PEVs in the M

Detroit Edison examines adoption of PEV scenarios to determine distribution system impacts.

By **Haukur Asgeirsson** *and* **Nick Carlson**, *Detroit Edison*

About 100 years ago, Henry Ford left Detroit Edison to start his own car company, said DTE Energy Chairman Tony Earley to attendees of the Edison Foundation's "Powering the People" conference held March 3, 2011. "And while he had a very successful automotive career, he also set off a revolution in the way we travel, where we live and how our nation has grown over the past century," said Earley. "Today, we are again welcoming seismic change in transportation. And that change is the world of electric cars and trucks. Electric power will transform transportation. It's already happening!

"Electric utilities are committed to making electric transportation a success," Earley continued. "Electrifying our transportation system will create new, high-quality jobs and help reduce our country's dependence on oil imports. And it's good news for the environment."

It is well known and certain that plug-in electric vehicles (PEVs) are entering the market. However, it is uncertain where and to what degree they will be adopted.

Where and When Will It Happen?

Only through accurate predictions can a utility properly

analy prepa Servi of PE Ener plicat adopt (DEW

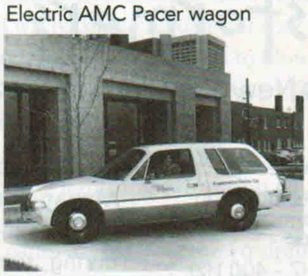
Th doml locati

Automotive History

DTE Energy/Detroit Edison is centered in Detroit, Michigan, U.S — the Motor City. So it is only fitting that Detroit Edison should be studying market adoption of plug-in electric vehicles and their effects on the utility distribution system.

Detroit Edison's electric overhead line truck, 1915

Electric AMC Pacer wagon



Limited deployment of electric Volkswagen Rabbit

Ford hybrid SUV

1915 | 1960s | 1970s | 1980s | 2009 | 2010

Model T electric taxi accumulated more than 46,000 miles in two years

Subaru electric van

A "Park & Charge" system used credit cards to track usage

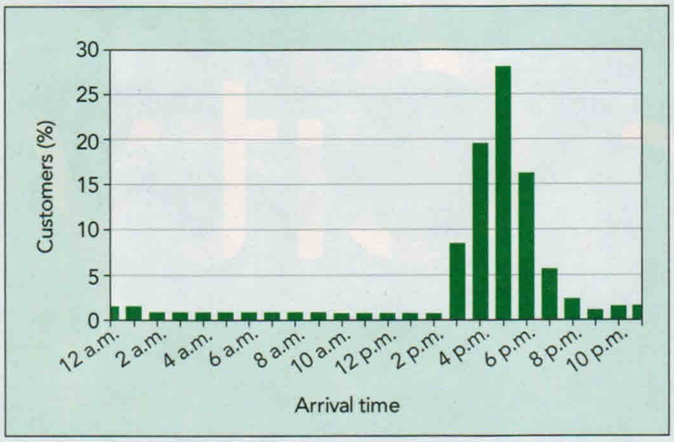
Chevrolet Volt

eMotor City

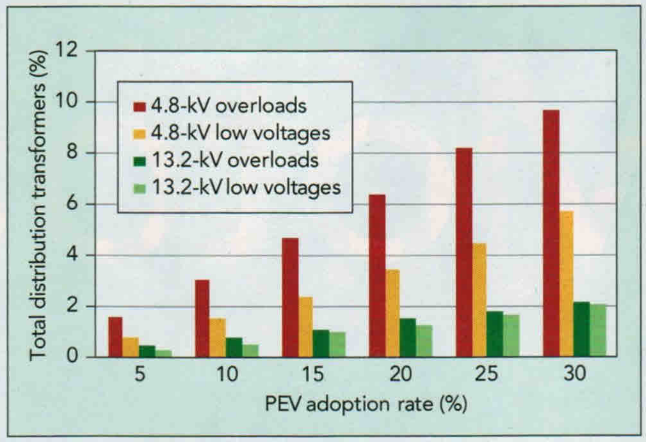
analyze the coming situation and take the steps necessary to prepare for PEVs. With support from the Michigan Public Service Commission, DTE Energy has studied the effects of PEVs on its distribution network. For this analysis, DTE Energy asked Electrical Distribution Design to create an application to aid in the analysis of the effects of various PEV adoption levels in the Distributed Engineering Workstation (DEW).

