

# FINAL REPORT

April 30, 2008

Grant No.:  
**ICAT 04-4**

Title:

**Innovative Means to Minimize Electric GSE Charging  
Infrastructure Costs**

Electric Transportation Engineering Corp.

Conducted under a grant by the California Air Resources Board of the  
California Environmental Protection Agency

The statements and conclusions in this report are those of the grantee and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

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Steve Church

Port of Oakland

Britt Johnson

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Larry Laney

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John Salter

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## Executive Summary

Use of electric ground support equipment (GSE) is considered a viable option for reducing non-aircraft exhaust emissions at airports. In 2002, eTec began a project with the California Air Resources Board (CARB) (administered by Sacramento Municipal Utility District [SMUD]) to develop a battery-powered aircraft pushback tractor for pushing aircraft away from the gate when ready for departure. This tractor was to be tested by United Airlines at San Francisco International Airport (SFO) to determine if a low-capacity, high power density battery combined with fast opportunity charging could meet the operational needs of the airlines.

In 2005, a related project—funded through CARB’s Innovative Clean Air Technology (ICAT) program—was added. This project called for the demonstration of eTec’s Bridge Power Manager (BPM), which allows the battery charger to share the jet bridge’s existing power circuit without overloading that circuit’s built-in protection. Time-sharing the power circuit in this way eliminates the need for, and cost of, installation of a new circuit, hopefully removing this obstruction to the introduction of electric GSE at many airports.

During the course of the project, the site was moved to Oakland International Airport (OAK) in partnership with Southwest Airlines (SWA). In September 2007, eTec, OAK and SWA planned and conducted the installation of the battery charger and BPM at gate 32 at OAK, and the system became operational in mid-October, 2007. The demonstration effort was conducted for a six-month evaluation period. During this time, the charger recorded data for each charge event, including interruptions required by the BPM to limit total power in the jet bridge circuit. The data show that the BPM technology was successful in allowing SWA to operate their electric GSE without loss of use due to lack of charger availability.

This demonstration enabled SWA to experience the operation of the BPM with their current battery charging equipment. As a result, SWA elected to purchase additional BPMs and chargers from ETEC to expand its use of electric GSE at OAK.

## Introduction

This document serves as the Final Report for ICAT grant ICAT 04-4, Innovative Means to Minimize Electric GSE Charging Infrastructure Costs. This project sought to develop and demonstrate a Bridge Power Manager technology to allow for the expansion of electric ground support equipment (GSE) at airports currently constrained by the lack of electric infrastructure.

## Innovative Technology

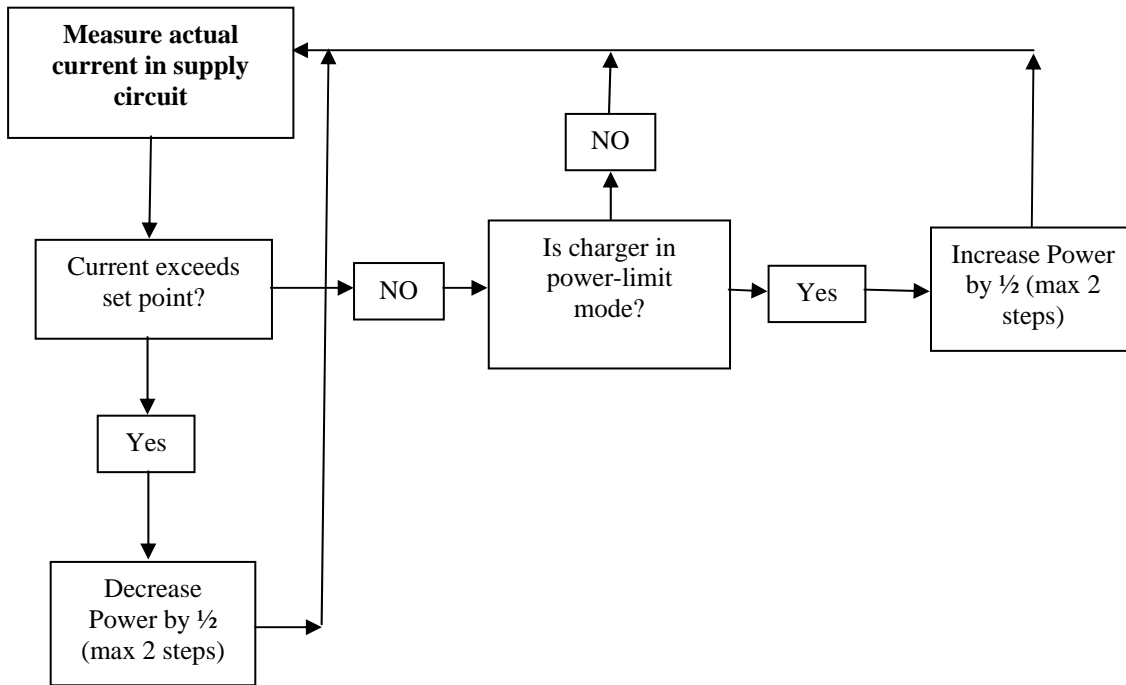
Use of electric ground support equipment (GSE) is considered a viable option for reducing non-aircraft exhaust emissions at airports. By replacing one-for-one diesel- and gasoline-powered equipment currently used by airlines with zero-emission electric equipment, it is expected that air pollution generated at airports can be reduced. One barrier to the use of electric GSE is the lack of available electric power at older airports. A significant portion of the cost for installing battery charging equipment can come from the need to bring in additional power capability to the air side of the airport terminal.

