Electric and Hybrid Vehicle Program Site Operator Program Quarterly Progress Report for July through September 1994 (Fourth Quarter of FY-94)

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Kansas State University
Los Angeles Department of Water and Power
Orcas Power and Light Company
Pacific Gas and Electric Company
Platte River Power Authority
Potomac Electric Power Company
Sandia National Laboratory
Southern California Edison
Texas A&M University
U.S. Navy
University of South Florida
York Technical College

Appendix B: Site Operator Data Tables

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Executive Summary

The DOE Site Operator Program was initially established to meet the requirements of the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. The Program has since evolved in response to new legislation and interests. Its mission now includes three major activity categories:

1. Advancement of Electric Vehicle (EV) technologies
2. Development of infrastructure elements needed to support significant EV use
3. Increasing public awareness and acceptance of EVs.

The 13 Program participants, their geographic locations, and the principal thrusts of their efforts are identified in Table ES-1. The EV inventories of each participant are summarized in Table ES-2.

Participants' experience with EV operation reflects three unrelated factors:

1. Operating climate and terrain

2. Current battery design and manufacturing technology, and charging/maintenance practices

3. Control and drive component technology and dependability

Factor 1 can noticeably influence the operating range of a vehicle. Factors 2 and 3, in that order, give rise to a great majority of the problems encountered. The effects of vehicle age, weight, and accumulated service mileage are also factors, and are noted by the operators in their service records. To summarize:

- Ambient temperature extremes and other climatic variations decrease
- vehicle range through both reduced battery capacity and increased accessory usage.

- Battery pack life for a given type is not uniform and frequently much shorter than expected; identical modules may show substantially different service lives.

- Electronic control system and drivetrain components are critical to vehicle operation and failures are not uncommon.

An appraisal of the overall current status of EVs for transportation emphasizes the following:

- Zero-emission vehicles have been mandated to specified percentages of
- new vehicles sold, by California law. Similar laws have been adopted by Massachusetts and New York and are under consideration in other states.

- For successful use of electric vehicles, conditions must be favorable, typically involving short-range service and infrastructure (i.e., charging and service) availability. Climate and terrain also impose limitations.

- Evaluation and test activities to date reflect the need for technology advances. Improved battery chemistry, design, and manufacturing practices are needed if adequate dependability is to be achieved. Powertrain and control system design will necessarily reflect battery technology changes, although control and powertrain design philosophy is potentially flexible. Examples are AC versus DC drive power, and the use (and operational problems) of regenerative braking. Some problems with weight overload when converting a chassis designed for ICE power have begun to surface.

- The additional cost of an EV over conventional ICE vehicles is largely in purchase price. Operating costs appear to be competitive.

- Vehicles representing relatively new designs (e.g., Solectria and USElectricar) are presenting a variety of equipment and operational problems to the users.

- Further effort is needed in hybrid vehicle development to achieve the necessary operating performance and overall dependability.

- Batteries and charging equipment continue to present generic problems, even in otherwise proven EV systems. Fast-charge technology is now under active investigation with several options available, and standardized testing protocols are being developed. A companion effort, the Rapid Battery Interchange Program, has been started at Pacific Gas and Electric Co.

Program Management covered a spectrum of activities:

- Reports of Program status.

- Public awareness activities.

- Purchase orders totaling 42 pickup conversions have been placed with two vendors subsequent to the Site Operator Users Task Force (SOUTF) bid evaluations. These units will be factory-equipped with the current version of the Mobile Data Acquisition System (MDAS). To date, a few deliveries have been made.

A Program Experience Overview, the result of analyzing Site Operator inputs, provides an insight into the variables that can affect electric vehicle performance and operating cost. These variables must be considered when making comparisons with conventional ICE-powered vehicles.

Graphic treatments of composite data for the reported G-Van, Escort, Chevrolet S-10, and VW Pickup, highlight the intrinsic differences among these vehicle types, as well as reflecting site-to-site differences attributable to operating requirements and environmentally seasonal influences. Separate presentations are made of (1) energy costs; (2) maintenance costs; (3) consolidated (all sites) energy costs; and, (4) service/repair costs for specified activity groups. The influences of vehicle type/weight, operating service requirements, operating environment, and vehicle age/cumulative usage are inherent in the results of the analysis.

