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DTE

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May 27, 2020

Ms. Lisa Felice
Executive Secretary
Michigan Public Service Commission
7109 West Saginaw Highway
Lansing, Michigan 48917

Re: In the matter of the Application of DTE Electric Company for authority to increase its rates, amend its rate schedules and rules governing the distribution and supply of electric energy, and for miscellaneous accounting authority.
MPSC Case No. U-20162

Dear Ms. Felice:

Attached for electronic filing in the above-captioned matter is DTE Electric Company's May 2020 Electric Vehicle-Grid Impact Study Summary Report.

Very truly yours,

Kelly M. Martorano
Digitally signed by Kelly M. Martorano
Date: 2020.05.27 15:47:48 -04'00'

Kelly M. Martorano

KMM/erb

Electric Vehicle-Grid Impact Study Summary Report

May 2020

DTE

TABLE OF CONTENTS

EXECUTIVE SUMMARY

As the popularity of electric vehicles (EVs) increases in the United States (US), it is important to understand the impact that these vehicles could have on electrical system infrastructure. This study seeks to identify power quality issues that emerge across various EV penetration scenarios and at what point the grid experiences violations that would require consequent action.

A representative sample of DTE circuits was analyzed, and propensity modeling mapped EV locations to the transformer level on the set of circuits. Class 1-8 vehicles and charging up to 500 kW were considered for the study. While EV impacts are extremely dependent on the specific circuit infrastructure and load allocation, the study has concluded the following at a high level:

- Up to 20% of EV penetration can be accommodated on many circuits without major upgrades, but clusters of early, high adoption will require localized investments.
- Because the timing of widespread EV adoption is uncertain, the suitability of grid infrastructure, planning criteria, and standards should continue to be evaluated and incorporated into DTE's multi-year standards update cycle. For example, where applicable, running three-phase wires to more premises will help reduce phase imbalance and deploying larger distribution transformers will mitigate unnecessary, expensive upgrade costs in the future.
- Continuing to pilot managed charging solutions and alternatives to infrastructure upgrades like battery storage will be important to minimize distribution system investment as EV penetration increases.

A key challenge is both timely and prudent investments in increasing the distribution capacity and voltage to support EVs while balancing customer affordability. This study provided engineering and planning tools to perform circuit impact scenario analysis, which can be extrapolated to similar circuit configurations and voltages to assess the potential infrastructure needs required. The infrastructure investments to support EVs will be incorporated in future distribution investment and maintenance plans.

INTRODUCTION AND PURPOSE

Several EV penetration scenarios were evaluated on DTE Electric (DTE) circuits to identify potential issues as adoption increases. These scenarios do not represent DTE's forecasts or a specific timeline of EV adoption. For the purposes of the study, time was not a factor in determining impacts, only the level of EVs in DTE territory.

The study's goals were to assess the impact of modern plug-in hybrid (PHEVs) and battery electric vehicles (BEVs) on DTE's distribution system (grid or system) and to determine at what levels of EV adoption the grid experiences violations that would require consequent action. A cross section of 12 representative DTE circuits were assessed at increasing EV penetration levels. The circuits were analyzed for equipment overloads, voltage, and power quality issues caused by EV charging for a wide range of customer and vehicle types.

The study did not consider the following items as they require location-specific factors that are difficult to extrapolate: in-road charging, managed charging, extreme fast charging for passenger vehicles larger than 150 kilowatts (kW), home chargers larger than eight kW, comprehensive electrified public transport, off-road vehicles besides agriculture (such as construction or on-site logistics vehicles), long-haul logistics centers, and autonomous vehicles.