ETEC developed the Bridge Power Manager (BPM) technology to address this problem. At most airports, passengers access an aircraft via a jet bridge located at the terminal gate. These bridges use electric traction motors to articulate in order to mate the bridge to the aircraft doors. These traction motors are typically supplied by a dedicated 30- or 60-amp, 480VAC 3-phase circuit. However, these circuits are used infrequently—most of the time they are on stand by. This presents an opportunity to use an existing electrical circuit to power a battery charger to service electric GSE. The issue has always been the risk of overloading the existing circuit when the bridge needs to be moved and a battery is being charged. Having a circuit breaker open (therefore, the bridge loses power) while an aircraft is attached to the bridge presents an untenable situation for the airline.

The Bridge Power Manager technology is designed to actively monitor the total throughput on the existing circuit (traction motor + battery charger consumption). If the total throughput approaches the design rating of the circuit, the BPM can turn down the power output of the battery charger via a communication link between the control systems of the BPM and charger. If the total throughput is still too high, the BPM can command the charger into a stand-by condition, effectively eliminating the power consumption by the charger. When the circuit becomes sufficiently available, the BPM can increase the charger's output back to the pre-limit condition. The BPM function is coordinated with the charging algorithm so that interruptions to the charging process do not affect the quality of the charge (e.g., no unnecessary overcharge) or cause the charging process to extend beyond the delay required by the BPM.

The BPM is tunable in that it can be set (in software) to activate at nearly any amperage load. That is, if the circuit to be protected is rated at 40 amps, the BPM can be tuned to activate at 40 amps or lower if a safety cushion is desired. Figure 1 presents a simplified flow chart for the operational logic of the BPM.

**Figure 1--BPM Logic Flow Chart**



ICAT Project

The present ICAT project was proposed to demonstrate the BPM technology at an airport—the real-world situation. Verifying the design and function of a technology in a lab is one thing, but real-world field trials are the ultimate test.

The project was initially proposed as a “piggy-back” to another CARB project that involved the development of a high-power electric tractor designed to push aircraft from the gate at San Francisco International Airport (SFO). That project was terminated before the ICAT project could demonstrate the BPM technology.

The ICAT project was amended to continue without the electric pushback tractor. Due to scheduling and availability conflicts, the project was moved to OAK. This turned out to be an excellent location due to the relative lack of availability of excess power for electric GSE chargers, the impending introduction of electric GSE and the willingness and eagerness of the Port of Oakland to trial a technology that could enable additional electric GSE at OAK.

Southwest Airlines (SWA) signed on as the operating partner for this project. SWA has been a leader among the various airlines in successfully implementing electric GSE around the United States. SWA was operating at OAK and was determined to bring electric GSE to that airport. SWA was willing to dedicate a gate and a charger to this project and to bring two electric belt loaders to OAK ahead of schedule to use for this project.

For reference, the project tasks and completion schedule are presented in Appendix A.

