EV and Charging Station Trends and Their Effect on the Electrical Network

Presentation to the IIEE 43rd National Annual Convention

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Electric Dreams
I only knew you for a while
I never saw your smile
Till it was time to go
Time to go away (time to go away)
Sometimes it's hard to recognise
Love comes as a surprise
And it's too late
It's just too late to stay
Too late to stay
We'll always be together
However far it seems
(Love never ends)
We'll always be together
Together in electric dreams
Because the friendship that you gave
Has taught me to be brave
No matter where I go, I'll never find a better prize
(Find a better prize)
Though you're miles and miles away
I see you every day
I don't have to try
I just close my eyes
I close my eyes
We'll always be together
However far it seems
(Love never ends)
We'll always be together
Together in electric dreams
Electric Dreams
EV 101
There are different types of electric vehicles, but not all require that they be plugged in. From the transitory HEV & PHEVs, more pure plug-in models are coming.

**What is an EV?:** Electric vehicles (EVs) use electric motors instead of an internal combustion engine (ICE) to propel a vehicle. The electric power is derived from a battery of one of several chemistries including lead acid, nickel metal hydride (NiMH) and lithium-ion (Li-ion).

**Types of EVs:**

- **HEV**
  - use an internal combustion engine supported by electric motors and a battery, but don't need to be charged
  - Toyota Prius
  - Honda Insight
  - Lexus CT200h
  - Lexus 450h

- **PHEV**
  - similar to HEVs, but the battery can be charged when the vehicle isn’t in use
  - Toyota Prius Prime
  - Chevy Volt
  - Toyota Prius Plug-in
  - Cadillac ELR
  - Lexus CT200h
  - Mercedes GLE 550e
  - Mercedes S650e

- **BEV**
  - use electric motors powered by a battery that needs to be plugged in to a charger
  - BMW 740e
  - Chrysler Pacifica Plug-in
  - Ford Fusion Energi
  - BMW X5 xDrive40e
  - Ford C-Max Energi
  - Volvo XC90
  - Audi A3 e-tron
  - Toyota Prius
  - Honda Insight
  - Lexus CT200h
  - Lexus 450h
  - Toyota Prius Prime
  - Chrysler Pacifica Plug-in
  - Ford Fusion Energi
  - BMW X5 xDrive40e
  - Ford C-Max Energi
  - Volvo XC90
  - Audi A3 e-tron

- **BEV with DC Fast Charge**
  - BEVs equipped with batteries capable of DC fast charging
  - Toyota RAV 4 EV
  - Honda Fit
  - smart EV
  - Mercedes B Class
  - Fiat 500 E
  - Mitsubishi Outlander
  - Chevy Bolt EV
  - Nissan LEAF
  - BMW i3 
  - Tesla Model S
  - Tesla Model X
  - Kia Soul EV
  - Mitsubishi i-MiEV
  - Hyundai Ioniq Electric

**Plug-In Models**

35+ currently available with many more coming

*Source (modified): Charge Point, Electric Vehicle Charging Stations: Advancing Smart Transportation*
There are also different charging levels, which require different sets of electrical infrastructure, but drastically affect the charging times for EVs

<table>
<thead>
<tr>
<th>Connector Type &amp; charging protocols</th>
<th>Level 1</th>
<th>Level 2</th>
<th>DC Fast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Specs</td>
<td>240 Volts AC 12-16 Amps (typical home appliance)</td>
<td>240 Volts AC 16-32 Amps (aircon / home washer &amp; dryer)</td>
<td>400/480 Volts DC 70-125 Amps, Three phase</td>
</tr>
<tr>
<td>Est. Range Added Per Hour of Charging</td>
<td>~5-8 kilometers</td>
<td>~20-40 kilometers</td>
<td>~160-320 kilometers++</td>
</tr>
<tr>
<td>Battery Applicability</td>
<td>Lead acid, Lithium-ion</td>
<td>Lithium-ion</td>
<td>Lithium-ion</td>
</tr>
<tr>
<td>Typical Time for Full Charge</td>
<td>8-12+ hours</td>
<td>~2-4 hours</td>
<td>~15-45 mins (@80%)</td>
</tr>
</tbody>
</table>