It is noted that lighter-weight EVs (for example, the EVcort) have better performance and maintenance records. The apparent absence of such information from the graphic composite data reflects two factors:

1. Not all Site Operators report specific operating and maintenance

2. data;

3. Some data are provided in a format that is not compatible with our analytical algorithm.

Conclusions

The conclusions reached from the overview results were:

- The larger, heavier G-Vans consume more energy than the smaller,
- lighter, Ford Escort, or the pickup trucks (i.e., Chevrolet S-10 or Volkswagen pickup).

- An electric vehicle that is used sporadically will use more energy/mile than one that is used more often, and for longer trips at uniform speeds. This is shown by the Ford Escort data.

- "Opportunity Charging" significantly affects the accuracy of the reported Site Operator data because energy added to the system during "opportunity charging" is often not recorded.

- Charging technology problems tend to impede effective utilization of EVs. These problems relate to:

  - Passenger comfort power demands

  - On-board charging equipment rate limitations

  - Charging equipment incompatibility with infrastructure features governed by local ordinance.

  - Effective solar charging has regional limitations, but may be economically feasible when surplus power can be sold via a grid connection.

- Routine maintenance costs are comparable for the four (4) types of vehicles reported, although major maintenance needs can make this difficult to detect.

Recommendations

The following recommendations are made as result of the data analysis:

- Use of in-vehicle data acquisition systems will be used to eliminate
- the effect of unrecorded "opportunity charging," and reduce the labor required to edit data records containing errors.

- The area of charging technology should be surveyed to identify (and rank) its related problems and

candidate approaches to controlling and minimizing their effects.

- More sites should report data utilizing the Site Operator Database. This would provide a larger data sample, give more reliable results, and reduce the amount of special handling required for data reported utilizing other media.

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Introduction

The Site Operator Program was initially established by the Department of Energy (DOE) to incorporate the electric vehicle activities dictated by the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976. In the ensuing years, the Program has evolved in response to new legislation and interests. The Program currently includes twelve sites located in diverse geographic, metrologic, and metropolitan areas across the United States (see Figure 1). Information is shared reciprocally with a thirteenth site, not under Program contract. The vehicles are operator-owned, except for two Griffon vans.

The Mission Statement of the Site Operator Program includes three major activities:

1. Advancement of electric vehicle technologies

2. Development of infrastructure elements necessary to support significant electric vehicle use; and

3. Increasing the awareness and acceptance of electric vehicles (EVs) by the public.

The current participants in the Site Operator Program are shown in Figure 1. Table 1 indicates the EVs in each of the Site Operator fleets. Table 2 provides baseline information on several EVs currently in use by the Site Operators, or which have evolved to the point that they may be introduced in the near future.

The Program is currently managed by personnel of the Electric and Hybrid Vehicle Program at the Idaho National Engineering Laboratory. The current principal management functions include:

- Coordination of Site Operator efforts in the areas of public awareness
- and infrastructure development (program-related meetings, and educational presentations).

- Technical and financial monitoring of programmatic activities, including periodic progress reports to DOE.

- Data acquisition, analysis, and dissemination. The data from the Site Operators are made available

to authorized users through the Idaho National Engineering Laboratory (INEL) Site Operator Database.

The ultimate thrust of program activities varies among sites, reflecting not only the Operator's business interests but also geographic and climate-related operating conditions. These considerations are identified below for each Program Status entry.

This fourth quarter report (FY-94) includes a summary of activities from the previous three quarters. The report section sequence has been revised to provide a more easily seen program overview, and specific operator activities are now found in Appendix A.

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Program Management

The Program report for the third quarter of FY-94 was issued.

Work continued on the proposed Program reorganization. A draft proposal for data collection/reporting standards presented to DOE-HQ is under review.

Two versions of MDAS have been received from Sigma Tec Systems, Inc. and are being tested at the INEL. Critical comparisons are made with the Laboratory Data Acquisition System at the INEL.