The new application uses a Monte Carlo simulation to randomly place PEVs as a function of customer class at locations on the circuit being studied. The simulation uses time-varying charging patterns to predict feeder load characteristics as a result of the new PEV loads, along with primary and secondary overloads and voltage problems that result from the PEV charging.

Since PEV technology is new to the mass market, information on how consumers will use PEVs is not available. Thus, the PEV application allows the user to assume expected patterns on how consumers will charge PEVs.



Distribution of home arrival times.



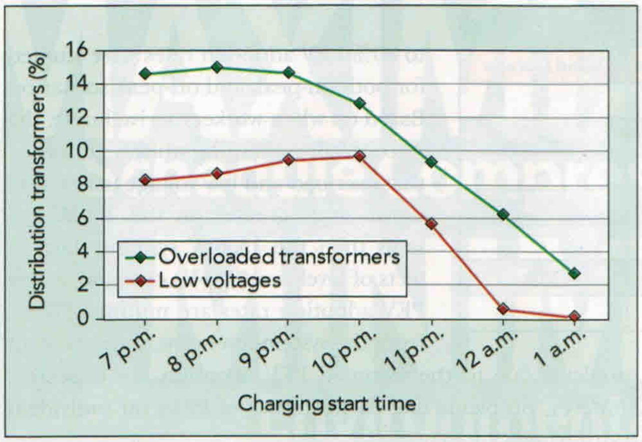
Uncontrolled charging of 4.8 kV versus 13.2 kV.

In the application, PEVs are assumed to be charged at the secondary voltage level of circuit distribution transformers as a function of customer billing class. It was assumed the battery is fully discharged when PEV charging occurs once a day. There are two likely voltages for charging: 120 V and 240 V. Both voltage levels are available for study.

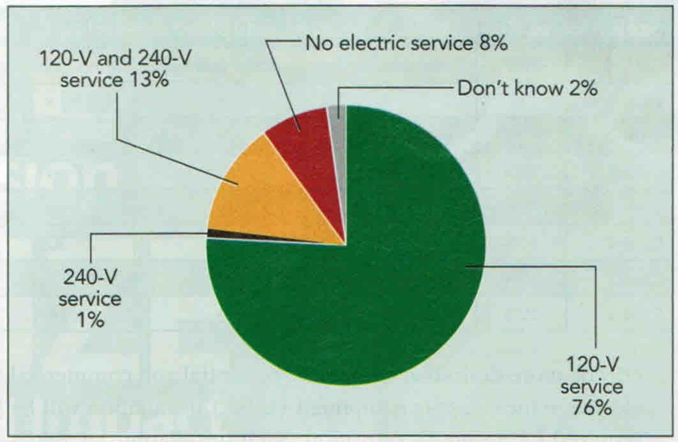
In the analysis, customer loads are estimated from averaged hourly supervisory control and data acquisition (SCADA) measurements, hourly customer kilowatt-hour (kWh) load data and monthly kWh load data processed by load research statistics to create hourly loading estimates for each customer. The PEV load, or other distributed electric resource, is then added to the specific customer's load estimate.

The application uses a PEV adoption rate as well as an annual growth rate that can extend years into the future. By applying a Monte Carlo simulation to the census data and relating travel time to miles traveled, a probability distribution of people arriving home from work was obtained. The program assumes the PEV owner will initiate recharging upon arriving home. The analysis reports both primary and secondary problems for both overloads and low voltages resulting from the PEV additions.

Using the PEV adoption application, effects of 5% to 30% PEV adoption rates were studied in both on-peak and off-peak



Results show distribution impacts of off-peak 240-V charging.



Residential electric service availability for at-home EV charging.

scenarios. These scenarios were conducted under the following worst-case assumptions:

- PEV charging occurred on the day of peak kWh consumption in 2009 for each distribution feeder analyzed.
- Batteries were fully depleted at charging start time and continued charging until full.
- In on-peak studies, PEV charging start times were distributed among customer arrival times at home after work.
- In off-peak studies, all PEVs began charging at the same time.