Several meetings took place at OAK with personnel from the Port, SWA and ETEC present. These meetings were used to explain the theory of the BPM technology, determine the ultimate location for the BPM and charger, determine the location and ampacity of the circuit driving the jet bridge traction motors and develop an installation plan and schedule.

On September 11, 2007 ETEC's Field Service Manager worked with the electrical sub-contractor at OAK to complete the installation and startup of the charger and BPM. While the electrical installation was uneventful (as well as correct) and the charger worked fine, the BPM was found to have a bad logic control circuit board, likely a result of damage sustained during shipment. On September 13, the circuit board was replaced and the BPM and charger system was tested and found to be working properly (see Appendix B for images of the installation).

The circuit used to power the jet bridge traction motor and the battery charger was determined to be rated at 60 amps. The battery charger is a 30-amp device, leaving 30 amps available to power the traction motor. In an effort to have the BPM interrupt the charger more often (thus, demonstrating the technology), the BPM was tuned to protect the circuit at 40 amps. That is, if the combined current draw of all devices approached 40 amps, the BPM would shut down the output of the charger.

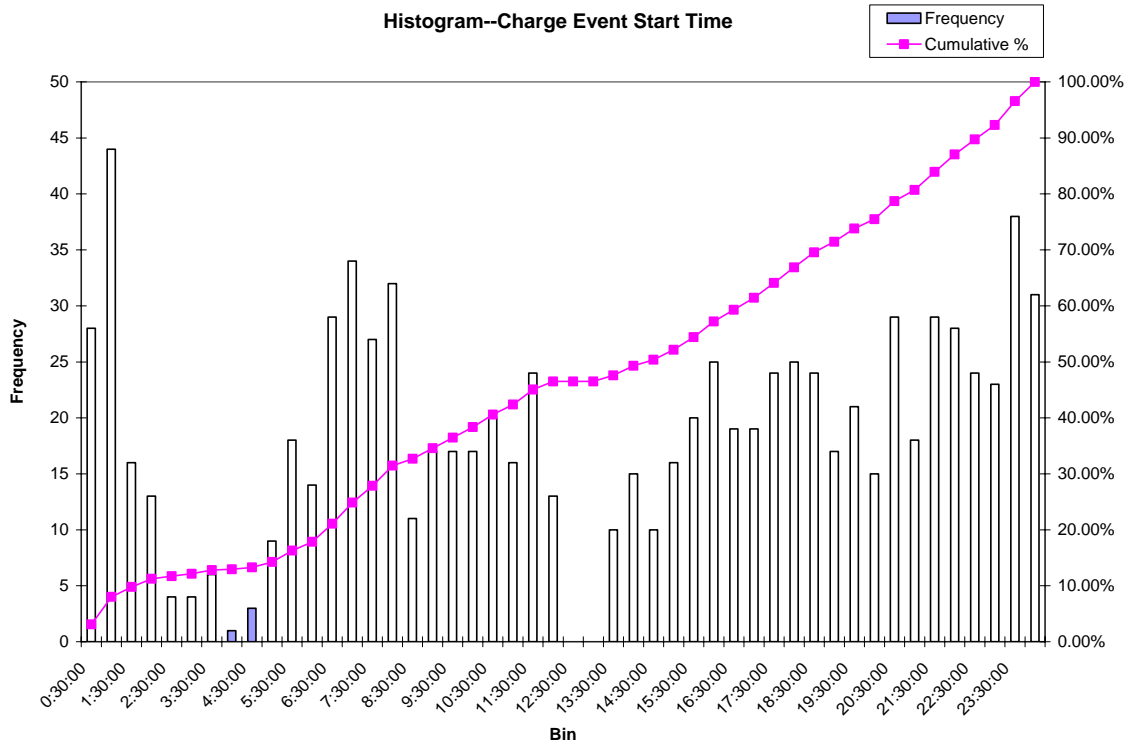
From September 13, 2007 through April 11, 2008<sup>1</sup>, the BPM and battery charger were operated at Gate 32 at OAK. The ETEC battery charger is equipped with a system that records data, including the number of interruptions (up to 10) caused by the BPM, from each charge event. These data were collected on a regular basis and analyzed for both charger performance and for interruptions from the BPM. During this period, three BPM interruptions were recorded. The first event occurred on April 8 at 9:06 am. The last two events occurred on April 10 when the system was demonstrated by ETEC for CARB (see below for more information).