STUDY STRUCTURE AND ASSUMPTIONS

As stated in the Order from proceeding U-20561, DTE committed to *"provide clear and explicit […] assumptions regarding EV adoption and charging"* in the summary report (p. 212). The study assessed EV penetration levels based on the total number of vehicles (EV and non-EV) that are currently present on the selected circuits. Benchmarking other utilities indicated that evaluating penetration at a vehicle-basis (compared to a load-basis) level was much more demonstrative of the impacts that would be seen.[1] There are over four million vehicles in DTE territory, with many households having between two and four vehicles.[2] Vehicle information was mapped to the circuit information to get an accurate picture of transportation electrification. This allows relatively easy mapping and assessment of impacts to the grid at various adoption scenarios.

Using propensity models from California and Arizona utilities as a benchmark, 1%, 2%, 10%, 20%, 30%, and a scaling model for higher levels were used as penetration scenarios for EVs as a percent of total vehicles on the circuit. As described above, these scenarios are not time-bound, but Table 1 highlights the approximate number of EVs to which they correspond. For reference, there are approximately 13,500 EVs on the road today in DTE territory.

Table 1: EV Penetration Scenarios and Corresponding Volumes

Penetration Scenario	DTE EV Volume
1%	40,000
2%	80,000
10%	400,000
20%	800,000
30%	1,200,000

Propensity modeling for residential EVs incorporated EV purchase trends, income level, education level, and number of household vehicles. Business EV propensity assessed the type of business, number of parking spots, and known fleet vehicle information. All vehicles were then categorized by profile type and assigned a charging level, which is described in more detail in the next section. Each type of vehicle was assigned the same percent level of penetration for each scenario. For the purposes of the study, actual parking spots and vehicle counts were made to assess the level of utilization at various times, and vehicle loads were assigned to the appropriate transformers on the circuit models.

The study utilized the following data sources:

- S&P Global for names, locations, and North American Industry Classification System (NAICS) codes for each business;

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[1] Industry benchmarking on EV penetration and propensity modeling approaches from utilities in California, Arizona, Hawaii, and North Carolina

[2] Equifax Mosaic data set and Zip+4 census data

- Census datasets using the Environmental Systems Research Institute (ESRI) Enrich Tool for vehicle and household counts per circuit and vehicle count per household;
- Hoover for information that affects EV purchase and public charging behavior;
- Equifax for household data and other factors that influence EV purchase;
- Google Maps/Earth for confirmation of other data sources, business vehicle and parking spot counts, and assessment of agriculture (including number of silos, diversity of equipment, cultivatable acreage and use, livestock pens, etc.).

TYPES OF EVS AND CHARGING

The Department of Energy (DOE) defines eight classes of vehicles based on weight, which typically determines power and energy consumption. Therefore, these vehicle classes can help determine the average charging level of each vehicle. The Society of Automotive Engineers (SAE) defines four levels of charging: AC Level 1 (AC1), AC Level 2 (AC2), DC Level 1 (DC1), and DC Level 2 (DC2). Since AC1 power output is low and impractical for wide propagation of EVs, it is assumed to be AC2 in the study. An overview of the vehicle definitions and primary charging levels is shown in Table 2.

Table 2: Overview of Charging Levels and DOE Vehicle Classes

SAE Charger Level	DOE Vehicle Class	Vehicle Descriptions	Charging Rates / Grid Demand
AC2	Light Duty (Class 1-2) < 10,000 pounds	Passenger vehicles, full-size pickups, vans, and box trucks	7.8 kW
DC1	Medium Duty (Class 3-6) 10,000-26,000 pounds	Box trucks, heavy-duty pickups, school buses, delivery vans, utility trucks, and single-axle semis	50 kW
DC2	Heavy Duty (Class 6-8) > 26,000 pounds	Garbage trucks, city buses, tractor trailers, and cement trucks	500 kW

Passenger vehicle charging was assumed to be primarily home and workplace charging. Commercial and fleet vehicle charging at workplaces was based on the NAICS business code and expected operating hours of the business. DC1 was considered for Class 1-2 vehicles at business locations and Class 3-5 vehicles at locations where they were not garaged. Depending on the business code, the charging occurred during loading times for delivery vehicles or after hours for fleet trucks. Farm equipment charging was assessed based on agricultural patterns and seasonality.

