommend charger changes to minimize cost and maximize utilization
- Collect, analyze, and report on data as identified

Utility Infrastructure:

Even with PosiCharge's lower infrastructure requirements, many older airports cannot provide the power required to charge electric GSE. One solution is to "share" existing installed power.

At many airports, there are centralized 400 Hz systems that supply power to each gate to support the planes when the APUs (Auxiliary Power Units) are off. Most 400Hz-centralized systems are designed to share power since all gates in the airport terminal are not in use at the same time. A modern communication system allows each gate controller to communicate the real time power requirements with the central 400Hz system.

Utility input for this demonstration was centralized, 400Hz power generated from an existing, on-site, INET Airport Systems motor generator. Power sharing between the aircraft power and the charging system allows the PosiCharge system to maximize usage of the utility connection.

Figure 3-1
Infrastructure for Gate 48A

Charger Hardware:

This test used a 400 Hz to 150 VDC converter Power Server. The Power Server communication integrated with the gate control box to allow for power management. The gate control box balanced the power demand of the aircraft and charging system. The aircraft received highest priority over the charging system. The available charging power was communicated to the master PowerStation to limit the charging rate to the individual PowerStations. One PowerStation was deployed (two charging ports.)

Figure 3-2
Charger Hardware

Vehicle Modifications:

The electric GSE vehicles were modified for fast charging by installing a PosiCharge Battery Monitor and Identifier (BMID) on the battery pack and a fast charge capable connector on the vehicle. The BMIDs communicate the specific battery charging parameters, real time voltage and temperature measurements, and store battery history required to maintain the battery warranty. The battery pack was a standard 80V, 560A-hr battery manufactured by Enersys (Exide). The fast charge connector chosen by American Airlines is a Burton, pin and sleeve style connector, part number BCDC-0008-P020 Cable assembly, DC 350A, 2/0.

Figure 3-3
Ground Support Equipment Vehicle - Modified

Location:

The system was installed at American Airlines gate 48A at Los Angeles International Airport (LAX) operating from centralized 400 Hz power generated by an INET Airport Systems motor generator.

Figure 3-4
Installation Site – Gate 48A Los Angeles International Airport (LAX)

4 DATA AND INFORMATION COLLECTION PLAN

Parameters planned to be measured to determine overall system capability, efficiency and power quality throughout the course of the project include:

1. Installation Costs
   Units: US Dollars
   Measurement Frequency: Upon completion of installation
   Method: AeroVironment Purchase Order report and scope of work including estimate of cost to install with labor and material breakdown estimates and labor rates if available. Include recommendation for turnkey solution.

2. Charger Installation Procedure
   Units: None
   Measurement Frequency: At completion of project
   Method: AeroVironment Published Installation Procedure

3. Gate Box Interface Protocol
   Units: None
   Measurement Frequency: Three times, prior to and after installation and at completion of project
   Method: AeroVironment Published Description of Gate Box Interface Protocol

4. Determine charging system input power and efficiency
   Units: AC kWs and kWhs
   Estimate or measurement frequency: AC kWhs totaled for measurement duration, AC kWs peak demand recorded daily
   Method: INET and AeroVironment Power Server input

5. 400 Hz power quality
   Units: None
   Measurement Frequency: Once during the project
   Method: INET measurement from laboratory results

6. Charging system output power
   Units: kW
   Measurement Frequency: Each charge event
   Method: AeroVironment Power Station log peak power

7. Available charging power vs clock time
   Units: kW
   Measurement Frequency: One representative week.
   Method: Laptop data collection from master power station measuring airplane load

8. Vehicle usage
   Units: Charge Ahs per day
   Measurement Frequency: 100 charge events
   Method: AeroVironment will capture and report data using BMID on vehicle

9. Vehicle charge time per day
   Units: 24-hour time clock
   Measurement Frequency: Every charge event
   Method: AeroVironment will capture and report data using BMID on vehicle