Source (modified): Charge Point, Electric Vehicle Charging Stations: Advancing Smart Transportation
EV charging can be done in various locations, from the comfort of one’s home, to a shared (private-public) facility, and up to fully commercialized set ups

<table>
<thead>
<tr>
<th>Home (Private) Charging</th>
<th>Semi-Public Charging</th>
<th>Public Charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle charging at users residences, in their garages, drive ways and at apartment complexes as well as street residential spaces. Generally it is expected to be slow charging (Level 1) and can be used to charge EVs overnight. Home charging takes 8 to 12 hours for complete battery charging</td>
<td>Vehicle charging at office workplaces which can charge company-owned and publicly-owned fleets. These too are also similar to home charging, which is expected to be mostly slow charging (level 1) apart from this they maybe fast charging (level 2) portable ones also. Its takes 2 to 3 hours for a complete charge</td>
<td>The non-residential and non-workplace charging to cater to public EV charging requirements. Expected to be a combination of fast charging (Level 2) and rapid charging (Level 3) for quick top-ups of battery power. Charging at this level is within a few minutes</td>
</tr>
</tbody>
</table>

| Homes and residences | Workplaces, Residential condos and apartments, Public utility vehicle depots, Leisure centers and sports facilities, Campus grounds, Retail outlets, Community facilities, Rail stations, Parks and green spaces, etc. | Fuel stations, Malls, City and town centers, Stand-alone outlets and restaurants, Highway stops, etc. |

- Source (modified): Frost & Sullivan, Outlook for the EV Market and Charging Infrastructure
Global EV Trends
Trend #1: EV sales continue to grow, topping 3 million units in 2017, but only a number of countries account for the major sales

EVs see record sales again in 2017

Over 1 million electric cars were sold in 2017 – a new record – with more than half of global sales in China. The total number of electric cars on the road surpassed 3 million worldwide, an expansion of over 50% from 2016.

Only a handful of countries have significant market share

In terms of share, Norway remains the world’s most advanced market for electric car sales, with over 39% of new sales in 2017. Iceland follows at 11.7%, then Sweden at 6.3%.

Driven by:

✓ Gov’t support & mandate
✓ User Incentives
✓ Tax-breaks / subsidies
✓ Higher tax on ICE vehicles
✓ Low RE prices
✓ More expensive fuel cost

Source: Global EV Outlook 2018 (www.iea.org)
Trend #2: Home (private) charging is still the main source of power for EVs, which is a concern for large-scale commercial deployments that need long travel range.

Private chargers continue to outnumber publicly accessible infrastructure

Private chargers at homes and workplaces were estimated to number almost 3 million worldwide in 2017. In addition, there were about 430,000 publicly accessible chargers worldwide in 2017, on one quarter of which were fast chargers. Fast chargers are especially important in densely populated cities and are also essential to increase the appeal of EVs by enabling long distance travel.

Charging outlets

- Highlights:
  - 3 Mn private (slow) chargers
  - Only 430k public fast chargers
  - 1 EV : 1.15 chargers

Source: Global EV Outlook 2018 (www.iea.org)
Trend #3: Lithium-ion prices have continued to go down as manufacturing volumes (due to EV sales) have increased through the years.

- ~ $190/kWh currently (80% drop since around 2010)
- ~ $100/kWh by 2020 (est.)

Notes: Axes are on a logarithmic scale. Electronics refer to power electronic batteries (only cells); electric vehicles refer to battery packs for EVs; utility and residential storage refer to Li-ion battery packs plus power conversion system and includes costs for engineering, procurement and construction.

Source: Adapted and updated from Schmidt et al. (2017).