SCENARIO CREATION AND CIRCUIT MODELING

Five grouping categories for circuits were chosen based on key physical characteristics that have impacted other modeling efforts in California, Hawaii, and North Carolina. The purpose of grouping the circuits was to evaluate impacts to DTE infrastructure based on different factors including circuit voltage, location (rural vs. urban), number of customers, and quantity of transformers over 100 kilovolt-amps (kVA). Twelve circuits were selected where up-to-date models and load data had been prepared from prior studies. The set of circuits are a representative sample of DTE's overall distribution infrastructure and are shown in Table 3 along with the grouping definitions.

Table 3: Circuit Grouping Categories and Selection

Group	Definition	Circuit	Substation	Location
1	13.2kV underground circuits - primarily in newer, suburban areas	AGSTA8718	Augusta	Macomb
		GRAYL8517	Grayling	Shelby Twp.
2	13.2kV mixed overhead/underground circuits - residential & commercial	APACE9017	Apache	Troy
		BECK8695	Beck	Roseville
3	13.2kV circuits with sections operating at 4.8kV	HINES9416	Hines	Livonia
		PHENX9846	Phoenix	Ann Arbor
		PINCK9878	Pinckney	Pinckney
		VICTR8721	Victor	Lenox
4	4.8kV urban circuits, including ringed circuits	CHIGO1415	Chicago	Detroit
		WHITR2750	Whittier	Royal Oak
5	4.8kV long circuits - primarily rural	BNGHM0302	Bingham	Ubly
		DERBY2604	Derby	Vassar

The following six base load scenarios were used:

- Spring Day – Spring day when solar irradiance was highest and demand was lowest;
- Spring Night – 11pm of Spring Day;
- Summer Day – Summer day peak hour;
- Summer Night – 11pm of Summer Day;
- Winter Day – Winter day peak hour; and
- Winter Night – Winter night peak hour.

Once these scenarios were selected and charging locations mapped to transformers based on the propensity analysis, several circuit analyses were performed for each penetration scenario, including load flow and voltage assessments in the distribution planning tool. Heat maps were created to visualize circuit areas which showed load density at different times of year and daytime vs. nighttime. Furthermore, these maps were colored to show voltage issues along the distribution system and pinpoint troubling areas within each circuit. Overall circuit loading was also compared to existing equipment ratings at the start of circuit and in the substation to assess the need for voltage and capacity upgrades.

CIRCUIT ASSESSMENT

Tables 4 and 5 show an example of the assignment of the vehicle loads by type and the increase to the circuit loading for one of the study circuits at different penetration levels.

Table 4: Demand Increase on PHENX9846 at Peak Charging by Profile (in kW)

EV Scenario	Residential (AC2)	Business (AC2)	Retail (AC2)	Private Transport (DC1)	Fleet (AC2)	Total
1%	255	0	0	0	0	255
2%	563	0	0	0	0	563
10%	1,545	405	120	0	15	2,085
20%	3,090	863	248	50	23	4,251
30%	4,635	1,268	368	100	38	6,409

Table 5: PHENX9846 Summary Table for Summer Night

	1%	2%	10%	20%	30%
Peak Demand[3] (Megawatt, MW)	6.7	7.0	8.5	10.7	12.8
Number of EVs	34	75	278	564	843
Transformer Overloads (%)	<1%	1%	8%	10%	15%
Transformer Undervoltages (%)	4%	13%	26%	30%	45%
Line Overloads Length (feet)	458	458	1,091	1,269	1,506