Forty-two S-10 pickup conversions are now on order from GE/Spartan and Hughes/U.S. Electricar. Thirty of these vehicles (15 from each supplier) will be delivered with current-model MDAS units installed. The MDAS permits automated real-time data acquisition for a range of pertinent operating parameters, as well as an uncomplicated data download for subsequent processing and storage. Delivery of these vehicles from U.S. Electricar has begun, with some retrofit required. GE/Spartan has so far delivered one vehicle.

Ten MDAS units are on order for use in the EV American Test Support effort involving testing at Virginia Electric Power Company.

The vehicle distribution to the ten Site Operator Program participants who have ordered them, and the type of operating environment for daily usage, are presented in Table 3.

Review of contract renewals for Program participants is essentially completed. Task recommendations will be based on funding availability. The PEPCO contract has been renewed; others will be renewed as they expire.

The Site Operator Users Task Force meeting, hosted by Platte River Power Authority, was held August 3-5, 1995 at Estes Park, CO.

The Interface Agreement between the Site Operator Program and EV America is in the review process.

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Overview

Because a principal interest, and corresponding activity, of the Site Operator Program is vehicle performance evaluation, various data acquisition and analysis methods and equipment are in use. Most recently, installation of the Mobile Data Acquisition System in 30 new Program vehicles is under way, and will provide real-time operating data. However, these vehicles will not be operated all at a single site, nor under closely similar conditions. It then becomes necessary to arrive at a sound basis for data comparisons, groupings, and statistical interpretations. The objective here is to determine how many vehicles must be tested, and for how long a time interval, to assure a 95% confidence level in the data.

A classical statistical analysis to determine this information was performed on manually gathered Site Operator Program operating data for seven Public Service Electric and Gas Co. (PSE&G) G-Vans (cargo). Similarly, multivariate analysis was carried out on MDAS data for a Virginia Power Corporation Solectria during testing at the INEL Vehicle Test Laboratory. The findings of the two different methods are in acceptable agreement.

In the case of the most common controlling event, premature battery pack failure, both statistical methods showed that three vehicles per site could be adequate for a 95% confidence level in the data. The final recommendation was for four vehicles per site, and at least 162 data samples for each vehicle. Since each sample represents a charge cycle of (generally) three or more days, the minimum sampling time period must be at least 486 days.

The principal vehicle types now used by the Site Operators, under this Program, are: G-Van, Griffon, EVcort, Ford Escort, Solectria Force, Unique Mobility, Chevrolet S-10, and Volkswagen Pickup. Site Operators that are reporting data utilizing the Site Operator Database are: Kansas State University (KSU), Pacific Gas & Electric (PG&E), University of South Florida (USF), and York Technical College (YORK). The remaining Site Operators are reporting data utilizing spread sheets, a dBase III version of the database, or Apple Computer software. These data require special handling for which algorithms have been developed to import the data. These algorithms have been utilized for reporting data for the fourth quarter of FY-94. Vehicles for which data has been reported are: G-Van, Griffon Vans, Ford Escort, Chevrolet S-10, Ford Ecostar, Mitshubishi Mirage, and Volkswagen Pickup. For the reported vehicle types, at the sites reporting, data, this section provides composites of:

- Energy Costs ($/mi) of Vehicle Operations for the Reporting Sites (Figure 2).

- Normalized Energy Costs ($/mi/klb) of Vehicle Operations for the reporting Sites (Figure 3), where normalization is with respect to the vehicle curb weight in kilo-pounds (klb).

- Maintenance Costs (maintenance $/mi) by Category of Vehicles for the reporting sites (Figure 4).

- Range of Energy Consumption (kWh/mi) for reported vehicles (Figure 5).

- Normalized Range of Energy Consumption (kWh/mi/klb) for reported vehicles (Figure 6), where normalization is with respect to vehicle curb weight in kilo-pounds (klb).

- Maintenance Costs (maintenance $/mi) of vehicles for the reporting Sites (Figure 7).

These data do not support unequivocal conclusions, although trends can often be identified:

- As with ICE-powered vehicles, maintenance requirements vary from one
- design to another and from one supplier to another. Further, increased requirements tend to accompany increased vehicle age, but the data analysis does not break out the age dependency.