Source: Global EV Outlook 2018 (www.iea.org)
Trend #4: Current battery factories have capacities of up to 8 GWh/year while those announced to come online will have capacities of up to 35 GWh/year

- Will help ensure lower EV battery prices
- Will support further production of EV models

<table>
<thead>
<tr>
<th>Country</th>
<th>Manufacturer</th>
<th>Production capacity (GWh/year)</th>
<th>Year of commissioning</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>BYD</td>
<td>8</td>
<td>2016</td>
<td>TL Ogan (2016)</td>
</tr>
<tr>
<td>United States</td>
<td>LG Chem</td>
<td>2.6</td>
<td>2013</td>
<td>BNEF (2018)</td>
</tr>
<tr>
<td>Japan</td>
<td>Panasonic</td>
<td>3.5</td>
<td>2017</td>
<td>BNEF (2018)</td>
</tr>
<tr>
<td>China</td>
<td>CATL</td>
<td>7</td>
<td>2016</td>
<td>BNEF (2018)</td>
</tr>
<tr>
<td><strong>Announced</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>TerraE</td>
<td>34</td>
<td>2028</td>
<td>TerraE (2017)</td>
</tr>
<tr>
<td>United States</td>
<td>Tesla</td>
<td>35</td>
<td>2018</td>
<td>Tesla (2018b)</td>
</tr>
<tr>
<td>India</td>
<td>Reliance</td>
<td>25</td>
<td>2022</td>
<td>Factor Daily (2017)</td>
</tr>
<tr>
<td>China</td>
<td>CATL</td>
<td>24</td>
<td>2020</td>
<td>Reuters (2017f)</td>
</tr>
<tr>
<td>Sweden</td>
<td>Northvolt</td>
<td>32</td>
<td>2023</td>
<td>Northvolt (2017)</td>
</tr>
<tr>
<td>Hungary</td>
<td>SK innovation</td>
<td>7.5</td>
<td>2020</td>
<td>SK innovation (2018)</td>
</tr>
</tbody>
</table>

Source: Global EV Outlook 2018 (www.iea.org)
Trend #5: Several national governments have pledged their intention to end the sales or registrations of internal combustion engine (ICE) vehicles by specific years.

<table>
<thead>
<tr>
<th>Country</th>
<th>2025</th>
<th>2030</th>
<th>2032</th>
<th>2040</th>
<th>2045</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td></td>
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<tr>
<td>Ireland</td>
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<tr>
<td>Netherlands</td>
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<tr>
<td>Norway</td>
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<td></td>
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<tr>
<td>Slovenia</td>
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<td>•</td>
<td></td>
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<tr>
<td>Sri Lanka</td>
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<td></td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td></td>
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<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Scotland</td>
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<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td></td>
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</tr>
</tbody>
</table>

- ICE sales ban or 100% ZEV sales target
- Fleet without ICES

Notes: All these national ICE bans refer to announcements pledging to terminate sales or registration of new diesel and gasoline cars (excluding PHEVs). In the case of Sri Lanka, it is specified that the government is aiming to replace all vehicles with electric or hybrid models by 2040 (Phys.org, 2017). In addition to the bans listed in the table, China is reportedly considering a national ban on the production and sales of ICE cars (Reuters, 2017a; Zhenhua, 2017).

- Governments play a big role in the push for EVs
- The fastest way to fast track EV adoption is through gov’t policy

Source: Global EV Outlook 2018 (www.iea.org)
The Local EV Experience
Unlike the global experience, Philippine EV adoption is driven by jeepneys/shuttles and trikes, the country’s biggest pollutants.
but the efforts are hampered by myriads of issues related to EV cost & supply, government support, and the current state of locally available EV technology.
The expected buyers of which are from socio eco class DE, with up to high school education, and varying degrees of (mostly self-taught) driving experience.
...and from whose daily income is expected to finance the cost to convert to EVs, even if they agree that the qualitative benefits of EVs are indeed far greater.