Modeling load flow and comparing load flow densities illustrate that as penetration increases, relative nighttime loads increase, causing broader EV charger-specific system issues at 10% penetration and above for this specific circuit. Summer Night generates the most voltage and overload issues, as it has the highest nighttime baseline load of any season. The scenario analysis also indicated several types of impacts from EV penetration including overloaded single-phase transformers that serve multiple customers and overloaded conductors. At higher penetrations, some circuits will exceed their operability ratings and will demonstrate constraints for load switching for planned work and trouble restoration. EV impacts are extremely dependent on specific circuit configuration, infrastructure condition, and load allocation. For example, on a small number of circuits, 2% penetration can require upgrades, while for other circuits, 100% penetration may not cause major problems on the existing infrastructure. The average circuit sees a shift to nighttime summer peaking at 20% and starts to see equipment issues between 20 and 30 percent EV penetration. Voltage or capacity upgrades will be required on most circuits at higher levels of EV penetration.

Imbalance

If multiple neighbors install chargers on a single phase, or a circuit has a disproportionate number of smaller customers on a single phase, the circuit has the potential to have rapidly imbalanced phasing as EV penetration levels increase. EV penetration quickly exacerbates existing imbalances, particularly in open-delta configured sections found in the 4.8kV system. Phase balancing or deploying three phases on laterals and services should be considered for future circuit reconfigurations.

Figure 1 below shows residential EV locations (based on propensity modeling) for the 10% penetration scenario on PINCK9878 color coded based on the phase to which those EVs and lines are connected. In this example, a daytime imbalance is significantly worsened by workplace charging, and load imbalance reaches as high as 50% during nighttime home charging. The worst cases occurred during the summer, but imbalance in all seasons increases. This adds considerable loading stress to the distribution equipment on the phase with the higher number of EVs. EV charging can be highly clustered on single-phase lines leading to large imbalance causing overloads and voltage issues on areas of the circuit. Much of DTE’s system is constructed of single-phase lines.

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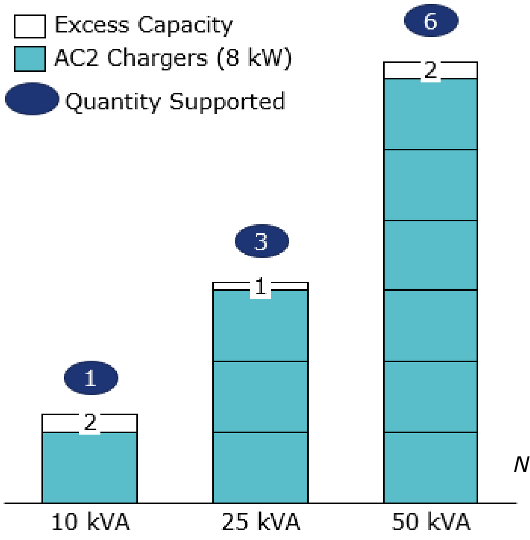
[3] Includes 6.4 MW of base load

Figure 1: Phases of EV Charging Locations on PHENX9846 at 10%

Distribution Transformer Overloads

Based on the propensity analysis, some smaller transformers (less than 25 kVA) will be overloaded by 200% or more and will need to be upgraded sooner if there is a pocket of adoption well before general adoption on the circuit reaches higher levels. As shown in Figure 2, the smallest transformers can only accommodate one AC2 charger but may have a few customers connected to them currently.

Figure 2: Depiction of Number of AC2 Chargers Standard Transformers Can Accommodate