The 109 distribution feeders chosen for DEW analysis are fed from heavily loaded substations in expected early adopter areas of Detroit Edison's service area serving 106,993 customers fed from 11,368 distribution transformers.

Modeling the Impacts of PEVs

Since EVs have never been present on a mass scale, consideration must be given to a number of items regarding the initial takeoff of this technology.

Although today's PEVs are being designed to allow plugging in to a standard 120-V home electrical outlet, a 240-V option has the ability to cut the charging time in half. This could mean saving anywhere from 4 hours to 8 hours, depending on the PEV's battery capacity. The faster option will undoubt-

Scenarios of Renewable Resources Adoption Analysis

	PEV	Solar generation	Solar storage	Wind generation	Wind storage
Base	×	×	×	×	×
Case 1	10%	×	×	×	×
Case 2	10%	30%	×	×	×
Case 3	10%	×	30%	×	×
Case 4	10%	×	×	30%	×
Case 5	10%	×	×	×	30%
Case 6	10%	10%	×	10%	×

edly be more desirable; therefore, residential and commercial electric vehicle supply equipment (EVSE) installation will be required for a smooth transition. Such installations, depending on the age and status of home electrical panels, also could require an upgrade to this panel.

EVSE installation is already underway, in support of electric vehicles (EVs) that entered service in late 2010. Only 14% of customers currently have 240-V access.

Distribution System Effects

The two main objectives of the electrical system impact studies are to understand various PEV adoption scenarios and to find charging start times to mitigate these effects.

The greatest impact on the grid in Michigan generally occurs during the summer when high ambient temperatures are >90°F (>32°C) along with high humidity. The effects of 5% to 30% PEV adoption rates were studied for both on-peak and off-peak scenarios. Based on when workers arrive home, the uncontrolled charging study determined that overload and low-voltage issues were significantly greater on the 4.8-kV systems than the 13.2-kV systems. The effects of level two (240-V) charging at low PEV adoption rates are minimal. Thus, from the system-level view, no significant problems due to the assumed PEV adoption are expected. However, problems due to clustering of PEVs on individual transformers are expected.

The analysis showed that transformer overloads peak around 8 p.m. and begin to decrease drastically after 11 p.m. Problems caused by localized residential PEV adoption can be significantly reduced by charging during off-peak hours beginning after 11 p.m. This was the basis for implementing a new EV time-of-use rate (approved by the Michigan Public Service Commission in August 2010) with the off-peak rate starting at 11 p.m. Off-peak pricing can save customers up to 40% on their annual PEV charging costs and defer distribution infrastructure upgrades.

The bottom line is the Detroit Edison electric distribution system is able to handle the increased load from the initial fleet of PEV adoption with little investment in infrastructure upgrades. Off-peak vehicle charging (after 11 p.m.) can reduce costs and defer investments in distribution infrastructure upgrades while still allowing vehicles to receive a full charge by morning. It is also possible that incentivizing customers to charge during off-peak hours can be done with time-of-use pricing.

System Perspective

The distribution system modeling study has provided valuable insight into the impact EVs will have on the electric utility's distribution system. Since the growth and adoption of EVs is expected to be relatively slow in the coming years, the anticipated impact EVs will have on the electric distribution system will be minimal. However, there is potential that a high concentration of these vehicles in certain areas may cause local transformer overloads and low voltages even in the near term.

The study confirms that major infrastructure problems for electric utilities can be mitigated if charging can be controlled (managed) during periods of peak demand. Incentivizing customers to charge during off-peak hours not only minimizes potential power-quality-

Understanding Customer Demographics

A key factor in predicting the takeoff of PEVs is developing a demographic profile of the typical customer. For this purpose, DTE Energy conducted focus groups and surveyed 1,016 members in its service territory. The following data was extracted from this survey.