10. Charger Feature Set
    Units: None
    Measurement Frequency: At beginning and end of program
    Method: AeroVironment Published charger feature list (may be proprietary information)

Schedule:

Table 4-1
Project Schedule Timeline

Timeline	Task	Actual Date	Comments
Week 1	Kick-off	January 16, 2002	
Week 2-8	Site Preparation	February 5 2002	Completed ahead of plan
Week 9	Installation	February 12, 2002	Completed ahead of plan
Week 10-18	Operation	February 12, 2002	Began ahead of plan
Week 19	Wrap-up	August 26, 2002	Test period extended
Week 20	Final Report	September 15, 2002	

The charger was operational beginning February 12, 2002. Final data was collected on August 1, 2002 for a total of 171 operational days

Results:

Parameters measured and data captured during the course of the project to determine overall system capability, efficiency and power quality are included below:

1. Installation Costs
   Units: U.S. Dollars
   Measurement Frequency: Upon completion of installation
   Method: AeroVironment Purchase Order report and scope of work including estimate of cost to install with labor and material breakdown estimates and labor rates if available. Includes recommendation for turnkey solution.
   Results: Installation cost for one server, one station and accompanying wiring, conduit, and mounting frames was $15,000 for this site. Approximately 70% of this cost was materials

and 30% was labor. INET Airport Systems conducted the installation. Installation costs were minimized by site selection close to the power source and physically configured for charger installation with existing bollards and appropriate space with access to vehicles.

Figure 4-1
Technical Review of Installed System

2. Charger Installation Procedure
   Units: None
   Measurement Frequency: At completion of project.
   Method: AeroVironment Published Installation Procedure
   Results: See Appendix 1 for a copy of the installation procedure.

3. Gate Box Interface Protocol
   Units: None
   Measurement Frequency: Three times, prior to and after installation and at completion of project.
   Method: AeroVironment Published Description of Gate Box Interface Protocol
   Results: A simple serial interface was selected with messages to exchange power available, power utilized and operating status. The interface was robust and appropriate for use with the gate box and technology employed. The interface was used continually throughout the demonstration project without issue. Details of the interface are proprietary.

4. Determine charging system input power and efficiency
   Units: AC kWs and kWhs
   Estimate or measurement frequency: AC kWhs totaled for measurement duration, AC kWs peak demand recorded daily
   Method: INET and AeroVironment power server input

Results: Charging system input power is 575VAC, 400Hz, 3-phase. Overall power server efficiency is approximately 91%. 60Hz to 400Hz power conversion at full load is 92%. 400Hz to 150VDC power conversion is 99%. Though not measured, the total energy usage was estimated. Over a representative 9 day measurement period there was a measured usage of 212 kWhs (23.7 kWhs per day) of DC energy from the 400 Hz PowerServer. Using the specified 91% efficiency of the server, approximately 26 kWhs of AC Energy was consumed per day. The charger was placed in operation on 2/12/02 and the final data was collected on 8/1/02 for a total of 170 days. The total energy is estimated to be 4,430 AC kWhs over the 170 days. The peak AC kWs is estimated to be 26.5 kWs for a single vehicle.

5. 400 Hz power quality
   Units: None
   Measurement Frequency: Once during the project
   Method: INET measurement from laboratory results.
   Results: Total harmonic distortion of voltage is less than 1.5% based upon laboratory measurements.

6. Charging system output power
   Units: kW
   Measurement Frequency: Each charge event
   Method: AeroVironment power station logged peak power.
   Results: A significant amount of data was collected. A representative sample is included on the following page in Figure 1-7, Daily Usage which shows the charge returned and charge time of each event. Average daily usage was 168 Ahs or 0.37 EBUs. Peak usage was 470 Ahs or 1.18 EBUs. Peak charger output is limited by battery capability to 22 kWs per vehicle. The charger is capable of 30 kWs max in dual port mode and 60 kWs max in single port mode. Representative data for actual charger power is shown in Figure 1-9, Actual Plane and Charger Power.