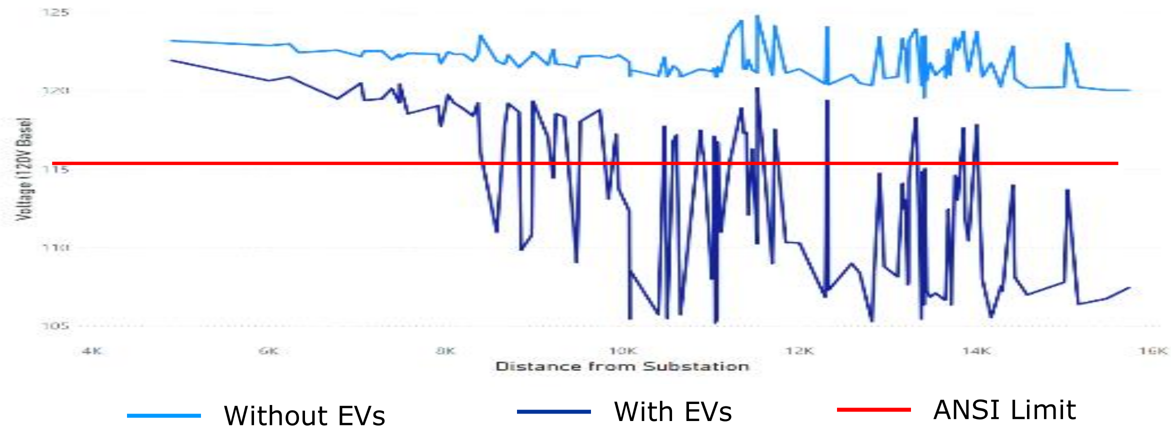
Note: Assumes no other load

Of the 450,000 transformers on DTE’s system, more than 35% are 25 kVA or smaller. These can only accommodate one to three chargers concurrently but typically have four to five customers connected. In the future, these customers may have more than one EV to charge or have vastly higher demand as automakers move to larger AC2 chargers (e.g., from 8kW to 20kW and up).

Voltage Drop

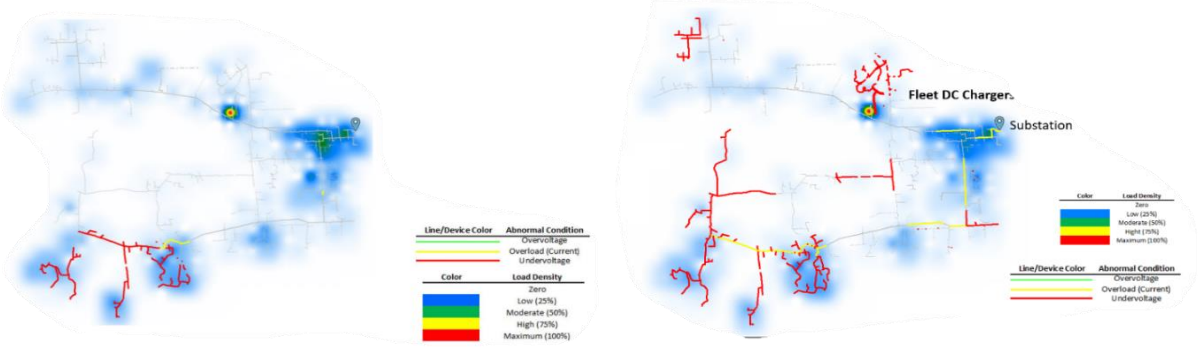
The farther a customer is from the substation, the more the voltage at the customer is reduced as load is added due to resistance in the wires. Figure 3 shows a voltage profile of a circuit studied with unmitigated voltage impacts due to the addition of 30% EV loads. The average voltage drops significantly with EV penetration, which can lower the voltage below the American National Standards Institute (ANSI) acceptable limits for normal operation. This voltage drop is sustained for the duration of the heavy charging periods when the circuit is under high loads.

Figure 3: Summer Night Voltage Profile vs Distance



In the next example, at 10% penetration, low voltage is seen in both older residential areas with small wires and residential areas farther from the substation. At 30% penetration, many additional areas begin to have under-voltage as shown by the red lines in Figure 4.