- The program is just beginning to acquire new vehicles which may incorporate new technologies. At the very least, then, an initial period of defacto testing and/or debugging can be expected as these vehicles enter service.

- A restatement of power usage in terms of combined weight and mileage is a more realistic approach than mileage alone, but must, of course, be qualified by the actual weights of the vehicles compared. The results will then reflect mainly the differences in design, use, and operating environment.

A continuing overview of Site Operator Program activities, as well as outside factors which influence or impact these activities, reveals certain trends in EV technology and usage:

- Vehicle technology, both design and operational control, is showing
- definite improvement. The light vehicles (for example, EVcorts) in more modern designs, approach equivalent ICE vehicles in overall operating costs. (This conclusion is drawn from the overall Site Operator submissions, not all of which, as stated earlier, are reflected in the graphic summaries presented in this report.)

- Conversion of an ICE vehicle to electric operation may overload the vehicle structure and some operating components as a consequence of the added battery weight. Such effects are being shown by maintenance type and frequency at relatively low mileage.

- Increased EV usage is, to an extent, being encouraged by political and/or environmental mandates.

- The current principal interest in EVs is for utility vehicles; cargo (rather than just passengers) is the primary emphasis.

- Infrastructure development (e.g., curbside charging capability) is proceeding at an accelerating pace, but a variety of technically feasible approaches must be evaluated.

The raw data were supplied by the Site Operators. Energy costs are computed from the kilowatt-hours measured in charging the vehicle batteries and an assumed energy rate of $0.07/kWh. Maintenance costs include only the labor hours, and costs are computed assuming a labor rate of $23.00/hr.

The data scatter reflect a spectrum of service and assignment related variables, either separately or in combination. The principal variables are:

- The type of service, such as personnel and equipment transport, public
- demonstration, commuter service or laboratory testing.

- Operating conditions, such as terrain, climate, and ambient
- temperature.

- Vehicle weight and age.

- Component variability and age.

- Battery charging method.

- Accuracy of data input.

Tables of the data are shown in Appendix B.

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Summary

The DOE Site Operator Program currently receives input from 14 sites in the U.S.A. The participants are public utilities, educational institutions, a National Laboratory, and the U.S. Navy. (No input was received from the Navy.) The number of electric vehicles now in use or undergoing test evaluations

exceeds 175, ranging in age from new to twelve years. Body styles are mainly for utility (van or pickup) or passenger service.

Program participant efforts reflect varying combinations of day-to-day use, laboratory testing and evaluation, and successful promotion of public awareness by demonstrations, exhibits, and media dissemination of related activities and information.

The foregoing status entries provide more specific information concerning the Program participants and their overall interests, their programmatic activities, and their experiences with electric vehicles and accompanying problems.

The principal operating problem reported is a decrease in vehicle range, usually a direct result of battery pack problems, but also a function of the climate, especially the ambient temperature, in the operating environment.

The principal maintenance problems relate first to batteries and then to failures of electric components in the control systems and the powertrain.

Program management activities relate to issuance of reports, communication with sponsors (DOE) and cooperating institutions, determination of program goals/objectives, and evaluation of advanced EV-related components and systems.

An overview of Program experience, derived from the operator inputs, demonstrates unequivocally the differences in energy and maintenance costs for operating the principal types of electric vehicles used by the participants. A categorical breakdown of service/repair costs in $/km identifies the principal problem groups associated with each vehicle type. This information, presented in Appendix A, is not all-inclusive of the Site Operators; for the others, the data were either not provided or were submitted in a form that is incompatible with the Program's data-handling algorithms.

It is for these reasons that in-vehicle automated data acquisition systems will be implemented in the near future. The DOE data requirements are currently being developed for automated data systems, and a summary of these developments will be presented in a future Site Operator Quarterly report.

Despite apparent commonalities of interests among the Program participants, their individual contributions have been adequately diverse, for a variety of reasons related to equipment, operating environment, operating philosophy, and the overall objectives of each participant. The three major categories of the Program Mission appear to be well served.

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