This indicates that the SWA electric GSE equipment was able to charge as needed without interruption. It might be concluded that the charger was operated only when the jet bridge was dormant; charging after midnight would meet this criteria. The data were analyzed to determine when vehicles were charged. Figure 2 presents a histogram of all charge events (time of connection to the charger) recorded during this field trial period.

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<sup>1</sup> As of April 30, 2008, the BPM and battery charger are still in operation at Gate 32.

**Figure 2—Charge Start Times (September 13, 2007 through April 11, 2008)**



The data show that charge times are well distributed across the day. There are very few connections to the charger between 2:30 am and 5:30 am; there is very little activity at this terminal during these hours. There is a strong spike at 1:00 am; the last flight is gone by then and activity to organize the ramp area is completed by that time. The remaining charge events occur throughout the day when it would be expected that the jet bridge is operated for arriving and departing flights.

Accounts from SWA ground operations personnel indicate that the charger has not displayed the Wait mode; an indication that the BPM has not interrupted the charge event.

In order to re-verify the operation of the BPM, a meeting was scheduled at OAK on April 10, 2008 to demonstrate to Steve Church (CARB) and Britt Johnson (Port of Oakland) that the BPM was functioning. During this meeting, SWA personnel and gate 32 were made available for testing. A belt loader with a depleted battery was parked at the charger. While on charge, the jet bridge was operated for an extended period. No charging interruption occurred. The BPM was re-tuned to activate at a 30-amp limit. The belt loader was again placed on charge and the jet bridge was operated for an extended period. The charger was observed to drop to 50% output. Within 60 seconds, the charger dropped to zero power and the Wait indication was illuminated on the charger (see Appendix C for images from this test). This indicates that the combined current draw from both the bridge traction system and charger was near the 30-amp control point. While the bridge circuit was rated at 60 amps, the actual draw under these conditions was



quite a bit less than that. The engineer who designed the electric distribution system would need to be consulted to explain why the circuit was apparently over-sized.

The question could be asked “if the BPM never operates, why use it in the first place?” While the operation of the charger and the jet bridge are such that the demanded power on the existing circuit never exceeds the design limit, it must be understood that the circuit was sized based on some anticipated conditions or loads. Therefore, local codes and/or the National Electric Code (NEC) do not allow additional loads to be placed on that existing circuit. The BPM acts as a load manager which is a recognized method for adding additional loads to an existing circuit. The BPM is Listed by TÜV as a load management system. In short, the BPM is a quick, inexpensive means of adding battery charging equipment to existing circuits.

The six-month field trial combined with the demonstration on April 10 validate the premise that electric GSE battery charging systems can be installed at airports utilizing existing circuits with the use of the BPM technology. That is, the project goals were accomplished. The data clearly show that SWA were able to maintain operation of their electric GSE without suffering delays caused by sharing power with external equipment. See Appendix D for a letter from the Port of Oakland summing up their views regarding the outcome of the project.

#### Status of the Technology

The BPM technology was successfully demonstrated during the field trial task for this project. ETEC successfully submitted the BPM for certification by TUV Rheinland North America so that it could be installed in accordance with the National Electric Code.

Based on the experience gained during this trial, SWA elected to purchase and begin the installation of six more BPMs before the field trial period was completed. These BPMs are installed at other gates at which SWA operates at OAK. As of the date of this report, battery chargers are being installed and connected to these BPMs. Additional electric GSE are scheduled to arrive at OAK after the battery charging infrastructure is in place.

The project also demonstrated that the BPM is a cost effective means of adding battery charging equipment to existing circuits. The BPM hardware purchase price is approximately \$5,000. The installation cost for the BPM at OAK (excluding the work related to installing the charger) cost approximately \$2000. In comparison, eTec recently completed the installation of five battery chargers and a new 2000-amp circuit to supply power to the chargers (with sufficient additional power for future charger installations and other equipment). The cost for the hardware and labor alone for installing the 2000-amp circuit was over \$100,000! The use of the BPM technology in this instance would have saved \$65,000 ( $\$100,000 - 5 * \$7,500 = \$65,000$ ).

This technology is now available to support the implementation of electric GSE to reduce emissions at airports throughout the State of California and elsewhere. eTec will make BPM units available for sale to airports and airlines who need to solve electric power infrastructure problems in order to impellent electric GSE.