Source: Gerweiss Motors (Mandaluyong eTrike experience)
which is why ingenious solutions have been thought about related to charging, to try to convince drivers to make the change to electric given its huge affordability vs gas.
Understanding that the solution cannot be at the hands of individual drivers, the DOTr is implementing a PUV Modernization Program for jeeps and buses.

New Franchising System:

- The routes will be planned by the government.
- Single unit operators will no longer be eligible for a franchise.
- Initially, the minimum number of jeepneys for franchise is 20. By 2019, the minimum number will be raised to 40.
- Standardize income of jeepney driver, provide them with regular employment benefits, and abolish boundary system.

Improved PUV to International Standards:

1. Vehicles with combustion engines must have low emissions in compliance with the EURO IV emission standards or better.
2. Speed limiters
3. Closed-circuit television (CCTV) camera for selected types of PUVs
4. Dashboard camera
5. GPS
6. Person with disability (PWD) friendly
7. Comfortable seats
8. Provision of Wi-Fi access
9. For buses, standing passengers must not exceed five persons
The national government will retire old jeepneys and usher in new franchises through operator cooperatives where the drivers will be classified as employees.

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Route Planning</strong></td>
<td>Public transport franchises are <strong>dependent</strong> on route proposals of operators</td>
<td>Public transport franchises are <strong>in accordance with Local Public Transport Plans</strong></td>
</tr>
<tr>
<td><strong>Driver Income</strong></td>
<td>Operators implement <strong>Boundary System</strong> where drivers need to <strong>compete</strong> for passengers</td>
<td>Drivers will be given <strong>regular salaries with corresponding employee benefits</strong></td>
</tr>
<tr>
<td><strong>Jeepney Types</strong></td>
<td>No restrictions</td>
<td><strong>Fully Electric</strong> or Euro-4 compliant</td>
</tr>
<tr>
<td><strong>Typical cost (brand-new)</strong></td>
<td>Php640K to Php850K</td>
<td>Ph1.2M to Ph2.2M</td>
</tr>
<tr>
<td><strong>Min Fleet Requirement</strong></td>
<td>1 unit</td>
<td>20 units (through operator cooperatives) (to be increased to 40 units in 2019)</td>
</tr>
<tr>
<td><strong>Financing</strong></td>
<td>No Financing available</td>
<td>Landbank and DBP offers a finance package</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ 5% downpayment, at 6% interest rate, over 7 years, with a maximum subsidy of P80,000/unit</td>
</tr>
<tr>
<td><strong>Timeline</strong></td>
<td>Launched in June 2017 with a 3 year transition period for full implementation by July 2020</td>
<td></td>
</tr>
</tbody>
</table>
The government is also eyeing the modernization of buses to support the EDSA MRT Augmentation / Rehabilitation as well as P2P routes.

<table>
<thead>
<tr>
<th>Proposed Route/s</th>
<th>EDSA Augmentation / Rehabilitation</th>
<th>P2P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median lane along EDSA from QC to Pasay</td>
<td>22 different routes for bidding</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fare Structure</th>
<th>Based on MRT fare matrix. MRT collects all fares</th>
<th>Fixed fare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Franchise Period</td>
<td>5 years contract</td>
<td>5 years, Renewable thereafter. Unbundled packages currently for bidding</td>
</tr>
<tr>
<td>Passenger Use</td>
<td>Stops at selected MRT stations during MRT operations only</td>
<td>Scheduled trips w/ designated stops for loading &amp; unloading</td>
</tr>
<tr>
<td>Min Fleet Requirement</td>
<td>Total of 360 units to be operated by 3 consortia</td>
<td>Authorized number of units depending on route</td>
</tr>
<tr>
<td>Bus Specification</td>
<td>Low flooring, minimum 11 meters in length, w/ PWD ramp, A/C, 2doors on RS &amp; 1 door on LS</td>
<td>Low floor entry, 11-13 meters in length, w/ PWD ramp, free wifi, A/C</td>
</tr>
<tr>
<td>Typical cost (brand-new)</td>
<td>Cost of Euro IV buses average between Ph6 to Ph10M</td>
<td>(Current) cost of electric bus is around Ph20 to Ph25M</td>
</tr>
</tbody>
</table>
In view of this, various entities and organizations have either started implementing or are planning to deploy fast charging solutions.
On the private vehicle front, Nissan, Mitsubishi and Hyundai have been gauging the local market and could offer their electric cars for sale as early as 2019.
FUTURE EV TRENDS AND THEIR EFFECT ON THE ELECTRICAL NETWORK
EVs are coming... and charging standards will continue to become more powerful as private users and commercial deployments need faster charging times.
This will put a stress on DU network facilities with the problem of “Charge Clustering” where EV users converge in specific locations without informing the DU.