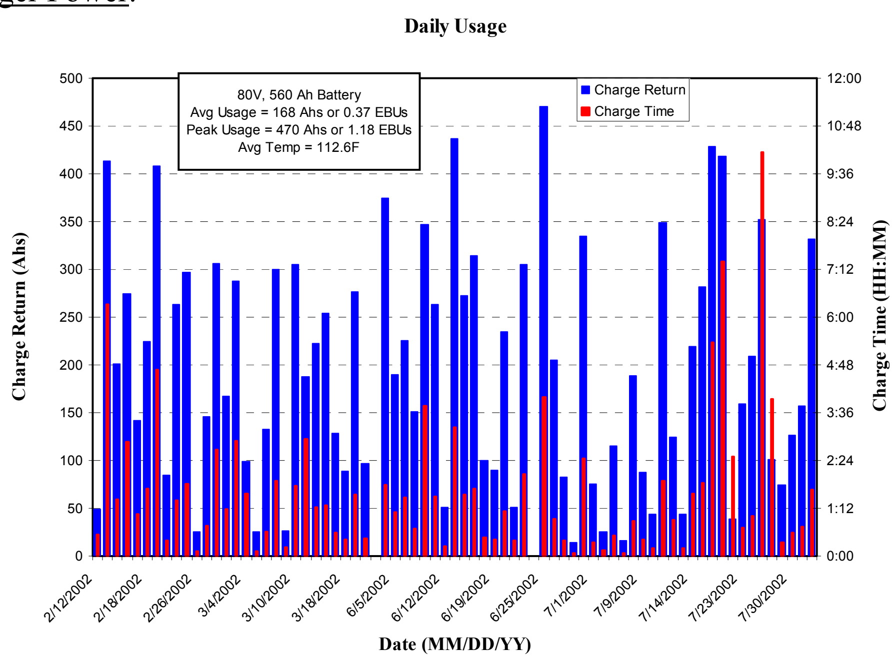

Figure 4-2
Daily Usage

7. Available charging power vs clock time
   Units: kW
   Measurement Frequency: One representative week.
   Method: Laptop data collection from Master Power station measuring airplane power load.
   Results: A significant amount of data was collected. A representative sample is included on the following page in Figure 1-10, Actual Plane and Available Charger Power. The total power available at the gate is 90kVA. Based upon power demands from the airplane over a representative week, the average available charge power is 58.7kWs which is adequate for powering a 60kW parallel charging system. The available power is sufficient to maintain charge of ten to sixteen electric GSE vehicles if opportunity charging is employed during breaks and time of vehicle non-use.

8. Vehicle usage
   Units: Charge Ahs per day
   Measurement Frequency: 100 charge events
   Method: AeroVironment will capture and report data using BMID on vehicle
   Results: A significant amount of data was collected. A representative sample is included on the following page in Figure 1-7, Daily Usage which shows the Charge returned and charge time of each event. Average temperature of the battery pack was 112.6F. Measurement Frequency is "Every Charge Event". The data is actually measured by the charger and stored in the battery-backed memory of the charger. AeroVironment stores the last 200 charge events in the charger memory. The BMID stores totals such at # of charge events, # of complete EQs, Total Ahs charged, highest temperature, lowest SOC, etc. The BMID showed that the vehicle was plugged in 815 times during the trial (average of 4.8 plug in per day) and charged a total of 25,550 Ahs and only had one complete equalization event.

9. Vehicle charge time per day
   Units: 24-hour time clock
   Measurement Frequency: Every charge event
   Method: AeroVironment will capture and report data from the charger.
   Results: A significant amount of data was collected. A representative sample is included on the following page in Figure 1-7, Daily Usage which shows the Charge returned and charge time of each event. Figure 1-10, Plane and Charger Power, provides additional information regarding vehicle charge time per day, indicating that duty cycles of the airplane and charger are complimentary and rarely coincide.