It should be noted that the BPM technology is not limited to airport and GSE applications. The core technology can support battery charging needs for electric fork

lifts in warehouses and on-road electric vehicle chargers; anywhere that inadequate electric infrastructure limits the installation of battery charging equipment.

Furthermore, eTec will continue to develop the technology in order improve the usefulness or enhance its function. For example, some jet bridge circuits may have sufficient spare power to supply two chargers. Additional software logic is required in order to communicate to and control two chargers in order to limit total power drawn on a circuit.

# APPENDIX A

## Project Tasks and Schedule

Task #	Task Content	Estimated Completion Date
1.	Establish gate bridge operating baseline; build and tune BPM for proper operation	<b>COMPLETE</b>
2.	Characterize pushback tractor battery (pre-demonstration)	<b>COMPLETE</b>
3.	Install BPM and instrument BPM and Pushback tractor	<b>COMPLETE</b>
4.	Operate BPM and pushback tractor	
	Start Operation	<b>CANCELLED</b>
	1 <sup>st</sup> Operation Progress Report	<b>CANCELLED</b>
	2 <sup>nd</sup> Operation Progress Report	<b>CANCELLED</b>
	3 <sup>rd</sup> Operation Progress Report	<b>CANCELLED</b>
5.	Characterize pushback tractor battery (post-demonstration)	<b>CANCELLED</b>
6.	Prepare final project report and seminar	<b>CANCELLED</b>
7.	Install BPM, Charger and data recording equipment	<b>COMPLETE as of 9/13/07</b>
8.	Operate BPM and Charger	<b>COMPLETE as of 4/11/08</b>
9.	Reporting and Seminar	<b>May 12, 2008</b>

# **APPENDIX B**

## **BPM and Charger Installation at OAK**

**Figure B1—BPM and Charger Installed at Gate 32 Bridge Pier**



**Figure B2—Charger In Service**



# **APPENDIX C**

## **BPM Charging Interruption—Demonstration**

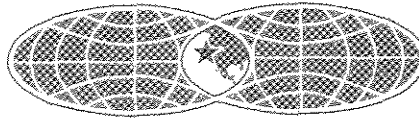
Figure C1—BPM in Wait mode





# **APPENDIX D**

## **Port of Oakland Support Letter**



# PORT OF OAKLAND

STEVEN J. GROSSMAN  
*Director of Aviation*

May 9, 2008

Bart Croes, Chief  
Research Division  
California Air Resources Board  
1001 I Street  
Sacramento, CA 95812

**Re: Bridge Power Manager Demonstration Project**

The Port of Oakland is pleased to have participated in the California Air Resources Board's (CARB) ICAT Bridge Power Manager (BPM) project to demonstrate an innovative means of charging electric Ground Support Equipment (GSE). As Oakland International Airport grows, the Port of Oakland will maintain a strong focus on air quality. In particular, minimizing the emissions from Ground Support Equipment (GSE) will continue to be a priority.

The Port of Oakland is working with our airline partners to convert standard diesel-powered GSE to alternative fuels, generally electric power. One significant barrier has been the cost of providing electric power infrastructure for rapid battery chargers. When the Port of Oakland was approached in 2007 by Electric Transportation Engineering Corporation (ETEC) and CARB to participate in this project, we recognized that the BPM could be just the technology needed to achieve our goal of cost-effectively implementing electric GSE.

The Port of Oakland is very happy with the results of this project. We have worked closely with ETEC and Southwest Airlines to monitor the status of the charger and BPM. While there was initial concern that the system would not provide the "up time" required to maintain the batteries used with electric GSE, it seems that there were no problems for the duration of the demonstration period.

In short, the Port of Oakland believes that the project proved to both the Airport and the airlines that electric GSE can be operated at Oakland Airport with the implementation of the BPM technology. Southwest Airlines has shown their continued support for the project by installing BPM at six (6) gates in Terminal 2 which did not have dedicated power for GSE.

Thank you for the opportunity to participate in this project. We look forward to the prospect of working again with CARB on any future airport air quality projects.

Sincerely,

  
Steven J. Grossman  
Director of Aviation

Cc : Joe Wong  
Richard Sinkoff  
Deborah Ale-Flint