Respondent Characteristics

- Overall, the sample population was middle-aged, educated and affluent.
- Only 14% of respondents already have access to 240-V electric service where they park at home.
- The majority of respondents reported driving less than 50 miles/day (80.5 km/day), with about half driving less than 30 miles/day (48.3 km/day).
- Respondents spend about 60% of their time driving at less than 50 mph.

Public Infrastructure Expectations

- At least on an occasional basis, anticipated public-charging station usage increased significantly when respondents were given a fast-charge option (10-minute to 15-minute full charge).
- 74% of respondents indicated that public fast-charging facilities will influence their decision to purchase a PEV.
- Given a home-charging cost of US$0.81/full charge, respondents are willing to pay an average of $1.40/full charge at public fast-charging facilities.

Charging Rate/Payment Scenarios

- The majority of respondents prefer to have the ability to charge at any time but still receive a discount if they deferred their charging to late evening.
- Strong PEV considerers were significantly more likely to opt for interruptible service and alternative energy sources for their PEV charging.

From this information, early adopters most likely will use standard 120-V outlets to charge their vehicles at first due to a lack of 240-V service. Over time, seeing that a faster charge is more desirable, it is expected that some customers will install EV supply equipment to enable 240-V home charging.

related issues for the customer, but also alleviates the need for upgrading transmission or distribution infrastructure in the near term.

Detroit Edison plans to continue studying the impacts of EVs on the electric distribution system through its own EVSE pilot project as well as a General Motors/U.S. Department of Energy Vehicle electrification demonstration. These ongoing demonstration projects will allow Detroit Edison to better understand customer charging behaviors, including battery state-of-charge levels and battery capacity. These projects will provide key data that will ultimately improve the accuracy of future studies.

Considering just the adoption of PEVs does not paint a complete picture of the future. The adoption of solar generation, wind generation, storage and other distributed resource technologies should be considered, and these technologies may help to offset the adoption of loads.

Distributed Resources Impact

After the PEV adoption program was completed for DTE Energy, the National Renewable Energy Lab funded the further development of the application to examine solar, wind and battery storage technology adoption. The expanded application enabled studies of the simultaneous adoption of the various technologies. One objective was to evaluate adoption levels of solar and wind generation supplemented with battery storage that would offset the adoption of EV loads.

The investigation analyzed the inherent variation in the performance of renewable energy resources by evaluating the exact same circuit during winter and summer loading conditions with different scenarios of renewable energy penetrations with and without storage. Because of the non-dispatchable characteristics of solar and wind, a significant impact on the load duration curve was not apparent until storage was included in the mix. TDW

Haukur Asgeirsson (asgeirssonh@dteenergy.com) is the manager of Power Systems Technologies at DTE Energy. Currently, he is managing grants related to PEVs, energy storage and solar integration, and the effect of distributed energy resources (DER) connecting to the grid. He is also responsible for managing a mobile fleet of DER for supporting distribution circuits and managing all DERs interconnecting to the Detroit Edison electric system. Asgeirsson holds BSEE and MSE degrees from the University of Michigan and is a registered professional engineer.

Nick Carlson (carlsonn@dteenergy.com) is a senior engineer at DTE Energy. He is currently responsible for managing various smart grid and PEV activities. Much of his recent focus has been on electronic transportation and infrastructure as well as distribution applications of energy storage technologies. Carlson holds a BSEE from Michigan Technological University and a MBA from Wayne State University.

Editor's note: The IEEE general meeting will be held on July 26-29, 2011, in Detroit. The transactions paper "Evaluation of DER Adoption in the Presence of New Load Growth and Energy Storage Technologies" will be presented and will expand considerably on the content of this article. The co-authors of this paper and implicit contributors to this article were: Jaesung Jung, Haukur Asgeirsson, Thomas Basso, Joshua Hambrick, Murat Dilek, Richard Seguin and Robert Broadwater.

Companies mentioned:

DTE Energy **www.dteenergy.com**
Edison Foundation **www.edisonfoundation.net**
Electrical Distribution Design **www.edd-us.com**
IEEE **www.ieee.org**
Michigan Public Service Commission **www.michigan.gov**
National Renewable Energy Lab **www.nrel.gov**
Department of Energy **www.energy.gov**