• The local distribution grid **may be insufficient** in areas where EVs are prevalent.

• An EV with a typical daily commuting distance of 40km requires 6-8kWh to recharge, which is equivalent to the daily power needs of a small household. In other words, **+n EV = +n small house load** for the DU.

• **Transformers are the most vulnerable element of the system.** Most residential transformers are designed to serve between 10-50kVA of load, while an EV with a 240V charging system consumes about 7kVA. With “charge clustering”, it may cause damage due to transformer overload.

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Source: https://www.fleetcarma.com/impact-growing-electric-vehicle-adoptions-electric-utility-grids/
“Peak Demand” is also another problem for the DU as EV users can charge anytime it is convenient to them, but also inadvertently at the same time as others.

- The risk of overloading local transformers is particularly high during peak hours. Imagine what will happen when all electric vehicles owners in the neighborhood decide to recharge them at the same time, in the early evening, after returning from work, which is more or less the same time households turn their cooking, cooling and other appliances on.

- With **no telemetry system built in the transformer**, the DU will not know when the overload occurs.

  ![Average Hourly Grid Electricity Use: Electric Car Households vs. Typical Households](image)

  *Opower energy data of 2,000 US households with EV cars*

But EVs also pose a benefit through V2G technology by acting as mobile battery energy storage systems (BESS)

- It is also possible for an electric car to operate in discharge mode, in which it acts as a **giant battery and injects the power back into the grid**. This is referred to as **Vehicle-to-Grid (V2G)**.

- EVs can **enhance the grid’s stability** when it is subjected to significant disturbances, such as generator and branch tripping, bus faults, or sudden large load changes.

- With a dynamic pricing system in place, **EV owners can make a profit** by charging when the demand is low (and energy is cheap), and then sell power to the grid when the energy demand spikes.

- As distributed energy storage, EVs can also act as a **backup power for renewable energy sources**. EVs can store the excess power capacity from solar and wind sources, and use it for the house or release it to the grid.

To understand these developments, Meralco set up an EV charging station in July 2013 to be able to test various charging technologies as they become available.

- 8-bay Meralco EV Power Station
- Level 3 DC 50kW and Level 2 Tesla AC fast charging technologies
- Solar and Wind Energy Facilities
- V2G DC 10kW fast charger
To manage all these, an EVSE Management System is beneficial to allow remote management and provide a linked network for all EVSEs franchise (and nation) wide.

- An EVSE Management System refers to the soft- and hard- ware facilities that will allow the **remote monitoring, management and control of EV charging infrastructure deployed**, and provides benefits to the following:

  - **Distribution Utilities:**
    - Demand Response
    - Dynamic Pricing
    - Remote Metering & Reading
    - Remote Connect / Disconnect

  - **EV Users:**
    - Charging Station Location
    - Charging Station Type
    - Charging Station Status
    - Usage Cost

  - **Charging Station Owners:**
    - App-based system
    - EV User Billing
    - Accounting & Reporting

THANK YOU