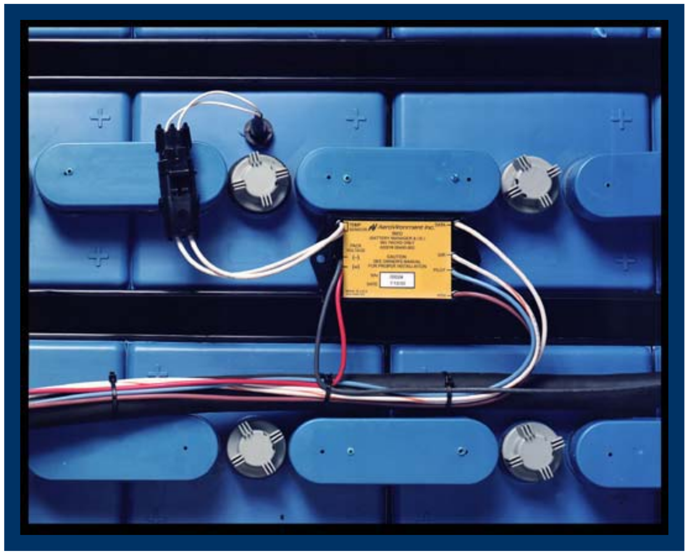

Figure 4-3
AeroVironment BMID

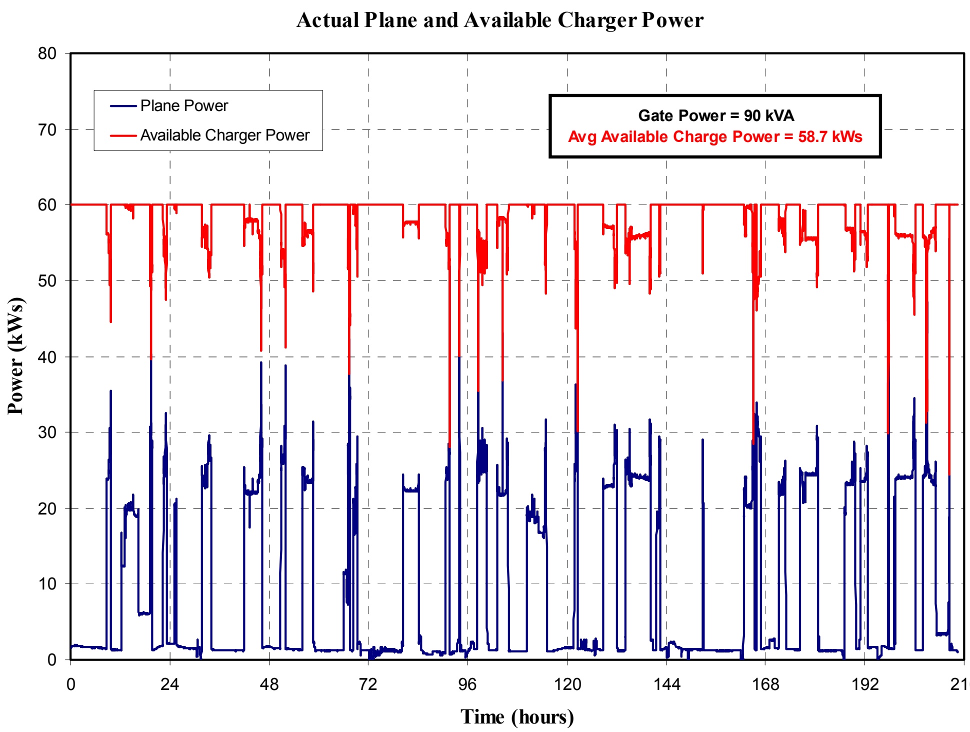

Figure 4-4
Actual Plane and Available Charger Power

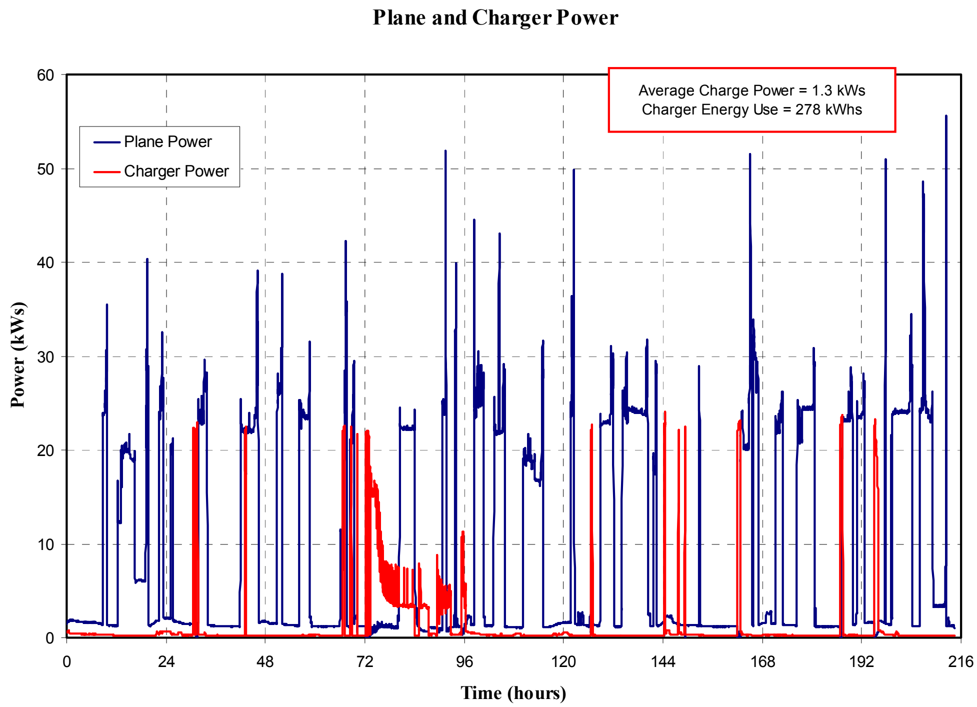

Figure 4-5
Plane and Charger Power

10. Charger Feature Set
    Units: None
    Measurement Frequency: At beginning and end of program
    Method: AeroVironment Published charger feature list
    Results: Major charger features include:

- Up to 16 vehicles simultaneously charged from one utility connection
- Fast charge and equalization conducted at any station
- Same system charges any battery type or voltage
- Automatic start and stop
- Meets all airport requirements
- Rated for outdoor use
- Flexible mounting: wall, ceiling or pedestal
- Operate from 400Hz, 60Hz or 50Hz utility infrastructure

5 CONCLUSIONS

The 400Hz Ground Support Equipment (GSE) Charging Infrastructure Project was conducted to demonstrate that existing, centralized 400Hz utility could power efficient, electric ground support equipment (GSE) rapid chargers. The project was successful demonstrating that electric GSE used by American Airlines at Los Angeles International Airport could be charged using existing, centralized 400Hz infrastructure generated on-site by an INET Airport Systems motor generator.

In addition, the project set out to demonstrate that installation of existing, centralized 400Hz systems is a viable option when 60Hz infrastructure is not available or cost prohibitive. Indeed, the project found that it is possible to install electric GSE rapid chargers when existing 400Hz infrastructure is utilized. Site selection and the availability of power resulted in a reduction of installation costs over a typical 60Hz installation.

During the course of the project, it was determined that electric GSE charging using AeroVironment's PosiCharge efficiently uses existing 400Hz power distribution, especially when the gate is not occupied as plane power demands and charging rarely occur concurrently. Based on the data, the 400 Hz charging system will support between 10 to 16 vehicles per gate without modifications to the 400 Hz infrastructure or reducing power required for plane operation.

Participants of the project agree and recommend further testing to demonstrate full power operation of an AeroVironment 60kW PosiCharge and the power-sharing feature of the demonstrated system.

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