Figure 4: Summer Night Circuit Impacts from Increased EV Penetration[4]



10% EV Penetration

30% EV Penetration

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[4] Yellow lines represent overcurrent (design limit of the lines is overvoltage because of the demand downstream); Shaded areas represent overloading of 50% (green), 75% (yellow), and 100% or higher (red)

KEY TAKEAWAYS

- Up to 20% of EV penetration can be accommodated on many circuits without major upgrades, but it is likely that many pole-top transformers and secondary wires will be too small to support the added load where clusters of multiple residential vehicles will be charging.
- Commercial and industrial locations with numerous fleet EVs or parking garages may not be able to be served with the existing infrastructure and will likely create exceptionally dense concentrations of loads requiring locations to be served from higher voltages and potentially dedicated industrial stations (even if the overall industrial load decreases).
- Many circuits will start to experience load imbalance issues on more remote, single-phase sections or in areas with high concentrations of load. Penetration above 20% causes phase imbalance to increase and day-to-day circuit operating limits to become an issue, so operability of the system may be constrained during peak loading times (because of the inability to shift load to adjacent areas).
- As penetration increases above 20%, voltage drops and higher system losses will increase, and many circuits will become nighttime peaking.
- Much of DTE’s system is comprised of single-phase lines, which will restrict where three-phase DC1 and DC2 chargers are sited in the future as demand for fast charging grows.
- Public fast charging (DC1) is more variable and harder to predict than home or workplace charging (AC2). Currently, DC1 charging is clustering at larger commercial locations with two to ten fast chargers in a location, leading to large variable loads.
- Workplace daytime managed charging will be constrained by vehicle dwell time and charger power levels. Attempting to move renewable energy from utility scale solar to daytime urban parking areas may be an issue where capacity will be highly constrained already. For example, at 100% penetration of workplace charging in Ann Arbor, daytime increases for charging will expand current peak from 25 MW to over 75 MW.

Potential Solutions

- At current replacement rates for distribution conductors and equipment in the US, infrastructure installations done today will still be in use in 2080.[5] Prudent changes in standards to upgrade items like insulators, conductors, and distribution transformers could prevent rework in the future.
- Planning for EV charging in new commercial installations and parking garages is necessary to make them EV-ready. Similar changes to building codes and standards for service in new homes or neighborhoods should also be considered. In the long run, this will reduce the chance of fires from overloaded household circuits in homes and garages.
- Changing the utility planning standards to run three-phase to more premises on the circuit will help reduce phase imbalance, provide more location options for siting DC1 charging, and have the side benefit of back-feeding more circuits, allowing faster restoration in an outage.

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[5] FERC Form 1 1994 to 2018 replacement rates for distribution

- Voltage or capacity upgrades including changes in conductor and insulator standards, pole classes and spacing on the pole top including change in conductor and insulator standards, taller poles, can be anticipated with a rebuild for sections of the circuits to accommodate increasing EV penetration and to provide a more resilient system. Deploying 50 or 100 kVA transformers in the future (instead of 25 kVA) is prudent, since the installation costs outweigh the equipment costs.
- It is likely that residential managed charging can reduce demand by up to 40%. Continuing to pilot managed charging to shift charging times will help determine both willingness of customers and potential value to the grid.
- Some DC1 load can be mitigated with local battery storage, and pilots should help define storage sizing and identify operational issues to develop this solution as a non-wires alternative (NWA).

Conclusion

The electrical system overall can support substantial amounts of EV adoption compared to today's EV penetration. However, clusters of high penetration may require upgrades. Significant installations of commercial, fleet and workplace charging can be handled through existing method of service and industrial planning practices.

While it is inevitable that early clustering of high adoption will require localized investments in grid infrastructure, the uncertainty on the timing of when widespread adoption will occur encourages the continued evaluation of the suitability of grid infrastructure, planning criteria, and standards to support the increasing levels of EV penetration. Additionally, programs and systems to manage charging and shift EV load to low load periods should continue. Examples of those programs include demand response, time-of-use pricing plans, and battery storage integration.

A key challenge is both timely and prudent investments in increasing the distribution capacity and voltage to support EVs while balancing customer affordability. The infrastructure investments needed to support EVs will be discussed in future distribution investment and maintenance plans.